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(54) Title: VALVE ASSEMBLY FOR A BATTERY COVER

(57) Abstract: A valve assembly for a battery cover is provided. The valve assembly may advantageously allow for testing prior to installation on a battery cover. A battery provided.



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VALVE ASSEMBLY FOR A BATTERY COVER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority as a non-provisional application of U.S. Application No. 5 62/438,233 filed December 22, 2016, the entire contents of which is hereby incorporated by reference in its entirety herein.

BACKGROUND

[0002] Batteries are commonly provided with a mechanism for venting gases generated during 10 the electrochemical reactions which take place in the battery. One known solution for venting gases in lead-acid batteries (which may include valve regulated lead acid or VRLA batteries) is the battery vent cap or valve assembly. Vent cap or valve assemblies are typically integrated into a battery housing cover, which is then provided onto a battery housing. During charging and discharging of the battery, gases need to be expelled or exhausted from the battery to prevent 15 undesirable buildup. Example gasses exhausted include hydrogen when the battery is new, and hydrogen and oxygen as the battery ages. While venting systems are known, these systems have various disadvantages.

[0003] Known valve assemblies may be assembled in a battery cover. Problems with the valve 20 assembly may occur, for example, improper seating of the valve, improper functioning of the valve, or improper positioning of the valve holder or cover. These troubles may result in problems with leaking, pressure, and sparking abnormalities. A faulty valve assembly may lead to battery failure.

[0004] By requiring installation into the battery cover, known valve assemblies may not be 25 identified as defective until production of the battery. Without testing, problems with the valve assembly may not be identified. Instead, problems with the valve assembly may result in battery failure as gasses fail to vent properly.

SUMMARY OF THE INVENTION

5 [0005] Therefore, the disclosed valve assembly seeks to remedy disadvantages of known valve assemblies. In various embodiments, the disclosed valve assembly may allow for testing of valve assembly functionality prior to installation in the battery cover. This may allow for identification of possible issues before installation into a battery (before possible battery failure or shortened battery life). In addition, the disclosed valve assembly may allow for optimization of the valve pressure. The disclosed valve assembly may also be used across a range of lead-acid
10 battery types. The disclosed valve assembly may also allow for controlled valve compression variance. Valve compression variance may advantageously allow for increase in valve opening pressure, valve closing pressure, and leak tightness.

[0006] The disclosed valve assembly may generally be comprised, in various embodiments, of three parts: valve cover, valve and valve holder. In one or more examples of embodiments, the
15 valve holder and valve cover may be heat welded or ultrasonically welded. The assembled valve assembly may be tested prior to installation in a battery cover.

[0007] Disclosed herein is a valve assembly which may comprise: a valve cover having a base coupled to a cylindrical projection and having an aperture with a first radius, wherein the cylindrical projection has an internal surface, the internal surface defining an internal chamber
20 and a second and third radius, wherein the aperture is in fluid communication with the internal chamber of the cylindrical projection; a valve holder provided within the cylindrical projection of the valve cover; and a valve provided between the valve holder and valve cover; wherein the valve assembly may be tested prior to installation on the battery cover. The disclosed valve assembly may further comprise wherein the valve cover is in communication with the internal
25 surface in an area of the cylindrical projection having the third radius. The disclosed valve assembly may further comprise wherein the base further defines a circumferential depression. The disclosed valve assembly may further comprise, wherein the valve holder comprises a base having a first side and a second side opposite the first side, wherein the base is coupled to the cylindrical body on the first side, and the base is coupled to the cylindrical projection on the
30 second side.

[0008] Disclosed herein is a valve assembly for a battery cover which may comprise: a valve cover having a base with an aperture having a first radius in fluid communication with an internal chamber defined by a cylindrical projection coupled to the base, the cylindrical projection having a second internal radius and a third internal radius, wherein the first radius is smaller than the second radius, which is smaller than the third radius; a valve provided in the internal chamber; and a valve holder provided in the internal chamber in a region of the internal chamber having the third internal radius. The disclosed valve assembly may further comprise wherein the base features a circumferential depression. The disclosed valve assembly may further comprise wherein the aperture is provided in the approximate center of the circumferential depression.

[0009] The disclosed valve assembly, in various embodiments, may be tested prior to installation on a battery cover. The disclosed valve assembly may be installed into a battery cover. The disclosed battery may be provided into a battery.

[0010] Also disclosed is a battery comprising: a housing having operable battery elements; a battery cover on the housing having a recess sized to accept a valve assembly; a valve assembly having a valve cover, valve, and valve holder; wherein the valve cover features a base having a cylindrical projection and an aperture, the aperture having a first radius in fluid communication with an internal chamber defined by the cylindrical projection, the cylindrical projection having a second internal radius and a third internal radius; and wherein the valve cover and valve are provided within the internal chamber. The valve assembly may further comprise wherein the first radius is smaller than the second radius, which is smaller than the third radius. The valve assembly may further comprise wherein the valve holder is provided in a section of the valve cover internal chamber having the third radius. The valve assembly may further comprise wherein the valve is provided between the valve holder and the cylindrical projection. The valve assembly may further comprise wherein the valve is positioned between the valve holder and the cylindrical projection in the internal chamber in an area having the third radius. The valve assembly may further comprise wherein a portion of the valve extends into an area in the internal chamber having a second radius. The valve assembly may further comprise wherein the base has a circumferential depression. The valve assembly may further comprise wherein the aperture is approximately in the center of the circumferential depression.

[0011] Further features and advantages may be understood from the figures and description provided herein.

BRIEF DESCRIPTION OF THE FIGURES

- 5 [0012] FIG 1 is a top view of a valve cover, according to various embodiments.
[0013] FIG 2 is a first cross-section of a valve cover, according to various embodiments.
[0014] FIG 3 is a second cross-section of a valve cover, according to various embodiments.
[0015] FIG 4 is a detail perspective of a valve cover, according to various embodiments.
[0016] FIG 5 is a second detail perspective of a valve cover, according to various embodiments.
10 [0017] FIG 6 is a third detail perspective of a valve cover, according to various embodiments.
[0018] FIG 7 is a fourth detail perspective of a valve cover, according to various embodiments.
[0019] FIG 8 is a bottom view of a valve cover, according to various embodiments.
[0020] FIG 9 is a first oblique view of a valve cover, according to various embodiments.
[0021] FIG 10 is a second oblique view of a valve cover, according to various embodiments.
15 [0022] FIG 11 is a top view of a valve holder, according to various embodiments.
[0023] FIG 12 is a cross-section of a valve holder, according to various embodiments.
[0024] FIG 13 is a second cross-section of a valve holder, according to various embodiments.
[0025] FIG 14 is a top oblique view of a valve holder, according to various embodiments.
[0026] FIG 15 is a bottom oblique view of a valve holder, according to various embodiments.
20 [0027] FIG 16 shows a top view of a valve assembly, according to various embodiments.
[0028] FIG 17 shows a cross-section of the valve assembly of FIG 16.
[0029] FIG 18 shows a bottom isometric view of a valve assembly, according to various
embodiments.
[0030] FIG 19 shows a top isometric view of a valve assembly, according to various
25 embodiments.
[0031] FIG 20 shows the assembly of a valve assembly, according to various embodiments.
[0032] FIG 21 shows a cross-section of a valve assembly, according to various embodiments.
[0033] FIG 22 shows a detail view of a cross-section of a valve assembly showing the valve
seated within, according to various embodiments.

[0034] FIG 23 shows a valve assembly provided within a battery cover, according to various embodiments.

[0035] FIG 24 shows a cover pocket for accepting a valve assembly in a battery cover, according to various embodiments.

5 [0036] FIG 25 shows a valve assembly provided in a battery cover, according to various embodiments.

[0037] FIG 26 shows multiple valve assemblies provided in a battery cover, according to various embodiments.

10 [0038] FIG 27 shows valve assembly components and a valve assembly, according to various embodiments.

[0039] FIG 28 shows a valve assembly provided in a cover section with a flame arrestor, according to various embodiments.

[0040] FIG 29 shows valve assembly components and a valve assembly, as well as a valve assembly provided in a cover section, according to various embodiments.

15 [0041] FIG 30 shows a CT scan of a valve assembly, according to various examples of embodiments.

[0042] FIG 31 shows a battery having a housing with a cover and operable battery elements which may be used with the disclosed valve assembly, according to various embodiments.

20 [0043] It should be understood that the drawings are not necessarily to scale. In certain instances, details that are not necessary to the understanding to the invention or render other details difficult to perceive may have been omitted. It should be understood, of course, that the invention is not necessarily limited to the particular embodiments illustrated herein.

DESCRIPTION OF THE INVENTION

25 [0044] The valve assembly 100 may, in various embodiments, be generally comprised of three parts: a valve cover 102, valve 190, and valve holder 150. Referring to the Figures, a valve assembly 100 according to various embodiments and its parts are disclosed.

Valve cover

[0045] Referring to FIGS 1-10, a valve cover 102 is disclosed, according to various embodiments. FIG 1 shows a first view of the valve cover 102. The valve cover 102 may be generally rectangular in shape, according to various embodiments. The valve cover 102 may have a generally rectangular base 104. The valve cover 102 may have a cylindrical projection 114 extending from the base 104 with a narrower internal radius at the base leading to a wider internal radius towards the top. It is noted that while specific geometries are disclosed for purposes of example—for example, the projection as “cylindrical”—variations thereon (e.g., oval, rectangular, polygonal, triangular, or any shapes formed of straight sides, non-straight sides, or combinations of the two) would not depart from the overall scope of the present invention. The base 104 may include a base first side 124. The base may include an aperture 106 having a first radius 107, the aperture being in fluid communication with a second radius 118 and third radius 116 in the cylindrical projection 114. The base 104 may include a number of projections 112 in each corner of the valve cover 102 as well as raised sides 110.

[0046] FIG 2 illustrates a section of the valve cover 102 taken along line A-A of FIG 1. The cylindrical projection 114 may define an open space or internal chamber 122. The cylindrical projection 114 may include an internal wall surface 120 surrounding the internal chamber 122. The shape of the internal chamber 122 of the cylindrical projection 114 may be defined first by a first aperture 106 in the base 104 having a first internal radius 107, a second internal radius 118 provided in a region above the first aperture 106, and a third internal radius 116 provided in an area above the area defined by the second internal radius 118. The first aperture 106 may be surrounded by a circumferential depression 108 provided in the base 104. The base 104 may likewise include raised sides 110 and projections 112.

[0047] The center of the cylindrical projection 114 may be open; that is, a first aperture 106 may be provided in the base 104 of the valve cover 102 allowing for fluid communication from the first aperture 106 out a top of the cylindrical projection 114. One or more additional apertures may be provided around the center of the circumferential projection 114. These apertures, in various embodiments, may be ring-shaped (other shapes such as rectangles, polygons, etc., contiguous and non-contiguous arcs or lines, etc. may be considered as within the scope of this disclosure) such as the circumferential depression 108. The aperture and/or circumferential

depression 108 according to various embodiments may be seen further in FIG 10. It should be understood that while the term aperture may be used, in various embodiments, the feature may be a depression; that is, it may not be open.

