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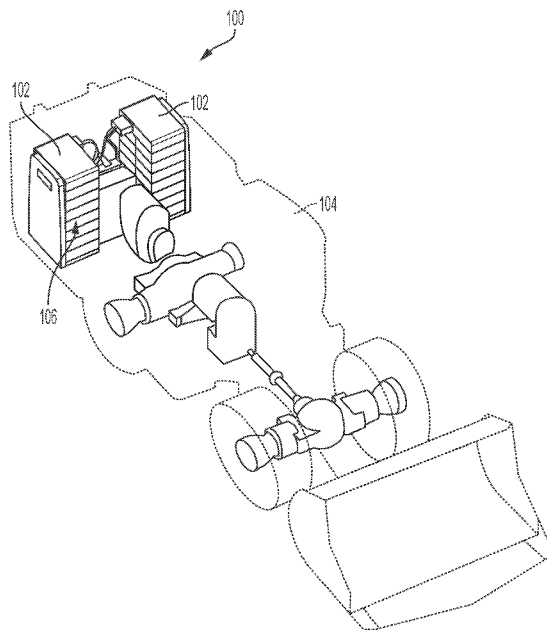


FIG. 1

(57) Abstract: A battery module (106) for construction of a battery pack (102) includes a battery sealed in a rectangular housing (108) with front and rear open ends (113) closed by front and rear plates (112), respectively. The rear plate (112) includes a plurality of rear plate (112) bores in axial alignment with a plurality of housing bores (142) proximal the rear open end (113) of the housing (108). The front plate (110) includes a plurality of front plate (110) bores in axial alignment with a plurality of housing bores (142) proximal the front open end (111) of the housing (108). The front plate (110) additionally includes positive and negative terminals electrically connected to the battery. At least one of the rear plate (112) and the front plate (110) further includes at least one inactive opening (410), and at least one of a grounding cable (412), a clipping structure (414) adapted to receive a cable (416), or a supplemental, non-conductive attachment is received by the inactive opening (410).

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Description

CABLE COUPLING AND GROUNDING ARRANGEMENT FOR A  
STRUCTURAL BATTERY MODULE AND BATTERY PACK

Technical Field

5                    This patent disclosure relates generally to batteries and, more particularly to a structural battery module to enable different battery pack configurations while providing for cable clipping and/or ground points.

Background

10                    Current industrial applications require a broad range of battery sizes and performance requirements. For example, battery pack requirements may range from 20kW to 300kWh and from 48V to 700V. Maintaining a broad range of battery sizes generally results in increased inventory and tooling costs, as well as increased investment in research and development. Further, diminished capacity or performance characteristics of batteries utilized in a given application  
15                    may result in increased costs and challenges in the disposal or recycling of such batteries.

                    In order to meet some of these challenges, manufacturers have developed arrangements where a plurality of battery modules may be assembled into a variety of sizes to meet individual requirements of various applications. For  
20                    example, Absolyte GP has developed a modular steel tray design wherein a plurality of single cell modules may be transported to a desired location and then assembled with a modular steel tray design and connected to provide required capacity, a modular steel tray being disposed between each row of modules.

                    The plurality of batteries, however, also provides a challenge in  
25                    the organization and maintenance of a large number of cables and connections. U.S. Patent Publication No. 2017/0237052A1 to FCA US discloses a cable bracket that includes a conductive base member, a conductive clamp member, a clamping fastener, and at least one conductive protrusion to be used as a grounding connection.

Summary

The disclosure describes, in one aspect, a battery module for construction of a battery pack. The battery module includes a battery disposed within a rectangular housing, and front and rear plates. The rectangular housing includes an upper face, a bottom face, a first side face extending between the upper face and the bottom face, a second side face extending between the upper face and the bottom face, a front open end and a rear open end. The housing also includes a plurality of housing bores extending substantially perpendicularly through the upper face, the bottom face, the first side face and the second side face proximal to the front open end, and a plurality of housing bores extending substantially perpendicularly through the upper face, the bottom face, the first side face and the second side face proximal to the rear open end. The rear plate closes the rear open end of the housing. The rear plate includes a plurality of rear plate bores in axial alignment with the plurality of housing bores proximal the rear open end of the housing. The front plate closes the front open end of the housing. The front plate includes a plurality of front plate bores in axial alignment with the plurality of housing bores proximal the front open end of the housing. The front plate also includes a positive terminal and a negative terminal electrically connected to the battery. The battery is sealed within the rectangular housing, the rear plate, and the front plate. The battery module further includes at least one of a grounding cable, a clipping structure adapted to receive a cable, or a supplemental, non-conductive attachment. At least one of the rear plate and the front plate includes at least one inactive opening, the at least one of the grounding cable, the clipping structure adapted to receive a cable, or the supplemental, non-conductive attachment being received by the inactive opening.

The disclosure describes, in another aspect, a battery pack including a plurality of battery modules, and at least two couplers. Each battery module includes a battery disposed within a rectangular housing, and front and rear plates. The rectangular housing includes an upper face, a bottom face, a first side face extending between the upper face and the bottom face, a second side face extending between the upper face and the bottom face, a front open end and

a rear open end. The housing also includes a plurality of housing bores extending substantially perpendicularly through the upper face, the bottom face, the first side face and the second side face proximal to the front open end, and a plurality of housing bores extending substantially perpendicularly through the upper face, the bottom face, the first side face and the second side face proximal to the rear open end. The rear plate closes the rear open end of the housing. The rear plate includes a plurality of rear plate bores in axial alignment with the plurality of housing bores proximal the rear open end of the housing. The front plate closes the front open end of the housing. The front plate includes a plurality of front plate bores in axial alignment with the plurality of housing bores proximal the front open end of the housing. The front plate also includes a positive terminal and a negative terminal electrically connected to the battery. The battery is sealed within the rectangular housing, the rear plate, and the front plate. The at least two couplers secure together at least a first battery module and a second battery module. At least a first of the couplers is disposed through at least one of the plurality of rear plate bores in axial alignment with at least one of the plurality of housing bores proximal the rear open end of the housing. At least a second of the couplers is disposed through at least one of the plurality of front plate bores in axial alignment with at least one of the plurality of housing bores proximal the front open end of the housing. At least one of the rear plate and the front plate of the battery pack further includes at least one inactive opening. The battery pack further includes at least one of a grounding cable, a clipping structure adapted to receive a cable, or a supplemental, non-conductive attachment received by the inactive opening.

The disclosure describes, in yet another aspect, method of constructing a battery pack. The method includes providing a plurality of battery modules. Each battery module includes a battery disposed within a rectangular housing, and front and rear plates. The rectangular housing includes an upper face, a bottom face, a first side face extending between the upper face and the bottom face, a second side face extending between the upper face and the bottom face, a front open end and a rear open end. The housing also includes a plurality

of housing bores extending substantially perpendicularly through the upper face, the bottom face, the first side face and the second side face proximal to the front open end, and a plurality of housing bores extending substantially perpendicularly through the upper face, the bottom face, the first side face and the second side face proximal to the rear open end. The rear plate closes the rear open end of the housing. The rear plate includes a plurality of rear plate bores in axial alignment with the plurality of housing bores proximal the rear open end of the housing. The front plate closes the front open end of the housing. The front plate includes a plurality of front plate bores in axial alignment with the plurality of housing bores proximal the front open end of the housing. The front plate also includes a positive terminal and a negative terminal electrically connected to the battery. The battery is sealed within the rectangular housing, the rear plate, and the front plate. The method further includes disposing a rectangular housing of a first battery module of the plurality of battery modules adjacent a rectangular housing of a second battery module of the plurality of battery modules. The method further includes disposing a first coupler through a rear plate bore of the first battery module, a housing bore through the rectangular housing of the first battery module, a housing bore through the rectangular housing of the second battery module, and a rear plate bore of the second battery module to secure the first and second battery module together. The method further includes disposing a second coupler through a front plate bore of the second battery module, a housing bore through the rectangular housing of the second battery module, a housing bore through the rectangular housing of the second battery module, and a front plate bore of the second battery module to secure the second and second battery module together. The method further includes disposing at least one of a grounding cable, a clipping structure adapted to receive a cable, or a supplemental, non-conductive attachment into at least one inactive opening in at least one of the rear plate and the front plate.

### Brief Description of the Drawings

Figure 1 is an isometric view of an exemplary mobile machine in which a battery system in accordance with teachings of this disclosure may be utilized.

5                   FIG. 2 is a rear isometric view of an exemplary embodiment of a battery pack according to teachings of this disclosure.

FIG. 3 is a front isometric view of the battery pack of FIG. 2.

FIG. 4 is an exploded rear isometric view of the battery pack of FIGS. 2 and 3.

10                   FIG. 5 is an enlarged, front isometric view of a battery module in accordance with teachings of this disclosure.

FIG. 6 is a front elevational view of the battery module of FIG. 5.

FIG. 7 is a rear elevational view of the battery module of FIG. 5.

15                   FIG. 8 is a fragmentary isometric view of a construction of an alternative embodiment of an exemplary battery pack utilizing the battery module of FIGS. 5-7.

FIG. 9 is an isometric view of further construction of the exemplary battery pack utilizing the battery module of FIG. 8.

20                   FIG. 10 is an isometric view of an embodiment of a battery module in accordance with teachings of this disclosure.

FIG. 11 is an enlarged fragmentary view of an end of the battery module of FIG. 10.

FIG. 12 is an isometric view of the embodiment of a battery module of FIGS. 10 and 11 including at least grounding cable.

25                   FIG. 13 is an exploded isometric view of the embodiment of a battery module of FIG. 12.

FIG. 14 is an isometric view of the embodiment of a battery pack of FIGS. 10 and 11 including at least one grounding cable and at least one cable clipping structure.

30                   FIG. 15 is an exploded isometric view of the embodiment of a battery module of FIG. 14.

FIG. 16 is an enlarged fragmentary view of an end of the battery module of FIGS. 14 and 15.

FIG. 17 is an isometric view of a battery pack including a faceplate according to teachings of this disclosure.

5                   FIG. 18 is an enlarged fragmentary view of a faceplate coupler of the battery pack of FIG. 17.

FIG. 19 is an isometric view of a battery pack including a coupling structure according to teachings of this disclosure.

10                   FIG. 20 is a partially exploded view of the coupling structure of the battery pack of FIG. 19.

#### Detailed Description

This disclosure relates to a battery system 100 that may be utilized to construct battery packs 102 for use in various applications, such as the machine 104 of FIG. 1. While the arrangement is illustrated in connection with a mobile machine, more particularly, a front end loader, the arrangement disclosed herein has universal applicability in various other types of machines as well. The term “machine” may refer to any machine that performs some type of operation associated with an industry such as mining, construction, farming, transportation, or any other industry known in the art. For example, the machine may be an earth-moving machine, such as a wheel loader, excavator, dump truck, backhoe, motor grader, material handler or the like. Moreover, an implement may be connected to the machine. Such implements may be utilized for a variety of tasks, including, for example, loading, compacting, lifting, brushing, and include, for example, buckets, compactors, forked lifting devices, brushes, grapples, cutters, shears, blades, breakers/hammers, augers, and others.

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The battery system 100 includes a plurality of battery modules 106 that may be coupled in various configurations in order to provide various battery packs 102 of desired power output and voltage output. An exemplary battery module 106 is illustrated in FIGS. 5-7, and includes a rectangular housing 108, a front plate 110, and a rear plate 112. The housing 108 has a channel construction,

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including an upper face 300, a bottom face, 302, and first and second side faces 304, 306 extending between the top and bottom faces 300, 302. The front plate 110 closes the front open end 111 of the housing 108, and the rear plate 112 closes the rear open end 113 of the housing 108 to form a sealed structure.

5                   The housing 108, and front and rear plates 110, 112 may be fabricated by any appropriate method and of any appropriate materials. For example, the housing 108 may be three-D printed, stamped, otherwise formed, molded or extruded of a filled or unfilled polymeric material. Similarly, the front and rear plates 110, 112 may be three-D printed, cast, or otherwise molded from a  
10                   filled or unfilled polymeric material.

Each battery module 106 houses a battery 114 that may be of any construction, as will be understood by those of skill in the art. Positive and negative terminals 116, 118 may be provided along the front plate 110. Inasmuch as the battery 114 is sealed within the battery module 106, the battery module 106  
15                   may be transported and handled for further construction of a desired battery pack 102. Returning to FIGS. 2-4, in order to electrically couple the battery modules 106, any appropriate electrical couplers, such as the plurality of cables 120 may be provided.

In at least one embodiment, the battery pack 102 further includes a  
20                   base 122 upon which a plurality of battery modules 106 may be supported and coupled together. While the base 122 may not be required in all embodiments, the base 122 may provide added support to the constructed battery pack 102 and may facilitate further handling, particularly in larger battery packs 102. As may be seen in the FIG. 4, in particular, the base 122 may be of a rectangular design, and  
25                   may include structural elements such as a rectangular frame 124 with cross-supports 126 that may enhance strength and stability, while minimizing weight. The base 122 may further include structure for enhancing attachment a battery module 106. For example, the frame 124 may include a plurality of bosses 128, which may be internally threaded for engagement with respective couplers 130,  
30                   such as bolts or screws, the significance of which will be discussed below. The illustrated base 122 is sized to support two battery modules 106. It will be

appreciated, however, that the battery system 100 may include a plurality of sizes of bases, such as bases sized to support one battery module 106, as well as three, four or more battery modules 106 side by side.

5 The battery pack 102 may optionally further include a distribution unit 132 if desired. The battery modules 106 may be electrically connected to the distribution unit 132, here, by way of the cables 120. The distribution unit 132 may act as a controller to allow distribution of power to one or more loads of a machine 104. For example, in an electrical machine, power may be provided to a drive system and/or individual components of the machine.

