US012392331B2

(12) **United States Patent**
Hughes et al.

(10) **Patent No.: US 12,392,331 B2**
(45) **Date of Patent: Aug. 19, 2025**

(54) **HYDRAULIC PUMP WITH TWO-STAGE OPERATION**

(71) Applicant: **Enerpac Tool Group Corp.**, Milwaukee, WI (US)

(72) Inventors: **Nathan Adam Hughes**, Cottage Grove, WI (US); **Curtis L. Van Weelden**, Waukesha, WI (US)

(73) Assignee: **Enerpac Tool Group Corp.**, Milwaukee, WI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 313 days.

(21) Appl. No.: **17/889,051**

(22) Filed: **Aug. 16, 2022**

(65) **Prior Publication Data**

US 2023/0039274 A1 Feb. 9, 2023

Related U.S. Application Data

(63) Continuation of application No. 15/981,869, filed on May 16, 2018, now Pat. No. 11,415,119.

(Continued)

(51) **Int. Cl.**
F04B 1/04 (2020.01)
F04B 23/02 (2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***F04B 1/04*** (2013.01); ***F04B 39/10*** (2013.01); *F04B 17/06* (2013.01); *F04B 23/025* (2013.01)

(58) **Field of Classification Search**
CPC F04B 9/045; F04B 17/06; F04B 17/03; F04B 1/00; F04B 49/08; F04B 23/025; F04B 39/10; F04B 2205/05; F04B 1/04
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,850,083 A		3/1932	Noltein	
3,053,186 A	*	9/1962	Gondek	F04B 23/106 417/252

(Continued)

FOREIGN PATENT DOCUMENTS

CN	1131233 A	9/1996
CN	201836150	5/2011

(Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion for PCT/US2018/033060 dated Sep. 24, 2018.

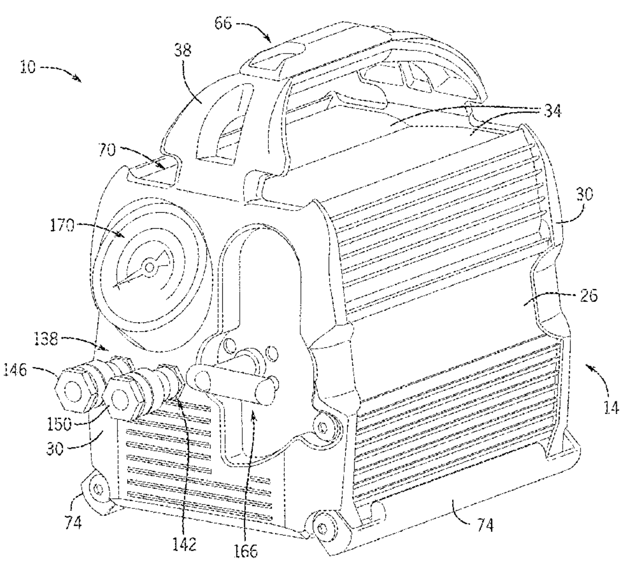
(Continued)

Primary Examiner — Nathan C Zollinger
(74) *Attorney, Agent, or Firm* — Andrus Intellectual Property Law, LLP

(57) **ABSTRACT**

A pump may generally include a frame including a reservoir. The reservoir stores a hydraulic fluid. The pump may also include a motor assembly supported by the frame and a pump assembly operably driven by the motor assembly. The pump assembly is in fluid communication with the reservoir and configured to dispense the hydraulic fluid out of the frame. The pump assembly includes a first piston and a second piston, wherein the first piston dispenses hydraulic fluid out of the frame between a first pressure and a second pressure greater than the first pressure, and the second piston dispenses hydraulic fluid out of the frame between the first pressure and a third pressure, the third pressure being greater than the second pressure.

