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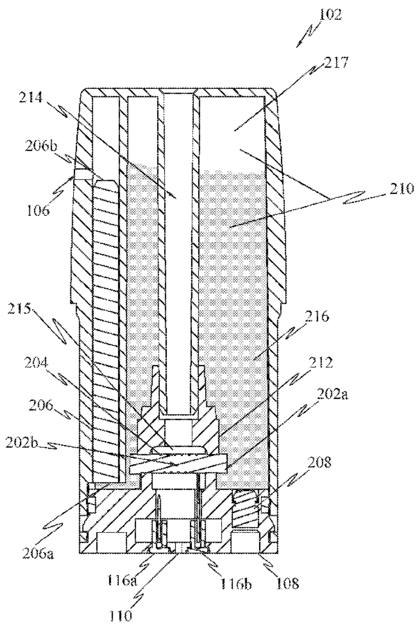

FIG. 2

(57) Abstract: Device (100) for vaporising liquid (216). The device (100) comprises a housing (102) and a pressure regulating member (206). The housing (102) defines a chamber (210) to store liquid (216), and the member (206) is engaged to the chamber (210). A first portion (206a) of the member (206) is exposed to the chamber (210), while a second portion (206b) is exposed to atmospheric pressure. The member (206) comprises of porous material, which absorbs the liquid (216), without any external energy input, when pressure inside the chamber (210) is sufficient to allow liquid (216) to partially overcome air barrier, without allowing the liquid (216) to leak into the atmosphere. Further, the material allows air from the atmosphere to enter the chamber (210) when pressure inside the chamber (210) drops to an extent that allows air to at least partially overcome liquid barrier formed by liquid (216) within some of the pores.

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DEVICE FOR VAPORIZING LIQUID

FIELD OF THE INVENTION:

[1] The subject described herein, in general, relates to an electronic cigarette. More particularly, but not exclusively, the subject matter relates to regulating pressure within a chamber storing the liquid in an electronic cigarette.

BACKGROUND

[2] Unless otherwise indicated herein, the materials described in this section are not prior art in this application and are not admitted to being prior art by inclusion in this section.

DISCUSSION OF THE RELATED ART:

[3] Electronic cigarettes (e-cigarette) are electronic devices that stimulate the feeling of smoke and has widely been used to replace the conventional tobacco cigarettes. E-cigarette includes a battery-powered atomizing device to atomize e-liquid containing nicotine or other active ingredients when activated by a user. Atomizers of some e-cigarettes are manually activated by user operated switch. In other cases, when the user simulates a smoking action by inhaling the e-cigarette, one or more sensors automatically activate an atomizer. The atomizer comprises a wick configured to absorb e-liquid stored in a liquid storing chamber. The e-liquid absorbed by the wick is then fed to a connected heating element for the conversion of the e-liquid to vapor or aerosol form, upon activation of the heating element. The space wherein this conversion of liquid into vapour takes place is frequently called as the vaporization zone. When a puff is initiated, the suction pressure applied by the user is transmitted to the vaporization zone. The vapour generated at the vaporization zone is inhaled by the user. However, certain disadvantages are associated with the conventional e-cigarettes such as inconsistent availability of the e-liquid at the vaporisation zone and leakage of the e-liquid from the e-cigarette.

[4] Inconsistent availability of the e-liquid or liquid at the wick / vaporization zone is one such disadvantage, which leads to inconsistent vaporization of the liquid. When a puff is taken, the liquid available at the vaporization zone is used-up and more liquid is absorbed by the wick from the chamber for providing more amount of vaporisable liquid for inhalation. Due to continuous puffing action of the user, the liquid level in the chamber is depleted resulting in the enhancement of non-liquid space inside the chamber. Consequentially, the air inside the chamber expands to occupy the enhanced non-liquid space leading to reduction of pressure inside the chamber. In most cases, this leads to development of negative air pressure (relative to atmosphere) inside the chamber. The negative pressure inside the chamber restricts the liquid from being pulled out from the chamber to the vaporization zone, thereby reducing the amount of vapour generation. Though the liquid still flows to the vaporization zone due to the suction pressure applied by the user, the generation of varying negative pressure inside the chamber results in inconsistent availability of the liquid at the wick / vaporization zone. When the puff initiated by the user is completed, the pressure at the vaporization zone is back to normal atmospheric pressure. In such a scenario, because of presence of negative pressure inside the chamber, some amount of the liquid which is available at the wick returns back to the chamber and creates a vacant path for air to enter inside the chamber. The air can enter the chamber through the wick only when the concentration of air at the wick goes above a particular threshold (empirically around 15%). When the air enters into the chamber and occupies the enhanced non-liquid space, it counteracts against the negative pressure that was generated earlier. Now the liquid may again get absorbed by the wick, thereby closing the air entry gap. Further, the entry of air into the chamber is only through the porous wick and possible only after completion of the puffing action by the user. During the initial stages of usage, the non-liquid space inside the chamber is much lesser as compared to the non-liquid space inside the chamber at later stages of usage. Therefore, the additional non-liquid space created due to consumption of liquid leads to development of relatively higher negative pressure at initial stages of device usage. Evidently, the issue of inconsistent availability of liquid at vaporization zone is accentuated during the initial stages of usage.

[5] Another disadvantage associated with the conventional e-cigarette models is leakage of e-liquid. When the mouthpiece of the e-cigarette faces up, the force of gravity continuously pushes the e-liquid from the chamber to the liquid absorption part i.e. the wick. Once the e-liquid absorbed by the wick reaches a saturation state, under various circumstances such as temperature variation or mechanical impacts, the e-liquid may drop down causing leakage of the e-liquid. Those skilled in the art to practice the present subject matter would appreciate the other reasons for leakage such as existence of micro-gaps in the assembly of the chamber and the wick-heater assembly. In most cases, such gaps are so small that the e-liquid cannot leak out unless forced out due to temperature / pressure changes or mechanical impacts. The leaked e-liquid in itself is a waste, and also if the leaked liquid is in contact with a printed circuit board (PCB) (a current PCB is manufactured to have a separate integral battery regardless of an auto or manual type, and thus has inconvenience and burden of expenses when the separate battery has to be replaced according to a power source operating manner), a defect of the PCB may occur and this causes a defect in the battery pack.

[6] In light of the foregoing, there is a need of an improved device, that helps in effectively regulating the pressure within the chamber and also prevents leakage of liquid from the wick.

SUMMARY

[7] In an embodiment, a device for vaporising liquid is disclosed. The device comprises a housing defining a chamber to store liquid, and a pressure regulating member engaged to the chamber. A first portion of the pressure regulating member is exposed to the chamber and a second portion of the pressure regulating member is exposed to atmospheric pressure. Further, the pressure regulating member comprises of porous material, which absorbs the liquid into some of the pores without any external energy input, when pressure inside the chamber is sufficient to allow liquid to partially overcome air barrier formed by air within some of the pores, while restricting the liquid leakage into the atmosphere under normal operating conditions. The porous material also allows air from the atmosphere to enter the chamber, when pressure inside the chamber drops to an extent that allows air to at least partially overcome liquid barrier formed by liquid within some of the pores.

BRIEF DESCRIPTION OF DRAWINGS

[8] Embodiments are illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

[9] FIG. 1A illustrates an assembled view of a device 100, in accordance with an embodiment of the present invention;

[10] FIG. 1B is a disassembled view of the device 100, in accordance with an embodiment of the present invention;

[11] FIG. 1C illustrates an isometric view of a housing 102, in accordance with an embodiment of the present invention;

[12] FIG. 1D illustrates a rear perspective view of the housing 102, in accordance with an embodiment of the present invention;

[13] FIG. 2 is a sectional view of the housing 102 along a section depicted in FIG. 1C, in accordance with an embodiment of the present invention;

[14] FIGs. 3A-3F and 5A-5F exemplary illustrates various arrangements of one or more pressure regulating members 206, with the wick 202 and the heating element aligned horizontally to the chamber 210 or the housing 102;

[15] FIGs. 4A- 4H and 6A-6F exemplary illustrates various arrangements of the one or more pressure regulating members 206, with the wick 202 and the heating element 204 aligned vertically to the chamber 210;

[16] FIG. 7A illustrates a battery assembly 104, in accordance with an embodiment of the present invention;

[17] FIG. 7B illustrates an airflow sensor 702 housed in the battery assembly 104, in accordance with an embodiment of the present invention;

[18] FIG. 7C illustrates a diffusor component 708, in accordance with an embodiment of the present invention;

[19] FIGs. 8A – 8D illustrates filling of the liquid 216 into the chamber 210, in accordance with an embodiment of the present invention;

[20] FIG. 8E illustrates rotation of the housing 102 on completion of the filling process, in accordance with an embodiment of the present invention; and

[21] FIG. 8F illustrates maintenance of non-liquid space 217 at the top portion of the chamber 210, in accordance with an embodiment of the present invention.

[22] FIG. 9A-9C illustrates the calculation of surface energy of an exemplar porous material used for pressure regulating member 206.

DETAILED DESCRIPTION

[23] The following detailed description includes references to the accompanying drawings, which form part of the detailed description. The drawings show illustrations in accordance with example embodiments. These example embodiments are described in enough details to enable those skilled in the art to practice the present subject matter. However, it may be apparent to one with ordinary skill in the art that the present invention may be practised without these specific details. In other instances, well-known methods, procedures and components have not been described in detail so as not to unnecessarily obscure aspects of the embodiments. The embodiments can be combined, other embodiments can be utilized, or structural and logical changes can be made without departing from the scope of the invention. The following detailed description is, therefore, not to be taken as a limiting sense.

[24] In this document, the terms “a” or “an” are used, as is common in patent documents, to include one or more than one. In this document, the term “or” is used to refer to a non-exclusive “or”, such that “A or B” includes “A but not B”, “B but not A”, and “A and B”, unless otherwise indicated.

[25] It should be understood, that the capabilities of the invention described in the present disclosure and elements shown in the figures may be implemented in various forms of hardware, firmware, software, recordable medium or combinations thereof.

OVERVIEW:

[26] A device for vaporising liquid is disclosed. The device comprises a housing defining a chamber to store the liquid, and a pressure regulating member engaged to the chamber. The housing comprises a wick, a heating element and the pressure regulating member. A first portion of the wick is configured to absorb liquid from the chamber. The liquid from the first portion of the wick is drawn to the second portion of the wick as the user initiates a puffing action. The liquid present in the second portion of the wick is heated by the heating element. Further, the pressure regulating member comprises a first portion exposed to the chamber, and a second portion which is exposed to atmospheric pressure. The pressure regulating member comprises of porous material, which absorbs the liquid into some of the pores without any external energy input, when pressure inside the chamber is sufficient to allow liquid to partially overcome air barrier formed by air within some of the pores, while restricting the liquid leakage into the atmosphere under normal operating conditions. A person skilled in art would appreciate that under abnormal conditions such as squeezing of chamber or high temperature increase or suction pressure at the second portion of the pressure regulating member, the liquid could be forced out of the pressure regulating member. Further, the porous material allows air from the atmosphere to enter the chamber when pressure inside the chamber drops to an extent that allows air to at least partially overcome liquid barrier formed by liquid within some of the pores. The device further comprises a battery assembly, wherein the housing is received by the battery assembly. The battery assembly may comprise of an airflow sensor, wherein the airflow sensor detects the attributes related to air flow into the device and sends a signal to the printed circuit board to deliver power to the heating element.

CONSTRUCTION OF THE DEVICE:

[27] Referring to FIG. 1A, an assembled view of a device 100, in accordance with an embodiment of the present invention is discussed. The device 100 is a vaporising device or a vaping device or an e-cigarette or any device configured to vaporise liquid or e-liquid. The device 100 comprises a housing 102, and a battery assembly 104. The housing 102 forms the first assembled unit and the battery assembly 104 forms the second assembled unit. The housing 102 is received by the battery assembly 104 to form a usable device 100. In an embodiment, the housing 102 may be detached from the battery assembly 104. FIG. 1B illustrates a disassembled view of the device 100, in accordance with an embodiment. In an embodiment, the housing 102 may be detached or separated from the battery assembly 104.

[28] FIG. 1C illustrates an isometric view of the housing 102, in accordance with an embodiment. In an embodiment, the housing 102 comprises a first end 102a and a second end 102b, which is opposed to the first end 102a. A first opening 112 is provided towards the first end 102a of the housing 102 for the exit of the vaporised liquid from the device 100, which is inhaled by the user. In an embodiment, the housing may comprise of a cap 114, wherein the cap 114 defines the first opening 112 that enables the exits of the vaporised liquid to be inhaled by the user.

[29] Referring to FIG. 1D, the housing 102 defines a second opening 106, a third opening108, a fourth opening 110, and at least two connecting ports 116a and 116b towards the second end 102b. The fourth opening 110 is configured to allow the entry of air into the housing 102 from the atmosphere. Further, the fourth opening 110 could be provided between the two connecting ports 116a and 116b.

[30] Referring to cross-section view of the housing in FIG. 2, the housing 102 comprises a wick 202 (comprising portions 202a and 202b), a heating element 204, a pressure regulating member 206 and an elastomeric component 208. In an embodiment, the third opening 108 is sealed with the elastomeric component 208 restricting the entry or exit of liquid or air through the third opening 108. The elastomeric component 208 may be for example, but not limited to, a silicon plug. The shape of the elastomeric component 208 is such that it easily fits into the channel associated with third opening 108 provided in the housing 102.

[31] In an embodiment, the housing 102 defines a chamber 210. The chamber 210 may be configured to store the liquid 216. The liquid 216 stored in the chamber 210 is heated to vaporize or transform from liquid state into vapor form for inhalation.

