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(54) **Titre : BOITIER DE BATTERIE INTUMESCENT**
(54) **Title: INTUMESCENT BATTERY HOUSING**

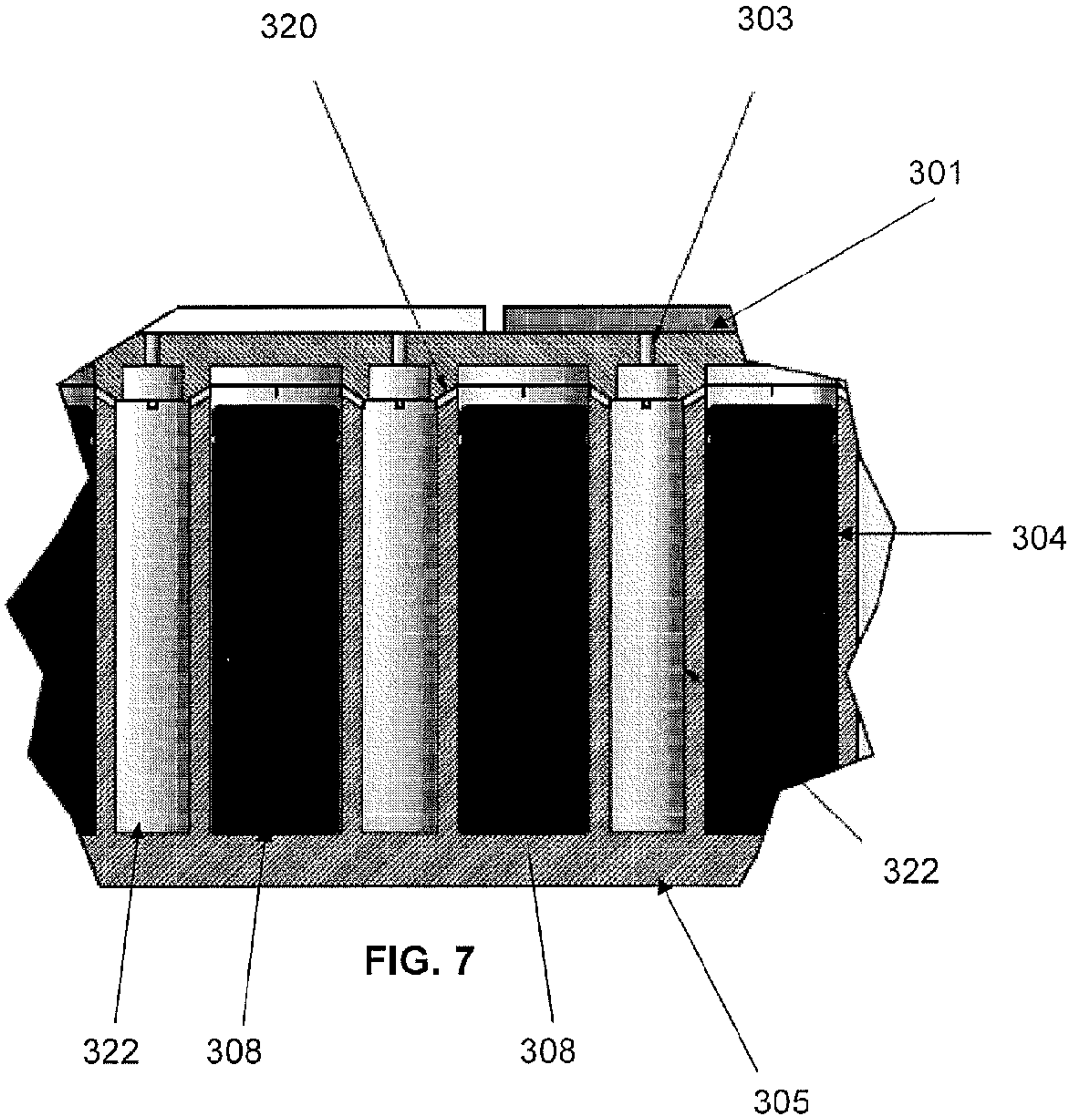

FIG. 7

(57) **Abrégé/Abstract:**
A battery housing has a body and a lid mateable with the body. The body and the lid, when mated, provide a chamber dimensioned to hold at least one battery; and a venting passageway from the chamber. At least a portion of at least one of the body and the lid comprises an intumescent flame retardant material with an expansion ratio sufficient to drive gas from the chamber through the venting passageway and to seal the chamber when the material intumesces in the event of thermal runaway of a battery housed in the chamber.

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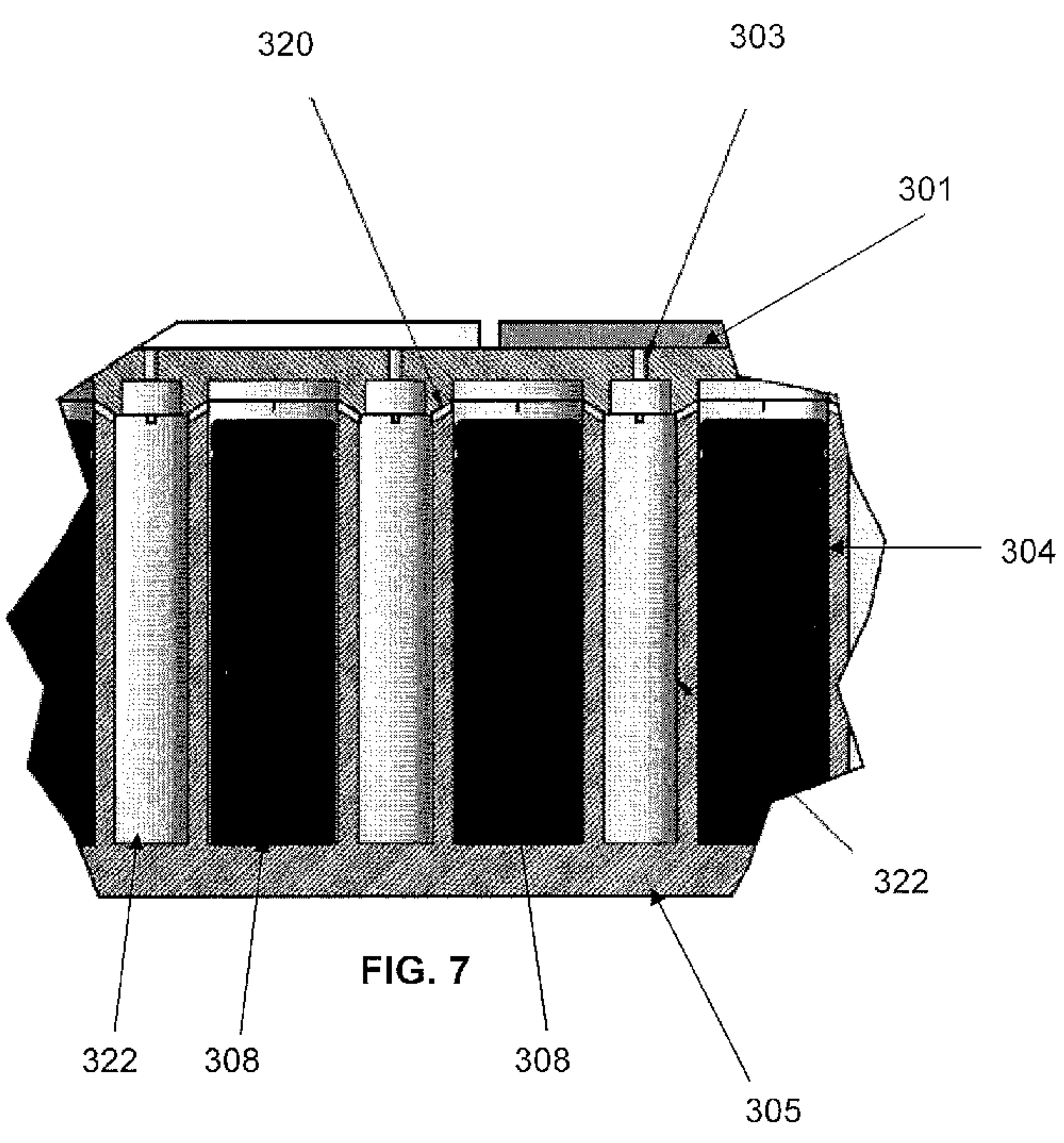

FIG. 7

(57) Abstract: A battery housing has a body and a lid mateable with the body. The body and the lid, when mated, provide a chamber dimensioned to hold at least one battery; and a venting passageway from the chamber. At least a portion of at least one of the body and the lid comprises an intumescent flame retardant material with an expansion ratio sufficient to drive gas from the chamber through the venting passageway and to seal the chamber when the material intumesces in the event of thermal runaway of a battery housed in the chamber.

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INTUMESCENT BATTERY HOUSING

BACKGROUND

[0001] This relates to a battery housing made from an intumescent flame retardant material that intumesces in the event of a thermal runaway of a housed battery.

[0002] Batteries have long been used as mobile power sources. In recent years, advancements have increased the power density of both primary (non-rechargeable) and secondary (rechargeable) batteries. For example, the power density of primary lithium batteries has reached 4.32 MJ/L, while the power density of secondary lithium ion batteries has reached 2.63 MJ/L. As a result, the use of lithium and lithium ion batteries has become wide spread in a variety of applications, including consumer electronics, medical devices, industrial equipment, and hybrid/electric automobiles.

[0003] However, many batteries, and particularly lithium and lithium ion batteries, are vulnerable to thermal runaways, during which heat and gas are rapidly discharged from a battery and a fire hazard is created. A thermal runaway may be caused by manufacturing defects, accumulation of heat, internal short circuits, or external impacts or trauma. Further, a thermal runaway of a single battery may trigger the thermal runaway of adjacent batteries, and thereby cause a dangerous chain reaction.

[0004] It is known to apply a fire-resistant coating to batteries or to enclose batteries within fire-resistant walls. However, a fire-resistant coating or wall often does not provide sufficient thermal insulation to prevent a thermal runaway from causing further thermal runaways of other batteries kept in close proximity. In fact, some fire-resistant materials used for coatings or walls, such as mica, have relatively high thermal conductivity. It is also known to apply an intumescent coating to batteries. However, intumescent coatings typically cannot be applied in a layer thick enough to overcome the drawbacks mentioned above. In any event, applying a coating introduces an additional manufacturing step. Further, the functionality of a coating may be compromised by scratching or peeling.

SUMMARY

[0005] To limit the consequences of a thermal runaway of a battery, battery housings incorporating an intumescent flame retardant material that intumesces in the event of a thermal runaway of a housed battery are provided.

[0006] In an aspect, there is provided a battery housing having a body and a lid mateable with the body. The body and the lid, when mated, provide a chamber dimensioned to hold at least one battery and a venting passageway from the chamber. At least a portion of at least one of the body and the lid comprises an intumescent flame retardant material with an expansion ratio sufficient to drive gas from the chamber through the venting passageway and to seal the chamber, when the material intumesces in the event of thermal runaway of a battery housed in the chamber.

[0007] In another aspect, there is provided a battery housing having a body and a lid mateable with the body. The body and the lid, when mated, provide a plurality of battery chambers, each dimensioned to hold at least one battery, and a plurality of venting passageways, each venting passageway extending from one battery chamber of the plurality of battery chambers. At least a portion of at least one of the body and the lid comprises an intumescent flame retardant material with an expansion ratio sufficient to drive gas from any given battery chamber of the plurality of battery chambers through at least one of the plurality of venting passageways, and seal the given battery chamber, when the material intumesces in the event of thermal runaway of a battery housed in the given battery chamber.

[0008] Other features will become apparent from the drawings in conjunction with the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] In the figures which show illustrative embodiments:

[0010] **FIG. 1A** is an exploded perspective view of a battery housing adapted to hold a battery;

[0011] **FIG. 1B** is an exploded cross-sectional view of the battery housing of **FIG. 1A**;

[0012] **FIG. 2** is a cross-sectional view of the battery housing of **FIG. 1A** with its lid and body mated;

[0013] **FIG. 2A** is a cross-sectional view of a battery housing according to a second embodiment;

[0014] **FIG. 3** is an exploded perspective view of a battery housing adapted to house a plurality of batteries;

[0015] **FIG. 4** is a bottom view of the lid of the battery housing of **FIG. 3**;

[0016] **FIG. 5** is an exploded perspective view of a battery housing adapted to house a plurality of batteries, in accordance with an alternate embodiment;

[0017] **FIG. 6** is a partial bottom view of the lid of the battery housing of **FIG. 5**;

[0018] **FIG. 7** is a partial cross-sectional view of the battery housing of **FIG. 5** with its lid and body mated;

[0019] **FIG. 8** is an exploded perspective view of a casing and a plurality of the battery housings of **FIG. 3**;

[0020] **FIG. 9A** is a top view of a battery housing body adapted to house seven batteries;

[0021] **FIG. 9B** is the side elevation view of the battery housing body of **FIG. 9A**;

[0022] **FIG. 10A** is a bottom view of a battery housing lid matable with the battery housing body of **FIG. 9A**;

[0023] **FIG. 10B** is a side elevation view of the battery housing lid of **FIG. 10A**; and

[0024] **FIG. 11** is a top view of the battery housing body of **FIG. 9A**.

DETAILED DESCRIPTION

[0025] **FIGs. 1A** and **1B** depict a battery housing **100** adapted to hold a battery **104**. Housing **100** has a body **105** and a removable lid **101**. Body **105** has a flat bottom **110** and a substantially cylindrical sidewall **112** defining a cavity **106** for receiving battery **104**. When lid **101** is mated to body **105**, lid **101** covers cavity **106** to form a chamber **108** substantially enclosing a battery received in cavity **106**. As depicted, battery **104** is a conventional lithium or lithium ion format 18650 battery. Chamber **108** is substantially cylindrical in shape and is sized to fit one format 18650 battery.

[0026] Bottom **110**, cylindrical sidewall **112**, and lid **101** are fabricated of an intumescent flame retardant (IFR) material, as detailed below. This IFR material intumesces in the event of a thermal runaway of battery **104** to entomb battery **104** within chamber **108** and prevent the thermal runaway from spreading to any other batteries.

[0027] As depicted, bottom **110**, sidewall **112**, and lid **101** are about 6.5 mm thick. In other embodiments, this thickness may be between about 0.5 mm to 50 mm. As will become apparent, bottom **110**, sidewall **112**, and lid **101** are formed to have a thickness that provides sufficient structural integrity and thermal insulation in the event of a thermal runaway. Therefore, the thickness of bottom **110**, sidewall **112**, and lid **101** depends on the material(s) from which lid **101** and body **105** are formed. Such materials are described in more detail hereinafter.