5 **[0048]** The circumferential depression 108 may be seen further in FIG 3. The valve cover 102 may have raised sides 110. In addition, the valve cover 102 may have projections 112 disposed in each corner. The projections 112 may, in various embodiments, be disposed of at a forty-five degree angle relative to the sides of the valve cover 102. FIG 3 also shows the cylindrical projection 114 and first aperture 106 defining an internal volume having a first internal radius 107, second internal radius 118, and third internal radius 116. The third internal radius 116 is
10 larger than the second internal radius 118 which is larger than the first internal radius 107.

[0049] FIG 3 shows a section of the valve cover 102 taken along line B-B of FIG 1. The cylindrical projection 114 may be seen in cross-section. The cylindrical projection 114 may have a second internal radius 118 and third internal radius 116. The third internal radius 116 may be seen near the top of the cylindrical projection 114, while the second internal radius 118
15 may be found in approximately the bottom half of the cylindrical projection 114. A first internal radius 107 may be found in the base of the valve cover 102. Further detail regarding the first internal radius 107 may be seen in FIG 10.

[0050] FIG 4 shows a detail view taken along line C-C of FIG 1. This detail view shows a corner projection 112 having, in various embodiments, a square top 128 (again, while specific
20 geometries are disclosed for purposes of example, variations thereon (e.g., oval, circular, triangular, polygonal) would not depart from the overall scope of the present invention). Likewise, a detailed view of a raised side 110 is shown. Similarly, FIG 5 shows another detail view of the valve cover 102 taken along line D-D of FIG 1. The projection 112 of FIG 5 is relatively narrower than the section of FIG 4.

25 **[0051]** FIG 6 shows another detail view of the valve cover 102 taken along line E-E of FIG 1. This line may be understood to be taken through the raised side 110 of the valve cover 102. The valve cover 102 sides may be, in various embodiments, a wall. The wall may be shaped as shown in FIG 6 or shaped according to another variation (e.g., flat, rounded, oval, circular, polygonal, straight, rounded, or combinations of straight and rounded) that may not depart from
30 the overall scope of the present invention.

[0052] FIG 7 shows another detail view of the valve cover 102 taken along detail J shown in FIG 2. This may be understood as a detailed view of a top of the cylindrical projection 114. The internal surface 120 of the cylindrical projection 114 may be seen. In various embodiments, the top of the circumferential projection may be formed at an angle (angled top 130).

5 [0053] FIG 8 shows a bottom view of the valve cover 102, according to various embodiments. The bottom of the valve cover 102 may feature a base 104 having a base second side 126. The circumferential depression 108 and first aperture 106 may also be seen.

[0054] FIG 9 shows a top isometric view of the valve cover 102. The base 104 having a base first side 124 may be seen. Projections 112 and raised sides 110 may be seen extending from the
10 base 104 in addition to the cylindrical projection 114. FIG 10 shows an isometric view of the bottom of the valve cover 102. The base 104 featuring a base second side 126 may be seen, along with the circumferential depression 108 and aperture 106.

Valve holder

15 [0055] A valve holder 150 may be seen, in various embodiments, in FIGS 11-15. As can be seen in the Figures, the valve holder 150 may have a body 154 that is generally cylindrical in shape (while specific geometries (i.e. cylindrical) are disclosed for purposes of example, other shapes or variations thereon would not depart from the overall scope of the present invention), with a circular base 152. The holder 150 may include a cylindrical projection 156 extending from the
20 base 152 that has a side cutout 158 (again, while specific geometries (i.e. cylindrical) are disclosed for purposes of example, other shapes or variations thereon would not depart from the overall scope of the present invention). A top view of the valve holder 150 featuring a base first side 160 may be seen in FIG 11. The cutout 158 provided in the base 152 may be seen in the bottom of the top view of FIG 11.

25 [0056] A first cross-section of the valve holder 150 taken along line A-A of FIG 11 may be seen in FIG 12. As can be seen, the cylindrical projection 156 may have a smaller radius (second radius 166) than a radius (first radius 164) of the cylindrical body 154.

[0057] A second cross-section taken along line B-B of FIG 11 can be seen in FIG 13. The cylindrical projection 156, base 152, and cylindrical body 154 can be seen, as well as the cutout
30 158. The cylindrical body 154 may have a first radius 164, while the cylindrical projection 156

may have a second radius 166. The cylindrical projection 156 may be provided on a second side 162 of the valve holder 150, while the cylindrical body 154 may be provided on the first side 160 of the valve holder 150. The cutout 158 may be understood to be provided in the base 152 as well as the cylindrical projection 156.

5 [0058] FIG 14 shows a side top view of the valve holder 150. This view shows the cylindrical body 154 extending upwards from a top side of the base 152 while the cylindrical projection 156 and cutout 158 are provided in a bottom side of the base 152.

[0059] FIG 15 shows a side bottom view of the valve holder 150. This view shows the cylindrical projection 156 extending upwards from a back side of the base, with the cutout 158
10 provided both in the cylindrical projection 156 and the base 152.

Valve

[0060] The valve 190 may be a one-way flap valve, a Bunsen valve, a diaphragm, an umbrella valve, a Belleville valve, a dome valve, and/or any other style of one-way valve, or other like
15 mechanism. The valve 190 may be a one-time pressure release valve. In various embodiments, the valve 190 may have or provide an optimized opening and closing pressure or operating range. In various embodiments, the operating range may be optimized by the valve and the way the valve is provided or oriented within the valve assembly 100. Preferably, the valve 190 is provided with an operating range suitable for the intended purpose of the valve or suitable for the
20 type of battery on which it is used. In various embodiments, the valve may operate in a range of approximately 2 PSI to approximately 10 PSI. The valve 190 and valve assembly 100 may be functional with a variety of battery types and grid geometries, for example, prismatic or coil-wound style battery. The valve 190 may be inserted into the valve holder 150 and secured in place, for example, through insertion into the valve cover 102 to form valve assembly 100.

25

Valve assembly

[0061] A full assembly including the valve cover 102, valve holder 150, and valve 190 may be seen in FIGS 16-20. FIG 16 shows a top view of an assembled valve assembly 100, according to various embodiments. The valve holder 150 having a valve holder first side 160 can be seen
30 inside the cylindrical projection 112 of the valve cover 102. Looking to FIG 17, which is a view

of the valve assembly 100 of FIG 16 taken along line A-A, the valve cover 102, valve holder 150, and valve 190 may be seen. The valve holder 150 may be seen disposed of inside of the circumferential projection of the valve cover 102. The valve may be seen disposed inside of the valve holder 150. As noted by FIG 17, the valve holder 150 may be thermally welded (or heat sealed) in the valve assembly 100 such that it is gas tight. FIG 18 shows a bottom view of the valve assembly 100. The circumferential depression 108 and aperture 106 may be seen in the base 104 of the valve cover 102. The aperture may be understood to allow for gas flow through the aperture into the cylindrical projection 112 housing the valve holder 150 and valve 190. The valve 190 may regulate the venting of such gasses from the aperture 106 through the valve 190 and out the cutout 158 of the valve holder 150. FIG 19 shows a top view of the valve assembly 100, the circumferential projection 114 of the valve cover 102 housing the valve holder 150 and valve 190 extends upwards from the base 104.

[0062] The valve 190 may be held in place by pressure. For example, the valve 190 may be held in place by pressure between the valve holder 150 and valve cover 102. In various embodiments, the assembly 100 may allow for customization of compression. Compression may allow for variance as to when the valve 190 opens in response to pressure in the battery 202. For example, the ratio of the valve holder 150 to the valve cover 102 may facilitate adjustment of valve 190 operating range. The component dimensions may allow for compression variance—changing the tool may vary the compression of the valve 190. Variance of the compression of the valve 190 affects the opening of the valve. For example, to increase the opening pressure, closing pressure, and leak tightness, the compression of the valve 190 could be increased. In various embodiments, the disclosed assembly 100 may have a larger surface area than known assemblies where the valve holder 150 contacts the valve cover 102 between the assembly components. While the range may be customized, the disclosed valve assembly 100 may also advantageously result in less variability in the operating range of the valve 190 during use. The ratio may also prevent the valve holder 150 from being inserted too far into the assembly, which may result in a higher than desired opening pressure. The heightened surface area may prevent over-insertion by stopping the valve holder 150 when it is properly seated in the valve cover 102 with the valve 190. The ratio may also improve the robustness of the assembly process, making assembly less sensitive.

Valve assembly with Cover Assembly

[0063] In order to assemble the valve assembly 100, the valve 190 may be provided into the valve holder 150, which is inserted into the valve cover 102. This progression may be seen, in various embodiments, in FIG 20. The valve 190 may be secured in place by the valve holder
5 150. The valve holder 150 and valve cover 102 may be heat welded or ultrasonically welded, although alternative assembly methods may also be acceptable. A cross section showing the seating of the valve 190 may be seen in FIG 21. The valve may be seen disposed inside the valve cover 102 also within the valve holder 150.

[0064] FIG 22 shows another step in the process, in which the perimeter 196 of the assembly
10 100 may be heat-sealed. Again, the valve 190 can be seen disposed of inside the valve holder 150 which is inside of the valve cover 102. FIG 23 shows the progression of the insertion of the valve assembly 100 into a battery cover assembly 200. The entire battery cover assembly may comprise one or more flame arrestors 204 and valve assemblies 100. In various embodiments, the flame arrestor 204 may be heat sealed to the pocket 206 (a pocket may be provided for the
15 assembly in the cover) and then the valve cover 102 may be heat sealed or ultrasonically welded. The heat sealed surface 208 may be seen in FIG 24.

[0065] A cross-section of the assembly may be seen in FIG 25. The valve assembly 100 may be seen disposed of within a cover. FIG 26 shows a bottom view of a cover. A first and second valve assembly 100 may be seen on a first and second end of the cover. While the cover 200 is
20 shown in a particular shape, it should be understood other cover 200 shapes and sizes, as well as positions of the valve assembly 100 are within the scope of this disclosure. The cover 200 may then be provided as part of a housing 210 containing operable battery elements 212 (see FIG 31).

[0066] The valve cover 102, valve holder 150, valve, and assembled valve assembly 100 may be seen in FIG 27. The valve cover 102, valve holder 150, and valve 190 may be seen both
25 separately and assembled as shown on the right-hand side of FIG 27.

Method of Testing

[0067] The assembly may be tested using a battery cover section with a flame arrestor 204 heat sealed as shown in FIG 28. This may be seen in connection with the valve assembly 100
30 separated out in FIG 29. The flame arrestor 204 may be heat sealed to the cover 200. The valve

holder 150 and valve cover 102 may be heat welded or ultrasonically welded. While specific methods of assembly are provided for purposes of example, variations thereon and alternatives thereto may also be acceptable.

