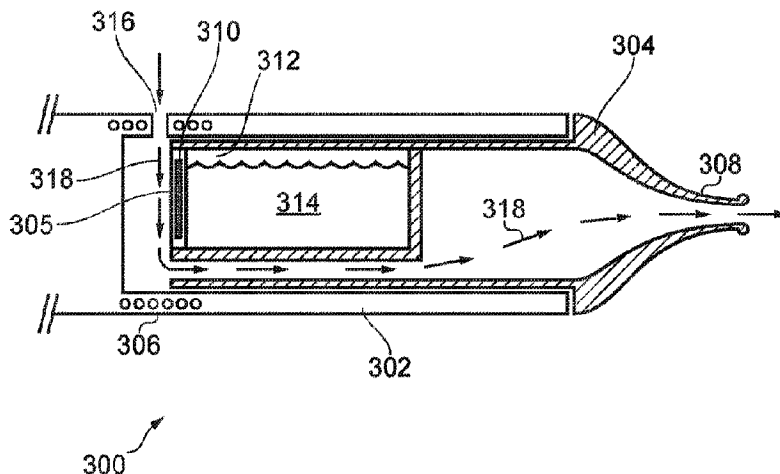




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(57) **Abrégé/Abstract:**

Inductive heating assemblies for generating an aerosol from an aerosol precursor material in an aerosol provision system are disclosed. The inductive heating assemblies include a susceptor, and a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor. In one inductive heating assembly, the susceptor comprises regions of different electrical resistivity, such that when in use the surface of the susceptor in the regions of different electrical resistivity are heated to different temperatures by the current flow induced by the drive coil. In another inductive heating assembly, the susceptor comprises openings defined by walls which disrupt the flow of induced current within the susceptor. In yet another inductive heating assembly, the susceptor comprises slotted openings extended inwardly from a periphery of the susceptor.

ELECTRONIC AEROSOL PROVISION SYSTEMS

ABSTRACT

Inductive heating assemblies for generating an aerosol from an aerosol precursor material in
5 an aerosol provision system are disclosed. The inductive heating assemblies include a
susceptor, and a drive coil arranged to induce current flow in the susceptor to heat the
susceptor and vaporise aerosol precursor material in proximity with a surface of the
susceptor. In one inductive heating assembly, the susceptor comprises regions of different
10 different electrical resistivity, such that when in use the surface of the susceptor in the regions of
different electrical resistivity are heated to different temperatures by the current flow induced
by the drive coil. In another inductive heating assembly, the susceptor comprises openings
defined by walls which disrupt the flow of induced current within the susceptor. In yet another
inductive heating assembly, the susceptor comprises slotted openings extended inwardly
from a periphery of the susceptor.

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ELECTRONIC AEROSOL PROVISION SYSTEMS

Field

5 The present disclosure relates to electronic aerosol provision systems such as electronic nicotine delivery systems (e.g. e-cigarettes).

Background

10 Figure 1 is a schematic diagram of one example of a conventional e-cigarette 10. The e-cigarette has a generally cylindrical shape, extending along a longitudinal axis indicated by dashed line LA, and comprises two main components, namely a control unit 20 and a cartomiser 30. The cartomiser includes an internal chamber containing a reservoir of liquid formulation including nicotine, a vaporiser (such as a heater), and a mouthpiece 35. The cartomiser 30 may further include a wick or similar facility to transport a small amount of
15 liquid from the reservoir to the heater. The control unit 20 includes a re-chargeable battery to provide power to the e-cigarette 10 and a circuit board for generally controlling the e-cigarette. When the heater receives power from the battery, as controlled by the circuit board, the heater vaporises the nicotine and this vapour (aerosol) is then inhaled by a user through the mouthpiece 35.

20 The control unit 20 and cartomiser 30 are detachable from one another by separating in a direction parallel to the longitudinal axis LA, as shown in Figure 1, but are joined together when the device 10 is in use by a connection, indicated schematically in Figure 1 as 25A and 25B, to provide mechanical and electrical connectivity between the control unit 20 and the cartomiser 30. The electrical connector on the control unit 20 that is used to connect
25 to the cartomiser also serves as a socket for connecting a charging device (not shown) when the control unit is detached from the cartomiser 30. The cartomiser 30 may be detached from the control unit 20 and disposed of when the supply of nicotine is exhausted (and replaced with another cartomiser if so desired).

30 Figures 2 and 3 provide schematic diagrams of the control unit 20 and cartomiser 30 respectively of the e-cigarette of Figure 1. Note that various components and details, e.g. such as wiring and more complex shaping, have been omitted from Figures 2 and 3 for reasons of clarity. As shown in Figure 2, the control unit 20 includes a battery or cell 210 for powering the e-cigarette 10, as well as a chip, such as a (micro)controller for controlling the e-cigarette 10. The controller is attached to a small printed circuit board (PCB) 215 that also
35 includes a sensor unit. If a user inhales on the mouthpiece, air is drawn into the e-cigarette through one or more air inlet holes (not shown in Figures 1 and 2). The sensor unit detects

this airflow, and in response to such a detection, the controller provides power from the battery 210 to the heater in the cartomiser 30.

As shown in Figure 3, the cartomiser 30 includes an air passage 161 extending along the central (longitudinal) axis of the cartomiser 30 from the mouthpiece 35 to the connector 25A for joining the cartomiser to the control unit 20. A reservoir of nicotine-containing liquid 170 is provided around the air passage 161. This reservoir 170 may be implemented, for example, by providing cotton or foam soaked in the liquid. The cartomiser also includes a heater 155 in the form of a coil for heating liquid from reservoir 170 to generate vapour to flow through air passage 161 and out through mouthpiece 35. The heater is powered through lines 166 and 167, which are in turn connected to opposing polarities (positive and negative, or vice versa) of the battery 210 via connector 25A.

One end of the control unit provides a connector 25B for joining the control unit 20 to the connector 25A of the cartomiser 30. The connectors 25A and 25B provide mechanical and electrical connectivity between the control unit 20 and the cartomiser 30. The connector 25B includes two electrical terminals, an outer contact 240 and an inner contact 250, which are separated by insulator 260. The connector 25A likewise includes an inner electrode 175 and an outer electrode 171, separated by insulator 172. When the cartomiser 30 is connected to the control unit 20, the inner electrode 175 and the outer electrode 171 of the cartomiser 30 engage the inner contact 250 and the outer contact 240 respectively of the control unit 20. The inner contact 250 is mounted on a coil spring 255 so that the inner electrode 175 pushes against the inner contact 250 to compress the coil spring 255, thereby helping to ensure good electrical contact when the cartomiser 30 is connected to the control unit 20.

The cartomiser connector is provided with two lugs or tabs 180A, 180B, which extend in opposite directions away from the longitudinal axis of the e-cigarette. These tabs are used to provide a bayonet fitting for connecting the cartomiser 30 to the control unit 20. It will be appreciated that other embodiments may use a different form of connection between the control unit 20 and the cartomiser 30, such as a snap fit or a screw connection.

As mentioned above, the cartomiser 30 is generally disposed of once the liquid reservoir 170 has been depleted, and a new cartomiser is purchased and installed. In contrast, the control unit 20 is re-usable with a succession of cartomisers. Accordingly, it is particularly desirable to keep the cost of the cartomiser relatively low. One approach to doing this has been to construct a three-part device, based on (i) a control unit, (ii) a vapouriser component, and (iii) a liquid reservoir. In this three-part device, only the final part, the liquid reservoir, is disposable, whereas the control unit and the vapouriser are both re-usable. However, having a three-part device can increase the complexity, both in terms of manufacture and user operation. Moreover, it can be difficult in such a 3-part device to

provide a wicking arrangement of the type shown in Figure 3 to transport liquid from the reservoir to the heater.

Another approach is to make the cartomiser 30 re-fillable, so that it is no longer disposable. However, making a cartomiser re-fillable brings potential problems, for example, a user may try to re-fill the cartomiser with an inappropriate liquid (one not provided by the supplier of the e-cigarette). There is a risk that this inappropriate liquid may result in a low quality consumer experience, and/or may be potentially hazardous, whether by causing damage to the e-cigarette itself, or possibly by creating toxic vapours.

Accordingly, existing approaches for reducing the cost of a disposable component (or for avoiding the need for such a disposable component) have met with only limited success.

Summary

The invention is defined in the appended claims.

According to a first aspect of certain embodiments there is provided an inductive heating assembly for generating an aerosol from an aerosol precursor material in an aerosol provision system, the inductive heating assembly comprising: a susceptor; and a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor, and wherein the susceptor comprises regions of different susceptibility to induced current flow from the drive coil, such that when in use the surface of the susceptor in the regions of different susceptibility are heated to different temperatures by the current flow induced by the drive coil.

According to a second aspect of certain embodiments there is provided an aerosol provision system comprising an inductive heating assembly for generating an aerosol from an aerosol precursor material in an aerosol provision system, the inductive heating assembly comprising: a susceptor; and a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor, and wherein the susceptor comprises regions of different susceptibility to induced current flow from the drive coil, such that when in use the surface of the susceptor in the regions of different susceptibility are heated to different temperatures by the current flow induced by the drive coil.

According to a third aspect of certain embodiments there is provided a cartridge for use in an aerosol provision system comprising an inductive heating assembly, wherein the cartridge comprises a susceptor that comprises regions of different susceptibility to induced current flow from an external drive coil, such that when in use the surface of the susceptor in the regions of different susceptibility are heated to different temperatures by current flows induced by the external drive coil.

According to a fourth aspect of certain embodiments there is provided an inductive heating assembly means for generating an aerosol from an aerosol precursor material in an aerosol provision system, the inductive heating assembly means comprising: susceptor means; and induction means for inducing current flow in the susceptor means to heat the susceptor means and vaporise aerosol precursor material in proximity with a surface of the susceptor means, wherein the susceptor means comprises regions of different susceptibility to induced current flow from the induction means such that in use the surface of the susceptor means in the regions of different susceptibility are heated to different temperatures by the current flow induced by the induction means.

According to a fifth aspect of certain embodiments there is provided a method of generating an aerosol from an aerosol precursor material, the method comprising: providing an inductive heating assembly comprising a susceptor and a drive coil arranged to induce current flow in the susceptor, wherein the susceptor comprises regions of different susceptibility to induced current flow from the drive coil so the surface of the susceptor in the regions of different susceptibility are heated to different temperatures by current flows induced by the drive coil, and using the drive coil to induce currents in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor to generate the aerosol. It will be appreciated that features and aspects of the invention described above in relation to the first and other aspects of the invention are equally applicable to, and may be combined with, embodiments of the invention according to other aspects of the invention as appropriate, and not just in the specific combinations described above.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic (exploded) diagram illustrating an example of a known e-cigarette.

Figure 2 is a schematic diagram of the control unit of the e-cigarette of Figure 1.

Figure 3 is a schematic diagram of the cartomiser of the e-cigarette of Figure 1.

Figure 4 is a schematic diagram illustrating an e-cigarette in accordance with some embodiments of the invention, showing the control unit assembled with the cartridge (top), the control unit by itself (middle), and the cartridge by itself (bottom).

Figures 5 and 6 are schematic diagrams illustrating an e-cigarette in accordance with some other embodiments of the invention.

Figure 7 is a schematic diagram of the control electronics for an e-cigarette such as shown in Figures 4, 5 and 6 in accordance with some embodiments of the invention.

Figures 7A, 7B and 7C are schematic diagrams of part of the control electronics for an e-cigarette such as shown in Figure 6 in accordance with some embodiments of the invention.

5 Figure 8 schematically represents an aerosol provision system comprising an inductive heating assembly in accordance with certain example embodiments of the present disclosure.

Figures 9 to 12 schematically represent heating elements for use in the aerosol provision system of Figure 8 in accordance with different example embodiments of the present disclosure.

10 Figures 13 to 20 schematically represent different arrangements of source liquid reservoir and vaporiser in accordance with different example embodiments of the present disclosure.

Detailed Description

15 Aspects and features of certain examples and embodiments are discussed / described herein. Some aspects and features of certain examples and embodiments may be implemented conventionally and these are not discussed / described in detail in the interests of brevity. It will thus be appreciated that aspects and features of apparatus and methods discussed herein which are not described in detail may be implemented in accordance with
20 any conventional techniques for implementing such aspects and features.

As described above, the present disclosure relates to an aerosol provision system, such as an e-cigarette. Throughout the following description the term "e-cigarette" is sometimes used but this term may be used interchangeably with aerosol (vapour) provision system.

25 Figure 4 is a schematic diagram illustrating an e-cigarette 410 in accordance with some embodiments of the invention (please note that the term e-cigarette is used herein interchangeably with other similar terms, such as electronic vapour provision system, electronic aerosol provision system, etc). The e-cigarette 410 includes a control unit 420 and a cartridge 430. Figure 4 shows the control unit 420 assembled with the cartridge 430
30 (top), the control unit by itself (middle), and the cartridge by itself (bottom). Note that for clarity, various implementation details (e.g. such as internal wiring, etc) are omitted.

As shown in Figure 4, the e-cigarette 410 has a generally cylindrical shape with a central, longitudinal axis (denoted as LA, shown in dashed line). Note that the cross-section through the cylinder, i.e. in a plane perpendicular to the line LA, may be circular, elliptical,
35 square, rectangular, hexagonal, or some other regular or irregular shape as desired.

The mouthpiece 435 is located at one end of the cartridge 430, while the opposite end of the e-cigarette 410 (with respect to the longitudinal axis) is denoted as the tip end

424. The end of the cartridge 430 which is longitudinally opposite to the mouthpiece 435 is denoted by reference numeral 431, while the end of the control unit 420 which is longitudinally opposite to the tip end 424 is denoted by reference numeral 421.

The cartridge 430 is able to engage with and disengage from the control unit 420 by movement along the longitudinal axis. More particularly, the end 431 of the cartridge is able to engage with, and disengage from, the end of the control unit 421. Accordingly, ends 421 and 431 will be referred to as the control unit engagement end and the cartridge engagement end respectively.

The control unit 420 includes a battery 411 and a circuit board 415 to provide control functionality for the e-cigarette, e.g. by provision of a controller, processor, ASIC or similar form of control chip. The battery is typically cylindrical in shape, and has a central axis that lies along, or at least close to, the longitudinal axis LA of the e-cigarette. In Figure 4, the circuit board 415 is shown longitudinally spaced from the battery 411, in the opposite direction to the cartridge 430. However, the skilled person will be aware of various other locations for the circuit board 415, for example, it may be at the opposite end of the battery. A further possibility is that the circuit board 415 lies along the side of the battery – for example, with the e-cigarette 410 having a rectangular cross-section, the circuit board located adjacent one outer wall of the e-cigarette, and the battery 411 then slightly offset towards the opposite outer wall of the e-cigarette 410. Note also that the functionality provided by the circuit board 415 (as described in more detail below) may be split across multiple circuit boards and/or across devices which are not mounted to a PCB, and these additional devices and/or PCBs can be located as appropriate within the e-cigarette 410.

The battery or cell 411 is generally re-chargeable, and one or more re-charging mechanisms may be supported. For example, a charging connection (not shown in Figure 4) may be provided at the tip end 424, and/or the engagement end 421, and/or along the side of the e-cigarette. Moreover, the e-cigarette 410 may support induction re-charging of battery 411, in addition to (or instead of) re-charging via one or more re-charging connections or sockets.

The control unit 420 includes a tube portion 440, which extends along the longitudinal axis LA away from the engagement end 421 of the control unit. The tube portion 440 is defined on the outside by outer wall 442, which may generally be part of the overall outer wall or housing of the control unit 420, and on the inside by inner wall 424. A cavity 426 is formed by inner wall 424 of the tube portion and the engagement end 421 of the control unit 420. This cavity 426 is able to receive and accommodate at least part of a cartridge 430 as it engages with the control unit (as shown in the top drawing of Figure 4).

The inner wall 424 and the outer wall 442 of the tube portion define an annular space which is formed around the longitudinal axis LA. A (drive or work) coil 450 is located within

this annular space, with the central axis of the coil being substantially aligned with the longitudinal axis LA of the e-cigarette 410. The coil 450 is electrically connected to the battery 411 and circuit board 415, which provide power and control to the coil, so that in operation, the coil 450 is able to provide induction heating to the cartridge 430.

5 The cartridge includes a reservoir 470 containing liquid formulation (typically including nicotine). The reservoir comprises a substantially annular region of the cartridge, formed between an outer wall 476 of the cartridge, and an inner tube or wall 472 of the cartridge, both of which are substantially aligned with the longitudinal axis LA of the e-cigarette 410. The liquid formulation may be held free within the reservoir 470, or
10 alternatively the reservoir 470 may be incorporated in some structure or material, e.g. sponge, to help retain the liquid within the reservoir.

