LEAK RESISTANT VAPORIZER DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The current application is related to/claims priority to U.S. provisional patent application serial number 62/398,494, filed on September 22, 2016 and entitled "Vaporizer Apparatuses for use with Cannabinoids," and is related to/claims priority to U.S. patent application serial number 15/396,584, filed on December 31, 2016 and entitled "Leak-Resistant Vaporizer Cartridges for use with Cannabinoids," both of which are incorporated by reference herein in their entirety.

TECHNICAL FIELD

[0002] The current subject matter relates generally to vaporizer devices and methods for use and/or making. Such devices broadly include systems and apparatus for generating and delivering an aerosol that includes a vaporizable material for inhalation by a user. More specifically, certain implementations of the current subject matter relate to approaches and structures that may result in reduction in leaks of liquid vaporizable material from vaporizable devices.

BACKGROUND

[0003] Vaporizer devices include a broad category of systems, apparatus, etc. capable of producing an inhalable aerosol by heating a vaporizable material such that at least some of the vaporizable material is vaporized into a flowing gas stream where the vaporized vaporizable material forms or combines with other components of the flowing gas stream to form the inhalable aerosol. Such devices can include electronic vaporizers, which generally heat the vaporizable material using resistive heating supplied form a battery or other power source to a heating element under control of an electronic control circuit, as well as vaporizers that employ

other heat sources (e.g. combustion or other oxidation of a fuel source, or the like). Vaporizer devices consistent with the current subject matter can be referred to by various terms such as inhalable aerosol devices, aerosolizers, vaporization devices, electronic vaping devices, electronic vaporizers, etc. Such devices are generally configured for use with one or more vaporizable materials to which heat is applied to cause the generation of the inhalable aerosol. The vaporizable material can, in various implementations of such devices, include solids (e.g. herbs, tobacco, cannabis, or the like (including products extracted from such materials)), liquids (e.g. extracts, waxes, specific compounds, solutions containing one or more of such materials, or the like), and combinations of both solids and liquids.

[0004] Certain types of vaporizer devices include or are configured to include a tank or other reservoir or volume that contains the vaporizable material. Such devices, particularly those that generate aerosol components by evaporating or vaporizing a liquid vaporizable material, may also include an air tube or other structures for directing flow of air along an air path, and an atomizer or vaporizer structure, which may include a wicking structure (e.g. a porous wick, which can be formed of a ceramic, a fibrous material, a fabric, and/or other materials) for drawing the liquid vaporizable material from the reservoir to a heating zone and a heat-delivering device in the heating region.

[0005] In some examples, the atomizer or vaporizer structure may include a wick and a resistive coil subassembly that generates the vapor. An example of a such an arrangement may include a cartridge and vaporizer body system in which the cartridge incorporates a reservoir that contains a vaporizable material that is at least partially in liquid form. Air may enter the cartridge via one or more inlets and be forced (e.g. drawn or otherwise caused to pass) through a heated zone where heating of the vaporizable material causes generation of vapor that is entrained in the flowing air. This process may result in the air becoming fully saturated with one or more gas-phase components of the vaporizable material. As the air containing this

vapor continues along the air path, it comes in contact with cooler surfaces, which may result in condensation of the entrained vapor. Such systems are generally configured to promote the formation of aerosol particle entrained in the flowing air via this condensation mechanism. However, some of the condensing gas-phase components may deposit directly on the cooler surfaces and be thereby removed from the flowing air back into a liquid phase in other parts of the cartridge or vaporizer device. Additionally, depending on the complexity of the air path, an additional mass of the vaporizable material may be lost from the flowing air stream via aerosol particle deposition onto surfaces of the air path or other parts of the vaporizer device. Such processes may result in some mass of liquid-phase vaporizable material and/or water or other liquids being present in parts of the vaporizer device other than the reservoir that originally contains the vaporizable material. Parts of the vaporizer device where the vaporizable material may condense or otherwise be deposited may include a mouthpiece, electronic circuitry, or the like. Depending on the amount and type of such vaporizable material deposited at these and/or other locations, user dissatisfaction (e.g. due to potentially unpleasant contact with liquid instead of inhalable aerosol) and/or problems with the electronic circuitry may result.

[0006] In some vaporizer device configurations, liquid vaporizable material and/or condensed water or other liquids may also be present at other locations within or on surfaces of a cartridge and/or a vaporizer body external to the reservoir due to leaks, which may occur due to pressure differentials (e.g. such as may result from changes in altitude associated with air travel, temperature changes, mechanical deformations of a non-rigid reservoir container structure, etc.) between the internal volume of the vaporizable material reservoir and ambient conditions.

SUMMARY

[0007] Aspects of the current subject matter relate to vaporizer devices and/or apparatus that include one or more absorbent pads or members oriented to prevent leakage without disrupting the airflow or formation of vapor within the devices and/or apparatus. In general, moisture and particles from the vapor can be deposited on a filter pad that is off-axis relative to the vapor path.

[0008] A vaporizer device consistent with implementations of the current subject matter includes a reservoir configured to contain a vaporizable material, a mouthpiece configured to deliver an aerosol comprising the vaporizable material to a user, an air flow path having an air flow path axis, a heating element configured to heat and cause vaporization of the vaporizable material into air drawn into the vaporizer device along the air flow path, the air flow path connecting an air inlet via which air from outside the vaporizer device enters the vaporizer device and the mouthpiece, the air flow path passing proximate to the heating element, and a pad positioned within or proximate to the mouthpiece and away from the air flow axis.

[0009] The details of one or more variations of the subject matter described herein are set forth in the accompanying drawings and the description below. Other features and advantages of the subject matter described herein will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0010] The accompanying drawings, which are incorporated in and constitute a part of this specification, show certain aspects of the subject matter disclosed herein and, together with the description, help explain some of the principles associated with the disclosed implementations. In the drawings:

[0011] FIGS. 1 and 2 show moisture and vapor deposition on a pair of filter pads that are off-axis relative to the airflow path of the device;

[0012] FIGS. 3A and 3B show a vaporization device with a pair of filter pads that are off-axis relative to the airflow path of the device;

[0013] FIGS. 4A and 4B show an exemplary vaporization device. This exemplary device includes two pairs of absorbent filter pads, as described herein. FIGS. 4A-4B show a cartridge placed within the reusable component of the device;

[0014] FIGS. 5A-5F illustrate the vaporizer body (e.g., a reusable component of the vaporizer device of FIGS. 4A-4B). FIG. 5A is a bottom perspective view; FIG. 5B is a front view, FIG. 5C is a top perspective view (looking into the cartridge receiver region including electrical contacts), FIG. 5D is a side view, FIG. 5E is a top view, and FIG. 5F is a bottom view, showing the electrical connection to a charger or other wired electrical connection;

[0015] FIGS. 6A-6D illustrate the cartridge of the device of FIGS. 4A-4B. FIG. 6A is a bottom perspective view, FIG. 6B is a bottom view, FIG. 6C is a top perspective view (showing the opening into the mouthpiece), and FIG. 6D is an exploded view of the cartridge of FIG. 6A;

[0016] FIGS. 7A-7F illustrate an alternative view of a cartridge as described herein. FIG. 7A shows a bottom perspective view; FIG. 7B is a top perspective view; FIG. 7C is a front view; FIG. 7D is a side view; FIG. 7E is a bottom view; and FIG. 7F is a top view;

[0017] FIGS. 8A-8G show a variation of a vaporizer base of a vaporizer apparatus into which a cartridge such as the one shown in FIGS. 7A-7F may be inserted. FIG. 8A is a bottom perspective view; FIG. 8B is a top perspective view showing the cartridge receiver portion of the vaporizer base; FIGS. 8C, 8D and 8E show front, side and back views, respectively, of the vaporizer base; and FIGS. 8F and 8G show bottom and top views, respectively, of the vaporizer base;

[0018] FIGS. 9A-9G show an assembled vaporizer apparatus including a vaporizer cartridge such as the one shown in FIGS. 7A-7F that has been fully seated and retained in a vaporizer base such as the one shown in FIGS. 8A-8G. FIGS. 9A and 9B show bottom perspective and top perspective views, respectively, of the assembled vaporizer apparatus; FIGS. 9C, 9D, and 9E show front, side and back views, respectively, of the assembled vaporizer apparatus; FIGS. 9F and 9G show bottom and top views, respectively, of the vaporizer apparatus;

[0019] FIG. 10A is an exploded view of the cartridge of FIGS. 7A-7F with the components arranged in line;

[0020] FIG. 10B is an alternative exploded view of the cartridge of FIGS. 7A-7F, showing the component parts positioned adjacent to each other at the approximate vertical position for assembly;

[0021] FIG. 11A is a semi-transparent view (in which the outer casing of the vaporizer base, mouthpiece, and cartridge housing have been made transparent) showing the air path through the assembled vaporizer apparatus such as the one shown in FIGS. 7A-9G;

[0022] FIGS. 11B and 11C show front and back views, respectively, of an example of a vaporizer base with the outer housing (case or shell) made transparent, showing the cartridge receiving end including connectors and air entry port therein;

[0023] FIG. 12 is an enlarged view of a section through a midline of the proximal (top) region of a cartridge (as shown by dashed line 12-12' in FIG. 9A), showing the air path from the vaporization chamber to the mouthpiece openings;

[0024] FIG. 13 is a section through the midline of a vaporizer apparatus (including a vaporizer base into which a vaporizer cartridge has been coupled), showing the air path during inhalation (puffing, drawing, etc.);

[0025] FIG. 14 shows a section through a cartridge, just beneath the mouthpiece (as shown by dashed line 14'-14' in FIG. 9B) showing the arrangement of the distal pair of absorbent pads offset from the airflow path;

[0026] FIG. 15A is a section through the midline of an assembled vaporizer apparatus such as the one shown in FIG. 9A (through line 15A-15A');

[0027] FIG. 15B is another section through an assembled vaporizer apparatus such as the one shown in FIG. 9A (through line 12-12');

[0028] FIG. 15C shows another section through the assembled vaporizer apparatus (through line 15C-15C' in FIG. 9B);

[0029] FIG. 15D is a section through a cartridge (through line 15D-15D' of a cartridge such as the one shown in FIG. 7A) showing a pair of overflow filter pads that are off-axis relative to the airflow path of the device;

[0030] FIG. 16 is a section through another of another exemplary vaporization device (at line 16-16' in FIG. 9B), near the base of the cartridge and inserted into the cartridge receiver of the vaporizer base;

[0031] FIG. 17 is an electrical schematic of a heating element and connectors showing the Seebeck coefficients for a simplified model of the components of the heating circuit;

[0032] FIG. 18 is a Seebeck measurement circuit for a vaporizer apparatus correcting for the Seebeck effect, configured as a two-terminal sensing circuit;

[0033] FIG. 19 is another example of a Seebeck measurement circuit for a vaporizer apparatus, configured as a four-terminal (four-point) circuit;

[0034] FIGS. 20A and 20B illustrate two examples of heating coils comprising different component conductors coupled to result in resistive heater from which a temperature measurement may be determined using a Seebeck sensing circuit as described herein;

[0035] FIG. 21 is one example of a user interface (UI) for interacting with the apparatuses described herein using an external controller (e.g., smartphone, pad, etc.);

[0036] FIG. 22 is another example of a UI for interacting with an apparatus as described herein; and

[0037] FIG. 23 shows a process flow chart illustrating features of a method consistent with implementations of the current subject matter.

[0038] When practical, similar reference numbers denote similar structures, features, or elements.