[0028] As depicted in **FIG. 1**, lid **101** includes three through-holes **103** for venting gas, heat, and pressure in the event of a thermal runaway of battery **104**. Each through-hole **103** provides a venting passageway that extends between chamber **108** and the exterior of housing **100**. As will be detailed below, through-holes **103** are self sealing in the event of a thermal runaway of battery **104**. Optionally, each venting passageway may be blocked by a blockage (not shown) to form a blind-hole. Such a blockage, which is described in more detail hereinafter in connection with another embodiment, fails when exposed to pressure created in chamber **108** during a thermal runaway, thereby converting a blind-hole to a through-hole.

[0029] Housing **100** includes two connectors **102** that allow electrical connection to battery **104** when held in chamber **108**. Thus, housing **100** may be used to hold battery **104** during operation of battery **104** (*e.g.*, charging or discharging). Each connector **102** includes a conductor that extends through housing **100**, *e.g.*, through bottom **110** or lid **101** (**FIG. 1B**). One end of each conductor is positioned to contact a corresponding electrode of battery **104** when held in chamber **108**, and the other end of each conductor is positioned to provide a contact external to housing **100**. Connectors **102** may be formed using an insert injection molding process to embed a conductor (*e.g.*, a metal plug) in lid **101** or body **105**.

[0030] Lid **101** is securely fastenable to body **105** to retain heat/fire within chamber **108** in the event of a thermal runaway of battery **104**. To this end, in the depicted embodiment, body **105** has interior screw threads **120** at its top end adapted to engage with complementary screwed threads **122** of lid **101**. Threads **120** and **122** allow lid **101** to be securely screwed to the top end of body **105**. In other embodiments, lid **101** may be secured to body **105** in other ways, *e.g.*, by way of clips, magnets, screws, bolts, or the like.

[0031] As noted, body **105** and lid **101** are made using an IFR material that includes one or more IFR polymer composites. Suitable IFR polymer composites may include base polymers, fire retardants, and blowing agents. If the base polymers are inherently fire retardant, such as PVC, CPVC, halogenated polyethylene Neoprene and phenolic resin, then the fire retardants can be omitted from the composite. Synergists such as antimony oxides and/or zinc borate can be added to improve the fire retardancy of a composite. Char-forming agents can be added to promote charring and increase yield (*i.e.*, final volume after intumescence), and thereby improve the fire retardancy and thermal insulation of a composite. Optionally, other components such as smoke suppressants, pigments, and compatibilizers can also be added.

[0032] Suitable blowing agents include, but are not limited to, expandable graphites, intumescent alkali metal hydrated silicates, and intumescent alkali metal hydrated silicates with certain amount of other components such as those described in U.S. Patent No. 6,645,278, the contents of which are incorporated herein by reference. The start expansion temperature (SET) of suitable blowing agents may vary between 130 °C to 300 °C. When expandable graphite is used as a blowing agent, electrically-insulating pads should be positioned between the surfaces of chamber **108** and the electrodes of any batteries held in chamber **108** to prevent a short circuit. Other suitable blowing agents will also be apparent to those of ordinary skill in the art. Blowing agents in the composite are generally used in amount of about 1 weight percent (wt %) to about 70 wt %.

[0033] Suitable fire retardants include, but are not limited to, polymeric halogen, monomeric halogen, alumina trihydrate, magnesium di-hydroxide, mica, talc, calcium carbonate, hydroxycarbonates, phosphorus compounds, red phosphorus, borate compounds, sulfur compounds, nitrogen compounds, silica, and/or various metal oxides. Other suitable fire retardants will also be apparent to those of ordinary skill in the art. The concentration of the fire retardants in a composite generally varies from 5 wt % to 55 wt %.

[0034] Suitable base polymers include, but are not limited to, thermoplastics, such as polyethylene, polypropylene, polyamide, ABS, polybutylene terephthalate, polyethylene terephthalate, EVA, thermosetting plastics, and elastomers, such as epoxy, Neoprene, cross-linked polyethylene, silicone, NBR, thermoplastic elastomers, or the blend of above. Other suitable base polymers will be apparent to those of ordinary skill in the art.

[0035] A mixture of the different components described above can be compounded into a composite. This composite can in turn be formed into desired geometries by known polymer processing methods such as injection molding, insert injection molding, extrusion, compression molding, blowing molding, transfer molding, calendaring, rotation molding, thermoforming, or the like. The melting temperature of the base polymers should be lower than the SET of the blowing agents in the composite. The temperature between the melting temperature of the base polymers and the SET of the blowing agents is the processing window for the composite. An IFR polymer composite formulated to have an expansion ratio of between 1.2 and 400 is suitable.

[0036] During a thermal runaway of battery **104**, a large amount of heat is rapidly generated. This causes the temperature of portions of battery **104** to rise significantly. In some cases, during a thermal runaway, the temperature in battery **104** may increase to about 900 ^{o}C, with localized hot spots reaching up to 1500 ^{o}C. At the same time, the thermal runaway generates a large volume of gas.

[0037] Battery **104**, as is conventional, includes a venting mechanism within its cap assembly. This venting mechanism can discharge pressurized gas generated by a thermal runaway, and regulates the internal gas pressure of battery **104**.

[0038] Unfortunately, the venting mechanism of battery **104** does not address the heat hazard created by a thermal runaway. In particular, a localized hot spot generated by a thermal runaway may perforate an exterior wall of battery **104** and allow heat/fire to spread. However, as detailed below, housing **100** intumesces in response to a thermal runaway of battery **104**, to entomb battery **104** within chamber **108** and prevent heat/fire from spreading.

[0039] In particular, in the event of a thermal runaway of battery **104**, the venting mechanism of battery **104** discharges gas, heat, and pressure into chamber **108**. Heat accumulating in chamber **108** causes the temperature of its surfaces (*i.e.*, interior surfaces of body **105** and lid **101**) to rise significantly. When the temperature of such surfaces reaches the SET of the blowing agent in the IFR polymer composite(s) of body **105** or lid **101**, body **105** or lid **101** will intumesce and char. The expansion ratio of the IFR material of body **105** and lid **101** is sufficient to cause expanding char to occupy any space in chamber **108**, and thereby drive gas out of chamber **108** by way of through-holes **103**. Driving gas from chamber **108** quickly quenches any developing fire. Further, the endothermic intumescent reaction of the IFR polymer composite material of lid **101**/body **105** will also absorb a large amount of heat while expanding.

[0040] After gas has been driven from chamber **108**, the above-noted expansion ratio is sufficient to cause the expanded char to seal through-holes **103**, thereby entombing battery **104** within chamber **108** to form a "dead cell".

[0041] Quickly quenching any developing fire in chamber **108** mitigates heat generation of a thermal runaway, as does the endothermic nature of the intumescent reaction. Further, charring of body **105**/lid **101** improves thermal insulation around chamber **108**. Each of these mechanisms minimizes the heat conducted out of chamber **108**, for example, to any adjacent batteries and prevents a thermal runway of battery **104** from inducing thermal runaway of those adjacent batteries. A chain reaction is thereby avoided.

[0042] Conveniently, multiple batteries can be safely placed in close proximity within respective housings **100**. For example, multiple batteries may be organized in close proximity to form battery packs/modules during storage, transportation, or operational use of the batteries.

[0043] **FIG. 2A** illustrates a modified embodiment wherein the sidewall **112'** of body **105'** of housing **100'** has an outbound portion **112A'** and an inbound portion **112B'**. In this embodiment, only the inbound portion **112B'** of the sidewall of body **105'** is made of an IFR material. The remainder of the body **105'** and lid **101'** are fabricated of other materials, such as metal. The inbound portion **112B'** of the sidewall may be a liner which is either integral with the outbound portion **112B'** of the sidewall or separable from it. Where the liner is separable, it may be fabricated of an IFR material which is flexible, such as an IFR foam, so that the liner may be wrapped around a battery **104** and then the liner and battery inserted in cavity **106'** of the housing **100'**. In either instance, the IFR material of the liner is chosen to have an expansion ratio sufficient to drive out gas from the battery chamber and seal the battery chamber in the event of thermal runaway of the battery held in the chamber.

[0044] **FIG. 3** depicts a battery housing **200**, exemplary of another embodiment. Whereas battery housing **100** is adapted to hold one battery, battery housing **200** is adapted to hold a plurality of batteries. In particular, as depicted, battery housing **200** is adapted to hold up to forty-nine format 18650 batteries (*e.g.*, batteries **204**).

[0045] Housing **200** has a body **205** and a removable lid **201**. Body **205** is substantially square in shape and includes forty-nine cavities **206** arranged in a grid, each for receiving one of batteries **204**. Of course, in other embodiments, body **205** may include a greater number or a fewer number of cavities, and the grid shape may vary. Each cavity **206** is spaced from adjacent cavities by a distance of approximately 6.5 mm. Cavities **206** around the perimeter of body **205** are spaced from the perimeter of body **205** by a distance of approximately 6.5 mm.

[0046] Referencing **FIG. 4** along with **FIG. 3**, removable lid **201** is substantially flat. However, the bottom of removable lid **201** has an array of circular lips **214**, each of which registers with one cavity **206** when lid **201** is mated to body **205**. The circular rim of each cavity **206** is chamfered so that a lip **214** will nestle into the rim when lid **201** is mated to body **205**. Thus, when lid **201** is mated to body **205**, lid **201** closes each cavity **206** to form a plurality of chambers substantially enclosing batteries received in cavities **206**. Such chambers are similar to chambers **108** (**FIG. 2**); for example, each chamber defined by lid **201** and body **205** is substantially cylindrical in shape and is sized to fit one format 18650 battery.

[0047] Lid **201** includes a plurality of blind-holes **203** for venting gas, heat, and pressure in the event of a thermal runaway. As depicted, blind-holes **203** are arranged such that three blind-holes **203** are aligned with each cavity **206**. In this way, each chamber defined by lid **201** and body **205** is connected to three blind-holes **203**. Each blind-hole **203** includes a venting passageway that extends between one chamber and the exterior of housing **200**. These venting passageways are blocked by one or more blockages adapted to fail when exposed to pressure created by the pressure created in a chamber during a thermal runaway of a battery held in that chamber, thereby converting a blind-hole **203** to a through-hole. In the depicted embodiment, the blockage of each venting passageway is a thin wall **209** integral to lid **201** and having a thickness such that it is broken by the pressure created in a chamber during a thermal runaway of a battery held in that chamber. As depicted in **FIG. 3**, these thin walls **209** prevent venting passageways from being visible from the top of lid **201**. Thin walls **209** may be formed integrally with lid **201** using an injection molding process and a suitable mold. As such, thin walls **209** may be formed of the same material as the remainder of lid **201**. In other embodiments, walls **209** may be replaced with a thin film applied and bonded to the top surface of lid **201**.

[0048] Lid **201** includes an upwardly projecting lip **210** extending about the perimeter of lid **201** to provide a space above housing **200** when stacked, *e.g.*, when another battery housing is stacked on top of housing **200**. In the depicted embodiment, the space provided above housing **200** may have a height of approximate 4.0 mm. In another embodiment, housing **200** may alternatively or additionally include a lip that projects downwardly from the bottom of housing **200** to provide a space below housing **200** when stacked, *e.g.*, when housing **200** is stacked on top of another battery housing.

[0049] Lip **210** may include one more interruptions, each providing a gap **211** to allow gas and pressure to vent out of the space above/below housing **200** in the event of a thermal runaway of a battery held therein. As depicted, gaps **211** are located at the four corners of lid **201**. When multiple stacks of housings are placed side-by-side, gas may travel from the space above/below a housing **200** to the space above/below an adjacent housing. In this way, pressure can be equalized among adjacent stacks of housings.

[0050] In some embodiments, gaps **211** may be omitted such that the space above/below housing **200** is substantially sealed when the housing **200** is stacked with other housings. Such embodiments may be suitable if housing **200** is expected to be used proximate to flammable materials (*e.g.*, styrofoam or cardboard boxes). Sealing gas within the space above or below the housing **200** helps prevent such flammable materials from being ignited by gas/heat vented during a thermal runaway.

[0051] Lid **201** is securely fastenable to body **205** by way of one or more snap-fit clips **212**. In other embodiments, lid **201** may be secured to body **205** in other ways, *e.g.*, by way of screws, magnets, bolts, or the like.

[0052] Body **205** includes a plurality of spaced transverse channels **213** that extend through body **205** beneath cavities **206**, from one side of body **205** to an opposite side of body **205**. Channels **213** are adapted to receive cooling conduits (not shown in **FIGS. 3** and **4**) that provide thermal communication between the interior and exterior of body **205**. These cooling conduits transfer waste heat generated by batteries **204** during operational use (*e.g.*, charging or discharging) out of housing **200**. The cooling conduits can also transfer heat generated during a thermal runaway out of housing **200**. Suitable cooling conduits can be made from a high heat conductivity material, such as metal. Optionally, the cooling conduits can be made from a fire-resistant material.

[0053] Housing **200** may include a plurality of interior electrical connectors (not shown) that allow some or all of batteries **204** held in housing **200** to be connected according to predefined series and/or parallel arrangements. Housing **200** may also include connectors similar to connectors **102** (**FIG. 1B**) that allow electrical connections to be made between some or all of batteries **204** and the exterior of housing **200**. Electrical connectors may be formed in housing **200** using an insert injection molding process.

[0054] Lid **201** and body **205** of housing **200** can be made from the same IFR polymer composite materials suitable for forming lid **101** and body **105** of housing **100** (**FIG. 1A**), discussed above. In the event of a thermal runaway of one of batteries **204** held in housing **200** (hereinafter, the "event" battery), gas, heat, and pressure are discharged into one of the chambers of housing **200** (hereinafter, the "event" chamber). This will cause the IFR material surrounding the event chamber to increase in temperature. When this temperature reaches the SET of the IFR material, the material will expand and char. At the same time, elevated pressure in the event chamber will break the thin walls **209** covering the blind-holes **203** connected to the event chamber, thereby converting those blind-holes **203** into through-holes that allow gas, heat, and pressure to vent out of housing **200**. When housing **200** is stacked, the gas, heat, and pressure may enter the aforementioned space above housing **200**, whereupon the gas, heat, and pressure may be further vented away from housing **200** by way of gaps **211**.

[0055] The expansion ratio of the IFR material surrounding the event chamber is sufficient to cause expanding char to occupy any space in the event chamber, and thereby drive out gas from the event chamber by way of the above-noted through-holes converted from blind-holes **203**. This quickly quenches any developing fire in the event chamber. Further, after gas has been driven out of the event chamber, the expanded char seals the through-holes connected to the event chamber, and thereby entombs the event battery within the event chamber, forming a "dead cell." The endothermic intumescent reaction of the IFR material of housing **200** absorbs heat during expansion. Further, cooling conduits received in channels **213** may transfer heat created by the thermal runaway out of housing **200**. In these ways, batteries held in the other chambers of housing **200** are protected from heat generated by the thermal runaway in the event chamber.