[32] In an embodiment, liquid 216 stored in the chamber 210 may be, for example propylene glycol (PG) and/or vegetable glycerine (VG) based liquid solution or may be a mixture of propylene glycol (PG), vegetable glycerine, water, flavours and active ingredient (usually nicotine). Table 1 represents surface tension and rotational viscosity of such typical liquids. Table 2 represents surface tension and its polar and dispersive components for few typical liquids. The surface tension of the liquid 216 is between 34 mN/m and 45 mN/m. The rotational viscosity of the liquid 216 is between 287 mPa.s and 769 mPa.s. Further, the liquid 216 stored in the chamber 210 may be any liquid that serves the purpose of the present invention, and not limited to liquids disclosed above.

TABLE 1		
E-liquid Sample No.	**Surface Tension (mN/m)**	**Rotational Viscosity (mPa.s)**
Liquid 1	34.83	590

Liquid 2	37.52	481
Liquid 3	38.12	426
Liquid 4	38.52	401
Liquid 5	38.70	426
Liquid 6	38.92	612
Liquid 7	39.03	599
Liquid 8	39.48	379
Liquid 9	39.54	567
Liquid 10	39.57	592
Liquid 11	39.61	626
Liquid 12	40.71	578
Liquid 13	41.26	541
Liquid 14	41.34	556
Liquid 15	42.04	554
Liquid 16	42.49	520
Average	**39.48**	**528**
Standard Deviation	**1.88**	**80**
Average + (3*St.Dev)	**45.13**	**769**
Average - (3*St.Dev)	**33.83**	**287**

TABLE 2

E-liquid Sample No.	**Surface Tension**	**Polar Component**	**Dispersive Component**	**Surface Polarity**
	mN/m	**mN/m**	**mN/m**	**%**
Liquid 17	33.61	8.21	25.4	24.44
Liquid 18	37.83	12.19	25.64	32.23
Liquid 19	39.38	13.76	25.62	34.94
Liquid 20	44.67	20.51	24.16	45.91

[33] In an embodiment, the heating element 204 and at least a portion of the wick 202 are enclosed within an enclosure 212. The enclosure 212 prevents the escape of the vapour or aerosol formed by heating the liquid 216 and enables the flow of the aerosols only through a central passage 214, towards the opening 112. The opening 112 is provided towards a mouthpiece of the device 100. Further, the space inside the enclosure 212, wherein the liquid 216 is converted into vapour is the vaporization zone 215.

[34] In an embodiment, the wick 202 is disposed towards the second end 102b of the housing 102. The wick 202 is a porous material configured to absorb or draw the liquid 216 from the chamber 210 by capillary action. The wick 202 comprises a first portion 202a and a second portion 202b. The first portion 202a of the wick 202 is exposed to the liquid 216 stored in the chamber 210 and configured to absorb the liquid 216 from the chamber 210. The second portion 202b of the wick 202 is in close vicinity with the heating element 214 and both are positioned inside the vaporization zone. In an embodiment, the heating element 204 is a coil formed from heating wire of suitable resistivity and is wound over the wick 202. In an embodiment, negative pressure (relative to atmosphere) is created inside the vaporisation zone 215 as the user initiates a puffing action. Further, due to the puffing action of the user, the fourth opening 110 draws air from the atmosphere. The liquid 216 is drawn to the second portion 202b of the wick through the first portion 202a of the wick 202 as the air is sucked through the fourth opening 110. The liquid is now available around the vicinity of the heating element 204 of the device 100. On completion of the puffing action, the pressure at the vaporisation zone 215 is back to normal atmospheric pressure.

[35] In an embodiment, preferably the surface energy of the wick 202 is greater than the surface tension of the liquid 216 in the chamber 210 to ensure complete wetting at most times. The surface energy of the wick 202 may be preferably greater than 45 mJ/m^2. The methodology of calculating surface energy and its components is described in detail later. Put in another manner, the contact angle between the wick 202 and the liquid 216 should preferably be 0°. Further, the wick 202 may be made of material that can withstand high temperature up to 350° C. This is because the wick 202 is in contact with the heating element 204. The materials that may be used as wick 202 are for example, but not limited to, ceramic, fiber glass and cotton, among others. Table 3 represents typical surface energies and polarities of such materials:

TABLE 3

Sample No.	Material	Surface Energy	Surface Polarity
		mJ/sq. m	%
Wick 1	100% natural cotton	62.41	66.98
Wick 2	Speciality Ceramic_2	52.40	52.58
Wick 3	Fiber Glass	50.11	49.27

[36] In an embodiment, the heating element 204 is configured to heat the liquid 216 absorbed by the wick 202. When the user initiates the puffing action, an airflow sensor 702 provided in the battery assembly 104 gets activated which sends signal to a PCB (printed circuit board) to supply power to the heating element 204. The heating element 204 may be a coil, a wire or any heating means that serves the purpose of the present invention. The liquid 216 on being heated by the heating element 204 is vaporised, the vapor is inhaled by the user. The vapor flows towards the first end 102a of the housing 102 via the central passage 214.

[37] In an embodiment, the chamber 210 comprise of two sections: space occupied by the liquid 216 and the non-liquid space 217. As the liquid 216 gets used up, the non-liquid space 217 increases and, in absence of any fresh air entry, the pressure inside the chamber reduces. Further, even if the volume of non-liquid space 217 doesn't change, the pressure within the chamber 210 can increase or decrease due to respective increase or decrease in temperature. The pressure within the chamber 210 is not a uniform value as it depends on the height of liquid column as well. Typically, the intra-chamber pressure variation could be between 0.1 kPa to 0.5 kPa.

[38] In an embodiment, the pressure regulating material 206 is configured to maintain a desired pressure, pressure less than atmospheric pressure, within the chamber 210. Further, within the chamber 210, the pressure regulating member 206 and the wick 202 are subjected to similar pressure condition.

[39] In an embodiment, the pressure regulating member 206 is positioned towards the second end 102b of the housing 102. The pressure regulating member 206 comprises a first portion 206a and a second portion 206b. The first portion 206a of the pressure regulating member 206 is positioned towards the second end 102b of the housing 102 such that the first portion 206a of the pressure regulating member 206 is in contact with the liquid stored in the chamber 210. In another embodiment, the first portion 206a of the pressure regulating material 206 interface with the liquid, when the device 100 is held in a position recommended during vaporisation i.e. position in which the wick 202 is in contact with the liquid 216. In other words, the first portion 206a of the pressure regulating member 206 should be in contact with the liquid stored in the chamber 210 to perform its function.

[40] Further, the second portion 206b of the pressure regulating material 206 is disposed towards the second opening 106 defined by the housing 102. The second opening 106 permits the entry of ambient air into the chamber 210 through the pressure regulating material 206. The liquid 216 from the chamber 210 is exposed to atmospheric pressure in the absence of the pressure regulating material 206. The pressure regulating material 206 is stationary relative to the housing 102 to avoid any leakage of the liquid from the chamber 210.

[41] In an embodiment, the pressure regulating member 206 is engaged to the chamber 210 and configured to maintain sub-atmospheric pressure within the chamber 210. In an embodiment, the pressure regulating member 206 comprises of porous material. The porous material is permeable to gas and prevents the outflow of the liquid from the chamber 210. The porous material is configured to absorb the liquid 216 from the chamber 210 into some of its pores, which are previously occupied by air, when the pressure inside the chamber 210 is sufficient to allow liquid 216 to partially overcome an air barrier formed by air within some of the pores, without allowing the liquid to leak into the atmosphere under normal operating conditions. The porous material will absorb more liquid when the pressure inside the chamber increases. It shall be noted that with the increase in temperature within the chamber 210, the pressure of air at the non-liquid space 217 also increases. Moreover, due to this higher pressure within the chamber 210, the flow of liquid 216 towards the wick 202 may be more or the wick 202 may absorb more amount of liquid 216 than required leading to leakage of the liquid 216 from the wick 202. In such scenario, the porous material plays a vital role to maintain the pressure within the chamber 210, by absorbing the liquid 216 from the chamber 210 as discussed above.

[42] The porous material also allows retraction of liquid 216 back to the chamber and entry of air from the atmosphere into the chamber 210, when the pressure inside the chamber 210 drops i.e. when the negative pressure (relative to atmosphere) crosses a threshold value. The pressure inside the chamber 210 may drop due to depletion of the liquid 216 level inside the chamber 210, which may be due to continuous puffing action of the user or depletion of liquid 216. The pressure inside the chamber 210 may also reduce due to drop in temperature.

[43] The maintenance of pressure within the chamber (existence of the above-mentioned phenomenon, threshold pressure limits, precision of control and speed of response) depends on individual and relative properties of the liquid 216 and the porous material.

[44] In an embodiment, the surface energy of the porous material is lesser than surface tension of the liquid in the chamber 210. Methodology for measurement of surface energy is discussed later.

[45] The porous material may be for example sintered PE, sintered PET, PE/PET fibers or ceramic specially designed, among others. The porous material may be any material that serves the purpose of the present invention and may have undergone surface treatment, such as, plasma treatment or surface coating with appropriate materials to modulate the surface energy. Further, the volume of the porous material is between 1 percent and 8 percent of maximum volume of the liquid stored in the chamber 210. Table 4 represents the type of material, the surface energy and polarity of typical porous materials. In Fig. 9A -9C, the raw experimental data and calculation of surface energy of Pressure Regulator 9 is presented.

Table 5 represents the Median Pore Diameter by volume, $D_{median}(V)$, of representative porous materials. The methodology for measuring pore size is discussed in detail later.

TABLE 4			
Sample No.	**Material**	**Overall Surface Energy**	**Surface Polarity**
		mJ/sq. m	**%**
Pressure Regulator 1	Speciality Ceramic_1	31.09	13.45
Pressure Regulator 2	Sintered PE	28.48	8.14
Pressure Regulator 3	PET Fibers	30.23	12.91
Pressure Regulator 4	Sintered PET_1	29.06	11.15
Pressure Regulator 5	Sintered PET_2	28.34	10.30
Pressure Regulator 6	Sintered PET_3	29.02	11.22
Pressure Regulator 7	Sintered PET_4	29.13	11.36
Pressure Regulator 8	Sintered PET_5	29.86	12.39
Pressure Regulator 9	Sintered PET_6	30.43	13.26

TABLE 5		
Sample No.	**Material**	**Median Pore Diameter (Volume)**
		micron
Pressure Regulator 6	Sintered PET_3	30.0
Pressure Regulator 9	Sintered PET_6	60.7

[46] In another embodiment, the surface energy of the porous material is preferably less than 34 mJ/m^2.

[47] In another embodiment, the contact angle between the porous material and the liquid is preferably between 25° and 65°.

[48] In another embodiment, the Median Pore Diameter by volume, $D_{median}(V)$, of the pressure regulating member 206 is preferably higher than 30 microns.

[49] In another embodiment, the rotational viscosity of the liquid 216 is preferably more than 290 mPa.s and less than 430 mPa.s.

[50] In another embodiment, the negative pressure (relative to atmosphere) maintained at the non-liquid space 217 of the chamber 210 is preferably 1kPa to 3kPa lower than atmospheric pressure.

[51] Referring to FIGs. 3A-3F, 4A-4H, 5A-5F and 6A-6F, various arrangements of one or more pressure regulating members 206 are discussed. The drawings are to be regarded in an illustrative rather than a restrictive sense. Although illustrations have been described with reference to specific examples, it will be evident that various modifications and changes may be made to these embodiments without departing from the broader spirit and scope of the system and method described herein. Specifically, though the pressure regulating member 206 is depicted as a body with uniform cross-section, the pressure regulating member 206 may well be a body with non-uniform cross-sectional.

[52] The housing 102 may comprise of a groove 302 (FIG. 3A) to house the pressure regulating member 206. The housing may also comprise of a base enclosure 301 (FIG. 3C) extending towards the second end 102b of the housing 102. The two sides of the housing 102 are depicted by 304a and 304b (FIG. 3B).

[53] In an embodiment, the device 100 may comprise of one pressure regulating member 206 (FIGs. 3A-3F, 4A-4H). In another embodiment, the device 100 may comprise at least two pressure regulating members 206. (FIGs. 5A-5F and 6A-6F). The second pressure regulating member is depicted by 206′ (FIG. 5A), while the corresponding first and second portion are depicted by 206a′ and 206b′ (FIG. 5D); and the corresponding second opening depicted by 106′ (FIG. 5B). In yet another embodiment, the device 100 may comprise plurality of pressure regulating members 206 having different properties, size, shapes and positions.

[54] In an embodiment, the wick 202 and the heating element 204 may be horizontally aligned to the chamber 210 (FIGs 3A-3F, 5A-5F). In another embodiment, the wick 202 and the heating element 204 may be vertically aligned to the chamber 210 (FIGs 4A-4H, 6A-6F).

[55] In an embodiment, the first portion 206a of the pressure regulating member 206 could be nearer, as compared to the second portion 206b of the pressure regulating member 206, to the second end 102b of the chamber 210 (FIG 3D, 3E, 3F, 4F, 4G, 4H, 5D, 6F). In another embodiment, the second portion 206b of the pressure regulating member 206 could be nearer, as compared to the first portion 206a of the pressure regulating member 206, to the second end 102b of the chamber 210 (FIG 3A, 3B, 3C, 4B, 4C, 4D, 4E, 5A, 5B, 5C, 5E, 5F, 6B, 6C, 6D, 6E).

