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(54) **MOTOR CONTROLLER WITH INDUCTOR MOUNTED TRANSVERSE TO CONTROL BOARD**

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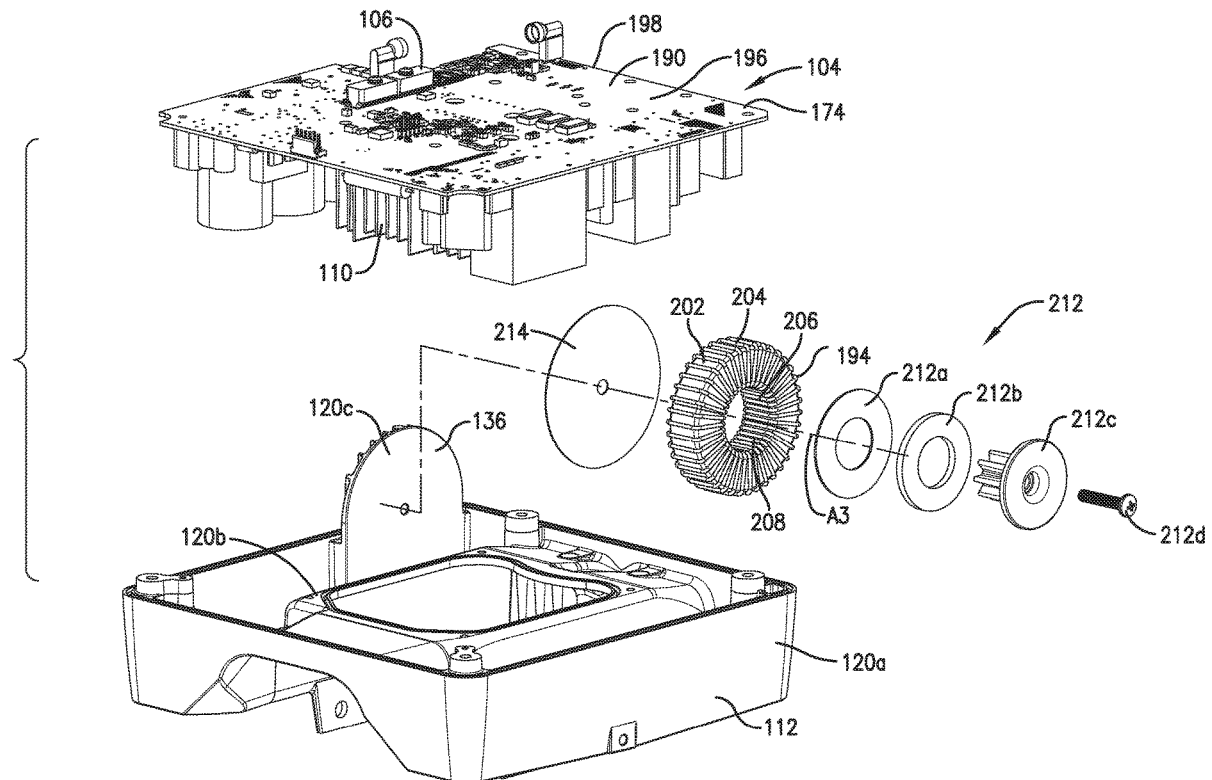
H02K 7/08 (2006.01)

H02K 9/06 (2006.01)

H02K 21/16 (2006.01)

(57) **ABSTRACT**

A motor control assembly is configured to operate an electric motor and includes a control housing and a controller. The control housing presents a controller chamber. The controller includes a control board mounted within the controller chamber. The controller further includes an inductor attached to the control housing and positioned within the controller chamber adjacent the control board. The inductor defines maximum first and second inductor dimensions measured along corresponding first and second directions parallel to a board plane and orthogonal to one another. The inductor further defines a maximum third inductor dimension measured along a third direction transverse to the board plane, with at least one of the first and second inductor dimensions being less than the maximum third inductor dimension.



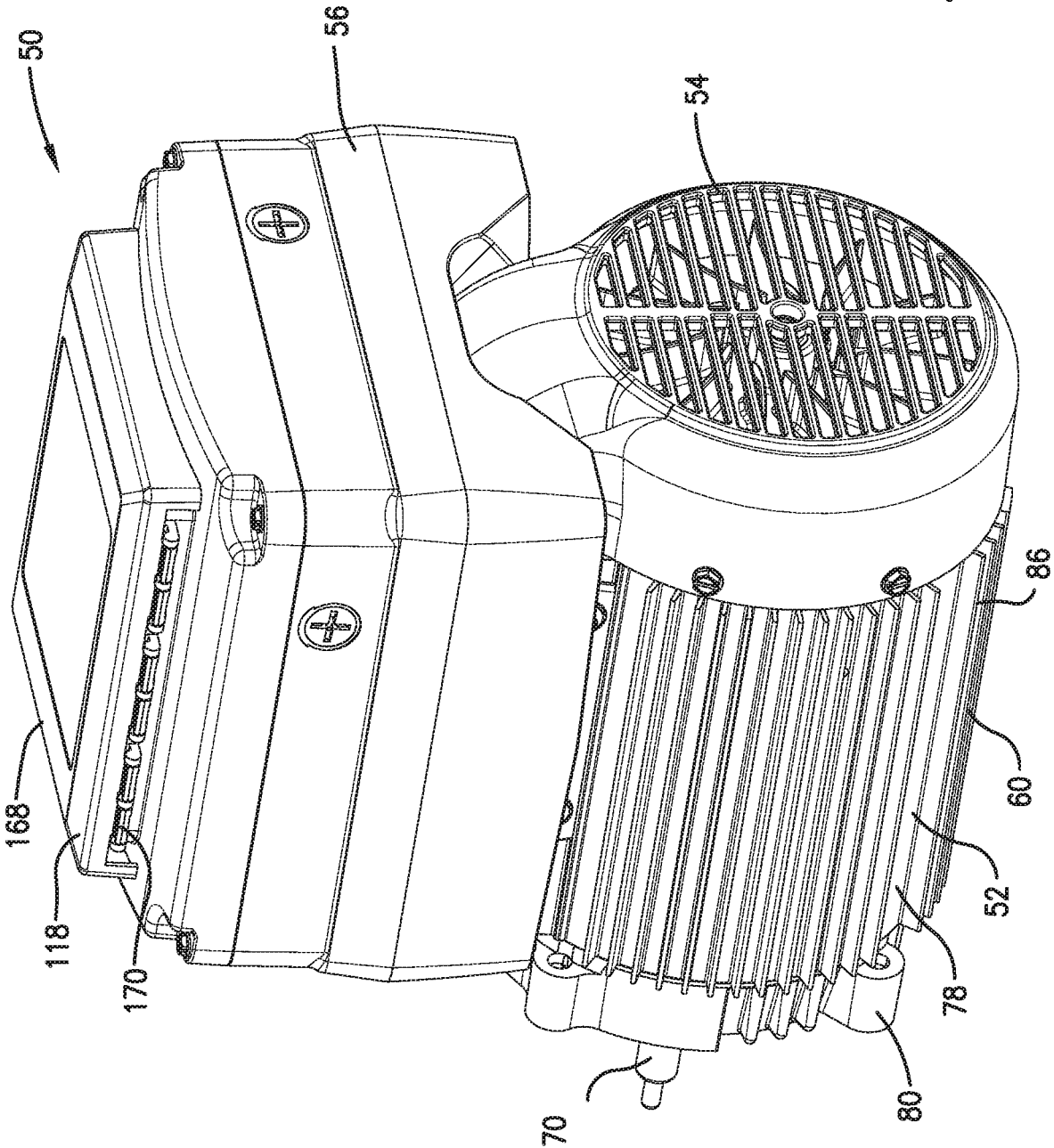


Fig. 1.

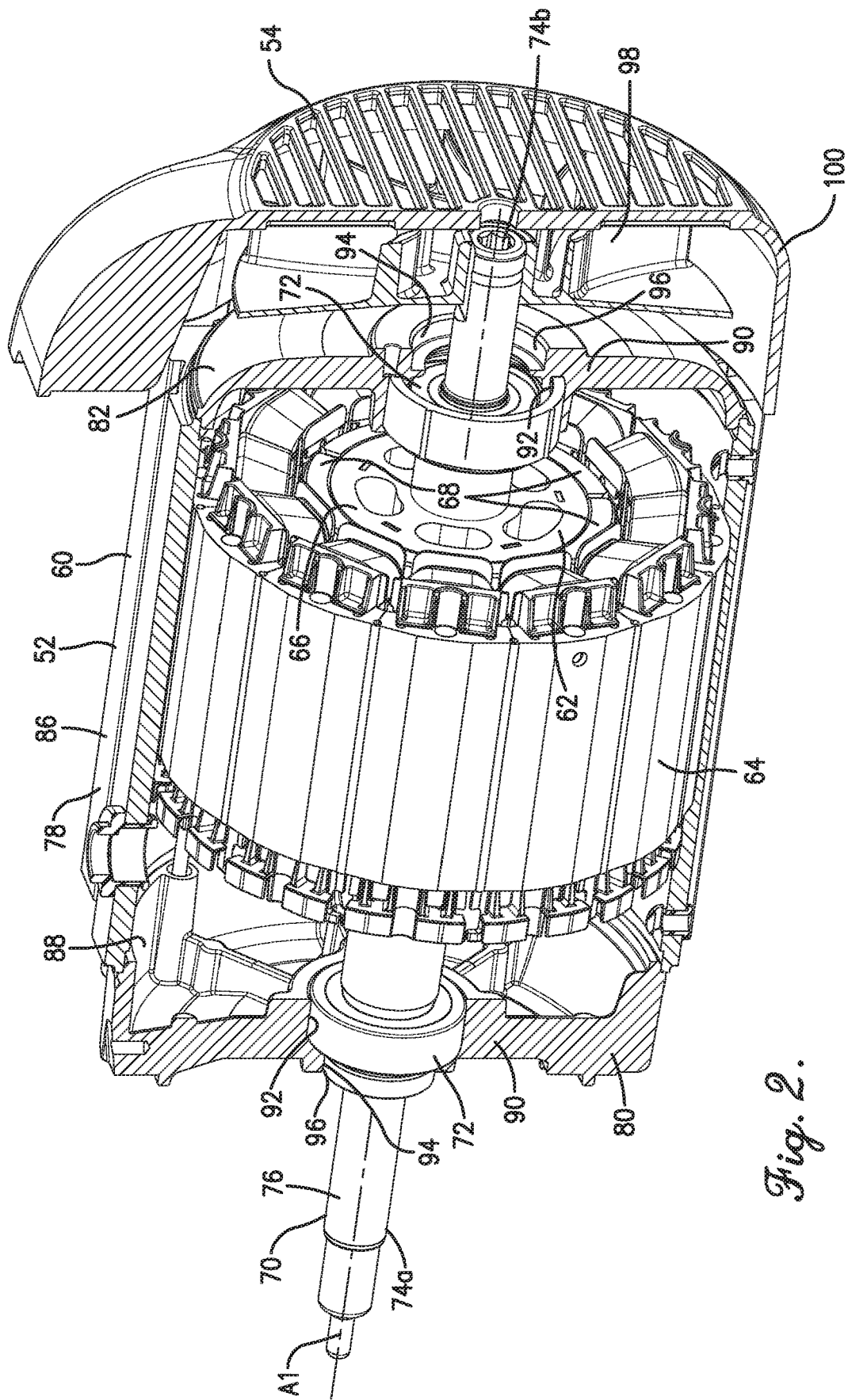


Fig. 2.

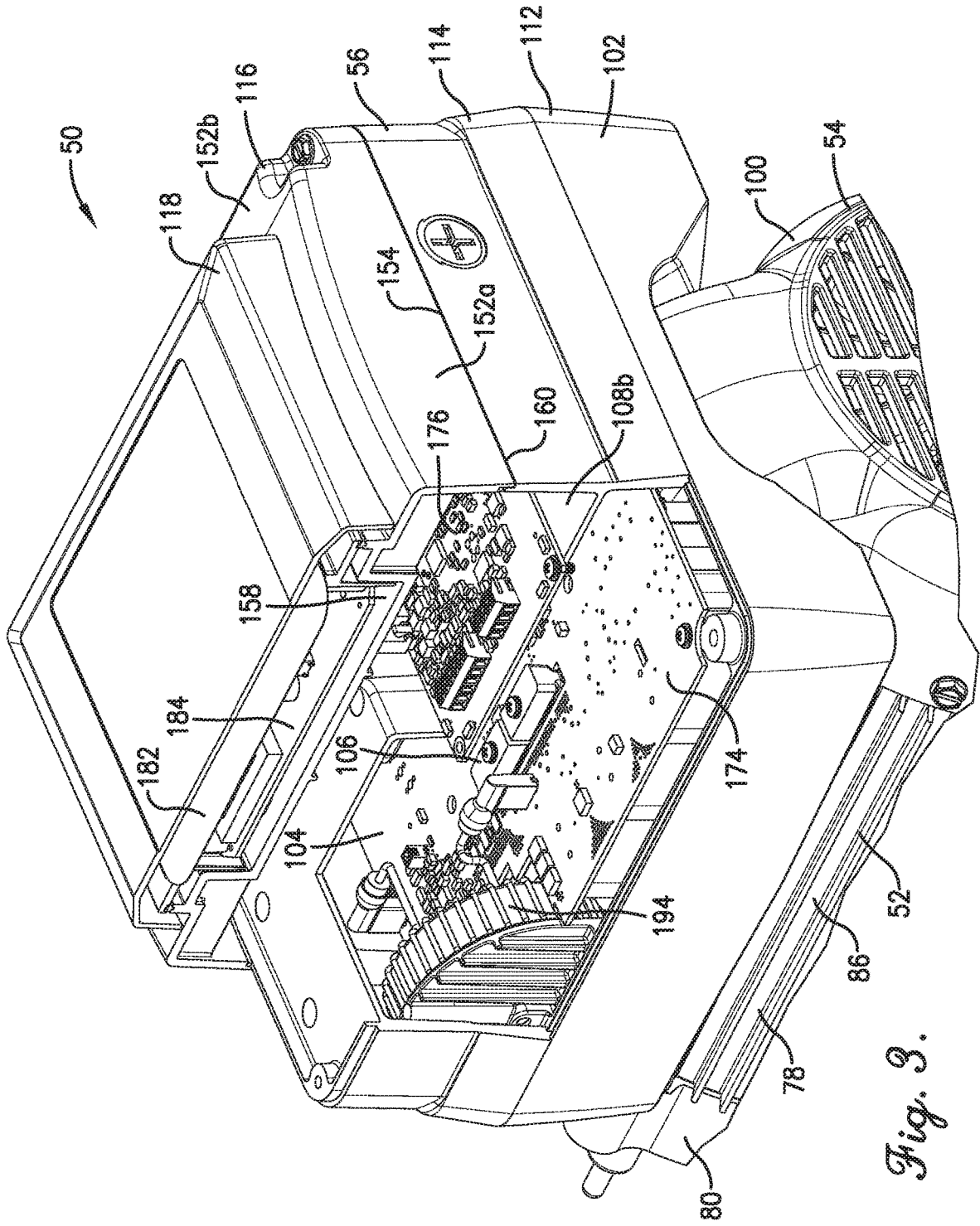


Fig. 3.

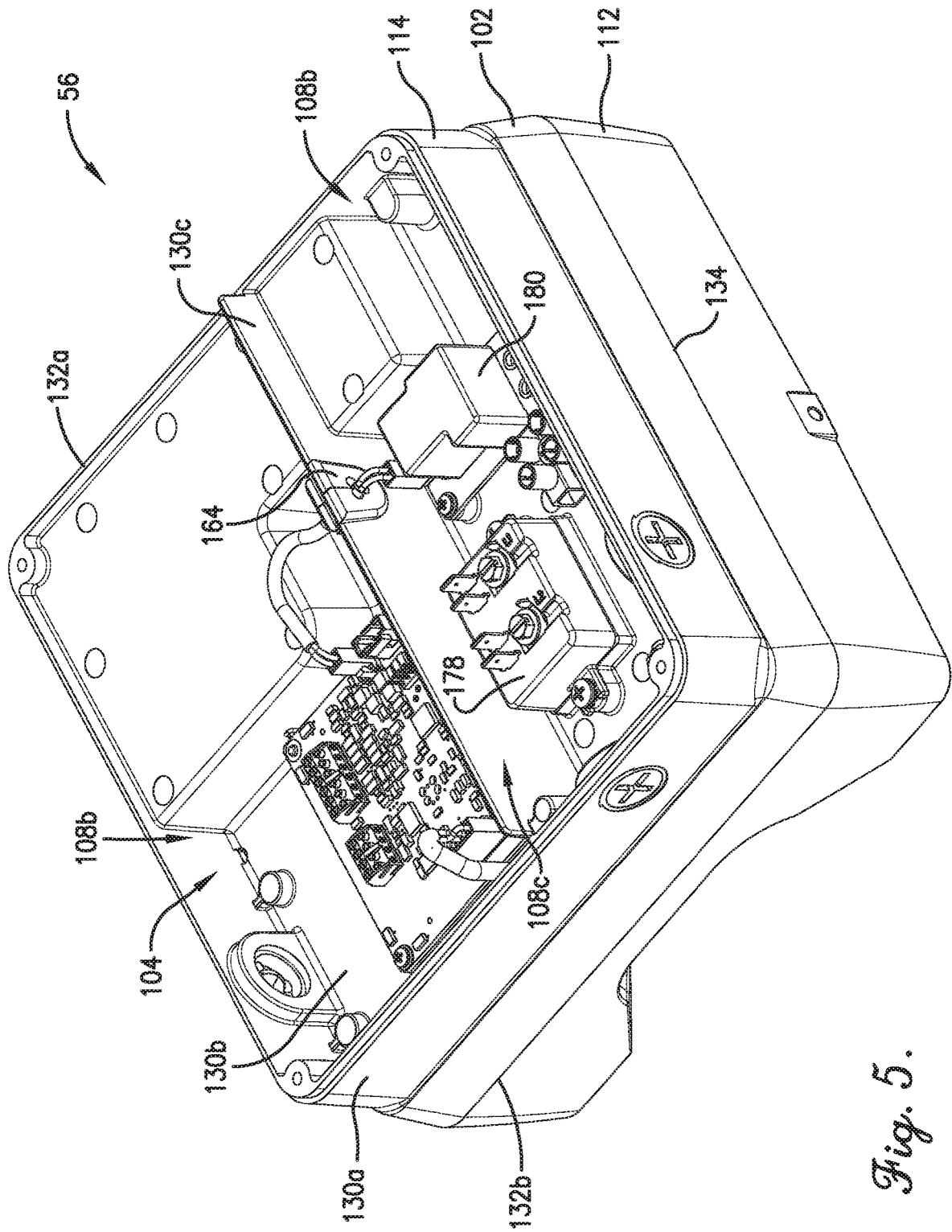


Fig. 5.

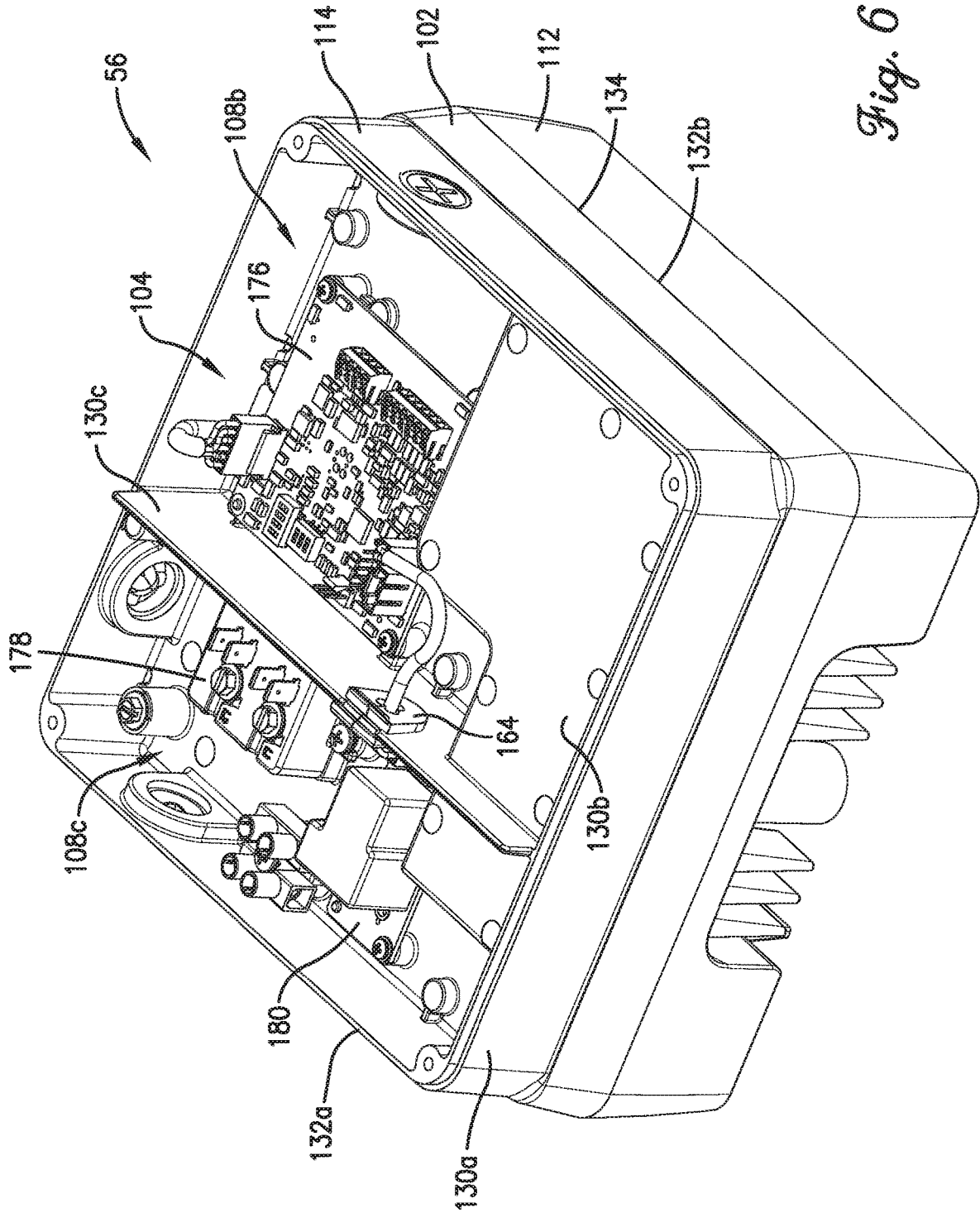


Fig. 6.