[0056] Batteries held in any adjacent housings are likewise protected from heat generated by the thermal runaway in the event chamber. Further, if heat discharged from housing **200** heats any IFR material of an adjacent housing beyond the SET of the IFR material of that adjacent housing, expansion in the adjacent housing will provide further protection.

[0057] **FIGS. 5-7** depict a battery housing **300**, exemplary of a further embodiment. Like battery housing **200** (**FIG. 3**), battery housing **300** is adapted hold a plurality of batteries. In particular, as depicted, battery housing **300** is adapted to hold up to thirty format 18650 batteries (*e.g.*, batteries **304**).

[0058] Housing **300** has a body **305** and a removable lid **301**. Like body **205** (**FIG. 3**), body **305** includes a plurality of cavities arranged in a grid, each for receiving a battery. In particular, as depicted in **FIG. 5**, body **305** includes thirty battery cavities **306**, each for receiving one of batteries **304**. In other embodiments, body **305** may include a greater number or a fewer number of battery cavities **306**, and the grid shape may vary. Each battery cavity **306** is spaced from adjacent battery cavities **306** by a distance of approximately 6.5 mm. Battery cavities **306** around the perimeter of body **305** are spaced from the perimeter of body **305** by a distance of approximately 6.5 mm.

[0059] Unlike body **205** (**FIG. 3**), in addition to cavities for receiving batteries, body **305** also includes a plurality of venting cavities **309**. As depicted, body **305** includes twenty venting cavities **309** arranged in a grid overlapping with the grid of battery cavities **306** such that each venting cavity **309** is disposed between diagonally-neighbouring battery cavities **306**. As further detailed below, each venting cavity **309** is for receiving gas vented from at least one adjacent battery cavity **306** during a thermal runaway of a battery received in that battery cavity. Each venting cavity **309** is spaced from adjacent battery cavities **306** by a distance of approximately 3.0 mm. Downward sloping open channels **313** connect each venting cavity **309** to its adjacent battery cavities **306**, as further discussed below. In other embodiments, body **305** may include a greater number or a fewer number of venting cavities **309**, so long as each battery cavity **306** is connected at least one venting cavity **309**. In some embodiments, a dedicated venting cavity **309** may be provided for each battery cavity **306**. As will be appreciated, providing venting cavities **306** in body **305** reduces the mass of housing **300**, which may ease transport of housing **300**.

[0060] Referencing **FIG. 6** along with **FIG. 5**, removable lid **301** is substantially flat. However, the bottom of removable lid **301** has an array of substantially circular lips **314**, each of which registers with one battery cavity **306** when lid **301** is mated to body **305**. The circular rim of each battery cavity **306** is chamfered so that a lip **314** will nestle into the rim when lid **301** is mated to body **305**. Thus, when lid **301** is mated to body **305**, lid **301** closes each battery cavity **306** to form a plurality of battery chambers **308** (**FIG. 7**) substantially enclosing batteries received in battery cavities **306**. Battery chambers **308** are similar to chambers **108** (**FIG. 2**); for example, each battery chamber **308** defined by lid **301** and body **305** is substantially cylindrical in shape and is sized to fit one format 18650 battery.

[0061] The bottom of removable lid **301** also has an array of substantially circular lips **316**, each of which registers with one venting cavity **309** when lid **301** is mated to body **305**. The circular rim of each cavity **309** is chamfered so that a lip **316** will nestle into the rim when lid **301** is mated to body **305**. Thus, when lid **301** is mated to body **305**, lid **301** closes each venting cavity **309** to form a plurality of substantially enclosed venting chambers **322** (**FIG. 7**) for holding gas vented during a thermal runaway of a battery held in an adjacent battery chamber **308**. As depicted, each venting chamber **322** is substantially cylindrical in shape, and has a diameter of approximately 9.0 mm and a height approximately equal to the height of battery chambers **308**. The size and shape of venting chambers **322** may vary in other embodiments.

[0062] As depicted, lips **316** protrude farther from the bottom surface of lid **301** than lips **314**. Tapered ribs **318** extend from the protruded end of each lip **316** to each adjacent lip **314**. Each tapered rib **318** registers with one downward sloping open channel **313** of body **305** when lid **301** is mated to body **305** to form a substantially enclosed battery chamber venting passageway **320** between a battery chamber **308** and each adjacent venting chamber **322**. Channels **313** and ribs **318** both slope at an angle of approximately 57 degrees relative to the bottom surface of lid **301**. As such, each passageway **320** is formed to slope downwardly from a battery chamber **308** to an adjacent venting chamber **322** at this angle when battery housing **300** is oriented horizontally.

[0063] Lid **301** includes a plurality of through-holes **303** which provide venting chamber venting passageways for venting gas, heat, and pressure in the event of a thermal runaway. As depicted, through-holes **303** are arranged such that a through-hole **303** is provided in each venting cavity **309**. In this way, each venting chamber **322** defined by lid **301** and body **305** is connected to a through-hole **303**. Each through-hole **303** provides a venting passageway that extends between one venting chamber **322** and the exterior of housing **300**. In the depicted embodiment, through-holes **303** have larger diameters than venting passageways **320**. In some embodiments, through-holes **303** may be replaced with blind-holes similar to blind-holes **203** (**FIG. 4**).

[0064] Lid **301** is otherwise similar to lid **201** (**FIG. 3**). For example, lid **301** includes an upward projecting lip **310** similar to lip **210**. Lip **310** extends about the perimeter of lid **301** to provide a space above housing **300** when stacked. In another embodiment, housing **300** may alternatively or additionally include a lip that projects downwardly from the bottom of housing **300** to provide a space below housing **300** when stacked. Like lip **210**, lip **310** may include one more interruptions, each providing a gap **311** to allow gas and pressure to vent out of the space above/below housing **300** in the event of a thermal runaway of a battery held therein. Lid **301** also includes one or more snap-fit clips **312** similar to snap-fit clips **212**. Snap-fit clips **312** allow lid **301** to be securely fastened to body **305**.

[0065] In some embodiments, body **305** may include a plurality of spaced transverse channels similar to channels **213** of body **205** (**FIG. 3**). Such channels extend through body **305** beneath battery cavities **306** and venting cavities **309**, and receive cooling conduits that provide thermal communication between the interior and exterior of body **305**.

[0066] Like housing **200** (**FIG. 3**), housing **300** may include a plurality of interior electrical connectors that allow some or all of batteries **304** held in housing **300** to be connected according to predefined series and/or parallel arrangements. Housing **300** may also include connectors similar to connectors **102** (**FIG. 1B**) that allow electrical connections to be made between some or all of batteries **304** and the exterior of housing **300**. Electrical connectors may be formed in housing **300** using an insert injection molding process.

[0067] Lid **301** and body **305** of housing **300** can be made from the same IFR polymer composite materials suitable for forming lid **101** and body **105** of housing **100** (**FIG. 1A**), discussed above.

[0068] In the event of a thermal runaway of one of batteries **304** held in housing **300** (hereinafter, the "event" battery **304**), gas, heat, and pressure from the event battery **304** are discharged into the battery chamber **308** holding that battery (hereinafter, the "event" chamber **308**). This will cause the IFR material surrounding the event chamber **308** to increase in temperature. When this temperature reaches the SET of the IFR material, the material will expand and char.

[0069] The expansion ratio of the IFR material surrounding the event chamber **308** is sufficient to cause expanding char to occupy any space in the event chamber **308**, and thereby drive out gas from the event chamber **308** to adjacent venting chambers **322** by way of sloping venting passageways **320**. Any developing fire in the event chamber **308** is thereby quickly quenched. Further, after gas has been driven out of the event chamber **308**, the expanded char seals venting passageways **320** connected to the event chamber **308**, and thereby entombs the event battery **304** within the event chamber **308**, forming a "dead cell."

[0070] Gas vented into a venting chamber **322** from the event chamber **308** is further vented to the exterior of housing **300** by way of a through-hole **303**. The slope of venting passageways **320** connecting other battery chambers **308** to the event chamber **308** increases the back pressure on the expanding gases from event battery **304**. This increased back pressure, along with the fact that venting passageways **320** have smaller diameters than through-holes **303**, help to direct these gases out of housing **300** by way of through-holes **303**. When the IFR material around a through-hole **303** is heated to its SET, this material will expand and char to seal the through-hole **303**. Similarly, when the IFR material around venting passageways **320** connecting the event battery chamber **308** to other batteries chambers **308** is heated to its SET, this material will expand and char to seal these venting passageways **320**.

[0071] In embodiments where through-hole **303** is replaced by a blind-hole, gas may accumulate in venting chamber **308** until increasing pressure in a venting chamber **308** causes the blockage blocking the venting passageway of the blind-hole to fail, thereby converting the blind-hole to a through-hole. In embodiments where through-holes **303** are omitted and not replaced by blind-holes, gas that accumulates in a venting chamber **322** is retained therein until lid **301** is removed, *e.g.*, when housing **300** is serviced.

[0072] Quickly quenching any developing fire in chamber **308** mitigates heat generation of a thermal runaway, as does the endothermic nature of the intumescent reaction. Meanwhile, charring of body **305**/lid **301** improves thermal insulation around chamber **308**. Further, as noted above, the slope of venting passageways **320** and the fact that venting passageways **320** have smaller diameters than through-holes **303** helps to direct gases generated by event battery **304** out of housing **300** by way of through-holes **303**. This reduces flow of such gases from venting chambers **309** to adjacent battery chambers **308**. Each of these mechanisms minimizes the heat conducted to other batteries **304**, and prevents a thermal runway of battery **308** from inducing thermal runaway of those other batteries.

[0073] Conveniently, as event chamber **308** vents into adjacent venting chambers

322 rather than directly to the exterior of housing **300**, flames/sparks escaping from event chamber **308** may be contained inside the adjacent venting chambers **322**. This helps to prevent fire from spreading to the exterior of housing **300**.

[0074] Optionally, during use, battery housings (*e.g.*, housings **200** or **300**) may be covered by a rigid fire-resistant plate or mat to protect any flammable materials placed on top of the housing in the event of a thermal runaway. This plate or mat can be made from the same IFR polymer composites discussed above, or other thermally-insulative materials know to those of ordinary skill in the art. The plate or mat may rest atop upwardly projecting lips **210/310** such that space is provided between the plate or mat and the top of the battery housing to allow venting.

[0075] **FIG. 8** depicts a casing **400** for encasing multiple battery housings, *e.g.*, multiple housings **200**. Casing **400** includes a body **405** and a removable lid **401**. As depicted, body **405** includes interior walls **412** that, along with exterior walls **410** of body **405**, define six compartments **414**, each for receiving one housing **200**. Interior walls **412** and exterior walls **410** include holes that align with channels **213** of battery housing **200** received by compartments **414** such that cooling conduits **406** may be extended through interior walls **412**, exterior walls **410** and one or more housings **200** along the length of casing **400**.

[0076] Lid **401** and body **405** can be made using steel, or another material that provides suitable mechanical rigidity. Lid **401** and body **405** may also be made from material to allow casing **400** to withstand explosions, including explosions of batteries within casing **400** and external explosions. Other suitable materials will also be readily apparent to those of ordinary skill in the art, such as, for example, carbon fiber/fiberglass reinforced polymer composites, ceramics, or the like. Lid **401** is securely fastenable to body **405** by screws (not shown). Other suitable fasteners that provide the above-mentioned mechanical rigidity or explosion-resistance to casing **400** may also be used.

[0077] When housings **200** are received in compartments **414** of body **405** and lid

401 is mated to body **405**, upwardly projecting lips **210** of housings **200** provide a space between each housing **200** and lid **401**. During a thermal runaway, gas, pressure, and heat may be discharged from one of housings **200** to this space. This gas, pressure, and heat may be retained in this space in embodiments where casing **400** is substantially sealed. In other embodiments, casing **400** may include holes or gaps that allow gas, pressure, and heat to be vented to the exterior of casing **400**.

[0078] Although the casing **400** holds only one layer of battery housings, in other embodiments, casing **400** can be modified to hold multiple layers of battery housings such that sufficient voltage, current, and power can be supplied from one casing **400** to satisfy the requirements a large device such as, for example, an electric car, an aircraft, or a submarine.

[0079] In other embodiments, casing **400** may be modified to encase other battery housings such as, *e.g.*, housing **300**. For example, the exterior and interior walls of casing **400** could be modified to resize compartments **414** to receive such other housings.

[0080] The operation of battery housings disclosed herein is further described with reference to tests conducted using a battery housing, as depicted in **FIGS. 9A/9B** and **10A/B**. **FIG. 9A** and **9B** are respectively top and side elevation views of body **605** of the housing. **FIGS. 10A** and **10B** are respectively bottom and side elevation views of lid **601** of the housing.

[0081] As best seen in **FIG. 9A**, the battery housing has seven cavities **606**, each for receiving one format 18650 battery. As depicted, body **605** is hexagonal in shape, and cavities **606** are arranged in body **605** such that they are substantially equidistant from each other, *e.g.*, at a distance of approximately 20 mm. As best seen in **FIG. 10A**, lid **601** includes a plurality of through-holes **603**. Each through-hole **603** is aligned with one of the seven cavities **606** and provides a venting passageway for venting one of the seven substantially enclosed chambers formed when lid **601** is mated to body **605**. Through-holes **603** are otherwise similar to through-holes **103**

(**FIG. 1A**).

[0082] Lid **601** and body **605** are formed using an IFR polymer composite material having the following composition, by weight percentage:

Intumescent powder:	30.0%;
High density polyethylene (HDPE):	42.0%;
Antioxidant:	0.2%;
Fusabond™ E265:	3.0%;
Titanium dioxide:	1.5%;
Brominated polyethylene:	17.5%;
Antimony trioxide:	5.8%.

[0083] The intumescent powder is a blowing agent manufactured according to the processes described in aforementioned U.S. Patent No. 6,645,278. The antioxidant improves the thermal stability of the HDPE and the brominated polyethylene for melt processing. Fusabond™ E265 is an anhydride modified high density polyethylene from DuPont™, which functions as a compatibilizer in the composite to improve adhesion among different components. Titanium dioxide inhibits smoke and improves the whiteness of the final articles. Brominated polyethylene is a fire retardant with excellent processability and compatibility. Antimony trioxide synergizes with bromine to improve the fire retardant effect.