DETAILED DESCRIPTION

[0039] Currently available vaporizer devices may not adequately address one or more of the challenges described above and/or other issues with management of liquid vaporizable material outside of the reservoir. For vaporizable liquids such as cannabis extract liquids, in which the liquid material may be particularly oily and/or viscous, and for which evaporation of the liquid material may result in a sticky residue that may impair the operation of the vaporizer, such issues may be particularly troublesome. Further, vaporization of cannabis extract liquids may be more technically difficult than vaporization of other liquids (such as nicotine solutions).

[0040] A solution to moisture build-up used in some conventional e-cigarettes and/or other vaporizer devices involves integration of a filter pad in line with air flow. A significant disadvantage with such a solution is that a filter pad in line with the air flow filters out and absorbs a large portion of the inhalable aerosol. Moreover, having a filter pad in line with the air flow can impede or restrict the air flow as the user draws on the mouthpiece. Furthermore, this restriction to air flow generally increases as the filter becomes more saturated with liquid material, which may necessitate a user changing his or her draw accordingly and may increase the possibility of drawing liquid of the product into the user's mouth.

[0041] In addition, the control of the temperature when vaporizing cannabis extracts and/or other vaporizable materials may require a high degree of precision. Improved power management and control of the heater (atomizer) may be desirable in many implementations of vaporizer devices. In particular, vaporizer devices well suited for vaporizing cannabis (e.g., liquid cannabis extract solutions or other plant-based extracts or oils) may benefit from precise and accurate control of the heater employed to form a vapor from vaporizable material including such materials.

[0042] It may also be beneficial, particularly when vaporizing a medicament such as cannabis, to provide an immediate approximate (visual) estimate of the amount of material consumed. Other benefits may be realized from the use of pre-loaded and tightly controllable cartridges for use in consuming cannabis extract liquids.

[0043] Implementations of the current subject matter relate to vaporizer devices (including but not limited to vaporizer cartridges) and methods of making, operating, and/or using them that may provide benefits related to one or more of these issues.

[0044] As noted above, an apparatus and/or method consistent with implementations of the current subject matter typically involve heating of a vaporizable material to result in production of one or more gas-phase components of the vaporizable material. A vaporizable material may include liquid and/or oil-type plant materials. The one or more gas-phase components of the vaporizable material may condense after being vaporized such that an aerosol is formed in a flowing air stream that is deliverable for inhalation by a user. Such vaporizer devices may in some implementations of the current subject matter be particularly adapted for use with an oil-based vaporizable material, such as for example cannabis oils.

[0045] One or more features of the current subject matter, including one or more of a cartridge (also referred to as vaporizer cartridges) and a reusable vaporizer device body (also referred to as a vaporizer device base, a body, a base, etc.) may be employed with a suitable

vaporizable material (where suitable refers in this context to being usable with a device whose properties, settings, etc. are configured or configurable to be compatible for use with the vaporizable material). The vaporizable material can include one or more liquids, such as oils, extracts, aqueous or other solutions, etc., of one or more substances that may be desirably provided in the form of an inhalable aerosol.

[0046] In some examples, the vaporizable material may include a viscous liquid such as a cannabis oil. In some variations, the cannabis oil comprises between 40-100% cannabis oil extract. The viscous oil may include a carrier for improving vapor formation, such as propylene glycol, glycerol, etc., at between 0.01% and 25% (e.g., between 0. 1% and 22%, between 1% and 20%, between 1% and 15%, and/or the like). In some variations the vapor-forming carrier is 1,3-Propanediol. A cannabis oil may include a cannabinoid or cannabinoids (natural and/or synthetic), and/or a terpene or terpenes. For example, any of the vaporizable materials described herein may include one or more (e.g., a mixture of) cannabinoid including one or more of: CBG (Cannabigerol), CBC (Cannabichromene), CBL (Cannabicyclol), CBV (Cannabivarin), THCV (Tetrahydrocannabivarin), CBDV (Cannabidivarin), CBCV (Cannabichromevarin), CBGV (Cannabigerovarin), CBGM (Cannabigerol Monomethyl Ether), Tetrahydrocannabinol, Cannabidiol (CBD), Cannabinol (CBN), one or more Endocannabinoids (e.g., anandamide, 2-Arachidonoylglycerol, 2-Arachidonyl glyceryl ether, N-Arachidonoyl dopamine, Virodhamine, Lysophosphatidylinositol), and/or a synthetic cannabinoids such as one or more of: JWH-018, JWH-073, CP-55940, Dimethylheptylpyran, HU-210, HU-331, SR144528, WIN 55,212-2, JWH-133, Levonantradol (Nantrodolum), and AM-2201. The oil vaporization material may include one or more terpene, such as Hemiterpenes, Monoterpenes (e.g., geraniol, terpineol, limonene, myrcene, linalool, pinene, Iridoids), Sesquiterpenes (e.g., humulene, farnesenes, farnesol), Diterpenes (e.g., cafestol, kahweol, cembrene and taxadiene), Sesterterpenes, (e.g., geranylfarnesol), Triterpenes (e.g.,

squalene), Sesquarterpenes (e.g, ferrugicadiol and tetraprenylcurcumene), Tetraterpenes (lycopene, gamma-carotene, alpha- and beta-carotenes), Polyterpenes, and Norisoprenoids. For example, an oil vaporization material as described herein may include between 20-80% cannabinoids (e.g., 30-90%, 40-80%, 50-75%, 60-80%, etc.), 0-40% terpenes (e.g., 1-30%, 10-30%, 10-20%, etc.), and 0-25% carrier (e.g., polyethylene glycol).

[0047] In any of the oil vaporization materials described herein (including in particular, the cannabinoid-based vaporization materials), the viscosity may be within a predetermined range. The range may be between about 30 cP (centipoise) and 115 KcP (kilocentipoise). For example, the viscosity may be between 40 cP and 113 KcP. Outside of this range, the vaporizable material may fail to wick appropriately to form a vapor as described herein. In particular, the oil may be made sufficiently thin to both permit wicking at a rate that is useful with the apparatuses described herein, while also limiting leaking (e.g., viscosities below that of ~40 cP might result in problems with leaking). The current subject matter may be particularly useful in relation to vaporizer devices configured for use with vaporizable materials that are highly vicious, sticky, and/or that may cause corrosion or otherwise interfere with a favorable user experience and/or may cause degradation or lack of durability of one or more vaporizer device components as leaks or other factors leading to the presence of such materials outside of the vaporizable material reservoir can be highly undesirable for reasons discussed elsewhere herein. FIGS. 7A-7F illustrate features of an example cartridge that is adapted for use with a viscous oil-based vaporizable material (having a viscosity at room temperature of between 40 cP and 113 KcP), such as a cannabis oil. In this example, the cartridge 700 includes a flattened body that is approximately oval in cross-sectional area (see, e.g., FIGS. 7E and 7F showing top and bottom views) and includes a mouthpiece that is attached over a body forming a reservoir region holding the vaporizable material. The body 790 may be transparent, translucent, or opaque. The mouthpiece may include one or more

openings 792 at the proximal end (top) out of which vapor may be inhaled, by drawing breath through the device. The bottom may also include a locking feature (e.g., tab, indent, magnetic lock, etc.) for coupling and securing the cartridge within a cartridge receiver of a vaporizer base, such as an example reusable vaporizer base 800, features of which are shown in FIGS. 8A-8G. In this example, the body of the vaporizer device 800 may be elongate and may include an outer shell or cover 890; the proximal end of the vaporizer base may include an opening forming a cartridge receiver 892. The cartridge receiver may include one or more openings therethrough (e.g., lateral openings) to allow airflow therein, as described in more detail below.

[0048] Any of these cartridges may also or alternatively include a rim, ridge, channel, protrusion, lip, etc. along the distal end region for engaging a complimentary portion of the vaporizer device. For example, in FIG. 7D, the cartridge 700 includes a channel or lip 795 at the distal end which may engage with a deflectable or deformable tab or protrusion in the cartridge receiving portion of the vaporizer; this may provide a snap fit. In general, the cartridge may fit within the cartridge receiver of the vaporizer by a friction fit. The snap-fit may provide audible and/or tactile confirmation that the cartridge is held in position. This fit may also lock or hold the cartridge within the receiver, but still allow it to be easily withdrawn to remove the cartridge.

[0049] As shown in FIG. 7C, the elongate and flattened body 790 may contain within it the tank region 791 (e.g., for holding the vaporizable material) and a distal overflow leak chamber 793. These structures may be formed by the internal components within the elongate and tubular body, as described below.

[0050] FIGS. 10A and 10B illustrate features, via exploded views, of an example cartridge adapted for use with a liquid vaporizable material in accordance with implementations of the current subject matter as described herein. In this example, the apparatus includes a cartridge body 1005 that may be clear (transparent), opaque, and/or

translucent. The cartridge body 1005 may form a reservoir for the liquid vaporizable material, and particularly for a viscous liquid vaporizable material such as the cannabinoid oils described herein. The cartridge may include an outer seal (e.g., O-ring 1009) that seals a mouthpiece 403 over the body 1005. The cartridge body 1005 may be sealed on the top (at the proximal end) under the mouthpiece 403 by a single-piece plug 888 that covers multiple openings which may be used for filling the tank. A vaporization chamber may be formed at the bottom (distal end) of the cartridge. The vaporization chamber may be formed from a cannula and housing piece 1011 that includes one or more openings into which a wick (wick portion of wick and coil 443) passes into the chamber. The walls forming the vaporization chamber separate it from the tank and mate with a back piece 1013 that forms the bottom (distal end) of the tank within the cartridge body. This piece may also be sealed (e.g., by an O-ring 1015) to the cartridge body from within the cartridge body, as shown. An air chamber is then formed between a bottom plate 1019 of the cartridge and the back piece 1013 of the tank. One or more (e.g., two) air openings 796, 796' (see FIG. 7E) formed through this bottom plate 1019 allow air to pass (after entering the cartridge receiver through one or more openings 894 (see FIG. 8D) in the side) into the distal end of the cartridge, into the air chamber region and then up through an opening into the vaporization chamber. The bottom plate 1019 forming the bottom of the cartridge may also accommodate or include one or more (e.g., two) electrical connectors that are configured to mate with the connectors on the vaporizer base. These contacts may be, for example wiper or scraping contacts. In FIGS. 10A and 10B, they are shown as cans 1021, 1021' having openings into which the pins from the vaporizer base project to form an electrical contact.

[0051] The vaporizer body may include a battery and one or more control circuits housed within the cover 890. The control circuitry may control the heater, which may be positioned in the cartridge. The heater may generally include a heating coil (resistive heater) in thermal contact with the wick; additional connectors formed of a different material (e.g.,

conductive material) may connect the heater coil to the electrical contacts on the base of the cartridge. The control circuitry may include one or more additional circuits, such as Seebeck measurement circuits, that correct for offsets and other inaccuracies in the determination of temperature and therefore the power applied to the apparatus. The control circuitry may also include and may control and/or communicate with a battery regulator (which may regulate the battery output, regulate charging/discharging of the battery, and provide alerts to indicate when the battery charge is low, etc.). The control circuitry may also include and may control and/or communicate with an output, such as a display, one or more LEDs, one or more LCDS, a haptic output, or any combination of these. In the example shown in FIGS. 7A-9G, the apparatus includes four (RGB) LEDs 897, arranged in a pattern (e.g., a circular, spiral or floral pattern; other patterns may include linear patterns, for example). Any of the apparatuses described herein may also include a wireless communication circuity that is part of, connected to, and/or controlled by the control circuitry. The apparatus may be configured to wirelessly communicate with a remote processor (e.g., smartphone, pad, wearable electronics, etc.); thus the apparatus may receive control information (e.g., for setting temperature, resetting a dose counter, etc.) and/or output information (dose information, operational information, error information, temperature setting information, charge/battery information, etc.).