[56] In an embodiment, the first portion 206a of pressure regulating member 206 is not submerged into the liquid 216, but has surface contact with it (FIG 3A, 3C, 3D, 3E, 3F, 4A,

4B, 4C, 4E, 4F, 4G, 4H, 5A, 5C, 5D, 5E, 5F, 6A, 6B, 6C, 6E, 6F). In another embodiment, the first portion 206a of pressure regulating member 206 is submerged into the liquid 216 (FIG 3B).

[57] In an embodiment, all sections of the first portion 206a of the pressure regulating member 206 are subjected to same pressure condition within the chamber 210 i.e. all sections of the first portion 206a of the pressure regulating member 206 are at the same height of the liquid column (FIG 3A, 3C, 3D, 3E, 3F, 4B, 4C, 4E, 4F, 4G, 4H, 5A, 5C, 5D, 5E, 5F, 6B, 6C, 6E, 6F)). In another embodiment, different sections of the first portion 206a of the pressure regulating chamber 206 are subject to slightly different pressure condition within the chamber 210 (FIG 3B, 4A, 4D, 5B, 6A, 6D).

[58] In an embodiment, within the chamber, the first portion 206a of the pressure regulating member 206 is subjected to same pressure condition as compared to the wick 202 i.e. the first portion 206a of the pressure regulating member 206 and the wick 202 are at the same elevation and experiences the same liquid 216 column pressure (FIG 3A, 5A, 5F, 6D). In another embodiment, within the chamber and during normal usage condition i.e. the second end 102b is facing towards gravity, the first portion 206a of the pressure regulating member 206 is subjected to slightly lower pressure condition as compared to the wick 202 (FIG. 3B, 4A, 6A). In yet another embodiment, within the chamber and during normal usage condition i.e. the second end 102b is facing towards gravity, the first portion 206a of the pressure regulating member 206 is subjected to slightly higher pressure condition as compared to the wick 202 (FIG. 3C, 3D, 3E, 3F, 4E, 5C, 5D, 5E, 6E).

[59] In an embodiment, the first portion 206a of the pressure regulating member 206 completely covers the second opening 106 (FIG 3A, 3B, 3C, 4A, 4B, 4C, 4D, 4E, 5A, 5B, 5C, 5F, 6A, 6B, 6C, 6D, 6E). In another embodiment, the first portion 206a of the pressure regulating member 206 does not cover the second opening 106 (FIG. 3D, 3E, 3F, 4F, 4G, 4H, 5D, 5E, 6F).

[60] In an embodiment, the longitudinal axis of the pressure regulating member 206 i.e. the axis joining the first portion 206a and the second portion 206b of the pressure regulating member 206 is parallel to the longitudinal axis of the housing 102 i.e. the axis joining the first end 102a and the second end 102b of the housing 102 (FIG. 3A-3F, 4B-4H, 5A-5F, 6B-6F). In another embodiment, the longitudinal axis of the pressure regulating member 206 and the longitudinal axis of the housing 102 are perpendicular to each other (FIG. 4A, 6A). In yet another embodiment, the longitudinal axis of the pressure regulating member 206 and the longitudinal axis of the housing 102 are at an angle to each other (not shown).

[61] In an embodiment, the second opening 106 is disposed towards the second end 102b of the housing 102 (FIG. 3A, 4C, 5A, 5E, 6C, 6D, 6E). In an embodiment, the second opening 106 is disposed towards the first end 102a of the housing 102 (FIG. 3D, 3E, 3F, 4F, 4G, 4H, 5D, 6F). In yet another embodiment, the second opening 106 may be disposed towards the first side 304a or second side 304b of the housing 102 (FIG. 3B, 3C, 4A, 4B, 4D, 4E, 5B, 5C, 5F, 6A, 6B)).

[62] In an embodiment, the housing 102 may also comprise of a base enclosure 301, which is disposed towards the second end 102b of the housing 102 (FIG. 3B, 3C, 4D, 4E, 5B, 5C, 5E, 6D, 6E).

[63] Referring to FIGs. 7A-7C, the battery assembly 104 comprises a housing tube 701, an airflow sensor 702 attached to an electronic circuitry, a battery 704, a LED light, at least two pogo pins 706 and a slot or port 710. Further, the battery assembly 104 defines at least one air inlet 712, wherein the air inlet 712 enables the entry of air from the atmosphere into the device 100. The battery assembly without the housing tube 701 is referred as the battery main body 717.

[64] Referring to FIG. 7B illustrates the airflow sensor 702 housed in the battery assembly 104, in accordance with an embodiment of the present invention. The airflow sensor 702 is configured to sense the usage of the device 100 by the user. For example, the airflow sensor 702 may sense the puffing action of the user. As the user initiates the puffing action, negative pressure (relative to atmosphere) is generated due to suction, which may be sensed by the sensor. Further, the air enters inside the battery assembly through the air inlet 712.

[65] In an embodiment, all the sides except the top portion of the airflow sensor 702 are covered by an elastomeric component. The top portion of the airflow sensor 702 comprises a passage that is in fluidic connection with the suction provided by the user. Due to exposure to suction and because the airflow sensor is covered from all side by the elastomeric component (except the passage) from all side, the air above the sensor gets sucked, thereby creating sufficient negative pressure to activate the air-flow sensor 702. On activation of airflow sensor 702 a signal is sent to electronic components such as printed circuit board (PCB), wherein power is supplied to the heating element 204. The ends of the heating element 204 is electrically connected to the pogo pins 706, wherein the pogo pins 706 are received by the connecting ports 116a and 116b provided towards the second end 102b of the housing 102. The battery 704 to power the heating element 204 may be a rechargeable for example but not limited to rechargeable lithium-ion battery.

[66] Referring to FIG.7C illustrates a diffusor component 708, in accordance with an embodiment of the present invention. In an embodiment, the battery assembly 204 comprises the LED, which is provided on the printed circuit board. The LED is covered by the diffusor component 708. The diffusor component 708 is a translucent component configured to diffuse the light emitted from LED.

[67] It should be noted that the battery assembly has not been described in detail so as not to unnecessarily obscure aspects of the current invention. For the purpose of the current invention, many well-known methods, procedures and components, which ultimately serve the purpose of supplying power to the housing for vaporization of liquid, could be used.

GENERATING CHAMBER NEGATIVE PRESSURE DURING LIQUID FILLING:

[68] In an embodiment, a negative pressure (relative to atmosphere) is generated inside the chamber 210 at the time of filling the device 100. The pressure to be maintained at the non-liquid space 217 within the chamber 210 is between 1kPa to 3kPa lower than the normal atmospheric pressure. This helps in preventing the leakage of the liquid 216 from the housing 102. Further the device 100 is an air sealed device, wherein the only route for the entry and exit of the air into the chamber 210 is via the wick 202 and the pressure regulating member 206.

[69] Referring to FIGs. 8A – 8D, in an embodiment, to fill the liquid into the chamber 210, the housing 102 is inverted (first direction) such that the wick 202, the pressure regulating member 206 are inverted with respect to gravity, while the first end 102a of the housing 102 is facing towards the gravity. Further, a filling needle 802 is pierced through the elastomeric component 208 to inject the liquid into the chamber 210. In FIG. 8A a tip portion of the filling needle 802 is configured to pierce the elastomeric component 208 to insert at least a portion of the filling needle 302 into the chamber 210 for injecting the liquid into the chamber 210. The filling needle 802 pierces the elastomeric component 208 and begins dispensing the liquid into the chamber 210 (FIG 8B). During the filling process the air inside the chamber 210 is displaced through the wick 202 and the pressure regulating member 206, maintaining the wick 202 and the pressure regulating member 206 in a dry condition. The wick 202 absorbs the liquid injected into chamber 210, as the wick 202 comes in contact with the liquid with the progress of the filling process (FIG.8C). During further filling, any air present within the chamber 210 is now vented out through the pressure regulating member 206. Further, the first portion 206a of the pressure regulating member 206 interface with the liquid when the chamber 210 is completely filled with the liquid. The filling needle 802 is retracted back on completion of the filling process, the force on the silicon plug from all directions enables closing the small opening that may be formed on piercing the silicon plug by the filling needle 802. The instant feature of the silicon plug prevents leakage of the liquid. FIG. 8E illustrates rotation of the housing 102 on completion of the filling process, in accordance with an embodiment of the present invention. The housing 102 is rotated to 180-degree angle on completion of the filling process, for inserting at least a portion of the housing 102 in the battery assembly 104 and initiate normal operation of the device 100. FIG. 8F illustrates maintenance of non-liquid space 217 at the top portion of the chamber 210, in accordance with an embodiment of the present invention. In an embodiment, negative pressure (relative to atmosphere) is generated at the non-liquid space 217 of the chamber 210 due to absorption of liquid by some of the pores of the pressure regulating member 206. Further, some air may enter into the chamber 210 through the pressure regulating member 206 to maintain desired sub-atmospheric pressure at the non-liquid space 217 of the chamber 210.

SURFACE ENERGY DETERMINATION METHODOLOGY:

[70] As mentioned earlier, the methodology for surface energy determination is now discussed in detail. Those skilled in the art to practice the present subject matter would appreciate that Surface Energy of a solid cannot be directly measured. Rather it is a calculated value from a set of liquid/solid contact angles, developed by bringing various liquids in contact with the solid. It is not possible to choose a universal set of liquids for use in testing solid surfaces; specific surface interactions, surface reactivities, and surface solubilities need to be considered. Obviously, one must have prior knowledge of the surface tension values of the liquids that are used. Matters get further complicated in case of porous solids. The contact angle of a liquid on a porous solid cannot be accurately obtained by direct optical measurement, because a wetting liquid will be penetrating into the pores of the solid as one is attempting to measure contact angle. Hence, contact angle needs to be calculated, using appropriate theory, based raw experimental data of specific parameters. Furthermore, there are several widely used theories for converting contact angle data into surface energy values. None of these theories are universal, because none of them model reality perfectly. Hence, reasonable assessment of surface energy values (and its components) of a porous solid requires careful selection of three independent variables: the liquids that are used, theory chosen for calculating contact angle and the theory chosen for converting contact angle data into surface energy values. Luckily, inherent in most surface energy theories is some type of error analysis. This often comes in the form of the quality of a linear fit which correlates the surface tension of the liquids used to some variable that is based on contact angle. The error analysis helps in ascertaining whether the methodology used is appropriate for the given case.

[71] It must be fairly clear that for application of the art, the methodology for surface energy measurement needs to be clearly expressed. In our case of interest, it was ascertained that Washburn Theory is applicable for contact angle calculation and Fowke's theory is an appropriate way to calculate the surface energy from the contact angle data. Error analysis was conducted to evaluate the appropriateness of the above chosen methodology. Further, those skilled in the art to practice the present subject matter would appreciate that the concepts, principles, theories, equations and physical implications of the equations described herein are pertinent, in a broader sense of understanding and explanation, to the invention as a whole.

[72] Washburn theory indicates that if a porous solid is brought into contact with a liquid, such that the solid is not submerged in the liquid, but rather is just touching the liquid's surface, then the rise of liquid into the pores of the solid due to capillary action will be governed by the following equation:

Equation 1

$$\cos\theta = \frac{m^2}{t}\frac{\eta}{\rho^2 \sigma c}$$

wherein **t** = time after the solid and the liquid are brought into contact, **m** = mass of liquid sucked into the solid, **η** = viscosity of the liquid, **ρ** = density of the liquid, **σ** = surface tension of the liquid, **θ** = contact angle between the solid and the liquid, and **c** = a material constant which is dependent on the porous architecture of the porous solid.

[73] Once the contact angle values between a porous solid and known liquids are known, Fowke's theory is used to calculate the surface energy of the given porous solid:

Equation 2

$$2 * \{(\sigma_L^D)^{1/2} * (\sigma_s^D)^{1/2}\} + \{(\sigma_L^P)^{1/2} * (\sigma_s^P)^{1/2}\} = \sigma (\cos\theta + 1)$$

Equation 3

$$\sigma_s = \sigma_s^P + \sigma_s^D$$

Equation 4

$$\sigma = \sigma_L^P + \sigma_L^D$$

Equation 5

$$P_s = \sigma_s^P / \sigma_s^D$$

wherein σ_s = Surface Energy of the solid, σ_s^P is the polar component of the surface energy of the solid, σ_s^D is the dispersive component of the surface energy of the solid, σ_L^P is the polar component of the surface tension of the liquid, σ_L^D is the dispersive component of the surface tension of the liquid and P_s is the Surface Polarity of a given solid.

[74] During testing, three liquids of known properties (n-hexane, water and diiodomethane) were used by the Washburn wicking method using Kruss K100 Tensiometer at room temperature (20° C). The properties of the three liquids are shown in the Table 6:

TABLE 6

Liquid	**Overall Surface Tension**	**Dispersive Component**	**Polar Component**	**Density**	**Viscosity**
	mN/m	**mN/m**	**mN/m**	**g/cc**	**cP**
Hexane	18.41	18.41	0.00	0.661	0.33
Diiodomethane	50.80	50.80	0.00	3.325	2.76
Water	72.80	26.40	46.40	0.998	1.02

[75] Raw experimental data of (m^2/t) was obtained for n-hexane, which was used to ascertain the solid material constant (c) because n-hexane's material constant is usually zero with most solids due to its low surface tension. Once the material constant is determined, raw experimental data of (m^2/t) was obtained for water and diiodomethane using fresh pieces of the same sample. Using Equation 1, contact angle (θ) of the porous solid with water and diiodomethane were determined. The value of diiodomethane contact angle was used with Equation 2 for determining σ_s^D, since σ_L^P of diiodomethane is zero and values of other parameters are known. Furthermore, the value of water contact angle was used with Equation 2 for determining σ_s^P, values of other parameters are already known. Subsequently, Surface Energy of the solid (σ_s) is calculated using Equation 3.