[0068] The disclosed valve assembly 100 may advantageously allow for testing prior to
5 installation in a battery cover 200. In various embodiments, the assembled valve assembly 100 (valve 190, valve holder 150, and valve cover 102) may be tested for performance. For example, the valve assembly 100 may be subject to a leak check and evaluated for opening pressure and closing pressure prior to installation in the battery cover 200. For example, this testing may be performed by blowing air through the assembly from above or below the valve. The testing may
10 be performed, in various embodiments, after heat sealing of the valve holder 150 to the valve cover 102. The heat sealing or ultra-sonic welding may allow for the connection between the valve holder and valve cover to be gas tight. Once the three components are formed pressure checks may be performed. These checks may be performed with or without a flame arrester element 204 additionally provided with the valve assembly 100. Additional testing may be
15 performed after the vent assembly 100 installation in the cover 200.

[0069] Looking to FIG 30, the valve 190 is shown seated in the assembly 100 between the valve holder 150 and the valve cover 102. In various embodiments, as detailed above, the functionality of the valve 190 may be modified through compression of the valve within the assembly. This compression may be varied prior to heat-sealing. In other words, depending on
20 the part tolerance and assembly the valve compression may change.

[0070] As utilized herein, the terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to
25 allow a description of certain features described and claimed without restricting the scope of these features to the precise numerical ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the invention as recited in the appended claims.

[0071] It should be noted that references to relative positions (e.g., “top” and “bottom”) in this description are merely used to identify various elements as are oriented in the Figures. It should

be recognized that the orientation of particular components may vary greatly depending on the application in which they are used.

[0072] For the purpose of this disclosure, the term “coupled” means the joining of two members directly or indirectly to one another. Such joining may be stationary in nature or moveable in nature. Such joining may be achieved with the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another. Such joining may be permanent in nature or may be removable or releasable in nature.

[0073] It is also important to note that the construction and arrangement of the system, methods, and devices as shown in the various examples of embodiments is illustrative only. Although only a few embodiments have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements show as multiple parts may be integrally formed, the operation of the interfaces may be reversed or otherwise varied, the length or width of the structures and/or members or connector or other elements of the system may be varied, the nature or number of adjustment positions provided between the elements may be varied (e.g. by variations in the number of engagement slots or size of the engagement slots or type of engagement). The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes and omissions may be made in the design, operating conditions and arrangement of the various examples of embodiments without departing from the spirit or scope of the present inventions.

[0074] While this invention has been described in conjunction with the examples of embodiments outlined above, various alternatives, modifications, variations, improvements and/or substantial equivalents, whether known or that are or may be presently foreseen, may become apparent to those having at least ordinary skill in the art. Accordingly, the examples of embodiments of the invention, as set forth above, are intended to be illustrative, not limiting.

Various changes may be made without departing from the spirit or scope of the invention. Therefore, the invention is intended to embrace all known or earlier developed alternatives, modifications, variations, improvements and/or substantial equivalents.

[0075] The technical effects and technical problems in the specification are exemplary and are not limiting. It should be noted that the embodiments described in the specification may have other technical effects and can solve other technical problems.

CLAIMS

1. A valve assembly for a battery cover, the valve assembly comprising:
a valve cover having a base coupled to a cylindrical projection and having an aperture with a first radius, wherein the cylindrical projection has an internal surface, the internal surface defining an internal chamber and a second and third radius, wherein the aperture is in fluid communication with the internal chamber of the cylindrical projection;
a valve holder provided within the cylindrical projection of the valve cover; and
a valve provided between the valve holder and valve cover;
wherein the valve assembly may be tested prior to installation on the battery cover.
2. The valve assembly of Claim 1, wherein the valve cover is in communication with the internal surface in an area of the cylindrical projection having the third radius.
3. The valve assembly of Claim 2, wherein the base further defines a circumferential depression.
4. The valve assembly of Claim 1, wherein the valve holder comprises a base having a first side and a second side opposite the first side, wherein the base is coupled to the cylindrical body on the first side, and the base is coupled to the cylindrical projection on the second side.
5. The valve assembly of Claim 1 provided in a battery cover.
6. The battery cover of Claim 5 provided in a battery.
7. A valve assembly for a battery cover, the valve assembly comprising:
a valve cover having a base with an aperture having a first radius in fluid communication with an internal chamber defined by a cylindrical projection coupled to the base, the

- cylindrical projection having a second internal radius and a third internal radius, wherein the first radius is smaller than the second radius, which is smaller than the third radius;
- a valve provided in the internal chamber; and
- a valve holder provided in the internal chamber in a region of the internal chamber having the third internal radius.
8. The valve assembly of Claim 7, wherein the base features a circumferential depression.
 9. The valve assembly of Claim 8, wherein the aperture is provided in the approximate center of the circumferential depression.
 10. The valve assembly of Claim 7, wherein the valve assembly may be tested prior to installation on a battery cover.
 11. A battery cover having the valve assembly of Claim 7.
 12. A battery having the battery cover of Claim 11.
 13. A battery comprising:
 - a housing having operable battery elements;
 - a battery cover on the housing having a recess sized to accept a valve assembly;
 - a valve assembly having a valve cover, valve, and valve holder;
 - wherein the valve cover features a base having a cylindrical projection and an aperture, the aperture having a first radius in fluid communication with an internal chamber defined by the cylindrical projection, the cylindrical projection having a second internal radius and a third internal radius; and
 - wherein the valve cover and valve are provided within the internal chamber.
 14. The battery of Claim 13, wherein the first radius is smaller than the second radius, which is smaller than the third radius.

15. The battery of Claim 13, wherein the valve holder is provided in a section of the valve cover internal chamber having the third radius.
16. The battery of Claim 15, wherein the valve is provided between the valve holder and the cylindrical projection.
17. The battery of Claim 16, wherein the valve is positioned between the valve holder and the cylindrical projection in the internal chamber in an area having the third radius.
18. The battery of Claim 17, wherein a portion of the valve extends into an area in the internal chamber having a second radius.
19. The battery of Claim 13, wherein the base has a circumferential depression.
20. The battery of Claim 19, wherein the aperture is approximately in the center of the circumferential depression.