 The outer wall 476 has a portion 476A of reduced cross-section. This allows this portion 476A of the cartridge to be received into the cavity 426 in the control unit in order to engage the cartridge 430 with the control unit 420. The remainder of the outer wall has a
15 greater cross-section in order to provide increased space within the reservoir 470, and also to provide a continuous outer surface for the e-cigarette – i.e. cartridge wall 476 is substantially flush with the outer wall 442 of the tube portion 440 of the control unit 420. However, it will be appreciated that other implementations of the e-cigarette 410 may have a more complex/structured outer surface (compared with the smooth outer surface shown in
20 Figure 4).

 The inside of the inner tube 472 defines a passageway 461 which extends, in a direction of airflow, from air inlet 461A (located at the end 431 of the cartridge that engages the control unit) through to air outlet 461B, which is provided by the mouthpiece 435. Located within the central passageway 461, and hence within the airflow through the
25 cartridge, are heater 455 and wick 454. As can be seen in Figure 4, the heater 455 is located approximately in the centre of the drive coil 450. In particular, the location of the heater 455 along the longitudinal axis can be controlled by having the step at the start of the portion 476A of reduced cross-section for the cartridge 430 abut against the end (nearest the mouthpiece 435) of the tube portion 440 of the control unit 420 (as shown in the top diagram
30 of Figure 4).

 The heater 455 is made of a metallic material so as to permit use as a susceptor (or workpiece) in an induction heating assembly. More particularly, the induction heating assembly comprises the drive (work) coil 450, which produces a magnetic field having high frequency variations (when suitably powered and controlled by the battery 411 and controller
35 on PCB 415). This magnetic field is strongest in the centre of the coil, i.e. within cavity 426, where the heater 455 is located. The changing magnetic field induces eddy currents in the conductive heater 455, thereby causing resistive heating within the heater element 455.

Note that the high frequency of the variations in magnetic field causes the eddy currents to be confined to the surface of the heater element (via the skin effect), thereby increasing the effective resistance of the heating element, and hence the resulting heating effect.

Furthermore, the heater element 455 is generally selected to be a magnetic material having a high permeability, such as (ferrous) steel (rather than just a conductive material). In this case, the resistive losses due to eddy currents are supplemented by magnetic hysteresis losses (caused by repeated flipping of magnetic domains) to provide more efficient transfer of power from the drive coil 450 to the heater element 455.

The heater is at least partly surrounded by wick 454. Wick serves to transport liquid from the reservoir 470 onto the heater 455 for vaporisation. The wick may be made of any suitable material, for example, a heat-resistant, fibrous material and typically extends from the passageway 461 through holes in the inner tube 472 to gain access into the reservoir 470. The wick 454 is arranged to supply liquid to the heater 455 in a controlled manner, in that the wick prevents the liquid leaking freely from the reservoir into passageway 461 (this liquid retention may also be assisted by having a suitable material within the reservoir itself). Instead, the wick 454 retains the liquid within the reservoir 470, and on the wick 454 itself, until the heater 455 is activated, whereupon the liquid held by the wick 454 is vaporised into the airflow, and hence travels along passageway 461 for exit via mouthpiece 435. The wick 454 then draws further liquid into itself from the reservoir 470, and the process repeats with subsequent vaporisations (and inhalations) until the cartridge is depleted.

Although the wick 454 is shown in Figure 4 as separate from (albeit encompassing) the heater element 455, in some implementations, the heater element 455 and wick 454 may be combined together into a single component, such as a heating element made of a porous, fibrous steel material which can also act as a wick 454 (as well as a heater). In addition, although the wick 454 is shown in Figure 4 as supporting the heater element 455, in other embodiments, the heater element 455 may be provided with separate supports, for example, by being mounted to the inside of tube 472 (instead of or in addition to being supported by the heater element).

The heater 455 may be substantially planar, and perpendicular to the central axis of the coil 450 and the longitudinal axis LA of the e-cigarette, since induction primarily occurs in this plane. Although Figure 4 shows the heater 455 and wick 454 extending across the full diameter of the inner tube 472, typically the heater 455 and wick 454 will not cover the whole cross-section of the air passage-way 461. Instead, space is typically provided to allow air to flow through the inner tube from inlet 461A and around heater 455 and wick 454 to pick up the vapour produced by the heater. For example, when viewed along the longitudinal axis LA, the heater and wick may have an "O" configuration with a central hole (not shown in Figure 4) to allow for airflow along the passageway 461. Many other configurations are

possible, such as the heater having a “Y” or “X” configuration. (Note that in such implementations, the arms of the “Y” or “X” would be relatively broad to provide better induction).

Although Figure 4 shows the engagement end 431 of the cartridge as covering the air inlet 461A, this end of the cartomiser may be provided with one or more holes (not shown in Figure 4) to allow the desired air intake to be drawn into passageway 461. Note also that in the configuration shown in Figure 4, there is a slight gap 422 between the engagement end 431 of the cartridge 430 and the corresponding engagement end 421 of the control unit. Air can be drawn from this gap 422 through air inlet 461A.

The e-cigarette may provide one or more routes to allow air to initially enter the gap 422. For example, there may be sufficient spacing between the outer wall 476A of the cartridge and the inner wall 444 of tube portion 440 to allow air to travel into gap 422. Such spacing may arise naturally if the cartridge is not a tight fit into the cavity 426. Alternatively one or more air channels may be provided as slight grooves along one or both of these walls to support this airflow. Another possibility is for the housing of the control unit 420 to be provided with one or more holes, firstly to allow air to be drawn into the control unit, and then to pass from the control unit into gap 422. For example, the holes for air intake into the control unit might be positioned as indicated in Figure 4 by arrows 428A and 428B, and engagement end 421 might be provided with one or more holes (not shown in Figure 4) for the air to pass out from the control unit 420 into gap 422 (and from there into the cartridge 430). In other implementations, gap 422 may be omitted, and the airflow may, for example, pass directly from the control unit 420 through the air inlet 461A into the cartridge 430.

The e-cigarette may be provided with one or more activation mechanisms for the induction heater assembly, i.e. to trigger operation of the drive coil 450 to heat the heating element 455. One possible activation mechanism is to provide a button 429 on the control unit, which a user may press to active the heater. This button may be a mechanical device, a touch sensitive pad, a sliding control, etc. The heater may stay activated for as long as the user continues to press or otherwise positively actuate the button 429, subject to a maximum activation time appropriate to a single puff of the e-cigarette (typically a few seconds). If this maximum activation time is reached, the controller may automatically de-activate the induction heater to prevent over-heating. The controller may also enforce a minimum interval (again, typically for a few seconds) between successive activations.

The induction heater assembly may also be activated by airflow caused by a user inhalation. In particular, the control unit 420 may be provided with an airflow sensor for detecting an airflow (or pressure drop) caused by an inhalation. The airflow sensor is then able to notify the controller of this detection, and the induction heater is activated accordingly. The induction heater may remain activated for as long as the airflow continues

to be detected, subject again to a maximum activation time as above (and typically also a minimum interval between puffs).

Airflow actuation of the heater may be used instead of providing button 429 (which could therefore be omitted), or alternatively the e-cigarette may require dual activation in order to operate – i.e. both the detection of airflow and the pressing of button 429. This requirement for dual activation can help to provide a safeguard against unintended activation of the e-cigarette.

It will be appreciated that the use of an airflow sensor generally involves an airflow passing through the control unit upon inhalation, which is amenable to detection (even if this airflow only provides part of the airflow that the user ultimately inhales). If no such airflow passes through the control unit upon inhalation, then button 429 may be used for activation, although it might also be possible to provide an airflow sensor to detect an airflow passing across a surface of (rather than through) the control unit 420.

There are various ways in which the cartridge may be retained within the control unit. For example, the inner wall 444 of the tube portion 440 of the control unit 420 and the outer wall of reduced cross-section 476A may each be provided with a screw thread (not shown in Figure 4) for mutual engagement. Other forms of mechanical engagement, such as a snap fit, a latching mechanism (perhaps with a release button or similar) may also be used. Furthermore, the control unit may be provided with additional components to provide a fastening mechanism, such as described below.

In general terms, the attachment of the cartridge 430 to the control unit 420 for the e-cigarette 410 of Figure 4 is simpler than in the case of the e-cigarette 10 shown in Figures 1-3. In particular, the use of induction heating for e-cigarette 410 allows the connection between the cartridge 430 and the control unit 420 to be mechanical only, rather than also having to provide an electrical connection with wiring to a resistive heater. Consequently, the mechanical connection may be implemented, if so desired, by using an appropriate plastic moulding for the housing of the cartridge and the control unit; in contrast, in the e-cigarette 10 of Figures 1-3, the housings of the cartomiser and the control unit have to be somehow bonded to a metal connector. Furthermore, the connector of the e-cigarette 10 of Figures 1-3 has to be made in a relatively precise manner to ensure a reliable, low contact resistance, electrical connection between the control unit and the cartomiser. In contrast, the manufacturing tolerances for the purely mechanical connection between the cartridge 430 and the control unit 420 of e-cigarette 410 are generally greater. These factors all help to simplify the production of the cartridge and thereby to reduce the cost of this disposable (consumable) component.

Furthermore, conventional resistive heating often utilises a metallic heating coil surrounding a fibrous wick, however, it is relatively difficult to automate the manufacture of

such a structure. In contrast, an inductive heating element 455 is typically based on some form of metallic disk (or other substantially planar component), which is an easier structure to integrate into an automated manufacturing process. This again helps to reduce the cost of production for the disposable cartridge 430.

5 Another benefit of inductive heating is that conventional e-cigarettes may use solder to bond power supply wires to a resistive heater coil. However, there is some concern that heat from the coil during operation of such an e-cigarette might volatilise undesirable components from the solder, which would then be inhaled by a user. In contrast, there are no wires to bond to the inductive heater element 455, and hence the use of solder can be
10 avoided within the cartridge. Also, a resistive heater coil as in a conventional e-cigarette generally comprises a wire of relatively small diameter (to increase the resistance and hence the heating effect). However, such a thin wire is relatively delicate and so may be susceptible to damage, whether through some mechanical mistreatment and/or potentially by local overheating and then melting. In contrast, a disk-shaped heater element 455 as
15 used for induction heating is generally more robust against such damage.

Figures 5 and 6 are schematic diagrams illustrating an e-cigarette in accordance with some other embodiments of the invention. To avoid repetition, aspects of Figures 5 and 6 that are generally the same as shown in Figure 4 will not be described again, except where relevant to explain the particular features of Figures 5 and 6. Note also that reference
20 numbers having the same last two digits typically denote the same or similar (or otherwise corresponding) components across Figures 4 to 6 (with the first digit in the reference number corresponding to the Figure containing that reference number).

In the e-cigarette shown in Figure 5, the control unit 520 is broadly similar to the control unit 420 shown in Figure 4, however, the internal structure of the cartridge 530 is
25 somewhat different from the internal structure of the cartridge 430 shown in Figure 4. Thus rather than having a central airflow passage, as for e-cigarette 410 of Figure 4, in which the liquid reservoir 470 surrounds the central airflow passage 461, in the e-cigarette 510 of Figure 5, the air passageway 561 is offset from the central, longitudinal axis (LA) of the cartridge. In particular, the cartridge 530 contains an internal wall 572 that separates the
30 internal space of the cartridge 530 into two portions. A first portion, defined by internal wall 572 and one part of external wall 576, provides a chamber for holding the reservoir 570 of liquid formulation. A second portion, defined by internal wall 572 and an opposing part of external wall 576, defines the air passage way 561 through the e-cigarette 510.

In addition, the e-cigarette 510 does not have a wick, but rather relies upon a porous
35 heater element 555 to act both as the heating element (susceptor) and the wick to control the flow of liquid out of the reservoir 570. The porous heater element may be made, for example, of a material formed from sintering or otherwise bonding together steel fibres.

The heater element 555 is located at the end of the reservoir 570 opposite to the mouthpiece 535 of the cartridge, and may form some or all of the wall of the reservoir chamber at this end. One face of the heater element is in contact with the liquid in the reservoir 570, while the opposite face of the heater element 555 is exposed to an airflow region 538 which can be considered as part of air passageway 561. In particular, this airflow region 538 is located between the heater element 555 and the engagement end 531 of the cartridge 530.

When a user inhales on mouthpiece 435, air is drawn into the region 538 through the engagement end 531 of the cartridge 530 from gap 522 (in a similar manner to that described for the e-cigarette 410 of Figure 4). In response to the airflow (and/or in response to the user pressing button 529), the coil 550 is activated to supply power to heater 555, which therefore produces a vapour from the liquid in reservoir 570. This vapour is then drawn into the airflow caused by the inhalation, and travels along the passageway 561 (as indicated by the arrows) and out through mouthpiece 535.

In the e-cigarette shown in Figure 6, the control unit 620 is broadly similar to the control unit 420 shown in Figure 4, but now accommodates two (smaller) cartridges 630A, and 630B. Each of these cartridges is analogous in structure to the reduced cross-section portion 476A of the cartridge 420 in Figure 4. However, the longitudinal extent of each of the cartridges 630A and 630B is only half that of the reduced cross-section portion 476A of the cartridge 420 in Figure 4, thereby allowing two cartridges to be contained within the region in e-cigarette 610 corresponding to cavity 426 in e-cigarette 410, as shown in Figure 4. In addition, the engagement end 621 of the control unit 620 may be provided, for example, with one or more struts or tabs (not shown in Figure 6) that maintain cartridges 630A, 630B in the position shown in Figure 6 (rather than closing the gap region 622).

In the e-cigarette 610, the mouthpiece 635 may be regarded as part of the control unit 620. In particular, the mouthpiece 635 may be provided as a removable cap or lid, which can screw or clip onto and off the remainder of the control unit 620 (or any other appropriate fastening mechanism can be used). The mouthpiece cap 635 is removed from the rest of the control unit 620 to insert a new cartridge or to remove an old cartridge, and then fixed back onto the control unit for use of the e-cigarette 610.

The operation of the individual cartridges 630A, 630B in e-cigarette 610 is similar to the operation of cartridge 430 in e-cigarette 410, in that each cartridge includes a wick 654A, 654B extending into the respective reservoir 670A, 670B. In addition, each cartridge 630A, 630B includes a heating element, 655A, 655B, accommodated in a respective wick, 654A, 654B, and may be energised by a respective coil 650A, 650B provided in the control unit 620. The heaters 655A, 655B vaporise liquid into a common passageway 661 that passes through both cartridges 630A, 630B and out through mouthpiece 635.

The different cartridges 630A, 630B may be used, for example, to provide different flavours for the e-cigarette 610. In addition, although the e-cigarette 610 is shown as accommodating two cartridges, it will be appreciated that some devices may accommodate a larger number of cartridges. Furthermore, although cartridges 630A and 630B are the same size as one another, some devices may accommodate cartridges of differing size. For example, an e-cigarette may accommodate one larger cartridge having a nicotine-based liquid, and one or more small cartridges to provide flavour or other additives as desired.

In some cases, the e-cigarette 610 may be able to accommodate (and operate with) a variable number of cartridges. For example, there may be a spring or other resilient device mounted on control unit engagement end 621, which tries to extend along the longitudinal axis towards the mouthpiece 635. If one of the cartridges shown in Figure 6 is removed, this spring would therefore help to ensure that the remaining cartridge(s) would be held firmly against the mouthpiece for reliable operation.

If an e-cigarette has multiple cartridges, one option is that these are all activated by a single coil that spans the longitudinal extent of all the cartridges. Alternatively, there may be an individual coil 650A, 650B for each respective cartridge 630A, 630B, as illustrated in Figure 6. A further possibility is that different portions of a single coil may be selectively energised to mimic (emulate) the presence of multiple coils.

If an e-cigarette does have multiple coils for respective cartridges (whether really separate coils, or emulated by different sections of a single larger coil), then activation of the e-cigarette (such as by detecting airflow from an inhalation and/or by a user pressing a button) may energise all coils. The e-cigarettes 410, 510, 610 however support selective activation of the multiple coils, whereby a user can choose or specify which coil(s) to activate. For example, e-cigarette 610 may have a mode or user setting in which in response to an activation, only coil 650A is energised, but not coil 650B. This would then produce a vapour based on the liquid formulation in coil 650A, but not coil 650B. This would allow a user greater flexibility in the operation of e-cigarette 610, in terms of the vapour provided for any given inhalation (but without a user having to physically remove or insert different cartridges just for that particular inhalation).

