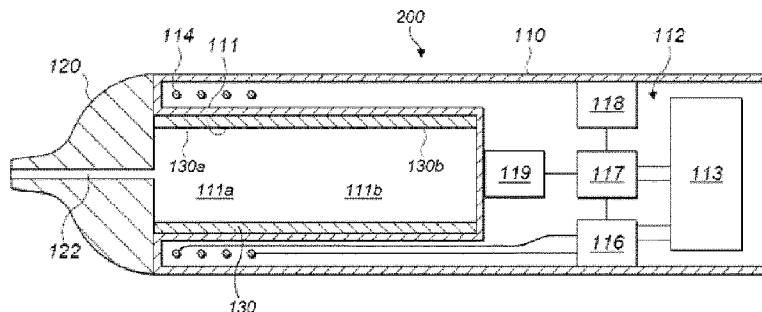




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 (54) Title: APPARATUS FOR HEATING SMOKABLE MATERIAL



(57) **Abrégé/Abstract:**

Disclosed is apparatus (100, 200) for heating smokable material to volatilise at least one component of the smokable material. The apparatus (100, 200) comprises: a heating zone (111) for receiving at least a portion of an article comprising smokable material; an outlet (122) for permitting volatilised components of the smokable material to pass from the heating zone (111) towards an exterior of the apparatus (100, 200) when the article is heated in the heating zone (111) in use; a heating element (115, 130) that is heatable by penetration with a varying magnetic field to heat the heating zone (111), wherein a first section (115a, 130a) of the heating element (115, 130) is located between a second section (115b, 130b) of the heating element (115, 130) and the outlet (122), and wherein the second section (115b, 130b) of the heating element (115, 130) is heatable in use by thermal conduction from the first section (115a, 130a) of the heating element (115, 130); and a magnetic field generator (112) for generating a varying magnetic field that penetrates the first section (115a, 130a) of the heating element (115, 130) and avoids the second section (115b, 130b) of the heating element (115, 130).

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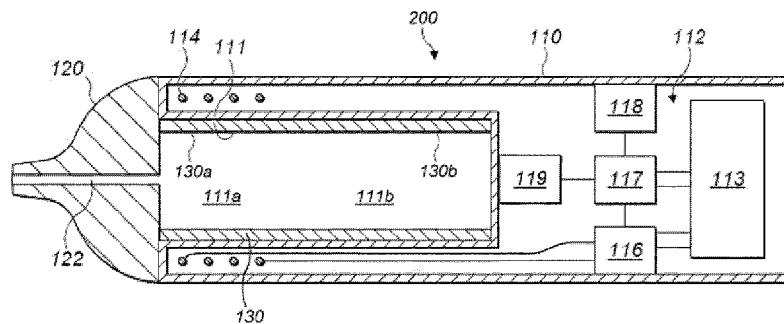


FIG. 2

(57) **Abstract:** Disclosed is apparatus (100, 200) for heating smokable material to volatilise at least one component of the smokable material. The apparatus (100, 200) comprises: a heating zone (111) for receiving at least a portion of an article comprising smokable material; an outlet (122) for permitting volatilised components of the smokable material to pass from the heating zone (111) towards an exterior of the apparatus (100, 200) when the article is heated in the heating zone (111) in use; a heating element (115, 130) that is heatable by penetration with a varying magnetic field to heat the heating zone (111), wherein a first section (115a, 130a) of the heating element (115, 130) is located between a second section (115b, 130b) of the heating element (115, 130) and the outlet (122), and wherein the second section (115b, 130b) of the heating element (115, 130) is heatable in use by thermal conduction from the first section (115a, 130a) of the heating element (115, 130); and a magnetic field generator (112) for generating a varying magnetic field that penetrates the first section (115a, 130a) of the heating element (115, 130) and avoids the second section (115b, 130b) of the heating element (115, 130).

WO 2018/002083 A1

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APPARATUS FOR HEATING SMOKABLE MATERIAL

5 TECHNICAL FIELD

The present invention relates to apparatus for heating smokable material to volatilise at least one component of the smokable material, to systems comprising such apparatus and articles comprising smokable material, and to methods of heating smokable material to volatilise at least one component of the smokable material.

10 BACKGROUND

Smoking articles such as cigarettes, cigars and the like burn tobacco during use to create tobacco smoke. Attempts have been made to provide alternatives to these articles by creating products that release compounds without combusting. Examples of such products are so-called “heat not burn” products or tobacco heating devices or products, which release compounds by heating, but not burning, material. The material may be, for example, tobacco or other non-tobacco products, which may or may not contain nicotine.

SUMMARY

20 A first aspect of the present invention provides apparatus for heating smokable material to volatilise at least one component of the smokable material, the apparatus comprising: a heating zone for receiving at least a portion of an article comprising smokable material; an outlet for permitting volatilised components of the smokable material to pass from the heating zone towards an exterior of the apparatus when the article is heated in the heating zone in use;

25 a heating element that is heatable by penetration with a varying magnetic field to heat the

heating zone, wherein a first section of the heating element is located between a second section of the heating element and the outlet, and wherein the second section of the heating element is heatable in use by thermal conduction from the first section of the heating element; and a magnetic field generator for generating a varying magnetic field that penetrates the first section
5 of the heating element and avoids the second section of the heating element.

In an exemplary embodiment, the apparatus is free from any magnetic field generator for generating a varying magnetic field that penetrates the second section of the heating element.

In an exemplary embodiment, the second section of the heating element is heatable in
10 use exclusively by thermal conduction.

In an exemplary embodiment, the heating element projects into the heating zone.

In an exemplary embodiment, the heating element extends at least partially around the heating zone.

In an exemplary embodiment, the magnetic field generator comprises a helical coil that
15 encircles only the first section of the heating element.

In an exemplary embodiment, the magnetic field generator is fixed relative to the heating element.

In an exemplary embodiment, the first section of the heating element is smaller or shorter than the second section of the heating element.

20 In an exemplary embodiment, the heating element comprises heating material that comprises one or more materials selected from the group consisting of: an electrically-conductive material, a magnetic material, and a magnetic electrically-conductive material.

In an exemplary embodiment, the heating element comprises heating material that comprises a metal or a metal alloy.

In an exemplary embodiment, the heating element comprises heating material that comprises one or more materials selected from the group consisting of: aluminium, gold, iron, nickel, cobalt, conductive carbon, graphite, plain-carbon steel, stainless steel, ferritic stainless steel, copper, and bronze.

5 In an exemplary embodiment, the first section of the heating element is made of a first material and the second section of the heating element is made of a second material that is different from the first material.

In an exemplary embodiment, the apparatus is for heating non-liquid smokable material to volatilise at least one component of the smokable material.

10 In an exemplary embodiment, the apparatus is for heating smokable material to volatilise at least one component of the smokable material without combusting the smokable material.

A second aspect of the present invention provides apparatus for heating smokable material to volatilise at least one component of the smokable material, the apparatus
15 comprising: a heating zone for receiving at least a portion of an article comprising smokable material; an outlet for permitting volatilised components of the smokable material to pass from the heating zone towards an exterior of the apparatus when the article is heated in the heating zone in use, wherein a first portion of the heating zone is located between a second portion of the heating zone and the outlet; and a magnetic field generator for generating a varying
20 magnetic field that penetrates the first portion of the heating zone and avoids the second portion of the heating zone.