10 In accordance with an aspect of this disclosure, the battery modules 106 may be secured together to provide a battery pack 102 that is structurally stable without the need for an external frame between stacked battery modules 106. In order to secure the battery modules 106 together, each battery module 106 includes a plurality of coupling arrangement at opposite plates 110, 15 112 of the battery module 106. More particularly, the front and rear plates 110, 112 include flanged surfaces 139 including a plurality of coupling bosses 140 through which a plurality of plate bores 141 extend, while the housing 108 includes a plurality of housing bores 142 disposed in alignment with the plate bores 141 of the coupling bosses 140. Further, while the front and rear plates 110, 20 112 have been illustrated with coupling bosses 140, it will be appreciated that the flanged surfaces 139 themselves may include the plate bores 141. A plurality of couplers 130, such as bolts or rivets, are provided for disposition through the coupling bosses 140 to couple the battery modules 106 together.

25 According to an aspect of this disclosure, the plate bores 141 and housing bores 142 may extend substantially perpendicular to the housing 108. In this way, couplers 130 may readily be assembled through the plate bores 141 and housing bores 142 of adjacently disposed battery modules 106. Those of skill in the art will appreciate that the coupling arrangement may provide enhanced stability to the battery module 106 in that the couplers 130 extend through both 30 plate bores 141 and housing bores 142, further stabilizing the relationship between the front and rear plates 110, 112 and the housing 108.

In assembly, a first battery module 150 may be optionally positioned on a base 122 sized to support a desired number of battery modules 106 in a horizontal configuration. In positioning the first battery module 150, the housing bores through the housing 151 and the aligned plate bores through the coupling bosses 152, 153 at the lower edge 154 of the rear plate 159 of the first battery module 150 are disposed in alignment with the bosses 128 of the base 122. Couplers 130 are then inserted into and secured within the coupling bosses 152, 153 of the rear plate 159 of the first battery module 150 and the bosses 128 of the base 122 to secure the first battery module 150 to the base 122. While this procedure has been explained in detail with regard to a rear plate 159 of the first battery module 150, this same procedure is followed with regard to a front plate 158 of the first battery module 150, inserting couplers 130 into plate bores along the front plate lower edge of the first battery module 150, the housing bores through housing 151, and bosses 128 of the base 122.

A second battery module 160 may be positioned on an upper surface of the first battery module 150; similarly, the housing bores through the housing 161 and the plate bores through coupling bosses 162, 163 along the lower edge 164 of the rear plate 169 of the second battery module 160 are positioned in alignment with the housing bores through the housing 151 and plate bores through the coupling bosses 155, 156 of the rear plate 159 along the upper edge 157 of the first battery module 150. Couplers 130 are then inserted into the housing bores of the housings 151, 161, and secured within the plate bores through the coupling bosses 162, 163 of the second battery module 160 and the plate bores through the coupling bosses 155, 156 of the first battery module 150 to secure the second battery module 160 to the first battery module 150. As with the securing of the first battery module 150 to the base 122, this same procedure is performed with regard to the front plates 158, 168 of the first and second battery modules 150, 160.

This process may be continued, securing a third battery module 170 at plate bores through coupling bosses 172, 173 to plate bores through coupling bosses 165, 166 along the upper edge 167 of the second battery module

160 at both its front and rear plates 168, 169. The process is further continued until a desired number of battery modules 106 are secured together.

According to another aspect of this disclosure, additional battery modules 106 may be coupled at the lateral faces 180, 181 of the first battery module 150, as well as subsequently coupled battery modules 160, 170. In the embodiment of FIGS. 2-4, for example, a fourth battery module 190 is positioned laterally from the first battery module 150. That is, the housing 191 of the fourth battery module 190 is positioned on the base 122 and adjacent the lateral face 181 of the first battery module 150. In positioning the fourth battery module 190, the housing bore through the housing 191 and the plate bore through coupling boss 192 along the lateral edge 193 of the fourth battery module 190 is positioned in axial alignment with the housing bore through housing 151 and the plate bore of the coupling boss 182 along the lateral edge 183 of the first battery module 150, and the plate bores through the housing 191 and the plate bores of coupling bosses 194, 195 along the lower edge 196 of the fourth battery module 190 are positioned in axial alignment with bosses 128 of the base 122. A mating coupler 130 is then engaged within the coupling boss 192 of the fourth battery module 190 and coupling boss 182 of the first battery module 150, and couplers 130 are engaged within coupling bosses 194, 195 of the fourth battery module 190 and bosses 128 of the base 122.

As with the assembly of the first, second, and third battery modules 150, 160, 170, while this procedure has been explained in detail with regard to a rear plate 198 of the fourth battery module 190, this same procedure is followed with regard to a front plate 197 of the fourth battery module 190, inserting couplers 130 into bores of the coupling bosses along the front plate lateral and lower edges of the fourth battery module 190 and the first battery module 150, and bosses 128 of the base 122. Similarly, a fifth battery module 185 may be secured to a lateral face 186 of the second battery module 160 and an upper face 199 of the fourth battery module 190. Again, this process may continue, adding a sixth battery module 187 and any additional battery modules 106 until a desired battery pack 102 is constructed.

If utilized, once all desired battery modules 106 have been coupled together, the distribution unit 132 may be secured to the battery pack 102. While the distribution unit 132 is secured to the upper face 134 of the coupled battery pack 102 in the embodiment illustrated in FIGS. 2-4, a distribution unit may  
5 alternatively be secured to a lateral face 136 of the battery pack 102 if appropriate for given application. Once secured together, the battery modules 106 may be electrically connected to each other, and to the distribution unit 132, if utilized, by way of cables 120 or the like.

While the embodiment illustrated in FIGS. 2-4 includes a battery  
10 pack 102 constructed of two columns of seven battery modules 106, it will be appreciated that battery packs of alternative voltage and power delivery, as well as different geometries may be constructed from the battery modules 106. That is, referring to FIG. 8, in at least one embodiment, the front and rear plates 210, 212 of the battery module 214 may be provided with coupling bosses 220, 221, 222,  
15 223, 224, 225 along each of the top edge 230, bottom edge 232, and lateral edges 234, 236, with corresponding plate bores (not visible in FIG. 8), and the housing 216 provided with axially aligned respective housing bores (not visible with regard to battery module 214 in FIG. 8). In this way, additional battery modules  
20 240, 242, 244, 246 may be secured at each of the upper face, bottom face, and lateral faces of the housing 216 of battery module 214. Further battery modules may be secured to battery modules 240, 242, 244, 246 secured with the battery module 214, allowing the construction of various sizes and geometric shapes of battery packs, as further illustrated in FIG. 9.

In at least one embodiment, the bosses 128 of the base 122 and the  
25 plate bores 141 of the coupling bosses 140 of the battery module 106 are internally threaded. In at least one embodiment, a portion of the bosses 128 of the base 122 and the plate bores 141 of the coupling bosses 140 of the battery module 106 are internally threaded, while the remaining bosses 128 of the base 122 and plate bores 141 of the coupling bosses 140 of the battery module 106 are not  
30 threaded; rather, the remaining bosses 128 of the base 122 and plate bores 141 of the coupling bosses 140 of the battery module 106 are unthreaded. In this way,

assembly of a battery pack 102 may be simplified. It will be noted, however, that when the bosses 128 of the base 122 and/or the bores 141 of the coupling bosses 140 of the battery module 106 include unthreaded bores, the couplers 130 are inserted first through the unthreaded bore and then threaded into the threaded  
5 bore.

By way of example only, in the embodiment illustrated in FIGS. 2-4, the bosses 128 of the base 122 may be internally threaded, while the coupling bosses 152, 153 of the first battery module 150 may include unthreaded plate bores. In this way, couplers 130 may be inserted through the unthreaded  
10 plate bores of the coupling bosses 152, 153 of the first battery module 150, and then secured within the threaded bores of the bosses 128 of the base 122. Similarly, the coupling bosses 155, 156 of the first battery module 150 may include threaded plate bores, while the coupling bosses 162, 163 of the second battery module 160 may include unthreaded plate bores such that couplers 130  
15 inserted through the unthreaded plate bores of the coupling bosses 162, 163 of the second battery module 160 may be secured within the threaded plate bores of the coupling bosses 155, 156 of the first battery module 150. Similarly, the coupling boss 192 of the fourth battery module 190 may include an unthreaded plate bore, while the coupling boss 182 of the first battery module 150 may include a  
20 threaded plate bore. In this way, a mating coupler 130 may be inserted through the unthreaded plate bore of the coupling boss 192 of the fourth battery module 190 and secured in the threaded plate bore of the coupling boss 182 of the first battery module 150.

Those of skill in the art will thus appreciate that the construction  
25 of a battery module 106 may thus be standardized. For example, the coupling bosses disposed along the lower edge of a face may include unthreaded plate bores, while the coupling bosses along the opposite, upper edge may include threaded plate bores; similarly, the coupling boss along one lateral edge of a face may include an unthreaded plate bore, while the coupling boss along the  
30 opposite, lateral edge may include a threaded plate bore.

Turning now to FIGS. 10-16, there is illustrated a further battery module 106 for construction of a battery pack 102. In this embodiment, similar structures are identified with the same reference numbers as FIGS. 5-9. While the arrangement is described with regard to the particular battery module 106 illustrated, aspects of the disclosure may be applicable to different designs of batteries. The battery module 106 includes a battery 114 sealed within a rectangular housing 108 having an upper face 134, a bottom face 135, and first and second lateral or side faces 136 extending between the upper face 134 and the bottom face 135 which define a front open end 111 and a rear open end 113. The battery module 106 further may include a rear plate 112 closing the rear open end 113 of the housing 108, and a front plate 110 closing the front open end 111 of the housing 108. Those of skill in the art will appreciate that an interior face of the front plate 110 is illustrated schematically for the sake of simplicity. In at least one embodiment, at least one of the front and rear plates 110, 112 is a casting.

In order to couple the front and rear plates 110, 112 to the rectangular housing 108, the housing 108 may include a plurality of housing bores 142 and the front and rear plates 110, 112 may each include a plurality or front and rear plate bores 141 in axial alignment with the plurality of housing bores 142, respectively. A plurality of connectors such as bolts (not illustrated in this embodiment but shown FIG. 8, for example) may be utilized to couple the front and rear plates 110, 112 to the rectangular housing 108.

At least one of the front and the rear plates 110, 112 includes at least one inactive opening 410. In at least one embodiment the at least one inactive opening 410 does not extend entirely through the front or rear plate 110, 112. In this way, the at least one inactive opening 410 does not electrically connect to the battery 114 sealed within the rectangular housing 108 and front and rear plates 110, 112. In the embodiment of FIGS. 10-16, four such inactive openings 410 are illustrated in the rear plate 112.

According to an aspect of this disclosure, the battery module 106 further includes at least one of a grounding cable 412 (see FIGS. 12-16), a

clipping structure 414 adapted to receive a cable 416 (see FIGS. 14-16), or a supplemental, non-conductive attachment 418 (see FIGS. 17-20). The at least one of a grounding cable 412 (see FIGS. 12-16), a clipping structure 414 adapted to receive a cable 416 (see FIGS. 14-16), or a supplemental, non-conductive  
5 attachment 418 (see FIGS. 17-20) is received in the inactive opening 410 to the battery module 106 or battery pack 102.

Turning further to FIGS. 12-16, there is illustrated an exemplary grounding cable 412 received within the inactive opening 410. As may be seen in FIGS. 13 and 15, the grounding cable 412 may include a probe 420 coupled to a  
10 cable 416. The probe 420 may be received within one of the inactive openings 410. Those of skill in the art will appreciate that this coupling of the grounding cable 412 does not electrically connect to the battery 114 sealed within the rectangular housing 108 and front and rear plates 110, 112.

In order to assist in organization of the cables coupled to the  
15 battery module 106 or battery pack 102, a clipping structure 414 adapted to receive a cable 416 may be provided. The clipping structure 414 may include a probe 422 and an annular channel 424 sized to receive a cable 416. The probe 422 is sized to be received within one of the inactive openings 410. While the clipping structure 414 may be of any appropriate design, in the illustrated  
20 embodiment, the clipping structure includes a band 426 that may be opened to provide an access opening to receive the cable 416 or tightened to secure the cable 416. While the cable 416 of the assembly of the grounding cable 412 is illustrated within the clipping structure 414, those of skill in the art will appreciate that any cable, including active connecting cables may be so coupled  
25 with the clipping structure 414.

While the probes 420, 422 and the inactive openings 410 may be of any appropriate design that allows the probes 420, 422 to be receive and held relatively securely within the inactive openings 410, one or more of the inactive openings 410 may include an engaging structure 428 adapted to inhibit separation  
30 of the probe 420, 422 from the inactive opening 410. For example, the engaging

structure 428 may be one or more protrusions, such as an annular protrusion, or an internal thread.

Turning now to FIGS. 17-18, the front plate 110 including a positive terminal 116 and a negative terminal 118 electrically connected to the battery 114 may likewise include the inactive openings 410. In order to shield the front plates 110 or a portion of the front plates 110 of a battery module 106 or battery pack 102, a faceplate 430 may be provided. A plurality of non-conductive coupling structures such as a plurality of faceplate couplers 432 may be provided. The faceplate couplers 432 may include, for example a tubular structure 434 through which an elongated threaded shaft 436 may extend. In the illustrated embodiment, the elongated threaded shaft 436 is receive within the inactive opening 410. The elongated threaded shaft 436 may extend through a tubular structure 434, or the threaded shaft and tubular structure may be unitarily formed. A bore (not visible) of the faceplate 430 may then be placed over the threaded shaft 436, and a coupler such as a nut 438 coupled to the threaded shaft 436 to secure the faceplate 430 with the inactive openings 410 of at least one of the front plate 110 and the rear plate 112.