16 Claims, 48 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/507,130, filed on May 16, 2017.

(51) **Int. Cl.**
F04B 39/10 (2006.01)
F04B 17/06 (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,487,431	A	12/1969	Forkner	
3,992,133	A	11/1976	Brunner	
4,597,717	A *	7/1986	Mohr	F04B 17/03 417/267
4,692,104	A	9/1987	Hansen	
4,791,838	A	12/1988	Bickford et al.	
4,834,632	A	5/1989	Gatecliff et al.	
4,864,903	A	9/1989	Bickford et al.	
5,094,599	A	3/1992	Budecker	
5,113,949	A	5/1992	Ohkubo et al.	
D327,075	S	6/1992	Tiedemann	
5,121,788	A	6/1992	Carollo	
5,181,837	A	1/1993	Niemiec	
5,261,796	A	11/1993	Niemiec et al.	
5,320,501	A	6/1994	Langosch et al.	
5,421,240	A	6/1995	Ohta et al.	
5,435,698	A	7/1995	Phillips	
5,668,328	A	9/1997	Steber et al.	
D447,148	S	8/2001	Antony et al.	
6,863,502	B2	3/2005	Bishop et al.	
7,036,892	B2	5/2006	Suzuki et al.	
D536,705	S	2/2007	Griffin et al.	
7,200,992	B2	4/2007	Wagner	
7,296,407	B2	11/2007	Rose	
D557,708	S	12/2007	Carpenter et al.	
D573,609	S	7/2008	Bilger	
D604,746	S	11/2009	Nishido et al.	
7,743,673	B2	6/2010	Wagner	
7,762,790	B2	7/2010	Steinfels et al.	
7,878,765	B2	2/2011	Gonnella et al.	
7,931,448	B2	4/2011	Achor et al.	
8,056,426	B2	11/2011	Hohmann et al.	
8,220,380	B2	7/2012	Andres et al.	
8,305,019	B2	11/2012	Tobari et al.	
D707,719	S	6/2014	Kamijyo	
D712,933	S	9/2014	DeOreo et al.	
D713,860	S	9/2014	Pedrollo	
8,899,378	B2	12/2014	Wood et al.	
8,997,904	B2	4/2015	Cryer et al.	
9,115,720	B2	8/2015	Rosinski et al.	
9,193,046	B2	11/2015	Landrum	
9,193,049	B2	11/2015	Gareis	
9,212,655	B2	12/2015	Neumair	
9,435,324	B2	9/2016	Richardson et al.	
9,476,414	B2	10/2016	Wallis	
9,562,534	B2	2/2017	Rosinski et al.	
9,587,639	B2	3/2017	Rosinski et al.	
D785,679	S	5/2017	Hartung	
D786,939	S	5/2017	Nelson et al.	
9,670,942	B2	6/2017	Karlsson et al.	
D810,145	S	2/2018	Sinico	
D822,718	S	7/2018	Hartung	
D826,282	S	8/2018	Mead et al.	
D826,283	S	8/2018	Mead et al.	
D838,746	S	1/2019	Gan	
D847,266	S	4/2019	Korankye	
D850,490	S	6/2019	Janardhan et al.	
10,564,657	B2	2/2020	Chu	
D878,423	S	3/2020	Andersson et al.	
10,851,909	B2	12/2020	Neumair et al.	
11,053,954	B2 *	7/2021	Loerner	F04B 49/03
11,157,208	B2	10/2021	Connor	
11,162,482	B2	11/2021	Dawson et al.	
11,193,508	B2	12/2021	Hughes et al.	
11,415,119	B2	8/2022	Hughes et al.	
11,451,119	B2 *	9/2022	Aso	H02K 1/146
11,572,900	B2	2/2023	Hughes et al.	
2003/0012672	A1	1/2003	Sowa et al.	
2004/0045729	A1	3/2004	Lehnert et al.	
2005/0207899	A1	9/2005	Furuta	
2005/0210872	A1	9/2005	Wagner	
2007/0214921	A1	9/2007	Fechter et al.	
2007/0217928	A1	9/2007	Isobe et al.	
2008/0265844	A1	10/2008	Smith et al.	
2009/0000397	A1	1/2009	Wagner et al.	
2010/0021313	A1	1/2010	Devan et al.	
2010/0116508	A1	5/2010	Oglesby	
2011/0206537	A1	8/2011	Simpson	
2013/0098239	A1	4/2013	Rodrigues	
2013/0115108	A1	5/2013	Segal et al.	
2013/0315758	A1	11/2013	Olson	
2014/0328704	A1 *	11/2014	Neumair	F04B 39/066 417/410.1
2015/0033720	A1	2/2015	Mate et al.	
2015/0078924	A1	3/2015	Zhang et al.	
2015/0147953	A1	5/2015	Park et al.	
2015/0300138	A1	10/2015	Michel	
2015/0345489	A1	12/2015	Fink	
2016/0366824	A1	12/2016	Richardson et al.	
2017/0058923	A1	3/2017	Boehler et al.	
2017/0107804	A1	4/2017	Krug et al.	
2017/0356438	A1	12/2017	Hughes	
2018/0313342	A1	11/2018	Dawson et al.	
2021/0156369	A1	5/2021	Sassi et al.	
2022/0049729	A1	2/2022	Abe et al.	
2022/0250214	A1	8/2022	Stickley	