[0052] The apparatus may also include one or more inputs, such as an accelerometer, a lip sensing input, a contact input, or the like. In vaporizer apparatuses in which the device does not include any visible buttons, switches, or external user input on an outer surface of the cartridge or vaporizer base, the input may be an accelerometer (coupled to, part of, and/or controlled by the control circuitry). The accelerometer and any accelerometer control circuitry may be configured to detect tapping on the apparatus (e.g., the case), rolling of the apparatus (e.g., around the long axis or the short axis of the device), and/or any other deliberate movement associated with the apparatus. In some variations the apparatus may include circuitry for

sensing/detecting when a cartridge is connected and/or removed from the vaporizer base. For example, cartridge-detection circuitry may determine when a cartridge is connected to the device based on an electrical state of the electrical contacts within the cartridge receiver in the vaporizer base. For example, with reference to the vaporizer base shown in FIG. 5C, two electrical contacts 595, 595' are illustrated. Without a cartridge inserted into the apparatus, the circuit is open (e.g., between 595 and 595'), and with a cartridge inserted, the electrical contacts 595, 595' (as shown in FIGS. 5C and 11B) engage with the cartridge contacts (such as wiping contracts which scrape to remove leaked and/or dried vaporizable material on the electrode contact surfaces). The controller (via a separate or integrated cartridge-detection circuit) may determine that a cartridge has been inserted when the resistance between these contacts changes to within a recognizable range (from the open circuit). Other cartridge detectors may alternatively or additionally be used, including a trip switch (activated when the cartridge is present) and/or the like. Any of the apparatuses described herein may also include one or more breath detectors, including a pressure sensor 1109 (e.g., microphone coil) having a connection to the inside of the cartridge receiver, as shown in FIG. 11B.

[0053] The vaporizer body may also include a connector 899 (as shown in FIG. 8F) at the distal end for coupling the device to a charger and/or data connection. The internal battery may be charged when coupling the device to a connector; alternatively other electrical connectors and/or inductive charging may be used.

[0054] FIGS. 9A-9G illustrate, via various views, an example of a vaporizer apparatus 900 in which the cartridge 700 has been inserted completely into the vaporizer body 800. The resulting device may be a small, lightweight, hand-held device that may be safely stored in a pocket, purse, or the like.

[0055] In operation, a user may (once charged sufficiently) activate the vaporizer by drawing (e.g., inhaling) through the mouthpiece. The device may detect a draw (e.g., using a

pressure sensor, flow sensors, and/or the like, including a sensor configured to detect a change in temperature or power applied to a heater element, e.g., anemometer detection) and may increase the power to a predetermined temperature preset. The power may be regulated by the controller by detecting the change in resistance of the heating coil and using the temperature coefficient of resistivity to determine the temperature. As described in greater detail below, the temperature determination and/or power applied may be optionally corrected in cases where there are different electrically conductive materials connecting the resistive heater to the power supply/power, in which the Seebeck effect may be an issue, using a sensing circuit to estimate and compensate for this potential source of inaccuracy.

[0056] In any of the apparatuses consistent with implementations of the current subject matter, the temperature may be adjusted or selected by the user. As mentioned, in some variations the apparatus may not include an exterior control or user input, but still allows the user to select the temperature from among a plurality (e.g., two or more, three or more, etc.) of pre-set heating/vaporizing temperatures above, for example, 100°C. This may be achieved by allowing the user to coordinate in time (e.g., within 60 seconds, within 50 seconds, within 45 seconds, within 40 seconds, within 30 seconds, within 20 seconds, within 10 seconds, between 1 second and 60 seconds, between 2 seconds and 60 seconds, between 3 seconds and 60 seconds, etc.) a pair of distinct inputs that are internal to the apparatus (e.g., not from controls on the surface of the apparatus). Such detection may be an accelerometer input (e.g., tapping, such as one or more, e.g., 3 or more, taps, rotations of the device in the long axis, etc.) within a predefined time after removing the cartridge and/or inserting the cartridge. For example, the apparatus may enter into a temperature selection mode, to allow a user to select the temperature, by removing the cartridge after shaking the apparatus (e.g., for 1 or more seconds, e.g., 2 or more seconds, etc.). Once in a temperature selection mode, the user may select from among a number (e.g., 4) of pre-set temperatures by, for example, tapping the housing of the device (or

another pre-configured action) to cycle through the pre-set temperatures, which may be displayed on an output (e.g., LED, monitor, LCD, etc.) on the apparatus.

[0057] Any other input on the device that is not (or not connected to) a button, and particularly an external button, may be used in a predetermined activation sequence (e.g., pattern of taps detected by the accelerometer, insertion/removal of cartridge, etc.) or in a set of sequential independent actuations. For example, the apparatus may enter into a temperature selection mode after removing and inserting a cartridge three times in quick successions (e.g., within 5 seconds of each step). In any of the variations described herein, merely shaking the apparatus may display information about the status of the device (e.g., the charge) using the output; the additional non-button input (e.g., removing the cartridge and/or inserting the cartridge) within the predetermined time may then allow the operating temperature to be selected.

[0058] In some variations, the apparatus includes multiple (e.g., 4) presets, and an optional additional preset (e.g., 5th preset or more) that may be user-settable. Alternatively or additionally, an external controller (smartphone, pad, computer, etc.) may communicate with the apparatus to allow setting and/or selecting the operating temperature.

[0059] In on example, the apparatus may be operated to allow the user to select the operating temperature (set mode) by shaking the device with a cartridge inserted. In some variations this may then change the display (e.g., multi-colored LEDs on the surface of the device), for example, displaying battery life using the multiple LEDs arranged in a particular pattern (e.g., in an X pattern 897, see, e.g., FIG. 8C). While in this state, removing the cartridge may result in entering temperature set mode. The device automatically cycles through the, for example, 4 (+1 or more, when user defined) presets. The user may then choose one by reinserting the cartridge at an appropriate time. In some variations, the preset temperatures may be: 270°C, 320°C, 370°C, 420°C. In some variations, the user may modify or include an

additional preset within a temperature range around each preset, e.g.: within an operational range of between 270-420°C. Other preset temperatures may be utilized.

[0060] As mentioned above, apparatuses consistent with implementations of the current subject matter, as described herein, may be operated with an external processor to receive input and/or output to control operation of the device. For example, the vaporizer apparatus may be operated with an application software ("app") that allows control of the temperature or other functional setting and/or allows storage, display, and/or transmission of operational and/or use information, including dose information. As described herein, an approximate estimate for dose may be determined based on the power applied to the heater (resistive coil) during inhalation (over time), e.g., power applied to coil multiplied by time of draw. This approximate 'dose' estimate may be accumulated over the use of a particular cartridge (e.g., once a cartridge is inserted, it may be accumulated and/or displayed until the cartridge is removed, roughly amounting to a "session" with that cartridge).

[0061] For example, FIGS. 21 and 22 illustrate exemplary user interfaces (UIs) for an application software that allows the user to set and or adjust the pre-set temperatures of the apparatus. In the UI shown in FIG. 21, the user may select the pre-set temperature. FIG. 22 illustrates the use of the app to control the appearance and activity of the apparatus. For example, the user may lock/unlock the apparatus, and track usage (e.g., by does estimation).

[0062] Apparatuses consistent with implementations of the current subject matter, as described herein, may allow the user to play one or more interactive "games" with the device. For example, any of these apparatuses may include an entertainment mode that may be entered by manipulating the device (e.g., by tapping, shaking, rotating, puffing in a predetermined pattern, etc.). In general, the entertainment mode may include one or more presentations (e.g., LED light displays, tones/music, patterns of vibrations, or combinations of these) and/or games. The device may be configured to allow selection of the presentation states or game

states (games) to be played, or it may randomly select one. In general the games may be interactive, allowing the user to provide input, e.g., via the one or more inputs, such as movement of the device, via motion sensing, touching the device, via a button and/or capacitive sensor (e.g., lip sensing, etc.), puff/airflow sensing, inserting and/or removing the cartridge, etc.

[0063] For example, the entertainment mode may include a game such as a pattern-following game, wherein the device presents an output (e.g., one or more LEDS illuminated in a pattern and/or color), and the device (e.g. controller) may determine if a response entered by the user on the input correlates with a predetermined response. In general, the same controller used to control the heater may be used to control the entertainment mode including the games. Alternatively a separate controller may be used, and may communicate with the controller controlling the heater.

[0064] The one or more games may include a memory game. For example, in a memory game the device may present an output sequence and determines if a sequence of responses entered by the user on the input correlates with a predetermined sequence of responses. The one or more games may include a triggered output game wherein the device presents an output in response to a predetermined user input. For example, the device may illuminate a series differently positioned and/or colored LEDs based on the angle or movement that the user holds the device.

[0065] The one or more games may include a chance type game, wherein the device is configured to display a random pattern of one or more of colors, tones or vibrations, in response to a predetermined user input. The entertainment mode may include a display game wherein the output comprises a plurality of LEDs and wherein the device is configured to cycle the LEDs through a predetermined sequence of colors in response to a predetermined user input. The entertainment mode may include a tone game wherein the output comprises a plurality of

tones and wherein the device is configured to play a predetermined sequence of tones in response to a predetermined user input.

[0066] As mentioned, the device may be configured to be toggled between the normal mode and the entertainment mode by applying one or more predetermined user manipulations to the input. For example, the device may be rotated. In some variations, the device input comprises an accelerometer, and the device may be configured to be toggled between the normal mode and the entertainment mode by rolling or rotating the device (e.g., three or more times) in one or more directions.

[0067] In addition to or alternative to the games, the entertainment mode may include an entertainment output (display) that is triggered upon entering into the entertainment mode. For example, as mentioned, the entertainment output may include one or more of: a display of a plurality of colors and/or patterns on the output, a tone or series of tones, a vibration or series of vibrations.

[0068] LEAK PREVENTION

[0069] Consistent with implementations of the current subject matter, apparatuses described herein may be configured to prevent or reduce leakage of the vaporizable material. As mentioned, leaking a liquid vaporizable material, such as an oil-based vaporizable material (and particularly cannabinoid oils), is particularly troublesome in a vaporizer because the vaporizable material may dry as a sticky, tarry substance that is both messy and may disrupt operation of the apparatus, particular the reusable (e.g., vaporizer base) portion. Leaking of other liquid vaporizable materials is also undesirable.

[0070] Consistent with implementations of the current subject matter, the apparatuses described herein may include one or more absorbent pads or members that are oriented to prevent leakage without disrupting the airflow or formation of vapor. In general, moisture and

particles from the vapor can be deposited on a filter pad that is off-axis relative to the vapor path.

[0071] Consistent with implementations of the current subject matter, the vaporization apparatuses (device and systems) may comprise a heating element, including a resistive heating element. The heating element may heat the vaporizable material such that the temperature of the material increases. Vapor may be generated as a result of heating the material.

[0072] In some cases, a vaporization device may have an "atomizer" or "cartomizer" configured to heat an aerosol forming solution (e.g., vaporizable material). The vaporizable material may be heated to a sufficient temperature such that it may vaporize (e.g., between 200°C and 500°C, e.g., between 250-450°C, between 270-420°C, etc.). The apparatus may include one or more pre-set vaporization temperatures and the apparatus may control (via controller including feedback logic) the temperature to a predetermined and/or selected temperature.