In an exemplary embodiment, the apparatus is free from any magnetic field generator for generating a varying magnetic field that penetrates the second portion of the heating zone.

In an exemplary embodiment, the magnetic field generator comprises a helical coil that
25 encircles only the first portion of the heating zone.

In an exemplary embodiment, the first portion of the heating zone is smaller or shorter than the second portion of the heating zone.

In an exemplary embodiment, the apparatus is arranged so that the article is insertable into the second portion of the heating zone via the first portion of the heating zone.

5 In an exemplary embodiment, the apparatus is for heating non-liquid smokable material to volatilise at least one component of the smokable material.

In an exemplary embodiment, the apparatus is for heating smokable material to volatilise at least one component of the smokable material without combusting the smokable material.

10 A third aspect of the present invention provides a system for heating smokable material to volatilise at least one component of the smokable material, the system comprising: an article comprising smokable material and a heating element that is heatable by penetration with a varying magnetic field to heat the smokable material; and apparatus, comprising: a heating zone for receiving at least a portion of the article; an outlet for permitting volatilised
15 components of the smokable material to pass from the heating zone when the article is heated in the heating zone in use; and a magnetic field generator for generating a varying magnetic field that penetrates a first section of the heating element between a second section of the heating element and the outlet, and avoids the second section of the heating element, when the article is located in the heating zone in use.

20 In an exemplary embodiment, the apparatus of the system of the third aspect is the apparatus of the second aspect. The apparatus of the system of the third aspect may have any one or more of the features discussed above as being present in respective exemplary embodiments of the apparatus of the second aspect.

A fourth aspect of the present invention provides a method of heating smokable material
25 to volatilise at least one component of the smokable material, the method comprising:

providing a heating element formed that is heatable by penetration with a varying magnetic field; providing smokable material in thermal contact with the heating element; penetrating a first section of the heating element with a varying magnetic field that avoids a second section of the heating element, thereby to heat the first section of the heating element and a first part
5 of the smokable material; and heating the second section of the heating element by thermal conduction from the first section of the heating element, thereby to heat a second part of the smokable material.

BRIEF DESCRIPTION OF THE DRAWINGS

10

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

Figure 1 shows a schematic cross-sectional view of an example of apparatus for heating smokable material to volatilise at least one component of the smokable material;

15 Figure 2 shows a schematic cross-sectional view of an example of another apparatus for heating smokable material to volatilise at least one component of the smokable material;

Figure 3 shows a schematic cross-sectional view of an example of another apparatus for heating smokable material to volatilise at least one component of the smokable material;

20 Figure 4 shows a schematic cross-sectional view of an example of a system comprising an article comprising smokable material, and the apparatus of Figure 3 for heating the smokable material to volatilise at least one component of the smokable material; and

Figure 5 shows a flow diagram showing an example of a method of heating smokable material to volatilise at least one component of the smokable material.

DETAILED DESCRIPTION

As used herein, the term “smokable material” includes materials that provide volatilised components upon heating, typically in the form of vapour or an aerosol. “Smokable material” may be a non-tobacco-containing material or a tobacco-containing material. “Smokable material” may, for example, include one or more of tobacco per se, tobacco derivatives, expanded tobacco, reconstituted tobacco, tobacco extract, homogenised tobacco or tobacco substitutes. The smokable material can be in the form of ground tobacco, cut rag tobacco, extruded tobacco, reconstituted tobacco, reconstituted smokable material, liquid, gel, gelled sheet, powder, or agglomerates, or the like. “Smokable material” also may include other, non-tobacco, products, which, depending on the product, may or may not contain nicotine. “Smokable material” may comprise one or more humectants, such as glycerol or propylene glycol.

As used herein, the term “heating material” or “heater material” refers to material that is heatable by penetration with a varying magnetic field.

Induction heating is a process in which an electrically-conductive object is heated by penetrating the object with a varying magnetic field. The process is described by Faraday’s law of induction and Ohm’s law. An induction heater may comprise an electromagnet and a device for passing a varying electrical current, such as an alternating current, through the electromagnet. When the electromagnet and the object to be heated are suitably relatively positioned so that the resultant varying magnetic field produced by the electromagnet penetrates the object, one or more eddy currents are generated inside the object. The object has a resistance to the flow of electrical currents. Therefore, when such eddy currents are generated in the object, their flow against the electrical resistance of the object causes the object to be heated. This process is called Joule, ohmic, or resistive heating. An object that is capable of being inductively heated is known as a susceptor.

It has been found that, when the susceptor is in the form of a closed circuit, magnetic coupling between the susceptor and the electromagnet in use is enhanced, which results in greater or improved Joule heating.

Magnetic hysteresis heating is a process in which an object made of a magnetic material is heated by penetrating the object with a varying magnetic field. A magnetic material can be considered to comprise many atomic-scale magnets, or magnetic dipoles. When a magnetic field penetrates such material, the magnetic dipoles align with the magnetic field. Therefore, when a varying magnetic field, such as an alternating magnetic field, for example as produced by an electromagnet, penetrates the magnetic material, the orientation of the magnetic dipoles changes with the varying applied magnetic field. Such magnetic dipole reorientation causes heat to be generated in the magnetic material.

When an object is both electrically-conductive and magnetic, penetrating the object with a varying magnetic field can cause both Joule heating and magnetic hysteresis heating in the object. Moreover, the use of magnetic material can strengthen the magnetic field, which can intensify the Joule heating.

In each of the above processes, as heat is generated inside the object itself, rather than by an external heat source by heat conduction, a rapid temperature rise in the object and more uniform heat distribution can be achieved, particularly through selection of suitable object material and geometry, and suitable varying magnetic field magnitude and orientation relative to the object. Moreover, as induction heating and magnetic hysteresis heating do not require a physical connection to be provided between the source of the varying magnetic field and the object, design freedom and control over the heating profile may be greater, and cost may be lower.

Referring to Figure 1 there is shown a schematic cross-sectional view of an example of apparatus according to an embodiment of the invention. The apparatus 100 is for heating smokable material to volatilise at least one component of the smokable material.

The apparatus 100 comprises a heating zone 111 for receiving at least a portion of an article comprising smokable material that is to be heated. The apparatus 100 has an outlet 122 for permitting volatilised components of the smokable material to pass from the heating zone 111 towards an exterior of the apparatus 100 when the article is heated in the heating zone 111 in use. The apparatus 100 also comprises a heating element 115 of heating material that is heatable by penetration with a varying magnetic field to heat the heating zone 111, and a magnetic field generator 112 for generating the varying magnetic field in use.

More specifically, the apparatus 100 of this embodiment comprises a body 110 and a mouthpiece 120. The mouthpiece 120 may be made of any suitable material, such as a plastics material, cardboard, cellulose acetate, paper, metal, glass, ceramic, or rubber. The mouthpiece 120 defines a channel 122 therethrough, which acts as the outlet 122. The mouthpiece 120 is locatable relative to the body 110 so as to cover an opening into the heating zone 111. When the mouthpiece 120 is so located relative to the body 110, the channel 122 of the mouthpiece 120 is in fluid communication with the heating zone 111. In use, the channel 122 acts as a passageway for permitting volatilised material to pass from an article inserted in the heating zone 111 to an exterior of the apparatus 100. In this embodiment, the mouthpiece 120 of the apparatus 100 is releasably engageable with the body 110 so as to connect the mouthpiece 120 to the body 110. In other embodiments, the mouthpiece 120 and the body 110 may be permanently connected, such as through a hinge or flexible member. In some embodiments, such as embodiments in which the article itself comprises a mouthpiece, the mouthpiece 120 of the apparatus 100 may be omitted. In such embodiments, an open end of the heating zone 111 (at the left-hand side of Figure 1 as drawn) may act as the outlet.