FOREIGN PATENT DOCUMENTS

CN	101900153		7/2012	
DE	2424391	A *	12/1975	B06B 1/183
DE	102007046660	A1	4/2009	
DE	102013002187	A1 *	8/2014	F04B 17/03
EP	2110205		11/2017	
EP	3259477		7/2021	
EP	3653888		1/2023	
EP	4191077		6/2023	
GB	534847		3/1941	
GB	648716		1/1951	
JP	2000-274377		10/2000	
RU	1830114		7/1993	
WO	WO 9420753		9/1994	
WO	WO-9420753	A2 *	9/1994	F04B 1/053
WO	WO 2008029624		3/2008	
WO	WO 2016133874		8/2016	
WO	WO 2017060777		4/2017	

OTHER PUBLICATIONS

Atlas Copco AB, "SP700 Smart Pump", Product Brochure, https://www.atlascopco.com/content/dam/atlas-copco/industrial-technique/general/documents/brochures-leaflets/hydraulic-tools/SP-01_SmartTorquePump_2018-09-03.pdf, 4 Pages.

Atlas Corp., "SP700 Smart Pump", Youtube video (https://www.youtube.com/watch?v=ZvysvFfl_BE), dated Aug. 2, 2019, 4 Screenshots.

Extended Search Report issued from the European Patent Office for related Application No. 19208915.9 dated Mar. 31, 2020 (11 Pages) .

Office Action issued from the US Patent Office for related U.S. Appl. No. 16/682,991 dated Mar. 3, 2021 (11 pages).

Examination Report issued from the European Patent Office for related Application No. 18729247.9 dated Mar. 15, 2022 (4 Pages).

Exam Report issued for European Patent Application No. 23195553.5, dated Oct. 14, 2024.

European Application No. 23195553.5, European Searh Report dated Dec. 20, 2023 (5 pages).