[0073] An atomizer may comprise a small heating element configured to heat and/or vaporize at least a portion of the vaporizable material and a wicking material that may draw a liquid vaporizable material into the atomizer (e.g., heater). When the apparatus includes a wicking material, the wicking material may comprise silica fibers, cotton, ceramic, hemp, stainless steel mesh, and/or rope cables. The wicking material may be configured to draw the liquid vaporizable material in to the atomizer without a pump or other mechanical moving part. A resistance wire may be wrapped around the wicking material and connected to a positive and negative pole of a current source (e.g., energy source). The resistance wire may be a coil. When the resistance wire is activated, the resistance wire (or coil) may have a temperature increase as a result of the current flowing through the resistive wire to generate heat. The heat may be transferred to at least a portion of the vaporizable material through conductive,

convective, and/or radiative heat transfer such that at least a portion of the vaporizable material vaporizes.

[0074] Alternatively or in addition to the atomizer, the vaporization device may be configured as a "cartomizer" to generate an aerosol from the vaporizable material for inhalation by the user. The cartomizer may comprise a cartridge and an atomizer. The cartomizer may comprise a heating element surrounded by a liquid-soaked poly-foam that acts as holder for the vaporizable material (e.g., the liquid). The cartomizer may be reusable, rebuildable, refillable, and/or disposable. The cartomizer may be used with a tank for extra storage of a vaporizable material.

[0075] Air may be drawn into the vaporization device to carry the vaporized aerosol away from the heating element, where it then cools and condenses to form liquid particles suspended in air, which may then be drawn out of the mouthpiece by the user. For example, any of the apparatuses described herein may include a draw channel or passage. The draw channel may be in fluid communication with the heater so that vapor formed by the heater passes into the draw channel, which is also in fluid communication with the mouthpiece, which may be integrated with the device (including a cartridge).

[0076] One or more aspects of the vaporization device may be designed and/or controlled in order to deliver a vapor with one or more specified properties to the user. For example, aspects of the vaporization device that may be designed and/or controlled to deliver the vapor with specified properties may comprise the heating temperature, heating mechanism, device air inlets, internal volume of the device, and/or composition of the material.

[0077] Energy may be required to operate the heating element. The energy may be derived from a battery in electrical communication with the heating element. Alternatively, a chemical reaction (e.g., combustion or other exothermic reaction) may provide energy to the heating element.

[0078] The term “aerosol” may generally refer to a colloid of fine solid particles or liquid droplets in air or another gas. In general, the aerosols described herein are liquid aerosols of primarily (e.g., >80%, >85%, >90%, >95%) liquid particles in air. The liquid or solid particles in an aerosol may have varying diameters of average mass that may range from monodisperse aerosols, producible in the laboratory, and containing particles of uniform size, to polydisperse colloidal systems, exhibiting a range of particle sizes. As the sizes of these particles become larger, they have a greater settling speed which causes them to settle out of the aerosol faster, making the appearance of the aerosol less dense, and to shorten the time in which the aerosol will linger in air. Interestingly, an aerosol with smaller particles will appear thicker or denser because it has more particles. Particle number has a much bigger impact on light scattering than particle size (at least for the considered ranges of particle size), thus allowing for a vapor cloud with many more smaller particles to appear denser than a cloud having fewer, but larger particle sizes.

[0079] A vapor may generally refer to a substance in the gas phase at a temperature lower than its critical point. As used herein, a vapor may include a liquid aerosol. For convenience the term vapor and aerosol, which may generally refer to liquid aerosols, may be used interchangeably herein, as is common in the art of electronic vaporization devices.

[0080] The methods and apparatuses described herein have a wide range of applications for inhalation of an active substance, such as botanicals, pharmaceuticals, nutraceuticals, or any other substance for inhalation to provide a benefit or sensation to an end user. In some embodiments, the devices described herein include a tank having a liquid containing an active ingredient, such as nicotine, cannabis, or a cannabinoid.

[0081] The term “cannabis” refers to plants of the genus Cannabis and loose-leaf products or extracts thereof. As mentioned above, the term “cannabinoid” refers to plant based or synthetic chemical compounds capable of acting on cannabinoid receptors and inducing a

biological effect. Cannabinoids include acids, salts, and bioactive stereo isomers. Exemplary cannabinoids include tetrahydrocannabinol (THC), cannabigerolic acid (CBGA), cannabigerol (CBG), tetrahydrocannabinolic acid (THCA), cannabichromene (CBC), cannabicyclol (CBL), cannabivarin (CBV), cannabichromevarin (CBCV), cannabigerovarin (CBGV), cannabigerol Monomethyl Ether (CBGM), delta-8-tetrahydrocannabinol (D8THC), delta-9-tetrahydrocannabinol (D9THC), tetrahydrocannabivarin (THCV), cannabinolic acid (CBNA), Cannabinol (CBN), cannabidiolic acid (CBDA), Cannabidivaric acid (CBDVA), cannabidiol (CBD), cannabichromenic acid (CBCA), Cannabichromene (CBC), or cannabicyclolic acid (CBLA) and/or any salt or stereo isomer of the above.

[0082] The devices described herein for generating an inhalable aerosol may include a body having a battery, a cartridge or tank including or configured to include the vaporizable material, at least one input (e.g., in some variations without any input on an outer surface of the apparatus, e.g., "button less"), and circuitry for controlling the device.

[0083] A vaporization device 200, consistent with certain implementations of the current subject matter, is shown in FIGS. 1 and 2. The vaporization device 200 includes two filter pads 222a, 222b. The filter pads 222a,b are positioned off of the central axis of the air path 212. As vapor travels down the air tube 208 and begins to return to liquid state, both condensation and particle aggregation will occur. As the vapor exits the air tube 208 into the air path 212, the moisture (see FIG. 1) and larger particles (see FIG. 2) filter onto the pads 222a,b (i.e., via gravity) without interfering with the user's draw on the device.

[0084] The one or more pads for use with a vaporizer device described herein (including pads 222a,b) may be made of an absorbent material. The absorbent material can both wick moisture quickly and allow it to disperse quickly therethrough. Thus, the absorbent material can be hydrophilic. Exemplary materials include but are not limited to cotton, e.g., a non-woven cotton lintner paper, felt, cellulose, or hydrophilic polymers. Further, the one or

more pads may be formed to have a curved shape or orientation, as shown in FIGS. 1 and 2. Alternatively, the one or more pads may be substantially flat panels. Consistent with some implementations of the current subject matter, the one or more pads can be made of two or more thin sheets of layered material.

[0085] The one or more pads may be positioned within or proximate to the mouthpiece so as to capture moisture just prior to inhalation by the user. Further, in some embodiments, as shown in FIGS. 1 and 2, the one or more pads may be pushed up against or near to the interior surface of the vaporizer so as to minimize interference with other components of the vaporizer. Alternatively, the one or more pads may be pulled away from the interior walls so as to maximize the surface area available for moisture absorption. The pads can be rectangular, circular, ovoid, triangular, square, or of another shape. The shape and size of the pads is chosen so as to minimize interference with the air path while maximizing moisture and particle collection.

[0086] Another example vaporizer 300 utilizing moisture deposition pads 322a,b is shown in FIGS. 3A and 3B. The vaporizer 300 includes a cartridge 301 that is attachable to a reusable component 311 (which can include the electronics to power the device, etc.). As shown in FIGS. 3A and 3B, the cartridge 301 includes a tank 302, a heater assembly 343, an air tube 308 creating an air path, and a mouthpiece 303. As shown, the pads 322a,b can be rectangular, flat, and positioned in parallel within the mouthpiece 303 on either side of the air tube 308 (i.e., off-axis with the air tube 308). The vaporizer 300 can further include any of the features described in U.S. Application No. 15/053,927, titled "VAPORIZATION DEVICE SYSTEMS AND METHODS," filed on Feb. 25, 2016, Publication No. US 2016-0174611 A1, the entirety of which is incorporated by reference herein.

[0087] Another example vaporizer 400 that can utilize one or more pads is shown in FIGS. 4A-6B. As shown in FIGS. 4A and 4B, the vaporizer 400 includes a reusable component

411 and a cartridge 401. The diameter of device 400 may be greater than the width (e.g., greater than 1.2x, 1.3x, 1.4x, 1.5x, 1.6x, 1.7x, 1.8x 1.9x, etc.), making the device have a substantially long and flat appearance.

[0088] Referring to FIGS. 5A and 5B, the reusable component 411 includes a shell 431, which can house the electronics for operating the vaporizer 400. Further, the reusable component 411 can include a visual indicator 421, such as one or more LEDs, for signaling the operating status of the vaporizer 400. The distal end of the reusable component 411 (shown in FIGS. 5A and 5F) includes a charging element 433 configured for charging the device. Further, the proximal end of the device (shown in FIG. 5E) includes contacts 595, 595' for maintaining an electrical connection with the cartridge 401.

[0089] The cartridge 401 is shown in FIGS. 6A-6D. As best shown in the exploded view of FIG. 6D, the cartridge 401 includes a tank 441 configured to hold a liquid vaporizable material therein, a heater (e.g. a wick and coil assembly) 443 configured to heat the vaporizable material in the tank 441, and an air tube 408 forming an air path extending from the tank 441 to a mouthpiece 403. The cartridge 401 may include an outer seal (e.g., O-ring 409) that seals the mouthpiece 403 over the tank 441. The tank 441 may be sealed on the top (at the proximal end) under the mouthpiece 403 by plugs 404a, 404b that covers multiple openings which may be used for filling the tank 441. Contacts 535a, b (see FIGs. 6B and 6D) are configured to connect with contacts 595, 595' on the reusable component 411 to provide power to activate the wick and coil assembly 443. At the distal end of the cartridge 401, the walls of the elongate and flattened tubular tank body 441 and a bottom cover plate 691 form an overflow leak chamber 699, which is shown with a pair of absorbent pads 445a,b positioned along the long walls (along the diameter) of the overflow leak chamber. One or more optional covers 693 (e.g., felt covers) may be included (also acting as an absorbent member).

[0090] As shown in FIGS. 4A-5D, the device 400 further includes openings, configured as air inlets 762a,b, on the side of the shell 431. The air inlets are proximate to openings (air inlets) 662a,b on the distal end of the cartridge 401 (see, e.g., FIGS. 6A and 6B) opening into the overflow leak chamber (not visible). Referring to FIG. 11A (which is a cross-section of the device 400 at the center), the air flow path 777 from inlets 762a,b to inlets 662a,b, extends through the tube 408 until it reaches the stop 433 (see also FIG. 12) and then divides into two separate paths that extend along the inner surface of the mouthpiece 402 (between pads 422a,b) and out through the outlets of the mouthpiece 403.

[0091] As shown in FIGS. 6D, 10A-B, and 12-14, parallel absorbent pads 422a,b can be positioned within the mouthpiece 403. The absorbent pads 422a,b may be rectangular and parallel with one another. The absorbent pads 422a,b may be positioned substantially parallel to the flat side of the device 400 (parallel with the plane of the length l and width w in FIG. 4A) and parallel with one another. The pads 422a,b can be biased fully against the inside walls of the mouthpiece 403 so as to easily capture liquid that rolls along the walls. A distance between the two pads 422a,b can be, for example, between 3 and 6mm, such as between 4 and 5mm, e.g., approximately 4.8mm. The gap between the absorbent pads 422a,b advantageously prevents the pads from interfering with the air flow path when a user draws on the mouthpiece 403.

[0092] Further, as shown in, for example, FIGS. 6D and 13, over-flow pads 445a,b are positioned proximate to the tank 441, i.e., within an overflow leak chamber below the tank, to absorb liquid that may leak out of the tank 441 during use. The over-flow pads 445a,b can be similarly placed parallel to one another and/or against the sides of the shell 431 as described above with respect to pads 422a,b.