The apparatus 100 may define an air inlet that fluidly connects the heating zone 111 with the exterior of the apparatus 100. Such an air inlet may be defined by the body 110 of the apparatus 100 and/or by the mouthpiece 120 of the apparatus 100. A user may be able to inhale the volatilised component(s) of the smokable material by drawing the volatilised component(s) through the channel 122 of the mouthpiece 120. As the volatilised component(s) are removed from the article, air may be drawn into the heating zone 111 via the air inlet of the apparatus 100.

In this embodiment, the body 110 comprises the heating zone 111. In this embodiment, the heating zone 111 comprises a recess 111 for receiving at least a portion of the article. In other embodiments, the heating zone 111 may be other than a recess, such as a shelf, a surface, or a projection, and may require mechanical mating with the article in order to co-operate with, or receive, the article. In this embodiment, the heating zone 111 is elongate, and is sized and shaped to accommodate the whole article. In other embodiments, the heating zone 111 may be dimensioned to receive only a portion of the article.

The heating zone 111 can be considered to comprise a first portion 111a and a second portion 111b, which are relatively arranged so that the first portion 111a of the heating zone 111 is located between the second portion 111b of the heating zone 111 and the outlet 122. The heating zone 111, and the apparatus 100 as a whole, is arranged so that the article is insertable into the second portion 111b of the heating zone 111 via the first portion 111a of the heating zone 111, when the mouthpiece 120 is disengaged from the body 110 of the apparatus 100.

In this embodiment, the magnetic field generator 112 comprises an electrical power source 113, a coil 114, a device 116 for passing a varying electrical current, such as an alternating current, through the coil 114, a controller 117, and a user interface 118 for user-operation of the controller 117.

The electrical power source 113 of this embodiment is a rechargeable battery. In other embodiments, the electrical power source 113 may be other than a rechargeable battery, such as a non-rechargeable battery, a capacitor, a battery-capacitor hybrid, or a connection to a mains electricity supply.

5 The coil 114 may take any suitable form. In this embodiment, the coil 114 is a helical coil of electrically-conductive material, such as copper. In some embodiments, the magnetic field generator 112 may comprise a magnetically permeable core around which the coil 114 is wound. Such a magnetically permeable core concentrates the magnetic flux produced by the coil 114 in use and makes a more powerful magnetic field. The magnetically permeable core
10 may be made of iron, for example. In some embodiments, the magnetically permeable core may extend only partially along the length of the coil 114, so as to concentrate the magnetic flux only in certain regions. In some embodiments, the coil may be a flat coil. That is, the coil may be a two-dimensional spiral.

 It will be understood from consideration of Figure 1 that in this embodiment the heating
15 element 115 projects into the heating zone 111. The heating element 115 has a length from a first end at which the heating element 115 is mounted to the rest of the body 110 to a free second end. The free end is arranged relative to the heating zone 111 so as to enter the article as the article is inserted into the heating zone 111. In some embodiments, the free end of the heating element 115 may be tapered, for example, to facilitate such entry into the article. In
20 some embodiments, the heating element 115 takes the form of a spike or a pin or a blade.

 The heating element 115 has a rectangular cross-section perpendicular to its length. The depth or thickness of the heating element 115 is relatively small as compared to the other dimensions of the heating element 115. Therefore, a greater proportion of the heating element 115 may be heatable by a given varying magnetic field, as compared to a heating element 115
25 having a depth or thickness that is relatively large as compared to the other dimensions of the

heating element 115. Thus, a more efficient use of material is achieved. In turn, costs are reduced. However, in other embodiments, the heating element 115 may have a cross-section that is a shape other than rectangular, such as circular, elliptical, annular, star-shaped, polygonal, square, triangular, X-shaped, or T-Shaped. In this embodiment, the cross-section
5 of the heating element 115 is constant along the length of the heating element 115. Moreover, in this embodiment, the heating element 115 is planar, or substantially planar. The heating element 115 of this embodiment can be considered a flat strip. However, in other embodiments, this may not be the case.

In this embodiment, the coil 114 encircles only a first section 115a of the heating
10 element 115, which is located between a second section 115b of the heating element 115 and the outlet 122. That is, the coil 114 does not encircle the second section 115b of the heating element 115. The magnetic field generator 112 is for generating a varying magnetic field that penetrates the first section 115a of the heating element 115 and avoids the second section 115b
15 of the heating element 115. That is, the varying magnetic field does not penetrate the second section 115b of the heating element 115. Indeed, the apparatus 100 of this embodiment is free from any magnetic field generator for generating a varying magnetic field that penetrates the second section 115b of the heating element 115. The second section 115b of the heating element 115 is heatable in use exclusively by thermal conduction from the first section 115a of the heating element 115.

20 Accordingly, when an article comprising smokable material is located in the heating zone 111 use, a portion of the article closest to the outlet 122 is heated first by heat emanating from the first section 115a of the heating element 115. This initiates volatilisation of at least one component of the smokable material of that portion of the article and formation of an aerosol therein. Over time, the temperature of the second section 115b of the heating element
25 115 increases due to thermal conduction from the first section 115a of the heating element 115.

This causes another portion of the article further from the outlet 122 to be heated by heat emanating from the second section 115b of the heating element 115. This initiates volatilisation of at least one component of the smokable material of the other portion of the article and formation of an aerosol therein. Accordingly, there is provided progressive heating of the article, and thus the smokable material of the article, over time. This helps to enable an aerosol to be formed and released relatively rapidly from an end of the article relatively close to the outlet 122, for inhalation by a user, yet provides time-dependent release of aerosol, so that aerosol continues to be formed and released even after the smokable material of the first portion of the article has ceased generating aerosol. Such cessation of aerosol generation may occur as a result of the smokable material of the first portion of the article becoming exhausted of volatilisable components of the smokable material.

When the article is located in the heating zone 111, the heating element 115 is in thermal contact with the smokable material of the article. Preferably, when the article is located in the heating zone 111, the heating element 115 is in surface contact with the smokable material of the article. Thus, heat may be conducted directly from the heating material to the smokable material. In other embodiments, the heating material may be kept out of surface contact with the smokable material. For example, in some embodiments, the article and/or the heating element 115 may comprise a thermally-conductive barrier that is free from heating material and that spaces the heating material from the smokable material of the article in use. In some embodiments, the thermally-conductive barrier may be a coating on the heating material. The provision of such a barrier may be advantageous to help to dissipate heat to alleviate hot spots in the heating material, or to aid cleaning of the heating element 115.