* cited by examiner

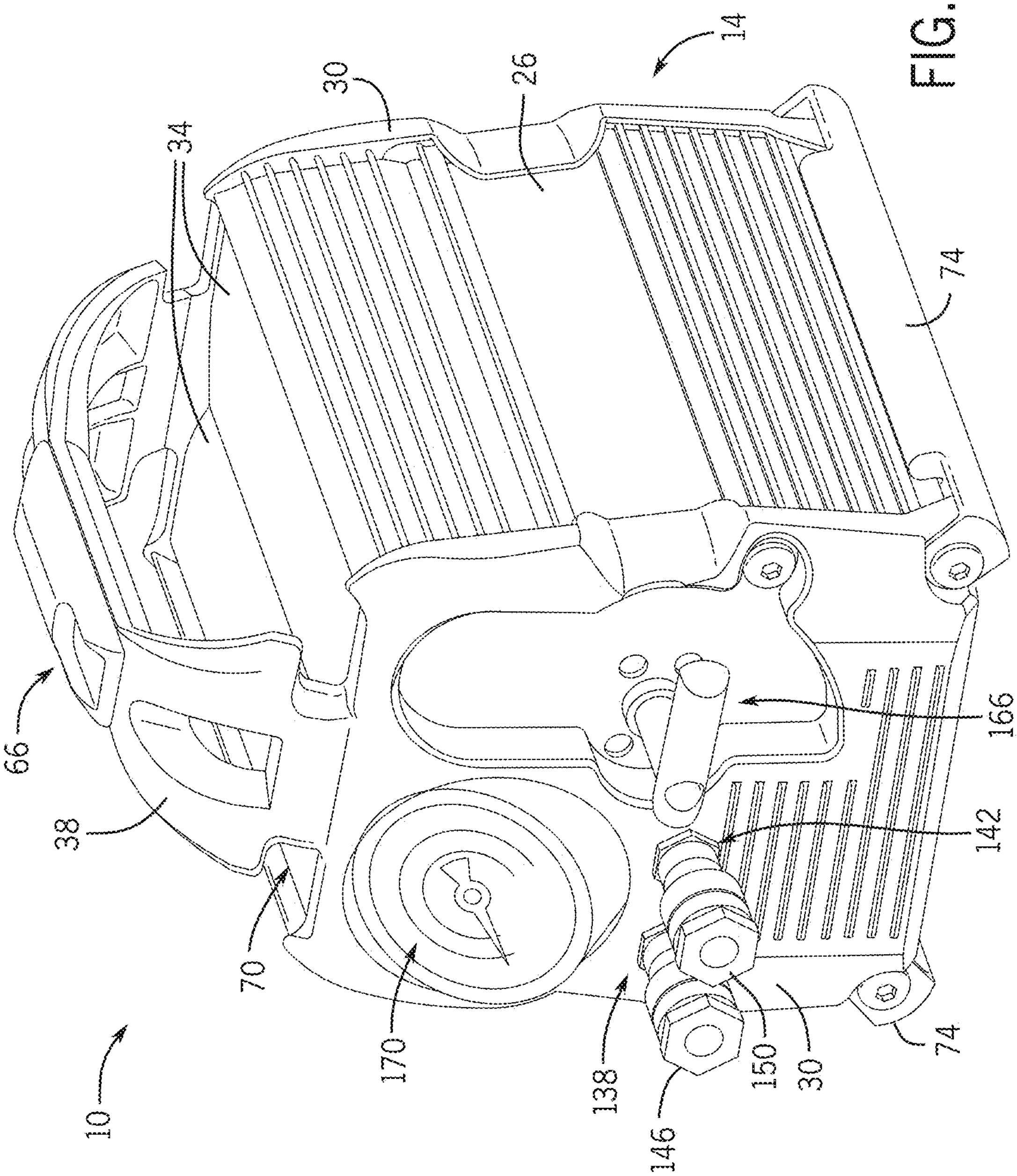


FIG. 1