Turning to FIGS. 19 and 20, the inactive openings 410 may likewise be utilized to secure one or more coupling structures 440 to a battery module 106 or battery pack 102. In this embodiment, coupling structures include elongated bands 442 disposed along the rear plates 112 of a battery pack 102, and a pair of supports 444 disposed between the elongated bands 442. The supports 444 are coupled through the elongated bands 442 to the inactive openings 410 with coupling structure couplers 446 or other arrangement. The elongated bands 442 or supports 444 may be utilized to couple the battery pack 102 to an installation, for example.

The method of constructing a battery pack 102, may thus include disposing at least one of a grounding cable 412, a clipping structure 414 adapted to receive a cable 416, or a supplemental, non-conductive attachment into at least one inactive opening 410 in at least one of the rear plate 112 and the front plate 110.

### Industrial Applicability

The present disclosure is applicable to battery packs utilized in various machines and applications. The battery system may include a plurality of battery modules including batteries of varying values of power output and voltage output, optional bases of varied sizes, and couplers, such as bolts or rivets, from which various sizes and configurations of battery packs may be constructed. As a result, the battery system may provide individualized battery packs of desired power output and voltage output based upon the configuration.

The battery system may provide an arrangement for organization and maintenance of a large number of cables and connections. The battery system may provide structure for grounding of cables with the battery module structure itself. Additionally, the battery system may provide structure for organization of connections within and between battery modules. The battery system may provide a mechanism for non-conductive connections with external structures without increasing the physical size of the battery module. Further, the battery system may provide connection points that serve a dual purpose. The battery system may provide a single casting that fits across a family of configurations. The battery system may provide an economical arrangement for increasing versatility of battery modules and packs.

The battery system may utilize a standard size of battery modules to address design needs of various applications. Inasmuch as battery packs may be assembled to meet the requirements of an application, the battery system may facilitate the construction of battery packs to meet the battery requirements and volumes of low volume applications as well as high volume applications.

This use of standardized sizes and performance may result in reduced costs and investment in inventory and warehousing, as well as investment in validation.

In at least some applications, the battery system may facilitate the construction of battery packs to not only meet the power output and voltage requirements, but also the physical constraints of the application. That is, in at

least some applications, a battery pack may be constructed to fit within a given geometric space afforded in a machine, for example.

Battery packs constructed according to the teachings of this disclosure may require no external framework or rack for support of the individual modules. This practical construction may simplify the design of battery packs, as well as minimize the manufacturing costs of such construction, particularly in low volume applications.

It will be appreciated that the assembly and electrical connection of at least some embodiments may be performed partially or completely at a manufacturing facility, an assembly facility, or on site, allowing flexibility in the construction and shipment of such battery packs.

As battery modules are used in various applications, the power output and voltage output may diminish over time. Accordingly, a battery system according to teachings of this disclosure may be utilized to repurpose battery modules for a second life in different battery packs. This repurposing may reduce the volume of batteries scrapped or disassembled for recycling of interior metals. Thus, this repurposing may result in an environmentally friendly arrangement in that it may minimize batteries sent to landfill.

It will be appreciated that the foregoing description provides examples of the disclosed system and technique. However, it is contemplated that other implementations of the disclosure may differ in detail from the foregoing examples. All references to the disclosure or examples thereof are intended to reference the particular example being discussed at that point and are not intended to imply any limitation as to the scope of the disclosure more generally. All language of distinction and disparagement with respect to certain features is intended to indicate a lack of preference for those features, but not to exclude such from the scope of the disclosure entirely unless otherwise indicated.

Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All

methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

The use of the terms “a” and “an” and “the” and “at least one” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of the term “at least one” followed by a list of one or more items (for example, “at least one of A and B”) is to be construed to mean one item selected from the listed items (A or B) or any combination of two or more of the listed items (A and B), unless otherwise indicated herein or clearly contradicted by context.

Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein or otherwise clearly contradicted by context.

Claims

1. A battery module (106) for construction of a battery pack (102), the battery module (106) comprising:
- 5 a rectangular housing (108), the housing (108) including an upper face (134), a bottom face (135), a first side face (136) extending between the upper face (134) and the bottom face (135), a second side face (136) extending between the upper face (134) and the bottom face (135), a front open end (111) and a rear open end (113), the housing (108) including a plurality of housing bores (142) extending substantially perpendicular through the upper face (134),
- 10 the bottom face (135), the first side face (136) and the second side face (136) proximal to the front open end (111), and a plurality of housing bores (142) extending substantially perpendicularly through the upper face (134), the bottom face (135), the first side face (136) and the second side face (136) proximal to the rear open end (113);
- 15 a battery (114) disposed within the rectangular housing (108);
- a rear plate (112), the rear plate (112) closing the rear open end (113) of the housing (108), the rear plate (112) including a plurality of rear plate (112) bores in axial alignment with the plurality of housing bores (142) proximal the rear open end (113) of the housing (108);
- 20 a front plate (110), the front plate (110) closing the front open end (111) of the housing (108), the front plate (110) including a positive terminal (116) and a negative terminal (118) electrically connected to the battery (114), the battery (114) being sealed within the rectangular housing (108), the rear plate (112), and the front plate (110), the front plate (110) including a plurality of front
- 25 plate (110) bores in axial alignment with the plurality of housing bores (142) proximal the front open end (111) of the housing (108); and
- at least one of a grounding cable (412), a clipping structure (414) adapted to receive a cable (416), or a supplemental, non-conductive attachment;
- at least one of the rear plate (112) and the front plate (110)
- 30 including at least one inactive opening (410), said at least one of said grounding

cable (412), the clipping structure (414) adapted to receive a cable (416), or the supplemental, non-conductive attachment being received by said inactive opening (410).

5                    2.        The battery module (106) of claim 1 wherein at least one of said inactive openings (410) includes an engaging structure (428) adapted to maintain the at least one of the grounding cable (412), the clipping structure (414) adapted to receive a cable (416), or the supplemental, non-conductive attachment, said engaging structure (428) inhibiting separation of the at least one  
10 of the grounding cable (412) and the clipping structure (414) from said inactive opening (410).

                    3.        The battery module (106) of claim 2 wherein the engaging structure (428) is at least one of at least one protrusion and at least one internal  
15 thread.

                    4.        The battery module (106) of claim 1 wherein the at least one of the rear plate (112) and the front plate (110) is a casting.

20                   5.        The battery module (106) of claim 1 wherein the clipping structure (414) includes a probe (422) adapted to be received within said at least one inactive opening (410).

                    6.        The battery module (106) of claim 5 wherein the clipping  
25 structure (414) further includes at least one annular channel (424) sized to receive a cable (416).

                    7.        The battery module (106) of claim 1 wherein the at least one inactive opening (410) is a recess, said recess not extending through the at  
30 least one of the rear plate (112) and the front plate (110).

8. A battery pack (102) comprising:

a plurality of battery modules (106) according to any of claims 1-7, further including

at least two couplers (130) securing together at least a first said  
5 battery module (106) and a second said battery module (106), at least a first of  
said couplers (130) being disposed through at least one of the plurality of rear  
plate bores (141) in axial alignment with at least one of the plurality of housing  
bores (142) proximal the rear open end (113) of the housing (108), and at least a  
second of said couplers (130) being disposed through at least one of the plurality  
10 of front plate bores (141) in axial alignment with at least one of the plurality of  
housing bores (142) proximal the front open end (111) of the housing (108); and  
a plurality of electrical couplers electrically coupling the terminals  
(116, 118) of the at least a first said battery module (106) and a second said  
battery module (106).

15

9. The battery pack (102) of claim 8 further including a

faceplate (430) and the non-conductive coupling structures includes a plurality of  
faceplate couplers (432), the faceplate couplers (432) securing the faceplate (430)  
with the inactive openings (410) of at least one of the front plate (110) and the  
20 rear plate (112).

10. A method of constructing a battery pack (102), the method  
comprising:

providing a plurality of battery modules (106) according to any of  
25 claims 1-7

disposing a rectangular housing (108) of a first battery module  
(106) of said plurality of battery modules (106) adjacent a rectangular housing  
(108) of a second battery module (106) of said plurality of battery modules (106);  
disposing a first coupler through a rear plate (112) bore of said  
30 first battery module (106), a housing bore (142) through the rectangular housing  
(108) of the first battery module (106), a housing bore (142) through the

- rectangular housing (108) of the second battery module (106), and a rear plate bore (141) of said second battery module (106) to secure the first and second battery module (106) together;
- 5 disposing a second coupler through a front plate (110) bore of said second battery module (106), a housing bore (142) through the rectangular housing (108) of the second battery module (106), a housing bore (142) through the rectangular housing (108) of the second battery module (106), and a front plate bore (141) of said second battery module (106) to secure the first and second battery module (106) together; and
- 10 disposing the at least one of a grounding cable (412), a clipping structure (414) adapted to receive a cable (416), or a supplemental, non-conductive attachment into at least one inactive opening (410) in at least one of the rear plate (112) and the front plate (110).