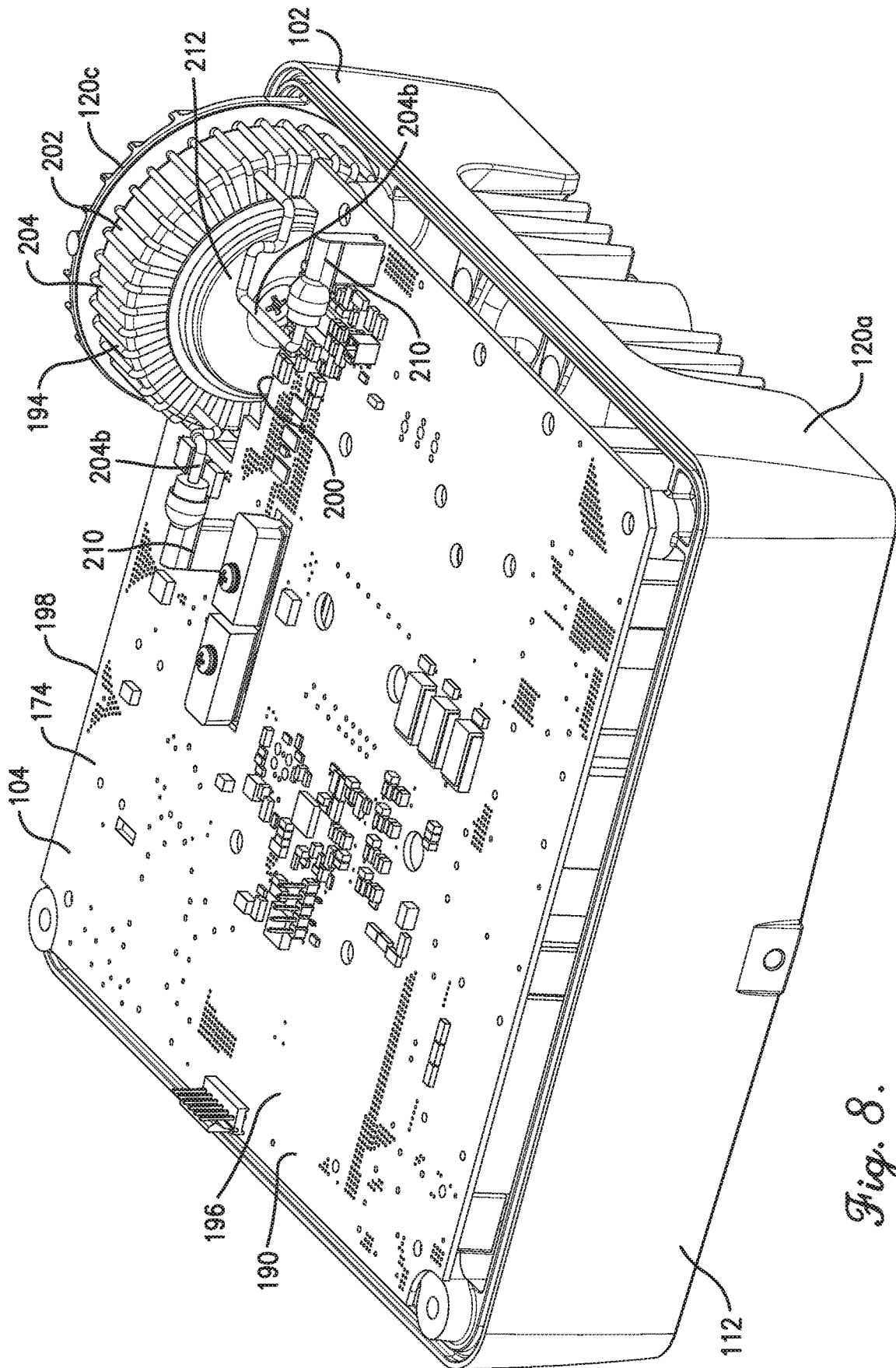


Fig. 8.

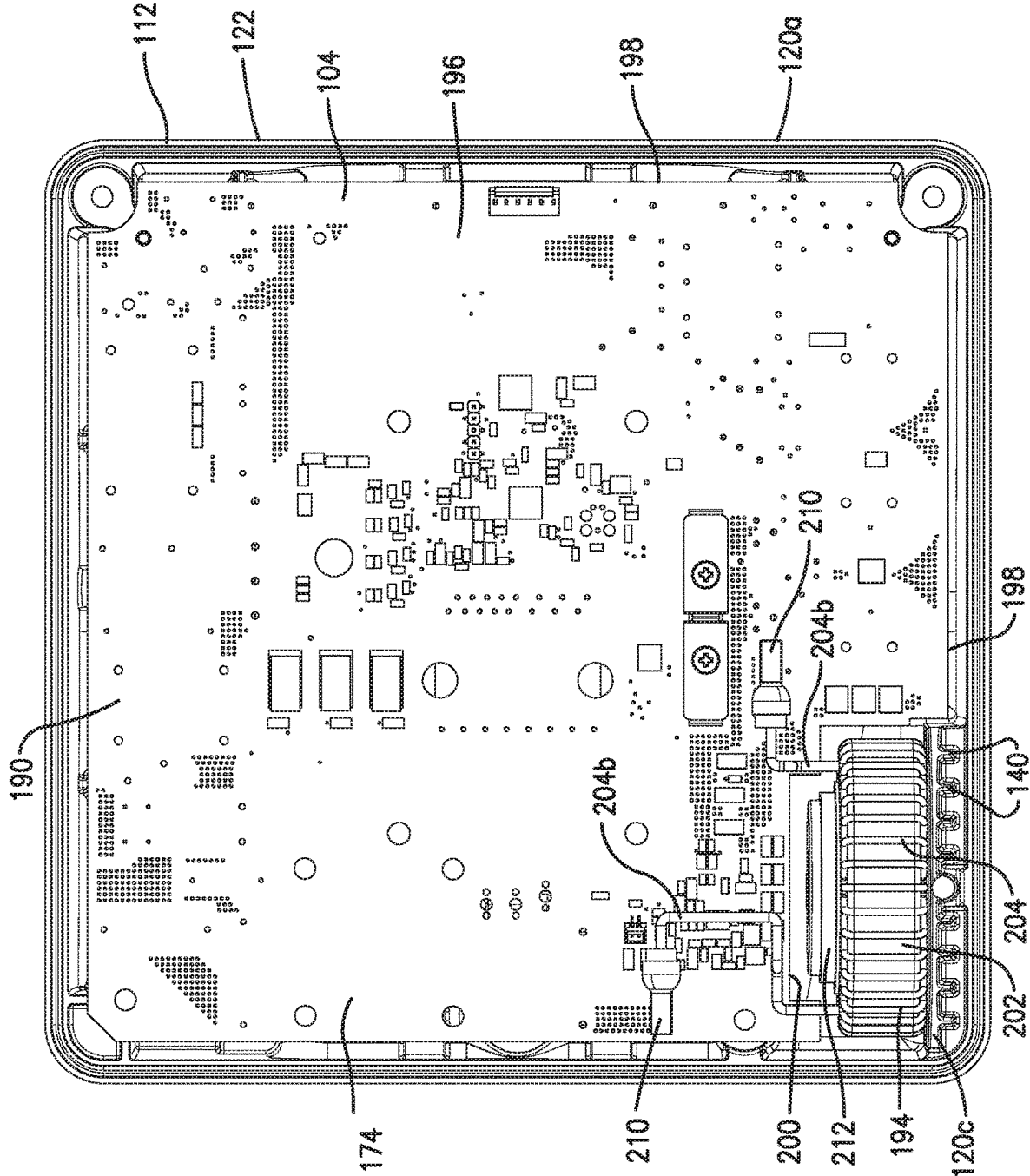


Fig. 9.

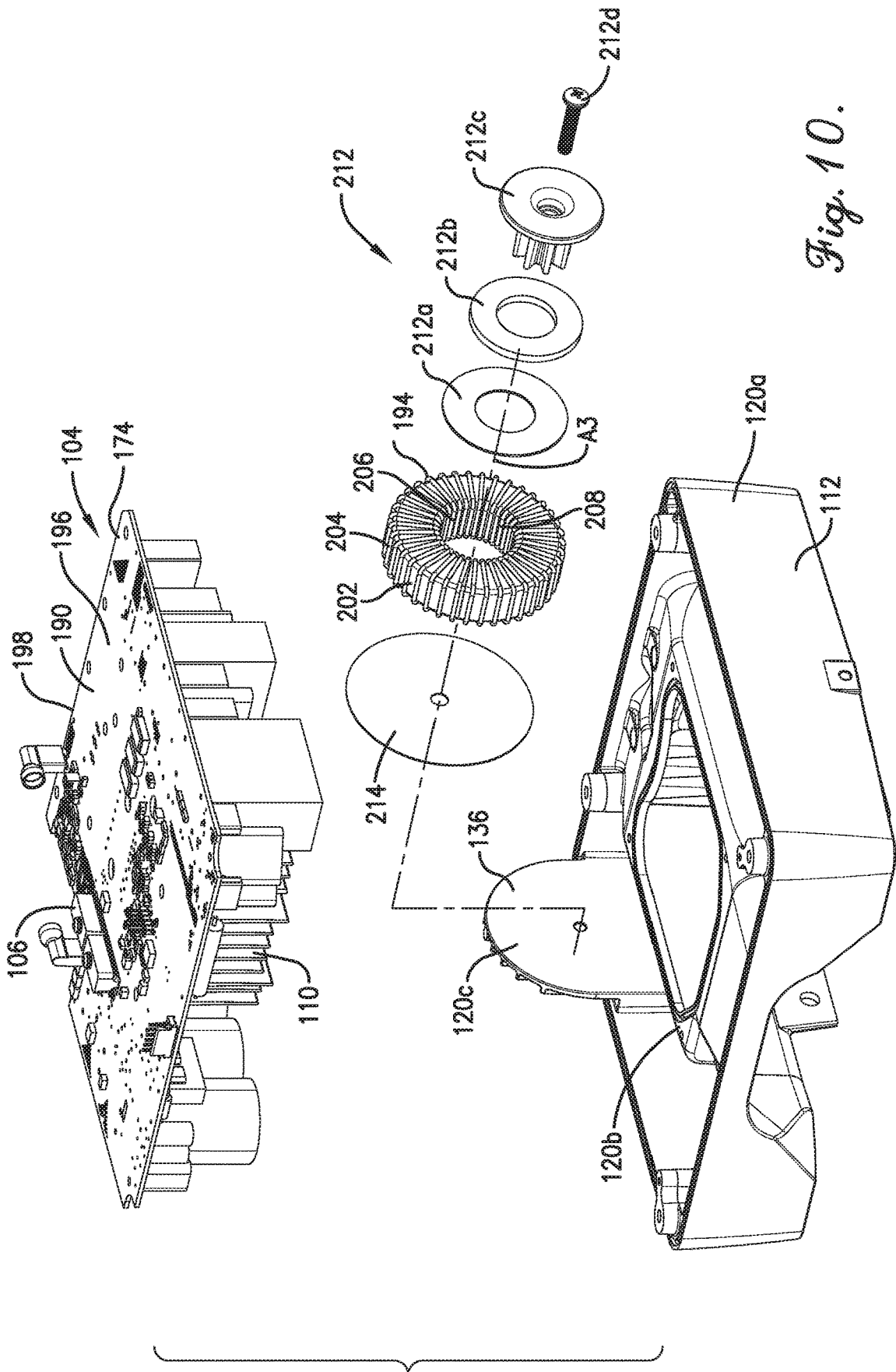
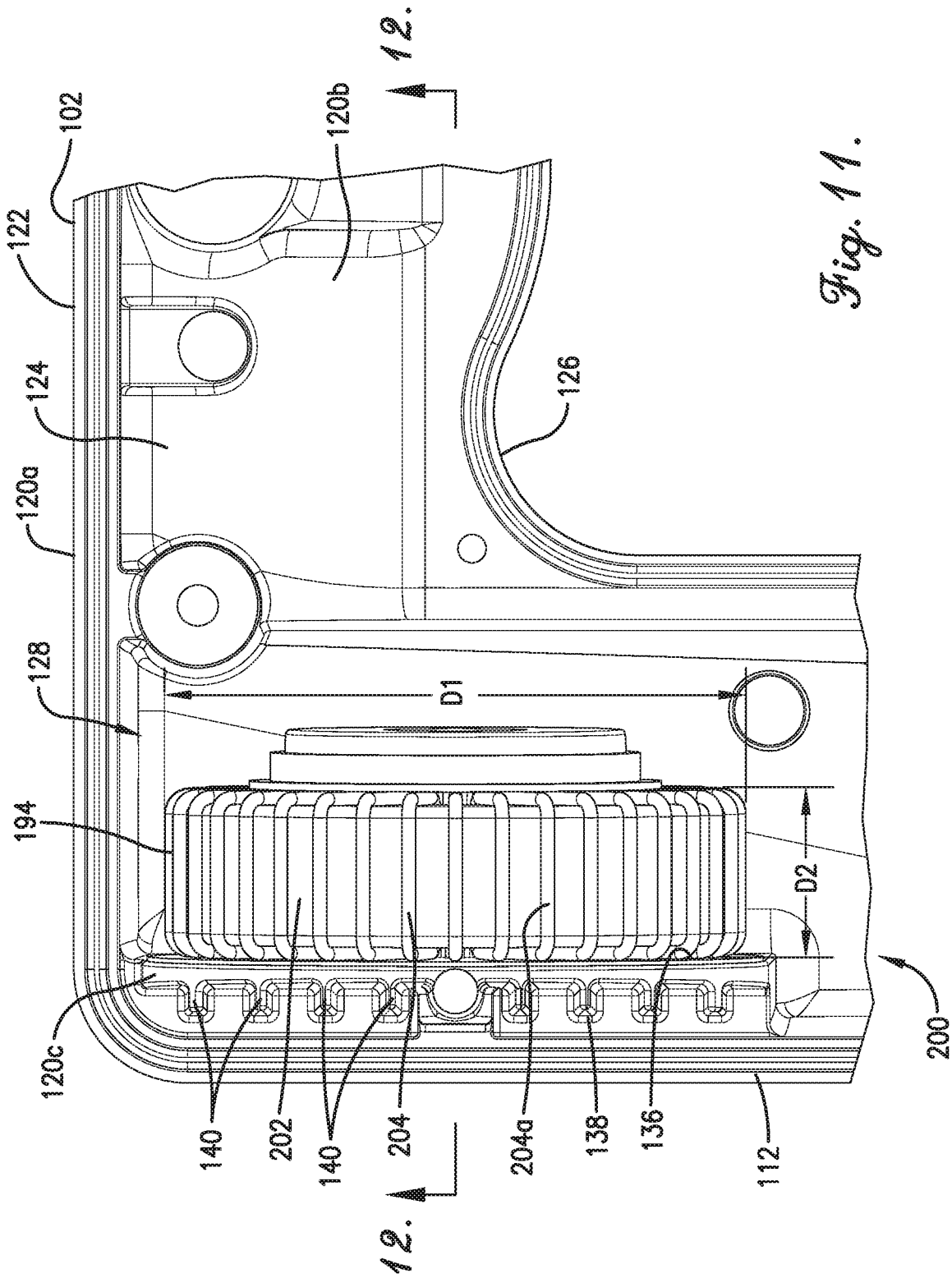


Fig. 10.



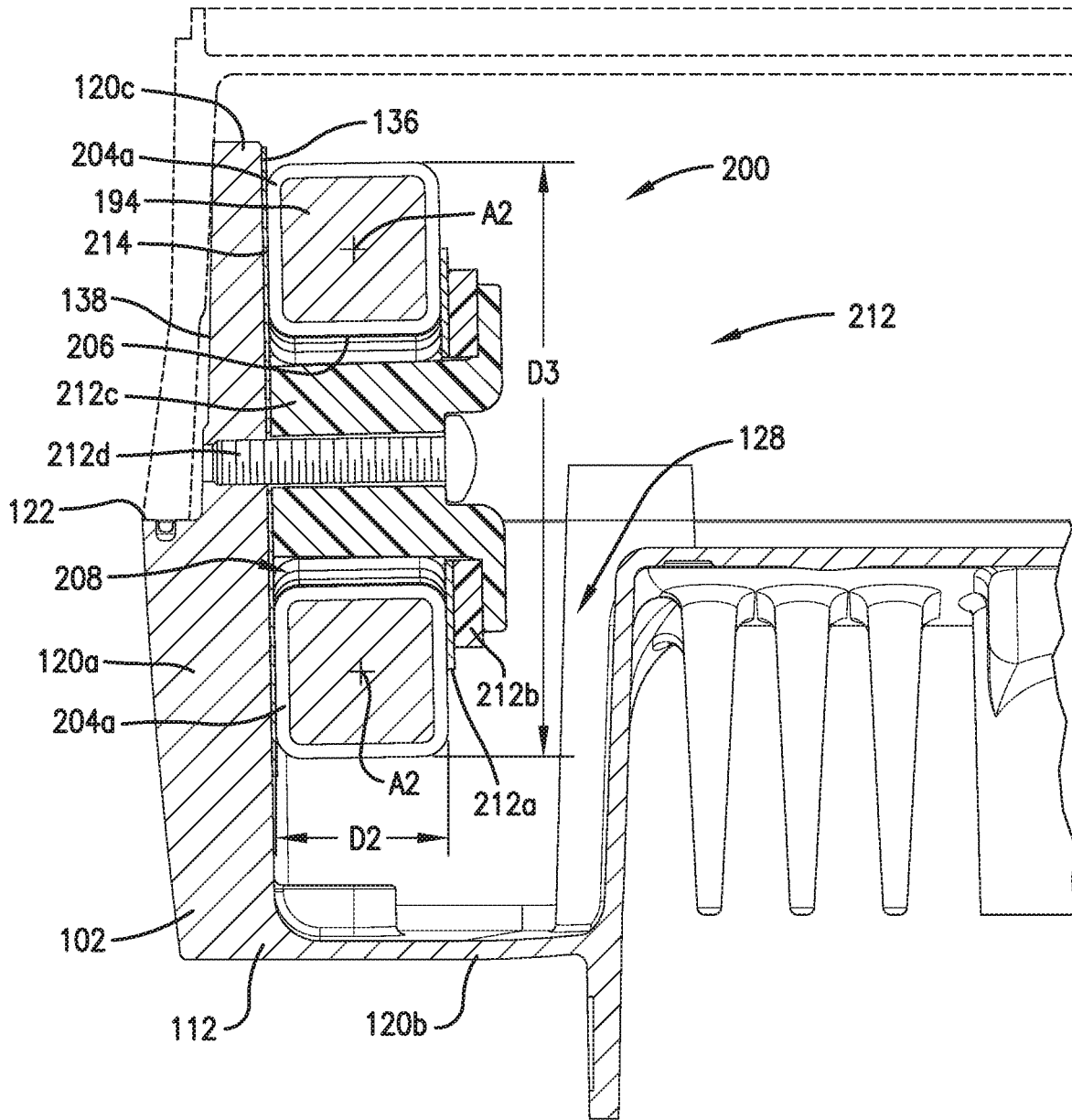


Fig. 12.

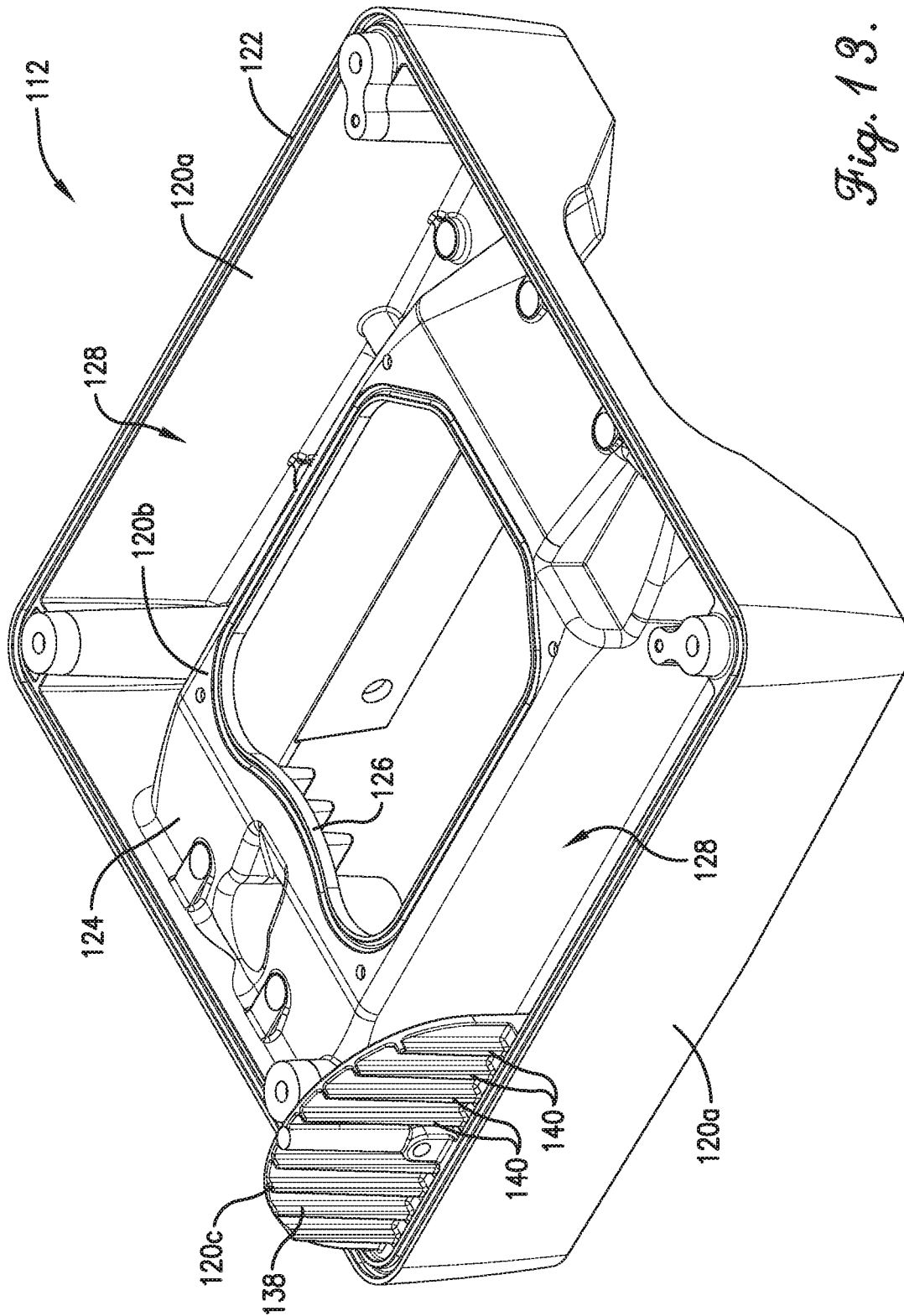


Fig. 13.

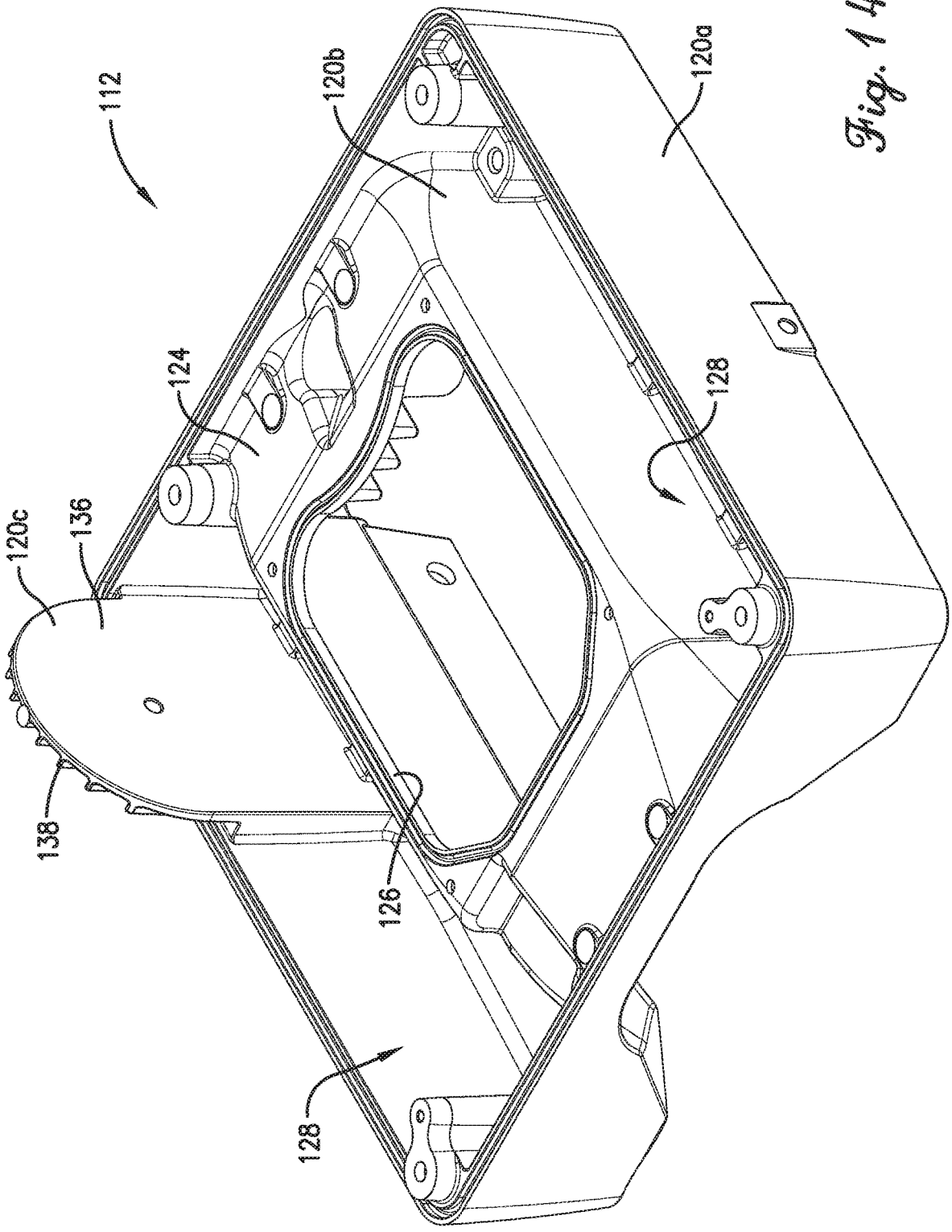


Fig. 14.