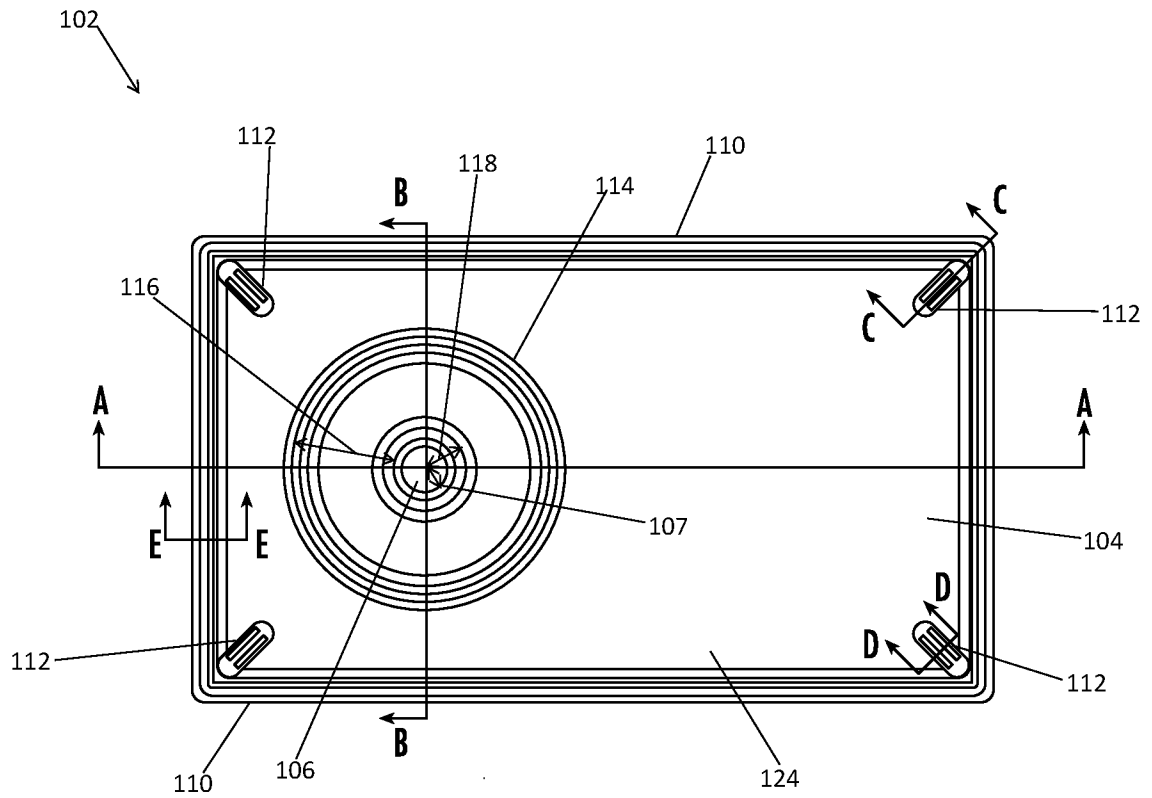


FIG. 1

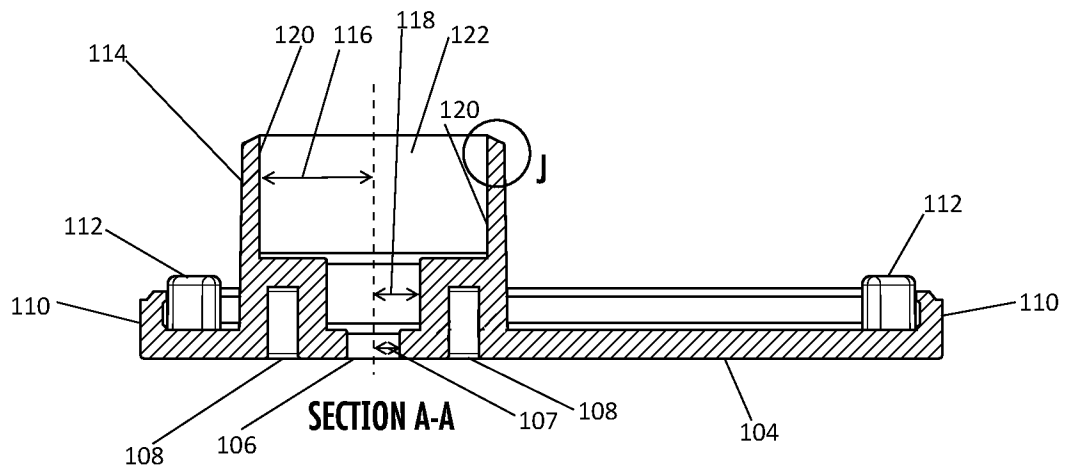


FIG. 2

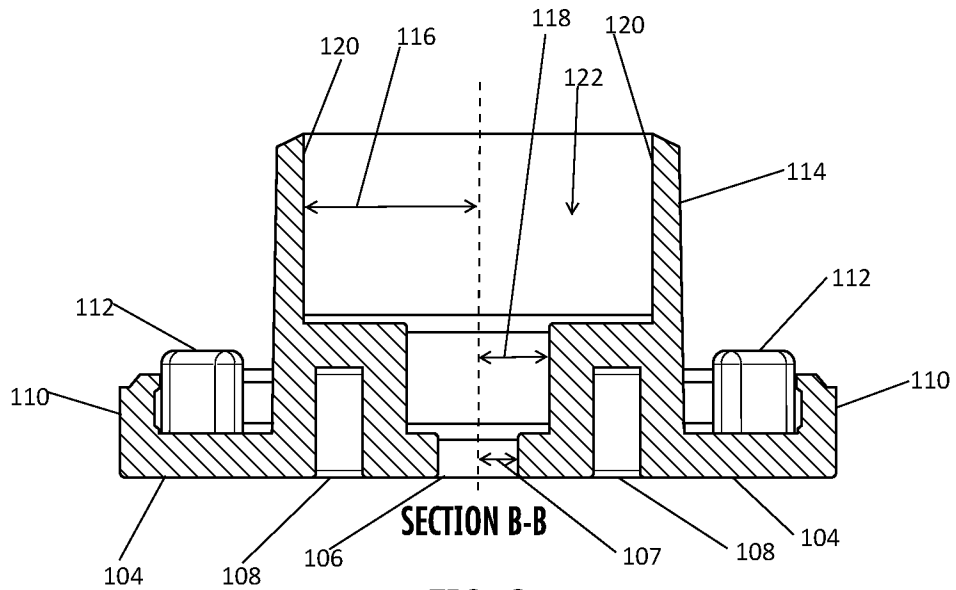
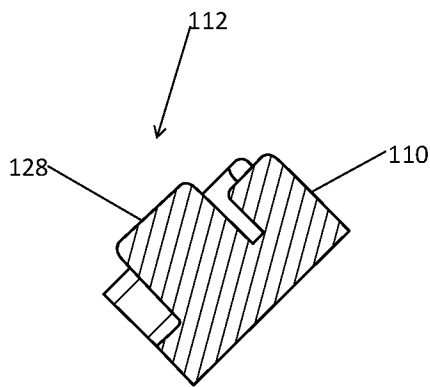
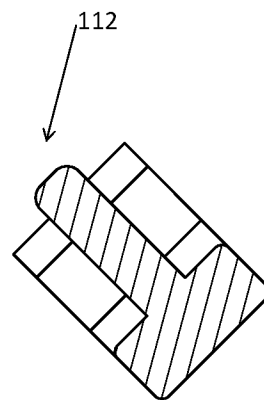


FIG. 3



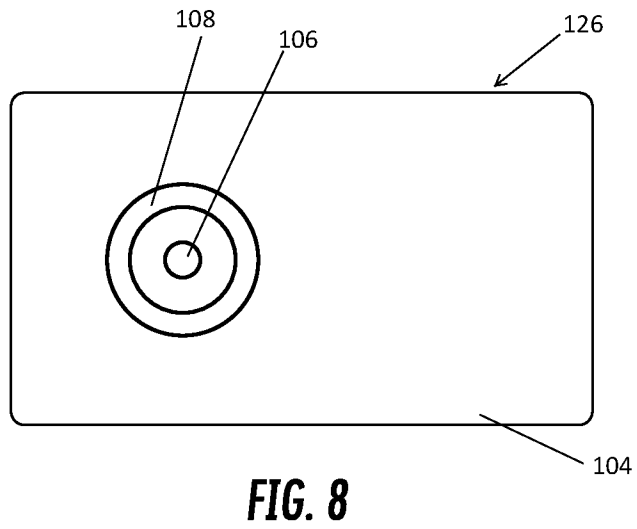
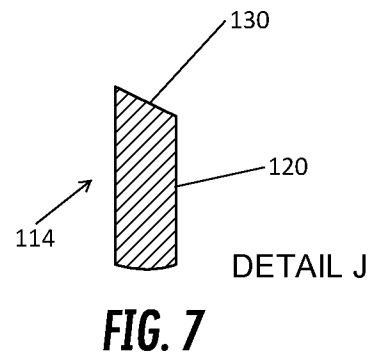