PORE SIZE MEASUREMENT:

[76] As mentioned earlier, the methodology for pore size measurement is now discussed in detail. Those skilled in the art to practice the present subject matter would appreciate that macropore characterization of a porous material can be done by different methods (such as Bubble Point Method, Mercury Intrusion Porosimetry, SEM etc) and the data provided by different techniques is not directly comparable. In our case, the characterization of Pore size was done through the relevant technique of Mercury Intrusion Porosimetry, which has a range of measurement of 3nm to 360 μ. Though the pores of a porous material can be randomly packed and non-uniformly shaped, the technique considers pores as cylindrical capillaries of varying diameters and is based on Washburn equation, which states that at any pressure, the pores into which mercury (or for that matter any liquid) has intruded have diameters greater than:

Equation 6

$$D = -4\,\sigma\cos\theta / P$$

wherein, D is the pore diameter, σ is the surface tension, θ is the contact angle and P is the pressure applied.

[77] The fundamental data produced during testing is the volume of mercury intruded into the sample as a function of applied pressure. Though this data is indicative of various characteristics of the pore space and physical properties of the solid material itself, the critical information of interest in this case is the cumulative volume of intrusion as a function of pore diameter. Also, information regarding Median Pore Diameter by volume, $D_{median}(V)$, is important. $D_{median}(V)$ is the diameter corresponding to 50% total intrusion volume on the Cumulative Intrusion versus Diameter plot. Further, those skilled in the art to practice the present subject matter would appreciate that the concepts, principles, theories, equations and physical implications of the equations described herein are pertinent, in a broader sense of understanding and explanation, to the invention as a whole.

[78] The present invention overcomes the drawbacks of the conventional e-cigarettes, by providing a pressure regulating member 206 wherein the first portion 206a of the pressure regulating member 206 is exposed to the chamber and is in contact with the liquid stored in the chamber 210. Further, the second portion 206b of the pressure regulating member 206 is exposed to the atmosphere, enabling the entry of air into the chamber when the pressure within the chamber 210 is decreased. Further, the pressure regulating member 206 comprises of porous material, which absorbs the liquid 216 into some of the pores without any external energy input, when pressure inside the chamber 210 is sufficient to allow liquid to partially overcome air barrier formed by air within some of the pores, while restricting the liquid leakage into the atmosphere under normal operating conditions.

[79] The present invention as discussed in this document with respect to different embodiments will be advantageous in providing consistent flow of liquid 216 to the wick 202. Further, the present invention also prevents leakage of liquid 216 from the porous wick 202 by maintaining sub-atmospheric pressure inside the chamber 210. Further, since the invention actively inhibits generation of very high negative pressure (relative to atmosphere) inside the chamber 210, it facilitates adequate amount of liquid 216 at the vaporization zone 215, thereby improving volume of vapour generated by the device 100. The advantages associated with the present invention are achieved by providing the pressure regulating member 206 in the device 100 disclosed in the present invention. Additional advantages not listed may be understood by a person skilled in the art in light of the embodiments disclosed above.

[80] Although embodiments have been described with reference to specific example embodiments, it will be evident that various modifications and changes may be made to these embodiments without departing from the broader spirit and scope of the system and method described herein. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

[81] It shall also be noted that the processes described above are described as sequence of steps; this was done solely for the sake of illustration. Accordingly, it is contemplated that some steps may be added, some steps may be omitted, the order of the steps may be re-arranged, or some steps may be performed simultaneously.

[82] Many alterations and modifications of the present invention will no doubt become apparent to a person of ordinary skill in the art after having read the foregoing description. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. It is to be understood that the description above contains many specifications; these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the personally preferred embodiments of this invention. Thus, the scope of the invention should be determined by the appended claims and their legal equivalents rather than by the examples given.

CLAIMS

We claim:

1. A device (100) for vaporising liquid (216), the device (100) comprising:
   a housing (102) defining a chamber (210) to store the liquid (216); and
   a pressure regulating member (206) engaged to the chamber (210), wherein:
      a first portion (206a) of the pressure regulating member (206) is exposed to the chamber (210);
      a second portion (206b) of the pressure regulating member (206) is exposed to atmospheric pressure;
      the pressure regulating member (206) comprises of porous material;
      the porous material absorbs the liquid (216) into some of the pores, which are previously occupied by air, without any external energy input, when pressure inside the chamber (210) is sufficient to allow the liquid (216) to partially overcome air barrier formed by air within some of the pores, without allowing the liquid (216) to leak into the atmosphere; and
      the porous material allows air from the atmosphere to enter the chamber (210) when pressure inside the chamber (210) drops to an extent that allows air to at least partially overcome liquid barrier formed by the liquid (216) within some of the pores.

2. The device (100) as claimed in claim 1, wherein the pressure regulating member (206) is stationary relative to the housing (102).

3. The device (100) as claimed in claim 1, wherein the surface energy of the porous material is lesser than surface tension of the liquid (216).

4. The device (100) as claimed in claim 3, wherein the surface energy of the porous material is preferably less than 34 mJ/m^2.

5. The device (100) as claimed in claim 3, wherein the surface tension of the liquid (216) is preferably between 34 mN/m and 45 mN/m.

6. The device (100) as claimed in claim 3, wherein the contact angle between the porous material and the liquid (216) is preferably between 25° and 65°.

7. The device (100) as claimed in claim 1, wherein the volume of the porous material is preferably between 1 percent and 8 percent of maximum volume of the liquid (216) stored in the chamber (210).

8. The device (100) as claimed in claim 1, wherein the pressure regulating member (206) maintains sub atmospheric pressure within the non-liquid space (217) of the chamber (210).

9. The device (100) as claimed in claim 1, wherein the pressure regulating member (206) maintains pressure of preferably 1kPa to 3kPa lower than atmospheric pressure at the non-liquid space (217) of the chamber (210).

10. The device (100) as claimed in claim 1, the Median Pore Diameter by volume, $D_{median}(V)$, of the porous material is preferably higher than 30 microns.

11. The device (100) as claimed in claim 1, the rotational viscosity of the liquid (216) is preferably more than 290 mPa.s and less than 430 mPa.s

12. The device (100) as claimed in claim 1, wherein the pressure regulating member (206) is positioned to have the first portion (206a) interface with the liquid (216), when the device (100) is held in a position recommended during vaporization.

13. The device (100) as claimed in claim 12, wherein the housing (102) comprises a first end (102a) and a second end (102b), which is generally opposed to the first end (102a), wherein vapour exits from an opening provided towards the first end (102a) and a wick (202) is disposed towards the second end (202b), wherein the first portion (206a) of the pressure regulating member (206) is positioned towards the second end (202b).

14. The device (100) as claimed in claim 1, wherein the housing (102) defines a second opening (106), wherein the pressure regulating member (206) is disposed towards the second opening (106), wherein, in the absence of the pressure regulating member (206), the second opening (106) exposes the liquid (216) to atmospheric pressure.

15. The device (100) as claimed in claim 1, further comprising a wick (202), wherein the surface energy of the wick (202) is greater than the surface tension of the liquid (216).

16. The device (100) as claimed in claim 15, wherein the surface energy of the wick (202) is greater than 45 mJ/m^2.

17. The device (100) as claimed in claim 15, wherein,

the housing (202) defines a fourth opening (110) exposed to atmosphere;

the pressure within the chamber (210) is sub atmospheric;

a second portion (202b) of the wick (202) is exposed to the fourth opening (110);

a first portion (202a) of the wick (202) is exposed to the liquid (216) in the chamber (210); and

liquid (216) is drawn into the second portion (202b) of the wick (202) through the first portion (202a) of the wick (202) when air is sucked through the fourth opening (110).

18. A method of filling liquid (216) into a device (100) for vaporising the liquid, the method comprising:

providing a pressure regulating member (206) comprising of porous material;

orienting the device (100) in a first direction that allows the liquid (216) to interface with the pressure regulating member (206) towards completion of filling of the liquid (216) into a chamber (210) of the device (100);

filling the chamber (210) with the liquid (216) with the device (100) oriented in the first direction;

reorienting the device (100) to allow the liquid (216) to apply pressure on the pressure regulating member (206); and

allow the pressure regulating member (206) to absorb at least a portion of the liquid (216) into some of its pores to create a non-liquid space (217) within the chamber (210), wherein sub atmospheric pressure is created in the chamber (210) as a result of the absorption of the liquid (216) by the pressure regulating member (206).