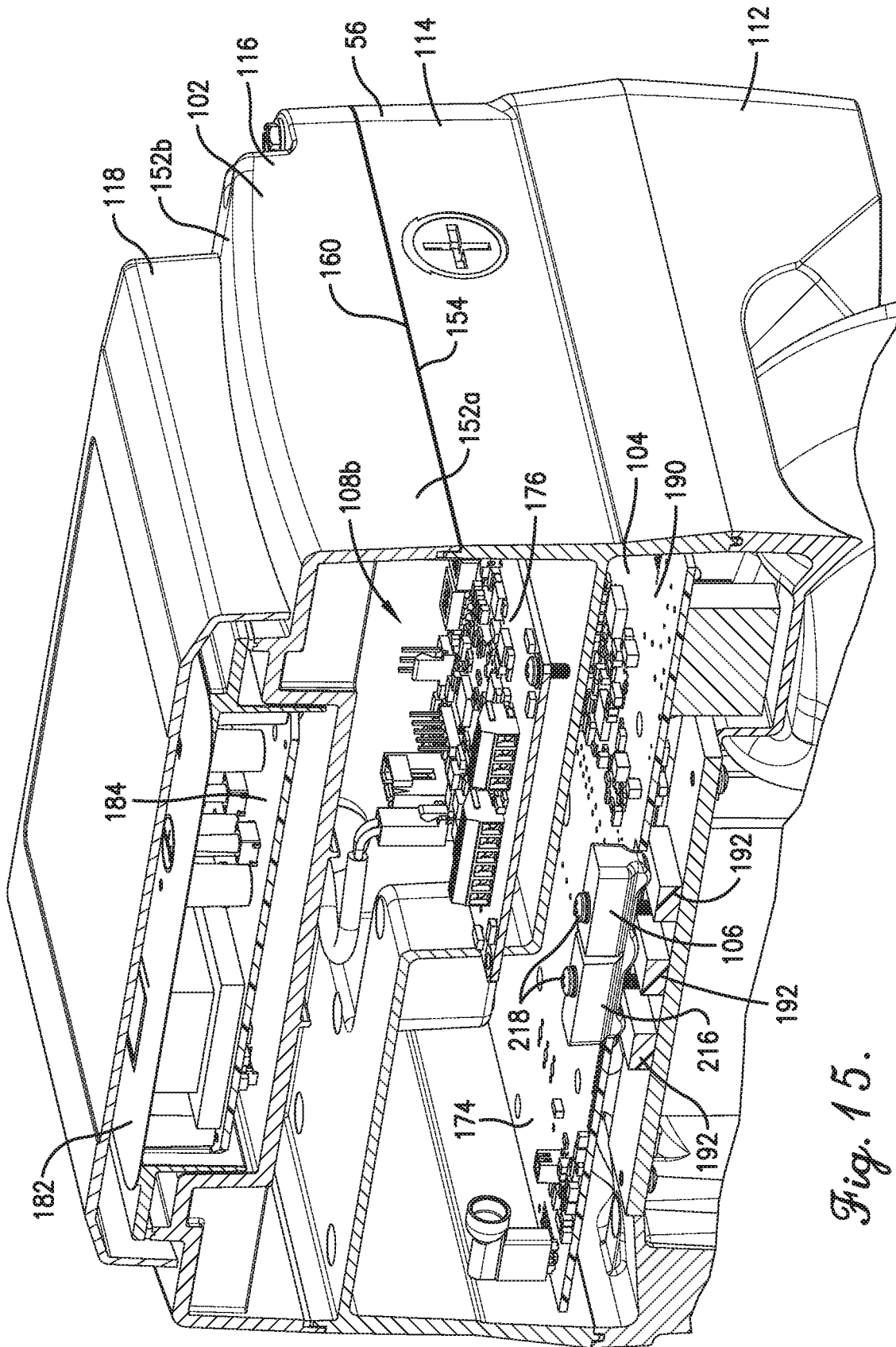


Fig. 15.

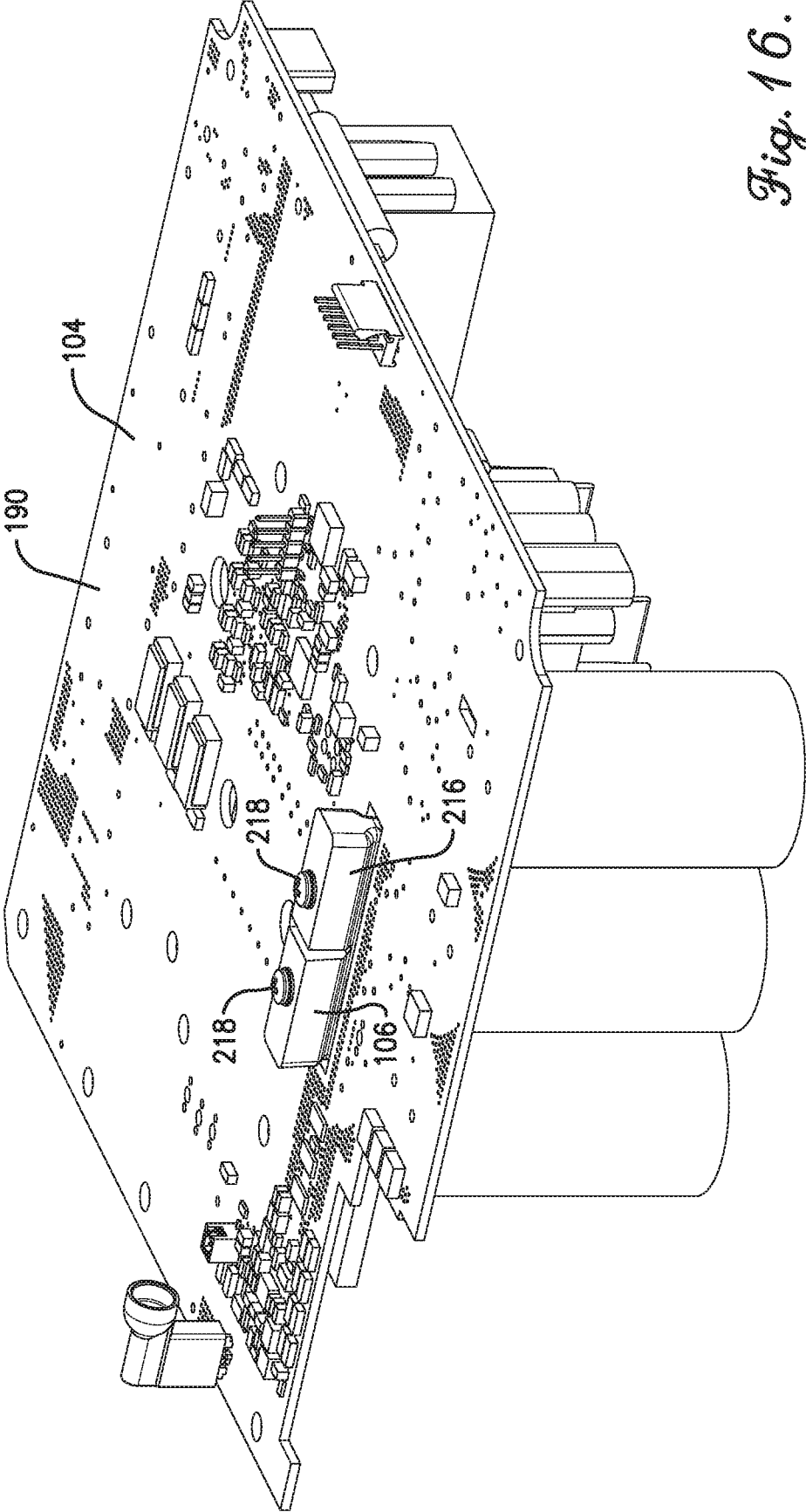


Fig. 16.

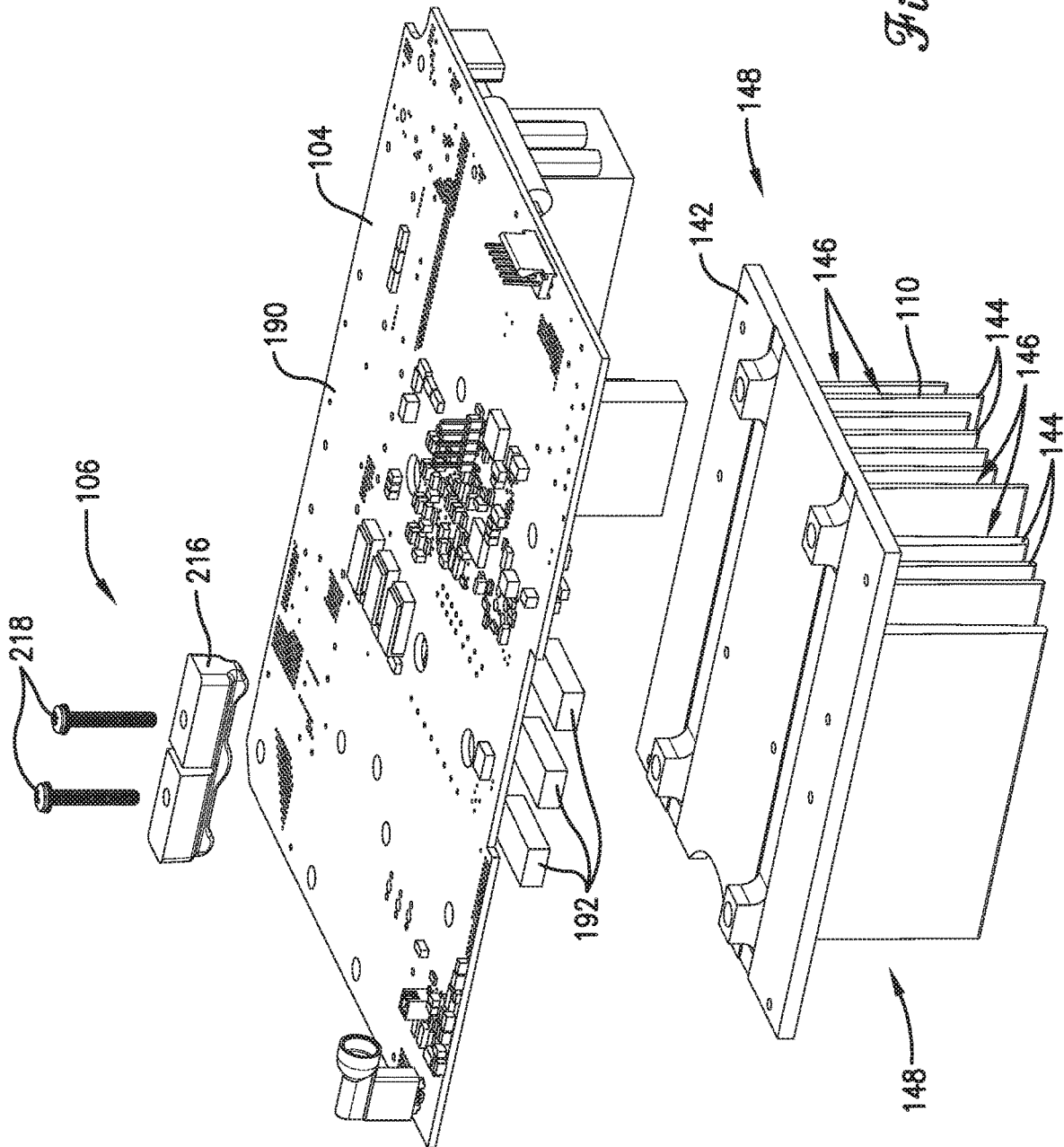


Fig. 17.

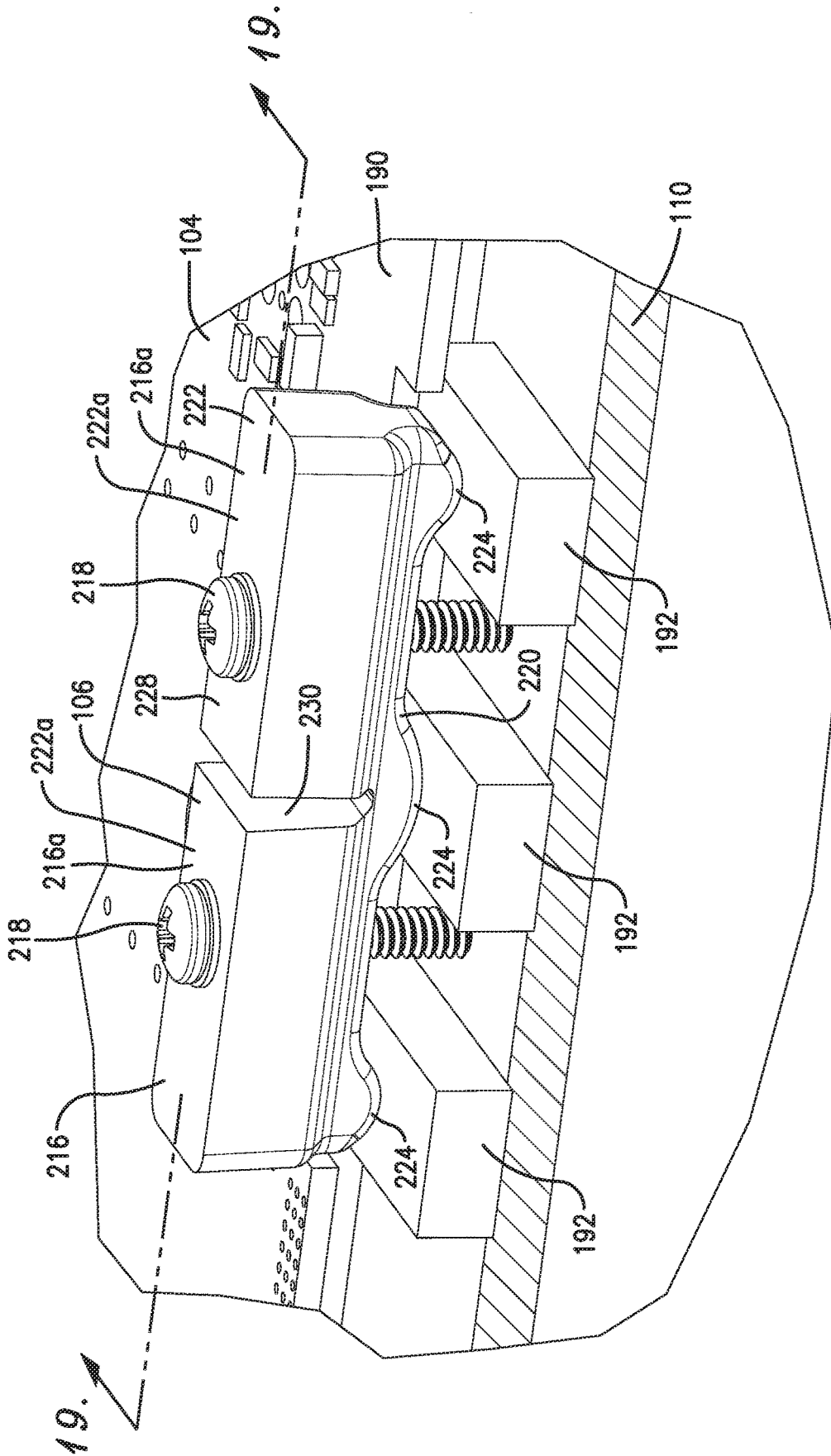


Fig. 18.

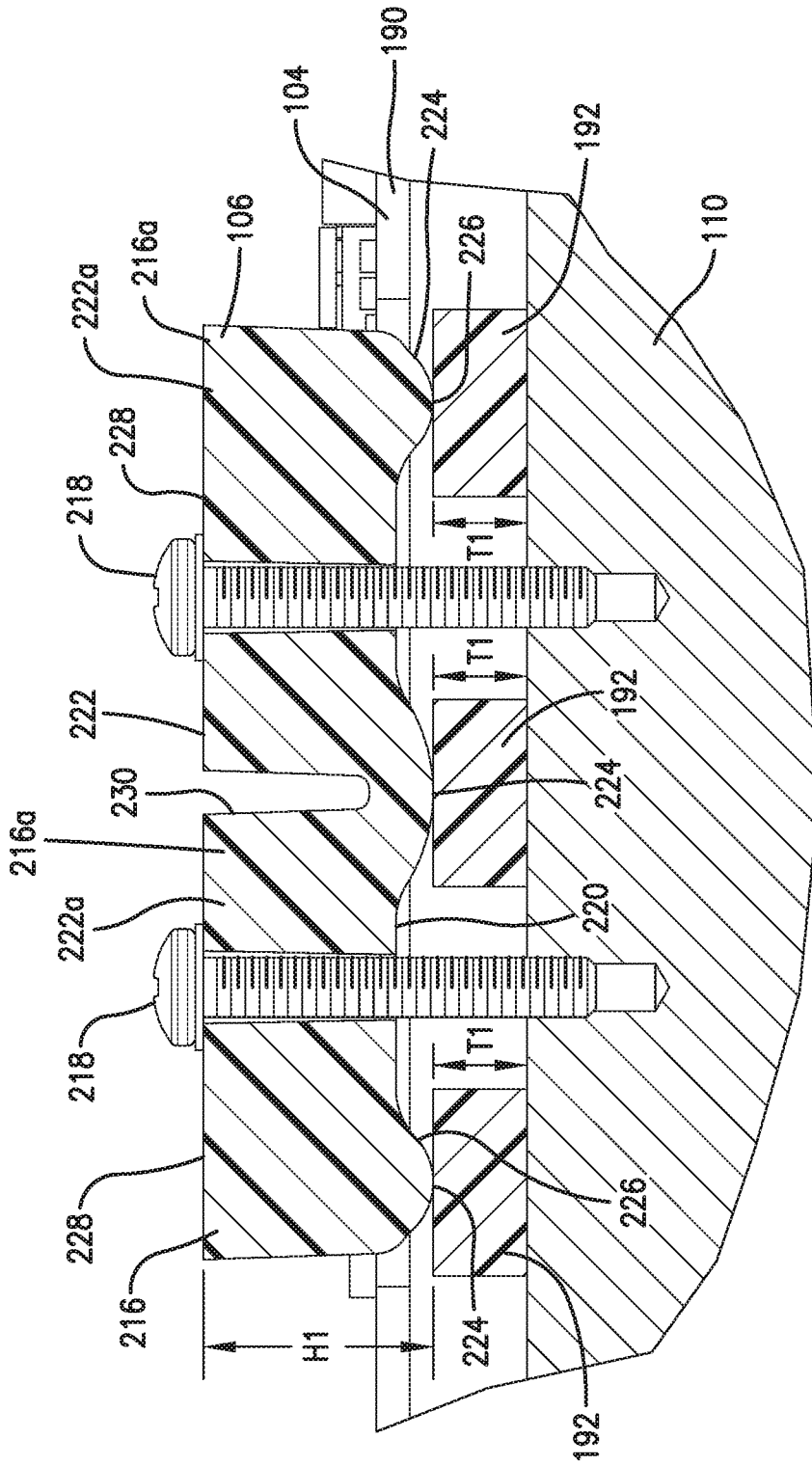


Fig. 19.

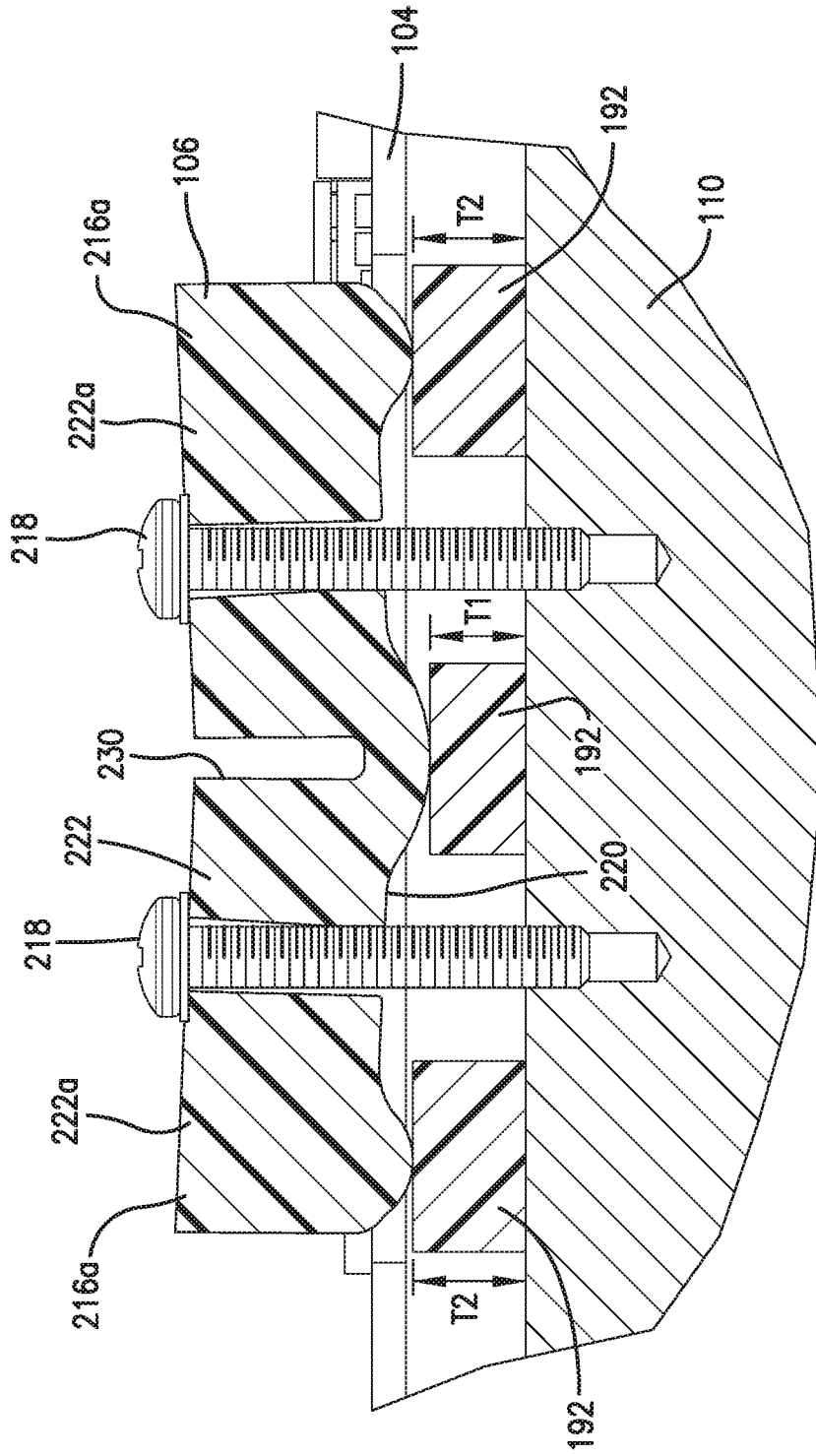


Fig. 20.