It will be appreciated that the various implementations of e-cigarette 410, 510 and 610 shown in Figures 4-6 are provided as examples only, and are not intended to be exhaustive. For example, the cartridge design shown in Figure 5 might be incorporated into a multiple cartridge device such as shown in Figure 6. The skilled person will be aware of many other variations that can be achieved, for example, by mixing and matching different features from different implementations, and more generally by adding, replacing and/or removing features as appropriate.

Figure 7 is a schematic diagram of the main electronic components of the e-cigarettes 410, 510, 610 of Figures 4-6 in accordance with some embodiments of the invention. With the exception of the heater element 455, which is located in the cartridge 430, the remaining elements are located in the control unit 420. It will be appreciated that since the control unit 420 is a re-usable device (in contrast to the cartridge 430 which is a disposable or consumable), it is acceptable to incur one-off costs in relation to production of the control unit which would not be acceptable as repeat costs in relation to the production of the cartridge. The components of the control unit 420 may be mounted on circuit board 415, or may be separately accommodated in the control unit 420 to operate in conjunction with the circuit board 415 (if provided), but without being physically mounted on the circuit board itself.

As shown in Figure 7, the control unit includes a re-chargeable battery 411, which is linked to a re-charge connector or socket 725, such as a micro-USB interface. This connector 725 supports re-charging of battery 411. Alternatively, or additionally, the control unit may also support re-charging of battery 411 by a wireless connection (such as by induction charging).

The control unit 420 further includes a controller 715 (such as a processor or application specific integrated circuit, ASIC), which is linked to a pressure or airflow sensor 716. The controller may activate the induction heating, as discussed in more detail below, in response to the sensor 716 detecting an airflow. In addition, the control unit 420 further includes a button 429, which may also be used to activate the induction heating, as described above.

Figure 7 also shows a comms/user interface 718 for the e-cigarette. This may comprise one or more facilities according to the particular implementation. For example, the user interface may include one or more lights and/or a speaker to provide output to the user, for example to indicate a malfunction, battery charge status, etc. The interface 718 may also support wireless communications, such as Bluetooth or near field communications (NFC), with an external device, such as a smartphone, laptop, computer, notebook, tablet etc. The e-cigarette may utilise this comms interface to output information such as device status, usage statistics etc to the external device, for ready access by a user. The comms interface may also be utilised to allow the e-cigarette to receive instructions, such as configuration settings entered by the user into the external device. For example, the user interface 718 and controller 715 may be utilised to instruct the e-cigarette to selectively activate different coils 650A, 650B (or portions thereof), as described above. In some cases, the comms interface 718 may use the work coil 450 to act as an antenna for wireless communications.

The controller may be implemented using one or more chips as appropriate. The operations of the controller 715 are generally controlled at least in part by software programs

running on the controller. Such software programs may be stored in non-volatile memory, such as ROM, which can be integrated into the controller 715 itself, or provided as a separate component (not shown). The controller 715 may access the ROM to load and execute individual software programs as and when required.

5 The controller controls the inductive heating of the e-cigarette by determining when the device is or is not properly activated - for example, whether an inhalation has been detected, and whether the maximum time period for an inhalation has not yet been exceeded. If the controller determines that the e-cigarette is to be activated for vaping, the controller arranges for the battery 411 to supply power to the inverter 712. The inverter 712
10 is configured to convert the DC output from the battery 411 into an alternating current signal, typically of relatively high frequency – e.g. 1 MHz (although other frequencies, such as 5kHz, 20 kHz, 80 KHz, or 300kHz, or any range defined by two such values, may be used instead). This AC signal is then passed from the inverter to the work coil 450, via suitable impedance matching (not shown in Figure 7) if so required.

15 The work coil 450 may be integrated into some form of resonant circuit, such as by combining in parallel with a capacitor (not shown in Figure 7), with the output of the inverter 712 tuned to the resonant frequency of this resonant circuit. This resonance causes a relatively high current to be generated in work coil 450, which in turn produces a relatively high magnetic field in heater element 455, thereby causing rapid and effective heating of the
20 heater element 455 to produce the desired vapour or aerosol output.

 Figure 7A illustrates part of the control electronics for an e-cigarette 610 having multiple coils in accordance with some implementations (while omitting for clarity aspects of the control electronics not directly related to the multiple coils). Figure 7A shows a power source 782A (typically corresponding to the battery 411 and inverter 712 of Figure 7), a
25 switch configuration 781A, and the two work coils 650A, 650B, each associated with a respective heater element 655A, 655B as shown in Figure 6 (but not included in Figure 7A). The switch configuration has three outputs denoted A, B and C in Figure 7A. It is also assumed that there is a current path between the two work coils 650A, 650B.

 In order to operate the induction heating assembly, two out of three of these outputs
30 are closed (to permit current flow), while the remaining output stays open (to prevent current flow). Closing outputs A and C activates both coils, and hence both heater elements 655A, 655B; closing A and B selectively activates just work coil 650A; and closing B and C activates just work coil 650B.

 Although it is possible to treat work coils 650A and 650B just as a single overall coil
35 (which is either on or off together), the ability to selectively energise either or both of work coils 650A and 650B, such as provided by the implementation of Figure 7, has a number of advantages, including:

a) choosing the vapour components (e.g. flavourants) for a given puff. Thus activating just work coil 650A produces vapour just from reservoir 670A; activating just work coil 650B produces vapour just from reservoir 670B; and activating both work coils 650A, 650B produces a combination of vapours from both reservoirs 670A, 670B.

5 b) controlling the amount of vapour for a given puff. For example, if reservoir 670A and reservoir 670B in fact contain the same liquid, then activating both work coils 650A, 650B can be used to produce a stronger (higher vapour level) puff compared to activating just one work coil by itself.

c) prolonging battery (charge) lifetime. As already discussed, it may be possible to operate
10 the e-cigarette of Figure 6 when it contains just a single cartridge, e.g. 630B (rather than also including cartridge 630A). In this case, it is more efficient just to energise the work coil 650B corresponding to cartridge 630B, which is then used to vaporise liquid from reservoir 670B. In contrast, if the work coil 650A corresponding to the (missing) cartridge 630A is not energised (because this cartridge and the associated heater element 650A are missing from
15 e-cigarette 610), then this saves power consumption without reducing vapour output.

Although the e-cigarette 610 of Figure 6 has a separate heater element 655A, 655B for each respective work coil 650A, 650B, in some implementations, different work coils may energise different portions of a single (larger) workpiece or susceptor. Accordingly, in such an e-cigarette, the different heater elements 655A, 655B may represent different portions of
20 the larger susceptor, which is shared across different work coils. Additionally (or alternatively), the multiple work coils 650A, 650B may represent different portions of a single overall drive coil, individual portions of which can be selectively energised, as discussed above in relation to Figure 7A.

Figure 7B shows another implementation for supporting selectivity across multiple
25 work coils 650A, 650B. Thus in Figure 7B, it is assumed that the work coils are not electrically connected to one another, but rather each work coil 650A, 650B is individually (separately) linked to the power source 782B via a pair of independent connections through switch configuration 781B. In particular, work coil 650A is linked to power source 782B via switch connections A1 and A2, and work coil 650B is linked to power source 782B via switch
30 connections B1 and B2. This configuration of Figure 7B offers similar advantages to those discussed above in relation to Figure 7A. In addition, the architecture of Figure 7B may also be readily scaled up to work with more than two work coils.

Figure 7C shows another implementation for supporting selectivity across multiple work coils, in this case three work coils denoted 650A, 650B and 650C. Each work coil is
35 directly connected to a respect power supply 782C1, 782C2 and 782C3. The configuration of Figure 7 may support the selective energisation of any single work coil, 650A, 650B,

650C, or of any pair of work coils at the same time, or of all three work coils at the same time.

In the configuration of Figure 7C, at least some portions of the power supply 782 may be replicated for each of the different work coils 650. For example, each power supply 782C1, 782C2, 782C3 may include its own inverter, but they may share a single, ultimate power source, such as battery 411. In this case, the battery 411 may be connected to the inverters via a switch configuration analogous to that shown in Figure 7B (but for DC rather than AC current). Alternatively, each respective power line from a power supply 782 to a work coil 650 may be provided with its own individual switch, which can be closed to activate the work coil (or opened to prevent such activation). In this arrangement, the collection of these individual switches across the different lines can be regarded as another form of switch configuration.

There are various ways in which the switching of Figures 7A-7C may be managed or controlled. In some cases, the user may operate a mechanical or physical switch that directly sets the switch configuration. For example, e-cigarette 610 may include a switch (not shown in Figure 6) on the outer housing, whereby cartridge 630A can be activated in one setting, and cartridge 630B can be activated in another setting. A further setting of the switch may allow activation of both cartridges together. Alternatively, the control unit 610 may have a separate button associated with each cartridge, and the user holds down the button for the desired cartridge (or potentially both buttons if both cartridges should be activated). Another possibility is that a button or other input device on the e-cigarette may be used to select a stronger puff (and result in switching on both or all work coils). Such a button may also be used to select the addition of a flavour, and the switching might operate a work coil associated with that flavour – typically in addition to a work coil for the base liquid containing nicotine. The skilled person will be aware of other possible implementations of such switching.

In some e-cigarettes, rather than direct (e.g. mechanical or physical) control of the switch configuration, the user may set the switch configuration via the comms/user interface 718 shown in Figure 7 (or any other similar facility). For example, this interface may allow a user to specify the use of different flavours or cartridges (and/or different strength levels), and the controller 715 can then set the switch configuration 781 according to this user input.

A further possibility is that the switch configuration may be set automatically. For example, e-cigarette 610 may prevent work coil 650A from being activated if a cartridge is not present in the illustrated location of cartridge 630A. In other words, if no such cartridge is present, then the work coil 650A may not be activated (thereby saving power, etc).

There are various mechanisms available for detecting whether or not a cartridge is present. For example, the control unit 620 may be provided with a switch which is

mechanically operated by inserting a cartridge into the relevant position. If there is no cartridge in position, then the switch is set so that the corresponding work coil is not powered. Another approach would be for the control unit to have some optical or electrical facility for detecting whether or not a cartridge is inserted into a given position.

5 Note that in some devices, once a cartridge has been detected as in position, then the corresponding work coil is always available for activation – e.g. it is always activated in response to a puff (inhalation) detection. In other devices that support both automatic and user-controlled switch configuration, even if a cartridge has been detected as in position, a user setting (or such-like, as discussed above) may then determine whether or not the
10 cartridge is available for activation on any given puff.

Although the control electronics of Figures 7A-7C have been described in connection with the use of multiple cartridges, such as shown in Figure 6, they may also be utilised in respect of a single cartridge that has multiple heater elements. In other words, the control electronics is able to selectively energise one or more of these multiple heater elements
15 within the single cartridge. Such an approach may still offer the benefits discussed above. For example, if the cartridge contains multiple heater elements, but just a single, shared reservoir, or multiple heater elements, each with its own respective reservoir, but all reservoirs containing the same liquid, then energising more or fewer heater elements provides a way for a user to increase or decrease the amount of vapour provided with a
20 single puff. Similarly, if a single cartridge contains multiple heater elements, each with its own respective reservoir containing a particular liquid, then energising different heater elements (or combinations thereof) provides a way for a user to selectively consume vapours for different liquids (or combinations thereof).

In some e-cigarettes, the various work coils and their respective heater elements
25 (whether implemented as separate work coils and/or heater elements, or as portions of a larger drive coil and/or susceptor) may all be substantially the same as one another, to provide a homogeneous configuration. Alternatively, a heterogeneous configuration may be utilised. For example, with reference to e-cigarette 610 as shown in Figure 6, one cartridge 630A may be arranged to heat to a lower temperature than the other cartridge 630B, and/or
30 to provide a lower output of vapour (by providing less heating power). Thus if one cartridge 630A contains the main liquid formulation containing nicotine, while the other cartridge 630B contains a flavourant, it may be desirable for cartridge 630A to output more vapour than cartridge 630B. Also, the operating temperature of each heater element 655 may be arranged according to the liquid(s) to be vaporised. For example, the operating temperature
35 should be high enough to vaporise the relevant liquid(s) of a particular cartridge, but typically not so high as to chemically break down (disassociate) such liquids.

There are various ways of providing different operating characteristics (such as temperature) for different combinations of work coils and heater elements, and thereby produce a heterogeneous configuration as discussed above. For example, the physical parameters of the work coils and/or heater elements may be varied as appropriate – e.g. different sizes, geometry, materials, number of coil turns, etc. Additionally (or alternatively), the operating parameters of the work coils and/or heater elements may be varied, such as by having different AC frequencies and/or different supply currents for the work coils.

The example embodiments described above have primarily focused on examples in which the heating element (inductive susceptor) has a relatively uniform response to the magnetic fields generated by the inductive heater drive coil in terms of how currents are induced in the heating element. That is to say, the heating element is relatively homogenous, thereby giving rise to relatively uniform inductive heating in the heating element, and consequently a broadly uniform temperature across the surface of the heating element surface. However, in accordance with some example embodiments of the disclosure, the heating element may instead be configured so that different regions of the heating element respond differently to the inductive heating provided by the drive coil in terms of how much heat is generated in different regions of the heating element when the drive coil is active.

Figure 8 represents, in highly schematic cross-section, an example aerosol provision system (electronic cigarette) 300 which incorporates a vaporiser 305 that comprises a heating element (susceptor) 310 embedded in a surrounding wicking material / matrix. The heating element 310 of the aerosol provision system represented in Figure 8 comprises regions of different susceptibility to inductive heating, but apart from this many aspects of the configuration of Figure 8 are similar to, and will be understood from, the description of the various other configurations described herein. When the system 300 is in use and generating an aerosol, the surface of the heating element 310 in the regions of different susceptibility are heated to different temperatures by the induced current flows. Heating different regions of the heating element 310 to different temperatures can be desired in some implementations because different components of a source liquid formulation may aerosolise / vaporise at different temperatures. This means that providing a heating element (susceptor) with a range of different temperatures can help simultaneously aerosolise a range of different components in the source liquid. That is to say, different regions of the heating element can be heated to temperatures that are better suited to vaporising different components of the liquid formulation.

Thus, the aerosol provision system 300 comprises a control unit 302 and a cartridge 304 and may be generally based on any of the implementations described herein apart from having a heating element 310 with a spatially non-uniform response to inductive heating.

The control unit comprises a drive coil 306 in addition to a power supply and control circuitry (not shown in Figure 8) for driving the drive coil 306 to generate magnetic fields for inductive heating as discussed herein.

5 The cartridge 304 is received in a recess of the control unit 302 and comprises the vaporiser 305 comprising the heating element 310, a reservoir 312 containing a liquid formulation (source liquid) 314 from which the aerosol is to be generated by vaporisation at the heating element 310, and a mouthpiece 308 through which aerosol may be inhaled when the system 300 is in use. The cartridge 304 has a wall configuration (generally shown with hatching in Figure 8) that defines the reservoir 312 for the liquid formulation 314, supports
10 the heating element 310, and defines an airflow path through the cartridge 304. Liquid formulation may be wicked from the reservoir 312 to the vicinity of the heating element 310 (more particular to the vicinity of a vaporising surface of the heating element) for vaporisation in accordance with any of the approaches described herein. The airflow path is arranged so that when a user inhales on the mouthpiece 308, air is drawn through an air inlet 316 in the
15 body of the control unit 302, into the cartridge 304 and past the heating element 310, and out through the mouthpiece 308. Thus a portion of liquid formulation 314 vaporised by the heating element 310 becomes entrained in the airflow passing the heating element 310 and the resulting aerosol exits the system 300 through the mouthpiece 308 for inhalation by the user. An example airflow path is schematically represented in Figure 8 by a sequence of
20 arrows 318. However, it will be appreciated the exact configuration of the control unit 302 and the cartridge 304, for example in terms of how the airflow path through the system 300 is configured, whether the system comprises a re-useable control unit and replaceable cartridge assembly, and whether the drive coil and heating element are provided as components of the same or different elements of the system, is not significant to the principles underlying the operation of a heating element 310 having a non-uniform induced
25 current response (i.e. a different susceptibility to induced current flow from the drive coil in different regions) as described herein.