[0084] To form the IFR material for lid **601** and body **605**, the powder and pellets of the different components were weighed stoichiometrically and mixed. The mixture was then compounded at 170 °C in a single-screw extruder and pelletized. The composite pellets were then injection molded to form lid **601** and body **605**.

[0085] The battery housing of **FIGs. 9A/9B**, **10A/10B** was tested by simulating a thermal runaway of a battery held therein. Lid **601** and body **605** were subjected to ambient condition for over 48 hours prior to testing. Testing was carried out at an ambient temperature of 24 °C and a relative humidity of 21%.

[0086] Two tests were conducted. In the first test, a heating cartridge was placed in central cavity B7 of the battery box of body **605** (**FIG. 11**). Six format 18650 lithium ion (lithium-ion-cobalt) batteries were placed in the six peripheral cavities B1-B6 of body **605**. A thermocouple was placed inside each cavity to measure temperature during the test. The thermocouple in each peripheral cavity was attached to the battery placed in that cavity at a location closest to the central cavity B7 to obtain the highest temperature measurement.

[0087] Lid **601** was then securely fastened to body **605** using a plurality of screws (not shown), thereby enclosing the heating cartridge and the six batteries respectively within seven chambers defined by lid **601** and body **605**.

[0088] The heating cartridge was then heated at 130 °C/min to 653.4 °C, and then immediately deactivated. Total heating duration was approximately 5 minutes. This duration was chosen to be far longer than the expected duration of a thermal runaway of a lithium ion battery, which typically lasts for approximately 30 to 55 seconds. Acquisition of temperature measurements by way of the thermocouples in each chamber was started before the heating cartridge was activated, and stopped after all the thermocouples showed decreasing temperature. The highest temperature measured by each thermocouple is shown in TABLE 1, below. Of note, the highest temperature for each of the batteries was recorded five minutes after the heating cartridge was deactivated.

TABLE 1

Thermocouple	Heating cartridge	Battery #1	Battery #2	Battery #3	Battery #4	Battery #5	Battery #6
Temperature (°C)	653.4	34.2	35.3	34.0	37.7	28.5	31.5

[0089] After removing lid **601** of the housing, all six batteries held in the peripheral chambers (corresponding to cavities B1-B6 of **FIG. 11**) were observed to be intact. Meanwhile the heating cartridge held in the central chamber (corresponding to cavity B7 of **FIG. 11**) was surrounded by a thick layer of char. The char was produced by heating the IFR polymer composite material of lid **601** and body **605** to a temperature above the SET of the intumescent powder (*i.e.*, approximately 200 °C), thereby causing the IFR material to intumesce.

[0090] The simulated thermal runaway in the central chamber did not increase temperatures in the peripheral chambers sufficiently to cause a thermal runaway of any of the batteries held in the peripheral chambers. As shown in TABLE I, the highest temperature measured within the peripheral cavities was only 37.7 °C, well below the 232 °C threshold at which thermal runaway of lithium ion batteries is typically initiated. The test results show that char produced in response to the simulated thermal runaway and the material of lid **601**/body **605** separating the chambers provided thermal insulation around the heating cartridge that greatly reduced heat transfer from the heating cartridge to the peripheral chambers. Further, the above-noted five minute delay between deactivation of the heating cartridge and measurement of the highest temperature in each of the peripheral chambers also evidences the effectiveness of the thermal insulation.

[0091] The second test was a nail-penetration test. In this test, a real thermal runaway and explosion of a battery held in the housing was induced. In particular, a battery having a 100% state of charge was penetrated with a metal nail to cause an internal short circuit. The effect of the induced thermal runaway and explosion event on other batteries held in the housing was observed.

[0092] Seven format 18650 lithium ion (lithium-ion-cobalt) batteries were placed into the seven cavities B1-B7 of housing body **605** (**FIG. 11**). Battery #5 placed in cavity B5 had a 100% state of charge. A thermocouple was attached to the surface of each of the seven batteries to measure temperature during the test. All of the thermocouples except the one attached to battery #5 were positioned at a location closest to cavity B5 to obtain the highest temperature measurement.

[0093] Again, lid **601** was securely fastened to body **605** using a plurality of screws (not shown), thereby enclosing the seven batteries respectively within seven chambers defined by lid **601** and body **605**.

[0094] A metal nail was drilled through body **605** to penetrate battery #5 and cause an internal short circuit. Acquisition of temperature measurements was started before penetration, and stopped after all the thermocouples showed decreasing temperatures. The highest temperature measured by each thermocouple is shown in TABLE 2, below.

TABLE 2

Thermocouple	Battery #5 (shorted)	Battery #1	Battery #2	Battery #3	Battery #4	Battery #6	Battery #7
Temperature (°C)	743.8	26.3	24.6	26.0	39.6	40.0	37.4

[0095] The results show that a thermal runaway was successfully triggered in battery #5 upon being penetrated by the metal nail. This thermal runaway caused battery #5 to reach a peak temperature of 743.8 °C. Gas, spark, and smoke vented from the through-hole **603** connected to chamber B5 holding battery #5 for approximately 15 seconds, after which the through-hole **603** was sealed. This venting period was much shorter than the typical thermal runaway period (30 to 55 seconds) of a lithium ion battery. The shorter venting period indicated that the thermal runaway was quenched by the expanding char at an early stage.

[0096] After gas/smoke finished venting from the through-hole **603**, the intumescing IFR material sealed off through-hole **603**, the interface between lid **601** and body **605**, as well as the hole created by the penetrating nail. The highest temperature measured in any of the chambers excluding the chamber holding battery #5 was 40.0 °C, far below the 232 °C typically required to induce a thermal runaway event.

[0097] Upon removing lid **601** following the test, it was observed that battery #5 was fully embedded in char, forming a "dead cell". At the same time, the six other batteries remained intact. Further, the housing, aside from the intentional penetration, maintained its overall structural integrity.

[0098] Although through-holes (*e.g.*, through-holes **103**, **303**, and **603**) and blind-holes (*e.g.*, blind holes **203**) are shown to be located on the lid of battery housings in the depicted embodiments, through-holes and blind-holes can also be located in the body of battery housings, *e.g.*, at the bottom or sides of the body. Further, the number of through-holes and blind-holes can vary, so long as at least one through-hole or blind-hole is provided to allow venting from each chamber for holding a battery. In the depicted embodiment, through-holes and blind-holes are shown to be round in shape. However, in other embodiments, through-holes and blind-holes may have another shape; for example, they may be slits. Any through-holes may be replaced with blind-holes, and conversely, any blind-holes may be replaced with through-holes.

[0099] Although chambers (*e.g.*, chambers **108**, **308**, and **608**) of the battery housings are shown to adapted to hold a format 18650 battery, in other embodiments, chambers can be adapted to hold any other type of primary or secondary batteries or cells, of difference sizes, configurations and chemistries. Further, although each chamber is shown to be adapted to hold only one battery, in other embodiments, a chamber could be adapted to hold multiple batteries, *e.g.,* stacked end-on-end or placed side-by-side.

[00100] In the embodiments of **FIGs. 3** and **4**; **FIGs. 5** to **7**, and **FIGs. 9A** to **11**, the, lids (*e.g.*, lids **201**, **301**, and **601**) and bodies (*e.g.*, body **205**, **305**, and **605**) of battery housings were described as fabricated of an IFR material. However, in other embodiments, a lid and/or a body could be partly fabricated of other materials. For example, similar to the embodiment of **FIG. 2A**, a body could incorporate liners fabricated of an IFR material at each battery chamber. In such instance, the IFR material of the liners is chosen to have an expansion ratio sufficient to drive out gas from a battery chamber and seal the battery chamber in the event of thermal runaway of a battery held in that chamber. As with the embodiment of **FIG. 2A**, the liners may be an integral part of the body or a separable part of the body. Where the liners are separable, they could be formed of a flexible IFR foam and removed from the battery housings to be wrapped around each battery before the batteries/liners are placed inside the battery housings.

[00101] In the depicted embodiments, cooling conduits (*e.g.*, conduits **406**) are shown to extend transversely. However, the arrangement of cooling conduits can be changed to any other arrangement (*e.g.*, running at a bias with respect to the sidewalls of the housing).

[00102] Optionally, any of the battery housings and casings disclosed herein may be lined with ceramic or other fire-resistant fabrics (e.g., KaowoolTM, basalt, NextelTM, and NomexTM), to improve flame penetration and thermal insulation performance.

[00103] In the foregoing, the term “battery” refers to any type of primary or secondary cell or battery.

[00104] The above described embodiments are intended to be illustrative only and in no way limiting. The described embodiments are susceptible to many modifications of form, arrangement of parts, details and order of operation, as will be appreciated by one of skill in the art. The invention is intended to encompass all such modification within its scope, as defined by the claims.

**AMENDED CLAIMS
received by the International Bureau on 03
June 2015 (03.06.2015)**

WHAT IS CLAIMED IS:

1. A battery housing comprising:

a first housing portion; and

a second housing portion mateable with said first housing portion;

said first housing portion and said second housing portion, when mated, providing:

a chamber dimensioned to hold at least one battery; and

a venting passageway from said chamber;

at least a portion of at least one of said first housing portion and said second housing portion comprising an intumescent flame retardant material with an expansion ratio sufficient to drive gas from said chamber through said venting passageway and to seal said chamber, when said material intumesces in the event of thermal runaway of a battery housed in said chamber.

2. The housing of claim 1, wherein said expansion ratio of said intumescent flame retardant material is at least 1.2.

3. The housing of claim 1, further comprising at least one conductor extending from said chamber to an exterior of said housing, for providing an electrical connection to a battery housed in said chamber.

4. The housing of claim 3, wherein said at least one conductor comprises a first metal plug embedded said first housing portion and a second metal plug embedded in said second housing portion.

5. The housing of claim 1, wherein said chamber is a battery chamber and wherein said first housing portion and said second housing portion, when mated, provide a venting chamber terminating said venting passageway from said battery chamber, said venting chamber for receiving gas driven from said battery chamber in the event of thermal runaway of a battery housed in said battery chamber.

6. The housing of claim 5, wherein said venting passageway is a battery chamber venting passageway and further comprising a venting chamber venting passageway extending between said venting chamber and an exterior of said housing.

7. The housing of claim 1, wherein said venting passageway is blocked by a blockage that fails when exposed to pressure created in said chamber by said thermal runaway.

8. The housing of claim 7, wherein said blockage is a wall having a thickness such that said wall is broken by said pressure.

9. The housing of any one of claim 1 to claim 8, further comprising a lip projecting from at least one of a top surface and a bottom surface of said housing, arranged so as to extend substantially about a perimeter of said one of said top surface and said bottom surface, to provide a space above or below said housing when stacked.

10. The housing of claim 9, wherein said lip has an interruption providing a gap that allows gas to travel out of said space during said thermal runaway.

11. The housing of any one of claim 1 to claim 8, wherein said housing is substantially cylindrical in shape and wherein said second housing portion is a lid comprising a screw thread and said first housing portion is a body comprising an open end having a complementary screw thread to allow said lid to be screwed to said body.

12. The housing of any one of claim 1 to claim 8, wherein said intumescent flame retardant material comprises a polymer and a blowing agent, said polymer comprising one of a thermoplastic and a thermosetting plastic.

13. The housing of claim 12, wherein said blowing agent comprises expandable graphite.

14. The housing of claim 12, wherein said blowing agent comprises an alkali metal hydrated silicate.

15. The housing of claim 12 wherein said blowing agent is between 1% and 70% by weight of said intumescent flame retardant material.

16. The housing of any one of claim 13 to claim 15, wherein said intumescent flame retardant material further comprises a fire retardant, said fire retardant being between 5% and 55% by weight of said intumescent flame retardant material.

17. The housing of any one of claim 1 to claim 8 wherein said first housing portion comprises a non-intumescent portion fabricated of a non-intumescent material and an intumescent portion fabricated of an intumescent flame retardant material, said intumescent portion lining said chamber.

18. The housing of claim 17 wherein said intumescent portion is a liner separable from said non- intumescent portion.

19. The housing of claim 4 wherein, when said first housing portion and said second housing portion are mated, said first metal plug is opposed to said second metal plug.

20. A battery housing comprising:

a body; and

a lid mateable with said body;

said body and said lid, when mated, providing:

a plurality of battery chambers, each dimensioned to hold at least one battery, and

a plurality of venting passageways, each venting passageway extending from one battery chamber of said plurality of battery chambers;

at least a portion of at least one of said body and said lid comprising an intumescent flame retardant material with an expansion ratio sufficient to drive gas from any given battery chamber of said plurality of battery chambers through at least one of said plurality of venting passageways, and seal said given battery chamber, when said material intumesces in the event of thermal runaway of a battery housed in said given battery chamber.

21. The battery housing of claim 20, wherein for each battery chamber of said plurality of battery chambers, one venting passageway of said plurality of venting passageways extends between said each battery chamber and an exterior of said housing.

22. The battery housing of claim 20, wherein said body and said lid, when mated, provide a plurality of venting chambers, each venting chamber interconnected with at least one of said plurality of battery chambers, each venting chamber for receiving gas driven from an interconnected battery chamber of said plurality of battery chambers in the event of thermal runaway of a battery housed in said interconnected battery chamber.

23. The battery housing of claim 22, wherein for each battery chamber of said plurality of battery chambers, one venting passageway of said plurality of venting passageways extends between said each battery chamber and one of said plurality of venting chambers.

24. The battery housing of claim 23, wherein said one venting passageway slopes from said each battery chamber to said one of said plurality of venting chambers.

AMENDED SHEET (ARTICLE 19)

25. The battery housing of claim 24, wherein said body comprises a plurality of open channels and said lid comprises a plurality of ribs, each of said open channels registering with one of said ribs to form one of said venting passageways when said body and said lid are mated.

26. The battery housing of claim 23, wherein for each venting chamber of said plurality of venting chambers, another venting passageway extends between said each venting chamber and an exterior of said housing.