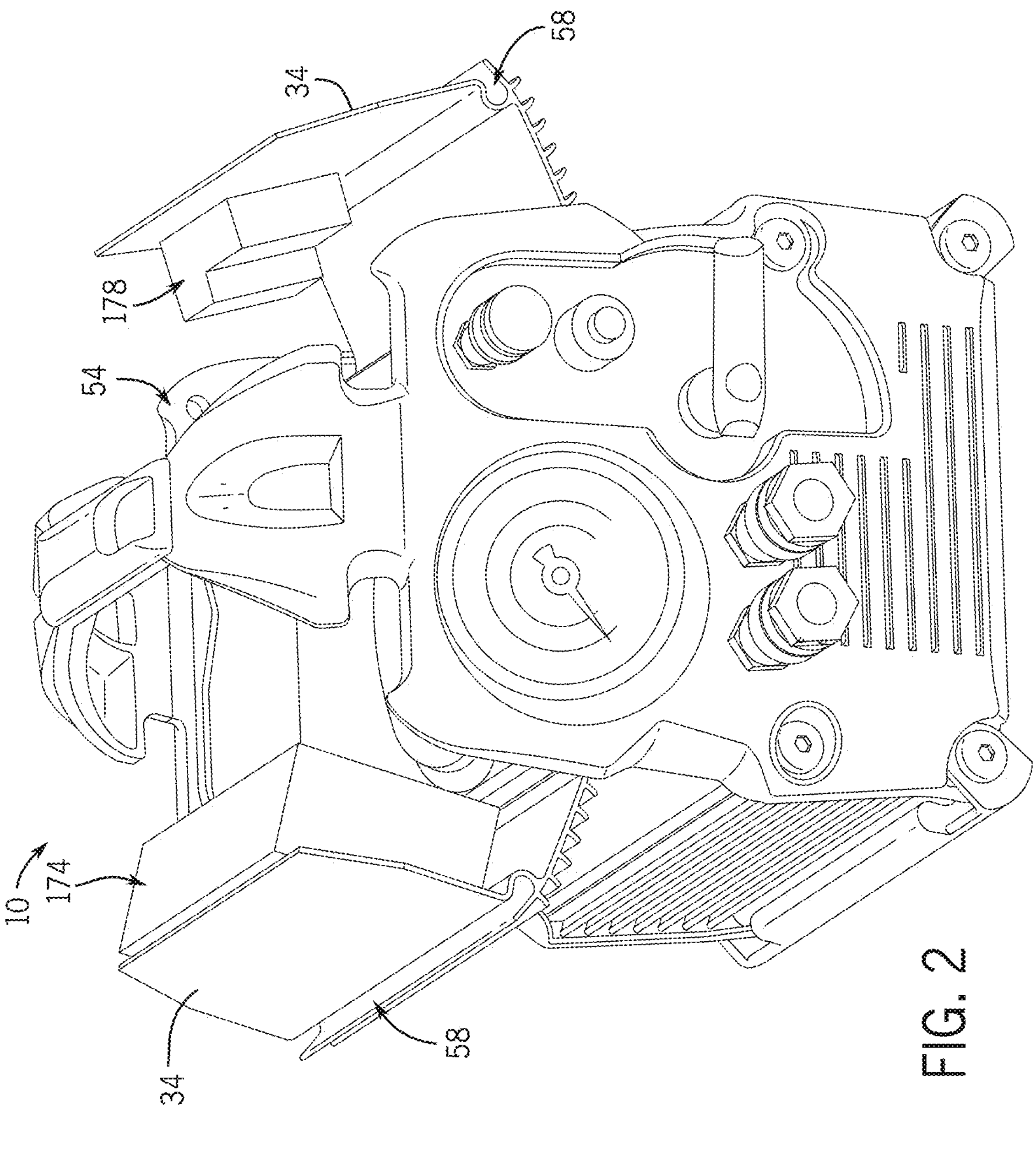


FIG. 2