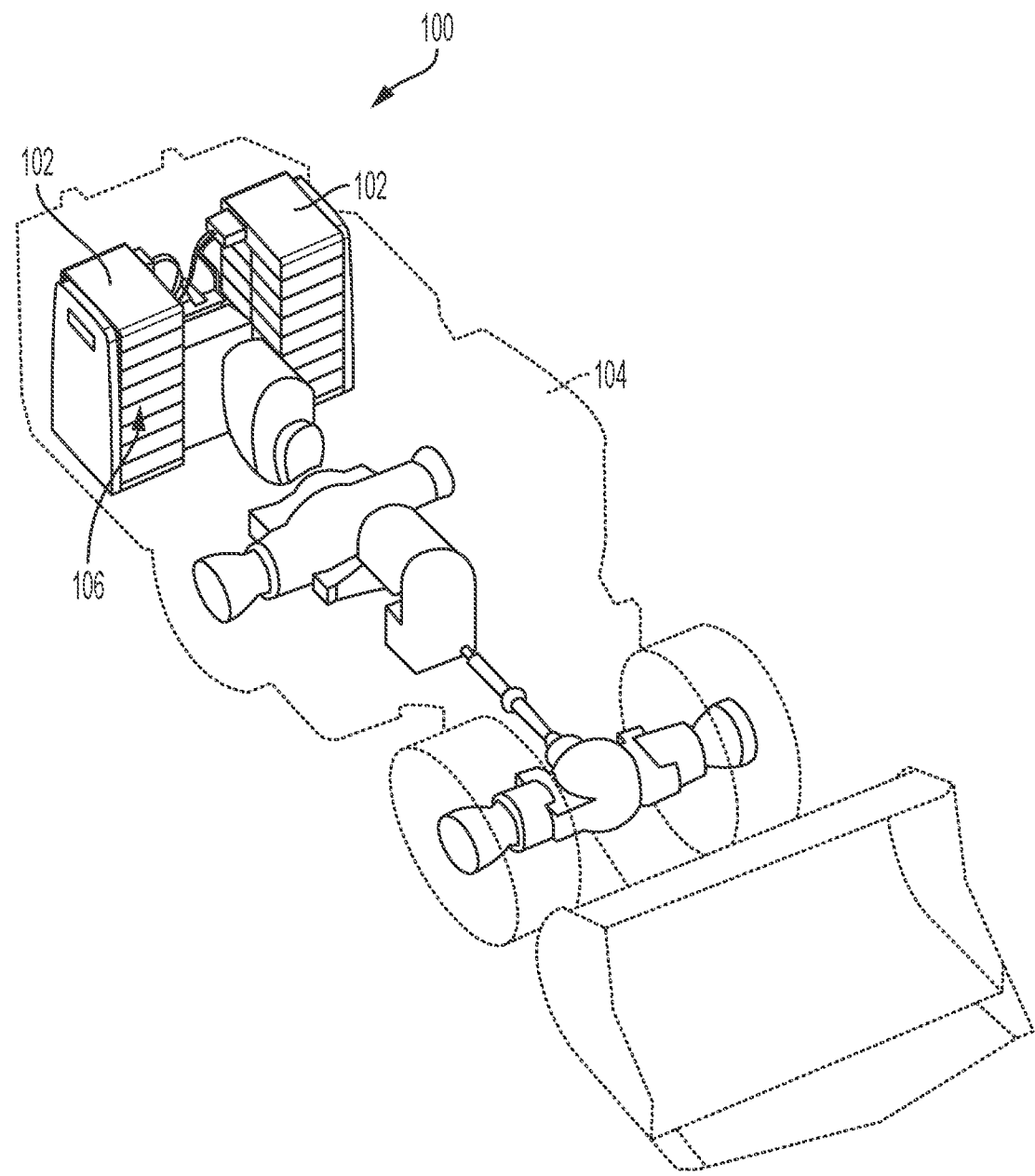


FIG. 1

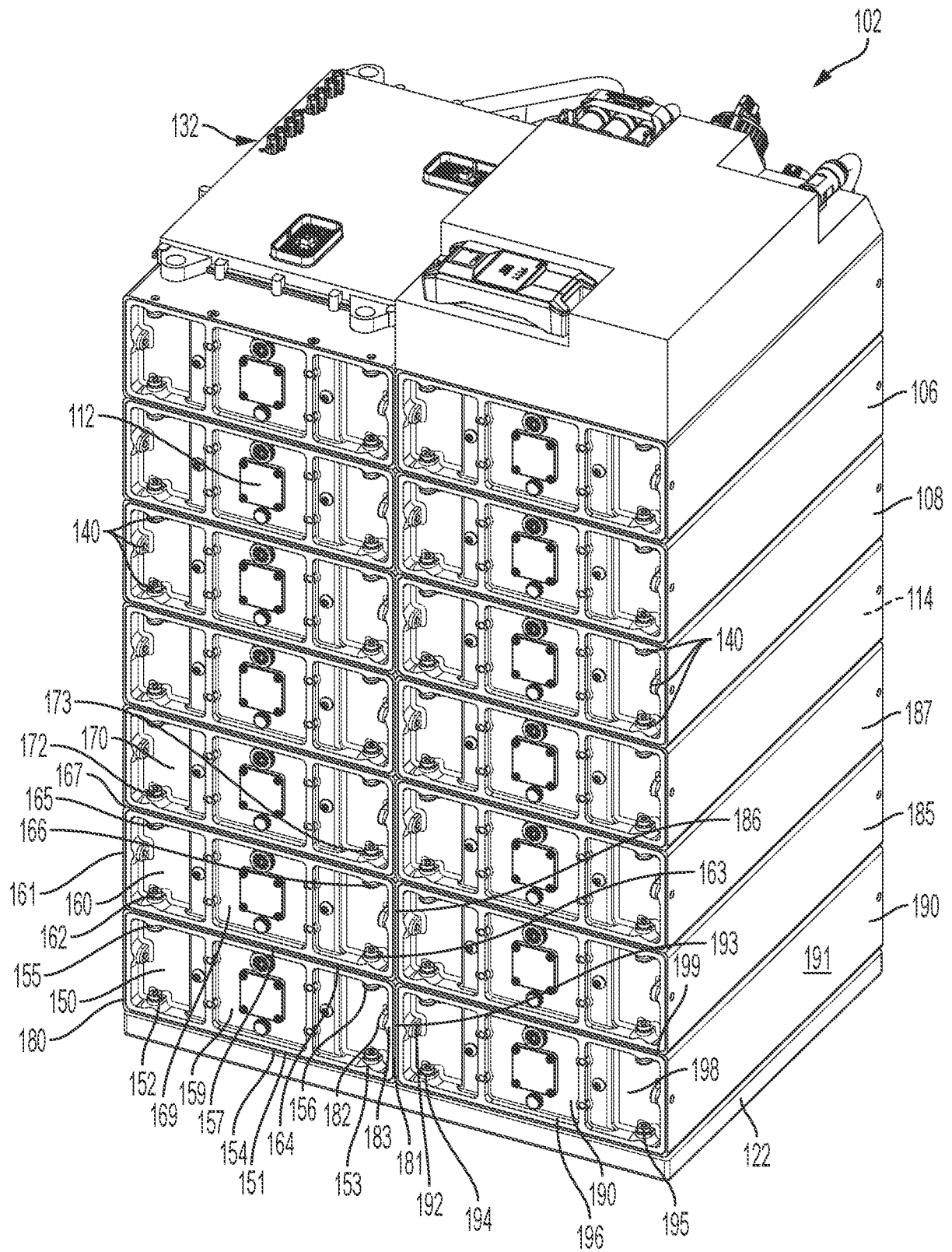


FIG. 2

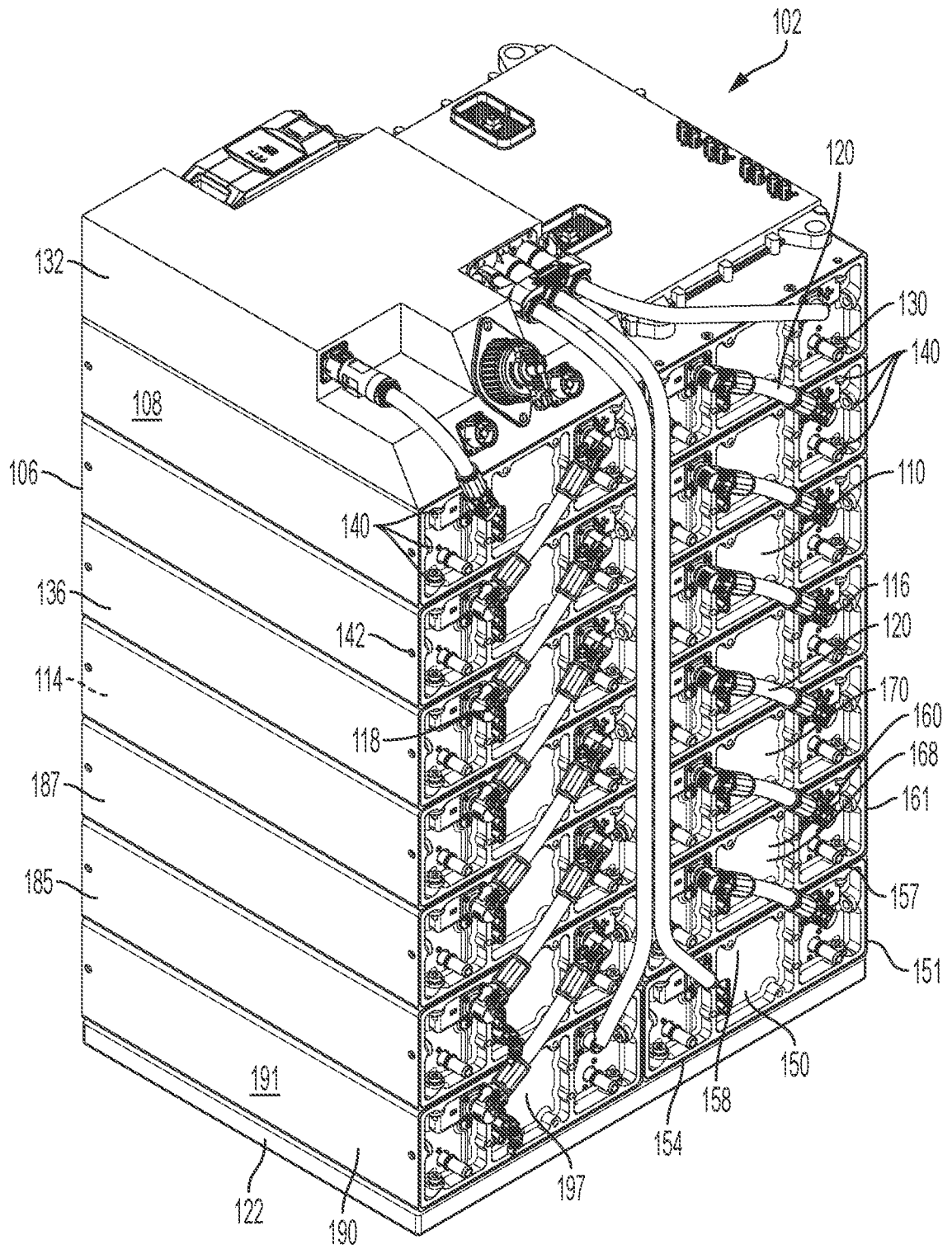
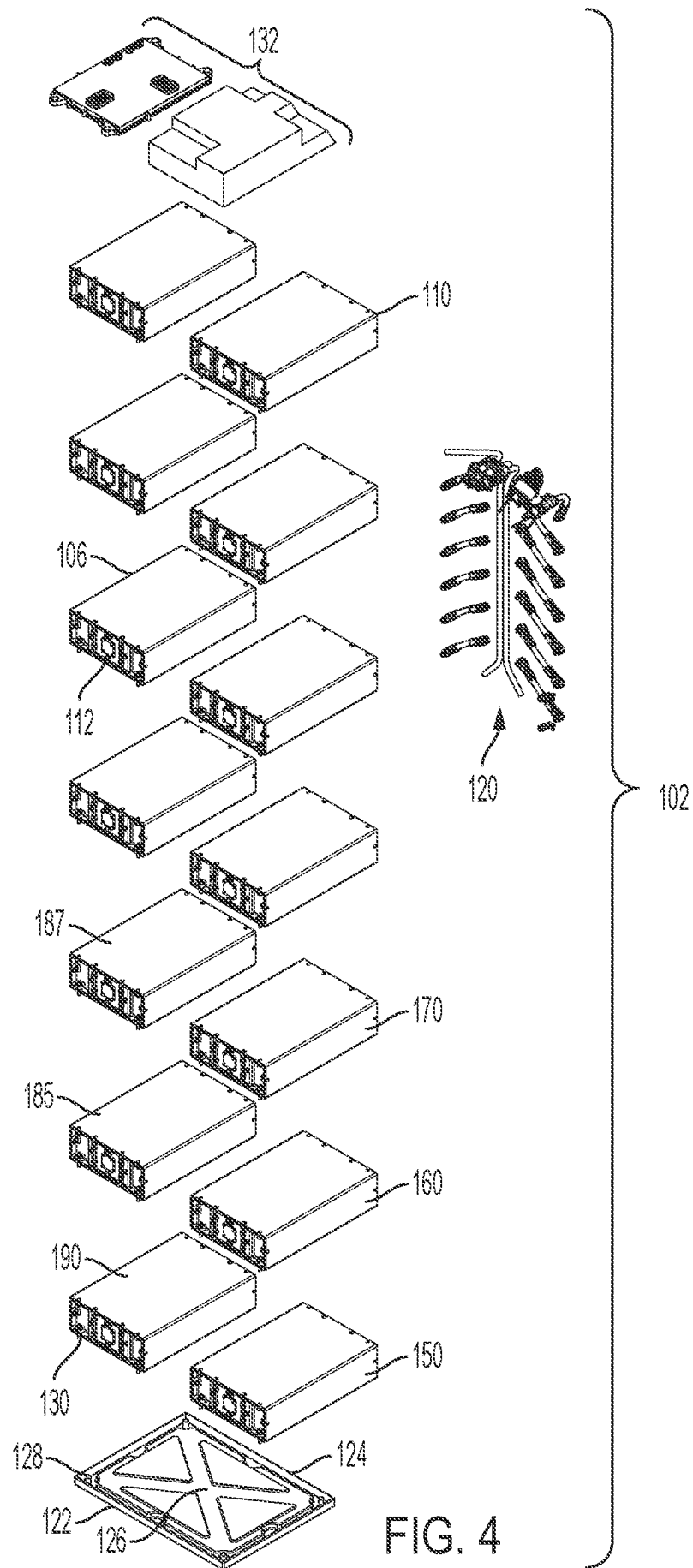