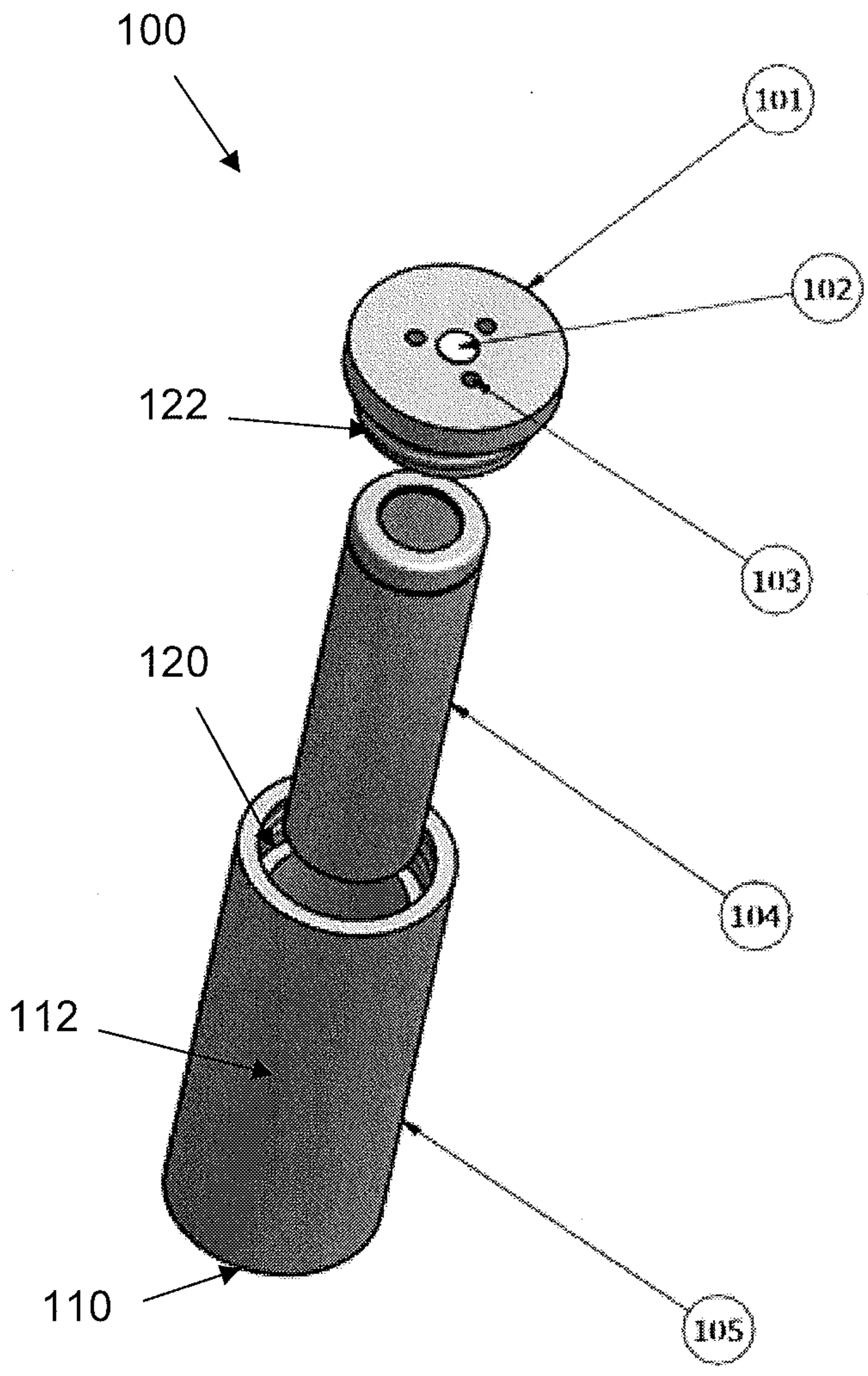
100
101
102
122
103
120
104
112
105
110

FIG. 1A

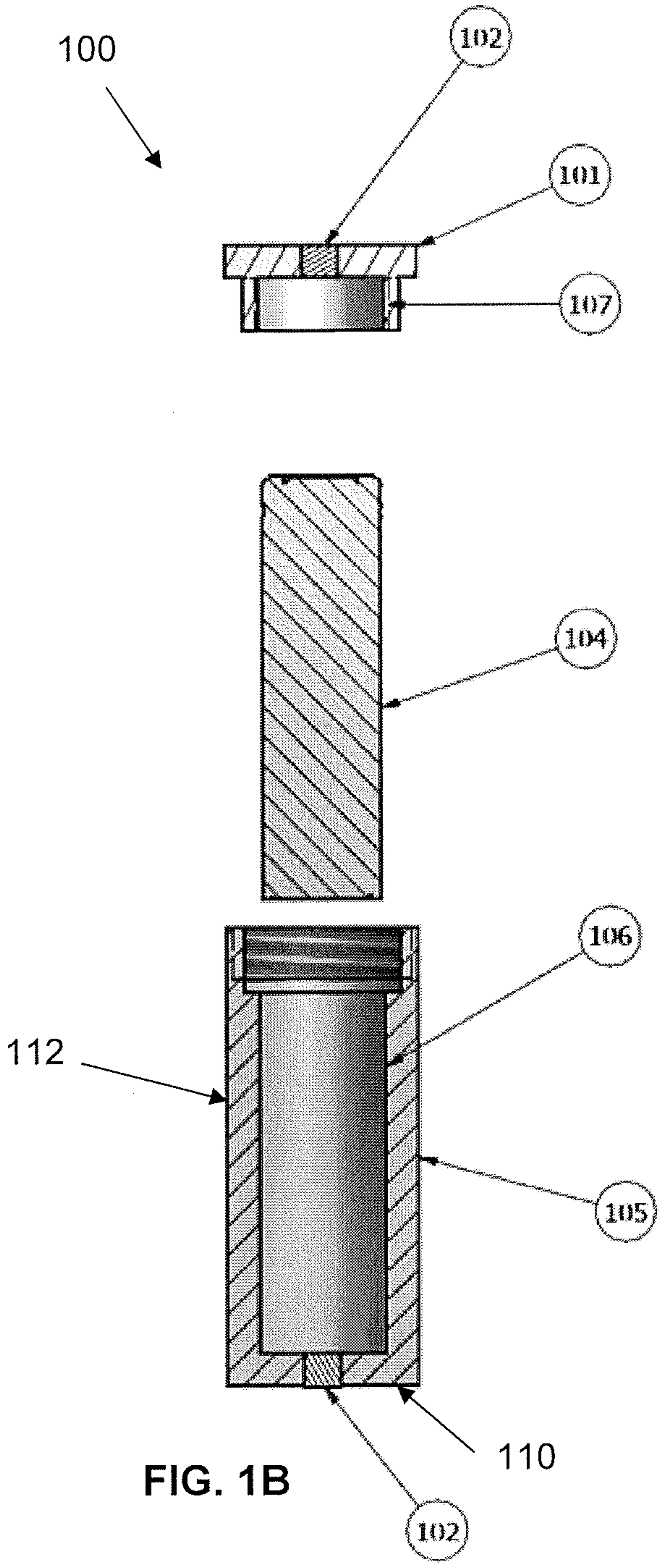
100
102
101
107
104
106
112
105
110
102

FIG. 1B

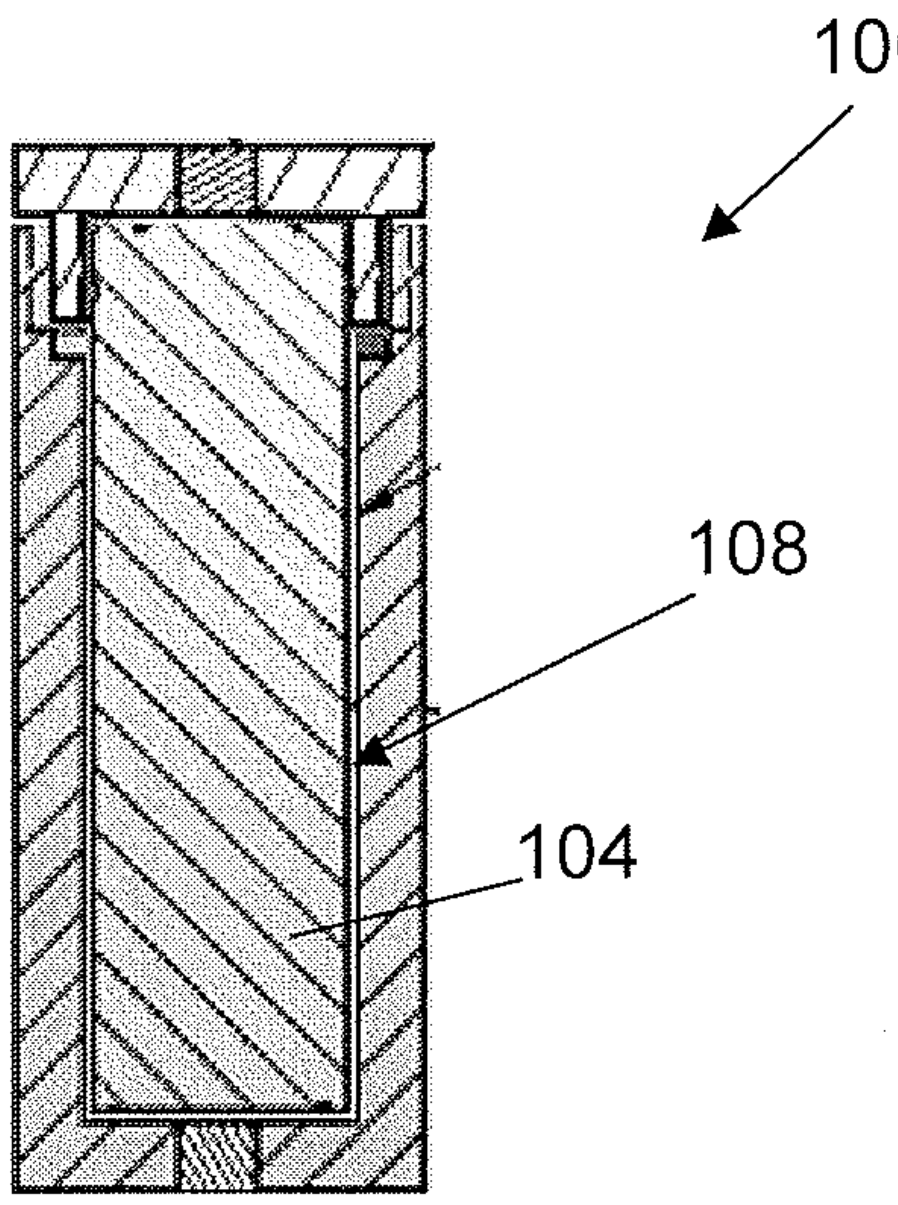

FIG. 2