[0093] FIG. 13 (which is a cross-section of the device 400 through the pads 422a,b and 445a,b) shows the air flow path 777 in dotted lines relative to the placement of the pads 442a,b

and 445a,b. The air path 777 extends alongside all of the pads 422a,b without extending therethrough. That is, the pads 422a,b and 445a,b extend off-axis relative to the air path 777 and do not interfere with user draw. However, the pads 422a,b and 445a,b are positioned so that the air path 777 travels along, besides, and/or in contact with the pads 422a,b and 445a,b for an extended period of time so as to allow maximum absorption of liquid.

[0094] In use (i.e., when the user draws on the device), the device 400 can be held horizontally with the width, w, in the vertical direction and the diameter, d, in the horizontal direction (see FIG. 4A). As such, at least one of the pads 422a,b and/or 445a,b will be substantially horizontal while the user draws on the device, ensuring that gravity will pull any moisture or particles down onto the lower pad 422a,b and/or 445a,b. Further, having two pads 422a,b and/or 445a,b advantageously ensures that moisture will be caught whether the user holds the device with pad 422a or 445a on top or 422b or 445b on top. This can both prevent interference with the electronics of the device and prevent the user from getting any liquid from the tank in his or her mouth when drawing on the device.

[0095] Referring to FIGS. 15A-15D, example device 800 is similar to device 400 (similar reference numbers are therefore used) except that it includes a single plug 888 in the proximal section of the cartridge portion (i.e., as opposed to two tank seals 404a,b shown in FIG. 6D). The plug 888 is configured to simultaneously seal both outlets of the mouthpiece 403 while also sealing around the tube 408.

[0096] Although sets of absorbent pads are shown and described with respect to the embodiments herein, only a single off-axis (i.e. “off air path”) pad may be used in each location. Likewise, more than two (e.g., 3, 4, 5, or more) off-axis pads, such as strips of absorbent material, may be used. Similarly, only a single set of pads may be used.

[0097] In accordance with some implementations of the current subject matter, the absorbent pads can be located only in the cartridge area (i.e., in the disposable portion). In

other implementations, additional absorbent pads can also be used in the reusable portion of the device.

[0098] The wick for use with any of the vaporizer devices consistent with implementations described herein can be sufficiently sized to handle higher viscosity liquids (e.g., liquids with cannabinoids). For example, the wick can be greater than 1.5mm in diameter, such as approximately 2mm in diameter.

[0099] Referring to FIG. 16, in accordance with some implementations of the current subject matter, openings (also referred to as air inlets) 962a,b to the cartridge 901 can include protective annular rings 992a,b or seals there-around that extend away from the inner wall of the cartridge. The rings 992a,b can help prevent any spilled liquid from splashing into the inlets 962a,b. The rings may be a lip or ridge projecting into the overflow leak chamber, as shown in FIG. 16.

[0100] Referring still to FIG. 16, In accordance with some implementations of the current subject matter, the contacts 935a,b of the reusable portion 911 of the device 900 can be pin contacts while the contacts 1035a,b of the cartridge 901 can be annular contacts or pin receptacles configured to mate with the pins. Further, in some embodiments, pin receptacles 1035 can include spring-loaded wiping mechanisms on the inner diameter thereof. The spring-loaded wiping mechanisms can be configured to wipe the pins as they pass therethrough. As a result, any vapor residue on the pins can be removed to maintain the proper electrical connection there between.

[0101] POWER AND TEMPERATURE CONTROL

[0102] In accordance with implementations of the current subject matter, a vaporizer apparatus may be controlled so that the temperature used to vaporize the vaporizable material is maintained within a preset range (e.g., one or more preset temperatures as discussed above, within +/- a few degrees (e.g., +/- 3 °C, 2°C, 1°C, 0.5°C, etc.)). In general, the microcontroller

may control the temperature of the resistive heater (e.g., resistive coil, etc.) based on a change in resistance due to temperature (e.g., TCR). For example, a heater may be any appropriate resistive heater, such as a resistive coil. The heater is typically coupled to the heater controller via two or more connectors (electrically conductive wires or lines) so that the heater controller applies power (e.g., from the power source) to the heater. The heater controller may include regulatory control logic to regulate the temperature of the heater by adjusting the applied power. The heater controller may include a dedicated or general-purpose processor, circuitry, or the like and is generally connected to the power source and may receive input from the power source to regulate the applied power to the heater.

[0103] For example, apparatuses consistent with implementations described herein may include logic for determining the temperature of the heater based on the TCR of the heating element (resistive coil), based on sensed resistance of the coil. The resistance of the heater (e.g., a resistive heater) may be measured (Rheater) and the controller may use the known properties of the heater (e.g., the temperature coefficient of resistance) for the heater to determine the temperature of the heater. For example, the resistance of the heater may be detected by a detection circuit connected at the electrical contacts that connect to the cartridge, and this resistance compared to a target resistance, which is typically the resistance of the resistive heater at the target temperature. In some cases this resistance may be estimated from the resistance of the resistive hearing element at ambient temperature (baseline).

[0104] In some variations, a reference resistor (Rreference) may be used to set the target resistance. The ratio of the heater resistance to the reference resistance (Rheater/Rreference) is linearly related to the temperature (above room temp) of the heater, and may be directly converted to a calibrated temperature. For example, a change in temperature of the heater relative to room temperature may be calculated using an expression such as (Rheater/Rreference – 1)* (1/TCR), where TCR is the temperature coefficient of

resistivity for the heater. In one example, TCR for a particular device heater is 0.00014/°C. In determining the partial doses and doses described herein, the temperature value used (e.g., the temperature of the vaporizable material during a dose interval, Ti, described in more detail below) may refer to the unit less resistive ratio (e.g., Rheater/Rreference) or it may refer to the normalized/corrected temperature (e.g., in °C).

[0105] When controlling a vaporization device by comparing a measure resistance of a resistive heater to a target resistance, the target resistance may be initially calculated and may be factory preset and/or calibrated by a user-initiated event. For example, the target resistance of the resistive heater during operation of the apparatus may be set by the percent change in baseline resistance plus the baseline resistance of the resistive heater, as will be described in more detail below. As mentioned, the resistance of the heating element at ambient is the baseline resistance. For example, the target resistance may be based on the resistance of the resistive heater at an ambient temperature and a target change in temperature of the resistive heater.

[0106] As mentioned above, the target resistance of the resistive heater may be based on a target heating element temperature. Any of the apparatuses and methods for using them herein may include determining the target resistance of the resistive heater based on a resistance of the resistive heater at ambient temperature and a percent change in a resistance of the resistive heater at an ambient temperature.

[0107] Consistent with certain implementations described herein, the resistance of the resistive heater of a vaporizer device may be measured (using a resistive measurement circuit) and compared to a target resistance by using a voltage divider. Alternatively or additionally any of the methods and apparatuses described herein may compare a measured resistance of the resistive heater to a target resistance using a Wheatstone bridge and thereby adjust the power to increase/decrease the applied power based on this comparison.

[0108] In any of the variations described herein, adjusting the applied power to the resistive heater may comprise comparing the resistance (actual resistance) of the resistive heater to a target resistance using a voltage divider, Wheatstone bridge, amplified Wheatstone bridge, or RC charge time circuit.

[0109] When using resistance and/or power applied to determine the temperature of the apparatus and/or to control temperature for vaporization, there may be a surprising disparity between the actual temperature and that predetected or determined using resistance of the heater alone. This problem becomes particularly acute when the distance between the heating element (e.g. resistive coil) and the electrical input into the cartridge (the power contacts from the vaporizer base) is long (as shown in FIG. 15A), or there is a change in the conductive material between the heater and the contacts. Where there is a change in the conductive material between the contacts, the electrical wiring, and the resistive coil, thermoelectric effects arising due to this change in electrical characteristics (resistance) may give rise to inaccuracies when determining the power applied.

[0110] In the example cartridges described above, the heating coil may be connected to the electrical contacts by extension wires 1054, 1054' (see, e.g., FIG. 10B). Because the extension wires are different materials, a voltage (EMF) may be generated at the junction between the different electrical conductors when there is a temperature gradient. This thermoelectric effect may be referred to as the Seebeck effect, and may generate a voltage that is based on the material properties of the different conductors. In the implementations described above, although the heating coil, extensions, and wick are nearly symmetric, during normal usage there may be uneven temperatures across the three, developing a temperature gradient. This may result in an uneven voltage being generated; this disparity may then lead to inaccuracies in controlling the heater (applied power) and/or estimation of the temperature.

[0111] Although at any particular time, the effect may be relatively minor (and therefore overlooked), the cumulative effect may lead to dramatic reductions in accuracy and temperature control; other systems may attempt to avoid this problem by modifying the resistance of the material used for the resistive heater, requiring a larger power; although this may reduce the overall contribution of the offset EMF voltage due to the thermoelectric property mismatch, it also requires a larger wattage and therefore battery (and resulting power) be applied.

[0112] Instead, any of the apparatuses described herein may include a precision resistance measurement circuit to track resistance of the heating element (e.g., a coil made from resistive heating alloy wire) when not heating and heating to control the temperature of the coil based on changes in coil resistance from room temperature to vaporization temperatures, as discussed above. For example, in some implementations, the measurement circuit is an amplified Wheatstone bridge where the heating element (when connected) is one half of one of the two voltage dividers in the Wheatstone bridge and the two divider voltages are inputs to a differential op amp circuit. This control circuit may be modified as described herein to account for the mismatch in thermoelectric properties leading to the offset voltage.

[0113] Currently known resistance measurement systems typically use a two-terminal sensing or four-terminal sensing circuit, and are prone to measurement error when the load to be measured is also a voltage source or has an additional unknown voltage applied to it. As just mentioned above, in vaporizers that use resistive heating elements (often coils), extension leads are often used to route power to the heating element with minimal Joule heating and losses in the path between the heating element (where Joule heating is desired) and the voltage source (often a battery or power supply). For manufacturability, these extension leads are often the only connection between the device (or contacts that connect to the device) and the heating element, so measurement of the resistance of the heating element invariably includes the

resistance of the extension leads and measurement error arising from the mismatched thermoelectric properties (Seebeck error). The heating element and extension leads (three conductors if considered individually) each have some temperature gradient along their lengths, and this temperature gradient generates an electromotive force (EMF, which is also a measureable voltage when the conductor is open circuit) in each conductor, which is Eemf = -S∇T, where S is the Seebeck coefficient of the conductor which depends heavily on the conductor material (but also on temperature of the conductor) and ∇T is the temperature gradient across the material. Because ideal materials for the heating element and extension leads often have different Seebeck coefficients, and since the temperatures at the two connection points between each extension lead and the heating element are likely to differ while heating (due to acceptable asymmetries in both heating element assembly and heat transferred from the heating element and extension leads that are expected in a mass-produced product), there will be a net EMF across the extensions and heating element (seen as one load in any vaporization system where one set of extension leads electrically connects the heating element to the device) which will skew the resistance measurement, making temperature control of the heating element using measured resistance impossible without correction for this effect. More generally, measured resistance of the heating element will be skewed by the mismatched thermoelectric properties (e.g., the Seebeck effect) whenever there is a temperature difference between and material transition at the two heating element terminals where contacts or extensions are connected.