Thus, the aerosol provision system 300 schematically represented in Figure 8 comprises in this example an inductive heating assembly comprising the heating element
30 310 in the cartridge 304 part of the system 300 and the drive coil 306 in the control unit 302 part of the system 300. In use (i.e. when generating aerosol) the drive coil 306 induces current flows in the heating element 310 in accordance with the principles of inductive heating such as discussed elsewhere herein. This heats the heating element 310 to generate an aerosol by vaporisation of an aerosol precursor material (e.g. liquid formation
35 314) in the vicinity of a vaporising surface the heating element 310 (i.e. a surface of the heating element which is heated to a temperature sufficient to vaporise adjacent aerosol precursor material). The heating element comprises regions of different susceptibility to

induced current flow from the drive coil such that areas of the vaporising surface of the heating element in the regions of different susceptibility are heated to different temperatures by the current flow induced by the drive coil. As noted above, this can help with simultaneously aerosolising components of the liquid formulation which vaporise / aerosolise at different temperatures. There are a number of different ways in which the heating element 310 can be configured to provide regions with different responses to the inductive heating from the drive coil (i.e. regions which undergo different amounts of heating / achieve different temperatures during use).

Figures 9A and 9B schematically represent respective plan and cross-section views of a heating element 330 comprising regions of different susceptibility to induced current flow in accordance with one example implementation of an embodiment of the disclosure. That is to say, in one example implementation of the system schematically represented in Figure 8, the heating element 310 has a configuration corresponding to the heating element 330 represented in Figures 9A and 9B. The cross section view of Figure 9B corresponds with the cross section view of the heating element 310 represented in Figure 8 (although rotated 90 degrees in the plane of the figure) and the plan view of Figure 9A corresponds with a view of the heating element along a direction that is parallel to the magnetic field created by the drive coil 306 (i.e. parallel to the longitudinal axis of the aerosol provision system). The cross section of Figure 9B is taken along a horizontal line in the middle of the representation of Figure 9A.

The heating element 330 has a generally planar form, which in this example is flat. More particularly, the heating element 330 in the example of Figures 9A and 9B is generally in the form of a flat circularly disc. The heating element 330 in this example is symmetric about the plane of Figure 9A in that it appears the same whether viewed from above or below the plane of Figure 9A.

The characteristic scale of the heating element may be chosen according to the specific implementation at hand, for example having regard to the overall scale of the aerosol provision system in which the heating element is implemented and the desired rate of aerosol generation. For example, in one particular implementation the heating element 330 may have a diameter of around 10 mm and a thickness of around 1 mm. In other examples the heating element 330 may have a diameter in the range 3 mm to 20 mm and a thickness of around 0.1 mm to 5 mm.

The heating element 330 comprises a first region 331 and a second region 332 comprising materials having different electromagnetic characteristics, thereby providing regions of different susceptibility to induced current flow. The first region 331 is generally in the form of a circular disc forming the centre of the heating element 330 and the second region 332 is generally in the form of a circular annulus surrounding the first region 331. The

first and second regions may be bonded together or may be maintained in a press-fit arrangement. Alternatively, the first and second regions may not be attached to one another, but may be independently maintained in position, for example by virtue of both regions being embedded in a surrounding wadding / wicking material.

5 In the particular example represented in Figures 9A and 9B, it is assumed the first and second regions 331, 332 comprise different compositions of steel having different susceptibilities to induced current flows. For example, the different regions may comprise different material selected from the group of copper, aluminium, zinc, brass, iron, tin, and steel, for example ANSI 304 steel.

10 The particular materials in any given implementation may be chosen having regard to the differences in susceptibility to induced current flow which are appropriate for providing the desired temperature variations across the heating element when in use. The response of a particular heating element configuration may be modelled or empirically tested during a design phase to help provide a heating element configuration having the desired operational
15 characteristics, for example in terms of the different temperatures achieved during normal use and the arrangement of the regions over which the different temperatures occur (e.g., in terms of size and placement). In this regard, the desired operational characteristics, e.g. in terms the desired range of temperatures, may themselves be determined through modelling or empirical testing having regard to the characteristic and composition of the liquid
20 formulation in use and the desired aerosol characteristics.

 It will be appreciated the heating element 330 represented in Figures 9A and 9B is merely one example configuration for a heating element comprising different materials for providing different regions of susceptibility to induced current flow. In other examples, the heating element may comprise more than two regions of different materials. Furthermore,
25 the particular spatial arrangement of the regions comprising different materials may be different from the generally concentric arrangement represented in Figures 9A and 9B. For example, in another implementation the first and second regions may comprise two halves (or other proportions) of the heating element, for example each region may have a generally planar semi-circle form.

30 Figures 10A and 10B schematically represents respective plan and cross-section views of a heating element 340 comprising regions of different susceptibility to induced current flow in accordance with another example implementation of an embodiment of the disclosure. The orientations of these views correspond with those of Figures 9A and 9B discussed above. The heating element may comprise, for example, ANSI 304 steel, and / or
35 another suitable material (i.e. a material having sufficient inductive properties and resistance to the liquid formulation), such as such as copper, aluminium, zinc, brass, iron, tin, and other steels.

The heating element 340 again has a generally planar form, although unlike the example of Figures 9A and 9B, the generally planar form of the heating element 340 is not flat. That is to say, the heating element 340 comprises undulations (ridges / corrugations) when viewed in cross-section (i.e. when viewed perpendicular to the largest surfaces of the heating element 340). These one or more undulation(s) may be formed, for example, by bending or stamping a flat template former for the heating element. Thus, the heating element 340 in the example of Figures 10A and 10B is generally in the form of a wavy circular disc which, in this particular example, comprises a single "wave". That is to say, a characteristic wavelength scale of the undulation broadly corresponds with the diameter of the disc. However, in other implementations there may be a greater number of undulations across the surface of the heating element. Furthermore, the undulations may be provided in different configurations. For example, rather than going from one side of the heating element to the other, the undulation(s) may be arranged concentrically, for example comprising a series of circular corrugations / ridges.

The orientation of the heating element 340 relative to magnetic fields generated by the drive coil when the heating element is in use in an aerosol provision system are such that the magnetic fields will be generally perpendicular to the plane of Figure 10A and generally aligned vertically within the plane of Figure 10B, as schematically represented by magnetic field lines \underline{B} . The field lines \underline{B} are schematically directed upwards in Figure 10B, but it will be appreciated the magnetic field direction will alternate between up and down (or up and off) for the orientation of Figure 10B in accordance with the time-varying signal applied to the drive coil.

Thus, the heating element 340 comprises locations where the plane of the heating element presents different angles to the magnetic field generated by the drive coil. For example, referring in particular to Figure 10B, the heating element 340 comprises a first region 341 in which the plane of the heating element 340 is generally perpendicular to the local magnetic field \underline{B} and a second region 342 in which the plane of the heating element 340 is inclined with respect to the local magnetic field \underline{B} . The degree of inclination in the second region 342 will depend on the geometry of the undulations in the heating element 340. In the example of Figure 10B, the maximum inclination is on the order of around 45 degrees or so. Of course it will be appreciated there are other regions of the heating element outside the first region 341 and the second region 342 which present still other angles of inclination to the magnetic field.

The different regions of the heating element 340 oriented at different angles to the magnetic field created by the drive coil provide regions of different susceptibility to induced current flow, and therefore different degrees of heating. This follows from the underlying physics of inductive heating whereby the orientation of a planar heating element to the

induction magnetic field affects the degree of inductive heating. More particularly, regions in which the magnetic field is generally perpendicular to the plane of the heating element will have a greater degree of susceptibility to induced currents than regions in which the magnetic field is inclined relative to the plane of the heating element.

5 Thus, in the first region 341 the magnetic field is broadly perpendicular to the plane of the heating element and so this region (which appears generally as a vertical stripe in the plan view of Figure 10A) will be heated to a higher temperature than the second region 342 (which again appears generally as a vertical stripe in the plan view of Figure 10A) where the magnetic field is more inclined relative to the plane of the heating element. The other regions
10 of the heating element will be heated according to the angle of inclination between the plane of the heating element in these locations and the local magnetic field direction.

The characteristic scale of the heating element may again be chosen according to the specific implementation at hand, for example having regard to the overall scale of the aerosol provision system in which the heating element is implemented and the desired rate
15 of aerosol generation. For example, in one particular implementation the heating element 340 may have a diameter of around 10 mm and a thickness of around 1 mm. The undulations in the heating element may be chosen to provide the heating element with angles of inclination to the magnetic field from the drive coil ranging from 90° (i.e. perpendicular) to around 10 degrees or so.

20 The particular range of angles of inclination for different regions of the heating element to the magnetic field may be chosen having regard to the differences in susceptibility to induced current flow which are appropriate for providing the desired temperature variations (profile) across the heating element when in use. The response of a particular heating element configuration (e.g., in terms of how the undulation geometry
25 affects the heating element temperature profile) may be modelled or empirically tested during a design phase to help provide a heating element configuration having the desired operational characteristics, for example in terms of the different temperatures achieved during normal use and the spatial arrangement of the regions over which the different temperatures occur (e.g., in terms of size and placement).

30 Figures 11A and 11B schematically represents respective plan and cross-section views of a heating element 350 comprising regions of different susceptibility to induced current flow in accordance with another example implementation of an embodiment of the disclosure. The orientations of these views correspond with those of Figures 9A and 9B discussed above. The heating element may comprise, for example, ANSI 304 steel, and / or
35 another suitable material such as discussed above.

The heating element 350 again has a generally planar form, which in this example is flat. More particularly, the heating element 350 in the example of Figures 11A and 11B is

generally in the form of a flat circular disc having a plurality of openings therein. In this example the plurality of openings 354 comprise four square holes passing through the heating element 350. The openings 350 may be formed, for example, by stamping a flat template former for the heating element with an appropriately configured punch. The openings 354 are defined by walls which disrupts the flow of induced current within the heating element 350, thereby creating regions of different current density. In this example the walls may be referred to as internal walls of the heating element in that they are associated with opening/holes in the body of the susceptor (heating element). However, as discussed further below in relation to Figures 12A and 12B, in some other examples, or in addition, similar functionality can be provided by outer walls defining the periphery of a heating element.

The characteristic scale of the heating element may be chosen according to the specific implementation at hand, for example having regard to the overall scale of the aerosol provision system in which the heating element is implemented and the desired rate of aerosol generation. For example, in one particular implementation the heating element 350 may have a diameter of around 10 mm and a thickness of around 1 mm with the openings having a characteristic size of around 2 mm. In other examples the heating element 330 may have a diameter in the range 3 mm to 20 mm and a thickness of around 0.1 mm to 5 mm, and the one or more openings may have a characteristic size of around 10% to 30% of the diameter, but in some case may be smaller or larger.

The drive coil in the configuration of Figure 8 will generate a time-varying magnetic field which is broadly perpendicular to the plane of the heating element and so will generate electric fields to drive induced current flow in the heating element which are generally azimuthal. Thus, in a circularly symmetric heating element, such as represented in Figure 9A, the induced current densities will be broadly uniform at different azimuths around the heating element. However, for a heating element which comprises walls that disrupt the circular symmetry, such as the walls associated with the holes 354 in the heating element 350 of Figure 11A, the current densities will not be broadly uniform at different azimuths, but will be disrupted, thereby leading to different current densities, hence different amounts of heating, in different regions of the heating element.

Thus, the heating element 350 comprises locations which are more susceptible to induced current flow because current is diverted by walls into these locations leading to higher current densities. For example, referring in particular to Figure 11A, the heating element 350 comprises a first region 351 adjacent one of the openings 354 and a second region 352 which is not adjacent one of the openings. In general, the current density in the first region 351 will be different from the current density in the second region 352 because the current flows in the vicinity of the first region 351 are diverted/disrupted by the adjacent

opening 354. Of course it will be appreciated these are just two example regions identified for the purposes of explanation.

5 The particular arrangement of openings 354 that provide the walls for disrupting otherwise azimuthal current flow may be chosen having regard to the differences in susceptibility to induced current flow across the heating element which are appropriate for providing the desired temperature variations (profile) when in use. The response of a particular heating element configuration (e.g., in terms of how the openings affect the heating element temperature profile) may be modelled or empirically tested during a design phase to help provide a heating element configuration having the desired operational characteristics, for example in terms of the different temperatures achieved during normal use and the spatial arrangement of the regions over which the different temperatures occur (e.g., in terms of size and placement).

10 Figures 12A and 12B schematically represents respective plan and cross-section views of a heating element 360 comprising regions of different susceptibility to induced current flow in accordance with yet another example implementation of an embodiment of the disclosure. The heating element may again comprise, for example, ANSI 304 steel, and / or another suitable material such as discussed above. The orientations of these views correspond with those of Figures 9A and 9B discussed above.

15 The heating element 360 again has a generally planar form. More particularly, the heating element 360 in the example of Figures 12A and 12B is generally in the form of a flat star-shaped disc, in this example a five pointed star. The respective points of the star are defined by outer (peripheral) walls of the heating element 360 which are not azimuthal (i.e. the heating element comprises walls extending in a direction which has a radial component). Because the peripheral walls of the heating element are not parallel to the direction of electric fields created by the time-varying magnetic field from the drive coil, they act to disrupt current flows in the heating element in broadly the same manner as discussed above for the walls associated with the openings 354 of the heating element 350 shown in Figures 11A and 11B.

20 The characteristic scale of the heating element may be chosen according to the specific implementation at hand, for example having regard to the overall scale of the aerosol provision system in which the heating element is implemented and the desired rate of aerosol generation. For example, in one particular implementation the heating element 360 may comprise five uniformly spaced points extending from 3 mm to 5 mm from a centre of the heating element (i.e. the respective points of the star may have a radial extent of around 2 mm). In other examples the protrusions (i.e. the points of the star in the example of Figure 12A) could have different sizes, for example they may extend over a range from 1 mm to 20 mm.

As discussed above, the drive coil in the configuration of Figure 8 will generate a time-varying magnetic field which is broadly perpendicular to the plane of a the heating element 360 and so will generate electric fields to drive induced current flows in the heating element which are generally azimuthal. Thus, for a heating element which comprises walls that disrupt the circular symmetry, such as the outer walls associated with the points of the star-shaped pattern for the heating element 360 of Figure 12A, or a more simple shape, such as a square or rectangle, the current densities will not be uniform at different azimuths, but will be disrupted, thereby leading to different amounts of heating, and hence temperatures, in different regions of the heating element.

Thus, the heating element 360 comprises locations which have different induced currents as current flows are disrupted by the walls. Thus, referring in particular to Figure 12A, the heating element 360 comprises a first region 361 adjacent one of the outer walls and a second region 362 which is not adjacent one of the outer walls. Of course it will be appreciated these are just two example regions identified for the purposes of explanation. In general, the current density in the first region 361 will be different from the current density in the second region 362 because the current flows in the vicinity of the first region 361 are diverted/disrupted by the adjacent non-azimuthal wall of the heating element.

In a manner similar to that described for the other example heating element configurations having locations with differing susceptibility to induced current flows (i.e. regions with different responses to the drive coil in terms of the amount of induced heating), the particular arrangement for the heating element's peripheral walls for disrupting the otherwise azimuthal current flow may be chosen having regard to the differences in susceptibility which are appropriate for providing the desired temperature variations (profile) when in use. The response of a particular heating element configuration (e.g., in terms of how the non-azimuthal walls affect the heating element temperature profile) may be modelled or empirically tested during a design phase to help provide a heating element configuration having the desired operational characteristics, for example in terms of the different temperatures achieved during normal use and the spatial arrangement of the regions over which the different temperatures occur (e.g., in terms of size and placement).

It will be appreciated broadly the same principle underlies the operation of the heating element 350 represented in Figures 11A and 11B and the heating element 360 represented in Figures 12A and 12B in that the locations with different susceptibilities to induced currents are provided by non-azimuthal edges / walls to disrupt current flows. The difference between these two examples is in whether the walls are inner walls (i.e. associated with holes in the heating element) or outer walls (i.e. associated with a periphery of the heating element). It will further be appreciated the specific wall configurations represented in Figures 11A and 12A are provided by way of example only, and there are

many other different configurations which provide walls that disrupt current flows. For example, rather than a star-shaped configuration such as represented in Figure 12A, in another example the sector may comprise slot openings, e.g., extended inwardly from a periphery or as holes in the heating element. More generally, what is significant is that the heating element is provided with walls which are not parallel to the direction of electric fields created by the time-varying magnetic field. Thus, for a configuration in which the drive coil is configured to generate a broadly uniform and parallel magnetic field (e.g. for a solenoid-like drive coil), the drive coil extends along a coil axis about which the magnetic field generated by the drive coil is generally circularly symmetric, but the heating element has a shape which is not circularly symmetric about the coil axis (in the sense of not being symmetric under all rotations, although it may be symmetric under some rotations).