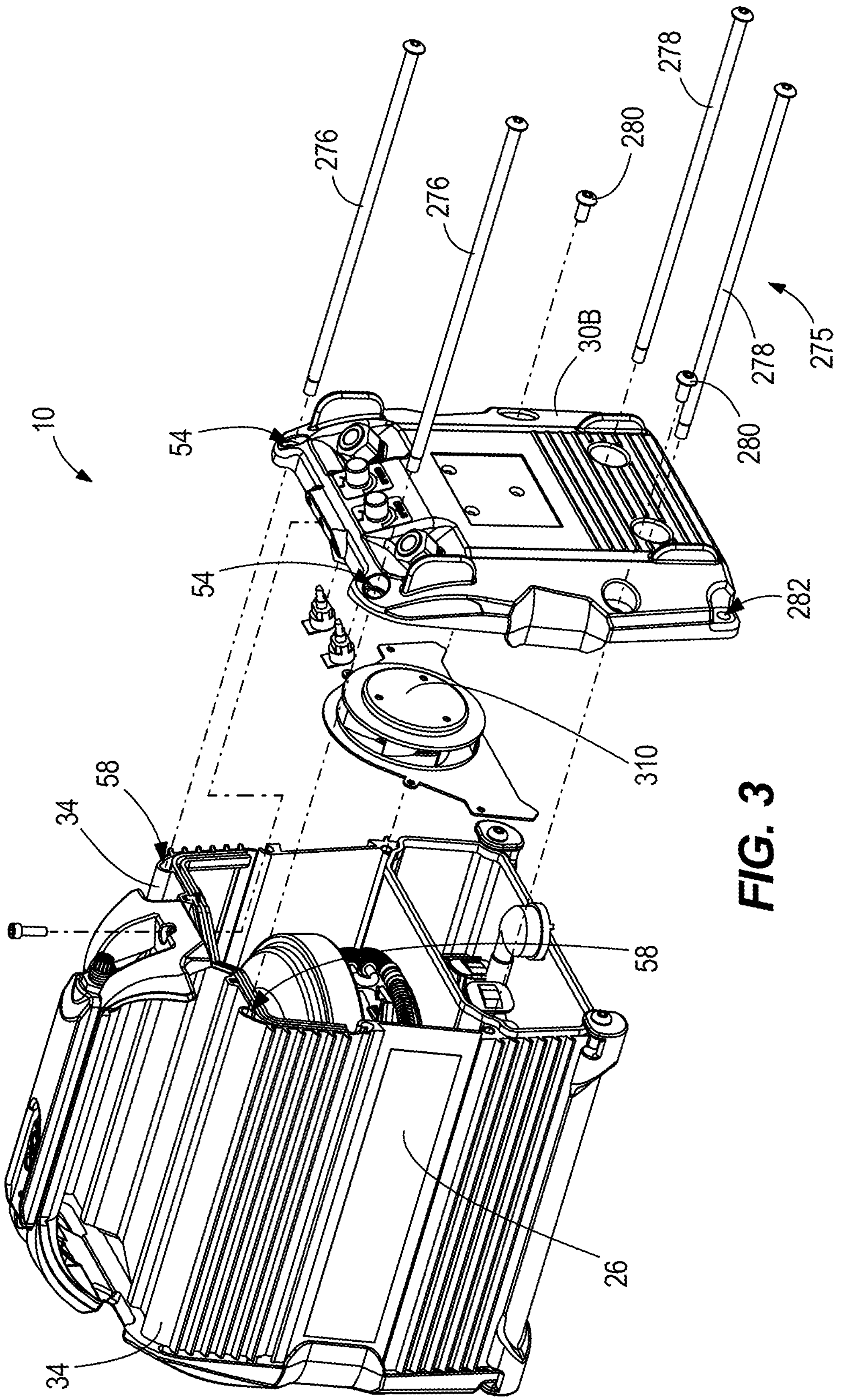


FIG. 3

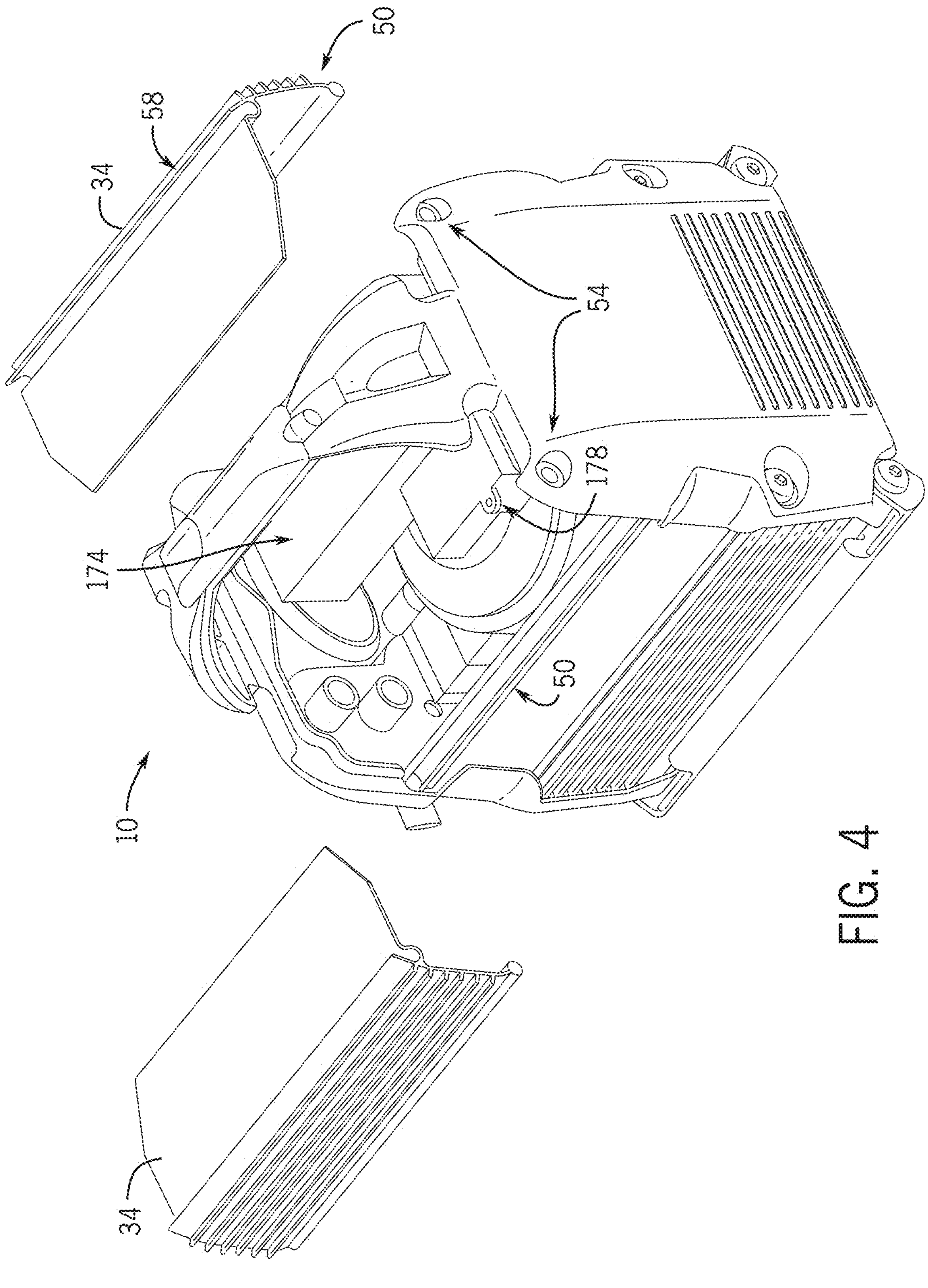