[0114] A simplified model of a heating element with two extension leads of the same material is shown in FIG. 17. In this example, the heating element and extension lead combination connects to the device at the open ends of the extension leads shown above, so the resistance measurement of the heating element is taken through the extension leads connecting to it. S1 and S3 are constant coefficients that depend on the material properties

(Seebeck coefficients) of each of the two extension lead materials, and S2 is the Seebeck coefficient of the heating element. T1 and T4 are temperatures at the ends of the extensions that electrically connect to the vaporization device. T2 and T3 are temperatures of the connections between the extension leads and heating element (which may be welds, crimps, solder joints, or other electrical connections). The EMF, Enet is expected to skew the resistance measurement if Enet is non-zero. Enet from the Seebeck effect is expected to be:

[0115] Enet = -S1(T2 - T1) – S2(T3 - T2) – S3(T4 - T3).

[0116] To illustrate how temperature differences between T2 and T3 can create a non-zero Enet, consider a further simplified model where temperatures at the two open (as shown) ends of the conductive path are assumed to be the same and close to the device temperature (T1 = T4), which is an acceptable simplification in systems like ours where extensions connect to electrical contacts with large thermal mass at T1 and T4. Seebeck coefficients for the two extensions are assumed to be the same since the two extension leads are of the same material (S1 = S3). This reduces the above expression to:

[0117] Enet = (S2 – S1)(T2 – T3)

[0118] From the above expression, if S2 and S1 are not equal (heating element and extension leads have different Seebeck coefficients) and T2 and T3 are not equal (non-zero net temperature gradient across the two points where heating element meets extensions), Enet will not be zero, and it will skew the resistance measurement taken by the device. For comparison, if there are no extension leads, EMF for the heating element alone can be considered:

[0119] Enet = S2(T2 – T3)

[0120] When the heating element is connected directly to electrical contacts that are large thermal masses, it is expected (and can be measured) that T2 and T3 are very close and Seebeck effect introduces negligible error in resistance measurement. In other systems where

extension leads are used, the Seebeck effect will skew measured resistance, making temperature control impossible when Seebeck effect is not corrected for.

[0121] Additionally, some systems without extension leads may still see a temperature difference between T2 and T3 depending on the device and heating element assembly. If this temperature difference is significant, this effect may need to be corrected for accurate resistance measurements. The simple model above with extension leads and heating element is provided to illustrate the source of heating element EMF. In most systems there will be additional material transitions and temperature gradients in each material in the resistance measurement path. As described below, a complete understanding or modeling of all material transitions and junction temperatures is not needed to correct for this effect. The heating element EMF (caused by the Seebeck effect) can simply be measured and used to correct for the error it introduces in resistance measurements.

[0122] In a vaporization device consistent with implementations described herein that uses measured heating element resistance for temperature control of the heating element as described above, heating element EMF may also measure and used to control the power applied and/or estimates of temperature. The Seebeck effect may be observed to be the main contributor to heating element EMF and is the only known contributor to heating element EMF when no current (or constant current) has been flowing through the element for some time. Measured heating element EMF can be used to correct for resistance measurement error caused by heating element EMF. The resistance measurement (skewed by Seebeck EMF) and the Seebeck EMF measurement together can be used to calculate accurate heating element resistances, which can be used to control average temperature of the heating element.

[0123] The effect of heating element EMF on the resistance measurement depends on the measurement circuit used. Heating element EMF will produce measurement error in all known resistance measurement circuits, so heating element EMF may be separately measured

to correct for the error it causes in the resistance measurement. Sensitivity of the resistance measurement to heating element EMF may be understood so that measured heating element EMF can be used correctly to calculate heating element resistance from the two measurements taken. For example, the same differential op-amp used for the resistance measurement may also be used for the heating element EMF measurement. In the resistance measurement, the heating element may be powered through a voltage divider so that there is a measureable voltage across the heater which is compared against a reference voltage or summed with other reference voltages and amplified by the differential op amp circuit. For heating element EMF measurement, no voltage is applied to the heating element, which allows for direct measurement of the EMF, which is compared against another close reference voltage and amplified by the same differential op amp circuit used for the resistance measurement.

[0124] Because the same amplification circuit may be used, the sensitivities of both the resistance measurement and the heating element EMF measurement to heating element EMF will be the same. The two measurements may then be used to calculate accurate heating element resistances, the raw reading difference between measured heating element EMFs when the device is heating and when device has not been heating for some time (note that Seebeck EMF is 0 when heating element reaches thermal equilibrium in device) and may be subtracted from the raw resistance measurement reading before other calculations are performed to yield heating element resistance from corrected resistance measurement reading.

[0125] FIG. 18 illustrates one example of a measurement circuit that may be used as part of a vaporization apparatus in accordance with certain implementations of the current subject matter. Operation of this circuit to control heating element resistance while heating may be as follows (with signal and component names below referencing signals and components from schematic of FIG. 18); except for H+ 1821, all output boxes (1801, 1803, 1805, 1807, 1809, 1811, 1813) are connected to the microcontroller, which is not shown; timing

noted below is for one exemplary software implementation and may be different or modified for different implementations). Heating element is connected between H+ 1821 and GND.

[0126] In FIG. 18, when device is heating, HEATER 1807 is driven with PWM to connect VBAT to H+ 1821 through Q5 (powering heating element with battery voltage) at some duty cycle to generate a known power in the heating element. When device is heating or in a wake state but not heating, every 3.9ms (256Hz measurement), HEATER 1807 is held off and HM_PWR 1805 is held on (powering differential op-amp circuit and voltage references required for measurements) for 268μs so that either the heating element resistance or heating element EMF can be measured. Heating element resistance and EMF are each measured every 7.8ms (each is measured during every other measurement window). The first 200us of this 268μs measurement window is settling time for the op-amp output as seen by microcontroller (HM_OUT 1809) to stabilize. ADC is performed by the microcontroller on HM_OUT 1809 between AREF_HM_OUT 1801 and GND during the last 68μs of the measurement window. For the heating element resistance measurement, HM_NEG_REF_EN 1803 is on to bias the heating element so that the voltage divider formed by R19 and the heating element can compared by the differential op amp circuit (comprised of U5, R21, R22, R23, and R33) against a fixed voltage divider formed by R20 and R32, and some combination of R28, R29, and R30, which are used to keep HM_OUT 1809 in a usable voltage range between AREF_HM_OUT 1801 and GND for the range of heating element resistances that the device might see. HM_SCALE_0-2 1813 are either allowed to float (high impedance) or connected to GND within the microcontroller to use R28-30 to set the resistance measurement range of the circuit.

[0127] For the heating element EMF measurement, HM_NEG_REF_EN 1803 is off to allow H+ to float to a voltage that is the heating element EMF (relative GND) and SEEBECK_REF_EN 1815 is on to make the fixed reference used by the differential op amp circuit close enough to heating element EMF that HM_OUT 1809 will be usable (will be

between AREF_HM_OUT 1801 and GND) over the range of heating element EMFs expected when heating element is heated. Heating element EMF may be as high as +/-3mV. The heating element EMF measurement circuit can measure between +/-5mV. The measurement circuit yields a non-zero ADC value when device has not been heating for some time and EMF is 0; this value is used to "zero" the heating element EMF readings when used in resistance calculations. Resistance calculations are as follows:

[0128] Heating Element Resistance = (resistance measurement ADC raw – (EMF measurement ADC raw – EMF measurement ADC zero)) * resistance measurement sensitivity + resistance measurement offset.

[0129] Resistance measurement sensitivities and offsets may depend on the active resistance measurement scale (selected using HM_SCALE_0-2 1813) and may be solved for using circuit component values and then included in the device (e.g., in the firmware, hardware or software of the apparatus).

[0130] Baseline resistance (measured resistance when heating element has not been heated for some time) may be used to calculate a target resistance that corresponds to a target average heating element temperature based on the heating element's resistivity vs. temperature curve.

[0131] The resistance measurement circuit may be a two-terminal sensing circuit, as just discussed. In other variations, a four-terminal sensing may be used to mitigate effects of variable contact resistance and trace or lead resistance in series with the heating element resistance measurement. Changing contact resistance and trace/lead resistance have a negligible impact on resistance measurement and temperature control, but these effects may be more pronounced in variations which have a lower resistance heating element and different heating element and device assembly. In this case, a four-terminal (also known as four-point) resistance and EMF measurement circuit, such as the one shown in FIG. 19, may be used.

[0132] Operation of the circuit shown in FIG. 19 to control heating element resistance while heating may be done as follows (with signal and component names below referencing signals and components from schematic above; signals 1903, 1905, 1907, 1909, 1911, 1913, 1915, 1917) are connected to the microcontroller, which is not shown; timing noted below is exemplary only, and may be different). In FIG. 19, HI+ 1822 and HV+ 1826 connect directly to one terminal of the heating element, while HV- 1828 and HI- 1824 connect directly to the other terminal of the heating element.

[0133] When device is heating, HEATER 1907 is driven with PWM to connect VBAT to H+ 1822 through Q2 (powering heating element with battery voltage) at some duty cycle to generate a known power in the heating element.

[0134] When device is heating or in a wake state but not heating, every 3.9ms (256Hz measurement), HEATER 197 is held off and HM_PWR 1905 is held on (powering the differential summing op-amp circuit and voltage references required for measurements) for 268μs so that either the heating element resistance or heating element EMF can be measured. Heating element resistance and EMF are each measured every 7.8ms (each is measured during every other measurement window). The first 200μs of this 268μs measurement window is settling time for the op-amp output as seen by microcontroller (HM_OUT 1915) to stabilize. ADC is performed by the microcontroller on HM_OUT 1915 between AREF_HM_OUT 1913 and GND during the last 68μs of the measurement window.

[0135] For the heating element resistance measurement, HM_WS_ISRC_EN 1903 is on to bias the heating element through R20 and HI+/- terminals so that the voltage across HV+/- can measured by the differential summing op amp circuit (comprised of U2, R19, R23-25, and optionally R10-14, R17, and R21). HM_WS_POS_REF_EN 1903 is on to sum GND through R19 with HV+ through R25. Some combination of HM_SCALE_0-5 are on to sum HV- through R24 with VBAT through some respective combination of R10-14 to keep HM_OUT

1915 in a usable voltage range between AREF_HM_OUT 1913 and GND for the range of heating element resistances that the device might see.

[0136] For the heating element EMF measurement, HM_WS_ISRC_EN 1903 is off to allow HV+ to float to a voltage that is the heating element EMF (relative HV-), HM_WS_POS_REF_EN 1909 is off to sum the R17, R21, R19 voltage divider through R19 with HV+ through R25, and HM_SCALE0-4 1911 are all off to provide no summing and only negative feedback at the negative input of the op-amp. This differential summing configuration keeps HM_OUT 1915 in a usable range (will be between AREF_HM_OUT 1913 and GND) over the range of heating element EMFs expected when heating element is heated. With the values shown above, the heating element EMF measurement circuit can measure between +/- 3.5mV. The measurement circuit yields a non-zero ADC value when device has not been heating for some time and EMF is 0; this value is used to "zero" the heating element EMF readings when used in resistance calculations.

[0137] Resistance calculations are as follows:

[0138] Heating Element Resistance = (resistance measurement ADC raw – (EMF measurement ADC raw – EMF measurement ADC zero)) * resistance measurement sensitivity + resistance measurement offset Resistance measurement sensitivities and offsets depend on the active resistance measurement scale (selected using HM_SCALE_0-4 1911) and may be solved for using circuit component values and then included in the device.

[0139] Baseline resistance (measured resistance when heating element has not been heated for some time) may be used to calculate a target resistance that corresponds to a target average heating element temperature based on the heating element's resistivity vs. temperature curve.