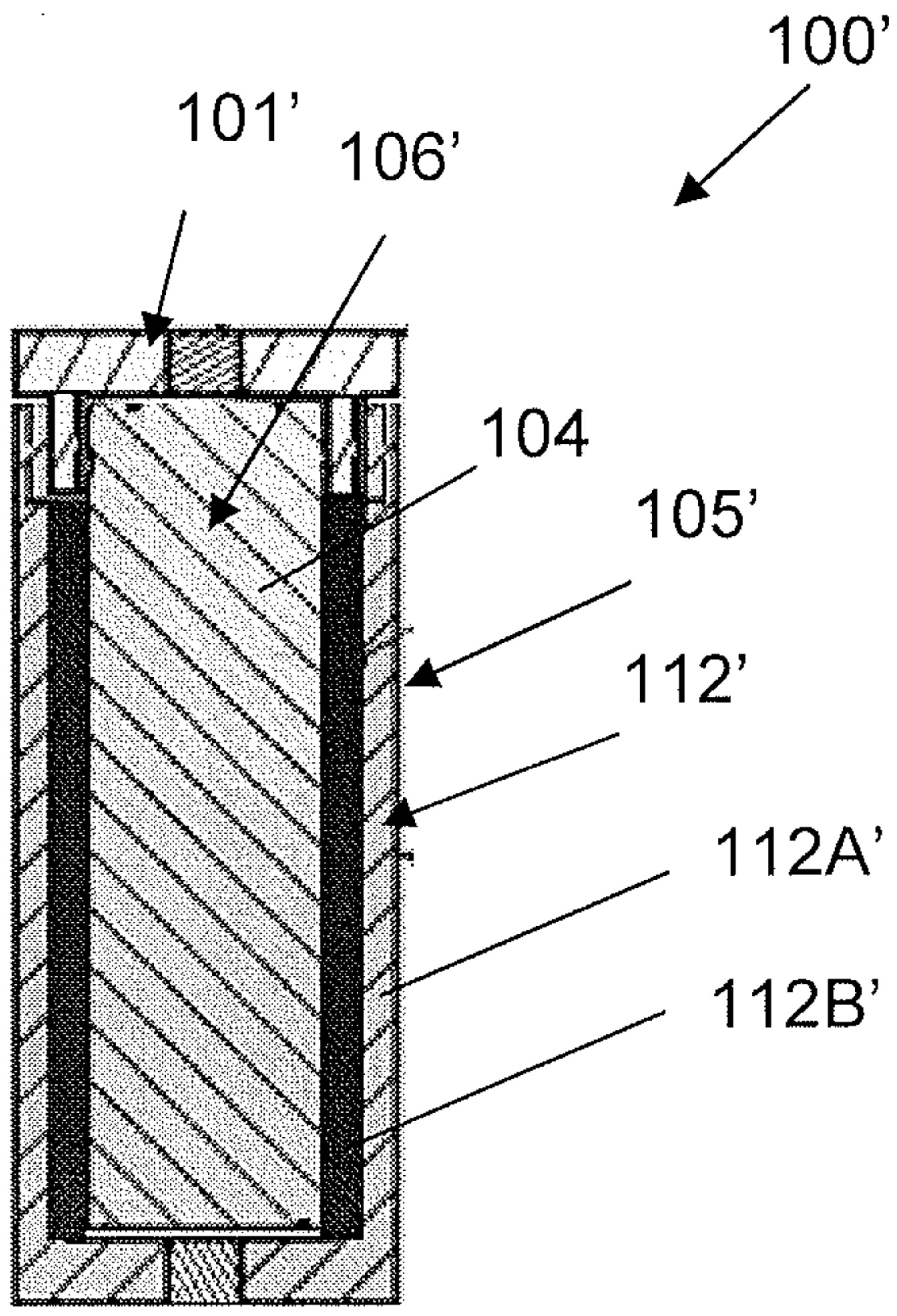

FIG. 2A

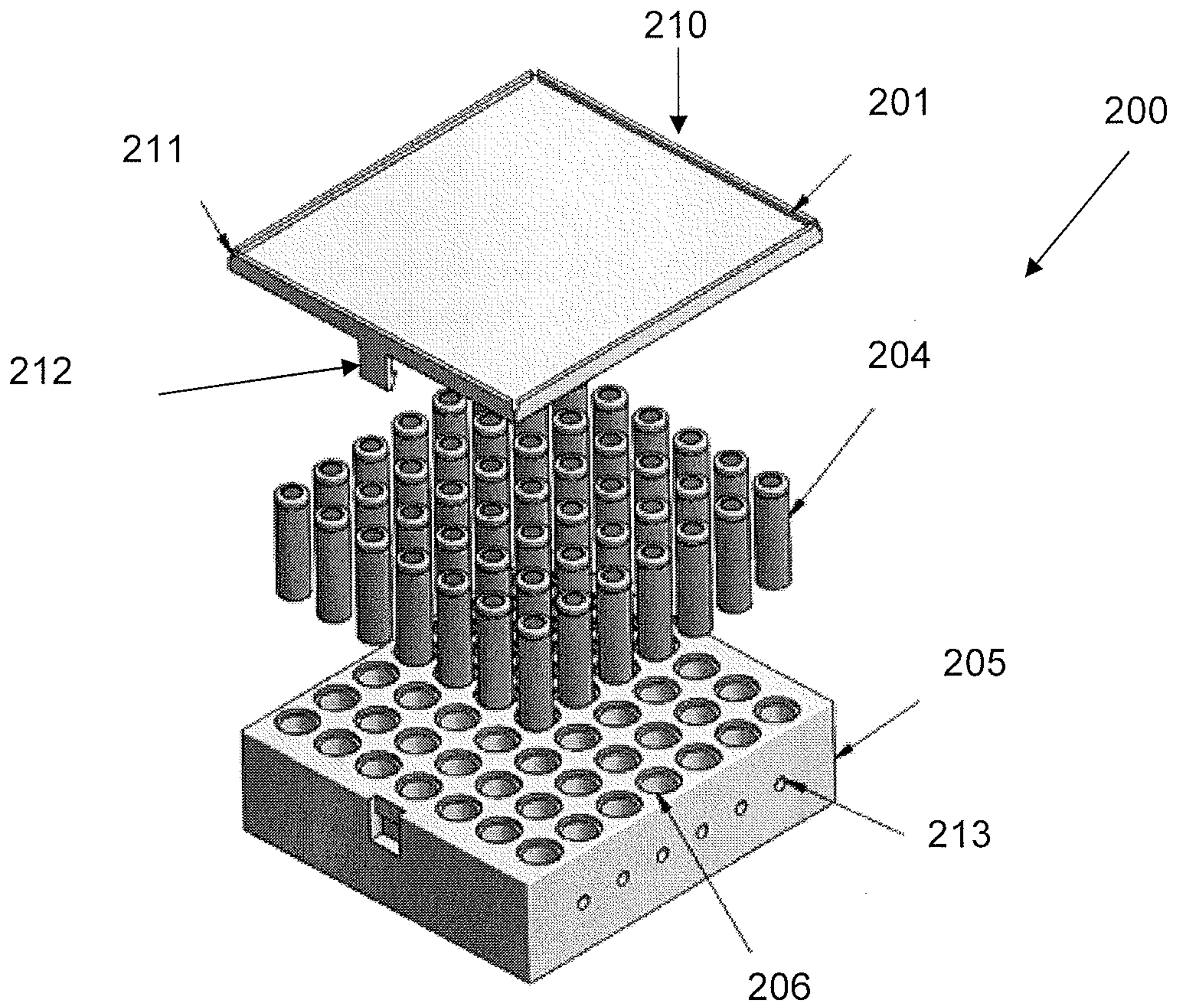

FIG. 3

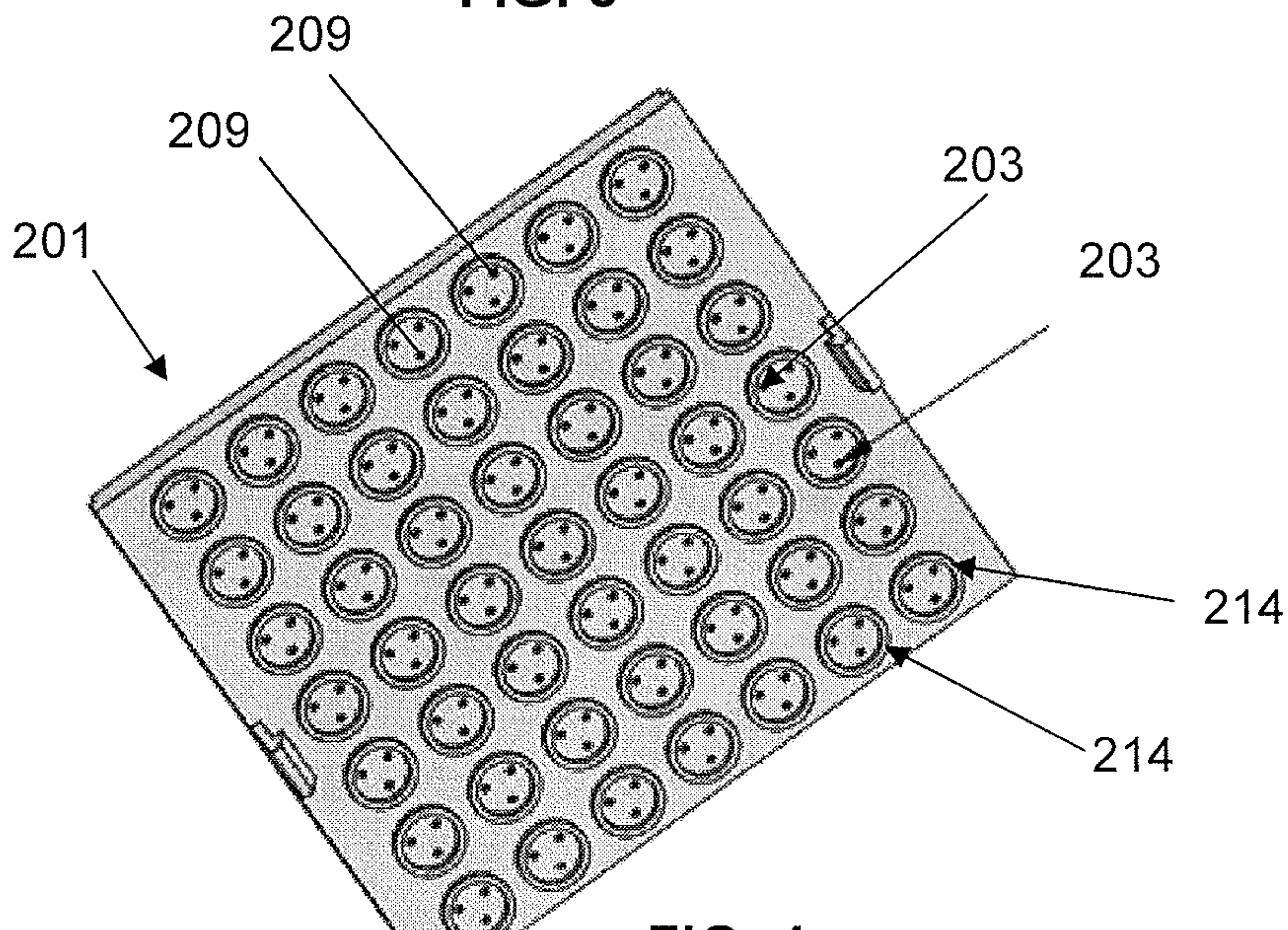

FIG. 4

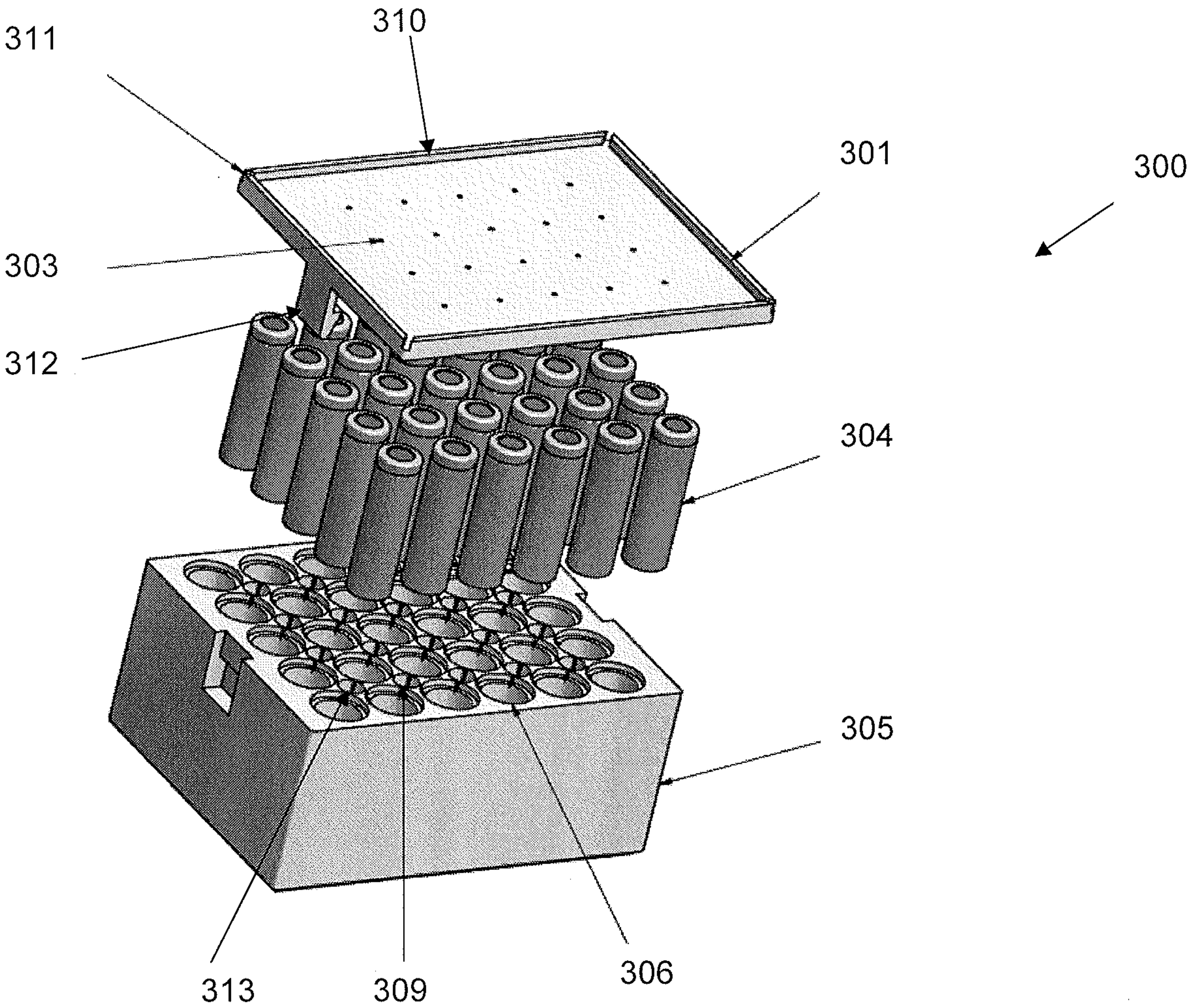

FIG. 5

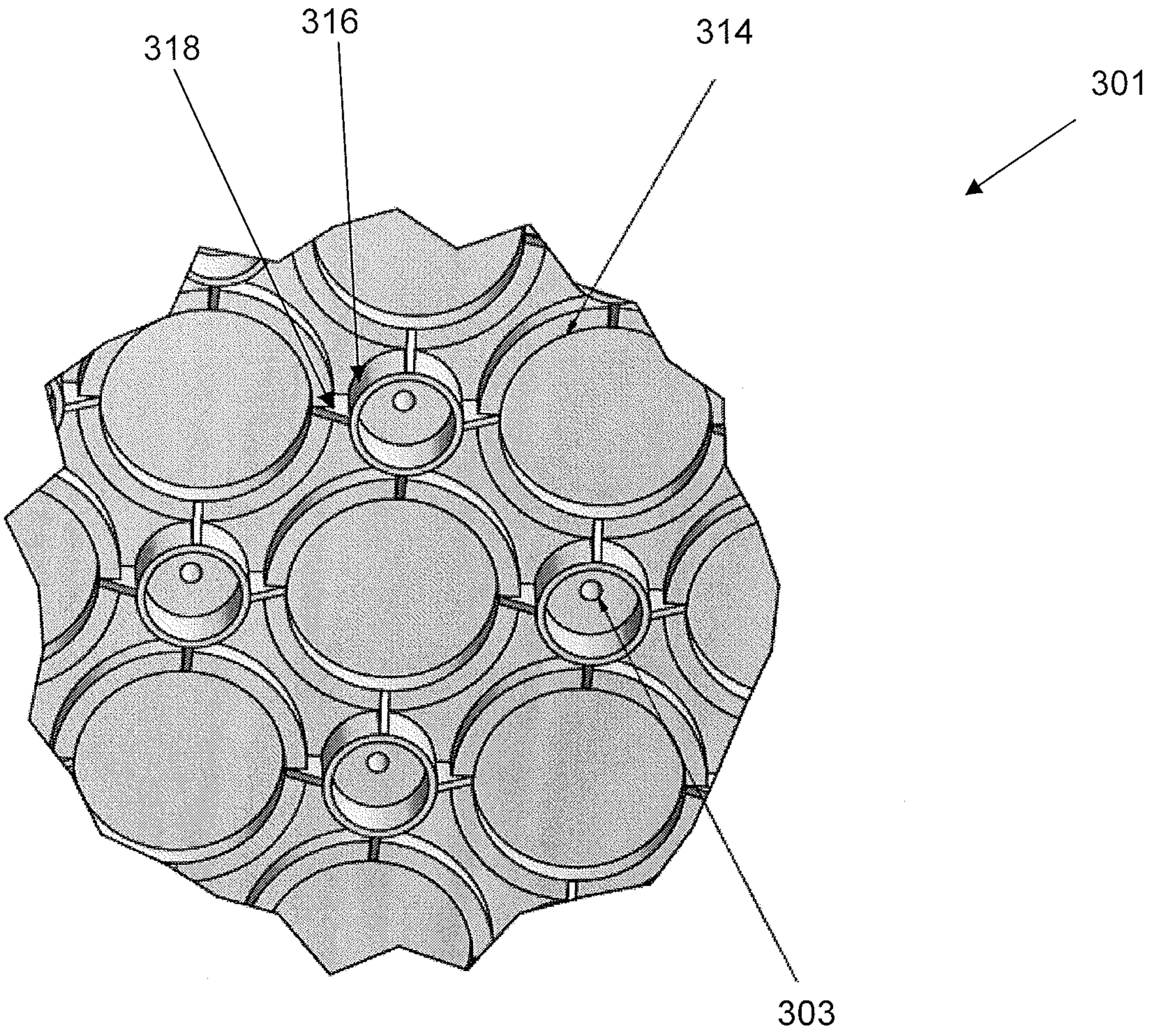