Thus, there has been described above a number of different ways in which a heating element in an inductive heating assembly of an aerosol provision system can be provided with regions of different susceptibility to induced current flows, and hence different degrees of heating, to provide a range of different temperatures across the heating element. As noted above, this can be desired in some scenarios to facilitate simultaneous vaporisation of different components of a liquid formulation to be vaporised having different vaporisation temperatures / characteristics.

It will be appreciated there are many variations to the approaches discussed above and many other ways of providing locations with different susceptibility to induced current flows.

For example, in some implementations the heating element may comprise regions having different electrical resistivity in order to provide different degrees of heating in the different regions. This may be provided by a heating element comprising different materials having different electrical resistivities. In another implementation, the heating element may comprise a material having different physical characteristics in different regions. For example, there may be regions of the heating element having different thicknesses in a direction parallel to the magnetic fields generated by the drive coil and / or regions of the heating element having different porosity.

In some examples, the heating element itself may be uniform, but the drive coil may be configured so the magnetic field generated when in use varies across the heating element such that different regions of the heating element in effect have different susceptibility to induced current flow because the magnetic field generated at the heating element when the drive coil is in use has different strengths in different locations.

It will further be appreciated that in accordance with various embodiments of the disclosure, a heating element having characteristics arranged to provide regions of different susceptibility to induced currents can be provided in conjunction with other vaporiser

characteristics described herein, for example the heating element having different regions of susceptibility to induced currents may comprise a porous material arranged to wick liquid formulation from a source of liquid formulation by capillary action to replace liquid formulation vaporised by the heating element when in use and / or may be provided adjacent to a wicking element arranged to wick liquid formulation from a source of liquid formulation by capillary action to replace liquid formulation vaporised by the heating element when in use.

5 It will furthermore be appreciated that a heating element comprising regions having different susceptibility to induced currents is not restricted to use in aerosol provision systems of the kind described herein, but can be used more generally in an inductive heat assembly of any aerosol provision system. Accordingly, although various example 10 embodiments described herein have focused on a two-part aerosol provision system comprising a re-useable control unit 302 and a replaceable cartridge 304, in other examples, a heating element having regions of different susceptibility may be used in an aerosol provision system that does not include a replaceable cartridge, but is a disposable system or a refillable system. Similarly, although the various example embodiments described herein 15 have focused on an aerosol provision system in which the drive coil is provided in the reusable control unit 302 and the heating element is provided in the replaceable cartridge 304, in other implementations the drive coil may also be provided in the replaceable cartridge, with the control unit and cartridge having an appropriate electrical interface for coupling power to the drive coil. 20

It will further be appreciated that in some example implementations a heating element may incorporate features from more than one of the heating elements represented in Figures 9 to 12. For example, a heating element may comprise different materials (e.g. as discussed above with reference to Figures 9A and 9B) as well as undulations (e.g. as 25 discussed above with reference to Figures 10A and 10B), and so on for other combinations of features.

It will further be appreciated that whilst some the above-described embodiments of a susceptor (heating element) having regions that respond differently to an inductive heater drive coil have focused on an aerosol precursor material comprising a liquid formulation, 30 heating elements in accordance with the principles described herein may also be used in association with other forms of aerosol precursor material, for example solid materials and gel materials.

Thus there has also been described an inductive heating assembly for generating an aerosol from an aerosol precursor material in an aerosol provision system, the inductive 35 heating assembly comprising: a heating element; and a drive coil arranged to induce current flow in the heating element to heat the heating element and vaporise aerosol precursor material in proximity with a surface of the heating element, and wherein the heating element

comprises regions of different susceptibility to induced current flow from the drive coil, such that when in use the surface of the heating element in the regions of different susceptibility are heated to different temperatures by the current flow induced by the drive coil.

5 Figure 13 schematically represents in cross-section a vaporiser assembly 500 for use in an aerosol provision system, for example of the type described above, in accordance with certain embodiments of the present disclosure. The vaporiser assembly 500 comprises a planar vaporiser 505 and a reservoir 502 of source liquid 504. The vaporiser 505 in this example comprises an inductive heating element 506 the form of a planar disk comprising ANSI 304 steel or other suitable material such as discussed above, surrounded by a wicking / wadding matrix 508 comprising a non-conducting fibrous material, for example a woven fibreglass material. The source liquid 504 may comprise an E-liquid formulation of the kind commonly used in electronic cigarettes, for example comprising 0-5% nicotine dissolved in a solvent comprising glycerol, water, and / or propylene glycol. The source liquid may also comprise flavourings. The reservoir 502 in this example comprises a chamber of free source liquid, but in other examples the reservoir may comprise a porous matrix or any other structure for retaining the source liquid until such time that it is required to be delivered to the aerosol generator / vaporiser.

The vaporiser assembly 500 of Figure 13 may, for example, be part of a replaceable cartridge for an aerosol provision system of the kinds discussed herein. For example, the vaporiser assembly 500 represented in Figure 13 may correspond with the vaporiser 305 and reservoir 312 of source liquid 314 represented in the example aerosol provision system 300 of Figure 8. Thus, the vaporiser assembly 500 is arranged in a cartridge of an electronic cigarette so that when a user inhales on the cartridge / electronic cigarette, air is drawn through the cartridge and over a vaporising surface of the vaporiser. The vaporising surface of the vaporiser is the surface from which vaporised source liquid is released into the surrounding airflow, and so in the example of Figure 13, is the left-most face of the vaporiser 505. (It will be appreciated that references to "left" and "right", and similar terms indicating orientation, are used to refer to the orientations represented in the figures for ease of explanation and are not intended to indicate any particular orientation is required for use.)

30 The vaporiser 505 is a planar vaporiser in the sense of having a generally planar / sheet-like form. Thus, the vaporiser 505 comprises first and second opposing faces connected by a peripheral edge wherein the dimensions of the vaporiser in the plane of the first and second faces, for example a length or width of the vaporiser faces, is greater than the thickness of the vaporiser (i.e. the separation between the first and second faces), for example by more than a factor of two, more than a factor of three, more than a factor of four, more than a factor of five, or more than a factor of 10. It will be appreciated that although the vaporiser has a generally planar form, the vaporiser does not necessarily have a flat planar

form, but could include bends or undulations, for example of the kind shown for the heating element 340 in Figure 10B. The heating element 506 part of the vaporiser 505 is a planar heating element in the same way as the vaporiser 505 is a planar vaporiser.

5 For the sake of providing a concrete example, the vaporiser assembly 505 schematically represented in Figure 13 is taken to be generally circularly-symmetric about a horizontal axis through the centre of, and in the plane of, the cross-section view represented in Figure 13, and to have a characteristic diameter of around 12 mm and a length of around 30 mm, with the vaporiser 505 having a diameter of around 11 mm and a thickness of around 2 mm, and with the heating element 506 having a diameter of around
10 10 mm and a thickness of around 1 mm. However, it will be appreciated that other sizes and shapes of vaporiser assembly can be adopted according to the implementation at hand, for example having regard to the overall size of the aerosol provision system. For example, some other implementations may adopt values in the range of 10% to 200% of these example values.

15 The reservoir 502 for the source liquid (e-liquid) 504 is defined by a housing comprising a body portion (shown with hatching in Figure 13) which may, for example, comprise one or more plastic moulded pieces, which provides a sidewall and end wall of the reservoir 502 whilst the vaporiser 505 provides another end wall of the reservoir 502. The vaporiser 505 may be held in place within the reservoir housing body portion in a
20 number of different ways. For example, the vaporiser 505 may be press-fitted and / or glued in the end of the reservoir housing body portion. Alternatively, or in addition, a separate fixing mechanism may be provided, for example a suitable clamping arrangement could be used.

Thus, the vaporiser assembly 502 of Figure 13 may form part of an aerosol provision
25 system for generating an aerosol from a source liquid, the aerosol provision system comprising the reservoir of source liquid 504 and the planar vaporiser 505 comprising the planar heating element 506. By having the vaporiser 505, and in particular in the example of Figure 13, the wicking material 508 surrounding the heating element 506, in contact with source liquid 504 in the reservoir 502, the vaporiser draws source liquid from the reservoir to
30 the vicinity of the vaporising surface of the vaporiser through capillary action. An induction heater coil of the aerosol provision system in which the vaporiser assembly 500 is provided is operable to induce current flow in the heating element 506 to inductively heat the heating element and so vaporise a portion of the source liquid in the vicinity of the vaporising surface of the vaporiser, thereby releasing the vaporised source liquid into air flowing around the
35 vaporising surface of the vaporiser.

The configuration represented in Figure 13 in which the vaporiser comprises a generally planar form comprising an inductively-heated generally planar heating element and

configured to draw source liquid to the vaporiser's vaporising surface provides a simple yet efficient configuration for feeding source liquid to an inductively heated vaporiser of the types described herein. In particular, the use of a generally planar vaporiser provides a configuration that can have a relatively large vaporising surface with a relatively small thermal mass. This can help provide a faster heat-up time when aerosol generation is initiated, and a faster cool-down time when aerosol generation ceases. Faster heat-up times can be desired in some scenarios to reduce user waiting, and faster cool-down times can be desired in some scenarios to help avoid residual heat in the vaporiser from causing ongoing aerosol generation after a user has stopped inhaling. Such ongoing aerosol generation in effect represents a waste of source liquid and power, and can lead to source liquid condensing within the aerosol vision system.

In the example of Figure 13, the vaporiser 505 includes the non-conductive porous material 508 to provide the function of drawing source liquid from the reservoir to the vaporising surface through capillary action. In this case the heating element 506 may, for example, comprise a nonporous conducting material, such as a solid disc. However, in other implementations the heating element 506 may also comprise a porous material so that it also contributes to the wicking of source liquid from the reservoir to the vaporising surface. In the vaporiser 505 represented in Figure 13, the porous material 508 fully surrounds the heating element 506. In this configuration the portions of porous material 508 to either side of the heating element 506 may be considered to provide different functionality. In particular, a portion of the porous material 508 between the heating element 506 and the source liquid 504 in the reservoir 502 may be primarily responsible for drawing the source liquid from the reservoir to the vicinity of the vaporising surface of the vaporiser, whereas the portion of the porous material 508 on the opposite side of the heating element (i.e. to be left in Figure 13) may absorb source liquid that has been drawn from the reservoir to the vicinity of the vaporising surface of the vaporiser so as to store / retain the source liquid in the vicinity of the vaporising surface of the vaporiser for subsequent vaporisation.

Thus, in the example of Figure 13, the vaporising surface of the vaporiser comprises at least a portion of the left-most face of the vaporiser and source liquid is drawn from the reservoir to the vicinity of the vaporising surface through contact with the right-most face of the vaporiser. In examples where the heating element comprises a solid material, the capillary flow of source liquid to the vaporising surface may pass through the porous material 508 at the peripheral edge of the heating element 506 to reach the vaporising surface. In examples where the heating element comprises a porous material, the capillary flow of source liquid to the vaporising surface may in addition pass through the heating element 506.

Figure 14 schematically represents in cross-section a vaporiser assembly 510 for use in an aerosol provision system, for example of the type described above, in accordance with certain other embodiments of the present disclosure. Various aspects of the vaporiser assembly 510 of Figure 14 are similar to, and will be understood from, correspondingly numbered elements of the vaporiser assembly 500 represented in Figure 13. However, the vaporiser assembly 510 differs from the vaporiser assembly 500 in having an additional vaporiser 515 provided at an opposing end of the reservoir 512 of source liquid 504 (i.e. the vaporiser and the further vaporiser are separated along a longitudinal axis of the aerosol provision system). Thus, the main body of the reservoir 512 (shown hatched in Figure 14) comprises what is in effect a tube which is closed at both ends by walls provided by a first vaporiser 505, as discussed above in relation to Figure 13, and a second vaporiser 515, which is in essence identical to the vaporiser 505 at the other end of the reservoir 512. Thus, the second vaporiser 515 comprises a heating element 516 surrounded by a porous material 518 in the same way as the vaporiser 505 comprises a heating element 506 surrounded by a porous material 508. The functionality of the second vaporiser 515 is as described above in connection with Figure 13 for the vaporiser 505, the only difference being the end of the reservoir 504 to which the vaporiser is coupled. The approach of Figure 14 can be used to generate greater volumes of vapour since, with a suitably configured airflow path passing both vaporisers 505, 515, a larger area of vaporisation surface is provided (in effect doubling the vaporisation surface area provided by the single-vaporiser configuration of Figure 13).

In configurations in which an aerosol provision system comprises multiple vaporisers, for example as shown in Figure 14, the respective vaporisers may be driven by the same or separate induction heater coils. That is to say, in some examples a single induction heater coil may be operable simultaneously to induce current flows in heating elements of multiple vaporisers, whereas in some other examples, respective ones of multiple vaporisers may be associated with separate and independently driveable induction heater coils, thereby allowing different ones of the multiple vaporiser to be driven independently of each other.

In the example vaporiser assemblies 500, 510 represented in Figures 13 and 14, the respective vaporisers 505, 515 are fed with source liquid in contact with a planar face of the vaporiser. However, in other examples, a vaporiser may be fed with source liquid in contact with a peripheral edge portion of the vaporiser, for example in a generally annular configuration such as shown in Figure 15.

Thus, Figure 15 schematically represents in cross-section a vaporiser assembly 520 for use in an aerosol provision system in accordance with certain other embodiments of the present disclosure. Aspects of the vaporiser assembly 520 shown in Figure 15 which are

similar to, and will be understood from, corresponding aspects of the example vaporiser assemblies represented in the other figures are not described again in the interest of brevity.

The vaporiser assembly 520 represented in Figure 15 again comprises a generally planar vaporiser 525 and a reservoir 522 of source liquid 524. In this example the reservoir 522 has a generally annular cross-section in the region of the vaporiser assembly 520, with the vaporiser 525 mounted within the central part of the reservoir 522, such that an outer periphery of the vaporiser 525 extends through a wall of the reservoir's housing (schematically shown hatched in Figure 15) so as to contact liquid 524 in the reservoir. The vaporiser 525 in this example comprises an inductive heating element 526 the form of a planar annular disk comprising ANSI 304 steel, or other suitable material such as discussed above, surrounded by a wicking / wadding matrix 528 comprising a non-conducting fibrous material, for example a woven fibreglass material. Thus, the vaporiser 525 of Figure 15 broadly corresponds with the vaporiser 505 of Figure 13, except for having a passageway 527 passing through the centre of the vaporiser through which air can be drawn when the vaporiser is in use.

The vaporiser assembly 520 of Figure 15 may, for example, again be part of a replaceable cartridge for an aerosol provision system of the kinds discussed herein. For example, the vaporiser assembly 520 represented in Figure 15 may correspond with the wick 454, heating element 455 and reservoir 470 represented in the example aerosol provision system / e-cigarette 410 of Figure 4. Thus, the vaporiser assembly 520 is a section of a cartridge of an electronic cigarette so that when a user inhales on the cartridge / electronic cigarette, air is drawn through the cartridge and through the passageway 527 in the vaporiser 525. The vaporising surface of the vaporiser is the surface from which vaporised source liquid is released into the passing airflow, and so in the example of Figure 15, corresponds with surfaces of the vaporiser which are exposed to the air path through the centre of the vaporiser assembly 520

For the sake of providing a concrete example, the vaporiser 525 schematically represented in Figure 15 is taken to have a characteristic diameter of around 12 mm and a thickness of around 2 mm with the passageway 527 having a diameter of 2mm. The heating element 526 is taken to have having a diameter of around 10 mm and a thickness of around 1 mm with a hole of diameter 4 mm around the passageway. However, it will be appreciated that other sizes and shapes of vaporiser can be adopted according to the implementation at hand. For example, some other implementations may adopt values in the range of 10% to 200% of these example values.

The reservoir 522 for the source liquid (e-liquid) 522 is defined by a housing comprising a body portion (shown with hatching in Figure 15) which may, for example, comprise one or more plastic moulded pieces which provide a generally tubular inner

reservoir wall in which the vaporiser is mounted so the peripheral edge of the vaporiser 525 extends through the inner tubular wall of the reservoir housing to contact the source liquid 524. The vaporiser 525 may be held in place with the reservoir housing body portion in a number of different ways. For example, the vaporiser 525 may be press-fitted and / or glued in the corresponding opening in the reservoir housing body portion. Alternatively, or in addition, a separate fixing mechanism may be provided, for example a suitable clamping arrangement may be provided. The opening in the reservoir housing into which the vaporiser is received may be slightly undersized as compared to the vaporiser so the inherent compressibility of the porous material 528 helps in sealing the opening in the reservoir housing against fluid leakage.