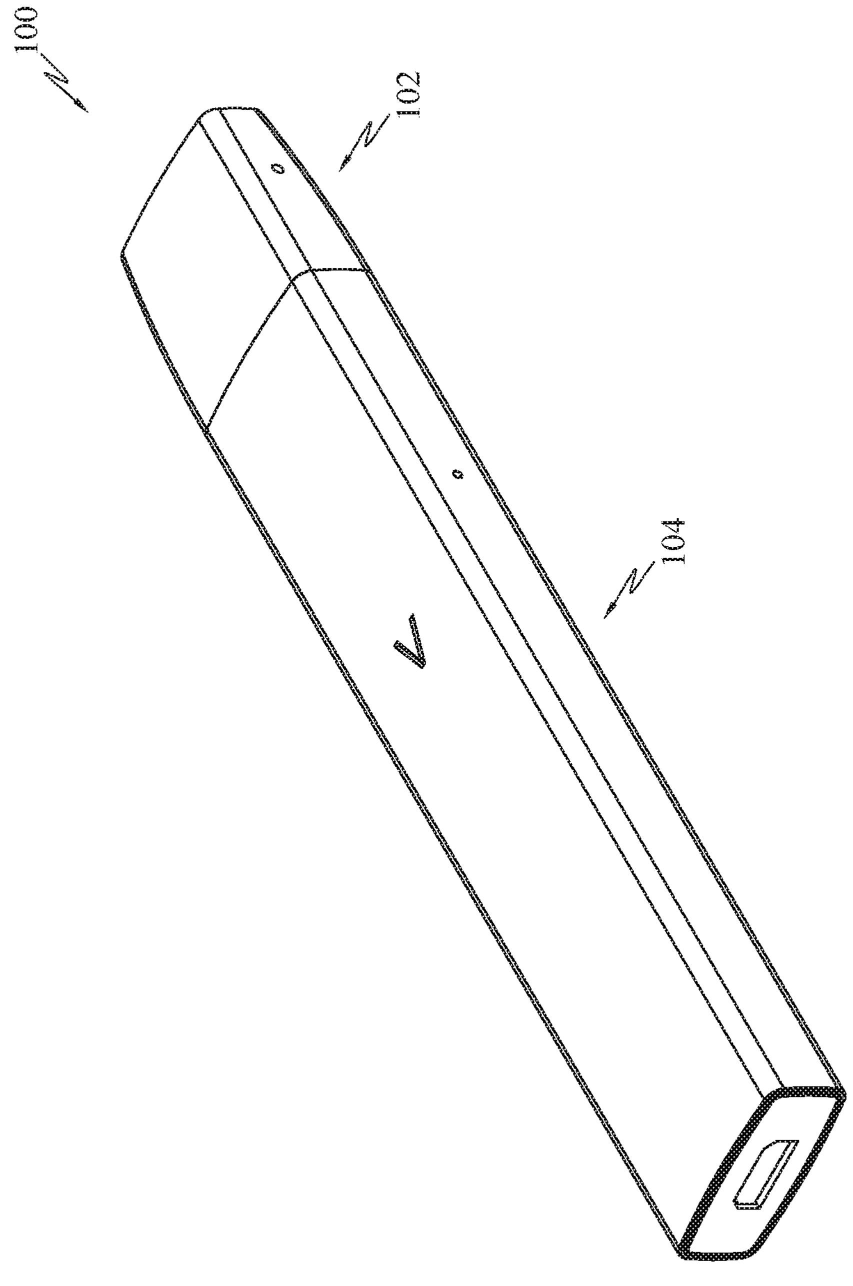


FIG. 1A

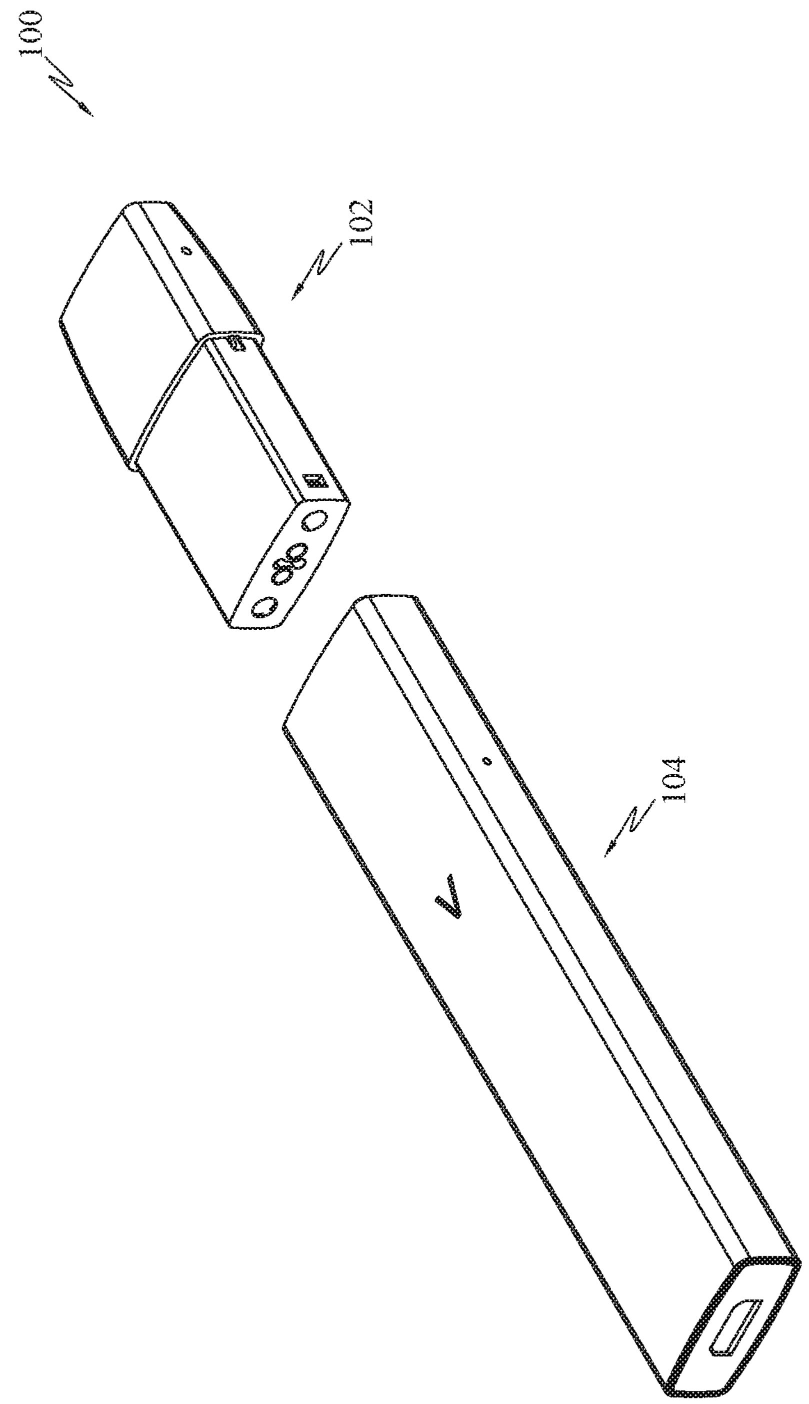


FIG. 1B

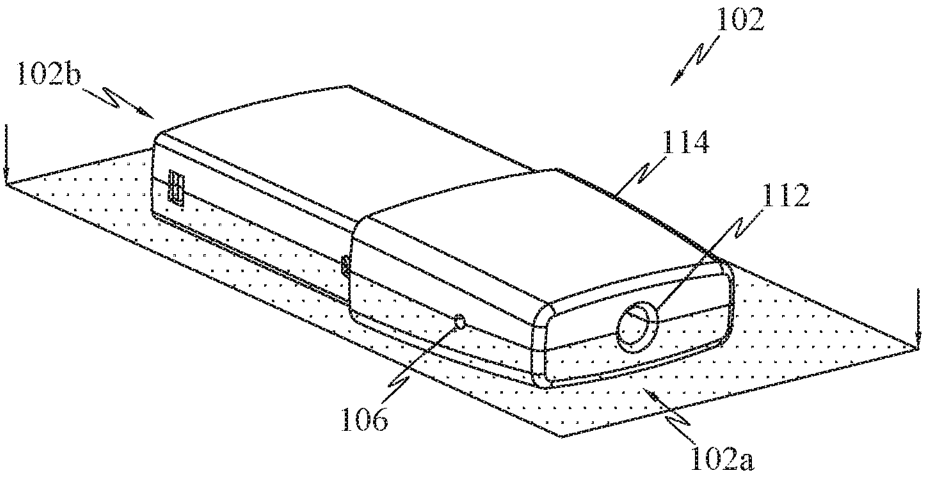


FIG. 1C

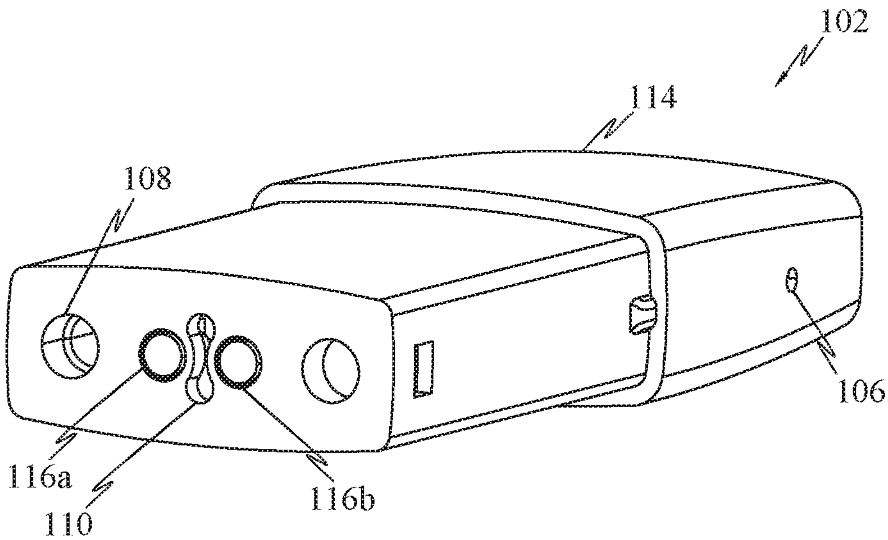


FIG. 1D

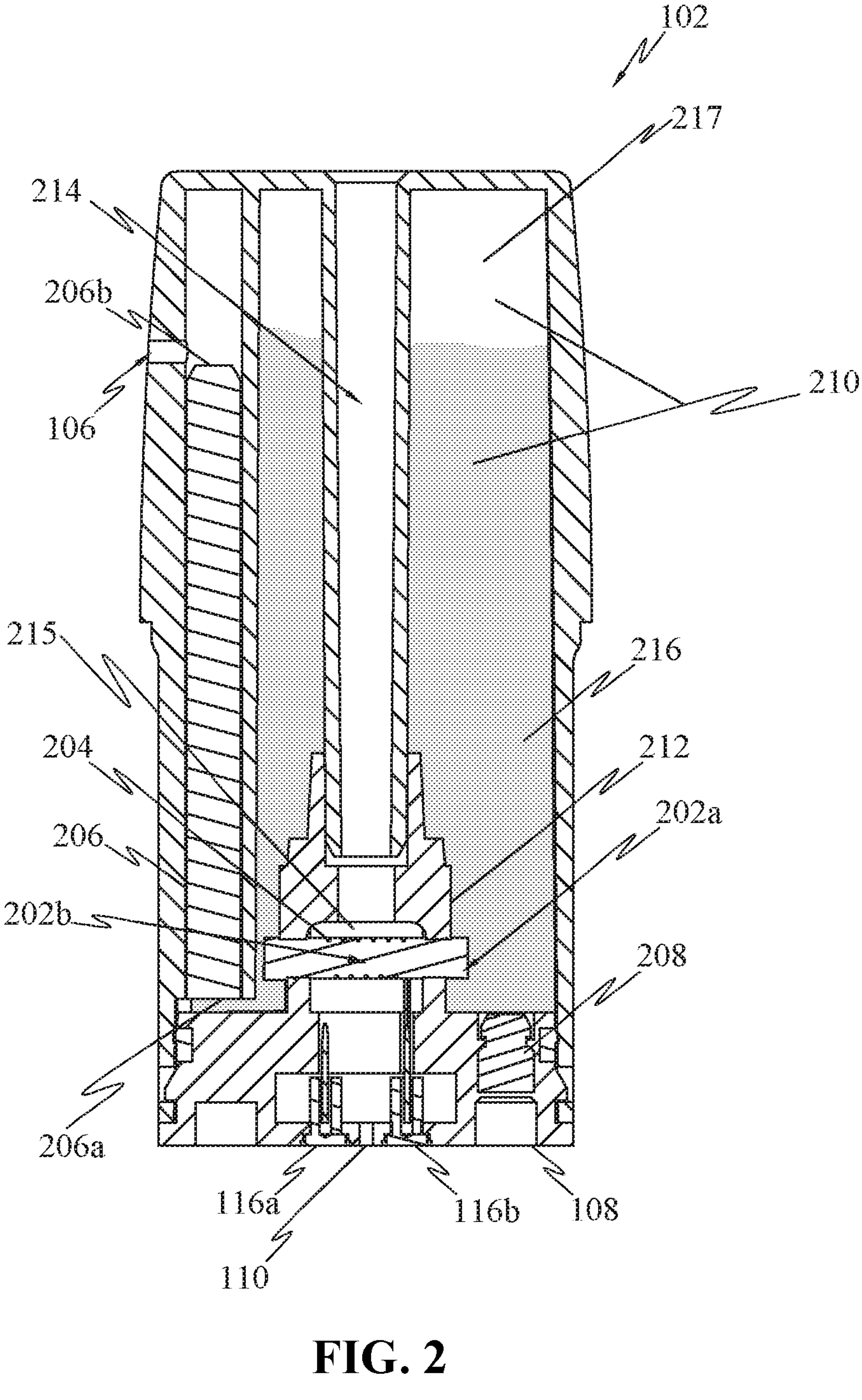

102
217
214
206b
210
106
215
216
204
212
202a
206
202b
208
206a
116a
116b
108
110