FIG. 3



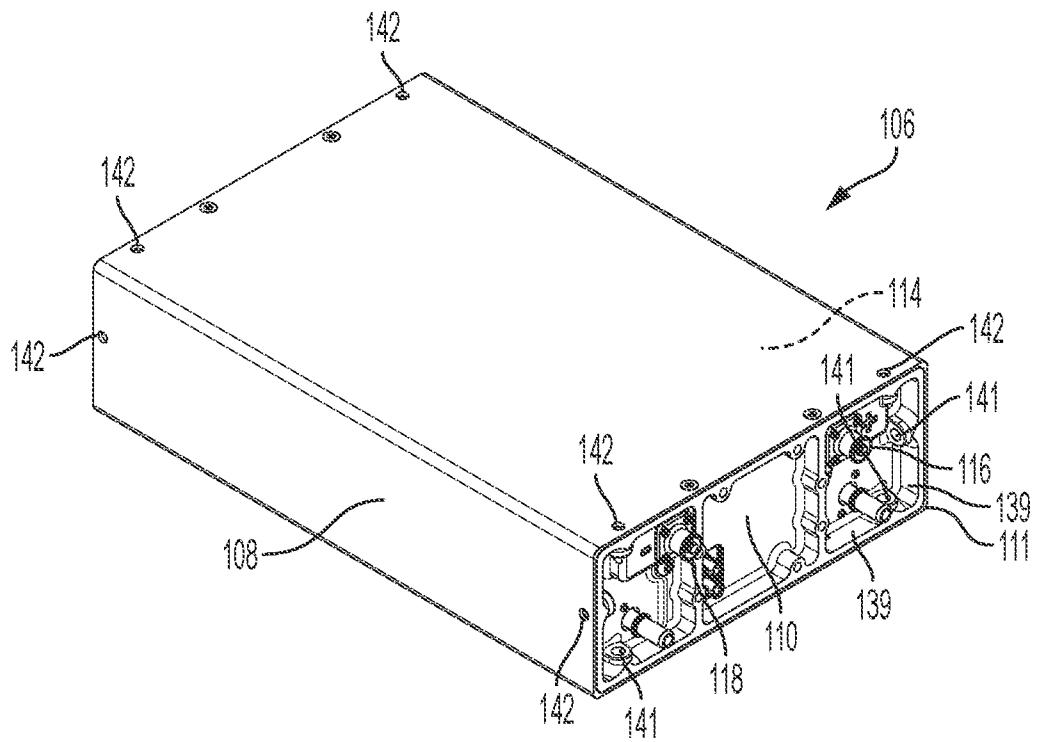


FIG. 5

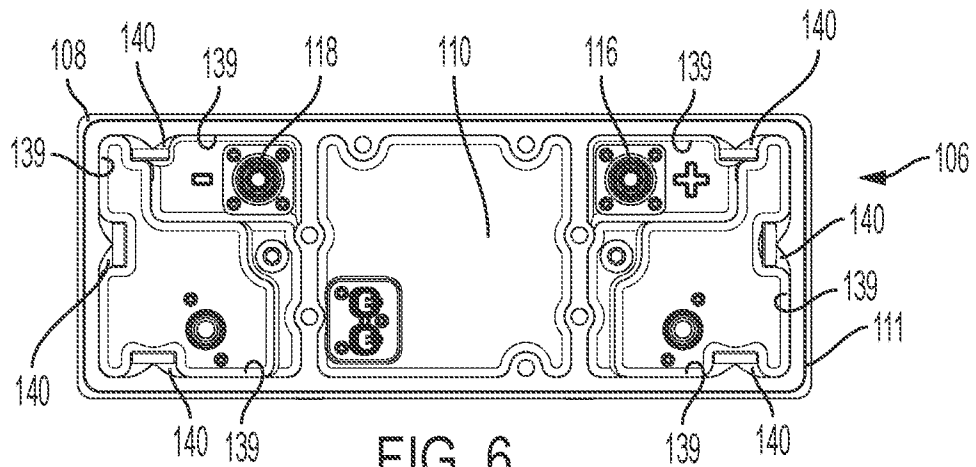


FIG. 6

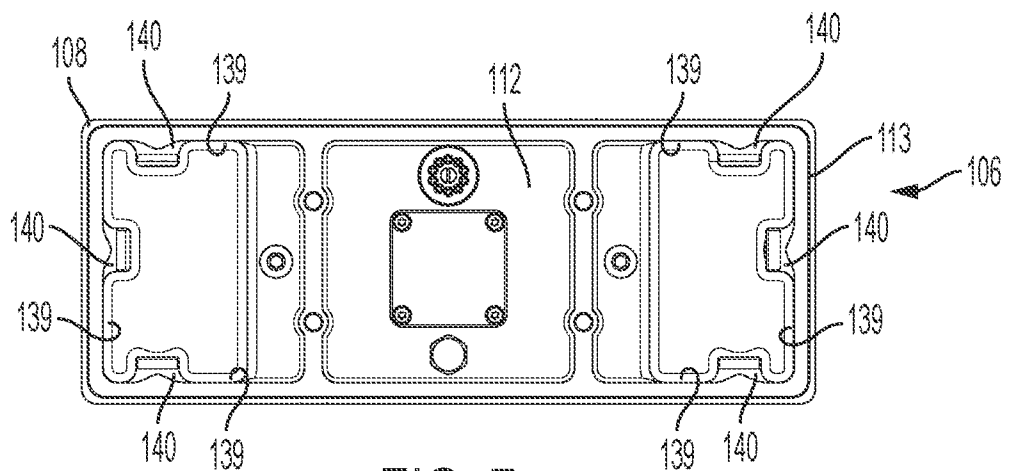


FIG. 7

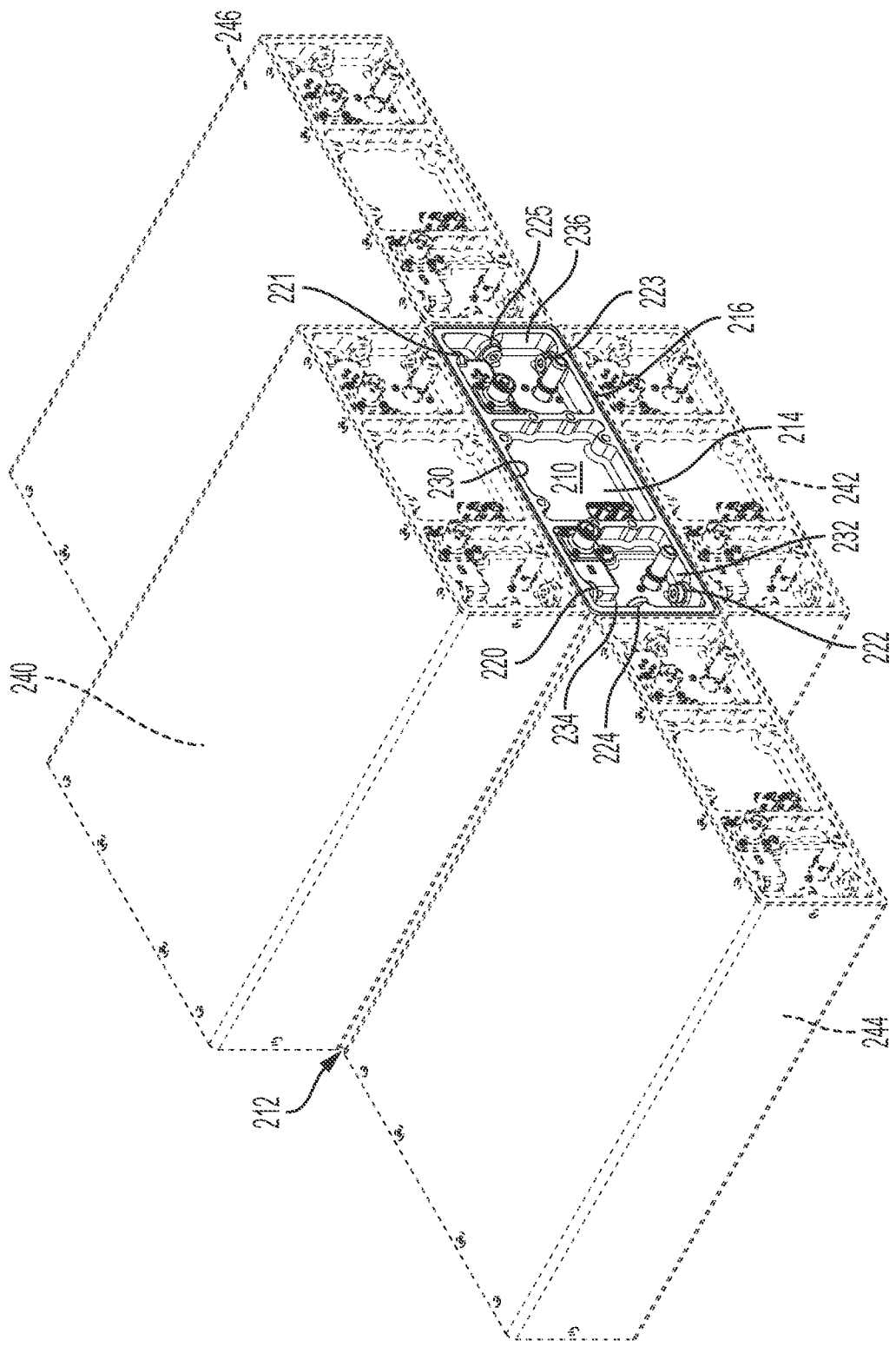
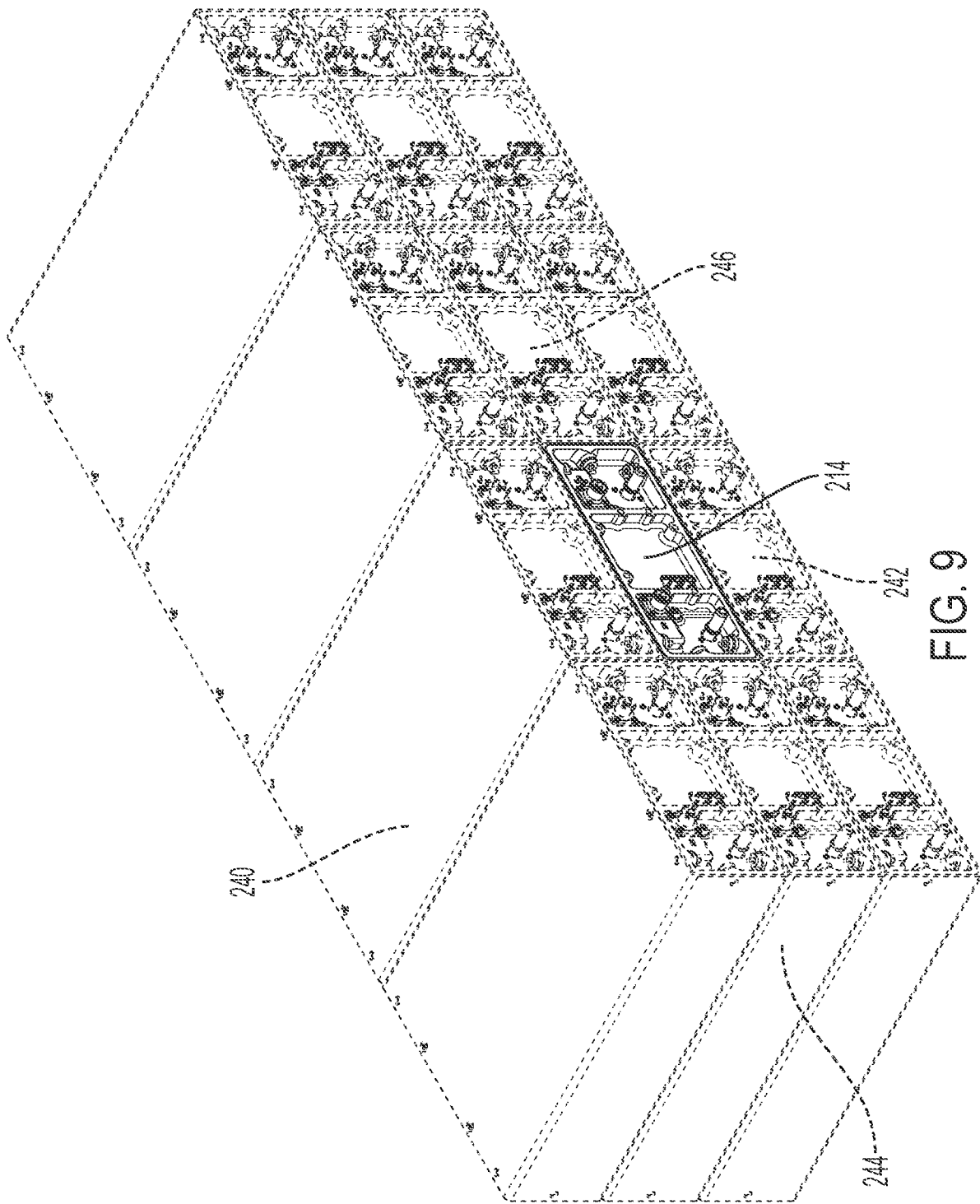