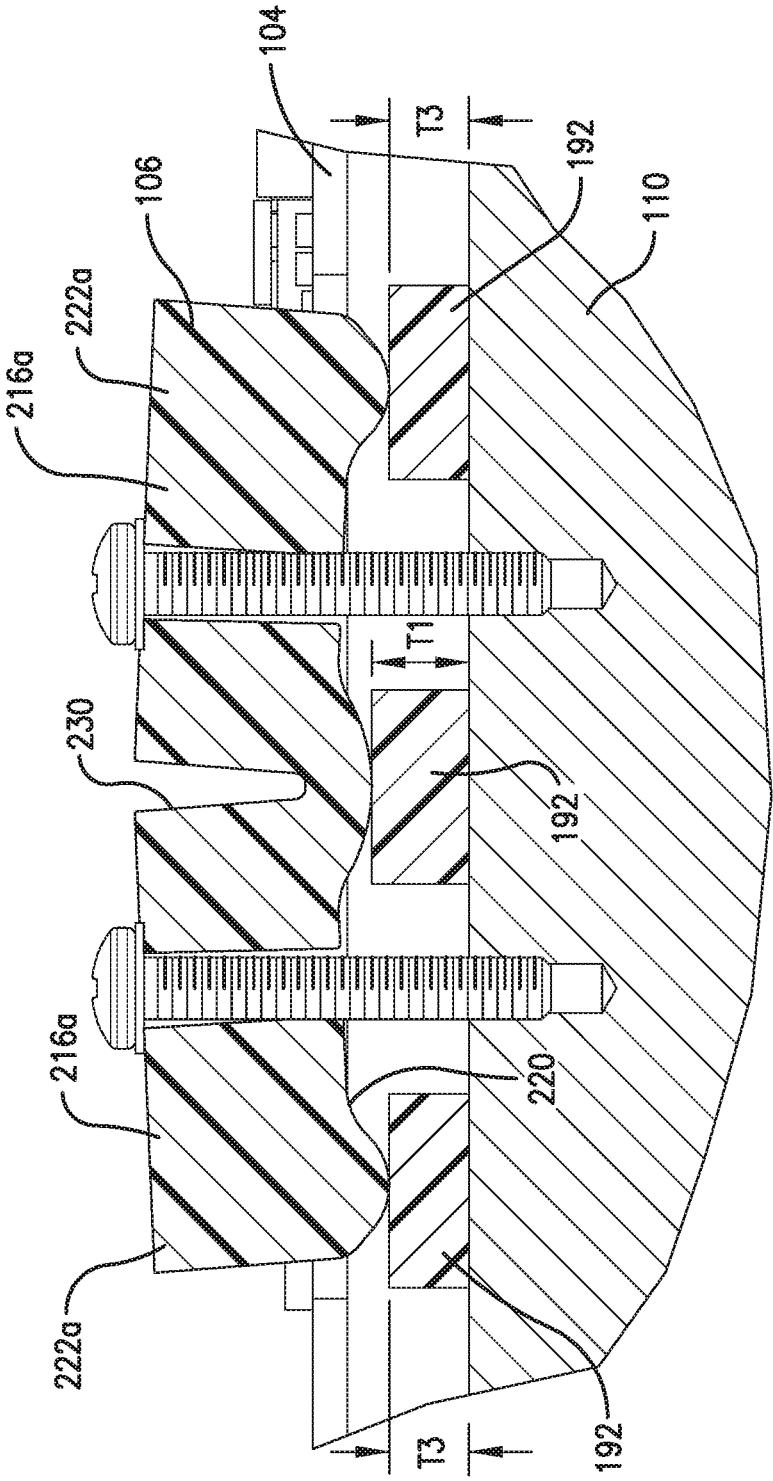


Fig. 21.

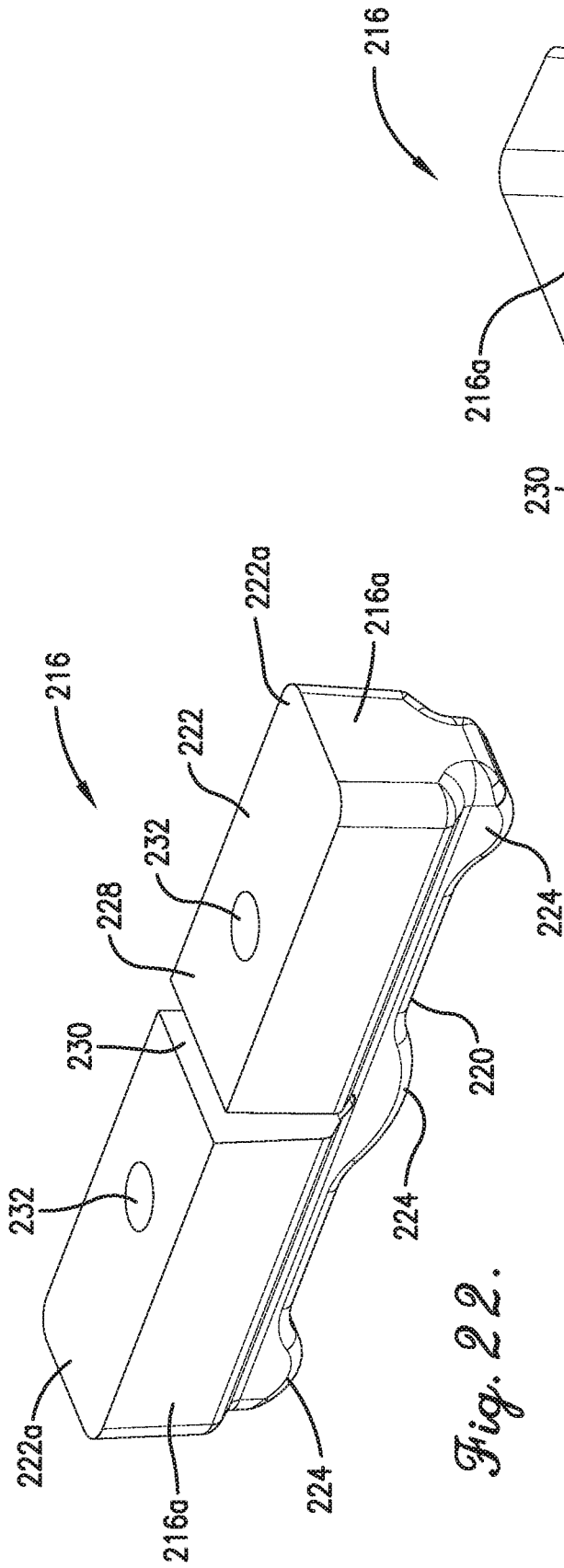


Fig. 22.

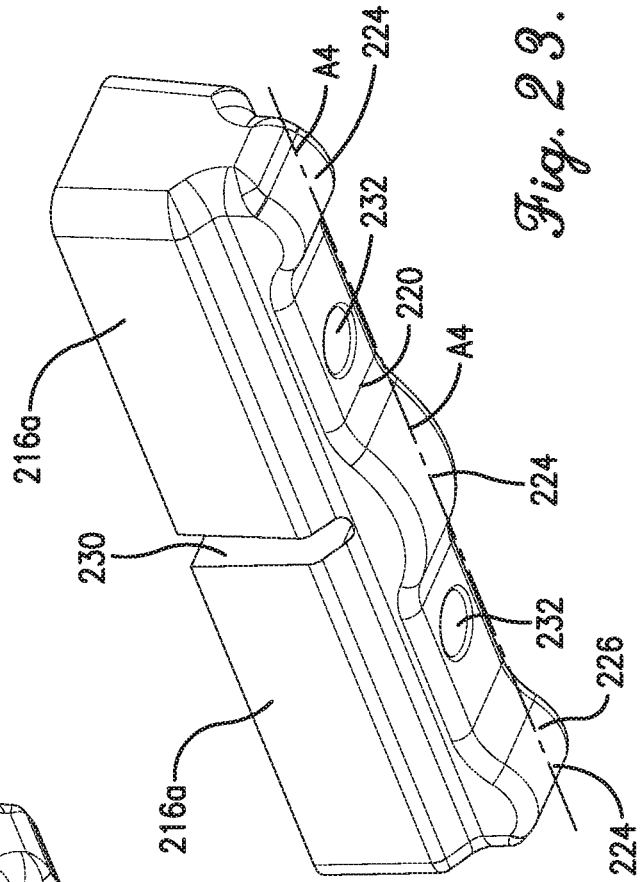


Fig. 23.

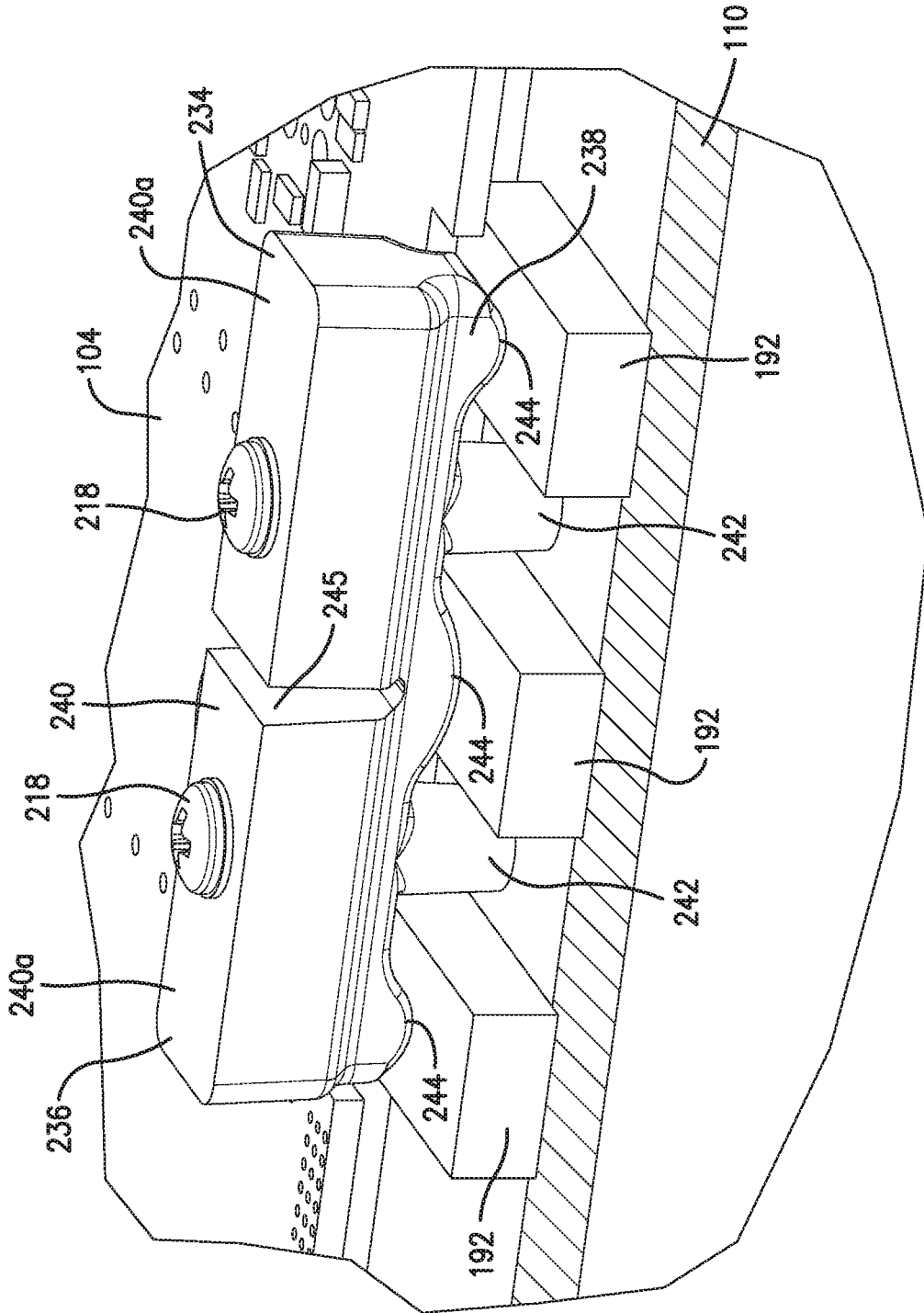


Fig. 24.

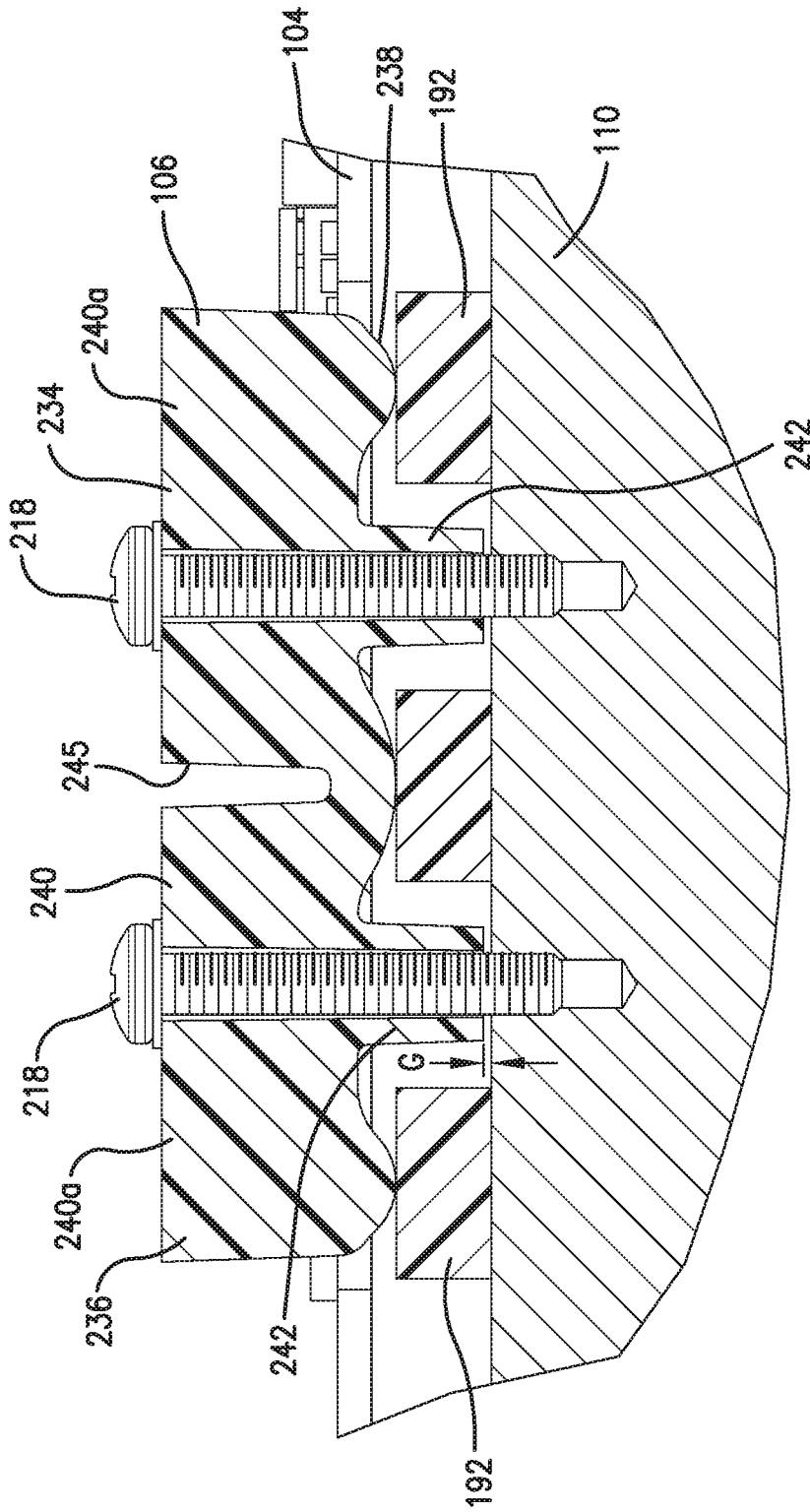
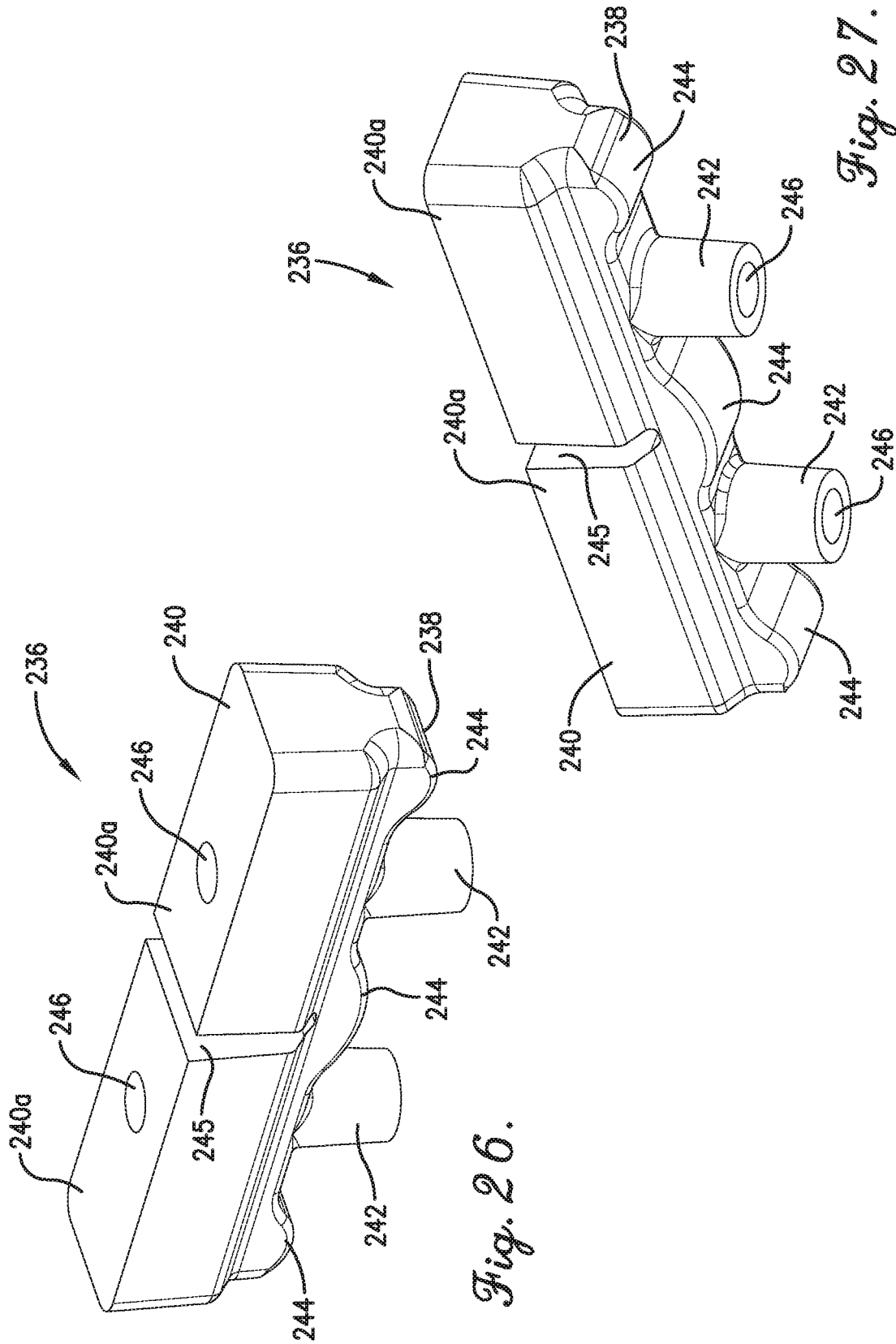


Fig. 25.



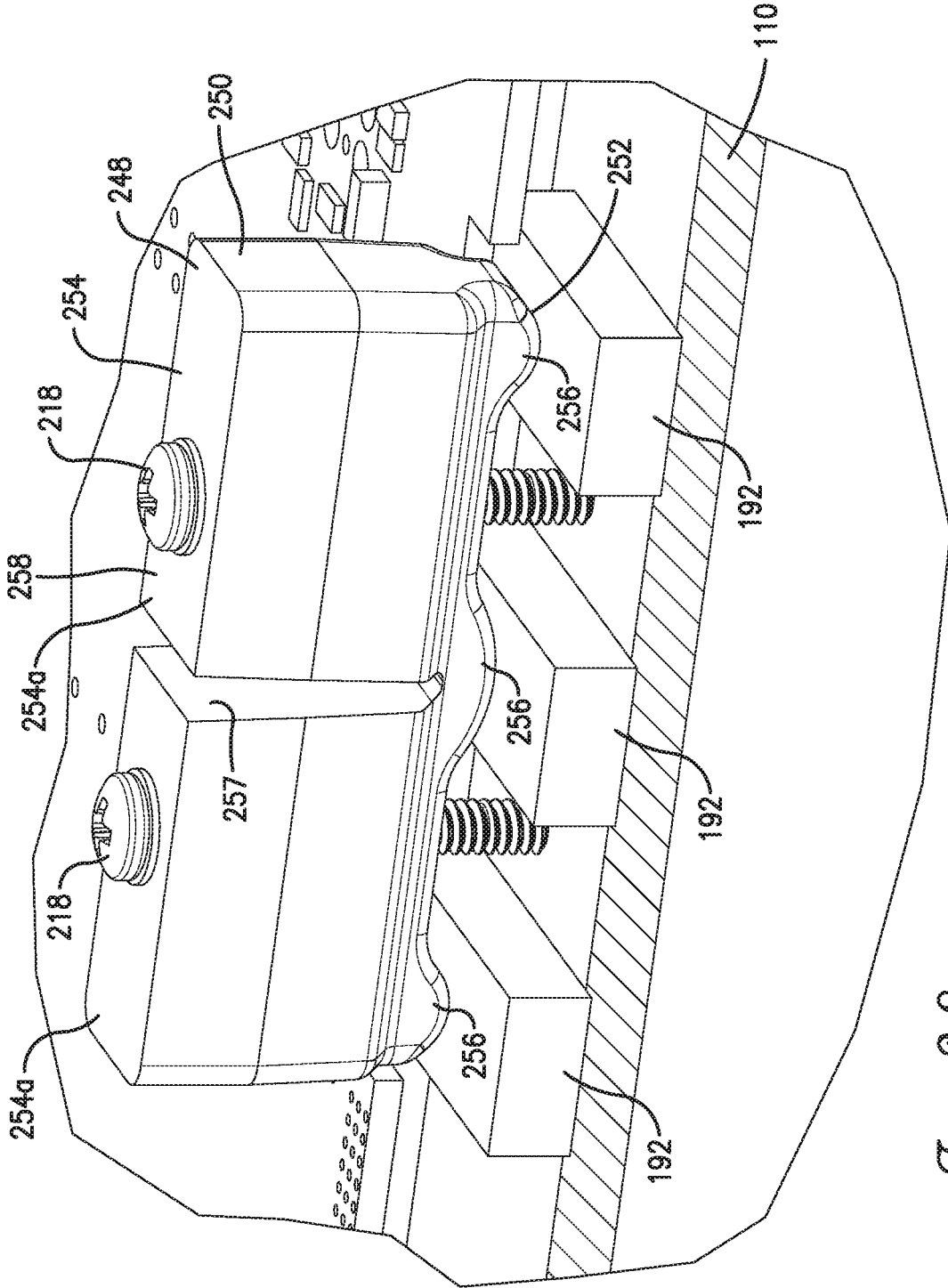


Fig. 28.