FIG. 2

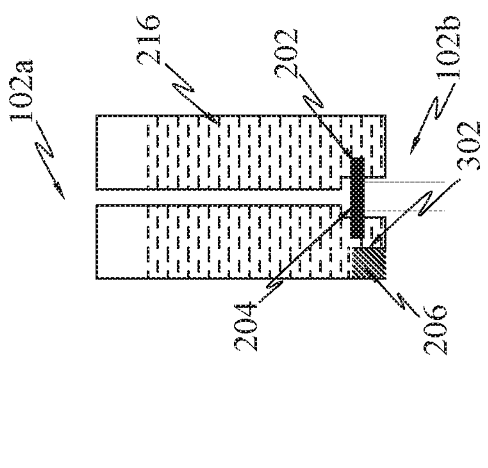


FIG. 3A

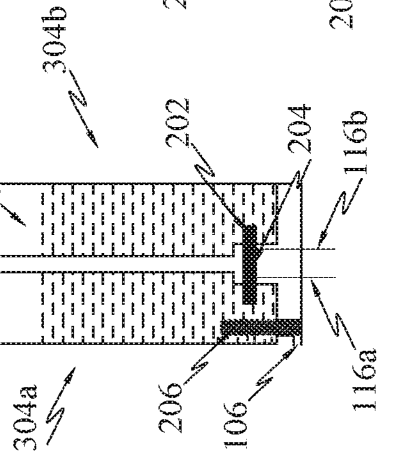


FIG. 3B

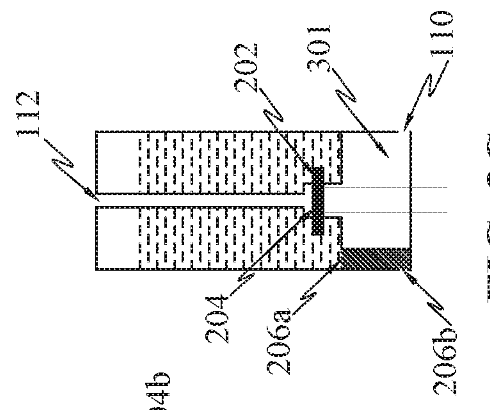


FIG. 3C

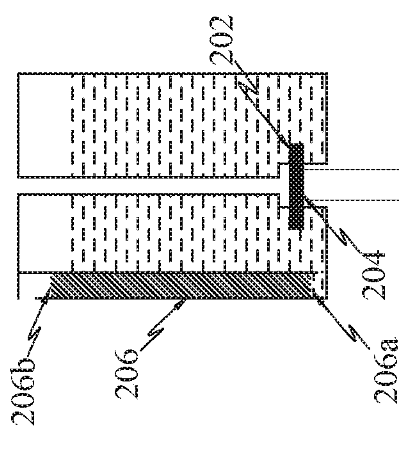


FIG. 3D

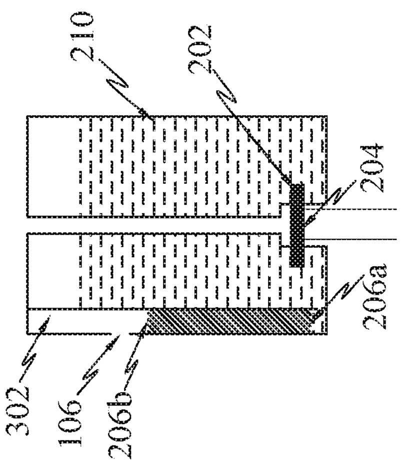


FIG. 3E

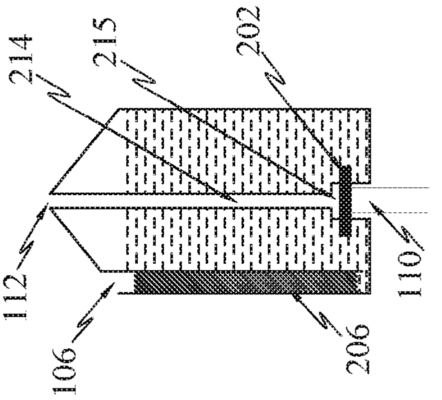


FIG. 3F

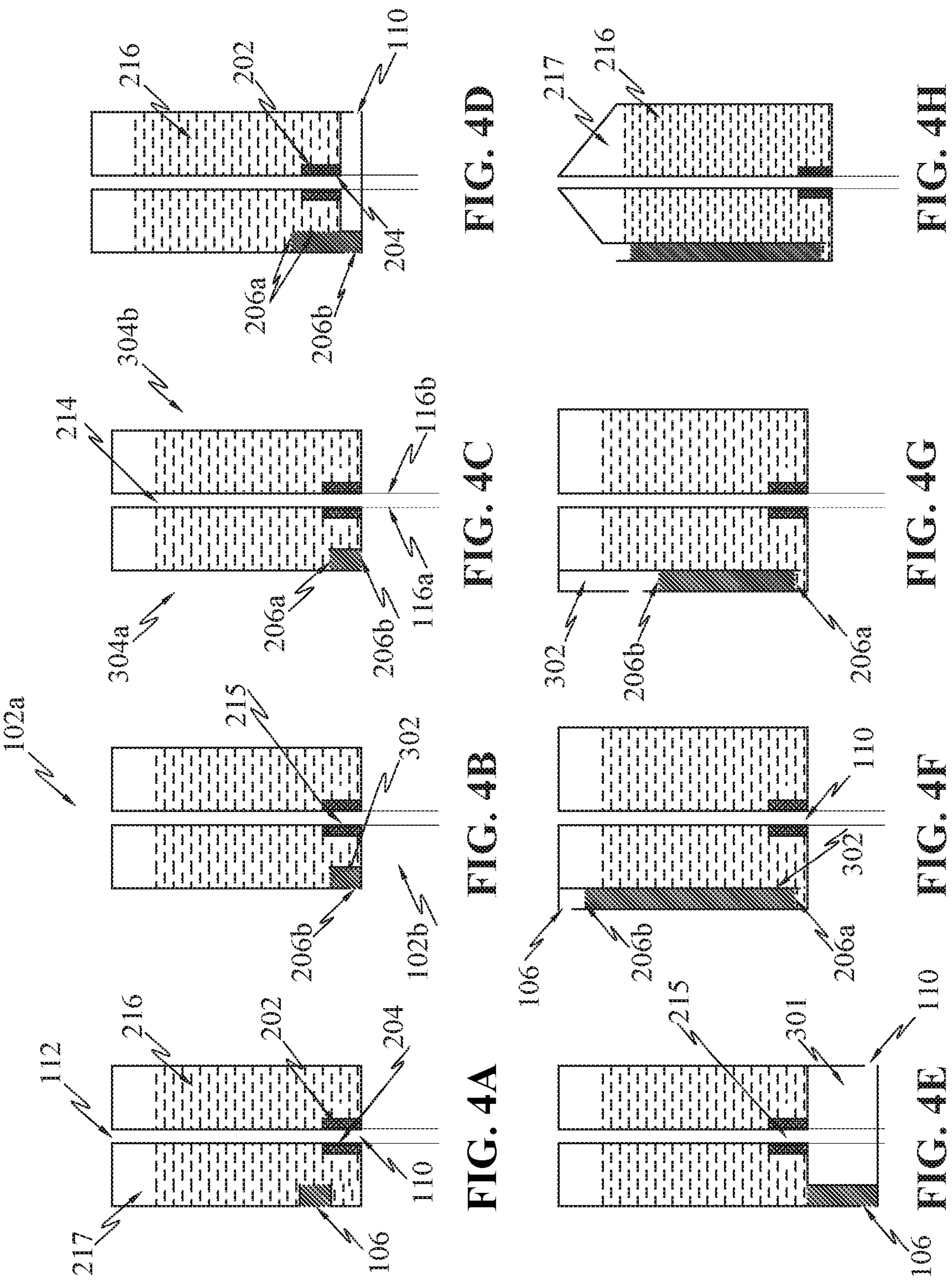


FIG. 4A FIG. 4B FIG. 4C FIG. 4D

FIG. 4E FIG. 4F FIG. 4G FIG. 4H

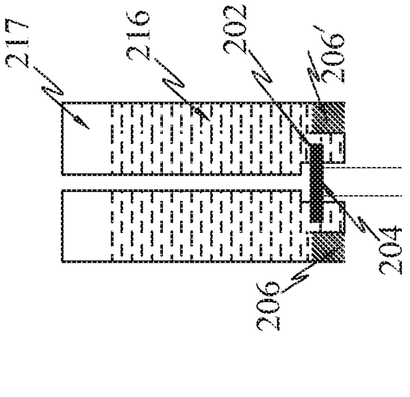


FIG. 5A

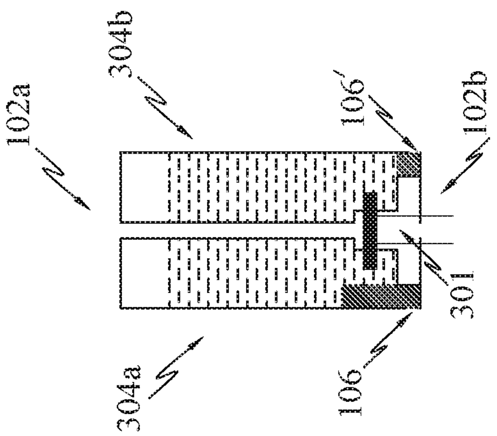


FIG. 5B

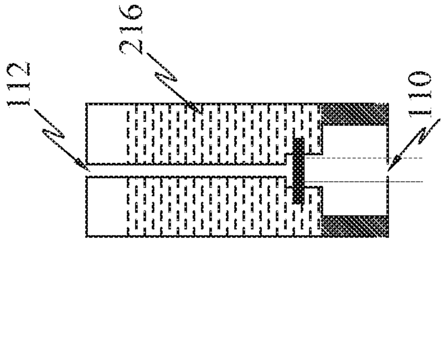


FIG. 5C

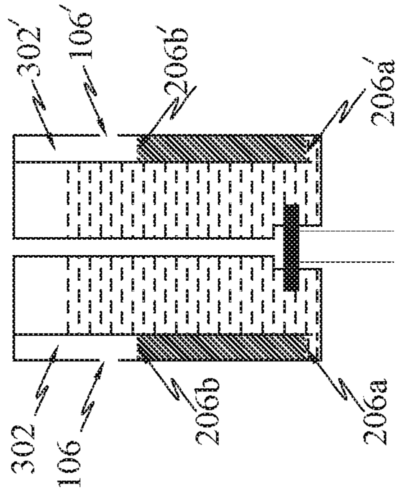


FIG. 5D

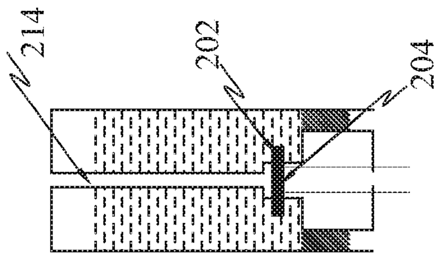


FIG. 5E

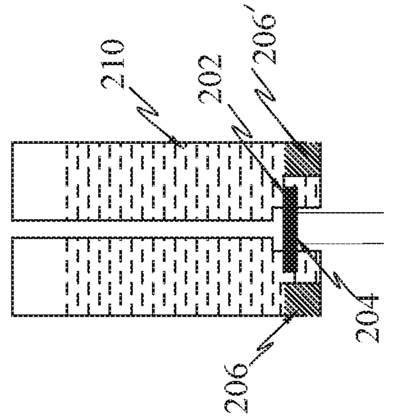


FIG. 5F

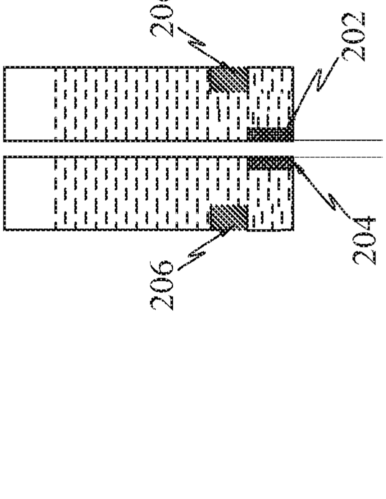


FIG. 6A

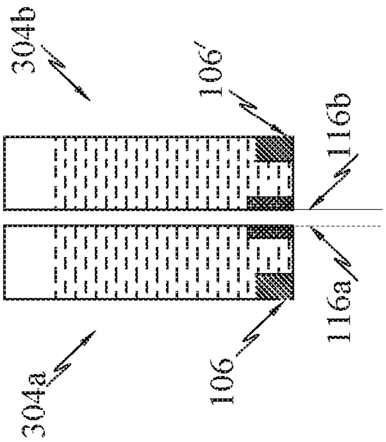


FIG. 6B

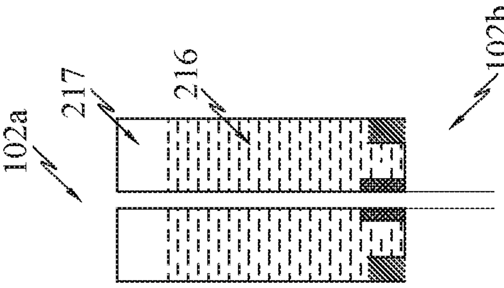


FIG. 6C