FIG. 8



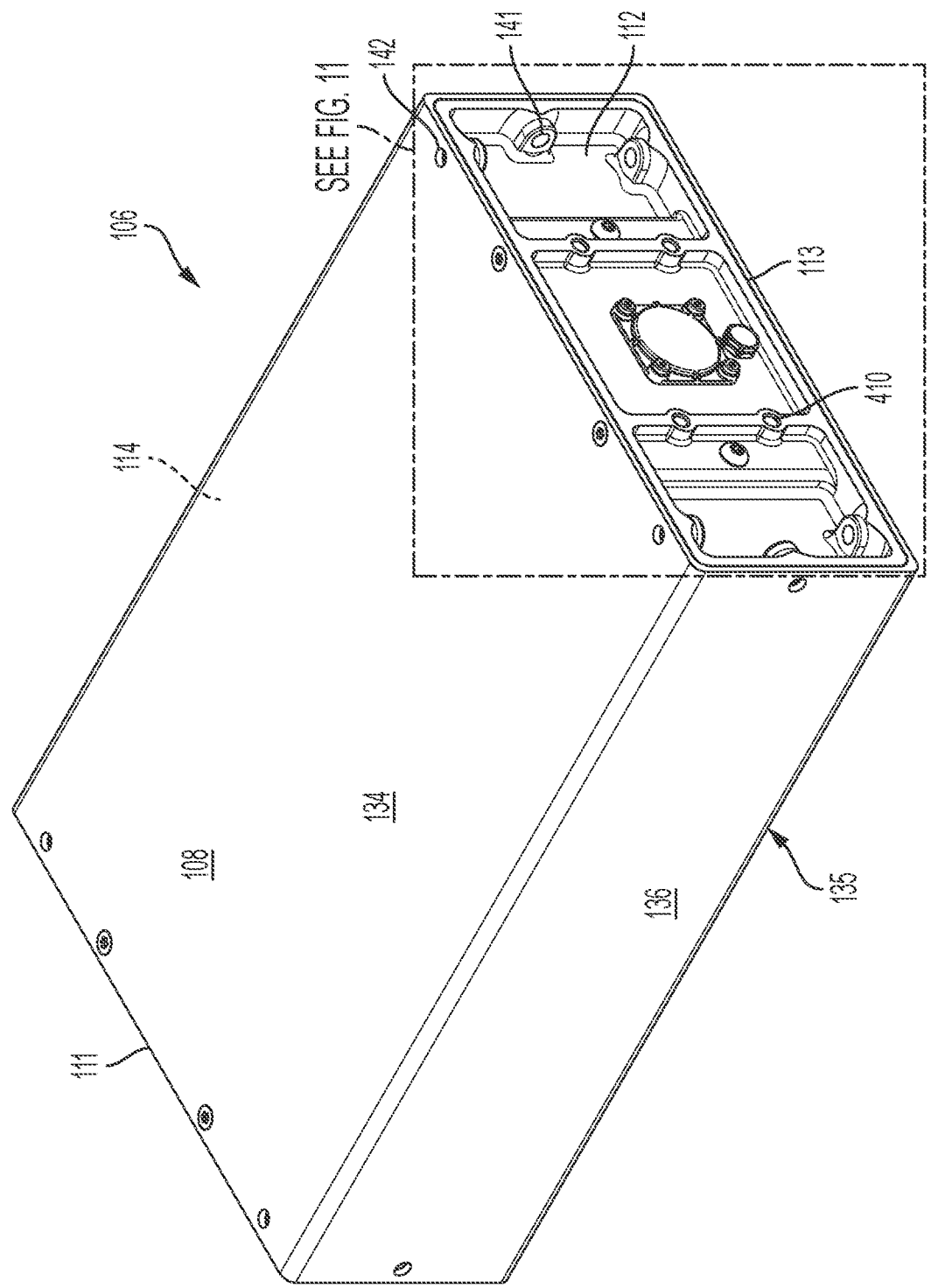


FIG. 10

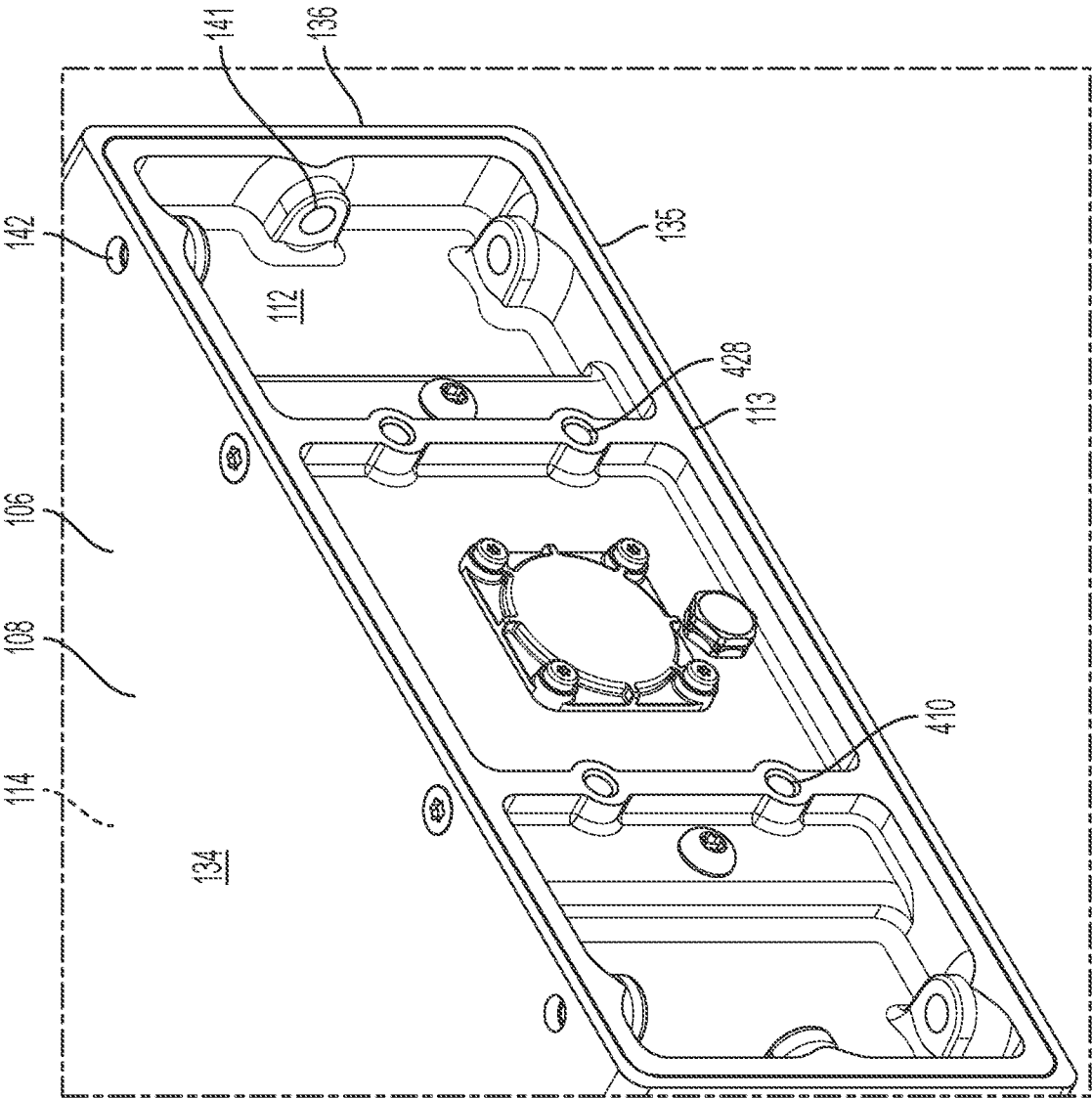
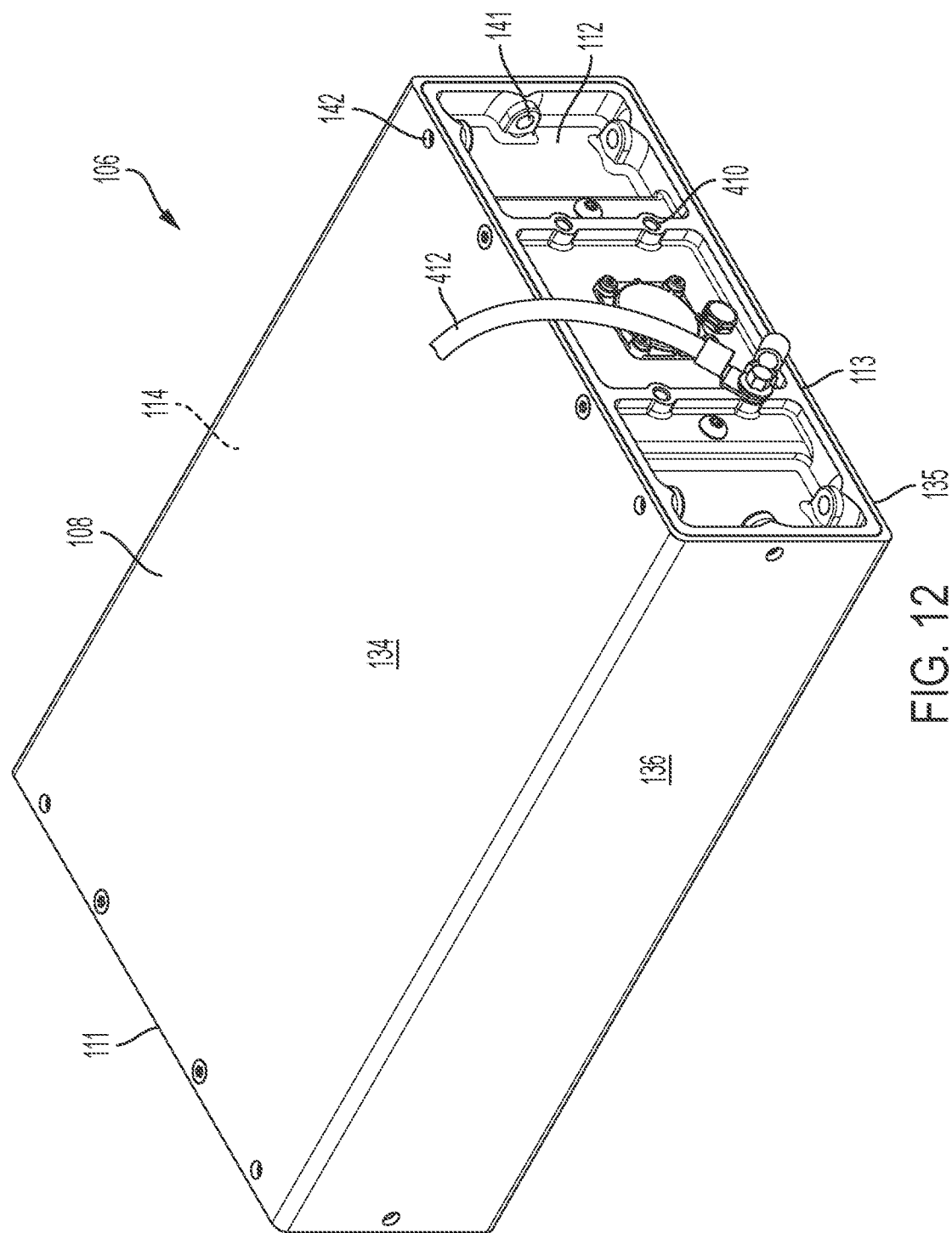
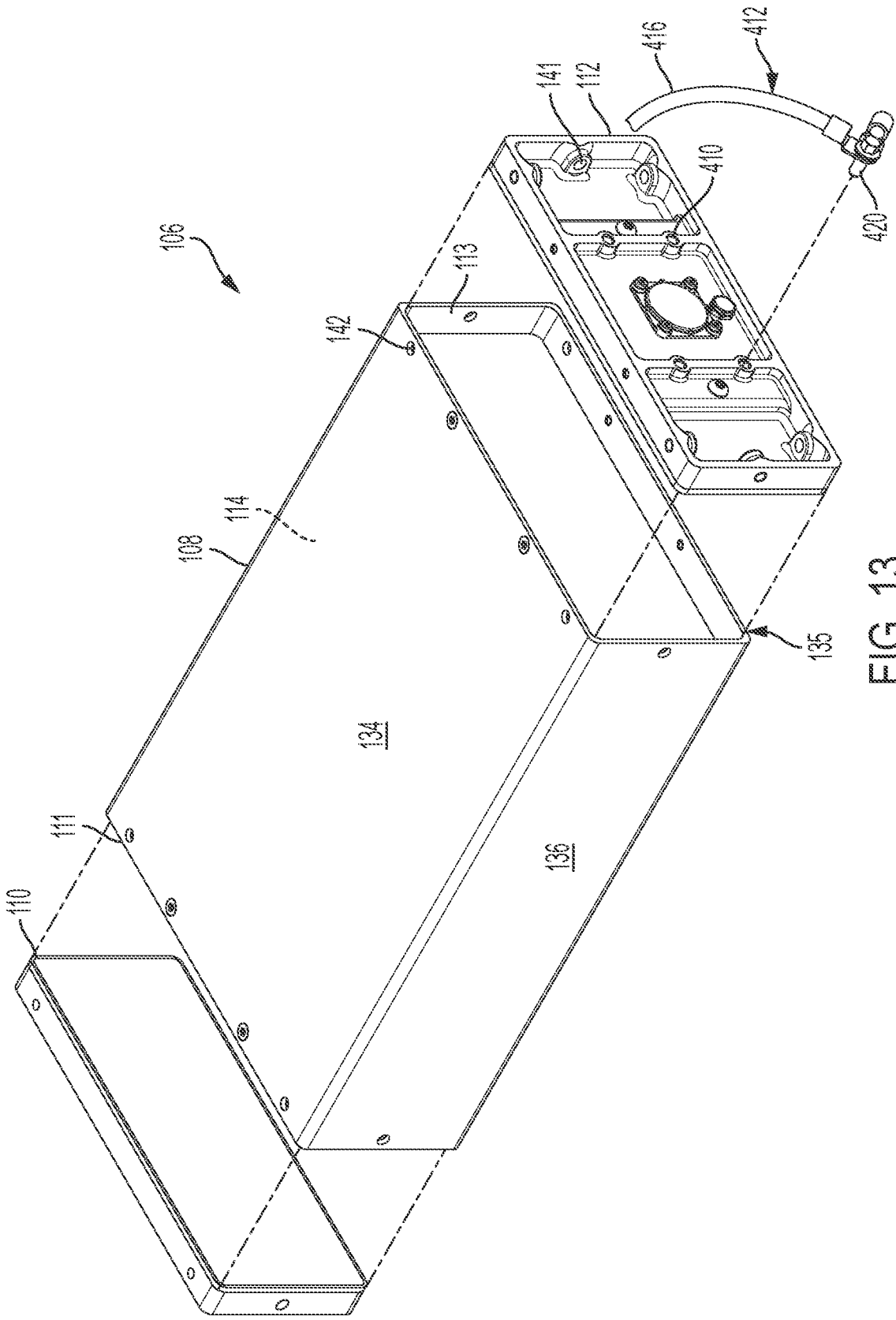
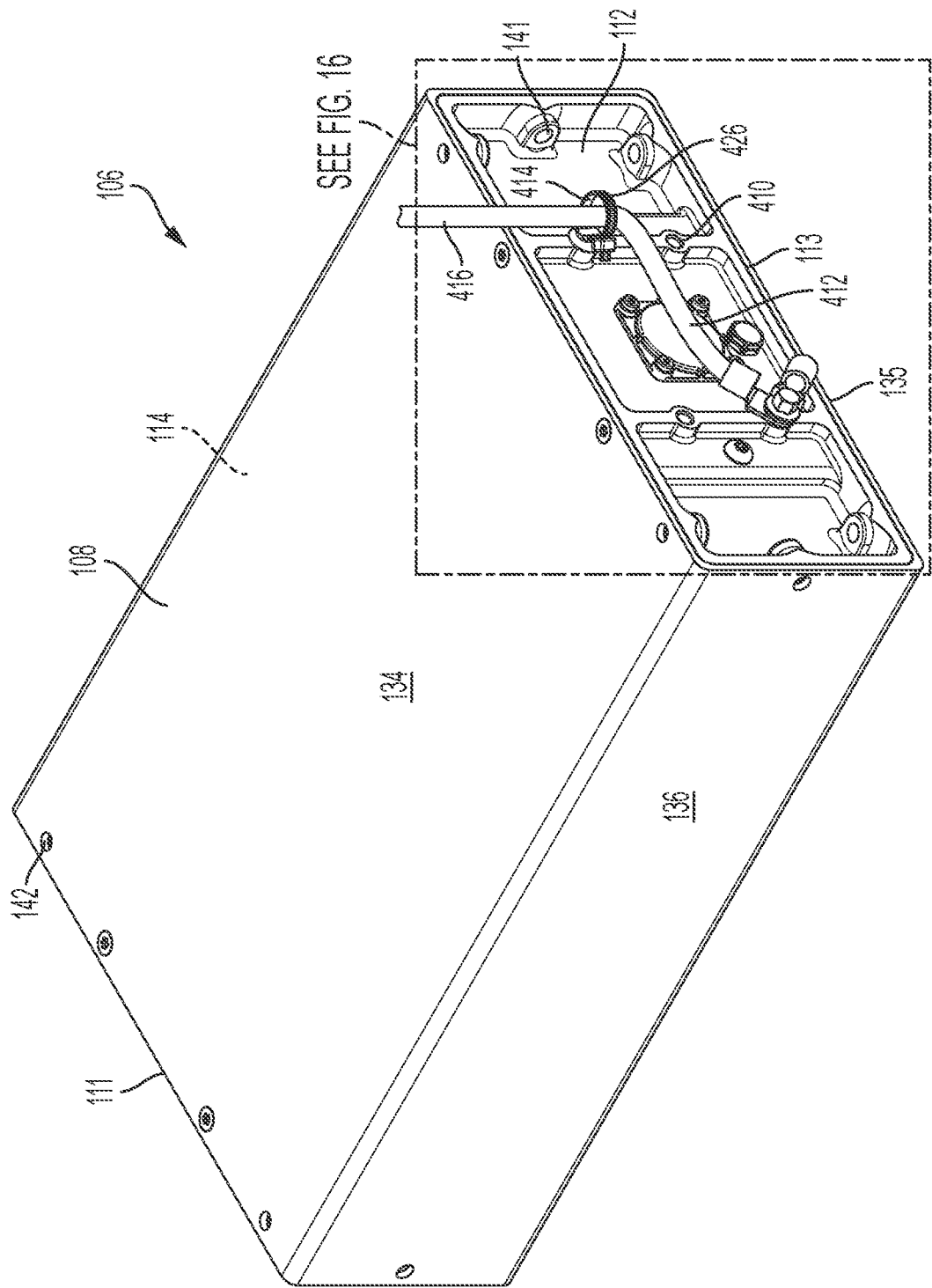
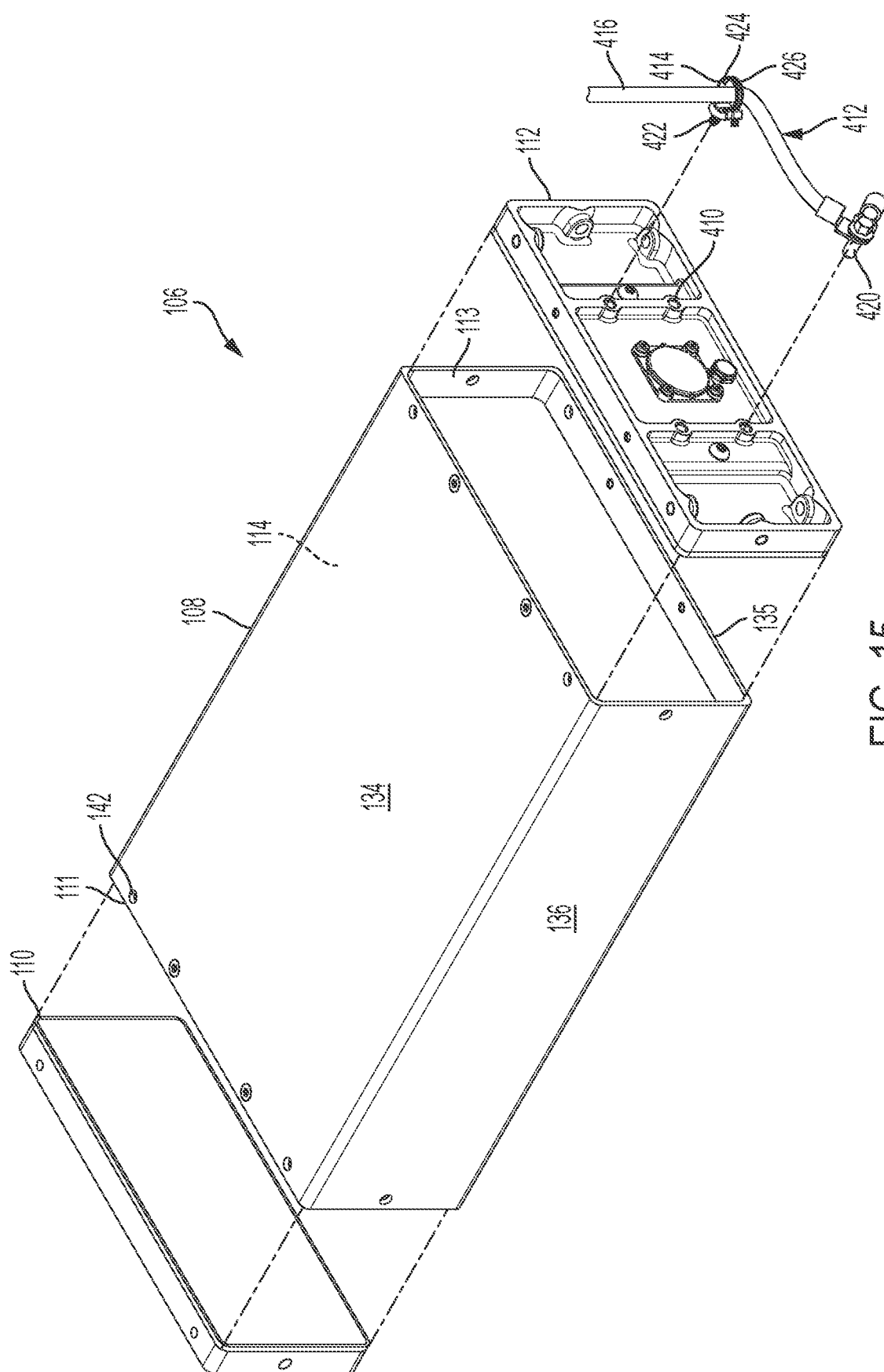