As noted above, the heating zone 111 has a first portion 111a and a second portion 111b. The first portion 111a of the heating zone 111 is that which the varying magnetic field generated by the magnetic field generator 112 penetrates in use. On the other hand, the second

portion 111b of the heating zone 111 is not penetrated by the varying magnetic field in use. The apparatus 100 is free from any magnetic field generator for generating a varying magnetic field that penetrates the second portion 111b of the heating zone 111. In some cases, the article to be used with the apparatus 100 may comprise a heating element of heating material that is

5 heatable by penetration with a varying magnetic field. The heating element may be arranged in the article so that, when the article is located in the heating zone 111, a first portion of the heating element of the article is located in the first portion 111a of the heating zone 111 and a second portion of the heating element of the article is located in the second portion 111b of the heating zone 111. Accordingly, a similar progressive heating effect to that discussed above

10 could be provided, whereby in use the first portion of the heating element of the article is heated inductively so as to heat a first part of the smokable material in the article, and the second portion of the heating element of the article is heated by thermal conduction from the first portion of the heating element of the article to heat a second part of the smokable material.

In this embodiment, the coil 114 extends along a longitudinal axis that is substantially

15 aligned with a longitudinal axis of the heating zone 111. The aligned axes are coincident. In a variation to this embodiment, the aligned axes may be parallel to each other. However, in other embodiments, the axes may be oblique to each other. Moreover, the coil 114 extends along a longitudinal axis that is substantially coincident with a longitudinal axis of the heating element 115. In other embodiments, the longitudinal axes of the coil 114 and the heating

20 element 115 may be aligned with each other by being parallel to each other, or may be oblique to each other. In this embodiment, the coil 114 and the rest of the magnetic field generator 112 is in a fixed position relative to the heating element 115 and the heating zone 111.

In this embodiment, the device 116 for passing a varying current through the coil 114 is electrically connected between the electrical power source 113 and the coil 114. In this

25 embodiment, the controller 117 also is electrically connected to the electrical power source

113, and is communicatively connected to the device 116 to control the device 116. More specifically, in this embodiment, the controller 117 is for controlling the device 116, so as to control the supply of electrical power from the electrical power source 113 to the coil 114. In this embodiment, the controller 117 comprises an integrated circuit (IC), such as an IC on a printed circuit board (PCB). In other embodiments, the controller 117 may take a different form. In some embodiments, the apparatus may have a single electrical or electronic component comprising the device 116 and the controller 117. The controller 117 is operated in this embodiment by user-operation of the user interface 118. In this embodiment, the user interface 118 is located at the exterior of the body 110. The user interface 118 may comprise a push-button, a toggle switch, a dial, a touchscreen, or the like. In other embodiments, the user interface 118 may be remote and connected to the rest of the apparatus wirelessly, such as via Bluetooth.

In this embodiment, operation of the user interface 118 by a user causes the controller 117 to cause the device 116 to cause an alternating electrical current to pass through the coil 114, so as to cause the coil 114 to generate an alternating magnetic field. The coil 114 and the heating element 115 of the apparatus 100 are suitably relatively positioned so that the varying magnetic field produced by the coil 114 penetrates the heating material of the heating element 115. When the heating material of the heating element 115 is an electrically-conductive material, this may cause the generation of one or more eddy currents in the heating material. The flow of eddy currents in the heating material against the electrical resistance of the heating material causes the heating material to be heated by Joule heating. In this embodiment, the heating material is made of a magnetic material, and so the orientation of magnetic dipoles in the heating material changes with the changing applied magnetic field, which causes heat to be generated in the heating material.

In this embodiment, an impedance of the coil 114 of the magnetic field generator 112 is equal, or substantially equal, to an impedance of the heating element 115. If the impedance of the heating element 115 were instead lower than the impedance of the coil 114, then the voltage generated across the heating element 115 in use may be lower than the voltage that may be generated across the heating element 115 when the impedances are matched. Alternatively, if the impedance of the heating element 115 were instead higher than the impedance of the coil 114, then the electrical current generated in the heating element 115 in use may be lower than the current that may be generated in the heating element 115 when the impedances are matched. Matching the impedances may help to balance the voltage and current to maximise the heating power generated at the heating element 115 in use. In some embodiments, the impedance of the device 116 may be equal, or substantially equal, to a combined impedance of the coil 114 and the heating element 115.

The apparatus 100 of this embodiment comprises a temperature sensor 119 for sensing a temperature of the heating zone 111. The temperature sensor 119 is communicatively connected to the controller 117, so that the controller 117 is able to monitor the temperature of the heating zone 111. On the basis of one or more signals received from the temperature sensor 119, the controller 117 may cause the device 116 to adjust a characteristic of the varying or alternating electrical current passed through the coil 114 as necessary, in order to ensure that the temperature of the heating zone 111 remains within a predetermined temperature range. The characteristic may be, for example, amplitude or frequency or duty cycle. Within the predetermined temperature range, in use the smokable material within an article located in the heating zone 111 is heated sufficiently to volatilise at least one component of the smokable material without combusting the smokable material. Accordingly, the controller 117, and the apparatus 100 as a whole, is arranged to heat the smokable material to volatilise the at least one component of the smokable material without combusting the smokable material. In some

embodiments, the temperature range is about 50°C to about 300°C, such as between about 50°C and about 250°C, between about 50°C and about 150°C, between about 50°C and about 120°C, between about 50°C and about 100°C, between about 50°C and about 80°C, or between about 60°C and about 70°C. In some embodiments, the temperature range is between about 170°C and about 220°C. In other embodiments, the temperature range may be other than this range. In some embodiments, the upper limit of the temperature range could be greater than 300°C. In some embodiments, the temperature sensor 119 may be omitted. In some embodiments, the heating material may have a Curie point temperature selected on the basis of the maximum temperature to which it is desired to heat the heating material, so that further heating above that temperature by induction heating the heating material is hindered or prevented.

Referring to Figure 2 there is shown a schematic cross-sectional view of an example of another apparatus according to an embodiment of the invention. The apparatus 200 of Figure 2 is identical to the apparatus 100 of Figure 1 except for the form of the heating element of the apparatus. Therefore, in the interest of conciseness, features common to the two embodiments will not be described again in detail. Any of the herein-described possible variations to the apparatus 100 of Figure 1 may be made to the apparatus 200 of Figure 2 to form separate respective embodiments.

As noted above, in the apparatus 100 of Figure 1, the heating element 115 projects into the heating zone 111. In contrast, in the apparatus 200 of Figure 2, the heating element 130 of heating material extends around the heating zone 111. Therefore, whereas in the embodiment of Figure 1 the heating zone 111 and any article therein in use is heated from the middle outwards, in the embodiment of Figure 2 the heating zone 111 and any article therein in use is heated from the outside inwards.

The heating element 130 is a tubular heating element 130 that encircles the heating zone 111. However, in other embodiments, the heating element 130 may not be fully tubular. For

example, in some embodiments, the heating element 130 may be tubular save for an axially-extending gap or slit formed in the heating element 130. The heating element 130 has a substantially circular cross-section. However, in other embodiments, the heating element may have a cross-section other than circular, such as square, rectangular, polygonal or elliptical.

5 The heating element 130 extends along a longitudinal axis that is substantially aligned with a longitudinal axis of the heating zone 111. In this embodiment, the aligned axes are coincident. In a variation to this embodiment, the aligned axes may be parallel to each other. However, in other embodiments, the axes may be oblique to each other.