FIG. 6

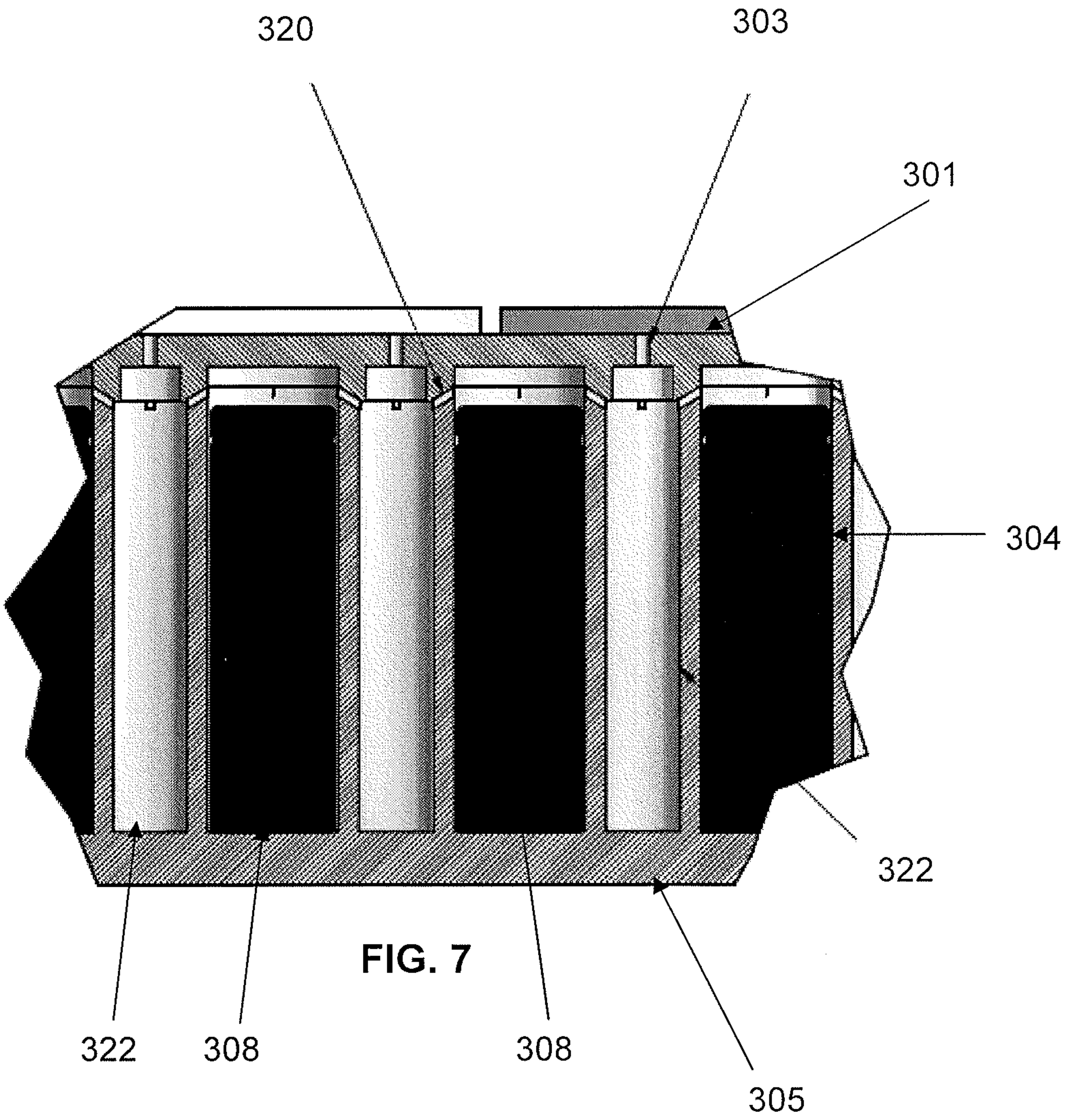

FIG. 7

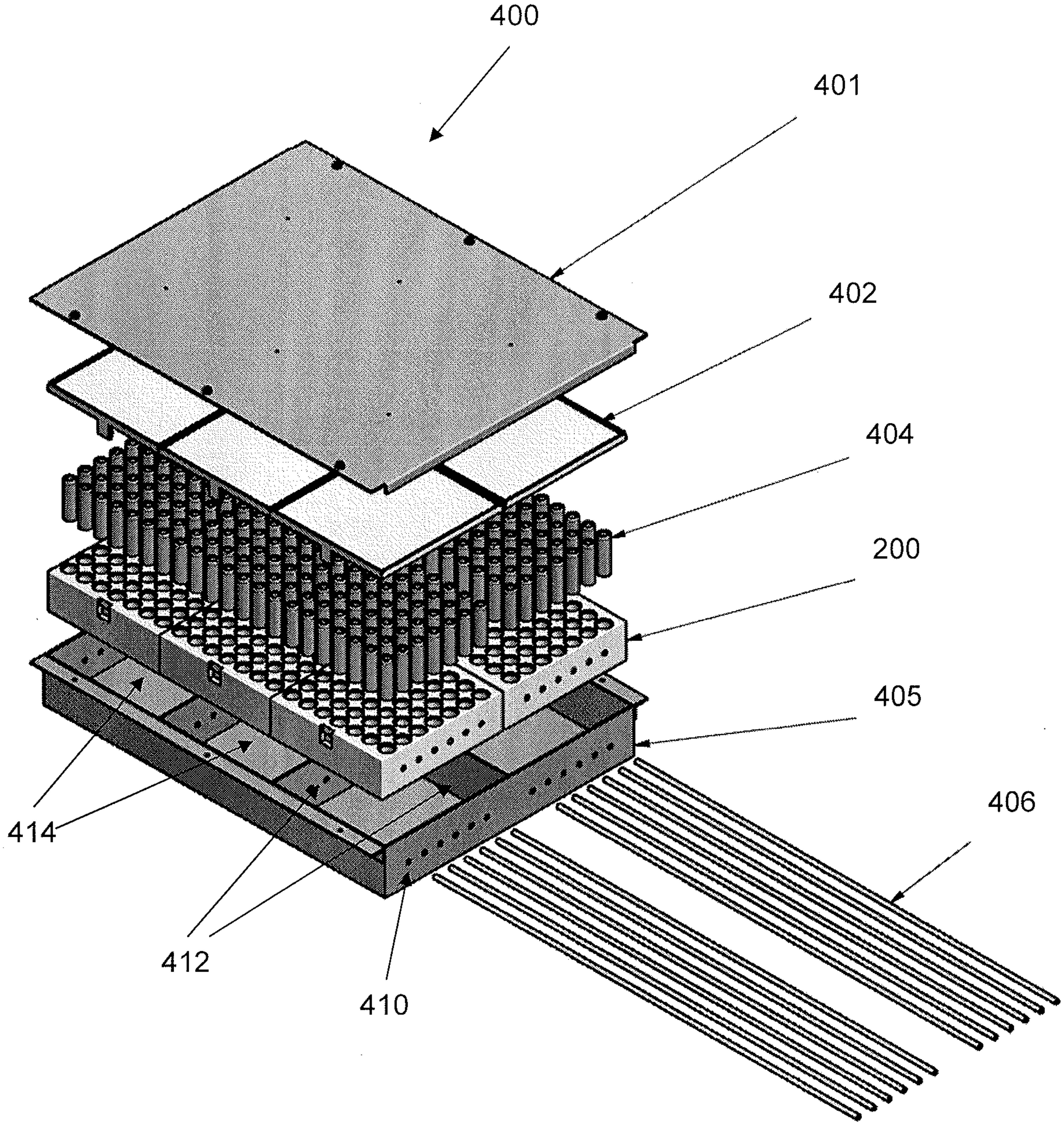

FIG. 8

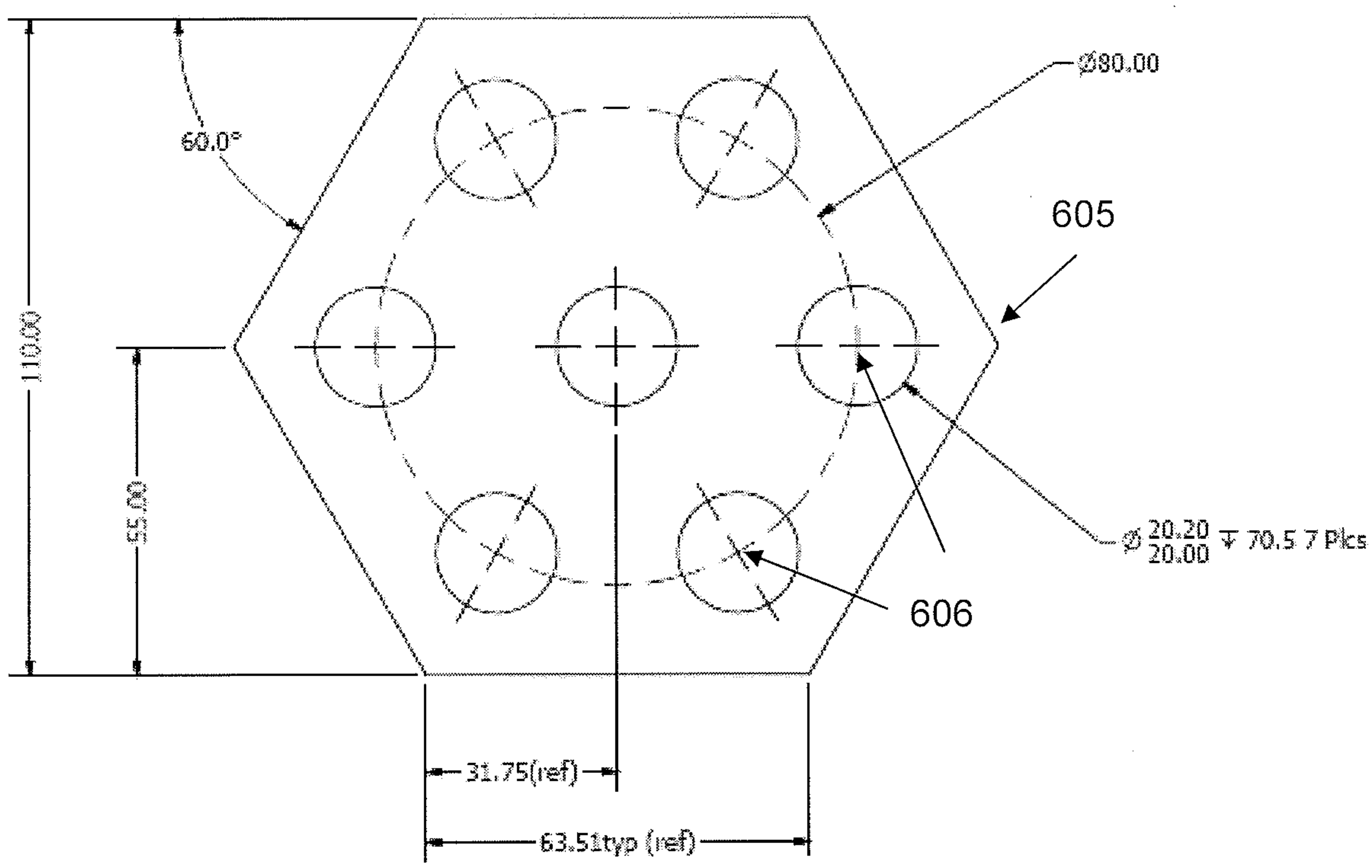
Ø80.00
605
60.0°
110.00
55.00
Ø 20.20 / 20.00 ↧ 70.5 7 Plcs
606
31.75(ref)
63.51typ (ref)