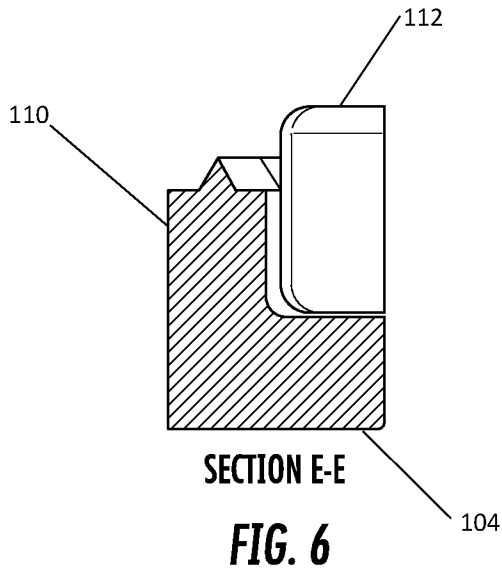
SECTION C-C

FIG. 4



SECTION D-D

FIG. 5



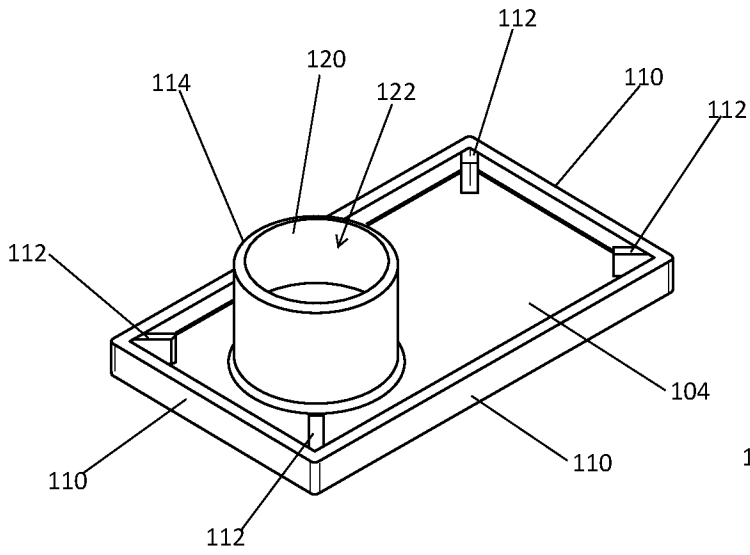


FIG. 9

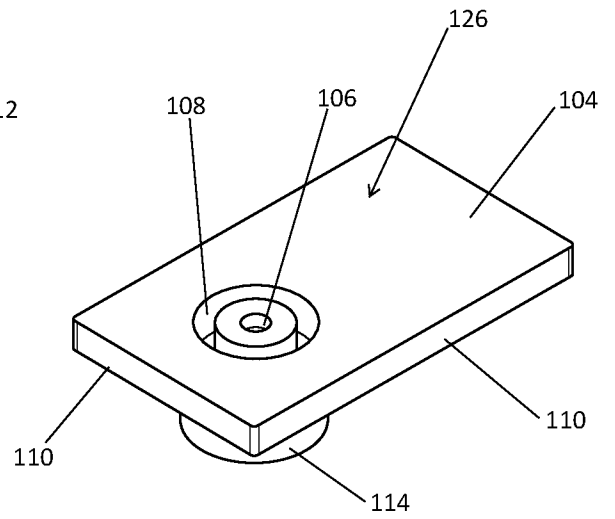


FIG. 10

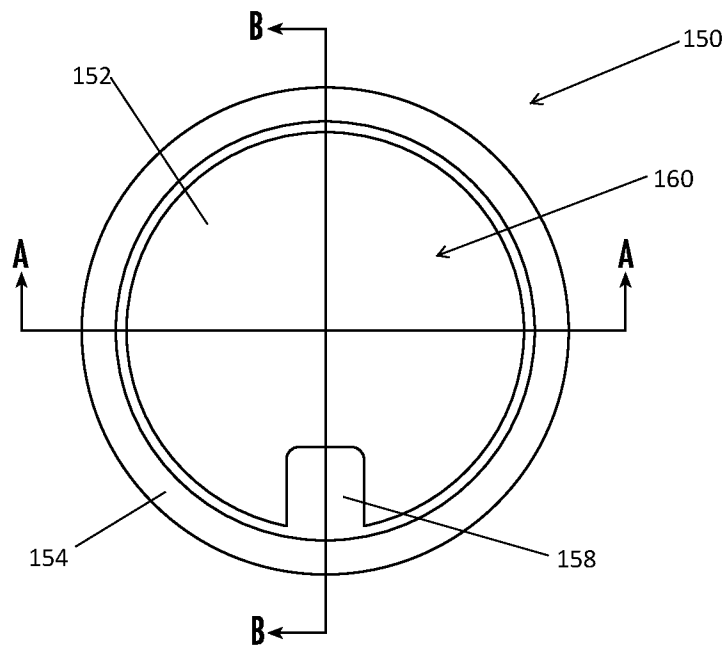
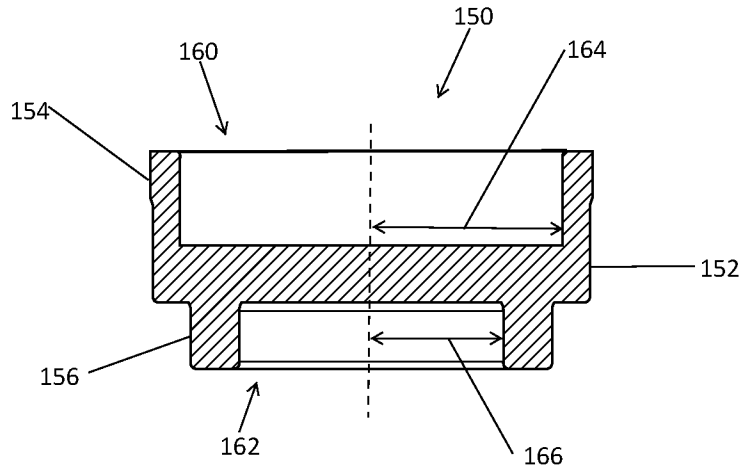
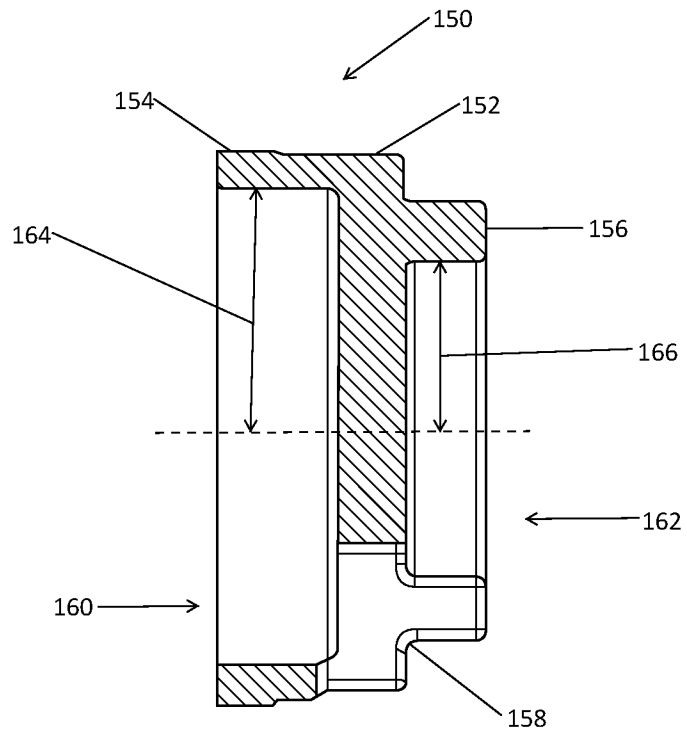