In this embodiment, the heating zone 111 is defined in part by the heating element 130. That is, the heating element 130 partially delineates or delimits the heating zone 111. When an article comprising smokable material is located in the heating zone 111, the heating element 130 is in thermal contact with the article. Preferably, when an article comprising smokable material is located in the heating zone 111, the heating element 130 is in surface contact with the article. Thus, heat may be conducted directly from the heating material to the article. In other embodiments, the heating material may be kept out of direct surface contact with the article. Examples of how this may be achieved, and benefits that may be attained by doing so, correspond to those discussed above.

Similarly to the heating element 115 of the embodiment of Figure 1, the heating element 130 of the embodiment of Figure 2 has a first section 130a and a second section 130b. The first section 130a of the heating element 130 is located between the second section 130b of the heating element 130 and the outlet 122. The coil 114 encircles only the first section 130a of the heating element 130. That is, the coil 114 does not encircle the second section 130b of the heating element 130. The magnetic field generator 112 is for generating a varying magnetic field that penetrates the first section 130a of the heating element 130 and avoids the second section 130b of the heating element 130. That is, the varying magnetic field does not penetrate

the second section 130b of the heating element 130. As for the embodiment of Figure 1, the apparatus 200 of this embodiment is free from any magnetic field generator for generating a varying magnetic field that penetrates the second section 130b of the heating element 130. The second section 130b of the heating element 130 is heatable in use exclusively by thermal
5 conduction from the first section 130a of the heating element 130. This helps provide progressive heating of the article, and thus the smokable material of the article, over time, in a similar manner to that discussed above.

In a variation to this embodiment, the apparatus may comprise both the heating element 130 that extends at least partially around the heating zone 111, and another heating element
10 that protrudes into the heating zone 111, similar to the heating element 115 of the embodiment of Figure 1. Such an embodiment may help deliver heating of the heating zone 111 and any article therein in use from both the middle and the outside.

In each of the above-described embodiments, the first section 115a, 130a of the heating element 115, 130 is smaller or shorter than the second section 115b, 130b of the heating element
15 115, 130. In other embodiments, this may not be the case. For example, in some embodiments the first and second sections 115a, 115b, 130a, 130b of the heating element 115, 130 may be substantially equally sized. The skilled person would be able to determine appropriate relative sizes of the first and second sections 115a, 115b, 130a, 130b of the heating element 115, 130 that provide for a desired level of progressive heating of the article and the smokable material
20 of the article.

Referring to Figure 3 there is shown a schematic cross-sectional view of an example of another apparatus according to an embodiment of the invention. The apparatus 300 of Figure
3 is identical to the apparatus 100 of Figure 1 except that the apparatus 300 of Figure 3 does not have a heating element that is penetrated by the varying magnetic field generated by the
25 magnetic field generator 112. Therefore, in the interest of conciseness, features common to

the two embodiments will not be described again in detail. Any of the herein-described possible variations to the apparatus 100 of Figure 1 may be made to the apparatus 300 of Figure 3 to form separate respective embodiments.

As discussed above with reference to Figure 1, the heating zone 111 comprises a first portion 111a and a second portion 111b, which are relatively arranged so that the first portion 111a of the heating zone 111 is located between the second portion 111b of the heating zone 111 and the outlet 122. The heating zone 111, and the apparatus 300 as a whole, again is arranged so that the article is insertable into the second portion 111b of the heating zone 111 via the first portion 111a of the heating zone 111, when the mouthpiece 120 is disengaged from the body 110 of the apparatus 300.

In this embodiment, the first portion 111a of the heating zone 111 again is that which the varying magnetic field generated by the magnetic field generator 112 penetrates in use. On the other hand, the second portion 111b of the heating zone 111 is not penetrated by the varying magnetic field in use. That is, the varying magnetic field avoids the second portion 111b of the heating zone 111. The apparatus 300 is free from any magnetic field generator for generating a varying magnetic field that penetrates the second portion 111b of the heating zone 111. As discussed below with reference to Figure 4, an article to be used with the apparatus 300 may comprise a heating element of heating material that is heatable by penetration with a varying magnetic field. The heating element may be arranged in the article so that, when the article is located in the heating zone 111, a first portion of the heating element of the article is located in the first portion 111a of the heating zone 111 and a second portion of the heating element of the article is located in the second portion 111b of the heating zone 111. Accordingly, a similar progressive heating effect to that discussed above could be provided, whereby in use the first portion of the heating element of the article is heated inductively and

the second portion of the heating element of the article is heated by thermal conduction from the first portion of the heating element of the article.

Similarly to the discussion above regarding the relative sizes of the first and second sections 115a, 115b, 130a, 130b of the heating elements 115, 130, in this embodiment the first portion 111a of the heating zone 111 is smaller or shorter than the second portion 111b of the heating zone 111. In other embodiments, however, this may not be the case. For example, in some embodiments the first and second portions 111a, 111b of the heating zone 111 may be substantially equally sized. Again, the skilled person would be able to determine appropriate relative sizes of the first and second portions 111a, 111b of the heating zone 111 that provide for desired progressive heating of the heating element of an article and the smokable material of the article in use.

Referring to Figure 4 there is shown a schematic cross-sectional view of an example of a system according to an embodiment of the invention. The system 3000 comprises the apparatus 300 of Figure 3 and an article 30 comprising smokable material 32, a heating element 34 of heating material that is heatable by penetration with a varying magnetic field, and a cover 36. Therefore, in the interest of conciseness, the apparatus 300 will not be described again in detail. Any of the herein-described possible variations to the apparatus 300 of Figure 3 may be made to the apparatus 300 of the system 3000 of Figure 4 to form separate respective embodiments of a system.

The cover 36 encircles the smokable material 32. The cover 36 helps to protect the smokable material 32 from damage during transport and use of the article 30. During use, the cover 36 may also help to direct the flow of air into and through the smokable material 32, and help to direct the flow of vapour or aerosol through and out of the smokable material 32.

In this embodiment, the cover 36 comprises a wrapper that is wrapped around the smokable material 32 so that free ends of the wrapper overlap each other. The wrapper thus

forms all of, or a majority of, a circumferential outer surface of the article 30. The wrapper may be formed from paper, reconstituted smokable material, such as reconstituted tobacco, or the like. The cover 36 of this embodiment also comprises an adhesive (not shown) that adheres the overlapped free ends of the wrapper to each other. The adhesive may comprise one or more
5 of, for example, gum Arabic, natural or synthetic resins, starches, and varnish. The adhesive helps prevent the overlapped free ends of the wrapper from separating.

The cover 36 defines an outer surface of the article 30 and may contact the apparatus in use. In this embodiment, the article 30 is elongate and cylindrical with a substantially circular cross-section. However, in other embodiments, the article 30 may have a cross-section
10 other than circular and/or not be elongate and/or not be cylindrical. In this embodiment, the article 30 has proportions approximating those of a cigarette.

In this embodiment, the smokable material 32 is in the form of a tube. The tube has a substantially circular cross-section. The smokable material 32 extends from one end of the article 30 to an opposite end of the article 30. Thus, in use, air may be drawn into the smokable
15 material 32 at one end of the article 30, the air may pass through the smokable material 32 and pick up volatilised components released from the smokable material 32, and then the volatilised components, typically in the form of vapour or an aerosol, may be drawn out of the smokable material 32 at the opposite end of the article 30. In this embodiment in which the article 30 is elongate, these ends of the article 30 between which the smokable material 32 extends are
20 opposite longitudinal ends of the article 30. However, in other embodiments, the ends may be any two ends or sides of the article, such as any two opposite ends or sides of the article.