FIG. 11









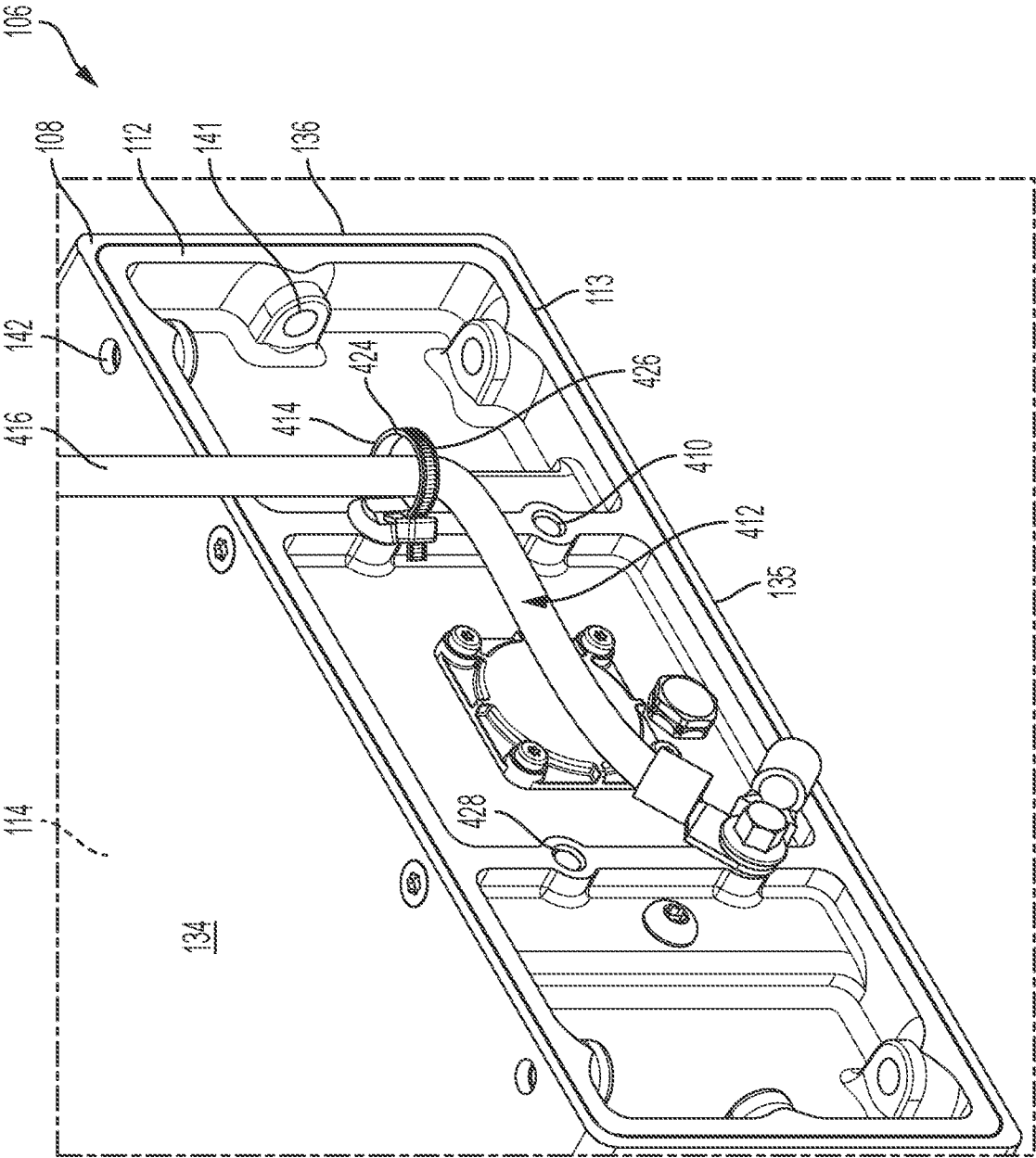


FIG. 16

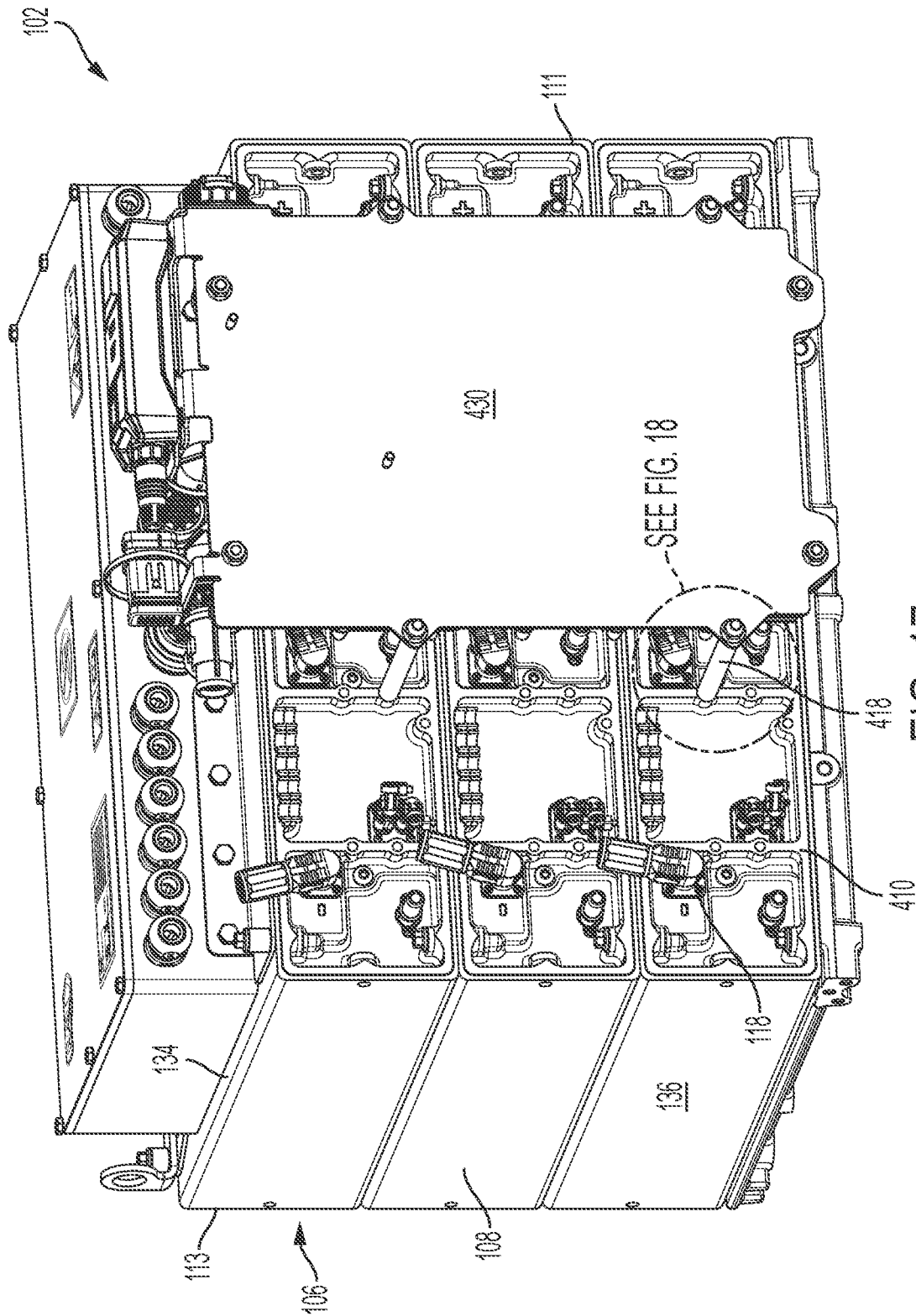


FIG. 17

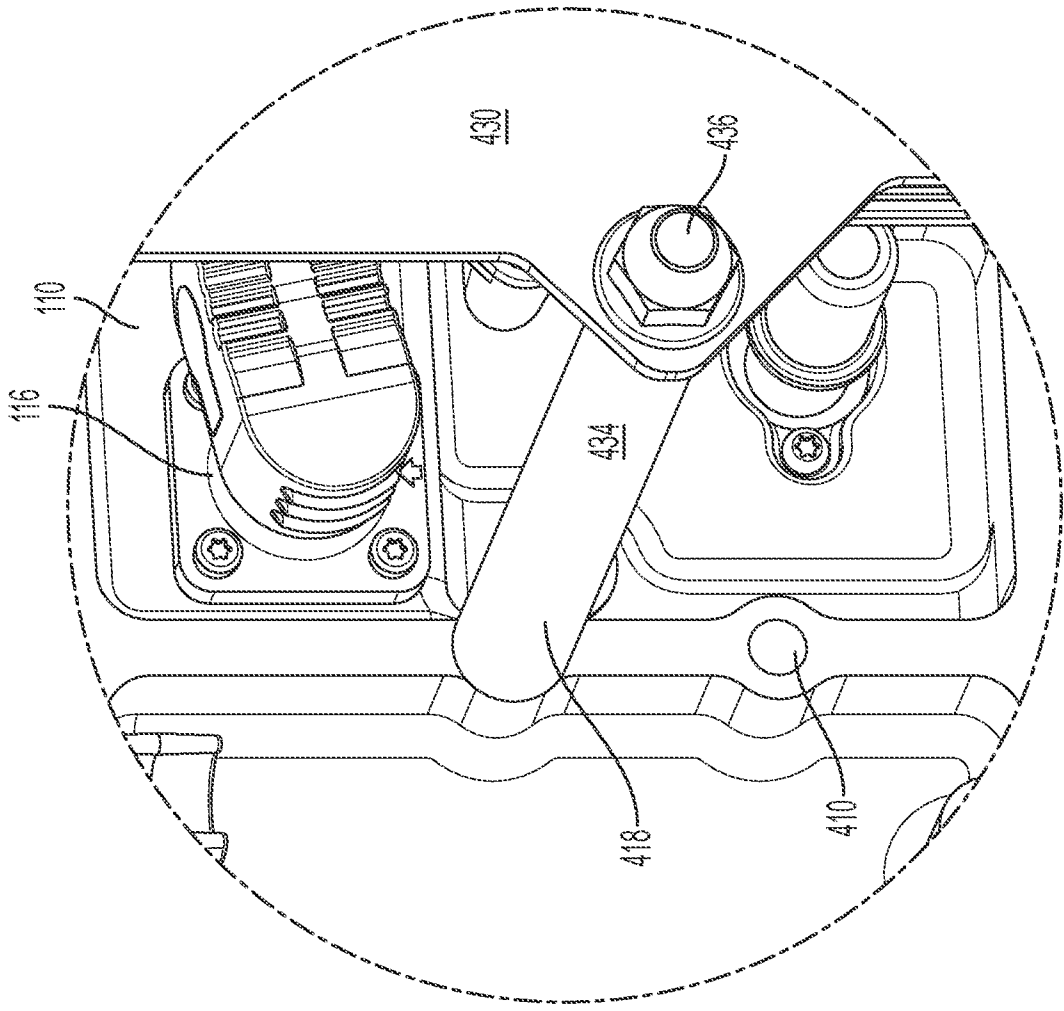
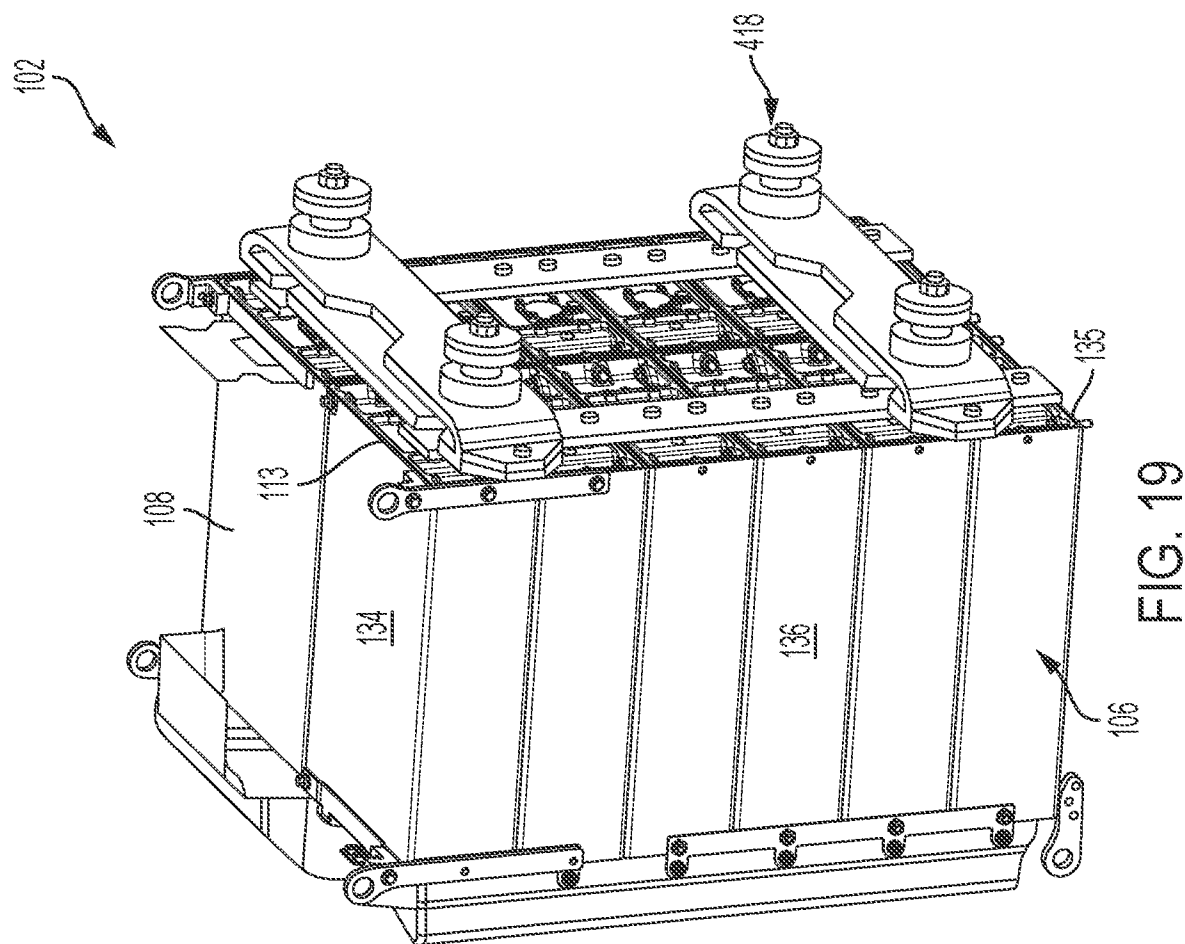


FIG. 18



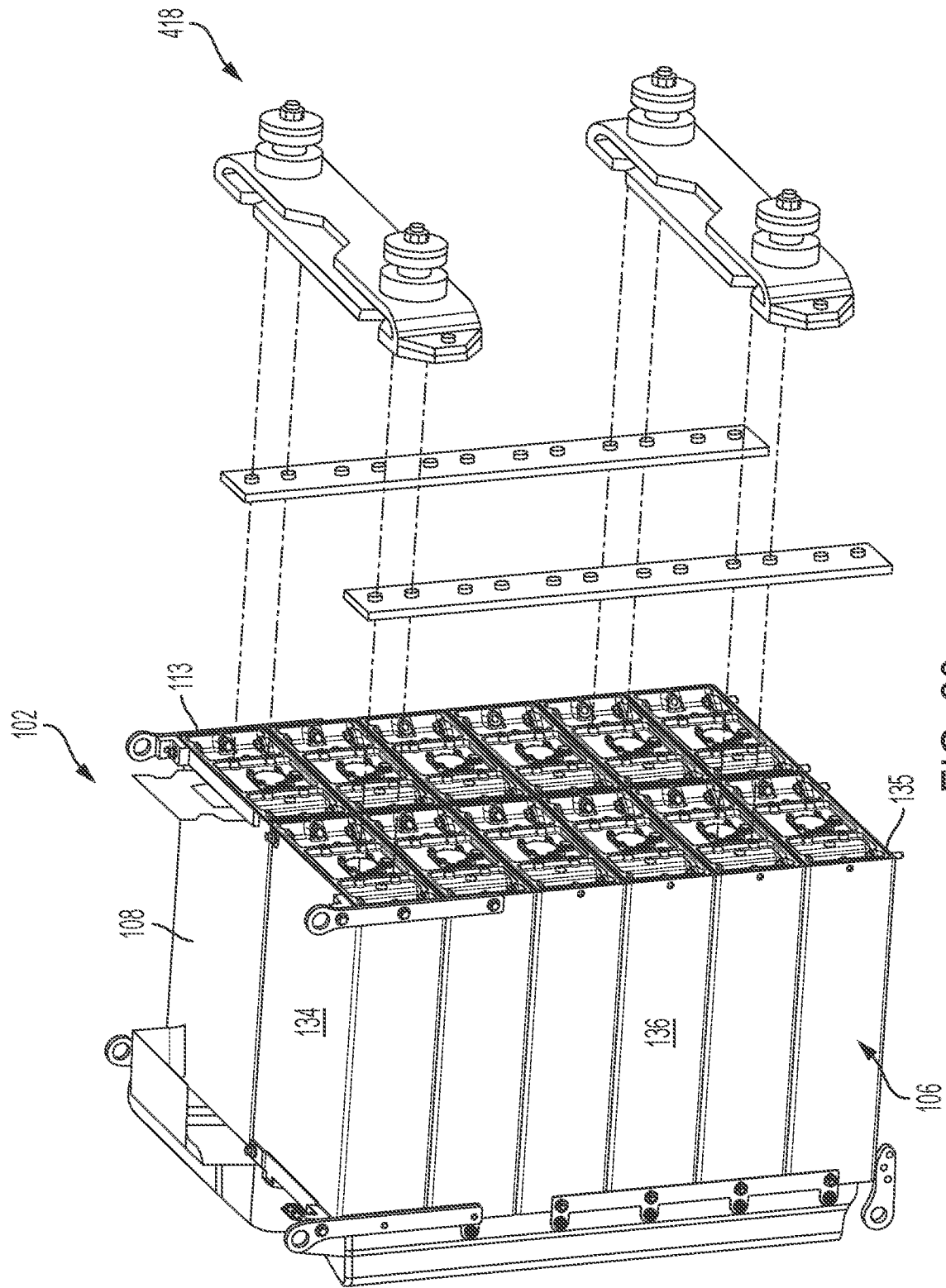


FIG. 20

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2023/019552

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br><b>INV.</b> H01M50/209 H01M50/298 H01M50/502 H01M50/517<br><b>ADD.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                             |                                                                             |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                             |                                                                             |
| <b>B. FIELDS SEARCHED</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                             |                                                                             |
| Minimum documentation searched (classification system followed by classification symbols)<br><b>H01M</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                             |                                                                             |
| 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)<br><b>EPO-Internal</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                             |                                                                             |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                             |                                                                             |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Citation of document, with indication, where appropriate, of the relevant passages                                                          | Relevant to claim No.                                                       |
| <b>Y</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>CN 113 178 653 A (GUOXUAN NEW ENERGY SUZHOU CO LTD) 27 July 2021 (2021-07-27) paragraphs [0054], [0055] figures 1-16</b><br>-----        | <b>1-10</b>                                                                 |
| <b>Y</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>EP 2 980 883 A1 (HONDA MOTOR CO LTD [JP]) 3 February 2016 (2016-02-03) paragraphs [0005] - [0010], [0055] - [0057] figure 6</b><br>----- | <b>1-10</b>                                                                 |
| <b>A</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>WO 2021/113251 A1 (BRIGGS &amp; STRATTON LLC [US]) 10 June 2021 (2021-06-10) paragraph [0039]; figure 8</b><br>-----                     | <b>1-10</b>                                                                 |
| <b>A</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>EP 3 016 173 A1 (LG CHEMICAL LTD [KR]) 4 May 2016 (2016-05-04) paragraphs [0028], [0029], [0061] - [0063]; figure 9</b><br>-----         | <b>1-10</b>                                                                 |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                             |                                                                             |
| * Special categories of cited documents :<br><div style="display: flex; justify-content: space-between;"> <div> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div> <p>"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</p> <p>"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</p> <p>"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</p> <p>"&amp;" document member of the same patent family</p> </div> </div> |                                                                                                                                             |                                                                             |