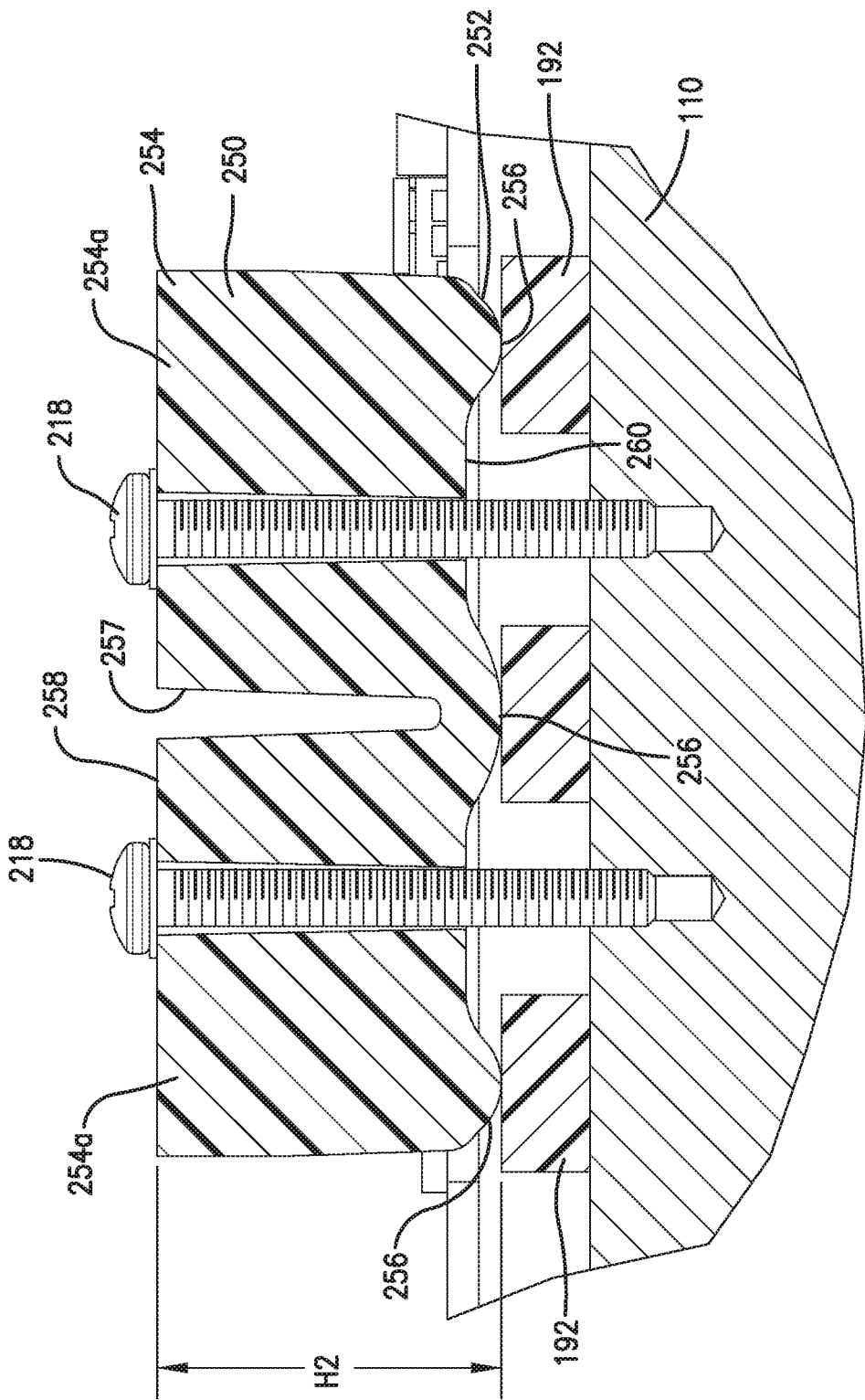


Fig. 29.

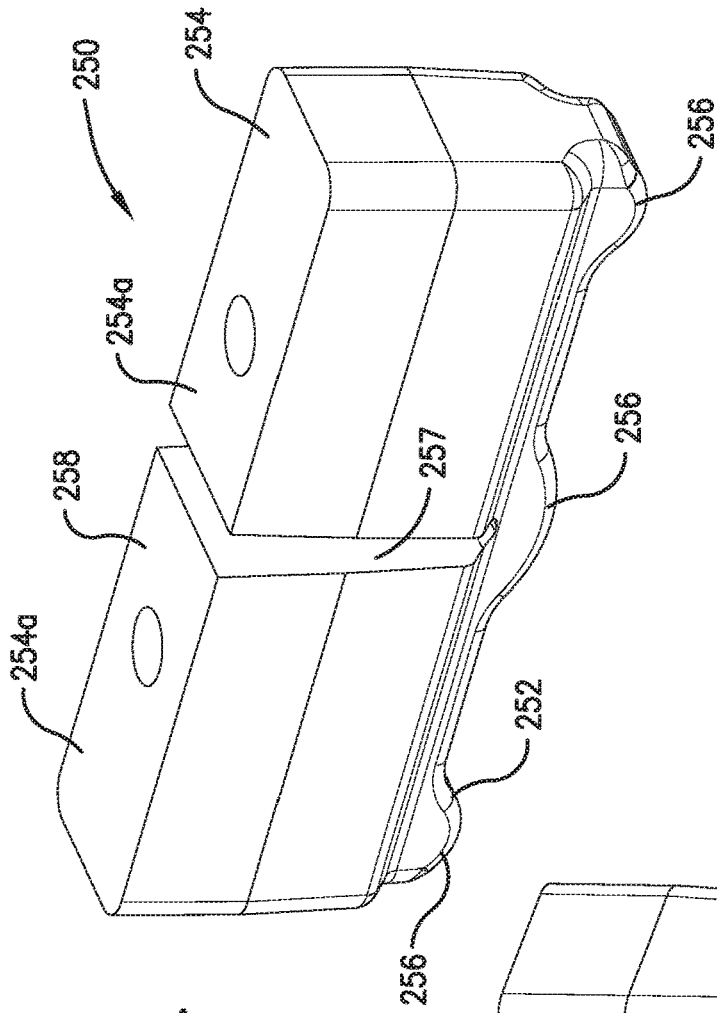


Fig. 30.

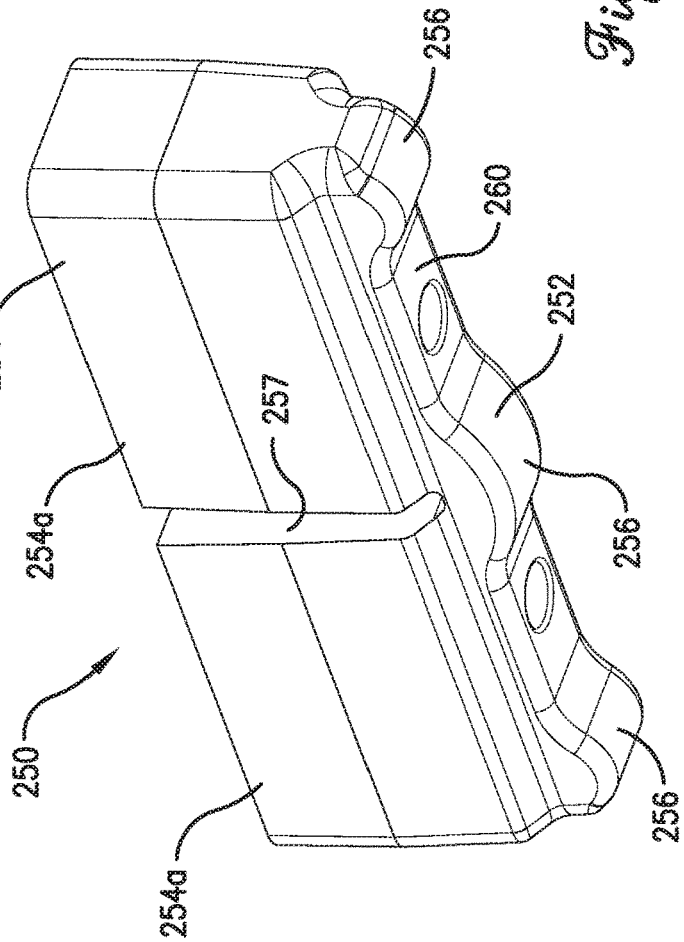


Fig. 31.

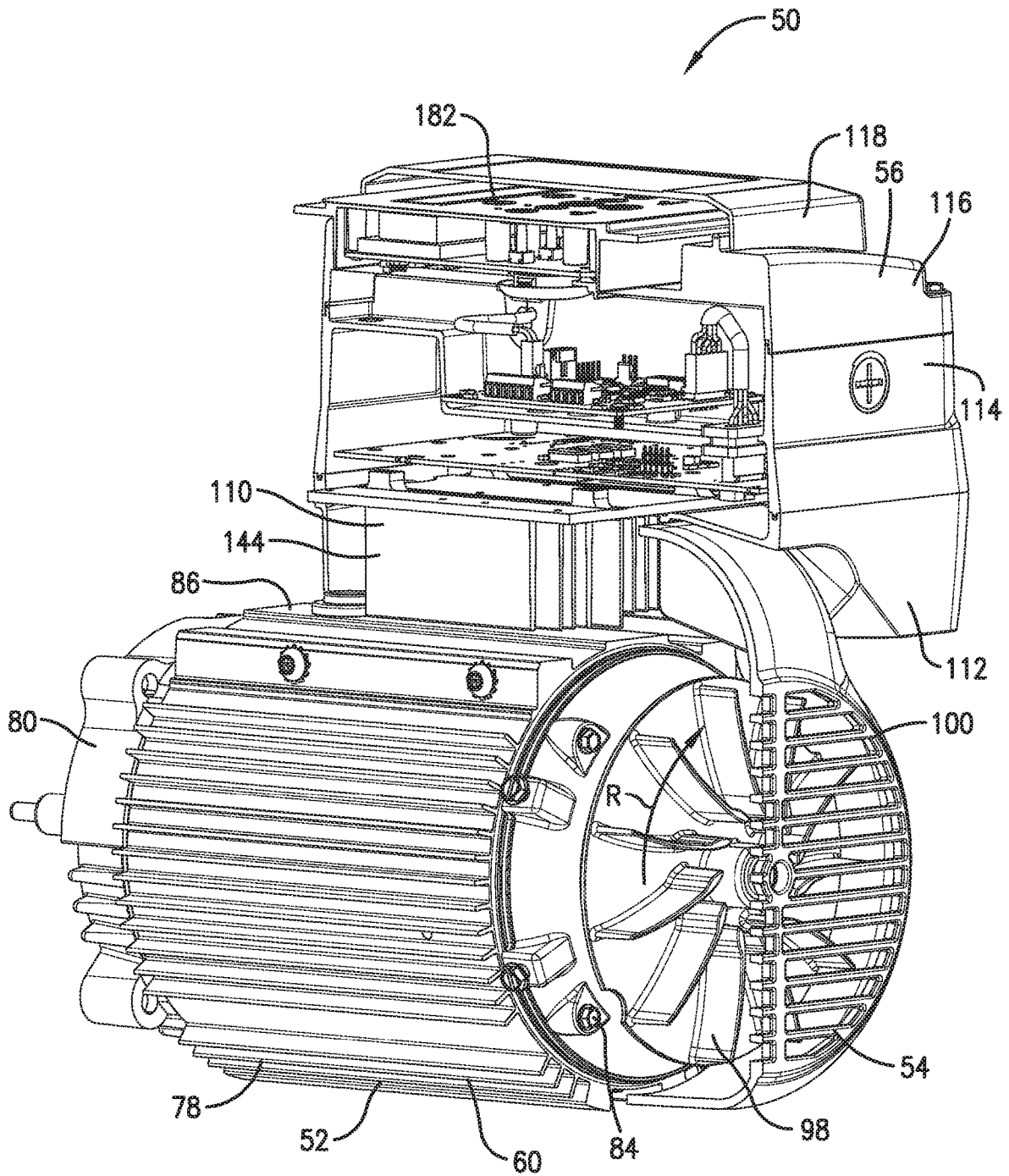


Fig. 32.

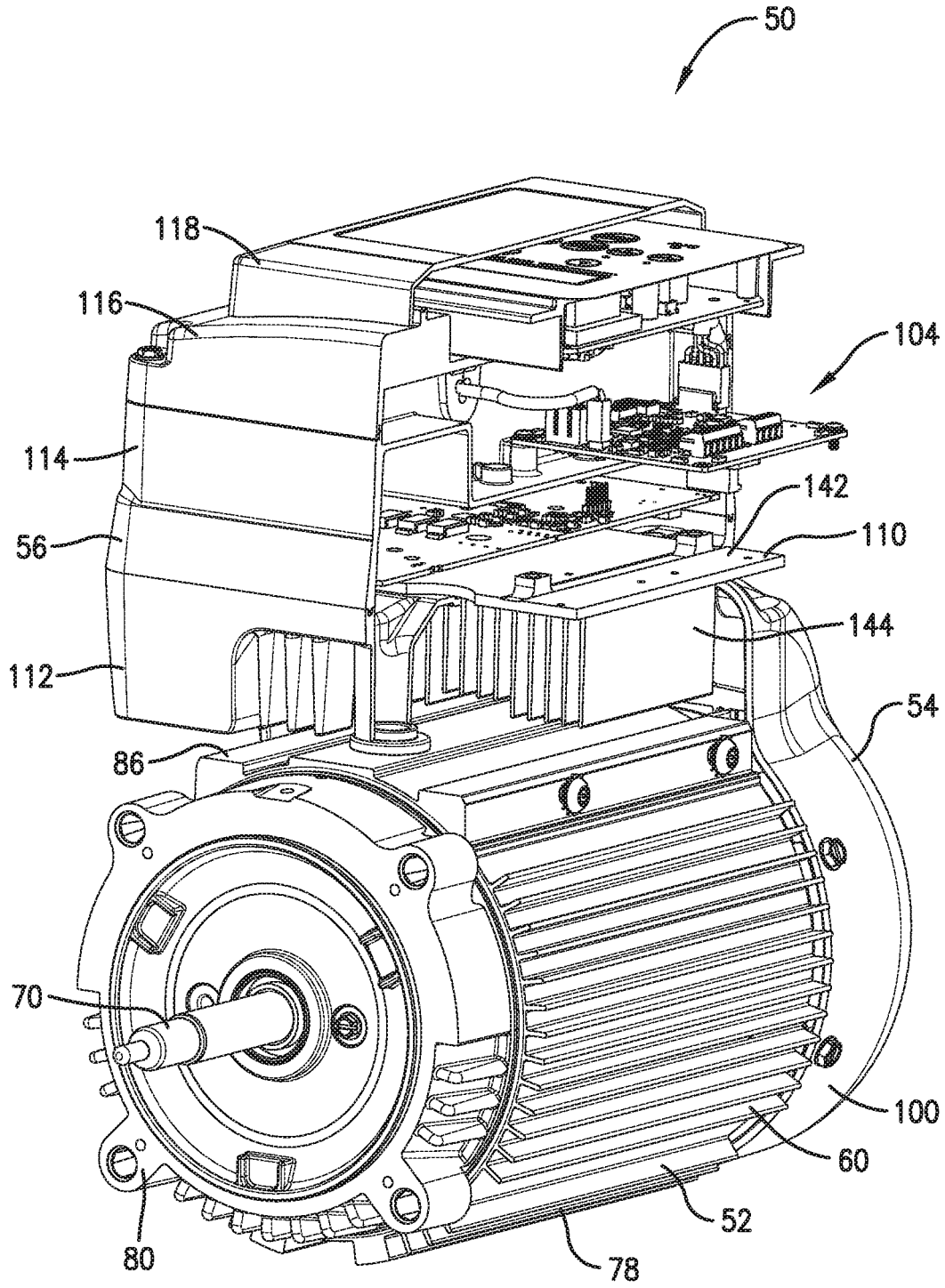


Fig. 33.

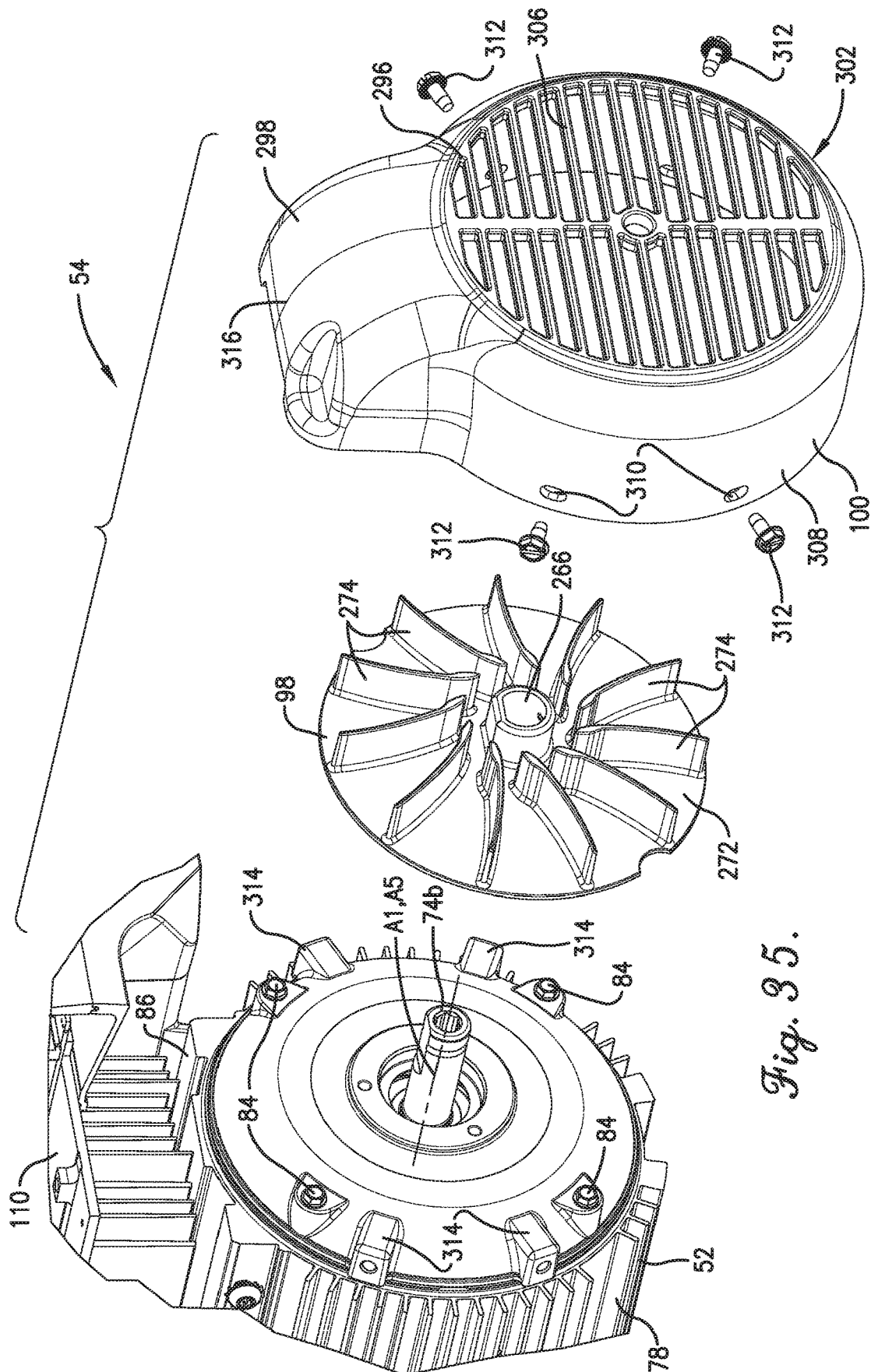


Fig. 35.

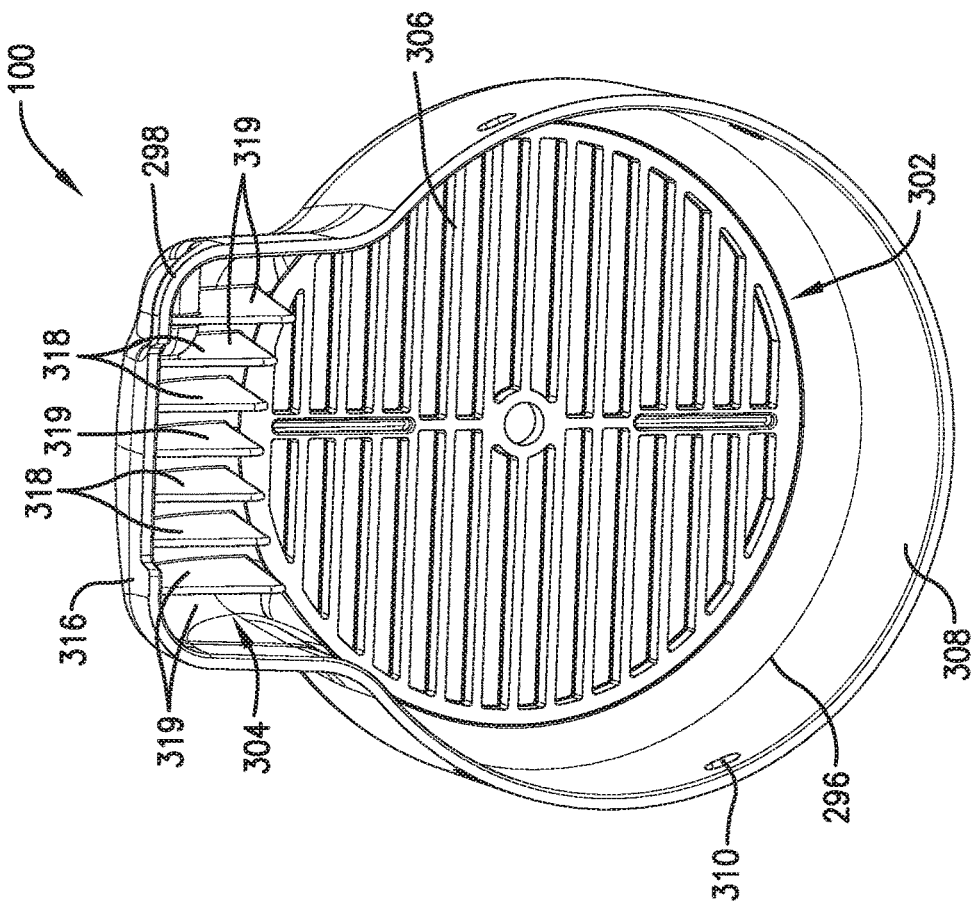


Fig. 37.

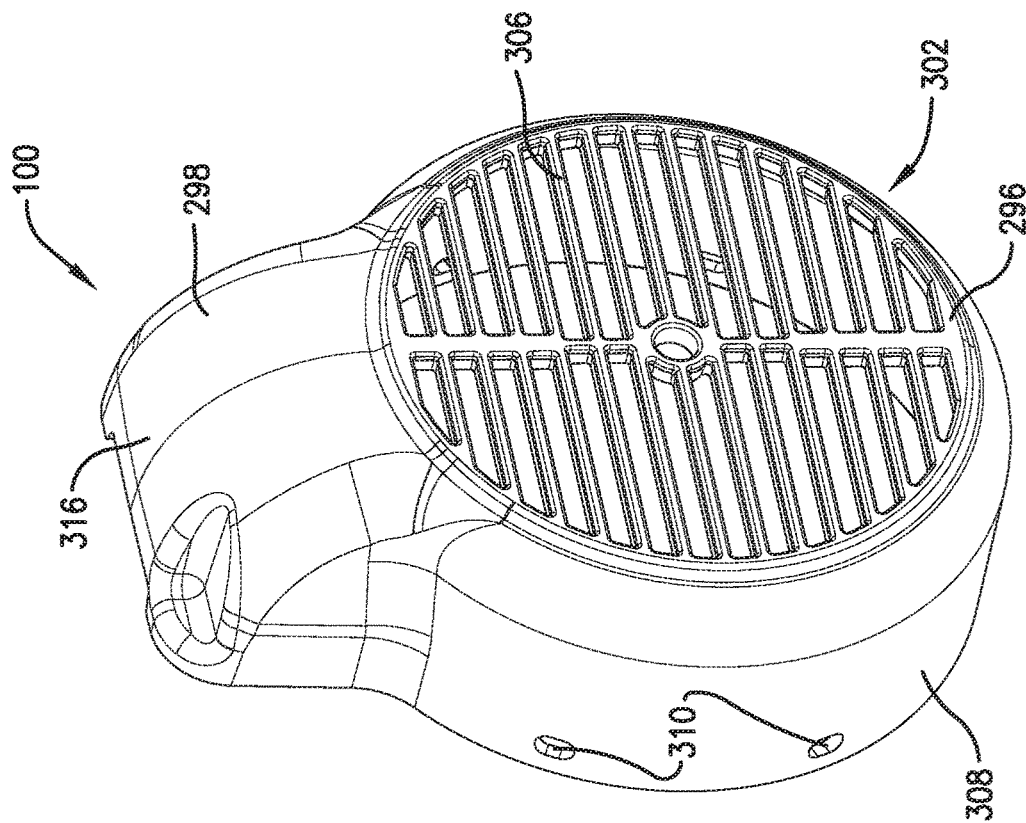


Fig. 36.