The heating element 34 is in thermal contact with the smokable material 32. Therefore, the heating element 34 is heatable in use to heat the smokable material 32. In this embodiment, the smokable material 32 is in surface contact with the heating element 34. This is achieved
25 by adhering the smokable material 32 to the heating element 34. However, in other

embodiments, the fixing may be by other than adhesion. In some embodiments the smokable material 32 may not be fixed to the heating element 34 as such.

The heating element 34 is elongate and extends from one end of the smokable material 32 to an opposite end of the smokable material 32. This can help to provide more complete heating of the smokable material 32 in use. However, in other embodiments, the heating element 34 may not extend to either of the opposite ends of the smokable material 32, or may extend to only one of the ends of the smokable material 32 and be spaced from the other of the ends of the smokable material 32.

The heating element 34 extends from one end of the article 30 to an opposite end of the article 30. This can aid manufacturing of the article 30. However, in other embodiments, the heating element 34 may not extend to either of the opposite ends of the article 30, or may extend to only one of the ends of the article 30 and be spaced from the other of the ends of the article 30.

In this embodiment, the heating element 34 extends along a longitudinal axis that is substantially aligned with a longitudinal axis of the article 30. This can aid manufacturing of the article 30. In this embodiment, the aligned axes are coincident. In a variation to this embodiment, the aligned axes may be parallel to each other. However, in other embodiments, the axes may be oblique to each other.

In this embodiment, the heating element 34 is encircled by the smokable material 32. That is, the smokable material 32 extends around the heating element 34. In embodiments in which the heating element 34 does not extend to either of the opposite ends of the smokable material 32, the smokable material 32 may extend around the heating element 34 and also cover the ends of the heating element 34, so that the heating element 34 is surrounded by the smokable material 32.

In this embodiment, the heating element 34 is impermeable to air or volatilised material, and is substantially free from discontinuities. The heating element 34 may thus be relatively easy to manufacture. However, in variations to this embodiment, the heating element 34 may be permeable to air and/or permeable to volatilised material created when the smokable material 32 is heated. Such a permeable nature of the heating element 34 may help air passing through the article 30 to pick up the volatilised material created when the smokable material 32 is heated.

The heating element 34 has a rectangular, or substantially rectangular, cross-section perpendicular to its length. The heating element 34 has two opposing major surfaces joined by two minor surfaces. Therefore, the depth or thickness of the heating element 34 is relatively small as compared to the other dimensions of the heating element 34. However, in other embodiments, the heating element 34 may have a cross-section that is a shape other than rectangular, such as circular, elliptical, annular, polygonal, square, triangular, star-shaped, radially-finned, X-shaped, T-shaped, hollow, or perforated.

In this embodiment, the cross-section of the heating element 34 is constant along the length of the heating element 34. Moreover, in this embodiment, the heating element 34 is planar, or substantially planar. The heating element 34 of this embodiment can be considered a flat strip or ribbon. However, in other embodiments, this may not be the case. For example, in some embodiments the heating element 34 may be hollow or perforated.

In some embodiments, the heating element 34 may be non-planar. For example, the heating element 34 may follow a wavelike or wavy path, be twisted, be corrugated, be helical, have a spiral shape, comprise a plate or strip or ribbon having protrusions thereon and/or indentations therein, comprise a mesh, comprise expanded metal, or have a non-uniform non-planar shape. Such non-planar shapes may help air passing through the article to pick up the volatilised material created when the smokable material 32 is heated. Non-planar shapes can

provide a tortuous path for air to follow, creating turbulence in the air and causing better heat transfer from the heating material to the smokable material 32. The non-planar shapes can also increase the surface area of the heating element 34 per unit length of the heating element 34. This can result in greater or improved Joule heating of the heating element 34, and thus greater
5 or improved heating of the smokable material 32.

In this embodiment, the article 30 is insertable into the heating zone 111 when the mouthpiece 120 is disengaged from the body 110 of the apparatus 300. More specifically, the article 30 is insertable into the second portion 111b of the heating zone 111 via the first portion 111a of the heating zone 111, when the mouthpiece 120 is disengaged from the body 110.
10 When the article 30 is located in the heating zone 111, a first portion 34a of the heating element 34 of the article 30 is located in the first portion 111a of the heating zone 111, and a second portion 34b of the heating element 34 of the article 30 is located in the second portion 111b of the heating zone 111. Accordingly, in use, the varying magnetic field generated by the magnetic field generator 112 that penetrates the first portion 111a of the heating zone 111 also
15 penetrates the first portion 34a of the heating element 34. However, the varying magnetic field does not penetrate the second portion 34b of the heating element 34. Therefore, a similar progressive heating effect to that discussed above could be provided. That is, in use the first portion 34a of the heating element 34 of the article 30 is heated inductively and the second portion 34b of the heating element 34 of the article 30 is heated by thermal conduction from
20 the first portion 34a of the heating element 34 of the article 30. This helps to enable an aerosol to be formed and released relatively rapidly from the smokable material 32 relatively close to the outlet 122, for inhalation by a user, yet provides time-dependent release of aerosol, so that aerosol continues to be formed and released even after that portion of the smokable material 32 has ceased generating aerosol.

Referring to Figure 5 there is shown a flow diagram showing an example of a method of heating smokable material to volatilise at least one component of the smokable material according to an embodiment of the invention.

The method 500 comprises providing 501 a heating element that is heatable by penetration with a varying magnetic field. The heating element could, for example, be a heating element of apparatus for heating smokable material to volatilise at least one component of the smokable material, such as the heating elements 115, 130 discussed above with reference to Figures 1 and 2. Alternatively, the heating element could, for example, be a heating element of an article comprising the smokable material, such as the heating element 34 discussed above with reference to Figure 4.

The method also comprises providing 502 smokable material in thermal contact with the heating element. The smokable material could be comprised in an article, such as that shown in Figure 4. The smokable material may be in thermal contact with the heating element as a result of the heating element also being part of the article, as is the case in Figure 4. Alternatively, the smokable material may be placed in thermal contact with the heating element as a result of inserting smokable material into the heating zone of an apparatus comprising the heating element, as is the case in Figures 1 and 2.

The method further comprises penetrating 503 a first section of the heating element with a varying magnetic field that avoids a second section of the heating element, thereby to heat the first section of the heating element and a first part of the smokable material. The method may be free from any step of penetrating the second section of the heating element with a varying magnetic field.

The method also comprises heating 504 the second section of the heating element by thermal conduction from the first section of the heating element, thereby to heat a second part of the smokable material. Examples of such thermal conduction are described above. This

heating 504 may comprise heating the second section of the heating element exclusively by thermal conduction from the first section of the heating element. The heating of the smokable material may be such as to volatilise at least one component of the smokable material without combusting the smokable material.