| Date of the actual completion of the international search<br><br><b>20 July 2023</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                             | Date of mailing of the international search report<br><br><b>27/07/2023</b> |
| Name and mailing address of the ISA/<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                             | Authorized officer<br><br><b>Knoflachner, Andreas</b>                       |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2023/019552

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date       |
|-------------------------------------------|---------------------|----------------------------|---------------------------|
| <b>CN 113178653</b>                       | <b>A</b>            | <b>27-07-2021</b>          | <b>NONE</b>               |
| <hr/>                                     |                     |                            |                           |
| <b>EP 2980883</b>                         | <b>A1</b>           | <b>03-02-2016</b>          | <b>BR 102015017527 A2</b> |
|                                           |                     |                            | <b>02-02-2016</b>         |
|                                           |                     | <b>EP 2980883 A1</b>       | <b>03-02-2016</b>         |
|                                           |                     | <b>JP 6238080 B2</b>       | <b>29-11-2017</b>         |
|                                           |                     | <b>JP 2016030581 A</b>     | <b>07-03-2016</b>         |
|                                           |                     | <b>TW 201612042 A</b>      | <b>01-04-2016</b>         |
|                                           |                     | <b>US 2016031307 A1</b>    | <b>04-02-2016</b>         |
| <hr/>                                     |                     |                            |                           |
| <b>WO 2021113251</b>                      | <b>A1</b>           | <b>10-06-2021</b>          | <b>CN 115004444 A</b>     |
|                                           |                     |                            | <b>02-09-2022</b>         |
|                                           |                     | <b>EP 4070402 A1</b>       | <b>12-10-2022</b>         |
|                                           |                     | <b>US 2022416312 A1</b>    | <b>29-12-2022</b>         |
|                                           |                     | <b>WO 2021113251 A1</b>    | <b>10-06-2021</b>         |
| <hr/>                                     |                     |                            |                           |
| <b>EP 3016173</b>                         | <b>A1</b>           | <b>04-05-2016</b>          | <b>EP 3016173 A1</b>      |
|                                           |                     |                            | <b>04-05-2016</b>         |
|                                           |                     | <b>JP 6166475 B2</b>       | <b>19-07-2017</b>         |
|                                           |                     | <b>JP 2016531395 A</b>     | <b>06-10-2016</b>         |
|                                           |                     | <b>KR 20150022389 A</b>    | <b>04-03-2015</b>         |
|                                           |                     | <b>US 2016164053 A1</b>    | <b>09-06-2016</b>         |
|                                           |                     | <b>WO 2015026103 A1</b>    | <b>26-02-2015</b>         |
| <hr/>                                     |                     |                            |                           |