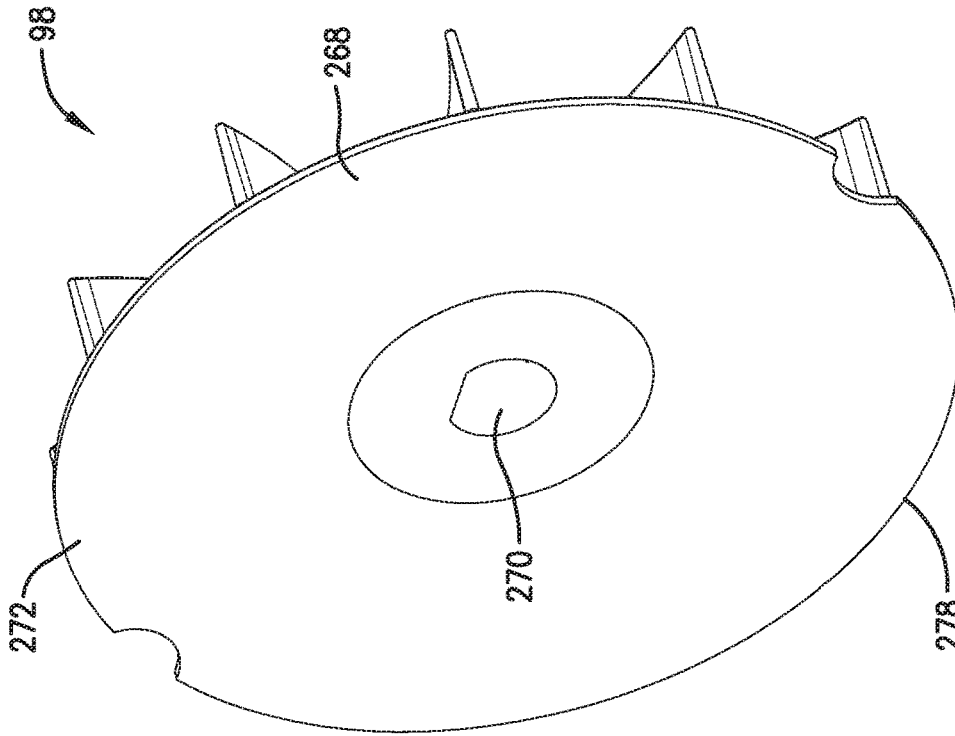


Fig. 39.

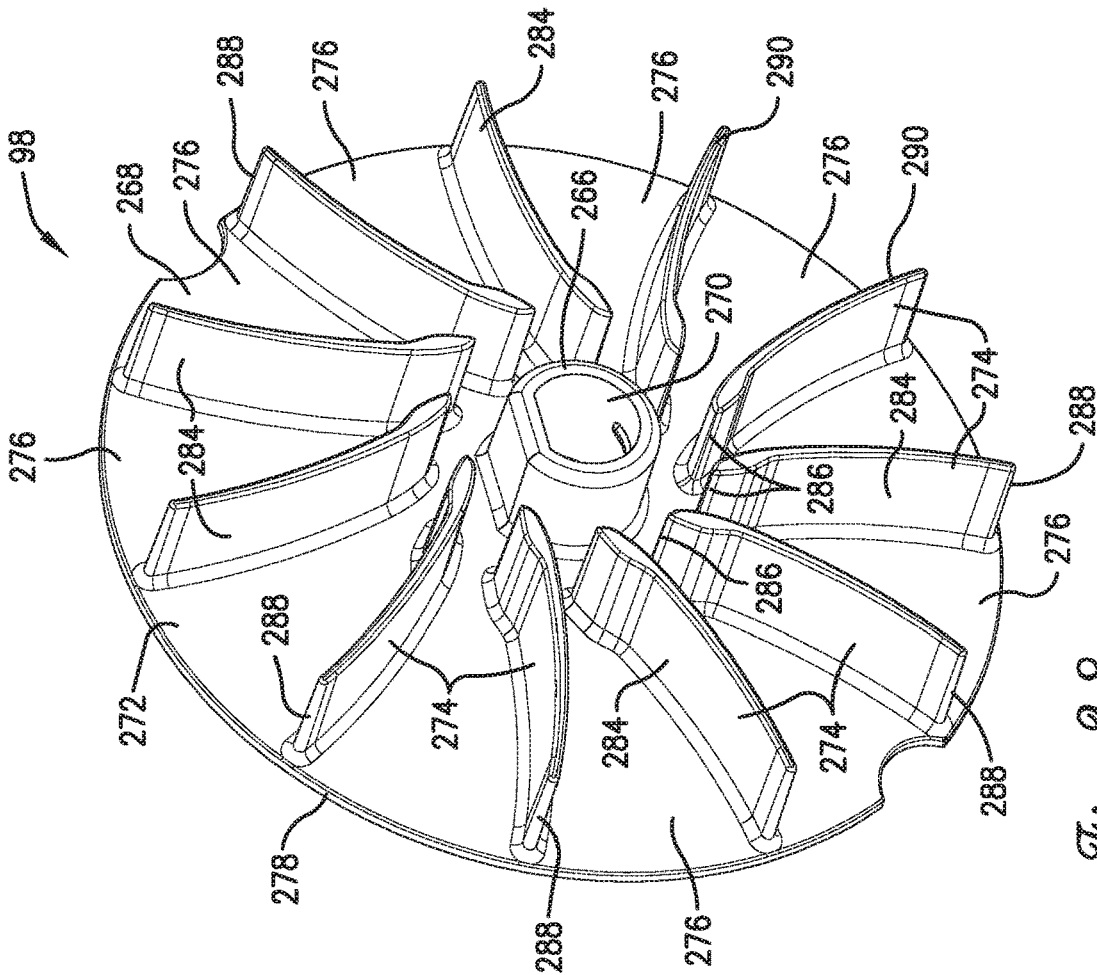


Fig. 38.

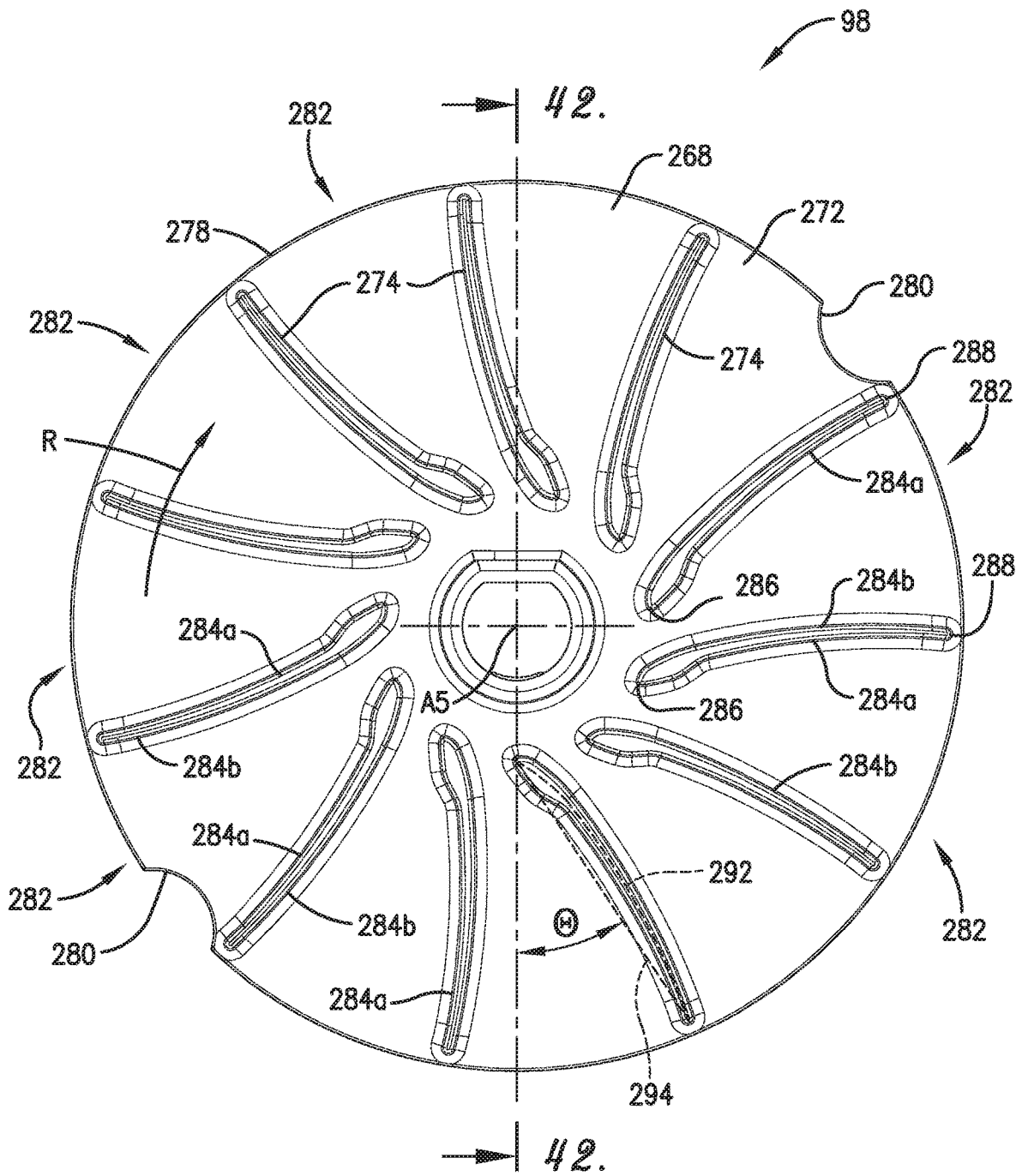


Fig. 40.

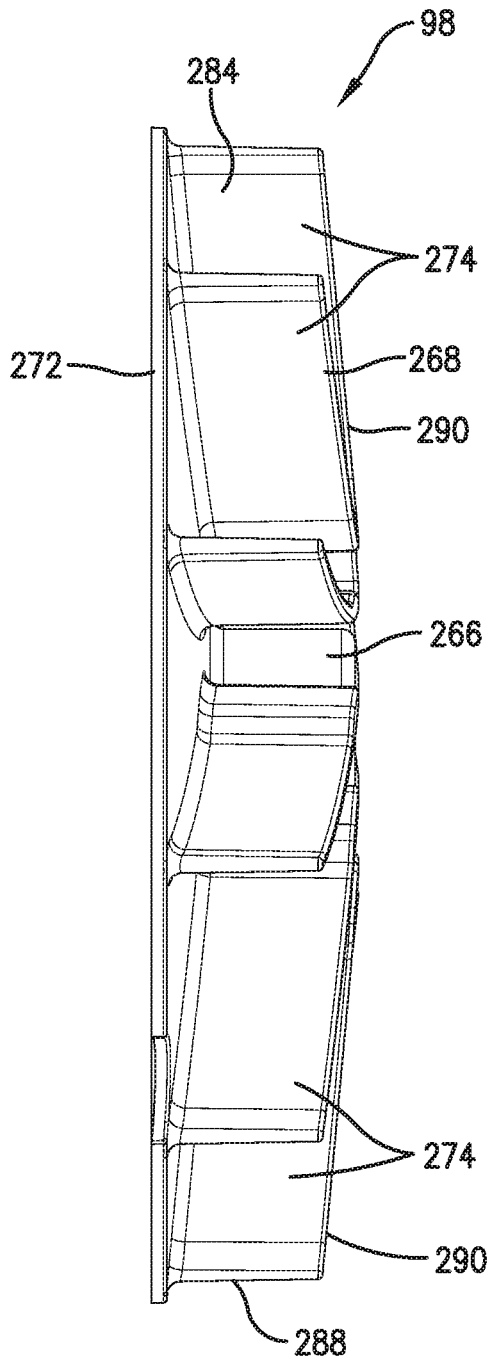


Fig. 41.

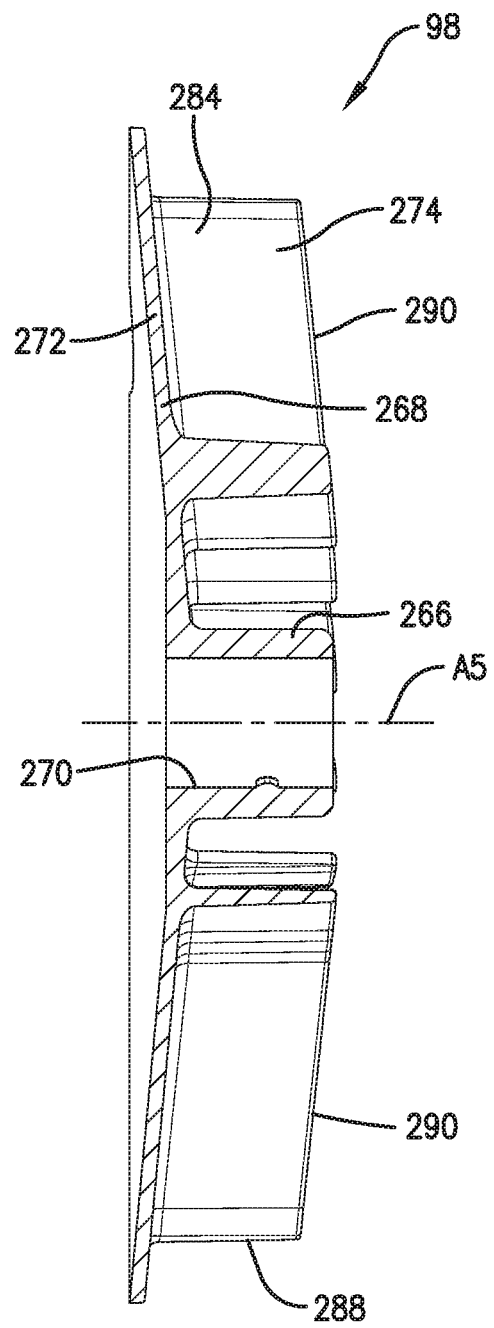


Fig. 42.

**MOTOR CONTROLLER WITH INDUCTOR
MOUNTED TRANSVERSE TO CONTROL
BOARD**

CROSS-REFERENCE TO RELATED
APPLICATIONS

[0001] This application is being filed contemporaneously with U.S. Nonprovisional application Ser. No. _____ entitled HEATSINK CLAMP FOR MULTIPLE ELECTRONIC COMPONENTS, U.S. Nonprovisional application Ser. No. _____ entitled MOTOR FAN AND GUARD FOR DIRECTING COOLANT AIR, U.S. Design application Ser. No. _____ entitled MOTOR CONTROLLER HOUSING, and U.S. Design application Ser. No. _____ entitled MOTOR AIR SCOOP, each of which is hereby incorporated in its entirety by reference herein.

BACKGROUND

1. Field

[0002] The present invention relates generally to electric motor controllers. More specifically, embodiments of the present invention concern a motor controller having an electronic circuit with an inductor.

2. Discussion of Prior Art

[0003] Electric motors are known to include a motor controller with electronic components to provide desired motor operation. Conventional motor controllers include a power factor correction (“PFC”) circuit to optimize the power factor associated with power supplied to the motor. Some prior art PFC circuits for electric motors utilize an interleaved circuit configuration that uses two or three board-mounted inductors to improve the power factor. Other prior art PFC circuits use a non-interleaved circuit configuration with a single large inductor.

[0004] Conventional motor controllers with PFC circuits have several deficiencies. For example, prior art PFC circuits with interleaved and non-interleaved configurations both require excessive amounts of space to house the PFC circuit. Although the non-interleaved circuit includes a single inductor, the circuit requires the use of a relatively large inductor in order to provide adequate power factor correction. The single inductor used in conventional non-interleaved controllers interferes with efficient packaging of the controller. The inductors associated with an interleaved circuit are relatively smaller than the inductor for the non-interleaved circuit. However, these inductors also preclude efficient packaging of the controller.

[0005] This background discussion is intended to provide information related to the present invention which is not necessarily prior art.

SUMMARY

[0006] The following brief summary is provided to indicate the nature of the subject matter disclosed herein. While certain aspects of the present invention are described below, the summary is not intended to limit the scope of the present invention.

[0007] Embodiments of the present invention provide a motor control assembly that does not suffer from the problems and limitations of prior art controllers, including those set forth above.

[0008] A first aspect of the present invention concerns a motor control assembly configured to operate an electric motor. The motor control assembly broadly includes a control housing and a controller. The control housing presents a controller chamber. The controller includes a control board mounted within the controller chamber. The control board defines a board plane. The controller further includes an inductor attached to the control housing and positioned within the controller chamber adjacent the control board. The inductor defines maximum first and second inductor dimensions measured along corresponding first and second directions parallel to the board plane and orthogonal to one another. The inductor further defines a maximum third inductor dimension measured along a third direction transverse to the board plane, with at least one of the first and second inductor dimensions being less than the maximum third inductor dimension.

[0009] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Other aspects and advantages of the present invention will be apparent from the following detailed description of the embodiments and the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWING
FIGURES

[0010] Preferred embodiments of the invention are described in detail below with reference to the attached drawing figures, wherein:

[0011] FIG. 1 is a perspective of an electric motor assembly constructed in accordance with a preferred embodiment of the present invention, showing an electric motor, a motor fan assembly mounted on the electric motor, and a motor control assembly operably coupled to the electric motor;

[0012] FIG. 2 is a fragmentary perspective of the electric motor and motor fan assembly shown in FIG. 1, with the motor housing and the motor fan assembly cross-sectioned to show components inside the motor housing and the motor fan assembly;

[0013] FIG. 3 is a fragmentary perspective of the electric motor assembly shown in FIG. 1, particularly depicting the control housing and motor controller of the motor control assembly, with the control housing being cross-sectioned to depict a lower housing section, middle housing section, upper housing section, and user interface housing of the control housing;

[0014] FIG. 4 is a fragmentary perspective of the control housing and motor controller similar to FIG. 3, but taken from the opposite side, depicting a cover of the user interface housing opened to provide access to a user interface, and showing the control housing cross-sectioned to depict a power factor correction circuit board, a drive interface board, a high-voltage interface, and the user interface of the motor controller;

[0015] FIG. 5 is a fragmentary upper perspective of the control housing and motor controller shown in FIGS. 3 and 4, showing the upper housing section and user interface housing removed to depict the middle housing section, with the middle housing section including a dividing wall to define a low-voltage chamber that receives the drive inter-

face board and a high-voltage chamber that receives the high-voltage interface and a relay board;

[0016] FIG. 6 is a fragmentary upper perspective of the control housing and motor controller similar to FIG. 5, but taken from the opposite side, with the dividing wall supporting a grommet to provide a feedthrough location, and showing a wire harness passing through the grommet to extend between the low-voltage chamber and the high-voltage chamber;

[0017] FIG. 7 is a fragmentary perspective of the electric motor assembly similar to FIG. 3, but taken from the opposite end of the electric motor, showing a control board and an inductor of the power factor correction circuit board mounted within a lower controller chamber;

[0018] FIG. 8 is a fragmentary upper perspective of the control housing and motor controller, but showing the middle housing section, upper housing section, and user interface housing removed, with the lower housing section receiving the power factor correction circuit board;

[0019] FIG. 9 is a fragmentary top view of the control housing and motor controller as shown in FIG. 8, particularly depicting the inductor positioned in an open space defined partly by the control board, with the inductor fastener assembly securing the inductor to an upright inductor wall;

[0020] FIG. 10 is a fragmentary exploded perspective of the control housing and motor controller shown in FIGS. 8 and 9, with the inductor fastener assembly including an insulation pad, silicone washer, spacer, and threaded fastener;

[0021] FIG. 11 is a fragmentary top view of the control housing and motor controller shown in FIGS. 8-10, showing the inductor secured to the upright inductor wall by the inductor fastener assembly;

[0022] FIG. 12 is a fragmentary cross section of the control housing and motor controller taken along line 12-12 of FIG. 11;

[0023] FIG. 13 is an upper perspective of the lower housing section shown in FIGS. 8-12;

[0024] FIG. 14 is an upper perspective of the lower housing section similar to FIG. 13, but taken from the opposite side;

[0025] FIG. 15 is a fragmentary perspective of the control housing and motor controller shown in FIG. 3, showing the power factor correction circuit board attached to a heat sink of the control housing, with heat-generating electrical components of the control board being clamped against the heat sink by a clamp assembly;

[0026] FIG. 16 is a fragmentary perspective of the heat sink and motor controller shown in FIGS. 3 and 15, showing the clamp assembly secured to the heat sink and spaced within a perimeter of the control board;

[0027] FIG. 17 is a fragmentary perspective of the heat sink and motor controller similar to FIG. 16, but showing the clamp assembly and heat sink exploded from the control board;

[0028] FIG. 18 is an enlarged fragmentary perspective of the heat sink and motor controller shown in FIGS. 3 and 15-17, showing a clamp bar and fasteners of the clamp assembly;

[0029] FIG. 19 is a fragmentary cross section of the heat sink and motor controller taken along line 19-19 in FIG. 18, with the clamp bar including a clamp margin and backing

flange, and showing projections of the clamp margin engaging respective electrical components;

[0030] FIG. 20 is a fragmentary cross section of the heat sink and motor controller similar to FIG. 19, but showing a first alternative set of heat-generating electrical components secured to the heat sink by the clamp assembly, with the clamp bar flexing so that the projections engage the respective electrical components;

[0031] FIG. 21 is a fragmentary cross section of the heat sink and motor controller similar to FIG. 20, but showing a second alternative set of heat-generating electrical components secured to the heat sink by the clamp assembly, with the clamp bar flexing in the opposite direction compared to FIG. 20 so that the projections engage the respective electrical components;

[0032] FIG. 22 is an upper perspective of the clamp bar shown in FIGS. 3 and 15-21;

[0033] FIG. 23 is a lower perspective of the clamp bar shown in FIGS. 3 and 15-22;

[0034] FIG. 24 is an enlarged fragmentary perspective of the heat sink and motor controller similar to FIG. 18, but showing a first alternative clamp assembly embodiment securing the electrical components against the heat sink;

[0035] FIG. 25 is a fragmentary cross section of the heat sink and motor controller shown in FIG. 24, with the alternative clamp bar including a clamp margin, backing flange, and spacers, and showing projections of the clamp margin engaging respective electrical components;

[0036] FIG. 26 is an upper perspective of the alternative clamp bar shown in FIGS. 24 and 25;

[0037] FIG. 27 is a lower perspective of the alternative clamp bar shown in FIGS. 24-26;

[0038] FIG. 28 is an enlarged fragmentary perspective of the heat sink and motor controller similar to FIG. 18, but showing a second alternative clamp assembly embodiment securing the electrical components against the heat sink;

[0039] FIG. 29 is a fragmentary cross section of the heat sink and motor controller shown in FIG. 28, with the alternative clamp bar including a clamp margin and backing flange, and showing projections of the clamp margin engaging respective electrical components;

[0040] FIG. 30 is an upper perspective of the alternative clamp bar shown in FIGS. 28 and 29;

[0041] FIG. 31 is a lower perspective of the alternative clamp bar shown in FIGS. 28-30;

[0042] FIG. 32 is a fragmentary perspective of the electric motor assembly shown in FIG. 1, with the motor fan assembly including a radial fan and a fan guard, and showing the control housing and the fan guard cross-sectioned, with the radial fan rotatably received in a fan chamber defined between the fan guard and the motor housing;

[0043] FIG. 33 is a fragmentary perspective of the electric motor assembly similar to FIG. 32, but taken from the opposite end of the electric motor;

[0044] FIG. 34 is a fragmentary side elevation of the electric motor assembly shown in FIG. 32, with the radial fan drawing air axially into the fan chamber and directing airflow radially outwardly to an air scoop of the fan guard, with the air scoop turning the airflow axially to flow through the heat sink and along the exterior motor surface;

[0045] FIG. 35 is a fragmentary exploded perspective of the electric motor assembly shown in FIGS. 32-34;

[0046] FIG. 36 is a perspective of the fan guard shown in FIGS. 32-35, with the fan guard including the air scoop;

[0047] FIG. 37 is a perspective of the fan guard similar to FIG. 36, but taken from the opposite side;

[0048] FIG. 38 is a perspective of the radial fan shown in FIGS. 32-35, with the radial fan including a hub and wheel;

[0049] FIG. 39 is a perspective of the radial fan similar to FIG. 38, but taken from the opposite side;

[0050] FIG. 40 is a front elevation of the radial fan shown in FIGS. 38 and 39, showing a wheel plate and blades of the wheel, and depicting the rotational direction of the radial fan;

[0051] FIG. 41 is a side elevation of the radial fan shown in FIGS. 38-40; and

[0052] FIG. 42 is a cross section of the radial fan taken along line 42-42 of FIG. 40.