FIG. 11



SECTION A-A

FIG. 12



SECTION B-B

FIG. 13

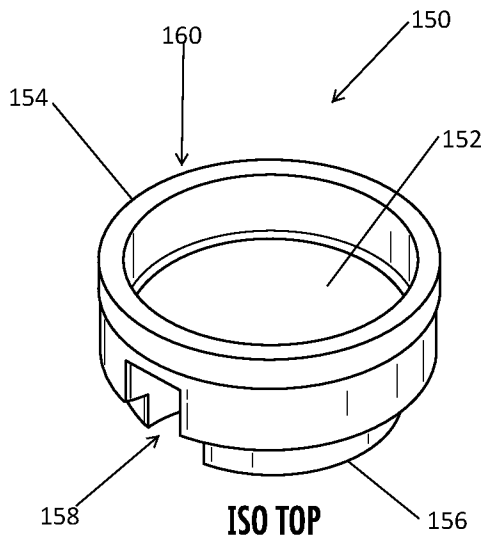


FIG. 14

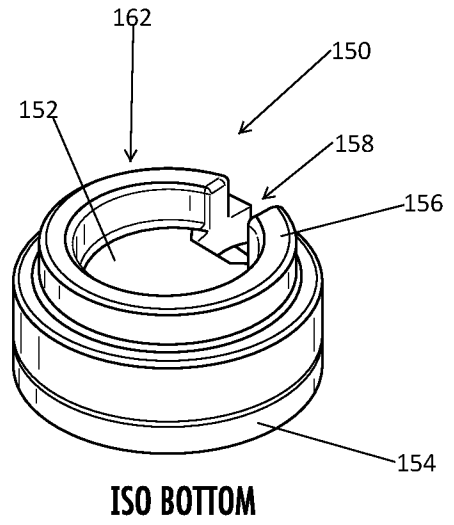


FIG. 15

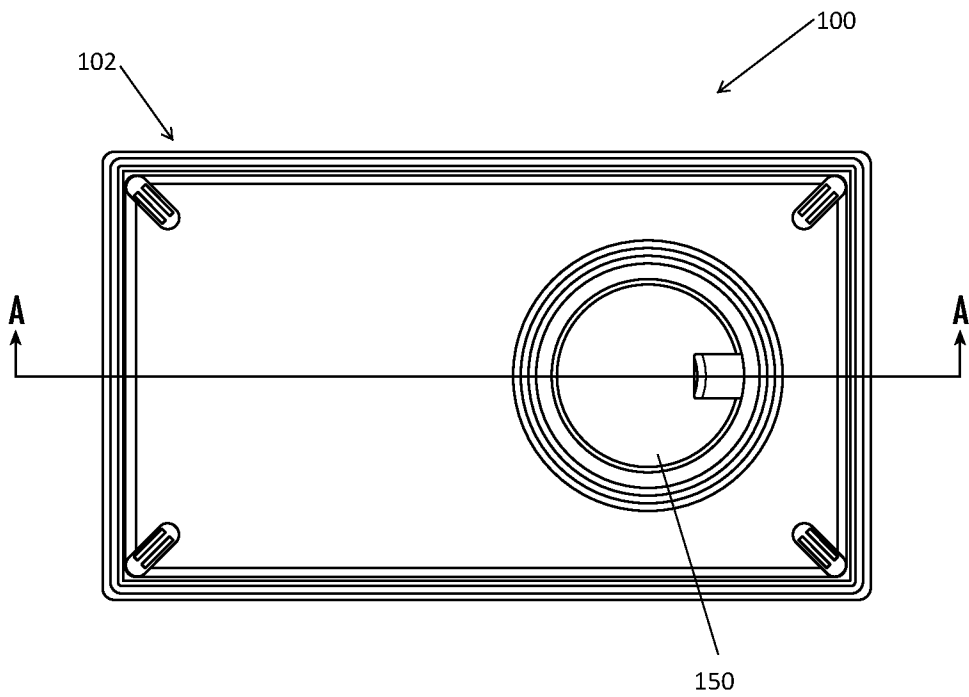


FIG. 16

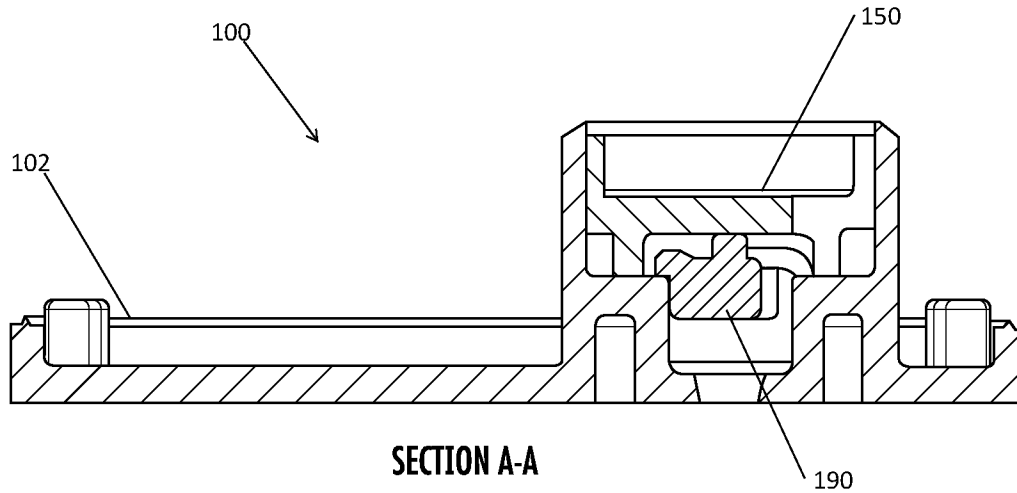


FIG. 17

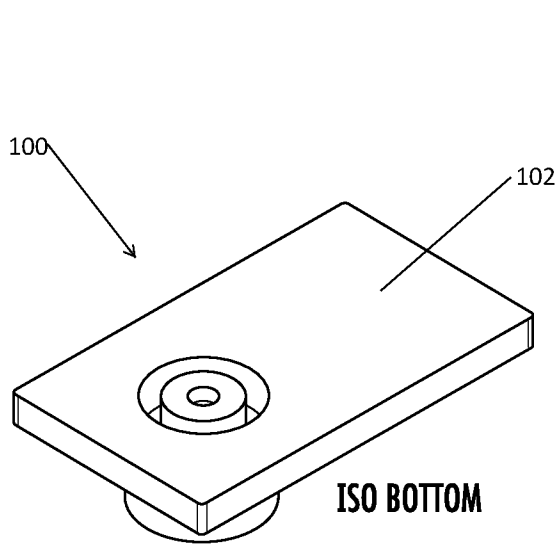


FIG. 18

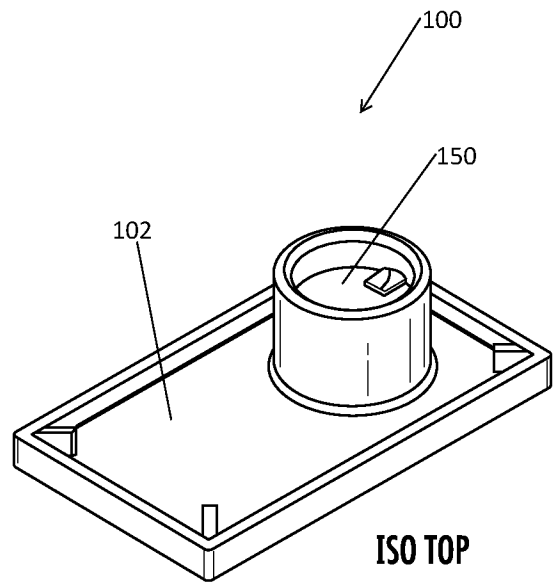


FIG. 19

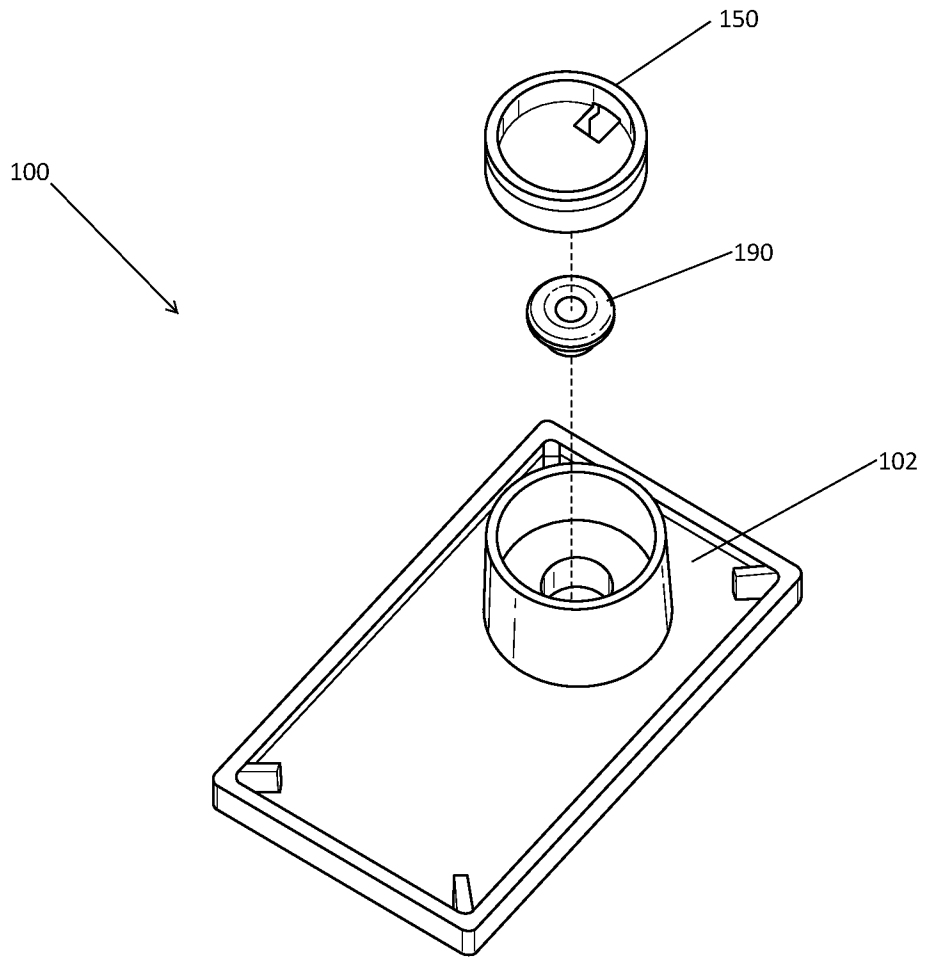
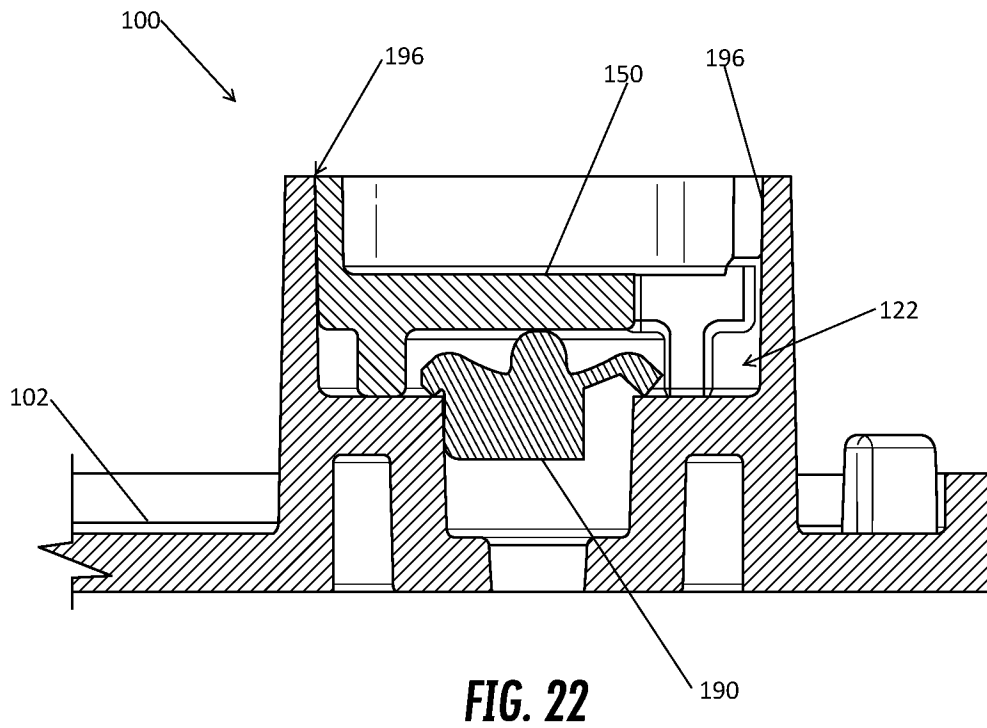
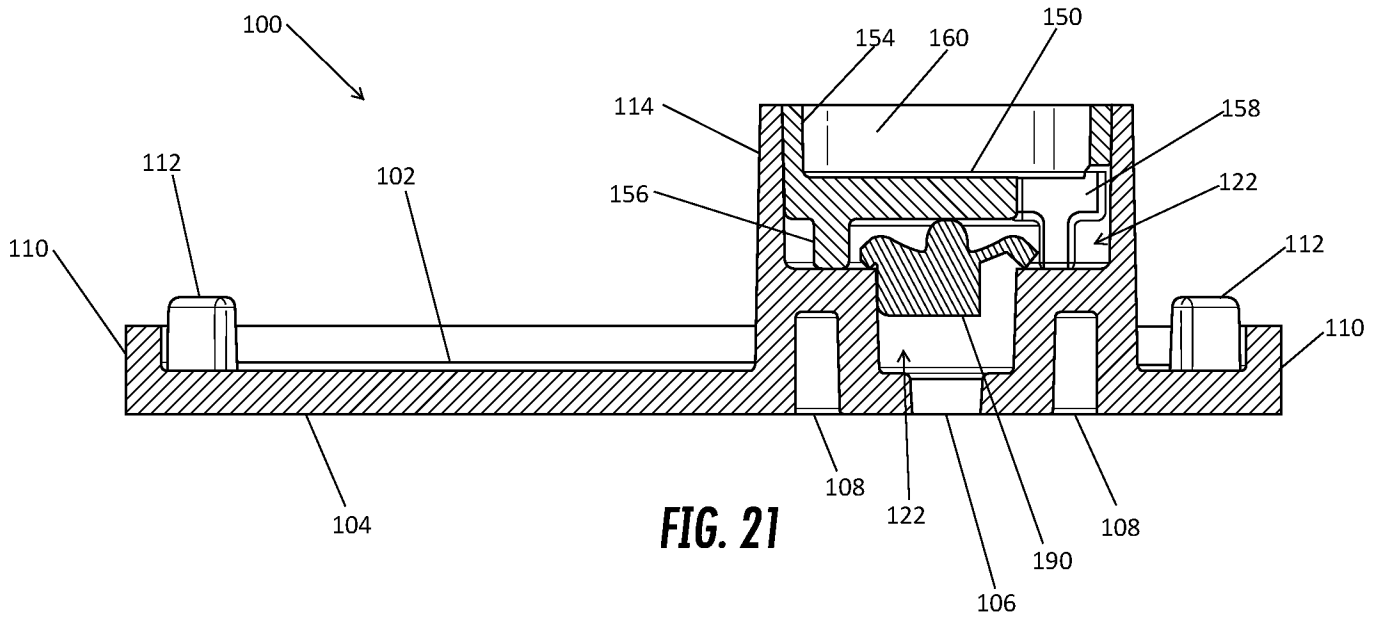