[0140] As described above, the mismatch in thermoelectric properties and the resulting EM (e.g., the Seebeck EMF) can be a potential source of resistance measurement error after

data taken from controlled tests of vaporizer prototypes (e.g., using heating elements with extension leads). A single heating element run with temperature control of the heating element (using measured heating element resistance without correction for this EMF) may consistently run with much higher power when connected in one polarity vs. the other polarity. It was discovered that asymmetries in the heating element (in this case the wick and coil) assembly could consistently produce hotter temperatures at one of the two heating element / extension lead junctions, resulting in consistent offset voltage at operating temperatures that skewed the resistance measurement in one direction with the heating element connected in one polarity and in the other direction with heating element connected in the other polarity. Although measured resistance was controlled during these tests, these devices were not accurately controlling heating element temperatures because measurements were skewed by this offset EMF resulting from the mismatch in thermoelectric properties of the components. With the correction described above, used to correct for the error in resistance measurement, it is observed that heating element polarity does not have an effect on the power required to hold the heating element at operating temperatures during controlled testing, which suggests that this correction yields accurate calculated heating element resistances that remove the effect of the offset EMF, providing much more accurate temperature control of the heating element than when not corrected.

[0141] Thus, in any of the variations described herein, the vaporizer apparatus consistent with implementations of the current subject matter may include an offset correction circuit (also referred to as a Seebeck correction circuit) to correct for the offset voltage resulting from the mismatch in thermoelectric properties between the resistive heating coil and the conductive connectors linking the resistive heating coil to the power input (e.g., from the vaporizer base, including the vaporizer power controller) in the cartridge. The offset correction circuit may be located in the vaporizer base and connected between the coupling connectors

595, 595’ to couple with the cartridge connectors and determine the offset voltage due to the mismatch in thermoelectric properties of the heating (resistive) coil and the wires linking the coil to the connector on the cartridge. Also described herein are methods of correcting for the mismatch (Seebeck effect) in thermoelectric properties between the coil and the wires (electrical extensions) connecting to the electrical connectors.

[0142] DOSE MONITORING

[0143] As mentioned above, vaporizer apparatuses consistent with implementations of the current subject matter described herein may also or alternatively detect and display the dose of material applied. U.S. patent application no. 14/960,259 (filed on 12/4/2015, and published as US-2016-0157524-A1), herein incorporated by reference in its entirety, describes examples of methods for determining dose (and apparatuses including dose determination). Generally these methods may be used to accurately calculate dose based on the power applied to the heater and the temperature of the heater (or a material in contact with the heater) during an immediately before a small increment of time; total dose may be determined by summing these small increments up over a desired time range. These methods may be incorporated herein, and may be made even more accurate by correcting the power applied as described above (e.g., accounting for the offset EMF due to the Seebeck effect).

[0144] Alternatively or additionally, described herein are methods and apparatuses that may provide a rough approximation of dose based on the power applied over time to vaporize the material within the cartridge. This may be referred to herein as the consumption (of the vaporizable material in the cartridge, an indication of consumption) of the cartridge or vaporizable material, or the like. In general, the apparatus may aggregate the power during operation of the apparatus (e.g., the power applied over time during a puff/inhalation and/or the power applied over this time multiplied times the duration of the inhalation).

[0145] The apparatus may further provide an output of the amount of consumption. This output may be, in particular, a qualitative approximation. For example, the output may be incrementally increasing the number, intensity and/or color of one or more LEDs on the surface of the apparatus. For example, in this case, the consumption amount (dose) is not an absolute amount, but is an indicator or readout of the power applied to vaporize the material (power applied to the coils) over time. In FIG. 9C, for example, when the user first installs a cartridge and the apparatus is set up to display consumption/dose, the four LEDS 897 may initially be unlit or lit to the neutral color (e.g., white). As the user draws on the device and vaporizes the material within the cartridge, the number of LEDS illuminated may be increased and the intensity and/or color of illumination may be increased to indicate increasing dosage or consumption; for example the calculation of power applied over time may determine based on a number or predetermined increments, whether to increase the number of illuminated LEDS of a particular color and/or intensity, to change color and/or intensity, etc.

[0146] The accumulated dose may be reset manually (e.g., using an app, shaking the device, etc.) or by removing the cartridge. Alternatively or additionally to the qualitative output described above, a quantitative estimate based on the power may be displayed or output to a remote processor (e.g. smartphone, etc.).

[0147] THERMOCOUPLE AS HEATER

[0148] In vaporizer apparatuses consistent with implementations of the current subject matter described herein, the heater may be configured as a thermocouple junction. See, e.g., FIGS. 20A and 20B. Thus, a thermocouple junction (comprising materials having dissimilar thermoelectric properties) may be used to measure temperature at a point along the heater coil. As discussed above, this may allow an apparatus to resistively determine temperature along the heater coil using the thermoelectric properties described above. Thus, similar to what is described above, the heating element performs both as a heater and a temperature sensor. For

example, a resistive heater may comprised of two dissimilar conductors (e.g., stainless steel and titanium) welded together, as shown in FIG. 20A. When the heater (heating coil) heats up, the dissimilar material will be heated differentially, resulting in a temperature gradient and a resulting offset voltage (EMF), due to the Seebeck effect discussed above, at the junction of the two dissimilar materials. This effect may be used to determine the temperature at that junction (whereas typically, we determine the average temperature of the entire heater by using TCR, temperature coefficient of resistance, as also discussed above.

[0149] The Seebeck effect also occurs at the junction between the heater end poles and passive electrical conduits. Although the correction circuits discussed above are aimed at correcting for the effect, it may also be possible to take advantage of the effect for a more localized temperature measurement. Compare, FIG. 20B to FIG. 20A, for example. In FIG. 20A, the junction is located in the middle of the heating element, and determining the offset voltage in this case, which is based on the temperature, may allow accurate temperature determination. This embodiment may be particularly relevant for a convection vaporizer, where you likely have a (relatively) large heater and you care about the temperature at just the air outlet end.

[0150] In vaporization systems where the heating element is connected to the device through extension leads, if Seebeck coefficients are known for both materials, the measured Seebeck EMF can be used to determine the net temperature gradient across the heating element. With some modeling, this measurement could be used to approximately control maximum heating element temperature instead of or in addition to average heating element temperature. This measurement can also be used to perform quality control where the heating element assembly is manufactured. In vaporization systems where the heating element is connected to the device through extension leads and the heating element is used to primarily heat air, if Seebeck coefficients are known for both materials, Seebeck EMF can be used to determine the

net temperature gradient across the heating element, which with a known air flow path and thermal modeling of the system can be used to predict average air temperature at some point down-stream of the heating element. As mentioned above, this may be particularly advantageous in convection (hot-air) vaporization systems as two measurements (resistance and Seebeck EMF) taken from the actuator can allow for accurate temperature control of air flowing from the outlet of the heating element without additional sensors in the air path or connected to the heating element.

[0151] As shown in FIG. 20A, the Seebeck effect alone or the Seebeck effect in conjunction with resistance measurement can be used for temperature control of a heating element that has a material transition (junction) at the position where temperature is to be controlled. This is essentially creating a thermocouple out of resistive heating alloys so that the Seebeck EMF can be measured in order to control temperature at the hot junction of the thermocouple resistive heater. The junction could be positioned where the heating element is expected to be hottest to control maximum temperature of the heating element. The control algorithm could use a target average temperature of the heating element (calculated using resistance and EMF measurements) as well as a maximum acceptable max temperature of the heating element (calculated using just the EMF measurement). A device that knows both the average temperature of the heating element and the maximum temperature of the heating element could know more about the temperature gradient along the heating element and be better at predicting mass of material vaporized while heating than a device that only knows either maximum or average heating element temperature (device knowing precise mass of material vaporized is critical for dose-control in vaporizers). If extensions are used in such a system, they could be the same material as the intended heating element but much larger gauge for reduced losses in the extensions. Alternatively, extensions with Seebeck coefficients that are very similar to the Seebeck coefficients of the two heating element sections could be used

so that Seebeck EMF is still usable for temperature control of the hot junction (small contribution of heating element / extension junctions to net Seebeck EMF).

[0152] VAPORIZERS WITHOUT CARTRIDGES

[0153] Any of the features described herein may be incorporated into a vaporizer apparatus that does not require the uses of a separate (e.g., removable cartridge), including vaporizer apparatuses such as loose-leaf vaporizer apparatuses.

[0154] Such apparatuses are described, for example, in each of the following applications, herein incorporated by reference in their entirety: U.S. Patent Application No. 13/837,438, filed on Mar. 15, 2013, Publication No. US 2013-0312742 A1; U.S. Patent Application No. 15/166,001, filed on May 26, 2016, Publication No. US 2016-0262459 A1; U.S. Patent Application No. 14/581,666, filed on Dec. 23, 2014, Publication No. US 2015-0208729 A1; U.S. Patent Application No. 15/053,927, filed on Feb. 25, 2016, Publication No. US 2016-0174611 A1; U.S. Patent Application No. 15/257,748, filed on Sep. 6, 2016; U.S. Patent Application No. 15/257,760, filed on Sep. 6, 2016, Publication No. US 2016-0374399 A1; and U.S. Patent Application No. 15/257,768, filed on Sep. 6, 2016, Publication No. US 2016-0366947 A1.

[0155] For example such a device may include preset functionality and allow the user to enter temperature set mode by holding down on a button (on or under the mouthpiece) for >0.6 seconds. Pressing the button again, for example, cycles through the 4+1 presets. To exit temperature set, again hold the button for >0.6 sec. The presets may be, e.g., : 180C, 193C, 204C, 216C.

[0156] Any of the apparatuses described herein may include haptic feedback that may include distinct profiles for different events: For example:

[0157] /‾\ - trapezoid - power on, and Bluetooth connect

[0158] || - quick click - manual power off, and Bluetooth disconnect

[0159] ⎸‾⎸⎸‾⎸ - 2 long clicks - temperature reached

[0160] ⎸‾⎸ - 1 long click - entered low temperature standby , and auto shutoff

[0161] Also the user may change the intensity of these envelopes via the app.

[0162] With reference to FIG. 23, a process flow chart 2300 illustrates features of a method, which may optionally include some or all of the following. At 2310, operations including heating and causing vaporization of a vaporizable material into air drawn into a vaporizer device along an air flow path having an air flow axis are performed. The air flow path connects an air inlet via which air from outside the vaporizer device enters the vaporizer device and a mouthpiece configured to deliver an aerosol comprising the vaporizable material to a user. At 2320, the air is passed over a pad positioned within or proximate to the mouthpiece, the pad configured to capture deposited and/or condensed liquid from the air without requiring the air to pass through the pad.

[0163] Although the disclosure, including the figures, described herein may described and/or exemplify these different variations separately, it should be understood that all or some, or components of them, may be combined.

[0164] Although various illustrative embodiments are described above, any of a number of changes may be made to various embodiments. For example, the order in which various described method steps are performed may often be changed in alternative embodiments, and in other alternative embodiments one or more method steps may be skipped altogether. Optional features of various device and system embodiments may be included in some embodiments and not in others. Therefore, the foregoing description is provided primarily for exemplary purposes and should not be interpreted to limit the scope of the claims.

[0165] When a feature or element is herein referred to as being “on” another feature or element, it can be directly on the other feature or element or intervening features and/or elements may also be present. In contrast, when a feature or element is referred to as being

"directly on" another feature or element, there are no intervening features or elements present. It will also be understood that, when a feature or element is referred to as being "connected", "attached" or "coupled" to another feature or element, it can be directly connected, attached or coupled to the other feature or element or intervening features or elements may be present. In contrast, when a feature or element is referred to as being "directly connected", "directly attached" or "directly coupled" to another feature or element, there are no intervening features or elements present. Although described or shown with respect to one embodiment, the features and elements so described or shown can apply to other embodiments. References to a structure or feature that is disposed "adjacent" another feature may have portions that overlap or underlie the adjacent feature.