5 In each of the embodiments discussed above the heating material is steel. However, in other embodiments, the heating material may comprise one or more materials selected from the group consisting of: an electrically-conductive material, a magnetic material, and a magnetic electrically-conductive material. In some embodiments, the heating material may comprise a metal or a metal alloy. In some embodiments, the heating material may comprise
10 one or more materials selected from the group consisting of: aluminium, gold, iron, nickel, cobalt, conductive carbon, graphite, plain-carbon steel, stainless steel, ferritic stainless steel, copper, and bronze. Other heating material(s) may be used in other embodiments. It has been found that, when magnetic electrically-conductive material is used as the heating material, magnetic coupling between the magnetic electrically-conductive material and an electromagnet
15 of the apparatus in use may be enhanced. In addition to potentially enabling magnetic hysteresis heating, this can result in greater or improved Joule heating of the heating material, and thus greater or improved heating of the smokable material.

The heating material may have a skin depth, which is an exterior zone within which most of an induced electrical current and/or induced reorientation of magnetic dipoles occurs.
20 By providing that the heating material has a relatively small thickness, a greater proportion of the heating material may be heatable by a given varying magnetic field, as compared to heating material having a depth or thickness that is relatively large as compared to the other dimensions of the heating material. Thus, a more efficient use of material is achieved and, in turn, costs are reduced.

In some embodiments, a first portion of the heating element 115, 130 may be made of a first material and a second portion of the heating element 115, 130 may be made of a second material that is different from the first material. For example, the first section 115a, 130a of the heating element 115, 130 may be made of the first material and the second section 115b, 130b of the heating element 115, 130 may be made of the second material. The first material would be a heating material that is heatable by penetration with a varying magnetic field. Examples of such heating materials are discussed above. The second material may, or may not, be a heating material that is heatable by penetration with a varying magnetic field. However, the second material should be thermally-conductive, so as to conduct heat from the first section 115a, 130a of the heating element 115, 130 in use.

In each of the above described embodiments, the smokable material comprises tobacco. However, in respective variations to each of these embodiments, the smokable material may consist of tobacco, may consist substantially entirely of tobacco, may comprise tobacco and smokable material other than tobacco, may comprise smokable material other than tobacco, or may be free from tobacco. In some embodiments, the smokable material may comprise a vapour or aerosol forming agent or a humectant, such as glycerol, propylene glycol, triacetin, or diethylene glycol.

In each of the above described embodiments, the smokable material is non-liquid smokable material, and the apparatus is for heating non-liquid smokable material to volatilise at least one component of the smokable material. In other embodiments, the opposite may be true.

In each of the above described embodiments, the article 30 is a consumable article. Once all, or substantially all, of the volatilisable component(s) of the smokable material 32 in the article 30 has/have been spent, the user may remove the article 30 from the apparatus 100, 200, 300 and dispose of the article 30. The user may subsequently re-use the apparatus 100,

200, 300 with another of the articles 30. However, in other respective embodiments, the article may be non-consumable, and the apparatus and the article may be disposed of together once the volatilisable component(s) of the smokable material has/have been spent.

5 In some embodiments, the apparatus 100, 200, 300 is sold, supplied or otherwise provided separately from the articles 30 with which the apparatus 100, 200, 300 is usable. However, in some embodiments, the apparatus 100, 200, 300 and one or more of the articles 30 may be provided together as a system, such as a kit or an assembly, possibly with additional components, such as cleaning utensils.

10 In order to address various issues and advance the art, the entirety of this disclosure shows by way of illustration and example various embodiments in which the claimed invention may be practised and which provide for superior apparatus for heating smokable material to volatilise at least one component of the smokable material, superior systems comprising such apparatus and such articles, and superior methods of heating smokable material to volatilise at least one component of the smokable material. The advantages and features of the disclosure are of a representative sample of embodiments only, and are not exhaustive and/or exclusive. 15 They are presented only to assist in understanding and teach the claimed and otherwise disclosed features. It is to be understood that advantages, 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 20 other embodiments may be utilised and modifications may be made without departing from the scope and/or spirit of the disclosure. Various embodiments may suitably comprise, consist of, or consist in essence of, various combinations of the disclosed elements, components, features, parts, steps, means, etc. The disclosure may include other inventions not presently claimed, but which may be claimed in future.

CLAIMS

1. Apparatus for heating smokable material to volatilise at least one component of the smokable material, the apparatus comprising:
- 5 a heating zone for receiving at least a portion of an article comprising smokable material;
- an outlet for permitting volatilised components of the smokable material to pass from the heating zone towards an exterior of the apparatus when the article is heated in the heating zone in use;
- 10 a heating element that is heatable by penetration with a varying magnetic field to heat the heating zone, wherein a first section of the heating element is located between a second section of the heating element and the outlet, and wherein the second section of the heating element is heatable in use by thermal conduction from the first section of the heating element;
- and
- 15 a magnetic field generator for generating a varying magnetic field that penetrates the first section of the heating element and avoids the second section of the heating element.
2. The apparatus of claim 1, wherein the apparatus is free from any magnetic field generator for generating a varying magnetic field that penetrates the second section of the
- 20 heating element.
3. The apparatus of claim 1, wherein the second section of the heating element is heatable in use exclusively by thermal conduction.
- 25 4. The apparatus of claim 1, wherein the heating element projects into the heating zone.

5. The apparatus of claim 1, wherein the heating element extends at least partially around the heating zone.
- 5 6. The apparatus of claim 1, wherein the magnetic field generator comprises a helical coil that encircles only the first section of the heating element.
7. The apparatus of claim 1, wherein the magnetic field generator is fixed relative to the heating element.
- 10
8. The apparatus of claim 1, wherein the first section of the heating element is smaller or shorter than the second section of the heating element.
9. The apparatus of claim 1, wherein the heating element comprises heating material that
15 comprises one or more materials selected from the group consisting of: an electrically-conductive material, a magnetic material, and a magnetic electrically-conductive material.
10. The apparatus of claim 1, wherein the heating element comprises heating material that comprises a metal or a metal alloy.
- 20
11. The apparatus of claim 1, wherein the heating element comprises heating material that comprises one or more materials selected from the group consisting of: aluminium, gold, iron, nickel, cobalt, conductive carbon, graphite, plain-carbon steel, stainless steel, ferritic stainless steel, copper, and bronze.

25

12. The apparatus of claim 1, wherein the first section of the heating element is made of a first material and the second section of the heating element is made of a second material that is different from the first material.

5 13. The apparatus of claim 1, wherein the apparatus is for heating non-liquid smokable material to volatilise at least one component of the smokable material.

14. Apparatus for heating smokable material to volatilise at least one component of the smokable material, the apparatus comprising:

10 a heating zone for receiving at least a portion of an article comprising smokable material;

an outlet for permitting volatilised components of the smokable material to pass from the heating zone towards an exterior of the apparatus when the article is heated in the heating zone in use, wherein a first portion of the heating zone is located between a second portion of the heating zone and the outlet; and

15 a magnetic field generator for generating a varying magnetic field that penetrates the first portion of the heating zone and avoids the second portion of the heating zone.

15. The apparatus of claim 14, wherein the apparatus is free from any magnetic field generator for generating a varying magnetic field that penetrates the second portion of the heating zone.

16. The apparatus of claim 14, wherein the magnetic field generator comprises a helical coil that encircles only the first portion of the heating zone.