Thus, and as with the vaporiser assemblies of Figures 13 and 14, the vaporiser assembly 522 of Figure 15 may form part of an aerosol provision system for generating an aerosol from a source liquid comprising the reservoir of source liquid 524 and the planar vaporiser 525 comprising the planar heating element 526. By having the vaporiser 525, and in particular in the example of Figure 15, the porous wicking material 528 surrounding the heating element 526, in contact with source liquid 524 in the reservoir 522 at the periphery of the vaporiser, the vaporiser 525 draws source liquid from the reservoir to the vicinity of the vaporising surface of the vaporiser through capillary action. An induction heater coil of the aerosol provision system in which the vaporiser assembly 520 is provided is operable to induce current flow in the planar annular heating element 526 to inductively heat the heating element and so vaporise a portion of the source liquid in the vicinity of the vaporising surface of the vaporiser, thereby releasing the vaporised source liquid into air flowing through the central tube defined by the reservoir 522 and the passageway 527 through the vaporiser 525.

The configuration represented in Figure 15 in which the vaporiser comprises a generally planar form comprising an inductively-heated generally planar heating element and configured to draw source liquid to the vaporiser vaporising surface provides a simple yet efficient configuration for feeding source liquid to an inductively heated vaporiser of the types described herein having a generally annular liquid reservoir.

In the example of Figure 15, the vaporiser 525 includes the non-conductive porous material 528 to provide the function of drawing source liquid from the reservoir to the vaporising surface through capillary action. In this case the heating element 526 may, for example, comprise a nonporous material, such as a solid disc. However, in other implementations the heating element 526 may also comprise a porous material so that it also contributes to the wicking of source liquid from the reservoir to the vaporising surface.

Thus, in the example of Figure 15, the vaporising surface of the vaporiser comprises at least a portion of each of the left- and right-facing faces of the vaporiser, and wherein

source liquid is drawn from the reservoir to the vicinity of the vaporising surface through contact with at least a portion of the peripheral edge of the vaporiser. In examples, where the heating element comprises a porous material, the capillary flow of source liquid to the vaporising surface may in addition pass through the heating element 526.

5 Figure 16 schematically represents in cross-section a vaporiser assembly 530 for use in an aerosol provision system, for example of the type described above, in accordance with certain other embodiments of the present disclosure. Various aspects of the vaporiser assembly 530 of Figure 16 are similar to, and will be understood from, corresponding elements of the vaporiser assembly 520 represented in Figure 15. However, the vaporiser
10 assembly 530 differs from the vaporiser assembly 520 in having two vaporisers 535A, 535B provided at different longitudinal positions along a central passageway through a reservoir housing 532 containing source liquid 534. The respective vaporisers 535A, 535B each comprise a heating element 536A, 536B surrounded by a porous wicking material 538A, 538B. The respective vaporisers 535A, 535B and the manner in which they interact with the
15 source liquid 534 in the reservoir 532 may correspond with the vaporiser 525 represented in Figure 15 and the manner in which that vaporiser interacts with the source liquid 524 in the reservoir 522. The functionality and purpose for providing multiple vaporisers in the example represented in Figure 16 may be broadly the same as discussed above in relation to the vaporiser assembly 510 comprising multiple vaporisers represented in Figure 14.

20 Figure 17 schematically represents in cross-section a vaporiser assembly 540 for use in an aerosol provision system, for example of the type described above, in accordance with certain other embodiments of the present disclosure. Various aspects of the vaporiser 540 of Figure 17 are similar to, and will be understood from, correspondingly numbered elements of the vaporiser assembly 500 represent in Figure 13. However, the vaporiser
25 assembly 540 differs from the vaporiser assembly 500 in having a modified vaporiser 545 as compared to the vaporiser 505 of Figure 13. In particular, whereas in the vaporiser 505 of Figure 13 the heating element 506 is surrounded by the porous material 508 on both faces, in the example of Figure 17, the vaporiser 545 comprises a heating element 546 which is only surrounded by porous material 548 on one side, and in particular on the side
30 facing the source liquid 504 in the reservoir 502. In this configuration the heating element 546 comprises a porous conducting material, such as a web of steel fibres, and the vaporising surface of the vaporiser is the outward facing (i.e. shown left-most in Figure 17) face of the heater element 546. Thus, the source liquid 504 may be drawn from the reservoir 502 to the vaporising surface of the vaporiser by capillary action through the
35 porous material 548 and the porous heater element 546. The operation of an electronic aerosol provision system incorporating the vaporiser of Figure 17 may otherwise be

generally as described herein in relation to the other induction heating based aerosol provision systems.

5 Figure 18 schematically represents in cross-section a vaporiser assembly 550 for use in an aerosol provision system, for example of the type described above, in accordance with certain other embodiments of the present disclosure. Various aspects of the vaporiser assembly 550 of Figure 18 are similar to, and will be understood from, correspondingly numbered elements of the vaporiser assembly 500 represented in Figure 13. However, the vaporiser assembly 550 differs from the vaporiser assembly 500 in having a modified vaporiser 555 as compared to the vaporiser 505 of Figure 13. In particular, whereas in the
10 vaporiser 505 of Figure 13 the heating element 506 is surrounded by the porous material 508 on both faces, in the example of Figure 18, the vaporiser 555 comprises a heating element 556 which is only surrounded by porous material 558 on one side, and in particular on the side facing away from the source liquid 504 in the reservoir 502. The heating element 556 again comprises a porous conducting material, such as a sintered / mesh steel
15 material. The heating element 556 in this example is configured to extend across the full width of the opening in the housing of the reservoir 502 to provide what is in effect a porous seal and may be held in place by a press fit in the opening of the housing of the reservoir and / or glued in place and / or include a separate clamping mechanism. The porous material 558 in effect provides the vaporisation surface for the vaporiser 555. Thus, the
20 source liquid 504 may be drawn from the reservoir 502 to the vaporising surface of the vaporiser by capillary action through the porous heater element 556. The operation of an electronic aerosol provision system incorporating the vaporiser of Figure 18 may otherwise be generally as described herein in relation to the other induction heating based aerosol provision systems.

25 Figure 19 schematically represents in cross-section a vaporiser assembly 560 for use in an aerosol provision system, for example of the type described above, in accordance with certain other embodiments of the present disclosure. Various aspects of the vaporiser assembly 560 of Figure 19 are similar to, and will be understood from, correspondingly numbered elements of the vaporiser assembly 500 represented in Figure 13. However, the
30 vaporiser assembly 560 differs from the vaporiser assembly 500 in having a modified vaporiser 565 as compared to the vaporiser 505 of Figure 13. In particular, whereas in the vaporiser 505 of Figure 13 the heating element 506 is surrounded by the porous material 508, in the example of Figure 19, the vaporiser 565 consists of a heating element 566 without any surrounding porous material. In this configuration the heating element 566
35 again comprises a porous conducting material, such as a sintered / mesh steel material. The heating element 566 in this example is configured to extend across the full width of the opening in the housing of the reservoir 502 to provide what is in effect a porous seal and

may be held in place by a press fit in the opening of the housing of the reservoir and / or glued in place and / or include a separate clamping mechanism. The heating element 546 in effect provides the vaporisation surface for the vaporiser 565 and also provides the function of drawing source liquid 504 from the reservoir 502 to the vaporising surface of the vaporiser by capillary action. The operation of an electronic aerosol provision system incorporating the vaporiser of Figure 19 may otherwise be generally as described herein in relation to the other induction heating based aerosol provision systems.

Figure 20 schematically represents in cross-section a vaporiser assembly 570 for use in an aerosol provision system, for example of the type described above, in accordance with certain other embodiments of the present disclosure. Various aspects of the vaporiser assembly 570 of Figure 20 are similar to, and will be understood from, correspondingly numbered elements of the vaporiser assembly 520 represented in Figure 15. However, the vaporiser assembly 570 differs from the vaporiser assembly 520 in having a modified vaporiser 575 as compared to the vaporiser 525 of Figure 15. In particular, whereas in the vaporiser 525 of Figure 15 the heating element 526 is surrounded by the porous material 528, in the example of Figure 20, the vaporiser 575 consists of a heating element 576 without any surrounding porous material. In this configuration the heating element 576 again comprises a porous conducting material, such as a sintered / mesh steel material. The periphery of the heating element 576 is configured to extend into a correspondingly sized opening in the housing of the reservoir 522 to provide contact with the liquid formulation and may be held in place by a press fit and / or glue and / or a clamping mechanism. The heating element 546 in effect provides the vaporisation surface for the vaporiser 575 and also provides the function of drawing source liquid 524 from the reservoir 522 to the vaporising surface of the vaporiser by capillary action. The operation of an electronic aerosol provision system incorporating the vaporiser of Figure 20 may otherwise be generally as described herein in relation to the other induction heating based aerosol provision systems.

Thus, Figures 13 to 20 show a number of different example liquid feed mechanisms for use in an inductively heater vaporiser of an electronic aerosol provision system, such as an electronic cigarette. It will be appreciated these example set out principles that may be adopted in accordance with some embodiments of the present disclosure, and in other implementations different arrangements may be provided which include these and similar principles. For example, it will be appreciated the configurations need not be circularly symmetric, but could in general adopt other shapes and sizes according to the implementation hand. It will also be appreciated that various features from the different configurations may be combined. For example, whereas in Figure 15 the vaporiser is mounted on an internal wall of the reservoir 522, in another example, a generally annular

vaporiser may be mounted at one end of a annular reservoir. That is to say, what might be termed an "end cap" configuration of the kind shown in Figure 13 could also be used for an annular reservoir whereby the end-cap comprises an annular ring, rather than a non-annular disc, such as in the Example of Figures 13, 14 and 17 to 19. Furthermore, it will be appreciated the example vaporisers of Figures 17, 18, 19 and 20 could equally be used in a vaporiser assembly comprising multiple vaporisers, for example shown in Figures 15 and 16.

It will furthermore be appreciated that vaporiser assemblies of the kind shown in Figures 13 to 20 are not restricted to use in aerosol provision systems of the kind described herein, but can be used more generally in any inductive heating based aerosol provision system. Accordingly, although various example embodiments described herein have focused on a two-part aerosol provision system comprising a re-useable control unit and a replaceable cartridge, in other examples, a vaporiser of the kind described herein with reference to Figures 13 to 20 may be used in an aerosol provision system that does not include a replaceable cartridge, but is a one-piece disposable system or a refillable system.

It will further be appreciated that in accordance with some example implementations, the heating element of the example vaporiser assemblies discussed above with reference to Figures 13 to 20 may correspond with any of the example heating elements discussed above, for example in relation to Figures 9 to 12. That is to say, the arrangements shown in Figures 13 to 20 may include a heating element having a non-uniform response to inductive heating, as discussed above.

Thus, there has been described an aerosol provision system for generating an aerosol from a source liquid, the aerosol provision system comprising: a reservoir of source liquid; a planar vaporiser comprising a planar heating element, wherein the vaporiser is configured to draw source liquid from the reservoir to the vicinity of a vaporising surface of the vaporiser through capillary action; and an induction heater coil operable to induce current flow in the heating element to inductively heat the heating element and so vaporise a portion of the source liquid in the vicinity of the vaporising surface of the vaporiser. In some example the vaporiser further comprises a porous wadding / wicking material, e.g. an electrically non-conducting fibrous material at least partially surrounding the planar heating element (susceptor) and in contact with source liquid from the reservoir to provide, or at least contribute to, the function of drawing source liquid from the reservoir to the vicinity of the vaporising surface of the vaporiser. In some examples the planar heating element (susceptor) may itself comprise a porous material so as to provide, or at least contribute to, the function of drawing source liquid from the reservoir to the vicinity of the vaporising surface of the vaporiser.

In order to address various issues and advance the art, this disclosure shows by way of illustration various embodiments in which the claimed invention(s) may be practiced. The advantages and features of the disclosure are of a representative sample of embodiments only, and are not exhaustive and/or exclusive. They are presented only to assist in understanding and to teach the claimed invention(s). It is to be understood that advantages, 5 embodiments, examples, functions, features, structures, and/or other aspects of the disclosure are not to be considered limitations on the disclosure as defined by the claims or limitations on equivalents to the claims, and that other embodiments may be utilised and modifications may be made without departing from the scope of the claims. Various 10 embodiments may suitably comprise, consist of, or consist essentially of, various combinations of the disclosed elements, components, features, parts, steps, means, etc. other than those specifically described herein, and it will thus be appreciated that features of the dependent claims may be combined with features of the independent claims in combinations other than those explicitly set out in the claims. The disclosure may include other inventions not 15 presently claimed, but which may be claimed in future.

Claims:

1. An inductive heating assembly for generating an aerosol from an aerosol precursor material in an aerosol provision system, the inductive heating assembly comprising:
5 a susceptor; and
a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor, and
wherein the susceptor comprises regions of different electrical resistivity, such that when in use the surface of the susceptor in the regions of different electrical resistivity are
10 heated to different temperatures by the current flow induced by the drive coil.

2. An inductive heating assembly for generating an aerosol from an aerosol precursor material in an aerosol provision system, the inductive heating assembly comprising:
a susceptor; and
15 a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor, and
wherein the susceptor comprises openings defined by walls which disrupt the flow of induced current within the susceptor.

- 20 3. The inductive heating assembly of claim 2, wherein the openings are arranged so as to provide regions of different susceptibility to induced current flow from the drive coil, such that when in use the surface of the susceptor in the regions of different susceptibility are heated to different temperatures by the current flow induced by the drive coil.

- 25 4. An inductive heating assembly for generating an aerosol from an aerosol precursor material in an aerosol provision system, the inductive heating assembly comprising:
a susceptor; and
a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor, and
30 wherein the susceptor comprises a wall which is not parallel to the direction of induced current flow, thereby disrupting the flow of induced currents in the susceptor to create regions of different current density.

5. The inductive heating assembly of claim 4, wherein the wall is an outer wall of the
35 susceptor or an inner wall of the susceptor.

6. An inductive heating assembly for generating an aerosol from an aerosol precursor material in an aerosol provision system, the inductive heating assembly comprising:
a susceptor; and
a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor, and
5 wherein the susceptor comprises slot openings extended inwardly from a periphery of the susceptor.
7. The inductive heating assembly of claim 6, wherein the slot openings are arranged so
10 as to provide regions of different susceptibility to induced current flow from the drive coil, such that when in use the surface of the susceptor in the regions of different susceptibility are heated to different temperatures by the current flow induced by the drive coil.
8. An inductive heating assembly for generating an aerosol from an aerosol precursor
15 material in an aerosol provision system, the inductive heating assembly comprising:
a susceptor; and
a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor, wherein the drive coil extends along a coil axis about which the magnetic field generated by the drive coil
20 when in use is generally circularly symmetric, and wherein the susceptor is not circularly symmetric about the coil axis.
9. An inductive heating assembly for generating an aerosol from an aerosol precursor
material in an aerosol provision system, the inductive heating assembly comprising:
25 a susceptor; and
a drive coil arranged to induce current flow in the susceptor to heat the susceptor and vaporise aerosol precursor material in proximity with a surface of the susceptor, wherein the susceptor has regions of different thicknesses along a direction parallel to the magnetic field generated at the susceptor when the drive coil is in use.
30
10. An inductive heating assembly for generating an aerosol from an aerosol precursor
material in an aerosol provision system, the inductive heating assembly comprising:
a susceptor; and
a drive coil arranged to induce current flow in the susceptor to heat the susceptor and
35 vaporise aerosol precursor material in proximity with a surface of the susceptor, and arranged so the magnetic field generated at the susceptor when the drive coil is in use has a different strength in different regions of the susceptor.

11. The inductive heating assembly of any one of claims 1 to 10, wherein the aerosol precursor material comprise comprises a solid material.
- 5 12. An aerosol provision system comprising the inductive heating assembly according to any one of claims 1 to 11, wherein the aerosol provision system comprises a host device and a cartridge, the host device comprising the drive coil of the inductive heating assembly and the cartridge comprising the susceptor of the inductive heating assembly.