[0166] Terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. For example, 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 "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items and may be abbreviated as "/".

[0167] Spatially relative terms, such as "under", "below", "lower", "over", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will 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 a device in the figures is inverted, elements described as "under" or "beneath" other elements or features

would then be oriented "over" the other elements or features. Thus, the exemplary term "under" can encompass both an orientation of over and under. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly. Similarly, the terms "upwardly", "downwardly", "vertical", "horizontal" and the like are used herein for the purpose of explanation only unless specifically indicated otherwise.

[0168] Although the terms "first" and "second" may be used herein to describe various features/elements (including steps), these features/elements should not be limited by these terms, unless the context indicates otherwise. These terms may be used to distinguish one feature/element from another feature/element. Thus, a first feature/element discussed below could be termed a second feature/element, and similarly, a second feature/element discussed below could be termed a first feature/element without departing from the teachings provided herein.

[0169] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising" means various components can be co-jointly employed in the methods and articles (e.g., compositions and apparatuses including device and methods). For example, the term "comprising" will be understood to imply the inclusion of any stated elements or steps but not the exclusion of any other elements or steps.

[0170] As used herein in the specification and claims, including as used in the examples and unless otherwise expressly specified, all numbers may be read as if prefaced by the word "about" or "approximately," even if the term does not expressly appear. The phrase "about" or "approximately" may be used when describing magnitude and/or position to indicate that the value and/or position described is within a reasonable expected range of values and/or positions. For example, a numeric value may have a value that is +/- 0.1% of the stated value

(or range of values), +/- 1% of the stated value (or range of values), +/- 2% of the stated value (or range of values), +/- 5% of the stated value (or range of values), +/- 10% of the stated value (or range of values), etc. Any numerical values given herein should also be understood to include about or approximately that value, unless the context indicates otherwise.

[0171] The examples and illustrations included herein show, by way of illustration and not of limitation, specific embodiments in which the subject matter may be practiced. As mentioned, other embodiments may be utilized and derived there from, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. Although specific embodiments have been illustrated and described herein, any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, are possible.

[0172] In the descriptions above and in the claims, phrases such as "at least one of" or "one or more of" may occur followed by a conjunctive list of elements or features. The term "and/or" may also occur in a list of two or more elements or features. Unless otherwise implicitly or explicitly contradicted by the context in which it used, such a phrase is intended to mean any of the listed elements or features individually or any of the recited elements or features in combination with any of the other recited elements or features. For example, the phrases "at least one of A and B;" "one or more of A and B;" and "A and/or B" are each intended to mean "A alone, B alone, or A and B together." A similar interpretation is also intended for lists including three or more items. For example, the phrases "at least one of A, B, and C;" "one or more of A, B, and C;" and "A, B, and/or C" are each intended to mean "A alone, B alone, C alone, A and B together, A and C together, B and C together, or A and B and

C together." Use of the term "based on," above and in the claims is intended to mean, "based at least in part on," such that an unrecited feature or element is also permissible.

[0173] The implementations set forth in the foregoing description do not represent all implementations consistent with the subject matter described herein. Instead, they are merely some examples consistent with aspects related to the described subject matter. Although a few variations have been described in detail herein, other modifications or additions are possible. In particular, further features and/or variations can be provided in addition to those set forth herein. For example, the implementations described above can be directed to various combinations and sub-combinations of the disclosed features and/or combinations and sub-combinations of one or more features further to those disclosed herein. In addition, the logic flows depicted in the accompanying figures and/or described herein do not necessarily require the particular order shown, or sequential order, to achieve desirable results. The scope of the following claims may include other implementations or embodiments.

CLAIMS

1. A cartridge device comprising:

a cartridge body extending in a distal to proximal axis and having a width and a diameter that are transverse to the distal to proximal axis, the cartridge body further having a proximal body end and a distal body end opposite the proximal body end along the distal to proximal axis;

a reservoir formed within the cartridge body, the reservoir configured to contain a vaporizable material;

a back piece forming a distal reservoir end of the reservoir and being sealed to the cartridge body from within the cartridge body;

a mouthpiece at the proximal body end of the cartridge body;

a bottom cover plate forming a distal end of the cartridge device, the bottom cover plate opposite the mouthpiece, the bottom cover plate comprising an external surface of the cartridge device, wherein an air chamber is formed between the back piece and the bottom cover plate;

an air flow path extending between the air chamber and the mouthpiece, the air flow path extending through the reservoir;

a heater within the air flow path;

a pair of electrical contacts in electrical communication with the heater; and

one or more air openings on the external surface of the cartridge device, wherein the one or more openings are fluidly connected with the air flow path.

2. The cartridge device of claim 1, wherein the pair of electrical contacts are positioned at the distal end of the cartridge device.

3. The cartridge device of any one of claims 1 to 2, wherein the cartridge body comprises internal sidewalls, and wherein the air chamber is formed between the bottom cover plate and the sidewalls.

4. The cartridge device of any one of claims 1 to 3, wherein the air chamber is enclosed within the distal body end of the cartridge body.

5. The cartridge device of any one of claims 1 to 4, wherein the heater is configured to heat and cause vaporization of the vaporizable material into the air flow path to form an aerosol, and wherein the mouthpiece is configured to deliver the aerosol to a user.

6. The cartridge device of any one of claims 1 to 5, wherein the mouthpiece is configured to fit over the proximal body end of the cartridge body.

7. The cartridge device of any one of claims 1 to 6, wherein the heater comprises a heating element and a wicking structure configured to draw the vaporizable material into the heater.

8. The cartridge device of claim 7, wherein the wicking structure comprises silica fibers, cotton, ceramic, and/or a stainless steel mesh.

9. The cartridge device of any one of claims 7 to 8, further comprising a housing piece configured to form a vaporization chamber comprising at least a portion of the heater that is separated from the reservoir.

10. The cartridge device of claim 9, wherein the wicking structure extends through one or more openings in the vaporization chamber such that the wicking structure is in fluid communication with the vaporizable material in the reservoir.

11. The cartridge device of any one of claims 1 to 10, wherein the back piece is sealed to the cartridge body by one or more seals, wherein the one or more seals comprises an o-ring.

12. The cartridge device of any one of claims 1 to 11, wherein the back piece is configured to be inserted into the distal body end of the cartridge body.

13. The cartridge device of any one of claims 1 to 12, wherein the one or more air openings are formed through the bottom cover plate.

14. The cartridge device of any one of claims 1 to 13, further comprising an air tube extending through the reservoir, wherein the air flow path extends through the air tube.

15. The cartridge device of any one of claims 1 to 14, further comprising one or more absorbent pads within the air chamber, wherein the one or more absorbent pads are configured to capture deposited and/or condensed liquid without requiring air to pass through the one or more absorbent pads.

16. The cartridge device of claim 15, wherein the one or more absorbent pads are parallel with one another, wherein a gap is formed between the one or more absorbent pads, and further wherein the one or more absorbent pads extend off-axis relative to the air flow path.

17. The cartridge device of any one of claims 15 to 16 wherein the one or more absorbent pads are positioned within the air chamber along the diameter, off-axis relative to the air flow path.

18. The cartridge device of any one of claims 1 to 17, wherein a length of the air chamber along the distal to proximal axis is between 0.5 and 2 times a length of the reservoir along the distal to proximal axis.

19. The cartridge device of any one of claims 1 to 18, wherein the cartridge body is elongate and flattened to form an approximately oval cross-sectional area transverse to the distal to proximal axis.

20. The cartridge device of any one of claims 1 to 19, wherein the diameter of the cartridge body is 1.2 times or greater than the width of the cartridge body.

21. A vaporizer device comprising:

a cartridge device according any of claims 1 to 20;

a reusable vaporizer device body having a proximal device end and a distal device end, the proximal device end including an opening into a cartridge receiver region configured to insertably receive the cartridge device.

22. The vaporizer device of claim 21, wherein the reusable vaporizer device body comprises a shell having air inlets configured to allow airflow into the cartridge receiver region, the air inlets formed through opposing sides of the shell, and the air inlets in fluid communication with the air flow path when the cartridge device is insertably received within the cartridge receiver region.

23. The vaporizer device of any one of claims 21 to 22, wherein the distal end of the cartridge device is configured to be secured by a friction fit within the cartridge receiver region.

24. The vaporizer device of any one of claims 21 to 23, wherein the reusable vaporizer device body comprises a pair of connectors configured to electrically communicate with the pair of electrical contacts of the cartridge device.

25. A vaporizer device comprising:

a cartridge comprising:

a reservoir configured to contain a vaporizable material;

a mouthpiece configured to deliver an aerosol comprising the vaporizable material to a user, the mouthpiece at a proximal end of the cartridge;

an air flow path having an air flow path axis;

an air inlet via which air from outside the cartridge enters the cartridge;

a heating element configured to heat and cause vaporization of the vaporizable material into air drawn into the cartridge along the air flow path, the air flow path connecting the air inlet and the mouthpiece, the air flow path passing proximate to the heating element; and

an overflow leak chamber at a distal end of the cartridge, opposite the mouthpiece; and

a reusable vaporizer device body having a proximal device end and a distal device end, the proximal device end including an opening into a cartridge receiver region configured to insertably receive the cartridge.

26. The vaporizer device of claim 25, wherein the cartridge further comprises a pair of electrical contacts on the distal end of the cartridge, the pair of electrical contacts in electrical communication with the heater, and wherein the reusable vaporizer device body further comprises a pair of connectors configured to electrically communicate with the pair of electrical contacts.

27. The vaporizer device of any one of claims 25 to 26, wherein the cartridge further comprises sidewalls and a bottom cover plate, wherein the overflow leak chamber is formed between the sidewalls and the bottom cover plate.

28. The vaporizer device of claim 27, wherein the cartridge further comprises a back piece, wherein the bottom cover plate forms a distal end of the cartridge, the bottom cover plate opposite the mouthpiece, and wherein the overflow leak chamber is formed between the back piece and the bottom cover plate.

29. The vaporizer device of claim 28, wherein the reservoir is configured to contain a vaporizable material within an internal volume of the reservoir, the internal volume being at least partially defined by the device body and a proximal portion of the back piece.

30. The vaporizer device of any one of claims 25 to 29, wherein the bottom cover plate comprises an external surface of the cartridge, and wherein the bottom cover plate further comprises one or more air openings fluidly connected with the air flow path.

31. The vaporizer device of any one of claims 25 to 30, wherein the air flow path extends between the overflow leak chamber and the mouthpiece.

32. The vaporizer device of any one of claims 25 to 31, wherein the mouthpiece is attached over the reservoir.

33. The vaporizer device of any one of claims 25 to 32, wherein the overflow leak chamber is enclosed within the distal end of the cartridge.

34. The vaporizer device of any one of claims 25 to 33, wherein the cartridge further comprises an air tube extending through the reservoir, wherein the air flow path extends through the air tube.

35. The vaporizer device of any one of claims 25 to 34, wherein the cartridge further comprises one or more absorbent pads within the overflow leak chamber and off-axis from the air flow axis, wherein the one or more absorbent pads are configured to capture deposited and/or condensed liquid without requiring air to pass through the pad.

36. The vaporizer device of claim 35, wherein the one or more absorbent pads is biased against a respective sidewall of the cartridge.