[0053] The drawing figures do not limit the present invention to the specific embodiments disclosed and described herein. While the drawings do not necessarily provide exact dimensions or tolerances for the illustrated components or structures, the drawings, not including any purely schematic drawings, are to scale with respect to the relationships between the components of the structures illustrated therein.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0054] Turning to FIGS. 1-3, an electric motor assembly 50 is constructed in accordance with a preferred embodiment of the present invention. The electric motor assembly 50 is particularly configured for extended service in humid or wet environments. The depicted electric motor assembly 50 is preferably operable with a water pump (not shown) to provide a powered pump assembly for a recreational swimming pool. It will be appreciated that the electric motor assembly 50 may alternatively be drivingly attached to another mechanism or machine, without departing from the spirit of certain aspects of the present invention.

[0055] The electric motor assembly 50 broadly includes an electric motor 52, a motor fan assembly 54, and a motor control assembly 56. The electric motor assembly 50 is preferably oriented such that a rotational shaft axis A1 extends horizontally. However, it is permissible according to some aspects of the present invention for the motor assembly to be alternatively oriented (e.g., where the shaft axis is arranged vertically).

Electric Motor

[0056] The electric motor 52 is configured for use in any suitable environment. The motor 52 broadly includes a housing 60, a rotor 62, and a stator 64 (see FIG. 2). The rotor 62 is preferably rotatable about the rotational shaft axis A1 (see FIG. 2). In preferred embodiments, the stator 64 at least substantially circumscribes the rotor 62, such that the motor 52 is an inner rotor motor. It is permissible according to some aspects of the present invention, however, for the motor to be an outer rotor motor.

[0057] The rotor 62 preferably includes a rotor core 66, a plurality of magnets 68, and a shaft 70 defining the shaft axis A1 for the rotor 62. The rotor core 66 and magnets 68 are generally located within the housing 60. The shaft 70 is rotatably supported relative to the motor housing 60 to rotate about the shaft axis A1. More specifically, the shaft 70 is rotatably supported by opposite, axially spaced bearings 72

(see FIG. 2). In the preferred embodiment, the rotor weight is generally shared by the bearings 72.

[0058] The shaft 70 preferably includes opposite exposed portions 74a,b that are exposed relative to the motor housing 60 (see FIGS. 2 and 35). The exposed portion 74a is configured to drivingly engage the pump, and the exposed portion 74b is configured to drivingly engage a radial fan (as will be discussed below).

[0059] The exposed portions 74a,b are preferably cantilevered relative to the motor housing 60 such that respective free ends of the shaft 70 are spaced from the housing 60 (see FIG. 2). However, for some aspects of the present invention, the shaft could have an exposed portion alternatively located along the length of the shaft (e.g., where the exposed portion is spaced between the ends of the shaft and, more optionally, between bearing supports such that the exposed portion is along a non-cantilevered portion of the shaft).

[0060] The depicted shaft 70 presents an outer shaft surface 76 to receive the radial fan (see FIG. 2), such that the exposed shaft portion 47b supports the fan. However, according to some aspects of the present invention, the fan may be indirectly driven by the rotor shaft (e.g., a transmission (not shown) could be provided between the rotor shaft and fan). It is also possible for certain inventive aspects for the radial fan to be mounted to a motor shaft that is not directly connected to the mechanism powered by the motor.

[0061] Preferably, the shaft 70 of the rotor 62 defines the output shaft of the motor 52, which is drivingly connected to the pump. It will be appreciated, however, that certain aspects of the present invention contemplate the motor output shaft not being the rotor shaft. For example, the motor may alternatively be provided with a transmission (e.g., a gear drive) between the rotor shaft and output shaft, with the shafts being drivingly connected but otherwise discrete and spaced apart.

[0062] The motor housing 60 preferably includes a shell 78, endshields 80,82, and fasteners 84 (see FIGS. 1-3, 32, and 35). The housing 60 also presents an exterior motor surface 86 (see FIGS. 32-35). The shell 78 and the endshields 80 and 82 preferably present an internal motor chamber 88 that at least substantially receives the stator 64 and the rotor 62 (see FIG. 2).

[0063] In a preferred embodiment, the shell 78 extends generally circumferentially about the stator 64. It is permissible according to some aspects of the present invention, however, for the shell to extend in such a manner as to provide one or more flat sides, in contrast to the preferred generally cylindrical form, or to be otherwise alternatively shaped.

[0064] The endshields 80,82 preferably support respective bearings 72. The depicted endshields 80 and 82 are preferably secured to the shell 78 by means of the fasteners 84. However, it is within the ambit of certain aspects of the present invention for the housing to have an alternative shell and/or alternative endshields. Furthermore, the shell and endshields could be alternatively secured to one another.

[0065] In the illustrated embodiment, the endshields 80 and 82 each include a bearing housing 90 that presents a bearing pocket 92 receiving the respective bearing 72 (see FIG. 2). The endshields 80 and 82 also present relief openings 94 (see FIG. 2). The bearing pocket 92 and the respective relief opening 94 cooperatively provide a shaft

opening 96 that permits the shaft 70 to extend therethrough from the motor chamber 88 to outside the housing 60 (see FIG. 2).

[0066] Again, the bearings 72 preferably cooperatively rotatably support the shaft 70. However, alternative or additional bearings, supports, or shaft supports may be provided without departing from the scope of the present invention.

[0067] As will be explained further below, the motor fan assembly 54 is operable to advance airflow along the exterior motor surface 86 of the motor housing 60 to cool the motor control assembly 56. The motor fan assembly 54 is mounted externally to the motor housing 60 and includes a radial fan 98 and a fan guard 100 (see FIGS. 32-35).

[0068] Although the illustrated radial fan 98 is preferably used with the depicted motor 52, the radial fan could be used in connection with a wide range of motor configurations. For example, the shaft 70 of the rotor 62 preferably extends into and out of the housing 60 so that the radial fan 98 is mounted directly on the shaft 70 and is thereby driven directly by the rotor 62. However, in alternative embodiments, the radial fan could be powered by the rotor without being mounted on the rotor shaft (as noted above). Further, as mentioned previously, according to certain aspects of the present invention, the radial fan and rotor shaft could be interconnected by a transmission (not shown). In such alternative embodiments, the transmission could provide a transmission output shaft separate from the rotor shaft, where the radial fan is mounted on the transmission output shaft.

Motor Control Assembly

[0069] Turning to FIGS. 3-14, the motor control assembly 56 is configured to provide adjustable operation of the electric motor 52. The illustrated electric motor 52 is operable to drive a water pump (not shown), although the electric motor 52 could be configured to power a variety of alternative devices without departing from the scope of certain aspects of the present invention. The motor control assembly 56 includes a control housing 102, a motor controller 104, and a clamp assembly 106.

Control Housing

[0070] The control housing 102 preferably provides enclosed controller chambers 108a,b,c that are water-tight and sealed from the exterior of the control housing 102 (see FIGS. 4 and 7). The controller chambers 108a,b,c are preferably sealed from the exterior to prevent water, other fluids, or other contaminants from reaching high-voltage and low-voltage components in the control housing 102. The depicted control housing 102 includes a heat sink 110, a lower housing section 112, middle housing section 114, upper housing section 116, and a user interface housing 118 (see FIG. 4).

[0071] Turning to FIGS. 11-14, the lower housing section 112 includes a continuous side wall 120a, a bottom wall 120b, and an upstanding housing wall 120c. The side wall 120a extends about the bottom wall 120b to form a continuous perimeter margin 122 of the lower housing section 112. The bottom wall 120b includes a raised section 124 that presents a central opening 126 to receive the heat sink 110. The side wall 120a and bottom wall 120b cooperatively define channels 128 located on opposite sides of the raised section 124.

[0072] Turning to FIGS. 4-8, the middle housing section 114 includes a continuous side wall 130a, a lateral wall 130b, and an intermediate dividing wall 130c. The side wall 130a extends about the lateral wall 130b and the dividing wall 130c to form upper and lower perimeter margins 132a,b of the middle housing section 114.

[0073] The housing sections 112,114 and the heat sink 110 cooperatively form an enclosed PFC controller chamber 108a (see FIGS. 4 and 7). As will be explained, the PFC controller chamber 108a is configured to receive a power factor correction (PFC) circuit. The lower housing section 112 and middle housing section 114 are complementally shaped and removably engaged with one another along margins 122,132b that cooperatively form a continuous tongue-and-groove sealing joint 134. The sealing joint 134 preferably forms a continuous, hermetic seal between the sections 112,114 to restrict fluid ingress relative to the lower controller chamber 108a.

[0074] Turning again to FIGS. 11-14, the inductor wall 120c is integrally formed with the side wall 120a and projects inboard from the side wall 120a. The inductor wall 120c and side wall 120a extend transversely to the control board of the motor controller 104. The side wall 120a extends around the control board and partly defines the PFC controller chamber 108a.

[0075] As will be explained, the motor controller 104 preferably has an inductor mounted to the inductor wall 120c. The depicted inductor wall 120c presents an inboard wall surface 136 and an outboard wall surface 138. The inboard wall surface 136 faces the inductor, and the inductor is secured against the inboard wall surface 136 within the PFC controller chamber 108a.

[0076] The outboard wall surface 138 is located opposite the inboard wall surface 136. The outboard wall surface 138 defines a plurality of spaced-apart fins 140. The fins 140 preferably extend transversely to a board plane of the control board. The inductor wall 120c, including the fins 140, is configured to dissipate heat from the inductor via the outboard wall surface 138.

[0077] Turning to FIGS. 17 and 32-34, the heat sink 110 is operable to remove heat generated within the control housing 102 and includes a base 142 and a plurality of fins 144. Adjacent pairs of fins 144 define corresponding fin channels 146 that extend between opposite ends 148 of the heat sink 110 (see FIG. 17). The fins 144 extend axially along the exterior motor surface 86. The heat sink 110 is preferably formed of an aluminum alloy, but could include other materials (e.g., another metallic material such as carbon steel or stainless steel) within the scope of the present invention. As will be explained below, the motor fan assembly 54 is configured to direct axial air flow through the fan channels 146 to facilitate heat transfer from the heat sink 110.

[0078] The lower housing section 112 and the heat sink 110 are removably engaged with one another along a continuous sealing joint 150 (see FIG. 34). The sealing joint 150 preferably extends along and surrounds the central opening 126. The sealing joint 150 also preferably forms a continuous, hermetic seal between the lower housing section 112 and the heat sink 110 to restrict fluid or contaminant ingress relative to the PFC controller chamber 108a.

[0079] Turning to FIGS. 3, 4, 7, and 15, the upper housing section 116 includes a continuous side wall 152a and an upper wall 152b. The side wall 152a extends about the upper

wall **152b** to form a continuous perimeter margin **154** of the upper housing section. The upper housing section **116** also includes a series of gussets **156** to reinforce the upper wall **152b** (see FIG. 4). The upper wall **152b** defines an upper pocket **158** to receive the user interface (see FIG. 3).

[0080] The middle housing section **114** and the upper housing section **116** cooperatively form a low-voltage controller chamber **108b** and a high-voltage controller chamber **108c** (see FIG. 4). The middle housing section **114** and upper housing section are complementally shaped and are removably engaged with one another along a continuous sealing joint **160**. The sealing joint **160** preferably forms a continuous, hermetic seal between the sections **114,116** to restrict fluid ingress relative to the controller chambers **108b** and **108c**.

[0081] The dividing wall **130c** of the middle housing section **114** and one of the gussets **156** are removably engaged with one another along a joint **162** to separate the low-voltage controller chamber **108b** and the high-voltage controller chamber **108c** from one another (see FIG. 4). The joint **162** preferably restricts fluid communication between the low-voltage controller chamber **108b** and the high-voltage controller chamber **108c**.

[0082] The dividing wall **130c** preferably receives an elastomeric grommet **164** that provides a sealed feedthrough location along the dividing wall **130c** (see FIGS. 5 and 6). The grommet **164** is operable to receive a wiring harness **165** and allow the wiring harness **165** to extend between the controller chambers **108b** and **108c** (see FIGS. 5 and 6). The grommet **164** cooperates with the dividing wall **130c** and the respective gusset **156** to provide the sealing joint **162** between the controller chambers **108b** and **108c**.

[0083] The user interface housing **118** includes a frame **166** and a user interface cover **168** rotatably connected to one another by a hinge **170** (see FIGS. 1 and 4). The frame **166** presents a frame opening **172** to operably receive the user interface of the motor controller **104** (see FIG. 4).

[0084] The lower housing section **112**, middle housing section **114**, upper housing section **116**, and user interface housing **118** are all preferably formed of a synthetic resin material, although one or more of these components could include an alternative material without departing from the ambit of certain aspects of the present invention.

[0085] The depicted control housing **102** is preferably configured to provide sealed controller chambers **108a,b,c** and operably enclose components of the motor controller **104**. The principles of the present invention are equally applicable where the control housing is alternatively configured to suitably house elements of the controller. For some aspects of the present invention, it will be understood that at least some components of the control housing and/or the controller could be integrally provided as part of the electric motor. It will also be appreciated that the shape of the control housing may vary without departing from the scope of the present invention. Furthermore, certain aspects of the present invention contemplate different housing sectional arrangements or no sectioning at all.

Motor Controller and Inductor

[0086] Referring again to FIGS. 3-14, the motor controller **104** preferably includes a power factor correction (PFC) circuit board **174**, a low-voltage drive interface board **176**, a high-voltage interface **178**, a relay board **180**, and a user interface **182** (see FIGS. 4-6).

[0087] In the customary manner, the user interface **182** enables the operator to change one or more motor settings associated with motor (and preferably pump) operation. The user interface **182** includes an interface circuit board **184**, a user interface display **186**, and user interface controls **188** (see FIG. 4).

[0088] The PFC circuit board **174** is configured to facilitate adjustment of motor settings and provide corresponding control of motor operation. The PFC circuit board **174** includes, among other things, a control board **190**, heat-generating electrical components **192**, and an inductor **194** (see FIGS. 10 and 17).

[0089] The control board **190** is configured to support various electrical components and is mounted within the PFC controller chamber **108a**. The control board **190** defines a board plane **196** and presents a perimeter margin **198** (see FIGS. 8 and 9). The perimeter margin **198** forms a notched opening that partly defines an open space **200** to receive the inductor **194** (see FIGS. 11 and 12).

[0090] In alternative embodiments, one or more elements of the control board **190** could be alternatively configured and/or positioned within the control housing (e.g., to provide suitable motor operation) without departing from the scope of the present invention.

[0091] Turning to FIGS. 8-12, the inductor **194** is operable for use as part of the PFC circuit board **174** to adjust the power factor associated with electrical power supplied to the electric motor **52**. Preferably, the PFC circuit, including the inductor **194**, is configured to increase the power factor, although other adjustments to the power factor are within the ambit of the present invention. The depicted inductor **194** includes a metal inductor core **202** and inductor windings **204** wrapped around the core **202** (see FIG. 8).

[0092] The illustrated inductor core **202** preferably has a toroidal core body with a generally circular core axis **A2** (see FIG. 12). The windings **204** are preferably wrapped about the core axis **A2** to form a series of loops **204a** (see FIG. 12).

[0093] Preferably, the inductor core **202** and inductor windings **204** cooperatively present an inner margin **206** that defines an inductor opening **208** (see FIG. 12). The inductor opening **208** extends through the inductor core **202** along an inductor axis **A3** (see FIG. 10).

[0094] The inductor **194** is operably coupled to the control board **190** by leads **204b** of the windings **204** (see FIGS. 8 and 9). The leads **204b** are coupled to contacts **210** associated with the control board **190** (see FIGS. 8 and 9).

[0095] The toroidal shape of the depicted inductor **194** is preferable. However, in alternative embodiments, the inductor could have an alternative inductor shape (e.g., cylindrical, rod-shaped, etc.) within the scope of the present invention.

[0096] The inductor **194** and the rest of the PFC circuit board **174** are preferably located within the control housing **102** to optimize the use of space within the control housing **102** and enable the design of the control housing **102** to have a small form factor.

[0097] The motor controller **104** includes an inductor fastener assembly **212** that extends through the inductor opening **208** to secure the inductor **194** to the control housing **102**. The inductor fastener assembly **212** includes an insulation pad **212a**, a silicone washer **212b**, a spacer **212c**, and a threaded fastener **212d** (see FIGS. 10 and 12).

[0098] The insulation pad **212a** and the silicone washer **212b** are received between the spacer **212c** and the inductor

194. The spacer **212c** extends through the inductor opening **208** and is secured to the inductor wall **120c** by the threaded fastener **212d**. A thermal pad **214** is positioned between the inductor **194** and the inductor wall **120c** and is operable to conduct heat from the inductor **194** to the inductor wall **120c** to facilitate dissipation of heat from the inductor **194** (see FIGS. **10** and **12**). Although the inductor fastener assembly **212** and the thermal pad **214** are preferred for mounting the inductor **194**, one or more of these components could be alternatively configured to suitably mount the inductor.

[**0099**] The inductor **194** is attached to the control housing **102** and positioned within the PFC controller chamber **108a** adjacent the control board **190**. When secured to the inductor wall **120c**, the inductor **194** is located at least partly within the open space **200** and extends into and out of the corresponding channel **128**. The inner margin **206** of the inductor **194** circumscribes the spacer **212c**. The inductor **194** is also positioned to extend radially relative to the inductor axis **A3** beyond opposite sides of the control board **190**. The inductor **194** is preferably arranged within the PFC controller chamber **108a** so that the inductor axis **A3** extends substantially parallel to the board plane **196**.

[**0100**] When mounted in the PFC controller chamber **108a**, the inductor **194** defines maximum first and second inductor dimensions **D1**, **D2** measured along corresponding first and second directions (see FIG. **11**). The first and second directions are generally parallel to the board plane **196** and orthogonal to one another. As used herein, when referring to a feature (e.g., a dimension) as being parallel to the board plane, it is within the scope of the present invention for such feature, if the feature includes or is part of a planar component, to be coplanar with the board plane.

[**0101**] The inductor **194** further defines a maximum third inductor dimension **D3** measured along a third direction transverse to the board plane **196** (see FIG. **12**). In the depicted embodiment, the second and third inductor dimensions **D2** and **D3** are diametrical dimensions of the inductor **194**. Preferably, at least one of the first and second inductor dimensions **D1**, **D2** is less than the maximum third inductor dimension **D3**. Again, because the illustrated inductor **194** is toroidal in shape, the second and third inductor dimensions **D2** and **D3** are substantially identical, with the first inductor dimension **D1** being less than both. When referring to a "maximum" dimension of the inductor, the maximum dimension refers to the maximum size of the inductor as measured in the corresponding direction. That is to say, the maximum dimension constitutes the greatest length of the inductor in the corresponding direction, regardless of where that maximum dimension might fall along the body.

[**0102**] In the depicted embodiment, the control board **190** and the board plane **196** extend laterally. As a result, the inductor **194** is arranged in a generally upright orientation. The inductor **194** is preferably oriented relative to the control board **190** to optimize the use of space within the control housing **102**. The illustrated inductor orientation also preferably enables the control housing **102** to have a small form factor.

[**0103**] Still referring to FIGS. **8-12**, the inboard wall surface **136** of the inductor wall **120c** faces the inductor **194** and restricts movement of the inductor **194** within the PFC controller chamber **108a**. In the illustrated embodiment, the inboard wall surface **136** spans the inductor **194** and is at least coextensive with the inductor **194**. In particular, the

inboard wall surface **136** is at least coextensive with the length of the first inductor dimension and the length of the third inductor dimension.

[**0104**] In alternative embodiments, the inductor wall **120c** could be alternatively configured to extend along and support the inductor (e.g., where the inductor wall is not coextensive with the inductor).

Clamp Assembly

[**0105**] Turning to FIGS. **15-23**, the clamp assembly **106** is configured to engage heat-generating electrical components **192** to facilitate transfer of heat from the components **192** to the heat sink **110**. In the depicted embodiment, the clamp assembly **106** is operable to engage at least three heat-generating electrical components **192** (which are preferably arranged side-by-side) and clamp the electrical components **192** relative to the heat sink **110**. The clamp assembly **106** preferably includes a clamp bar **216** and threaded fasteners **218** to secure the clamp bar **216** to the heat sink **110**.

[**0106**] The electrical components **192** clamped in place by the clamp assembly **106** are preferably MOSFETs, but other heat-generating electrical components could be engaged by the clamp assembly **106**. As will be discussed, the electrical components **192** each present a thickness dimension.

[**0107**] The disclosed motor controller **104** preferably has three (3) electrical components **192** arranged along and operably coupled to the control board **190** (see FIG. **15**). However, the principles of the present invention are applicable where an alternative number of electrical components **192** (whether the components **192** include MOSFETs and/or other heat-generating electrical components) are positioned along the control board **190**.

[**0108**] The electrical components **192** are preferably arranged in series along the length of the clamp bar **216**. Furthermore, the electrical components **192** are generally axially aligned with one another along a longitudinal clamp axis **A4** (see FIG. **23**). However, the electrical components **192** could be alternatively positioned consistent with the scope of the present invention. In alternative embodiments, the electrical components could be arranged in series along the clamp bar length, but with one or more components being laterally offset from the longitudinal clamp axis.

[**0109**] The clamp bar **216** preferably includes a clamp margin **220** and a backing flange **222**. The backing flange **222** essentially serves as a support for the clamp margin **220** (see FIGS. **22** and **23**). The depicted clamp margin **220** extends continuously along the length of the clamp bar **216**. The clamp margin **220** preferably defines three (3) spaced apart projections **224** and presents a clamping surface **226** (see FIGS. **22** and **23**). The backing flange **222** presents a flange surface **228** opposite the clamping surface **226** (see FIGS. **19** and **22**). The clamping surface **226** and flange surface **228** cooperatively define a maximum clamp height dimension **H1** (see FIG. **19**). The clamp bar **216** also presents a slot **230** and a pair of fastener openings **232** (see FIGS. **22** and **23**).

[**0110**] Preferably, the slot **230** extends transversely to the clamp axis **A4** and is positioned between two of the projections **224**. The depicted slot **230** also defines respective clamp bar sections **216a** on opposite sides of the slot **230**. In particular, the slot **230** intersects the flange surface **228** and extends transversely from the flange surface **228** toward the clamping surface **226**. Preferably, the slot **230** extends through the backing flange **222** to present flange sections

222a separated by the slot **230**. In the depicted embodiment, the flange sections **222a** are associated with respective clamp bar sections **216a**.

[0111] The depicted slot **230** is described as extending transversely to the clamp axis **A4**. While the illustrated slot **230** and clamp axis **A4** are generally perpendicular to one another, it will be understood that the slot and clamp axis could extend transversely to one another without being perpendicular. That is, the slot could simply extend across the clamp axis, and it will be appreciated that the angle formed therebetween could vary within the ambit of the present invention.

[0112] Although the slot **230** extends through the backing flange **222**, in alternative embodiments, the slot **230** could extend through at least one of the clamp margin **220** and the flange **222** to provide desirable clamp functionality. For instance, the slot **230** could be variously configured so that the clamp bar **216** is flexible along its length and allows the clamp bar sections **216a** to shift relative to one another.

[0113] The configuration of slot **230** and the clamp margin **220** permits the clamp bar sections **216a** to shift relative to one another about a transverse axis to facilitate clamping engagement of the projections **224** with the electrical components **192**. In particular, the reduced cross-sectional dimension of the clamp bar **216** at the location of the slot **230** facilitates flexing. More particularly, the clamp margin **220** is flexible, thereby facilitating shifting of the clamp bar sections **216a** generally about the portion of the clamp margin **220** interconnecting the clamp bar sections (i.e., the portion of the clamp margin **220** underlying the slot **230**). Yet further, the slot **230** serves to space the flange sections **222** apart to allow shifting of the clamp bar sections **216a**. Therefore, the slot **230** and clamp margin **220** cooperatively permit shifting of the clamp bar sections **216a** toward one another (see FIG. 20) or away from one another (see FIG. 21). As will be discussed, the clamp bar sections **216a** are preferably relatively shiftable so that the clamp bar **216** engages each of the electrical components **192**.

[0114] The clamp bar **216** is preferably formed of a synthetic resin material. By including a synthetic resin material, the clamp bar **216** preferably serves as an insulator. The synthetic resin material also preferably permits flexing of the clamp bar, as discussed above. For certain aspects of the present invention, the clamp bar could include, alternatively or additionally, a metallic material (such as carbon steel or aluminum). It will be appreciated that metallic features of the clamp bar could be cast, machined, and/or formed by other manufacturing methods.