25

17. The apparatus of claim 14, wherein the first portion of the heating zone is smaller or shorter than the second portion of the heating zone.
18. The apparatus of claim 14, wherein the apparatus is arranged so that the article is
5 insertable into the second portion of the heating zone via the first portion of the heating zone.
19. The apparatus of claim 14, wherein the apparatus is for heating non-liquid smokable material to volatilise at least one component of the smokable material.
- 10 20. A system for heating smokable material to volatilise at least one component of the smokable material, the system comprising:
an article comprising smokable material and a heating element that is heatable by penetration with a varying magnetic field to heat the smokable material; and
apparatus, comprising:
15 a heating zone for receiving at least a portion of the article;
an outlet for permitting volatilised components of the smokable material to pass from the heating zone when the article is heated in the heating zone in use; and
a magnetic field generator for generating a varying magnetic field that penetrates a first section of the heating element between a second section of the heating
20 element and the outlet, and avoids the second section of the heating element, when the article is located in the heating zone in use.

21. A method of heating smokable material to volatilise at least one component of the smokable material, the method comprising:

providing a heating element formed that is heatable by penetration with a varying magnetic field;

5 providing smokable material in thermal contact with the heating element;

penetrating a first section of the heating element with a varying magnetic field that avoids a second section of the heating element, thereby to heat the first section of the heating element and a first part of the smokable material; and

10 heating the second section of the heating element by thermal conduction from the first section of the heating element, thereby to heat a second part of the smokable material.

1 / 2

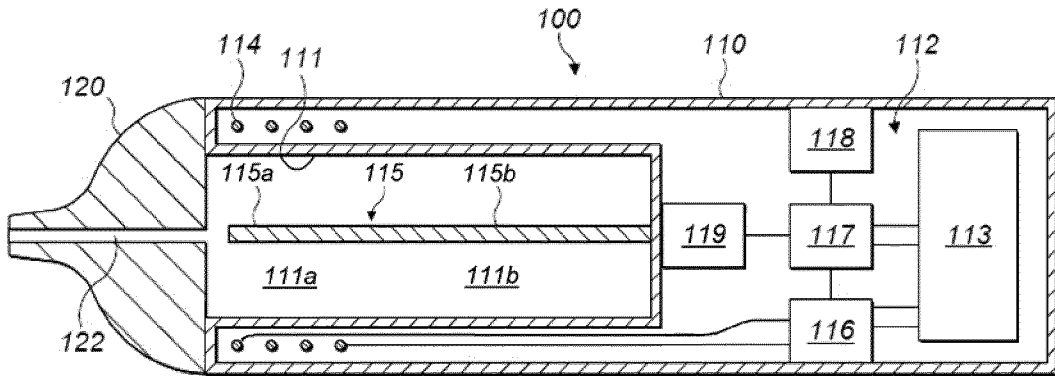


FIG. 1

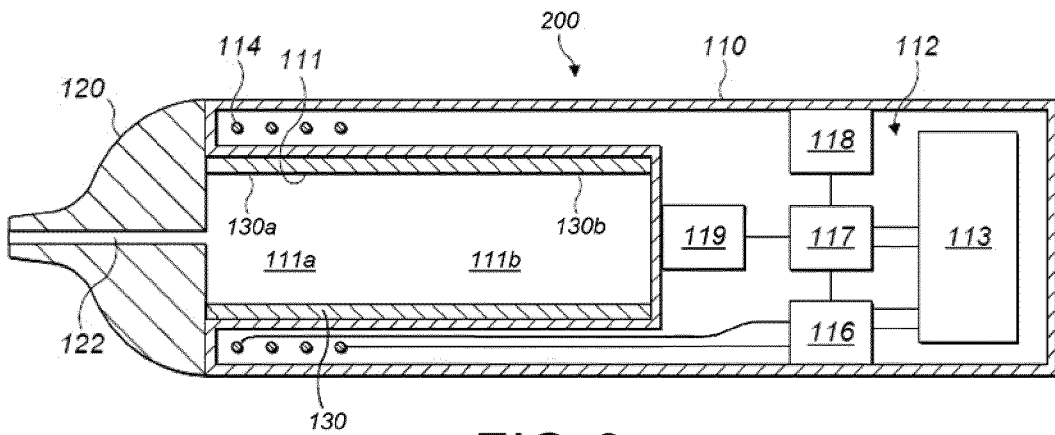


FIG. 2

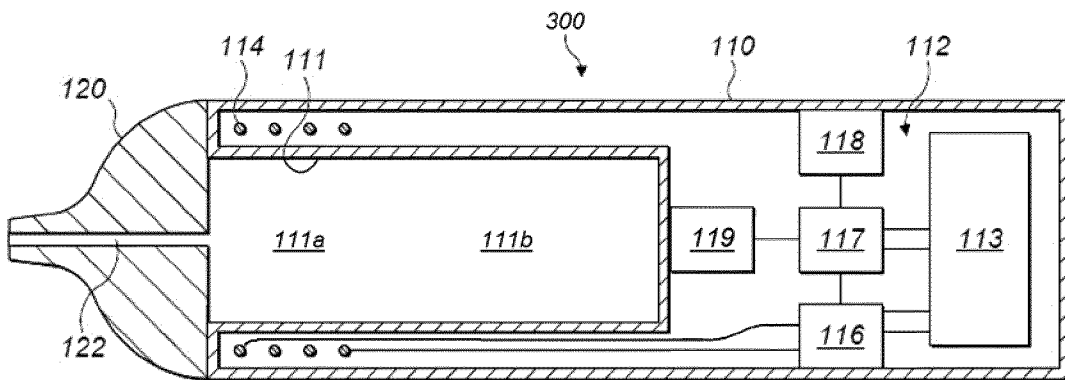


FIG. 3

2 / 2

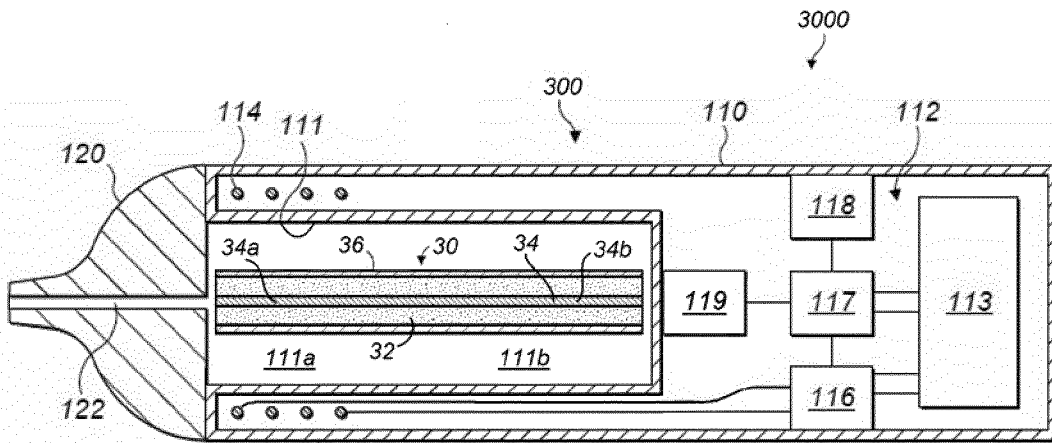


FIG. 4

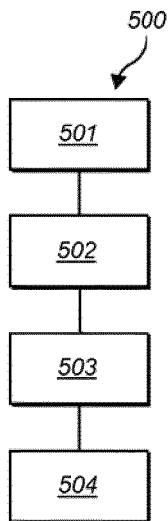


FIG. 5