FIG. 9A

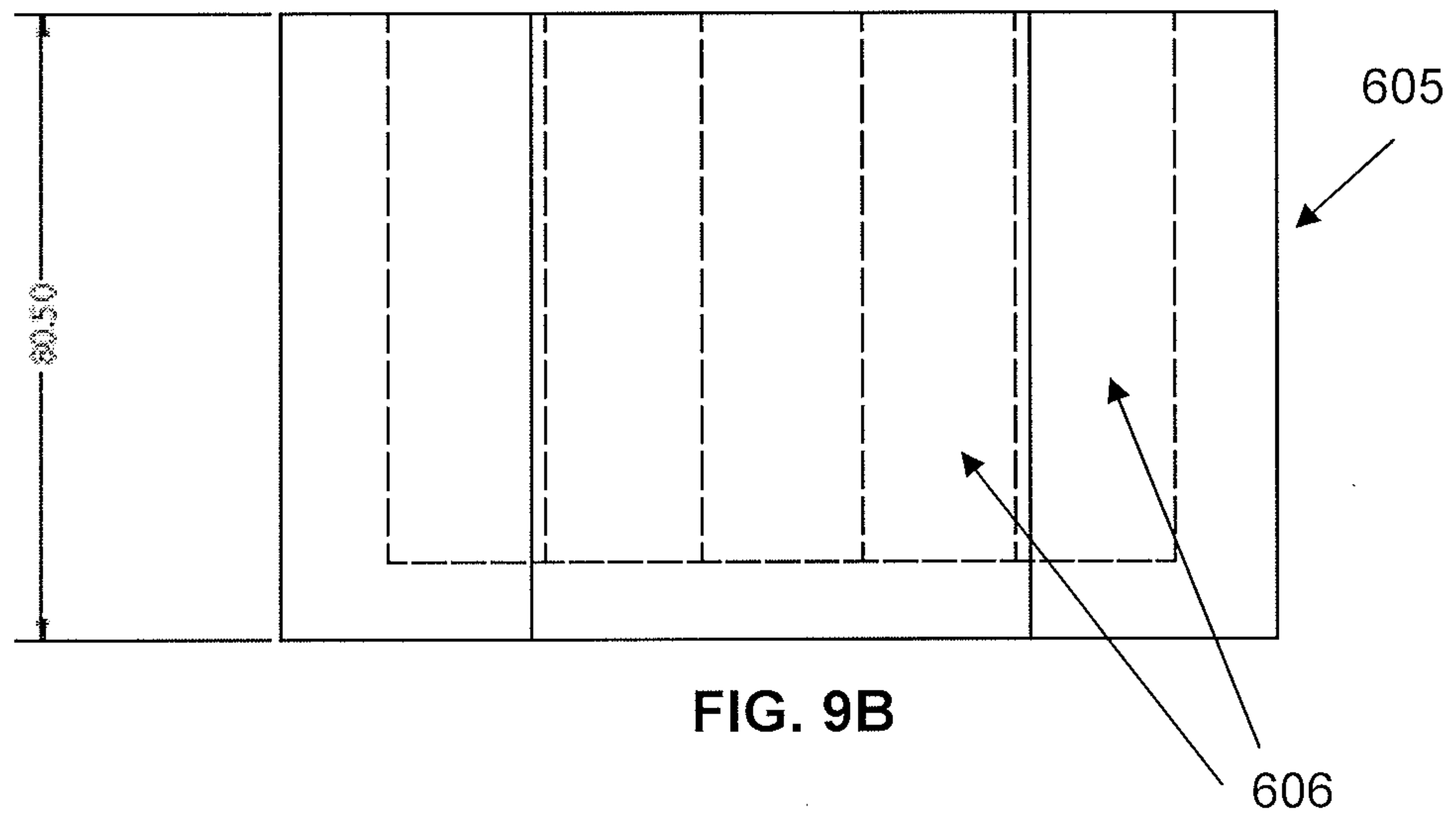
605
80.50
606

FIG. 9B

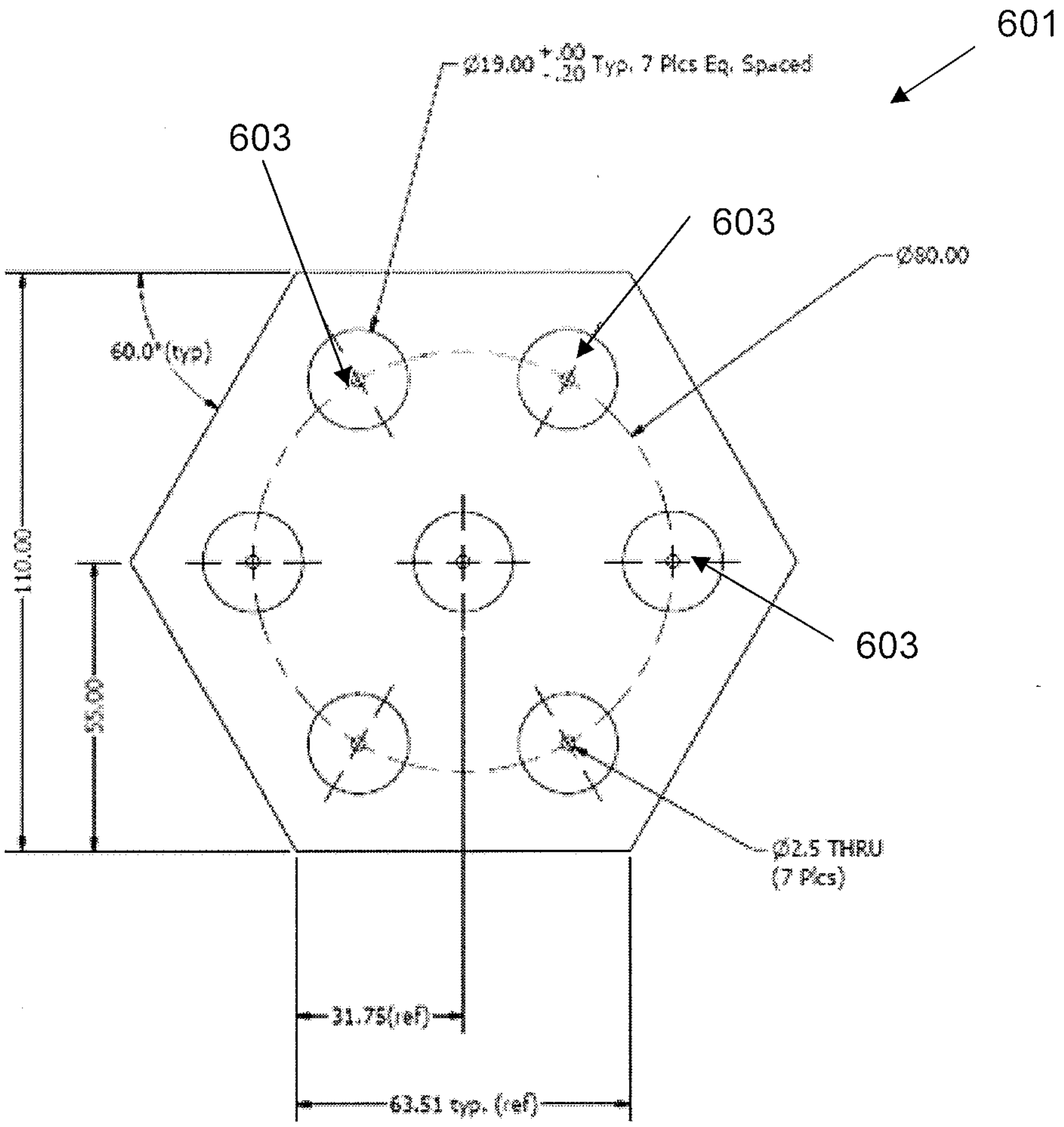

FIG. 10A

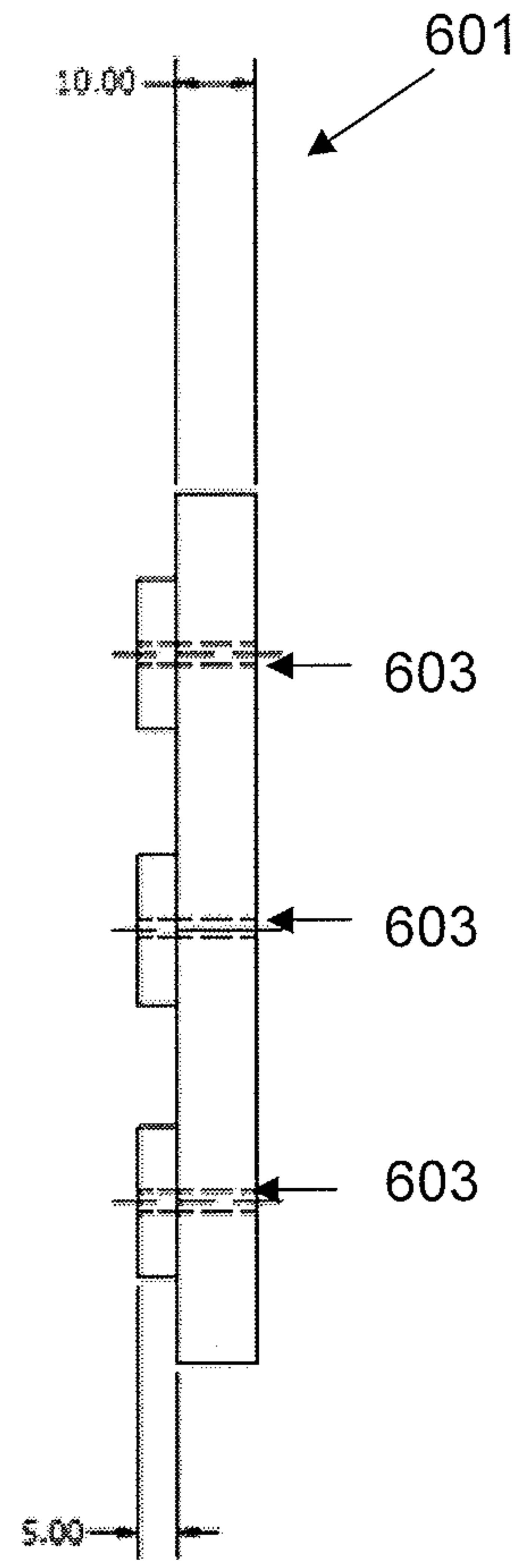

FIG. 10B

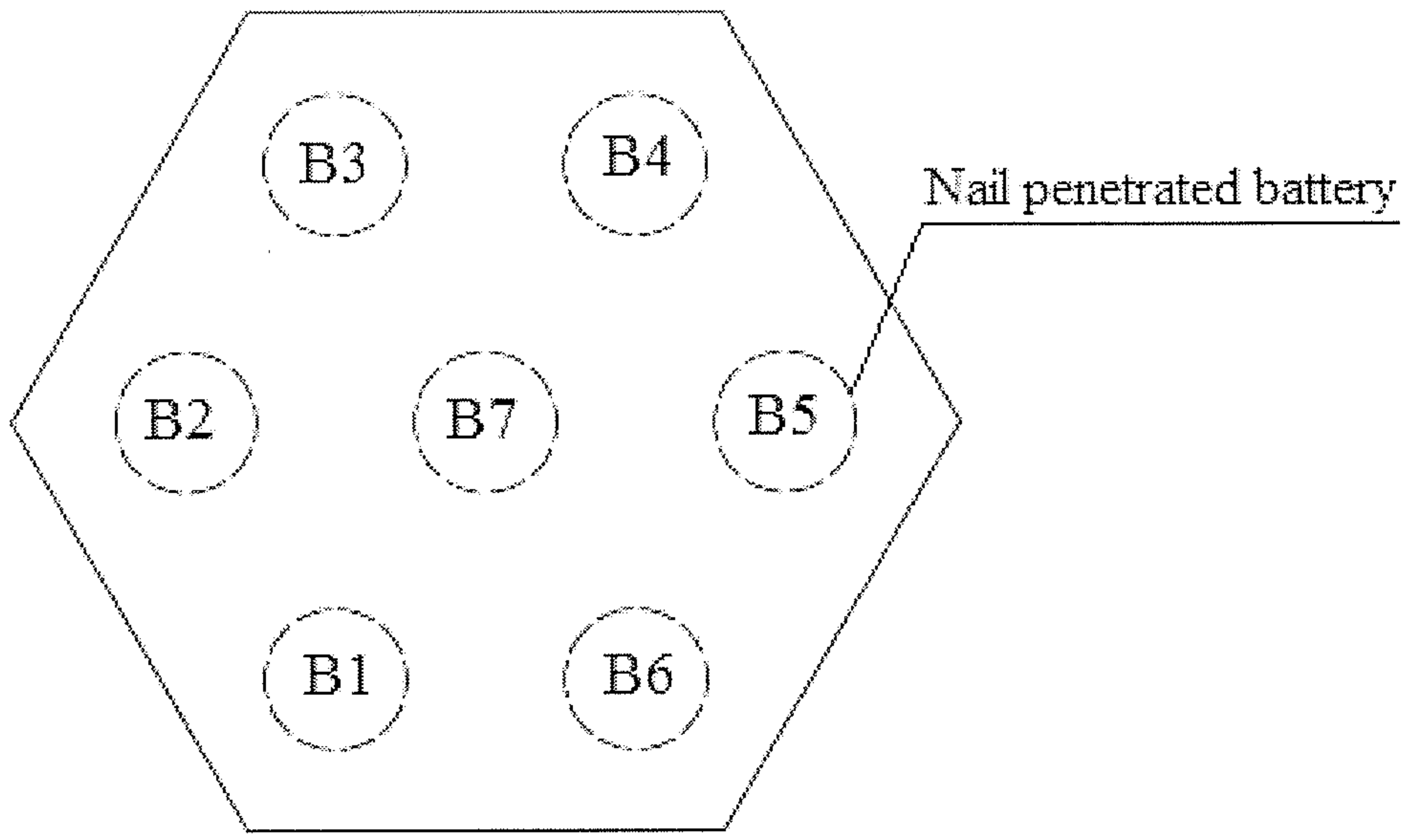

FIG. 11

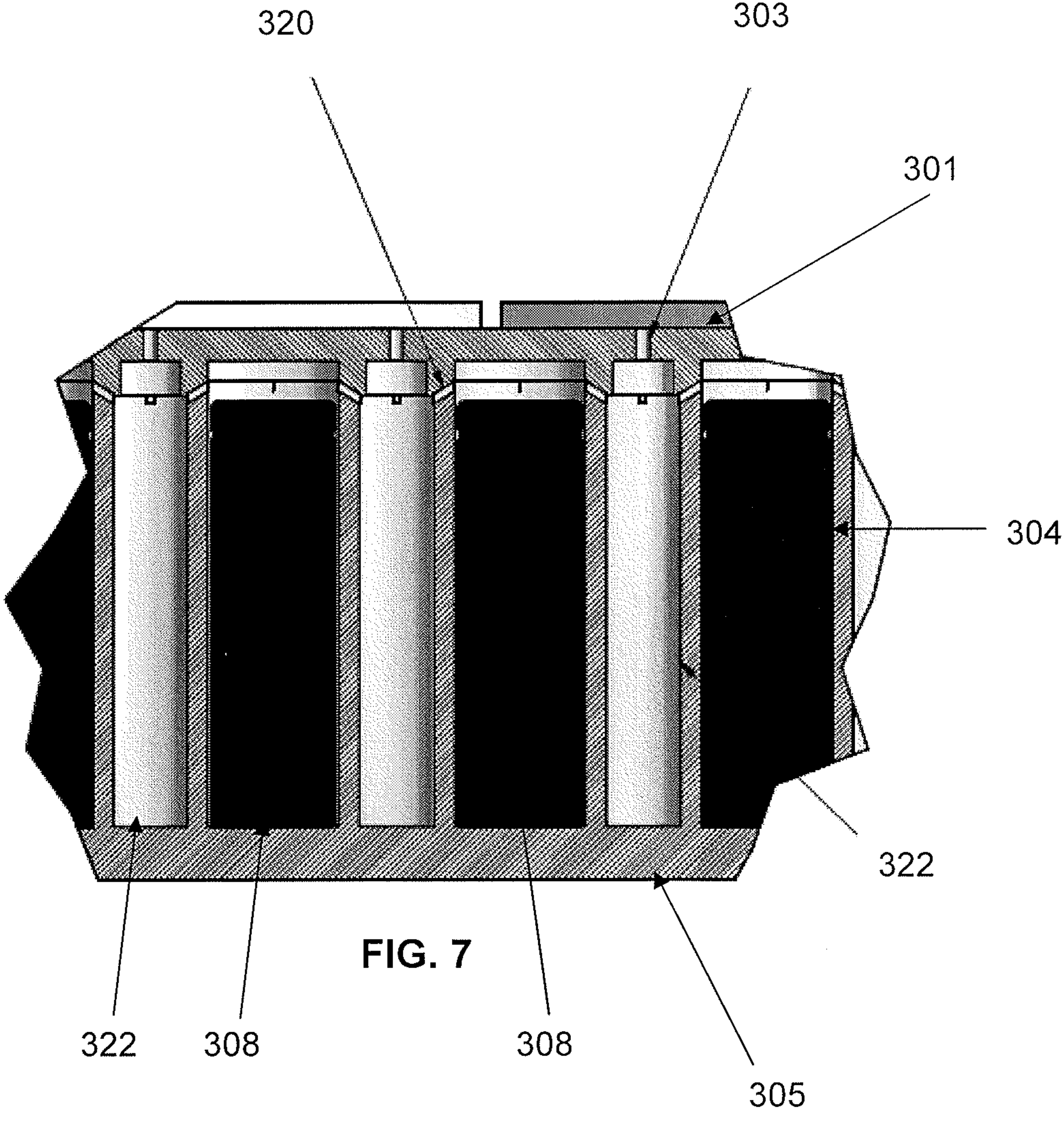

FIG. 7