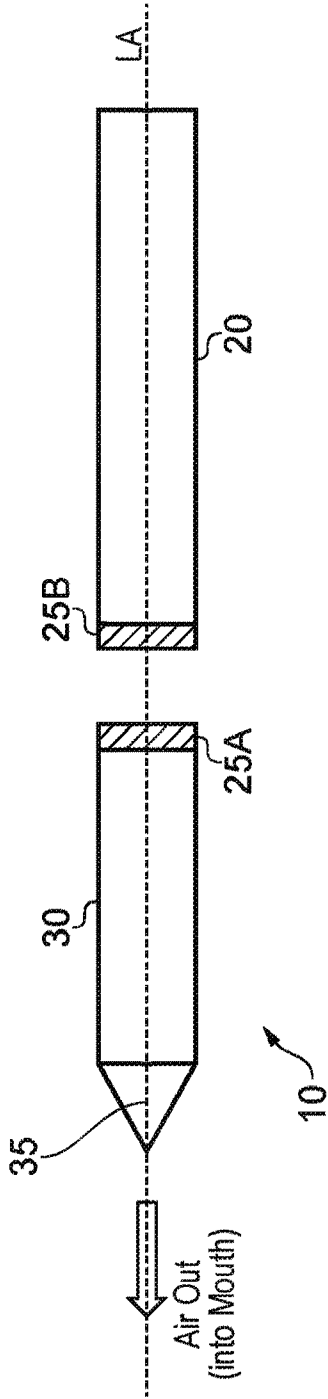


FIG. 1 (PRIOR ART)

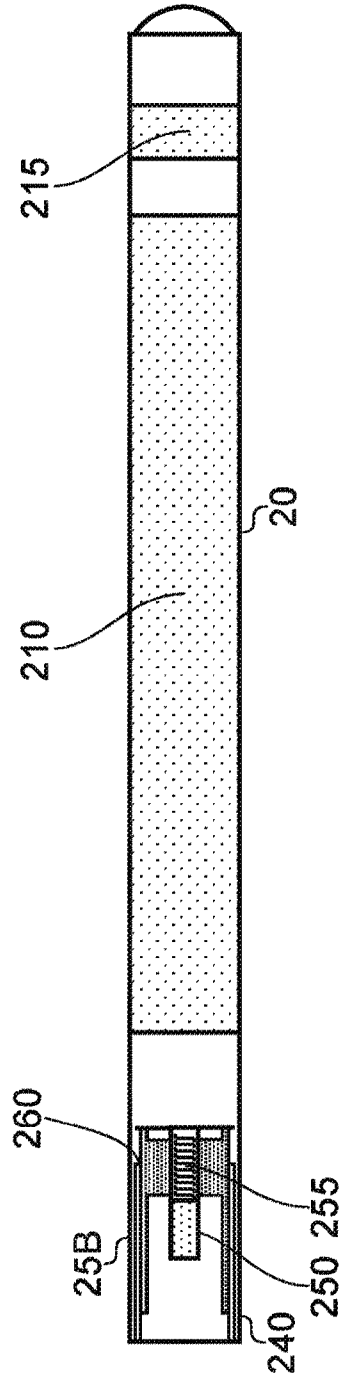


FIG. 2 (PRIOR ART)

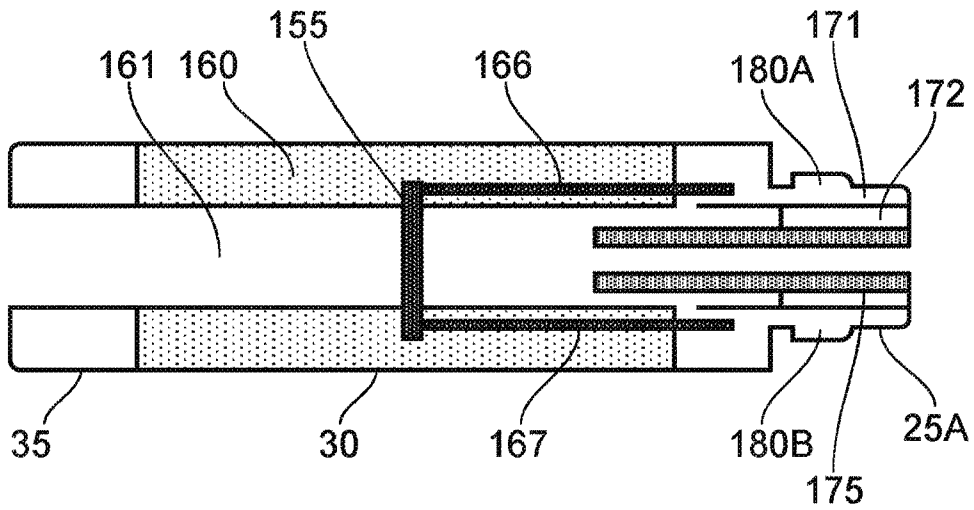


FIG. 3 (PRIOR ART)

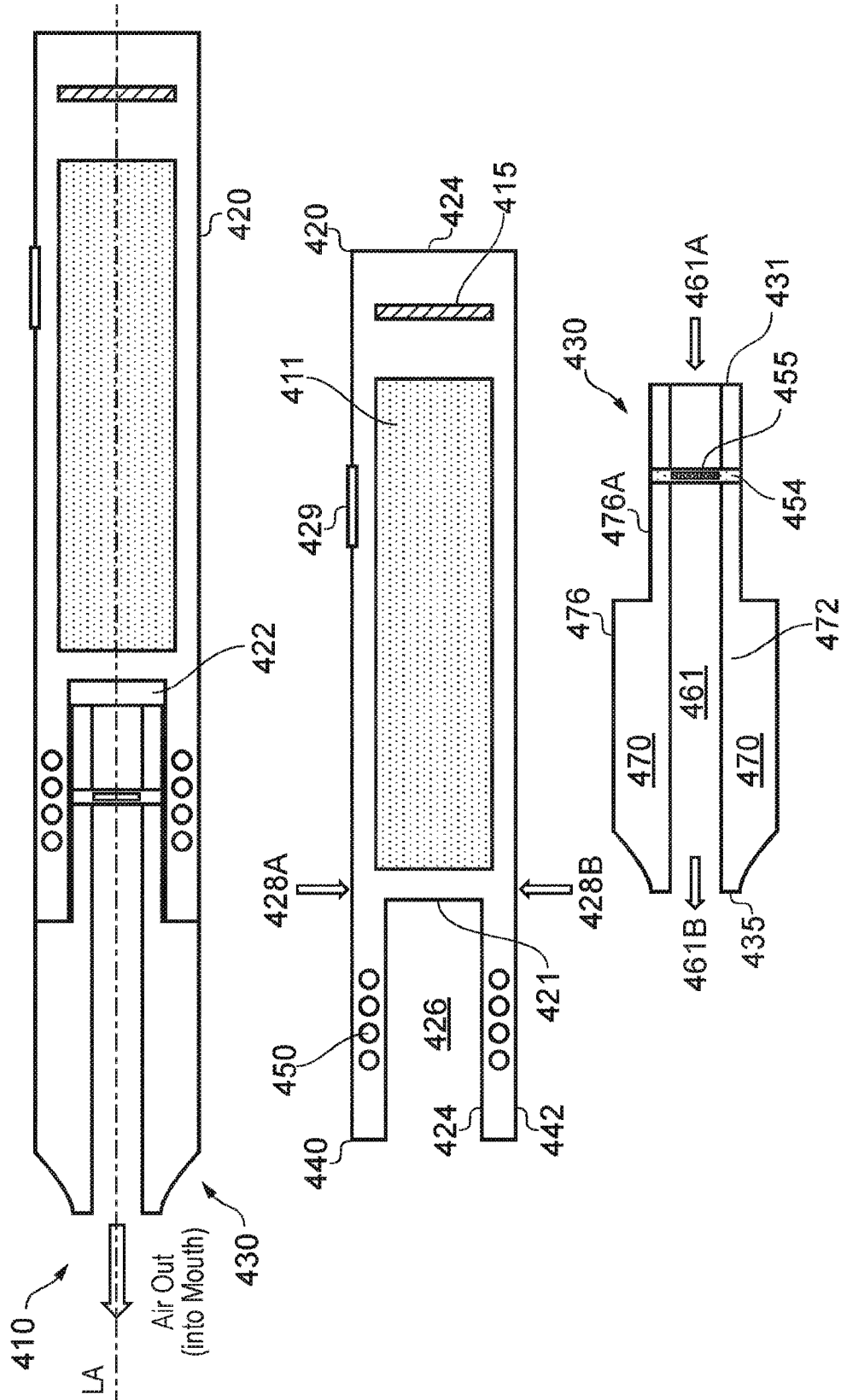


FIG. 4

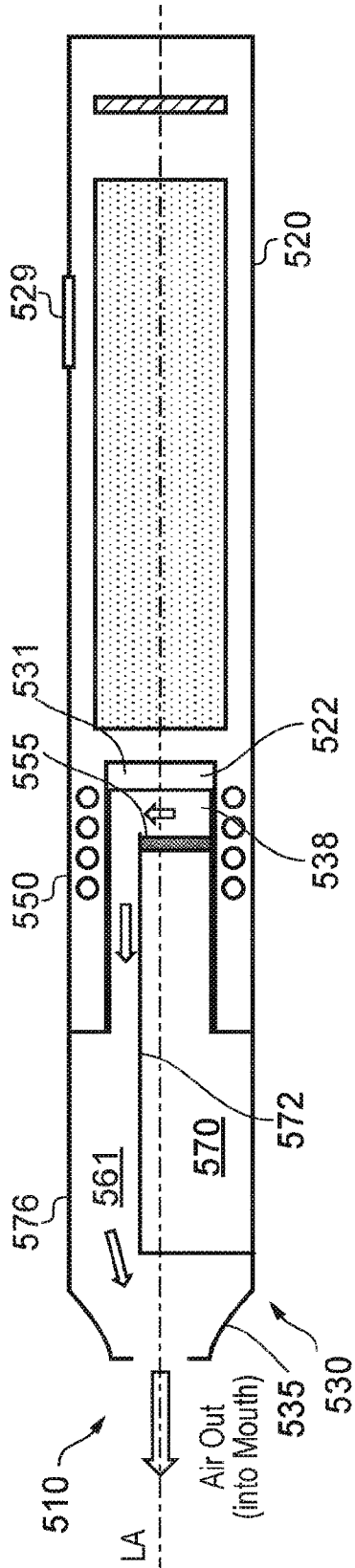


FIG. 5

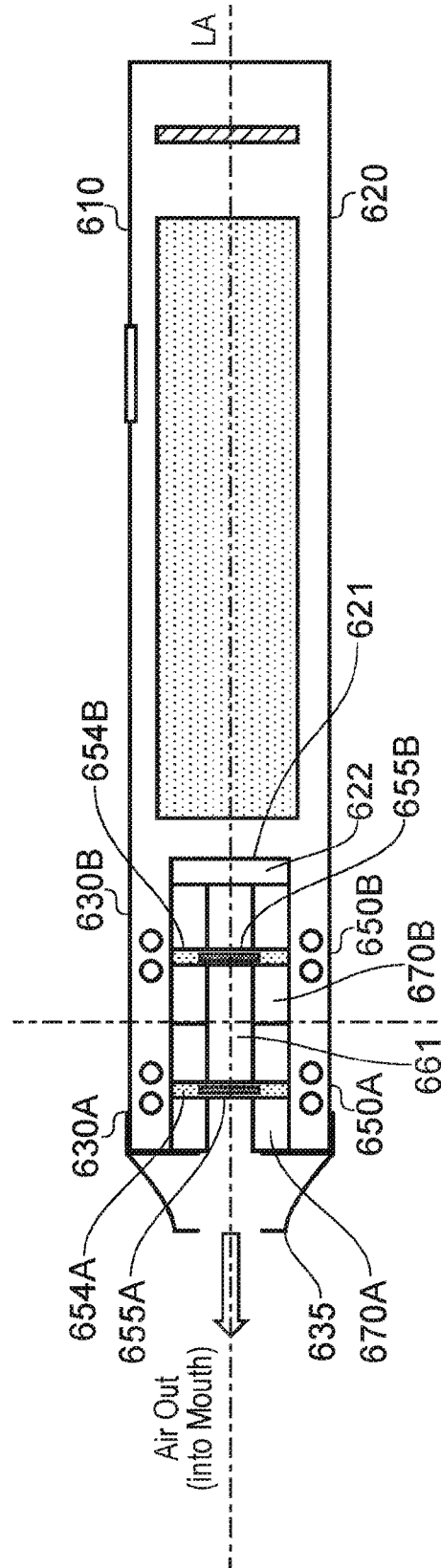


FIG. 6

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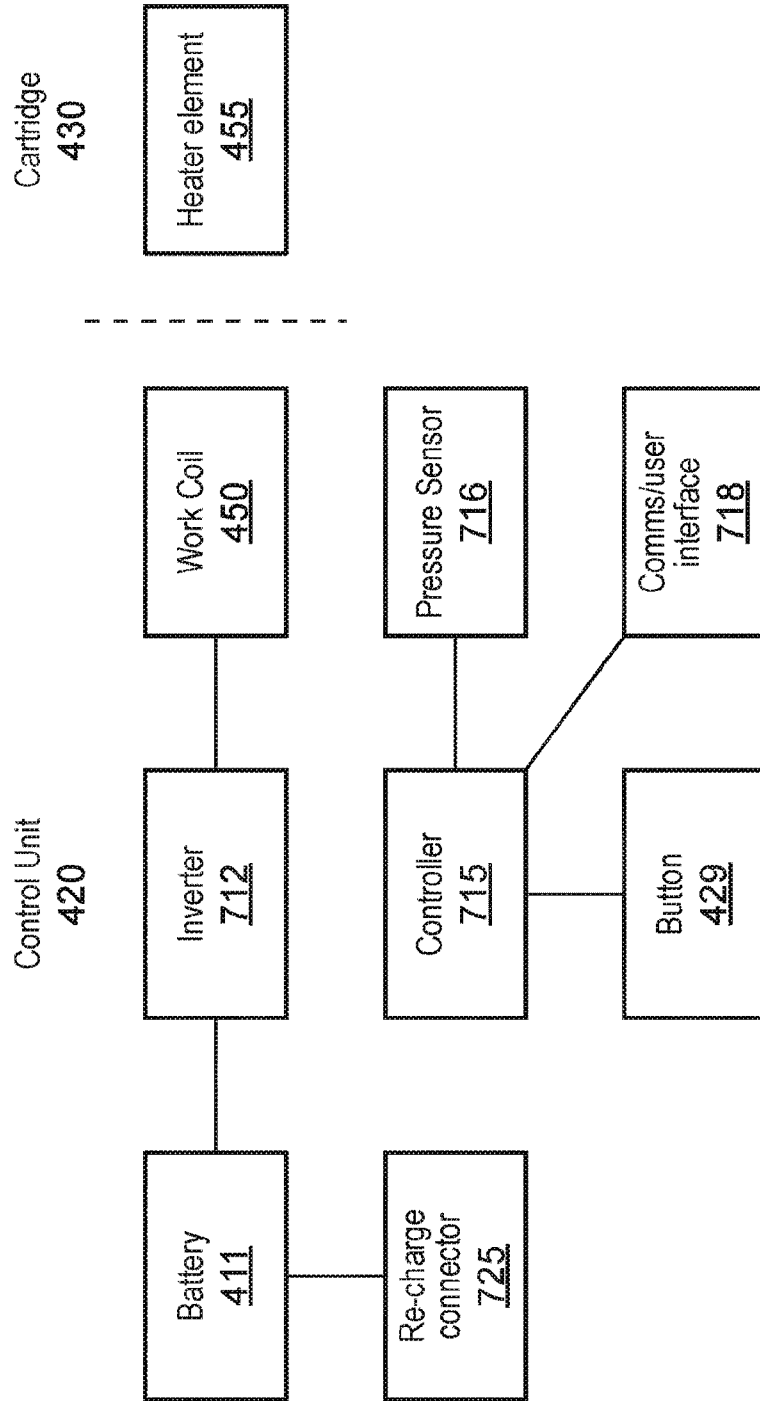


FIG. 7

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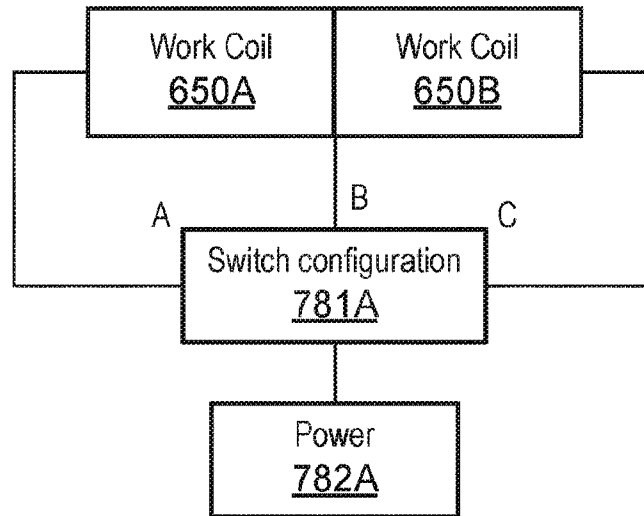