FIG. 20



10/16

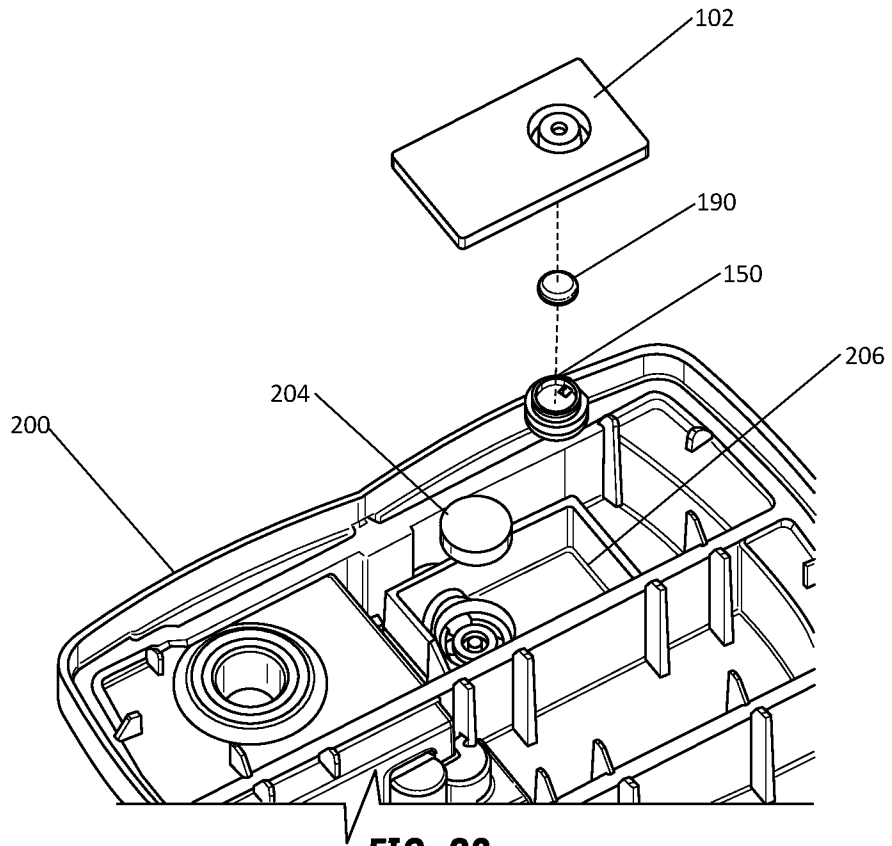


FIG. 23

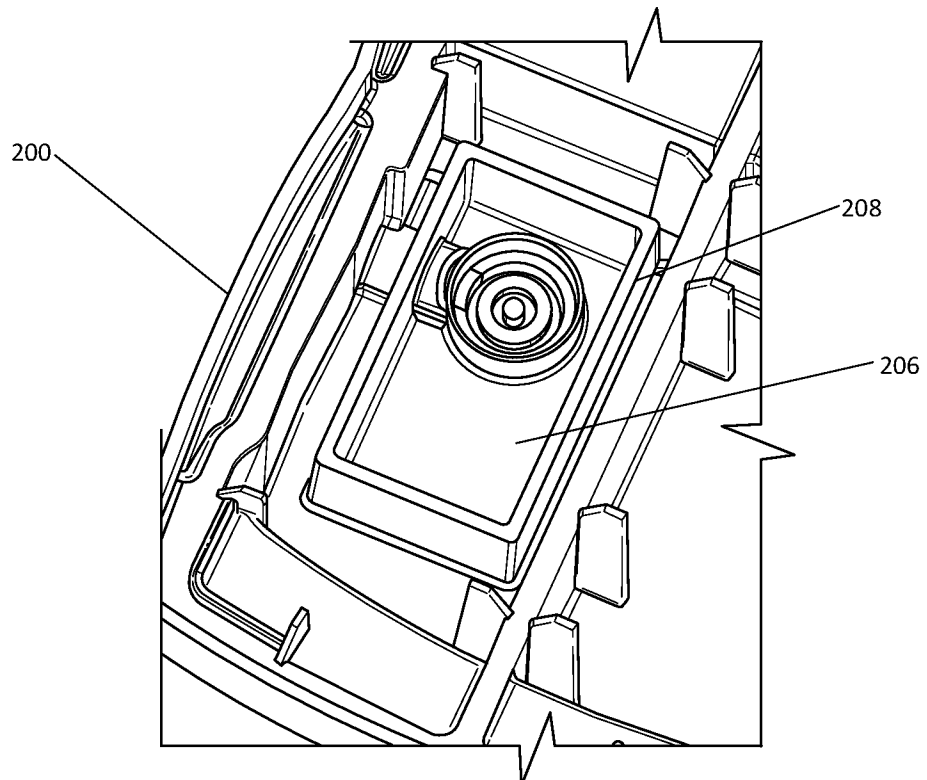
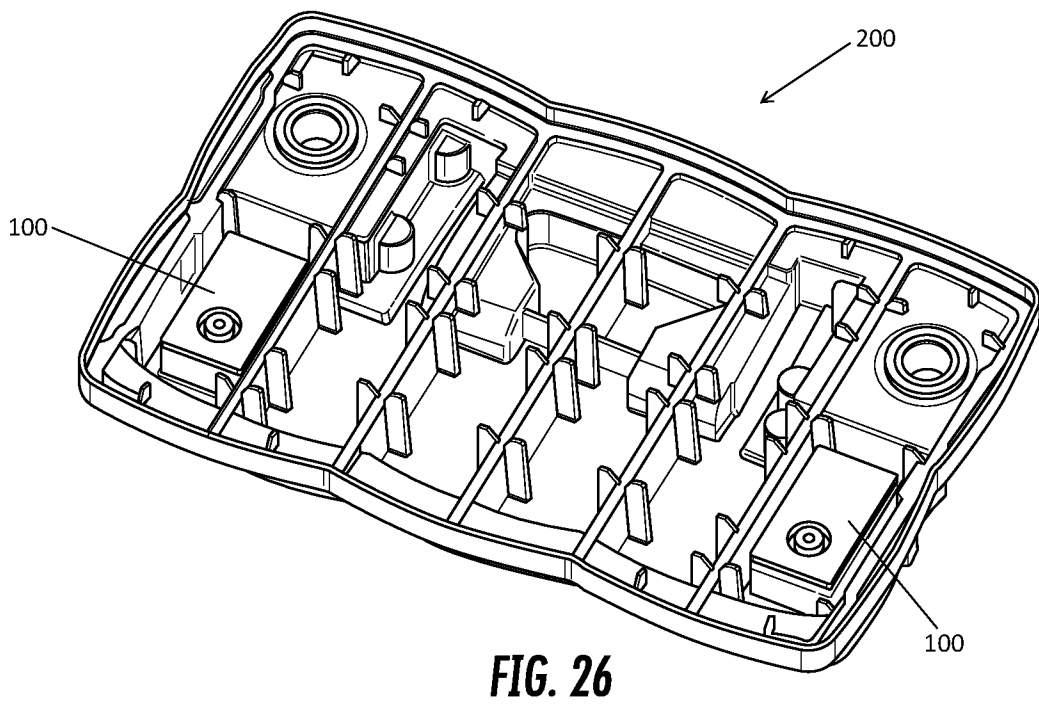
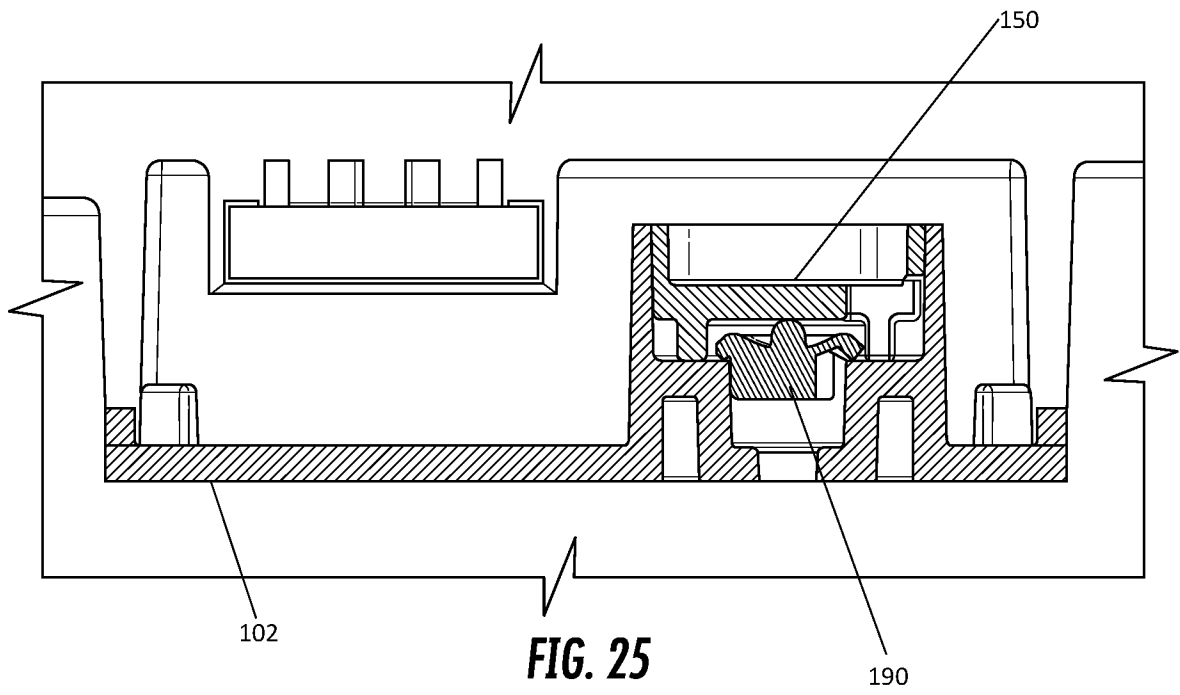