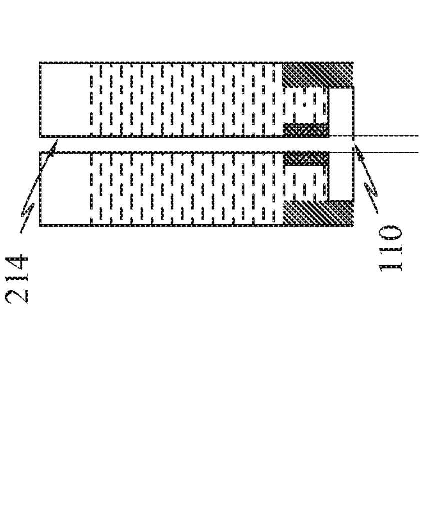


FIG. 6D

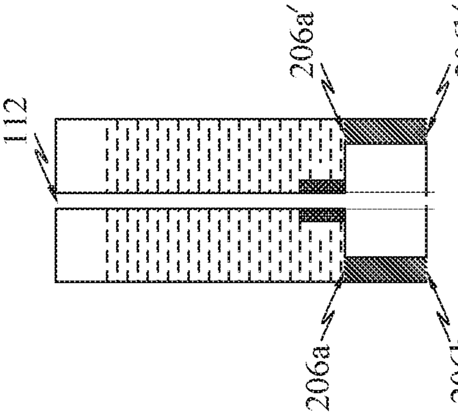


FIG. 6E

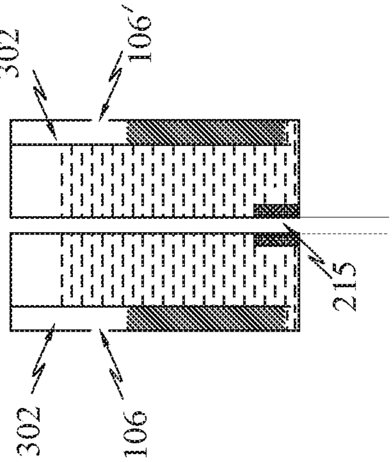


FIG. 6F

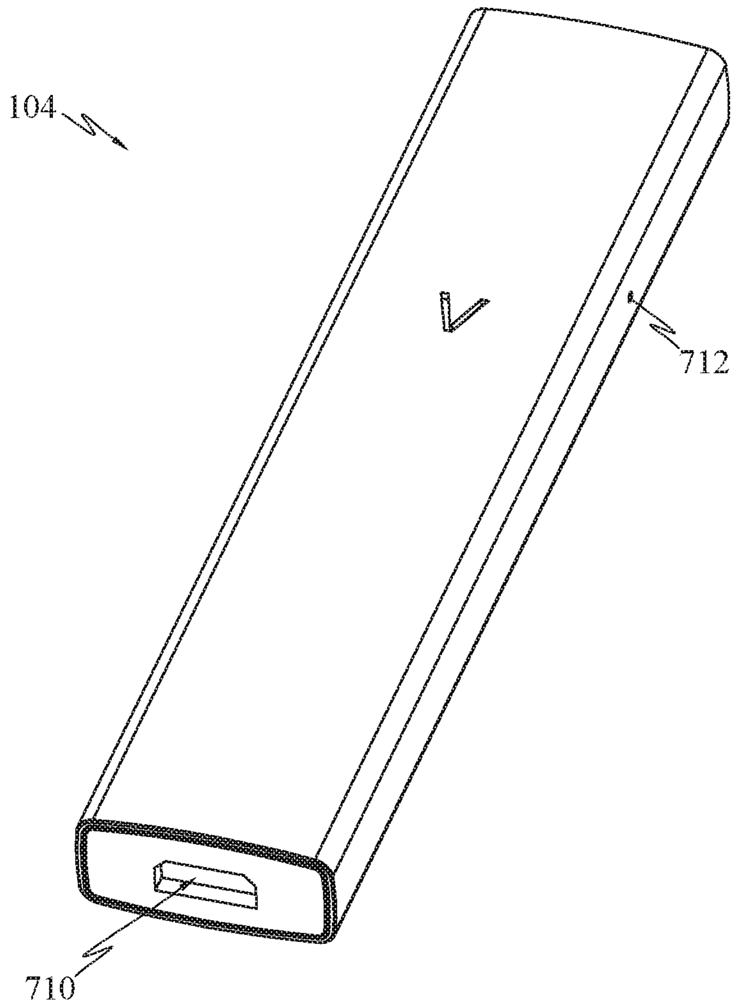


FIG. 7A

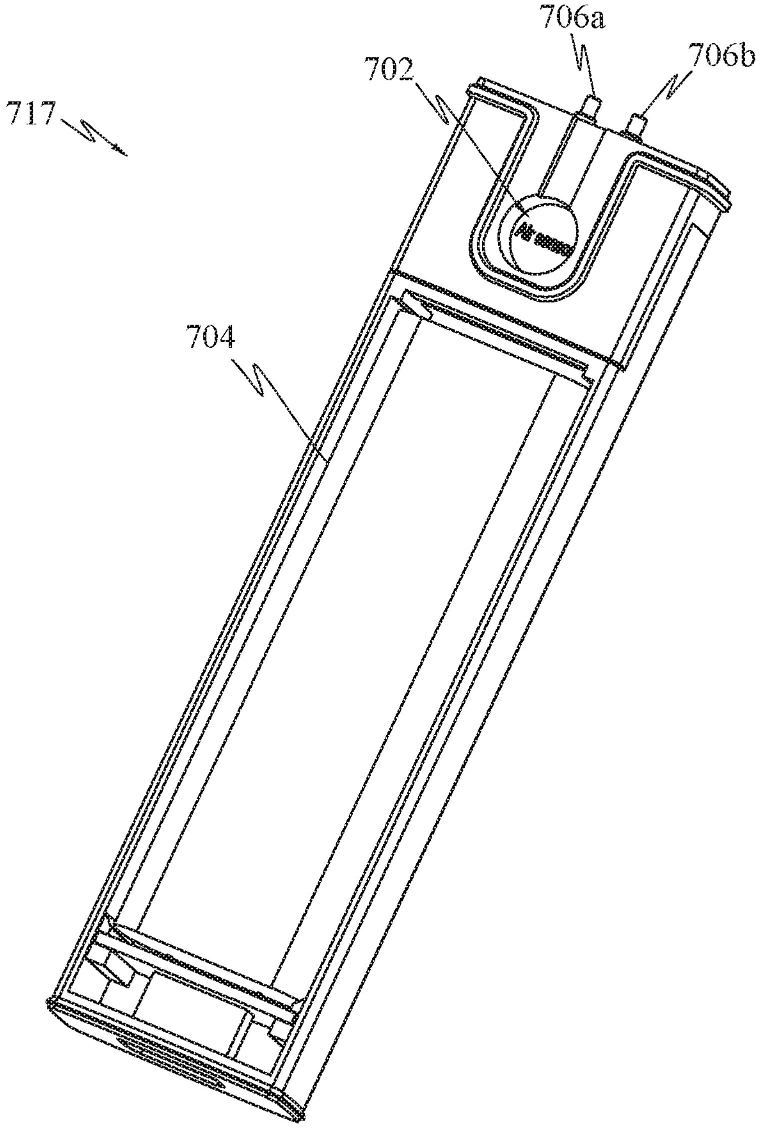


FIG. 7B

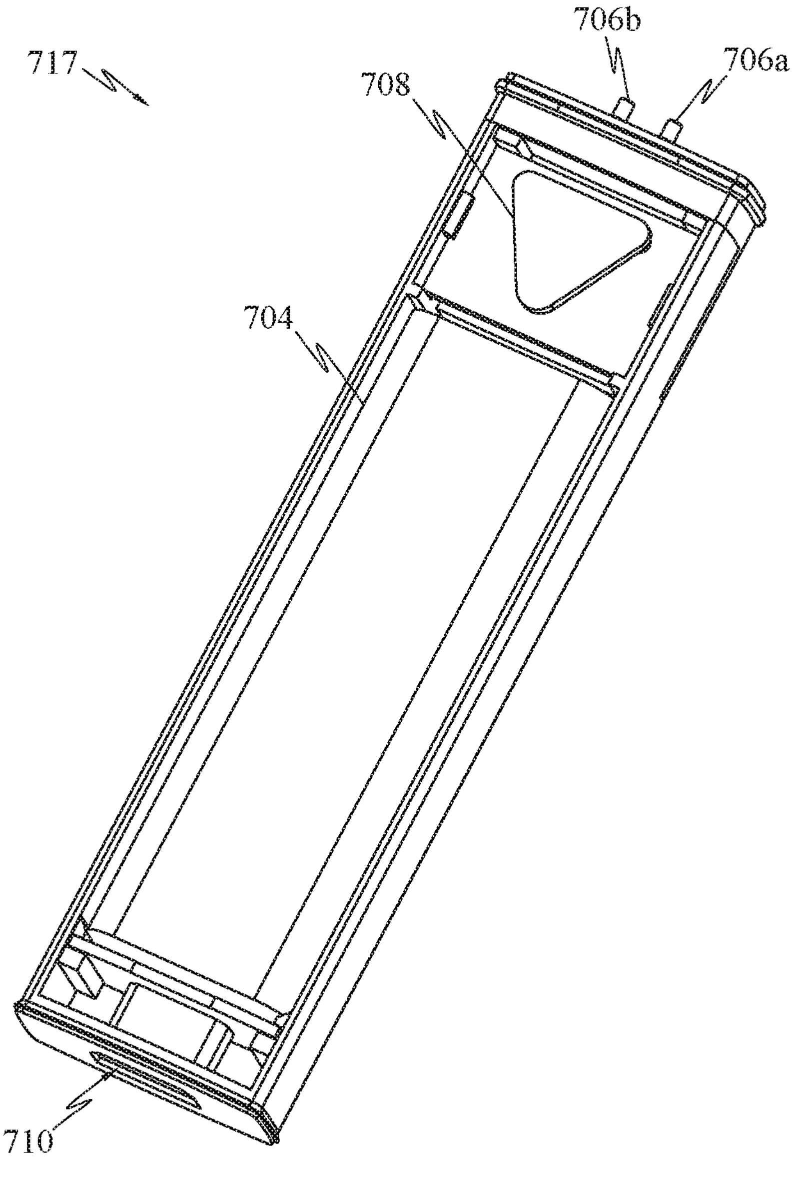


FIG. 7C

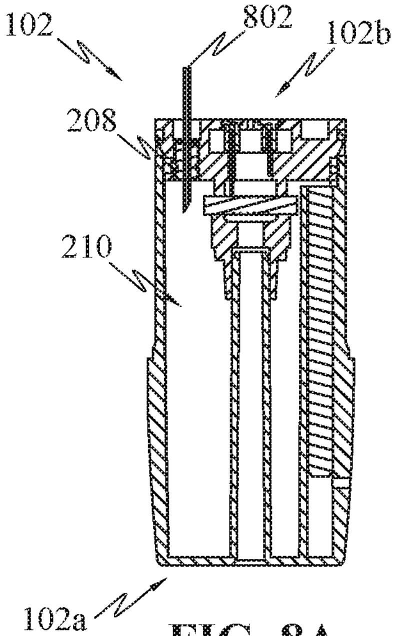


FIG. 8A

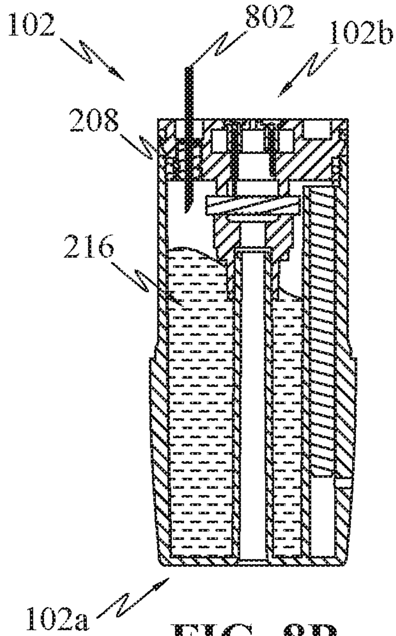


FIG. 8B

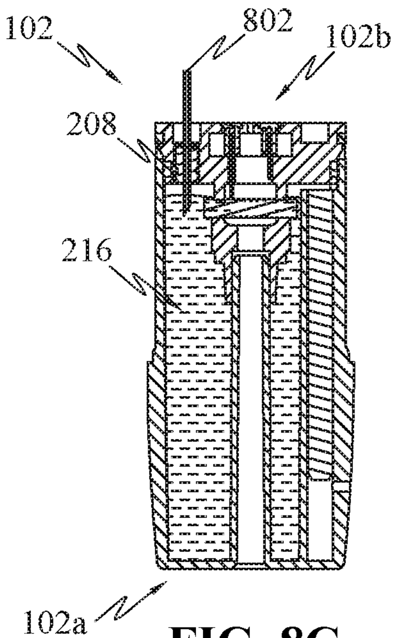


FIG. 8C

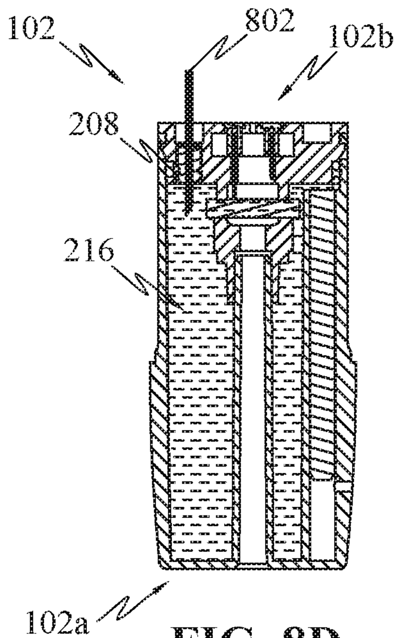


FIG. 8D

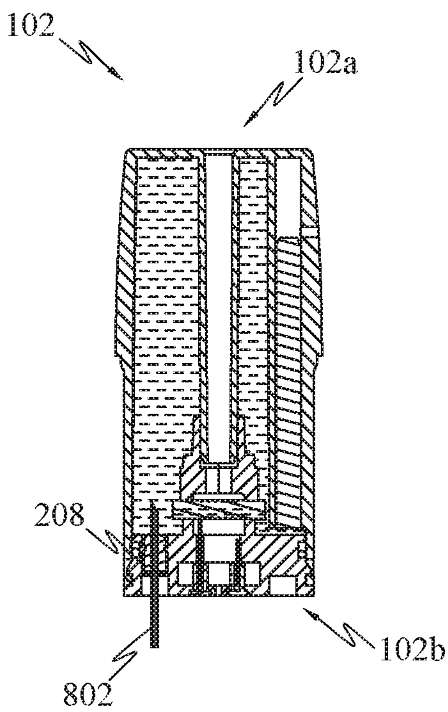


FIG. 8E

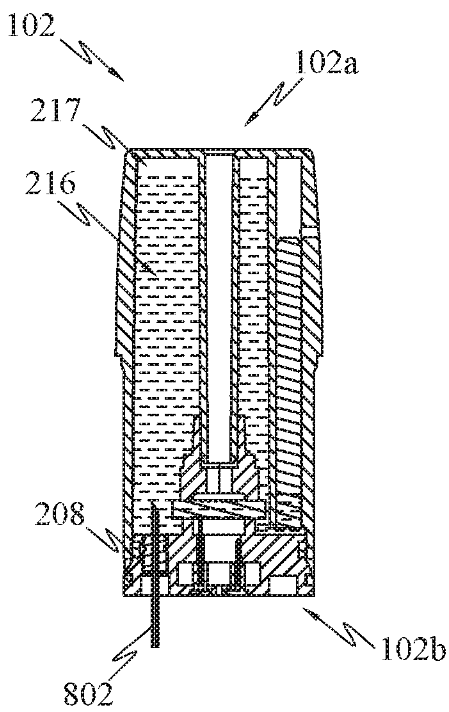


FIG. 8F

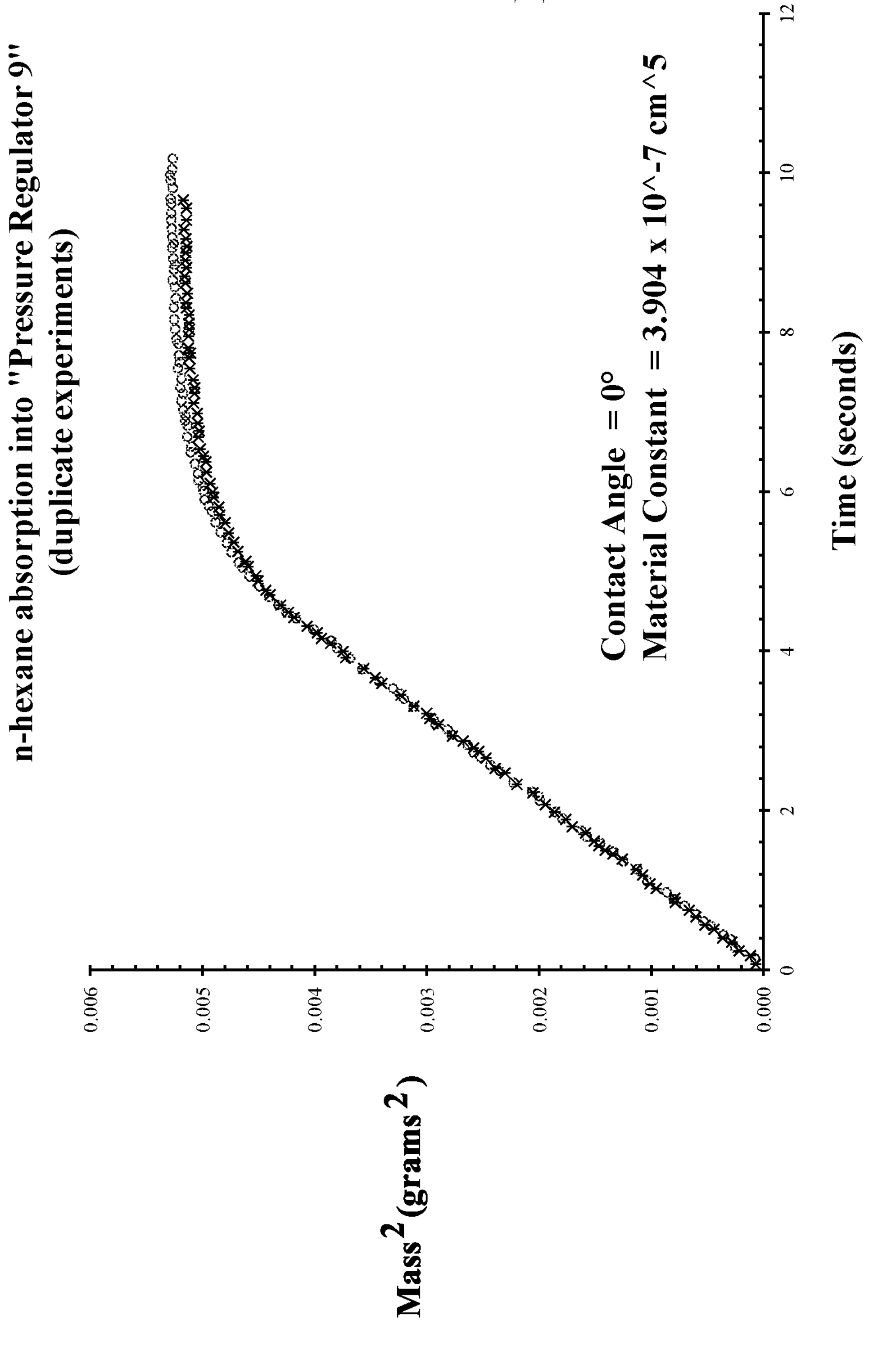

n-hexane absorption into "Pressure Regulator 9"
(duplicate experiments)
Contact Angle = 0°
Material Constant = 3.904 x 10^-7 cm^5
Mass^2 (grams^2)
Time (seconds)
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0
2
4
6
8
10
12