FIG. 7A

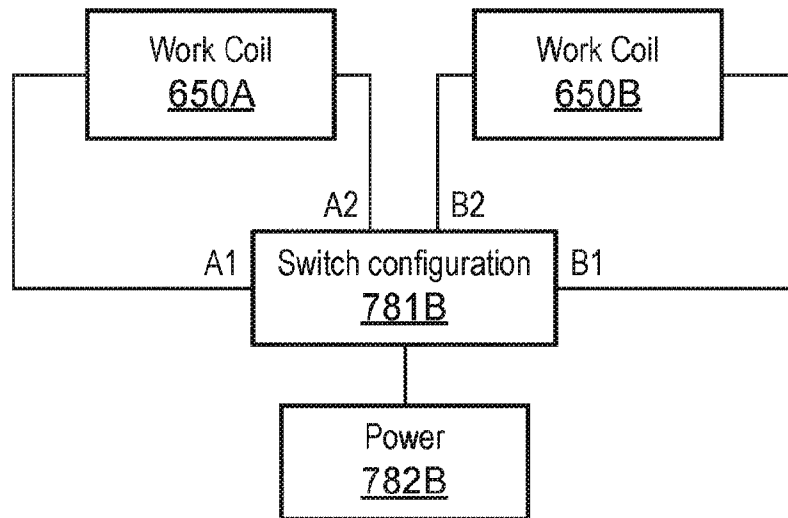


FIG. 7B

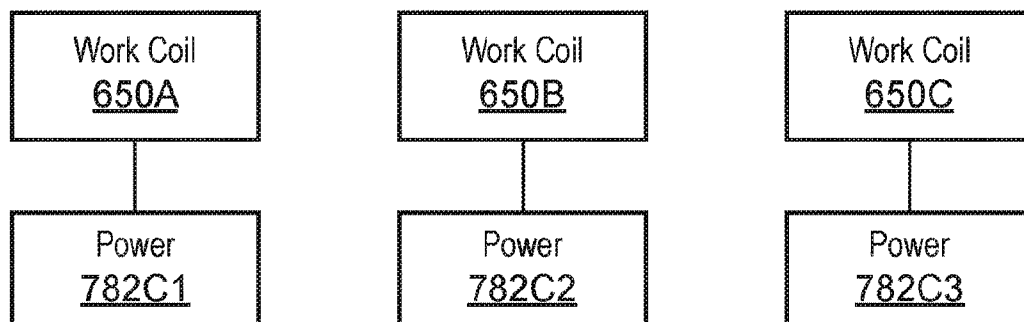


FIG. 7C

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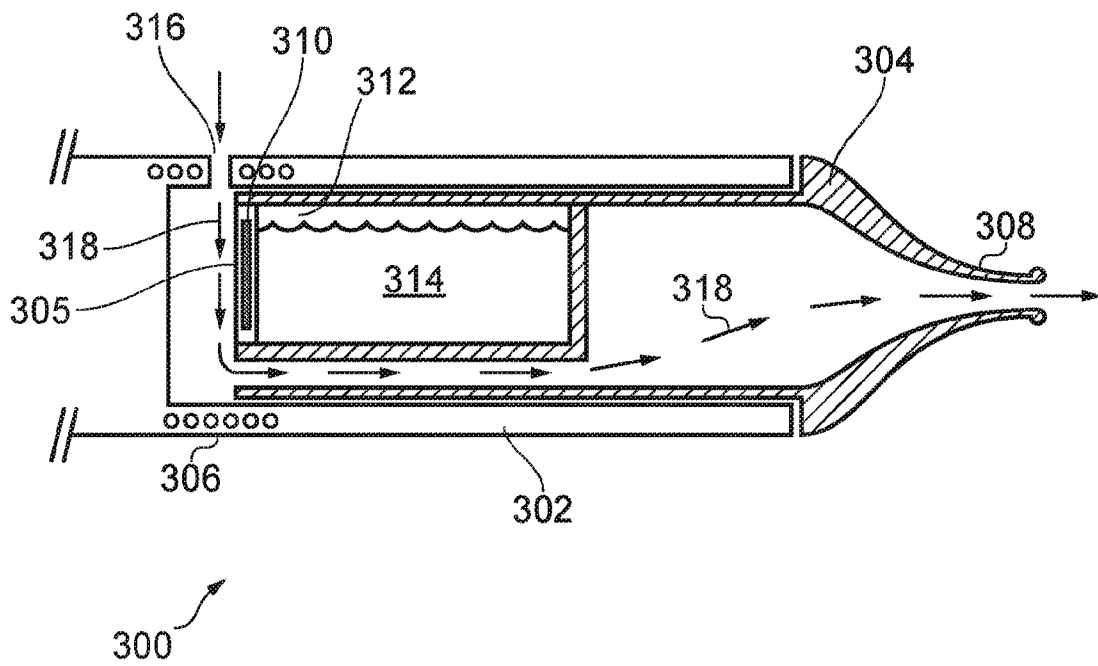


FIG. 8

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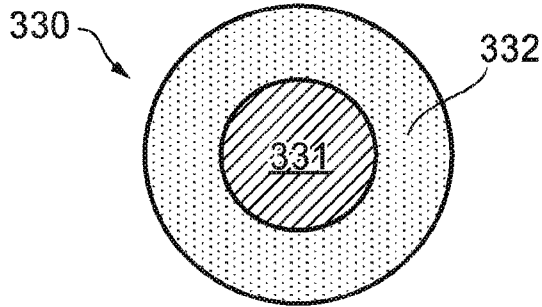


FIG. 9A

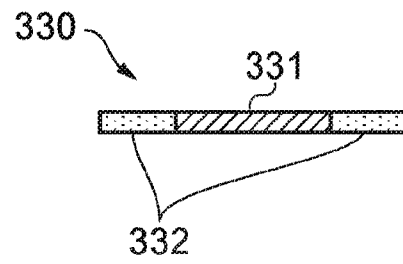


FIG. 9B

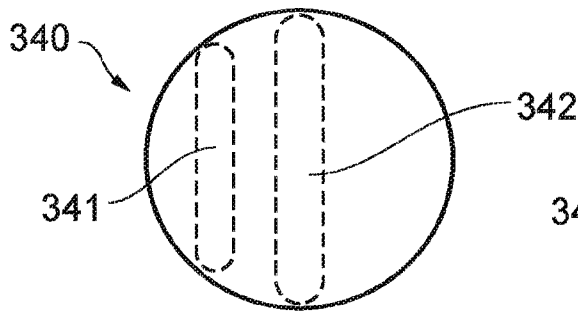


FIG. 10A

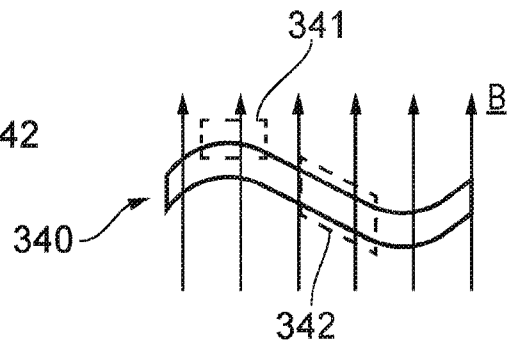


FIG. 10B

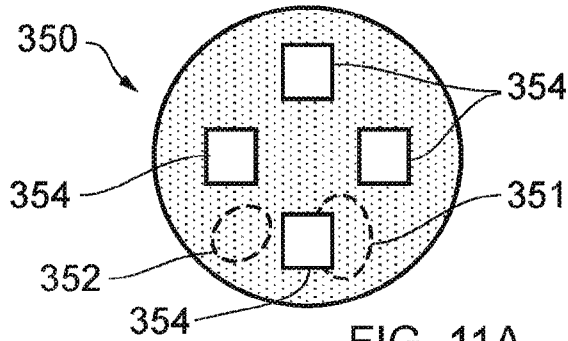


FIG. 11A

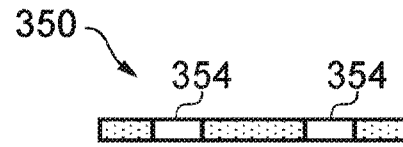


FIG. 11B

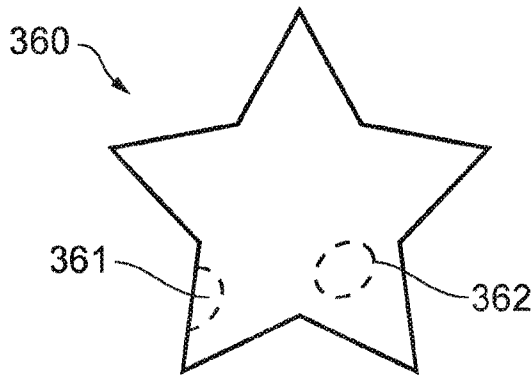


FIG. 12A



FIG. 12B

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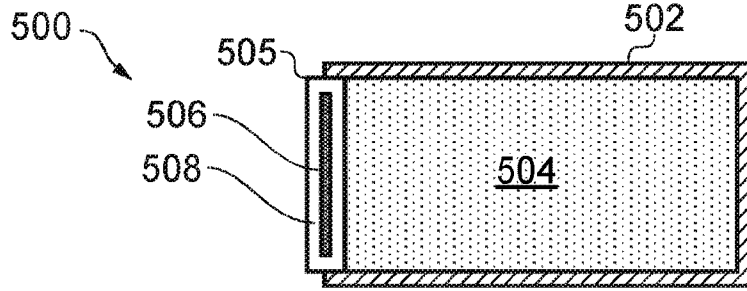


FIG. 13

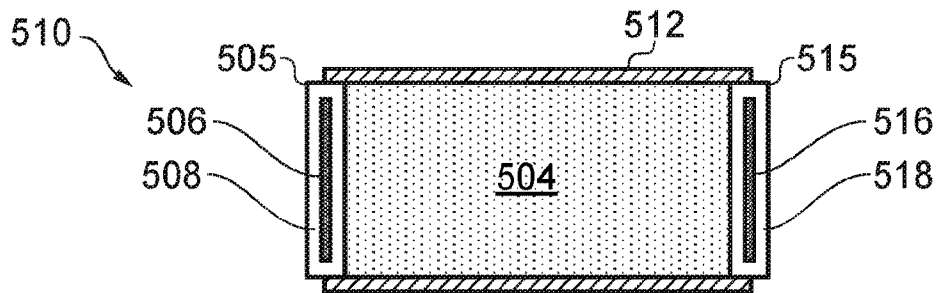


FIG. 14

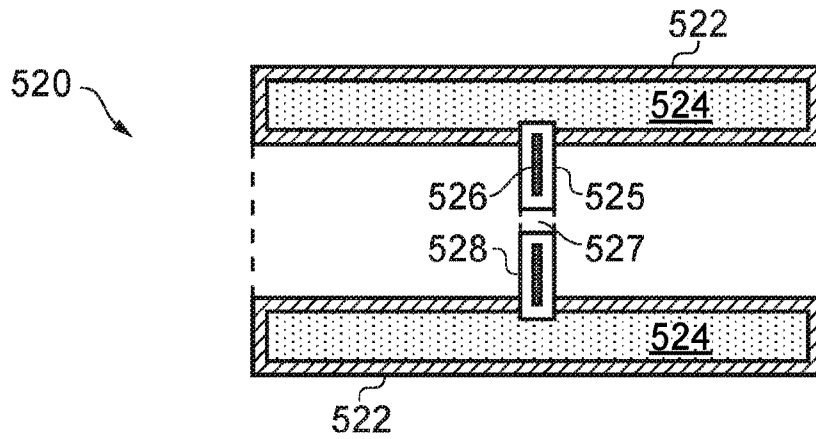


FIG. 15

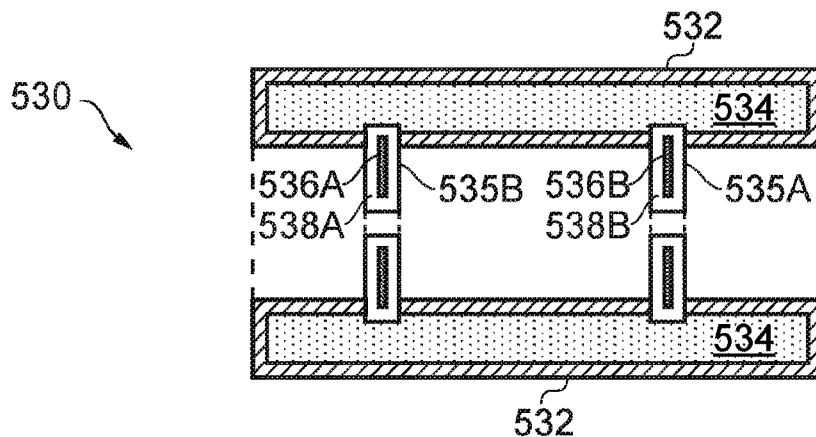


FIG. 16

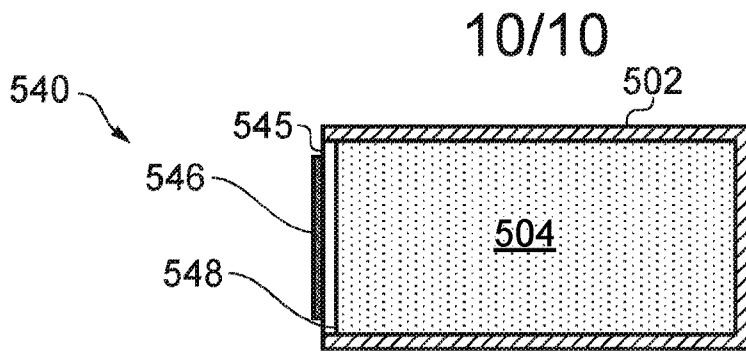


FIG. 17

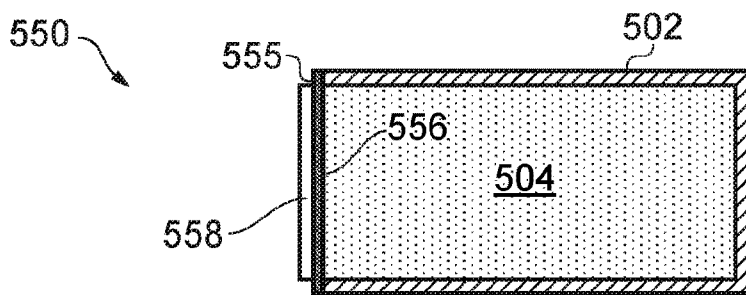


FIG. 18

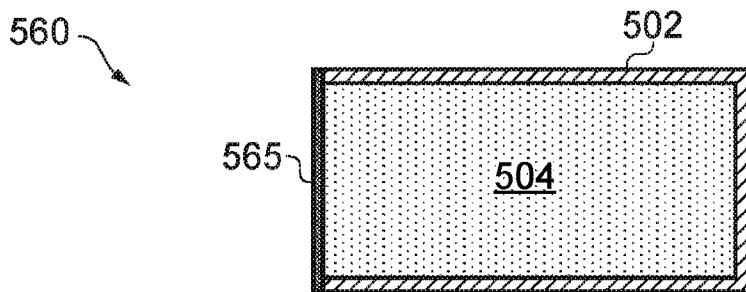


FIG. 19

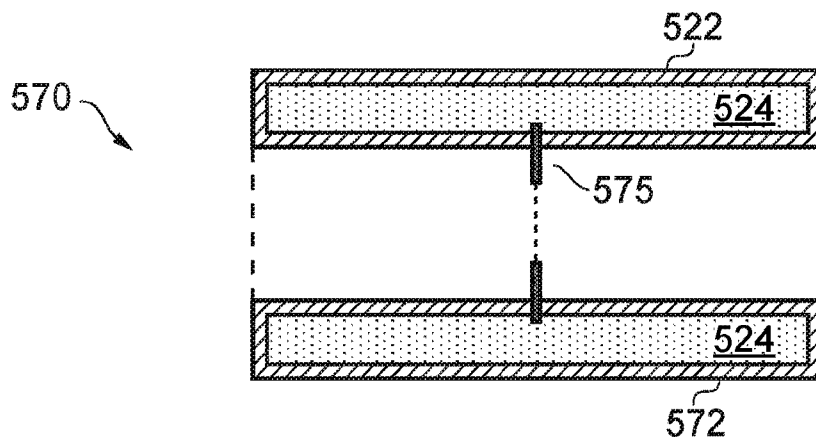


FIG. 20