FIG. 24



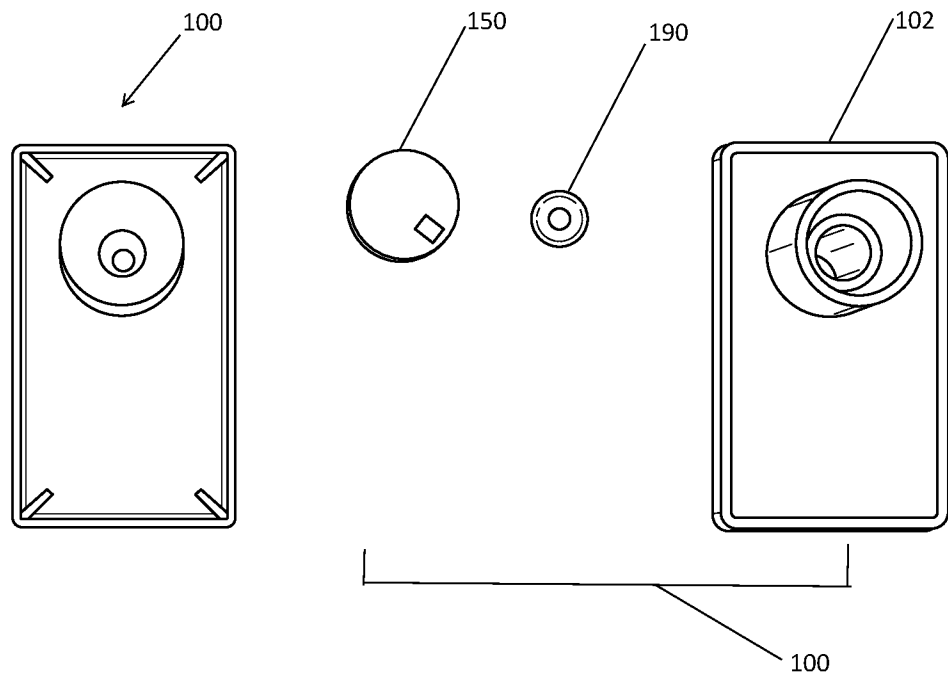


FIG. 27

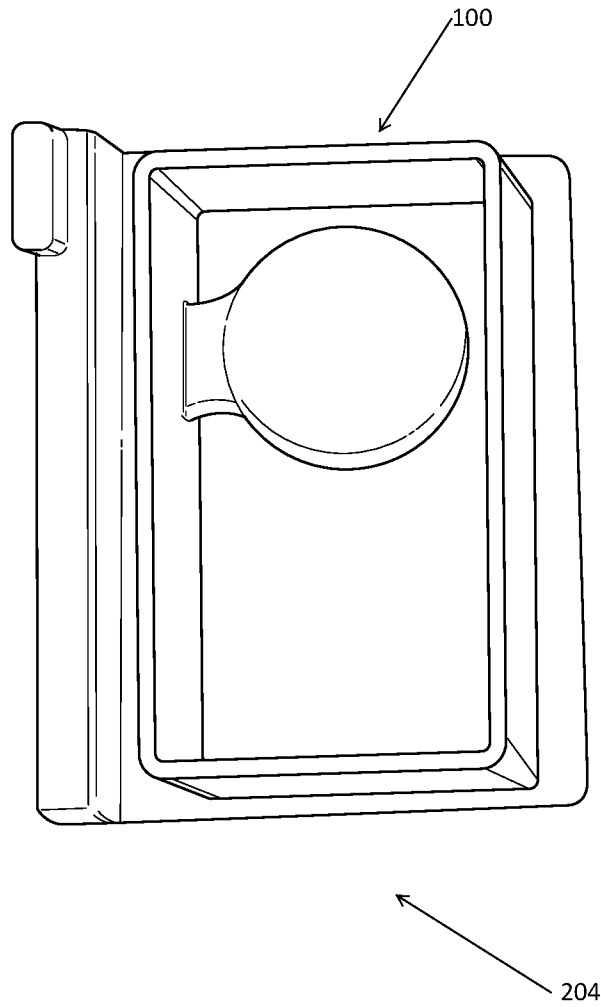


FIG. 28

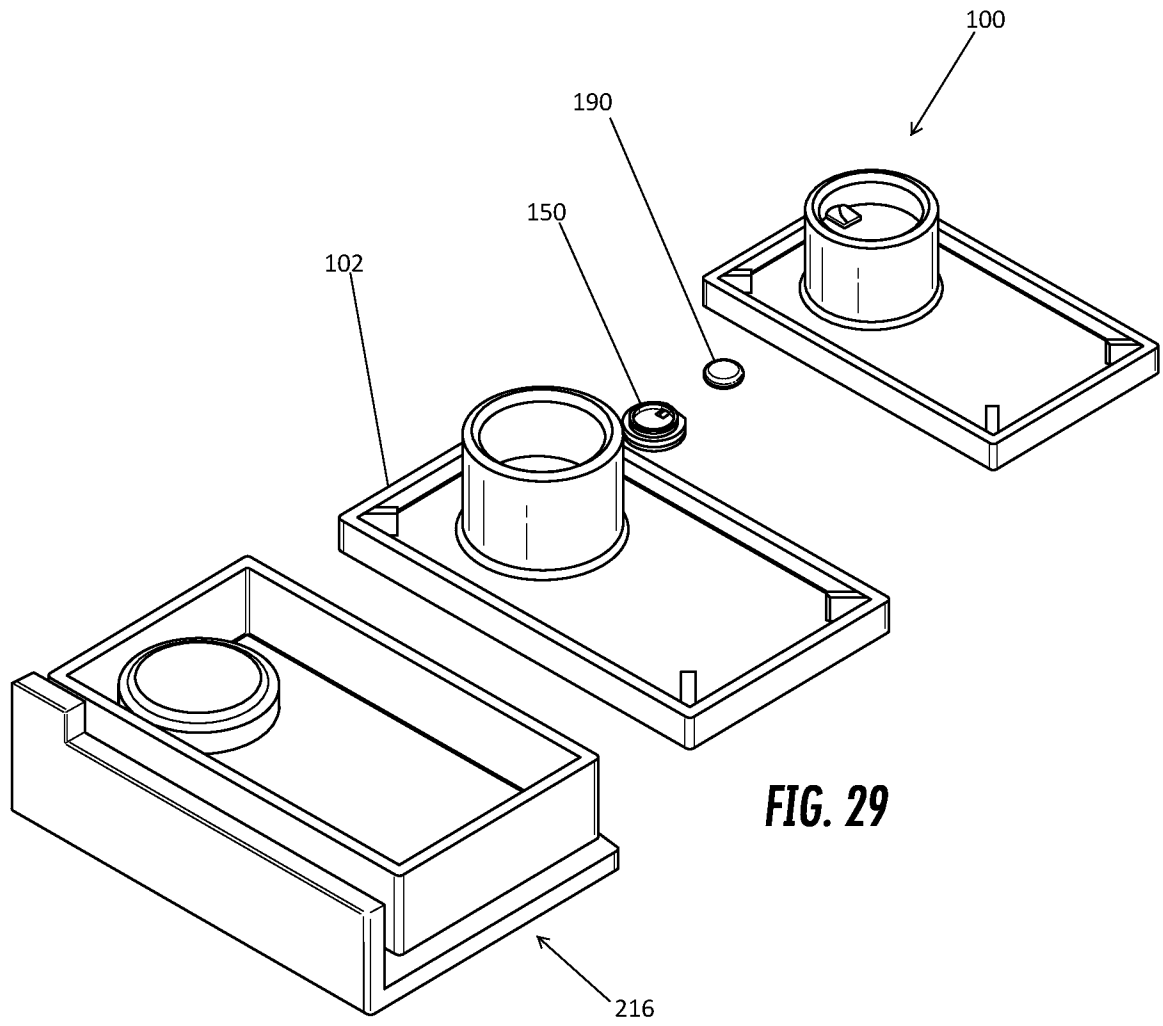


FIG. 29

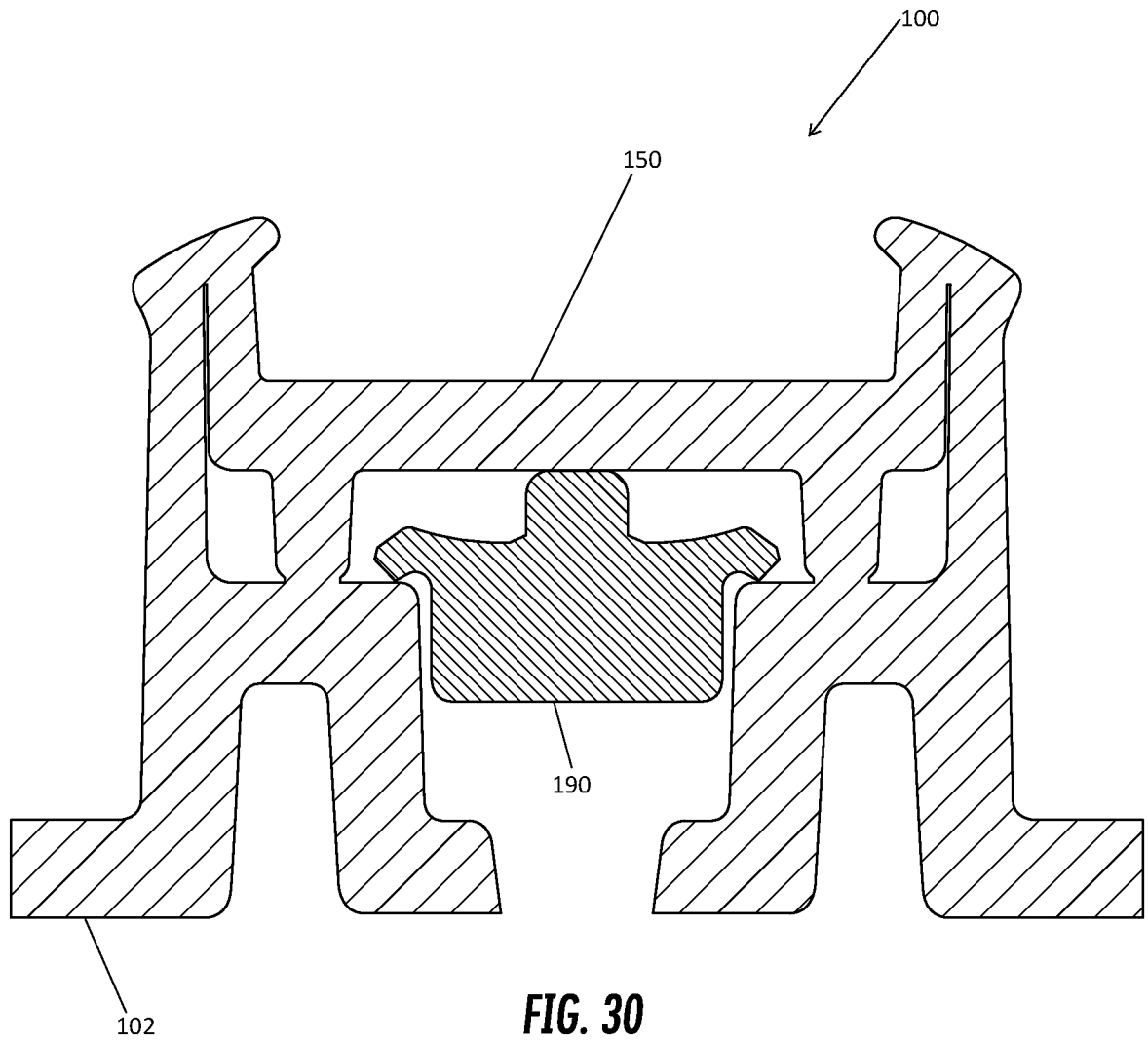


FIG. 30

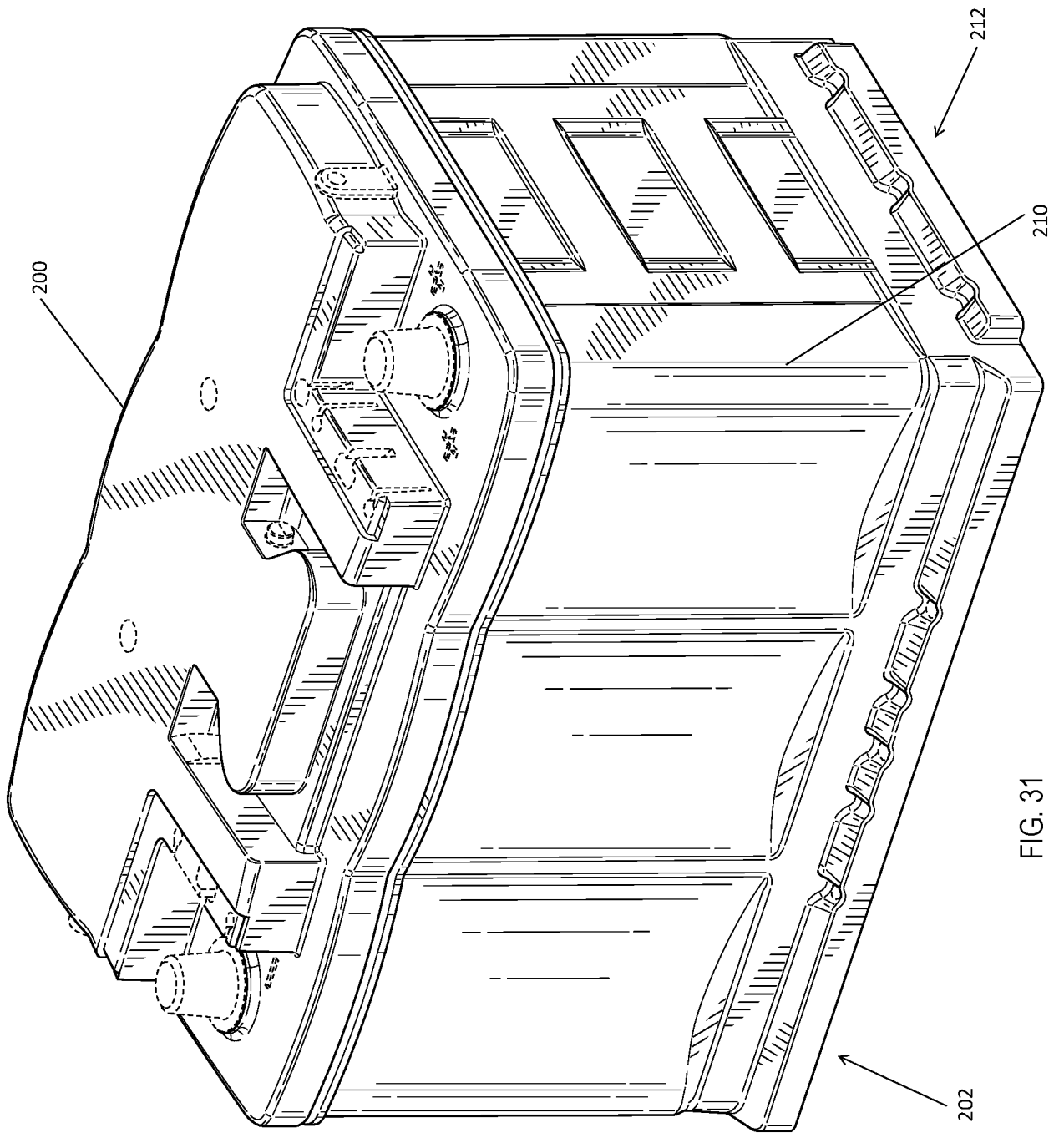


FIG. 31

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/067913

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H01M2/12
 ADD.
 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)
 H01M
 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)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 052 534 A (DEVITT JOHN L) 4 October 1977 (1977-10-04) the whole document -----	1-20

Further documents are listed in the continuation of Box C.

See patent family annex.

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- "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 16 February 2018	Date of mailing of the international search report 05/03/2018
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Cappadonia, Marcella
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/067913

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4052534	A	NONE	04-10-1977