[0115] In alternative embodiments where the clamp bar includes a metallic material, the alternative clamp bar also preferably includes at least some insulation material (e.g., a synthetic resin) used in combination with a metallic portion of the clamp bar. The insulation material can be variously provided with the metallic portion within the scope of the present invention. For instance, an insulation portion comprised of synthetic resin could be molded onto the metallic portion. Similarly, one or more insulation layers could be attached (e.g., adhered) relative to the metallic portion.

[0116] The projections **224** are configured to be located in engagement with the respective electrical components **192**. The projections **224** are depicted as being in direct contact with the electrical components **192**. However, when referring to the projections as being in engagement with the electrical components, it will be understood that one or more

material layers may be interposed between the projections and electrical components. For instance, such interposed layers may include a film (e.g., a film including a synthetic resin material, such as Mylar®), fabric, paste, grease, liquid, and/or other material. One or more interposed layers may be considered as integrally part of the electrical components. In any event, any interposed layers are preferably configured to permit the clamp bar to apply a clamping force to the electrical components.

[0117] In the depicted embodiment, the projections **224** are spaced in series along the length of the clamp bar **216** to provide opposite endmost projections **224** and an intermediate projection **224**. The depicted projections **224** are spaced along and define the clamp axis **A4**. The clamp margin **220** extends continuously between the endmost projections to join the clamp bar sections **216a**. In the depicted embodiment, the slot **230** is longitudinally aligned with the intermediate projection **224**.

[0118] The fastener openings **232** each extend transversely through the clamp margin **220** and the backing flange **222**. Each fastener opening **232** is preferably positioned between a respective pair of adjacent projections **224**. In this manner, the clamp assembly **106** is preferably configured so that each fastener **218** is located between the respective pair of adjacent projections **224** (and also between corresponding electrical components **192**). The fastener openings **232** are preferably arranged in series along the length of the clamp bar **216** and generally axially aligned with one another along the longitudinal clamp axis **A4**.

[0119] Although the clamp bar **216** includes a pair of fastener openings **232**, alternative embodiments of the clamp bar could have more than two fastener openings or a single fastener opening. For instance, the clamp bar could have four projections and three fastener openings, with each fastener opening located between a respective adjacent pair of projections. For certain aspects of the present invention, the clamp bar could also present a common opening to receive two or more fasteners. In such an alternative embodiment, the clamp bar could present an elongated slotted opening that extends transversely through the clamp margin **220** and the backing flange **222** while extending along the clamp axis.

[0120] It is also within the ambit of the present invention where the fastener openings are alternatively located along the clamp bar. For instance, the fastener openings could be arranged in series, but with one or more fastener openings being laterally offset from the longitudinal axis. For some aspects of the present invention, the clamp bar could be devoid of fastener openings (e.g., where an alternative fastener is used to secure the clamp bar).

[0121] The fasteners **218** are configured to engage the flange sections **222a** to hold the clamp bar **216** against the electrical components **192**. The fasteners **218** comprise conventional machine screws that are removably received by the clamp bar **216**, but could include other types of fastening devices or elements within the ambit of the present invention. For example, in alternative embodiments, a fastener could comprise one or more of a bolt, nut, washer, pin, rivet, adhesive, or weld. It is also within the scope of the present invention where at least part of the fastener is integrally formed with the clamp bar.

[0122] Although the clamp bar **216** includes a pair of fasteners **218**, alternative embodiments of the clamp bar could have more than two fasteners or a single fastener. It is

also within the ambit of the present invention where the fasteners are alternatively located along the clamp bar. For instance, the fasteners could be arranged in series, but with one or more fasteners being laterally offset from the longitudinal axis. For some aspects of the present invention, the clamp bar assembly could be devoid of fasteners.

[0123] In use, the clamp bar **216** is configured to engage heat-generating electrical components **192** and urge the electrical components against the heat sink **110**. The electrical components are depicted as being in direct contact with the heat sink **110**. However, when referring to the electrical components as being in engagement with the heat sink, it will be understood that one or more material layers may be interposed between the electrical components and the heat sink. For instance, such interposed layers may include a film (e.g., a film including a synthetic resin material, such as Mylar®), fabric, paste, grease, liquid, and/or other material. Again, one or more interposed layers may be considered as integrally part of the electrical components. An interposed layer between the electrical components and the heat sink is preferably to facilitate heat conduction from the electrical components to the heat sink. Any interposed layers are preferably configured to permit the electrical components to be clamped against the heat sink.

[0124] The clamp assembly **106** is preferably configured to engage various arrangements of electrical components. In one embodiment, the clamp bar **216** is illustrated as engaging electrical components **192** that each have substantially the same thickness dimension T1 (see FIG. 19). However, the clamp bar **216** is preferably operable to engage electrical components **192** with different thickness dimensions T1, T2, T3 (see FIGS. 20 and 21).

[0125] Again, the clamp bar sections **216a** are preferably relatively shiftable so that the clamp bar **216** can engage each electrical component **192**. More specifically, the clamp bar **216** is configured to flex to facilitate clamping engagement of the projections **224** with the electrical components **192**. This configuration enables the clamp bar **216** to engage electrical components having different thickness dimensions T1, T2, T3.

[0126] In one such example, the clamp bar sections **216a** can flex away from the heat sink **110** to engage an intermediate electrical component **192** with a thickness dimension T1 shorter than a thickness dimension T2 of adjacent electrical components **192** (see FIG. 20).

[0127] In another example, the clamp bar sections **216a** can flex toward the heat sink **110** to engage endmost electrical components **192** with a thickness dimension T3 shorter than a thickness dimension T1 of an intermediate electrical component **192** (see FIG. 21). For certain aspects of the present invention, the clamp bar could be secured so that one clamp bar section flexes toward the heat sink and another clamp bar section flexes away from the heat sink.

[0128] Again, in the depicted embodiment, the projections **224** are arranged in series along the length of the clamp bar **216**. Furthermore, the projections **224** are generally axially aligned with one another along the longitudinal clamp axis A4 of the clamp bar **216**.

[0129] However, the projections **224** could be alternatively positioned according to certain aspects of the present invention. In alternative embodiments, the projections could be arranged in series along the clamp bar length, but with one or more projections being laterally offset from the

longitudinal axis. In one alternative example, the clamp bar could have three (3) projections arranged in a triangular configuration such that each projection is located at a respective point of the triangle. In such an alternative embodiment, it will be understood that any pair of projections would cooperatively define a respective clamp axis.

[0130] Turning to FIGS. 24-27, an alternative clamp assembly **234** is depicted as part of the motor controller. The alternative clamp assembly **234** includes an alternative clamp bar **236** and fasteners **218**.

[0131] The clamp bar **236** preferably includes an alternative clamp margin **238**, a backing flange **240**, and spacers **242** projecting from the clamp margin **238**. The clamp margin **238** defines three spaced apart projections **244**.

[0132] The depicted spacers **242** each preferably include a sleeve having a generally tubular shape. The spacers **242** are located between respective adjacent pairs of projections **244**. However, one or more spacers could be alternatively configured and/or positioned without departing from the scope of the present invention.

[0133] The flange **240** includes flange sections **240a** defined on opposite sides of a slot **245**. The clamp bar **236** also presents fastener openings **246** extending transversely through the flange sections **240a**, the clamp margin **238**, and through respective spacers **242**.

[0134] The inside diameter of the fastener openings **246**, particularly along the spacers **242**, is preferably oversized relative to the outside diameter of the threaded body of the fasteners **218**. The oversized fastener openings **246** preferably accommodates a slight angular cant of the spacers **242** (and, generally, the clamp bar sections) associated with flexing of the clamp bar.

[0135] The spacers **242** serve a number of purposes. For example, in certain arrangements, the spacers **242** may restrict the clamp bar **236** from applying too much clamping force to the electrical components **192** (i.e., by overly tightening the fasteners **218**). When in clamping engagement with the electrical components **192**, the spacers **242** and the heat sink **110** preferably define a slight gap G therebetween (see FIG. 25), although contact between the bottom of the spacer **242** and the heat sink **110** will restrict or limit the clamping force. Furthermore, the spacers generally encapsulate the fasteners **218** (which are preferably metal and possibly electrically conductive) and thereby reduce the risk of arcing to the fasteners.

[0136] In FIGS. 28-31, another alternative clamp assembly **248** is depicted. The alternative clamp assembly **248** includes an alternative clamp bar **250** and fasteners **218**.

[0137] The clamp bar **250** preferably includes a clamp margin **252** and a backing flange **254** to support the clamp margin **252**. The clamp margin **252** defines three (3) spaced apart projections **256**.

[0138] The backing flange **254** includes flange sections **254a** defined on opposite sides of a slot **257**. The backing flange **254** presents a flange surface **258** opposite a clamping surface **260**. The clamping surface **260** and flange surface **258** cooperatively define a maximum clamp height dimension H2. The clamp bar **250** is similar to clamp bar **216**, but the clamp bar **250** preferably has a maximum clamp height dimension H2 greater than the height dimension H1 of clamp bar **216**. More preferably, the ratio of the maximum clamp height dimension H2 of clamp bar **250** to the height dimension H1 of clamp bar **216** is about 2/1, although this

ratio could also range from about 1.5/1 to about 3/1 within the scope of the present invention.

Motor Fan Assembly

[0139] Turning to FIGS. 2 and 32-42, the motor fan assembly 54 serves to direct airflow toward the heat sink 110, thereby facilitating heat dissipation from the heat sink 110. The motor fan assembly 54 broadly includes the radial fan 98 and the fan guard 100.

[0140] The radial fan 98 is configured to drive airflow to the heat sink 110. The radial fan 98 is preferably mounted on the rotatable shaft 70 exteriorly of the motor housing 60 and is rotatable with the shaft 70 in a rotation direction R (see FIGS. 32 and 40) to direct airflow radially outwardly.

[0141] In the illustrated embodiment, the radial fan 98 is unitary and includes a hub 266 and a wheel 268. The radial fan 98 presents a rotational axis A5 about which the radial fan 98 rotates (see FIGS. 40 and 42). It will be appreciated that the rotational axis A5 and the shaft axis A1 are substantially coaxial in the illustrated embodiment. In the usual manner, the hub 266 presents a shaft hole 270 receiving the exposed portion 74b of the shaft 70 when the radial fan 98 is mounted on the shaft 70.

[0142] The radial fan 98 is fixed relative to the shaft 70 outside the housing 60 and is rotatable with the shaft 70 to direct air flow radially outwardly. Most preferably, the radial fan 98 is fixedly attached directly to the shaft 70. Again, it is within the scope of the present invention where the radial fan 98 is mounted on an output shaft other than the shaft 70 (e.g., a transmission output shaft). In such an alternative embodiment, it will be understood that the rotational axis and the rotor shaft axis could be coaxial or axially offset from one another (e.g., depending on the configuration of the transmission).

[0143] In the preferred embodiment, the shaft hole 270 is complementally sized and shaped so that the shaft 70 is snugly received in the shaft hole 270. In the depicted embodiment, the radial fan 98 is preferably frictionally engaged with the shaft 70 so as to be fixedly attached thereto (see FIG. 7).

[0144] However, it is within the scope of certain aspects of the present invention for the hub to be alternatively configured for driving attachment to the output shaft. For instance, although the illustrated hub provides a non-circular bore, the hub could have a profile shape that is splined or has a circular shape for mating with a corresponding shape of the output shaft.

[0145] In various alternative embodiments, the hub could be alternatively fixed to the output shaft, whether or not the output shaft extends entirely through the hub. For instance, the hub could be secured to the output shaft with one or more fasteners (e.g., a set screw, cotter pin, etc.). In addition, the hub may be press fit to the shaft. Also in alternative embodiments, the hub could be configured so that the output shaft extends only partly through the hub or does not project from both ends of the hub.

[0146] The illustrated wheel 268 drives airflow radially outwardly. Preferably, the wheel 268 includes a wheel plate 272 and a plurality of radially extending fan blades 274. Preferably, the wheel plate 272 and fan blades 274 cooperatively form a series of passages 276 (see FIG. 40) extending radially outward relative to the hub 266.

[0147] The wheel plate 272 is supported by the hub 266 and located axially outboard of the housing 60 when the

motor 52 is secured for operation. The wheel plate 272 of the illustrated embodiment is preferably continuous and extends to an outer plate margin 278 (see FIG. 40). The outer plate margin 278 extends circumferentially so that the wheel plate 272 is generally circular in shape and presents opposed notches 280.

[0148] For some aspects of the present invention, the wheel plate 272 could be alternatively constructed (e.g., where the wheel plate 272 is not continuous). The depicted wheel plate 272 is fixed to the hub 266 and is preferably positioned so that the center of the outer plate margin 278 corresponds to the rotational axis A5. Those of skill in the art will also appreciate that the wheel plate could be alternatively shaped without departing from the principles of the present invention.

[0149] The fan blades 274 partly define the passages 276 and facilitate airflow in a radially outward direction within the passages 276. Each adjacent pair of fan blades 274 presents a fan discharge opening 282 through which airflow is discharged from the corresponding passage 276 (see FIG. 40).

[0150] Each fan blade 274 presents an exterior blade surface 284 having a curvilinear airfoil profile (see FIG. 38). The airfoil profile defines a leading edge 286, a trailing edge 288, and a longitudinal edge 290 (see FIG. 38). The leading edge 286 is spaced radially inside the trailing edge 288. The airfoil profile also defines a curved camber line 292 extending between the leading edge 286 and the trailing edge 288 (see FIG. 40).

[0151] The exterior blade surface 284 of each fan blade 274 includes pressure and suction surfaces 284a,b on opposite sides of the camber line 292 and extending radially between the leading edge 286 and the trailing edge 288 (see FIG. 40). Preferably, the pressure surface 284a faces into the rotational direction R, and a portion of the pressure surface 284a is concave. The suction surface 284b preferably faces oppositely from the rotational direction R, and at least part of the suction surface 284b is convex.

[0152] However, the pressure surface and/or suction surface of the fan blade could be alternatively configured without departing from the scope of certain aspects of the present invention. For instance, although a majority of the pressure surface 284a is concave, the pressure surface could have one or more alternative portions that include convex, flat, and/or concave features. Similarly, although the suction surface 284b is generally convex, the suction surface could have one or more alternative portions that include convex, flat, and/or concave features.

[0153] The airfoil profile of each fan blade 274 also preferably has a chord line 294 comprising a straight line that extends through the leading edge 286 and the trailing edge 288 (see FIG. 40). Each fan blade 274 is associated with a radial line extending through the rotational axis A5 and the leading edge 286. The chord line 294 and the radial line of the depicted fan blades 274 are off-axis to define an angle of attack θ therebetween (see FIG. 40). Preferably, the chord line 294 extends from the radial line along a direction opposite the rotational direction R.

[0154] Again, in accordance with certain aspects of the present invention, the fan blades could also have an alternative blade shape. For instance, the fan blades could have an alternative curved airfoil shape (e.g., to induce a greater airflow). For some aspects of the present invention, one or more fan blades could include flat blade sections.

[0155] The radial fan 98 preferably comprises a synthetic resin material, such as an elastomeric material. It is equally within the ambit of the present invention where the radial fan includes, alternatively or additionally, one or more other materials. For instance, the radial fan could include one or more metallic materials (e.g., carbon steel, stainless steel, and/or aluminum).

[0156] In the illustrated embodiment, the radial fan 98 preferably comprises a one-piece construction. However, for some aspects of the present invention, the radial fan could include multiple components that are attached to one another (e.g., where the components are welded, adhered, fastened, and/or otherwise secured to one another).

[0157] Turning to FIGS. 34-37, the illustrated fan guard 100 preferably protects the radial fan 98, particularly during fan operation. The fan guard 100 is also preferably operable to direct airflow from the radial fan 98 toward the heat sink 110. The fan guard 100 preferably includes a fan cover 296 and an air scoop 298 that are integrally formed with one another.

[0158] The fan guard 100 is mounted relative to the motor housing 60 and extends over the radial fan 98. The fan guard 100 cooperates with the motor housing 60 to define a fan chamber 300 and a fan outlet opening 302 (see FIG. 34). The fan chamber 300 extends between a fan inlet opening 304 and the fan outlet opening 302.

[0159] The fan cover 296 includes a central grate 306 and a peripheral skirt 308 that extends axially from the central grate 306. The skirt 308 extends circumferentially about the central grate 306 and presents multiple fastener openings 310.

[0160] In the depicted embodiment, the central grate 306 presents the fan inlet opening 304. The radial fan 98 is operable to draw air axially into fan chamber 300 via the fan inlet opening 304.

[0161] The skirt 308 is preferably sized to be received on one end of the motor housing 60. Radially-extending threaded fasteners 312 are inserted in the openings 310 and threaded into bosses 314 associated with the endshield 82 (see FIG. 35). The fan guard 100 is arranged so that the radial fan 98 is axially outboard of the fasteners 312.

[0162] Although the fan guard 100 preferably includes the fan cover 296, the fan cover could be alternatively configured without departing from the scope of the present invention. For certain aspects of the invention, the motor fan assembly could be devoid of a fan cover. For instance, the motor fan assembly could use an air scoop without using a fan cover.

[0163] In the illustrated embodiment, the air scoop 298 is operable to receive radial airflow from the radial fan 98 and turn the airflow axially. The air scoop 298 preferably includes a scoop body 316 and spaced apart axially extending airflow vanes 318. The airflow vanes 318 at least partly define scoop channels 319 that extend axially along the airflow vanes 318 (see FIG. 37). The airflow vanes 318 guide the airflow as the air scoop 298 turns the airflow axially.

[0164] The air scoop 298 partly defines the fan outlet opening 302 of the fan chamber 300, with axial airflow being discharged by the fan outlet opening 302. The air scoop 298 presents an air scoop inlet 320 and an air scoop outlet 322 (see FIG. 34). The scoop body 316 preferably presents a curved inside face 324 located between the air scoop inlet 320 and the air scoop outlet 322. The curved

inside face 324 generally defines the airflow turn provided by the air scoop 298. In the depicted embodiment, the airflow vanes 318 project from the inside face 324. For certain aspects of the present invention, the inside face of the air scoop (or other parts of the air scoop) could have an alternative shape and/or configuration for turning the airflow axially.

[0165] The airflow vanes 318 extend between the air scoop inlet 320 and the air scoop outlet 322. The fan blades 274 extend along an axial blade dimension D4 (see FIG. 34). The depicted air flow vanes 318 are aligned axially with at least part of the axial blade dimension D4. Within the ambit of the present invention, the air flow vanes could be configured to extend along only part of the axial extent of the fan blades. For certain aspects of the present invention, the air flow vanes could be entirely axially offset from the fan blades.

[0166] The air scoop outlet 322 is associated with the fan outlet opening 302 in the depicted embodiment. The air scoop 298 extends radially outwardly relative to the radial fan 98 and axially along the rotational axis A5 to receive radial airflow and turn the airflow axially to flow through the air scoop outlet 322 and along the exterior motor surface 86.

[0167] The fan guard 100 is installed so that the fan outlet opening 302 is generally aligned with and communicates with one end 148 of the heat sink 110. Preferably, at least some of the airflow vanes 318 are in general alignment with corresponding fins 144 of the heat sink 110. The scoop channels 319 are also preferably in at least partial alignment with respective fin channels 146 of the heat sink 110. Thus, as the radial fan 98 produces airflow, the airflow is turned axially by the air scoop 298 and discharged axially to flow through the fin channels 146 of the heat sink 110. In this manner, the motor fan assembly 54 facilitates heat transfer out of the heat sink 110 during motor operation.

[0168] Although the above description presents features of preferred embodiments of the present invention, other preferred embodiments may also be created in keeping with the principles of the invention. Such other preferred embodiments may, for instance, be provided with features drawn from one or more of the embodiments described above. Yet further, such other preferred embodiments may include features from multiple embodiments described above, particularly where such features are compatible for use together despite having been presented independently as part of separate embodiments in the above description.

[0169] The preferred forms of the invention described above are to be used as illustration only, and should not be utilized in a limiting sense in interpreting the scope of the present invention. Obvious modifications to the exemplary embodiments, as hereinabove set forth, could be readily made by those skilled in the art without departing from the spirit of the present invention.

[0170] The inventors hereby state their intent to rely on the Doctrine of Equivalents to determine and assess the reasonably fair scope of the present invention as pertains to any apparatus not materially departing from but outside the literal scope of the invention as set forth in the following claims.

1. A motor control assembly configured to operate an electric motor, said motor control assembly comprising:

a control housing presenting a controller chamber; and a controller including a control board mounted within the controller chamber, said control board defining a board plane,
 said controller further including an inductor attached to the control housing and positioned within the controller chamber adjacent the control board,
 said inductor defining maximum first and second inductor dimensions measured along corresponding first and second directions parallel to the board plane and orthogonal to one another,
 said inductor further defining a maximum third inductor dimension measured along a third direction transverse to the board plane, with at least one of the first and second inductor dimensions being less than the maximum third inductor dimension.

2. The motor control assembly as claimed in claim 1, said inductor including a toroidal metal core and windings wrapped around the core,
 said inductor defining an inductor axis about which the core extends,
 said inductor axis extending substantially parallel to the board plane.

3. The motor control assembly as claimed in claim 2, said first direction extending generally parallel to the inductor axis,
 said second and third directions being orthogonal to the first direction so that the second and third inductor dimensions are diametrical dimensions of the inductor.

4. The motor control assembly as claimed in claim 2, said inductor being positioned to extend radially relative to the inductor axis beyond opposite sides of the control board.

5. The motor control assembly as claimed in claim 2, said control housing including a housing wall that projects transversely to the board plane to extend at least partly around the control board and at least partly define the controller chamber, with the inductor being mounted to the housing wall.

6. The motor control assembly as claimed in claim 5, said housing wall presenting a wall surface that faces the inductor and against which the inductor is secured within the controller chamber.

7. The motor control assembly as claimed in claim 6, said wall surface being at least coextensive with the inductor in the third direction.

8. The motor control assembly as claimed in claim 6, said housing wall presenting an opposite wall surface facing oppositely relative to the first-mentioned wall surface,
 said opposite wall surface defining a plurality of spaced-apart fins, with the housing wall configured to discharge heat from the inductor via the opposite wall surface.

9. The motor control assembly as claimed in claim 2, said inductor presenting an inductor opening that extends axially through the metal core,
 said controller including a fastener assembly that extends through the inductor opening to secure the inductor relative to the control housing.

10. The motor control assembly as claimed in claim 9, said fastener assembly including a spacer and a fastener, said inductor presenting an inner margin that defines the inductor opening, with the inner margin circumscribing the spacer.

11. The motor control assembly as claimed in claim 10, said control housing including a housing wall that projects radially relative to the inductor axis,
 said fastener being attached to housing wall so that the fastener assembly secures the inductor to the housing wall.

12. The motor control assembly as claimed in claim 1, said inductor being positioned to extend transversely on opposite sides of the control board.

13. The motor control assembly as claimed in claim 12, said control housing including a housing wall that projects transversely to the board plane to extend at least partly around the control board and at least partly define the controller chamber, with the inductor being mounted to the housing wall.

14. The motor control assembly as claimed in claim 13, said housing wall presenting a wall surface that faces the inductor and against which the inductor is secured within the controller chamber.

15. The motor control assembly as claimed in claim 14, said wall surface being at least coextensive with the inductor in the third direction.

16. The motor control assembly as claimed in claim 14, said housing wall presenting an opposite wall surface facing oppositely relative to the first-mentioned wall surface,
 said opposite wall surface defining a plurality of spaced-apart fins, with the housing wall configured to discharge heat from the inductor via the opposite wall surface.

17. The motor control assembly as claimed in claim 1, said control housing including a housing wall that projects transversely to the board plane to extend at least partly around the control board and at least partly define the controller chamber, with the inductor being mounted to the housing wall.

18. The motor control assembly as claimed in claim 17, said housing wall presenting a wall surface that faces the inductor and against which the inductor is secured within the controller chamber.

19. The motor control assembly as claimed in claim 18, said wall surface being at least coextensive with the inductor in the third direction.

20. The motor control assembly as claimed in claim 18, said housing wall presenting an opposite wall surface facing oppositely relative to the first-mentioned wall surface,
 said opposite wall surface defining a plurality of spaced-apart fins, with the housing wall configured to discharge heat from the inductor via the opposite wall surface.

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