FIG. 9A

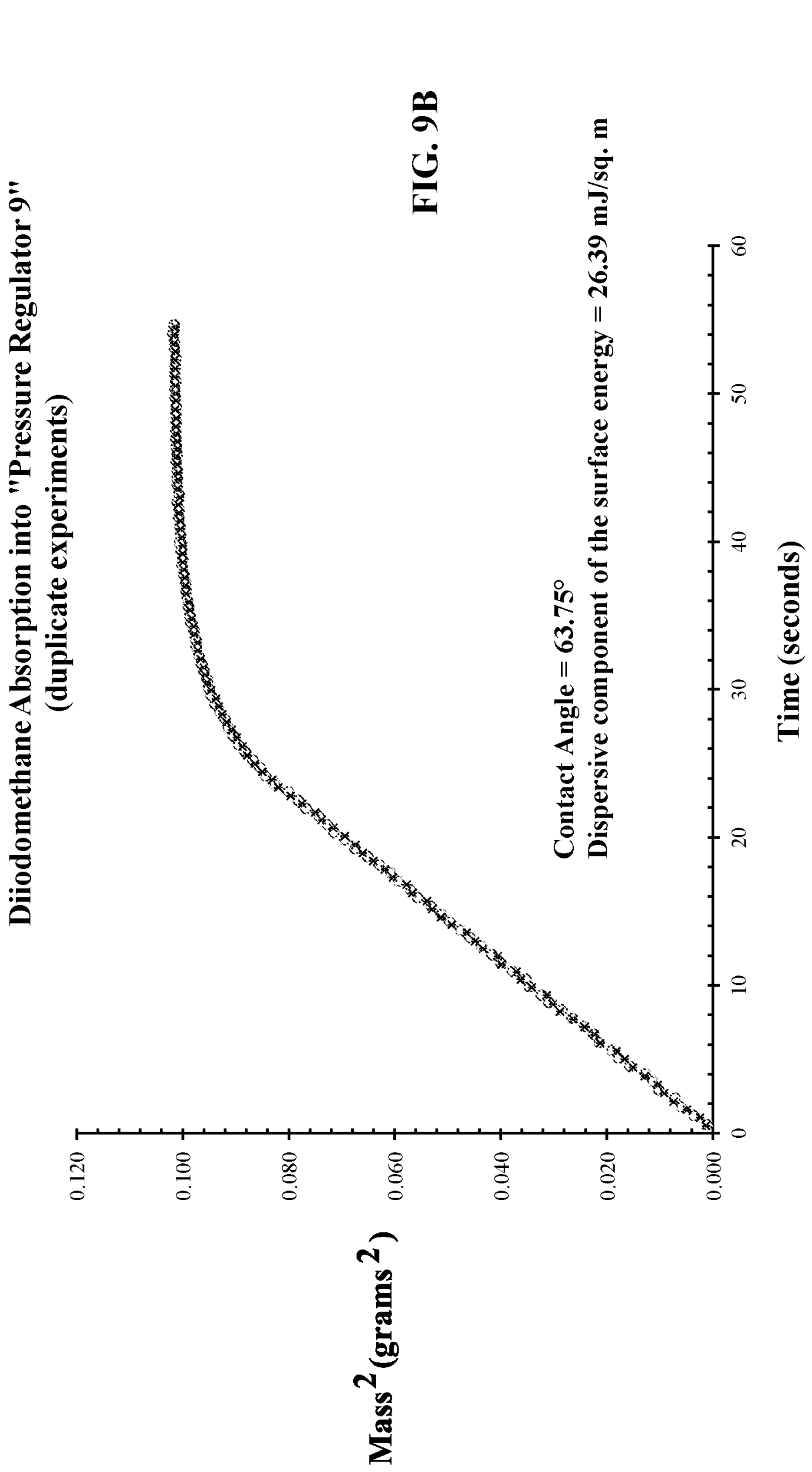
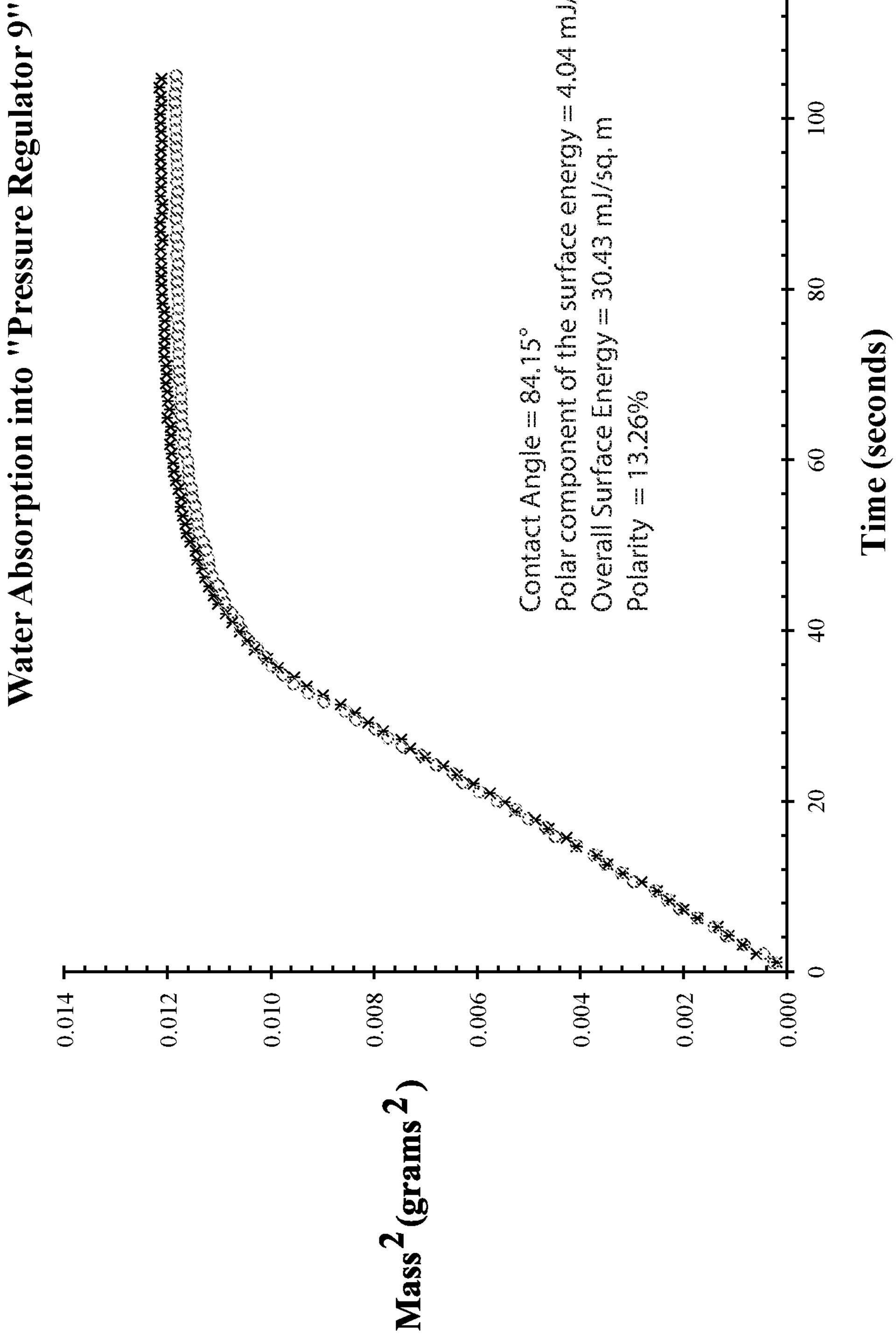

Diiodomethane Absorption into "Pressure Regulator 9"
(duplicate experiments)
Contact Angle = 63.75°
Dispersive component of the surface energy = 26.39 mJ/sq. m
Mass^2 (grams^2)
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0
10
20
30
40
50
60
Time (seconds)

FIG. 9B

FIG. 9C


Water Absorption into "Pressure Regulator 9"
Mass^2 (grams^2)
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
20
40
60
80
100
120
Time (seconds)
Contact Angle = 84.15°
Polar component of the surface energy = 4.04 mJ/sq. m
Overall Surface Energy = 30.43 mJ/sq. m
Polarity = 13.26%

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2020/053785

A. CLASSIFICATION OF SUBJECT MATTER

A24F 47/00(2020.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A24F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI; SIPOABS; CNABS; CNTXT;shunya labs,cigarette,electronic,e-cigarette, vapori+,atomiz+, regulat+ ,balanc+,equaliz+,equilibri+,pressure,inner,outer,stor+,+liquid,oil,chamber,cavity,tobacco,nicotine,vacuum,negative, air,atmosphere,hole,pore?,porous,micropore?,leak+,wick.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	IN 201921016819 A (SHUNYA LABS PRIVATE LTD.) 21 June 2019 (2019-06-21) claims 1-18	1-18
X	CN 105795522 A (SHENZHEN HANXINGXIANG TECHNOLOGY CO., LTD.et al.) 27 July 2016 (2016-07-27) description, paragraphs 37-38, 42-43, 46-56, figures 1-7	1-18
X	EP 3254574 A1 (SHENZHEN FIRST UNION TECHNOLOGY CO., LTD.) 13 December 2017 (2017-12-13) description, paragraphs 6-22, figures 1-6	1-18
A	CN 206453248 U (CHANGZHOU PAITENG ELECTRONIC TECH. SERVICE CO., LTD.) 01 September 2017 (2017-09-01) description, paragraphs 3-12, figures 1-9	1-18
A	CN 207040889 U (SHENZHEN FIRST UNION TECHNOLOGY CO., LTD.) 27 February 2018 (2018-02-27) description, paragraphs 2-23, figures 1-5	1-18

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 July 2020	**24 July 2020**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China	**WANG,Jingjing**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)53962738**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2020/053785

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 109077359 A (DONGGUAN ZHONGLONG PUMP TECH. CO., LTD.) 25 December 2018 (2018-12-25) description, paragraphs 17-23, figures 1-4	1-18
A	WO 2017139963 A1 (SHENZHEN SMOORE TECHNOLOGY LTD.) 24 August 2017 (2017-08-24) the whole text	1-18
A	CN 207011687 U (CHINA TOBACCO HUNAN IND. CO., LTD. et al.) 16 February 2018 (2018-02-16) description, example 2, figure 7	1-18
A	WO 2018161254 A1 (O-NET AUTOMATION TECH. SHENZHEN LTD.) 13 September 2018 (2018-09-13) the whole text	1-18
A	CN 108136141 A (BEYOND TWENTY LTD.) 08 June 2018 (2018-06-08) description, paragraphs 585-617	1-18

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2020/053785

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
IN	201921016819	A	21 June 2019	None			
CN	105795522	A	27 July 2016	CN	105795522	B	26 October 2018
EP	3254574	A1	13 December 2017	US	2017281883	A1	05 October 2017
				EP	3254574	B1	06 March 2019
				CN	206808661	U	29 December 2017
CN	206453248	U	01 September 2017	None			
CN	207040889	U	27 February 2018	None			
CN	109077359	A	25 December 2018	None			
WO	2017139963	A1	24 August 2017	EP	3417726	A4	04 September 2019
				US	2020120983	A1	23 April 2020
				EP	3417726	A1	26 December 2018
CN	207011687	U	16 February 2018	None			
WO	2018161254	A1	13 September 2018	None			
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				RU	2019137564	A	10 January 2020
				US	2018184722	A1	05 July 2018
				RU	2018111354	A	02 October 2019
				WO	2017037457	A1	09 March 2017
				GB	201614821	D0	19 October 2016
				RU	2018111354	A3	02 October 2019
				AU	2016313955	A1	12 April 2018
				AU	2016313955	A2	14 June 2018
				EP	3344315	A1	11 July 2018
				US	10285449	B2	14 May 2019
				JP	2018534909	A	29 November 2018
				CA	2997119	A1	09 March 2017
				GB	2542012	B	01 April 2020
				GB	2542012	A	08 March 2017
				RU	2707892	C2	02 December 2019