FIG. 4

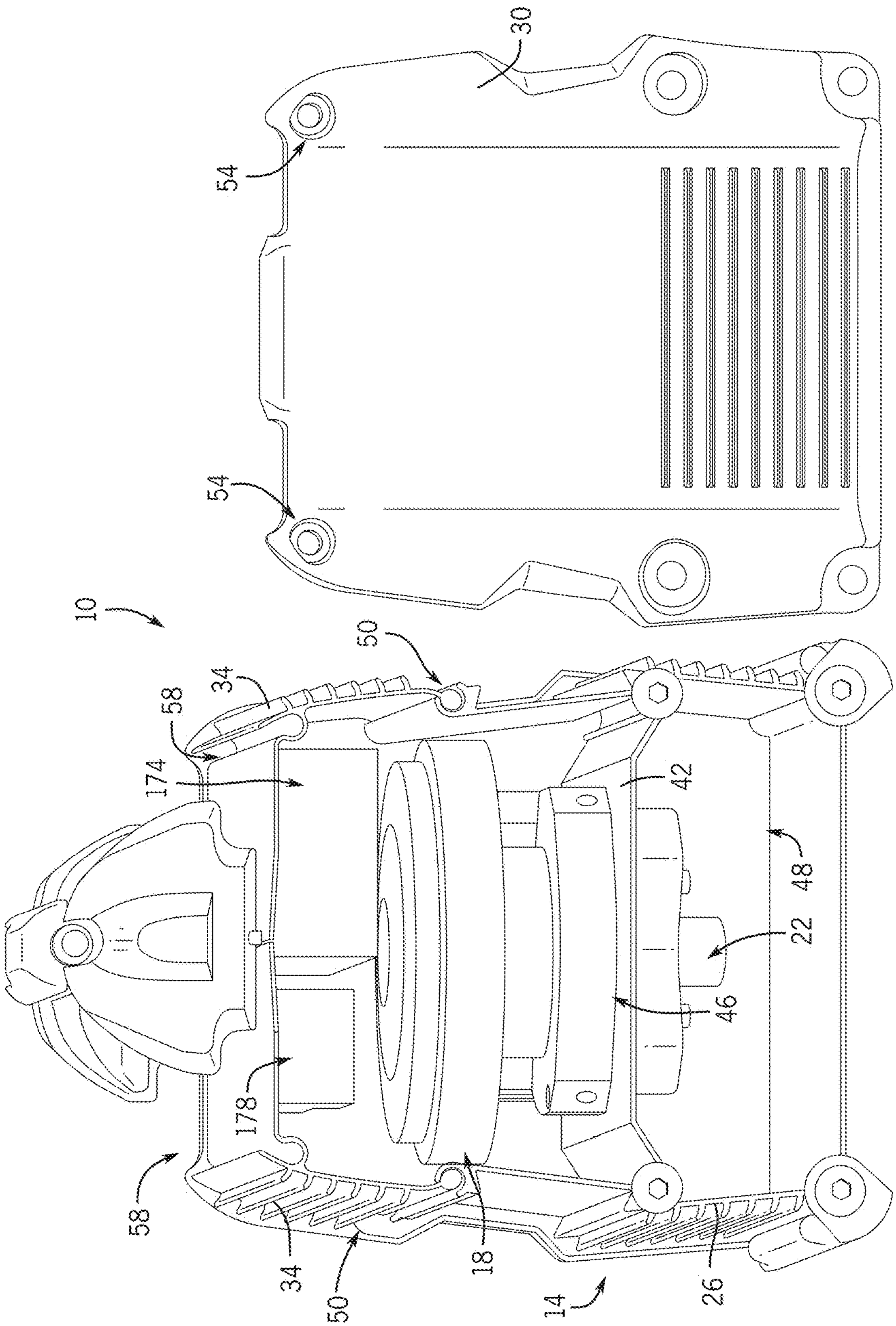


FIG. 5

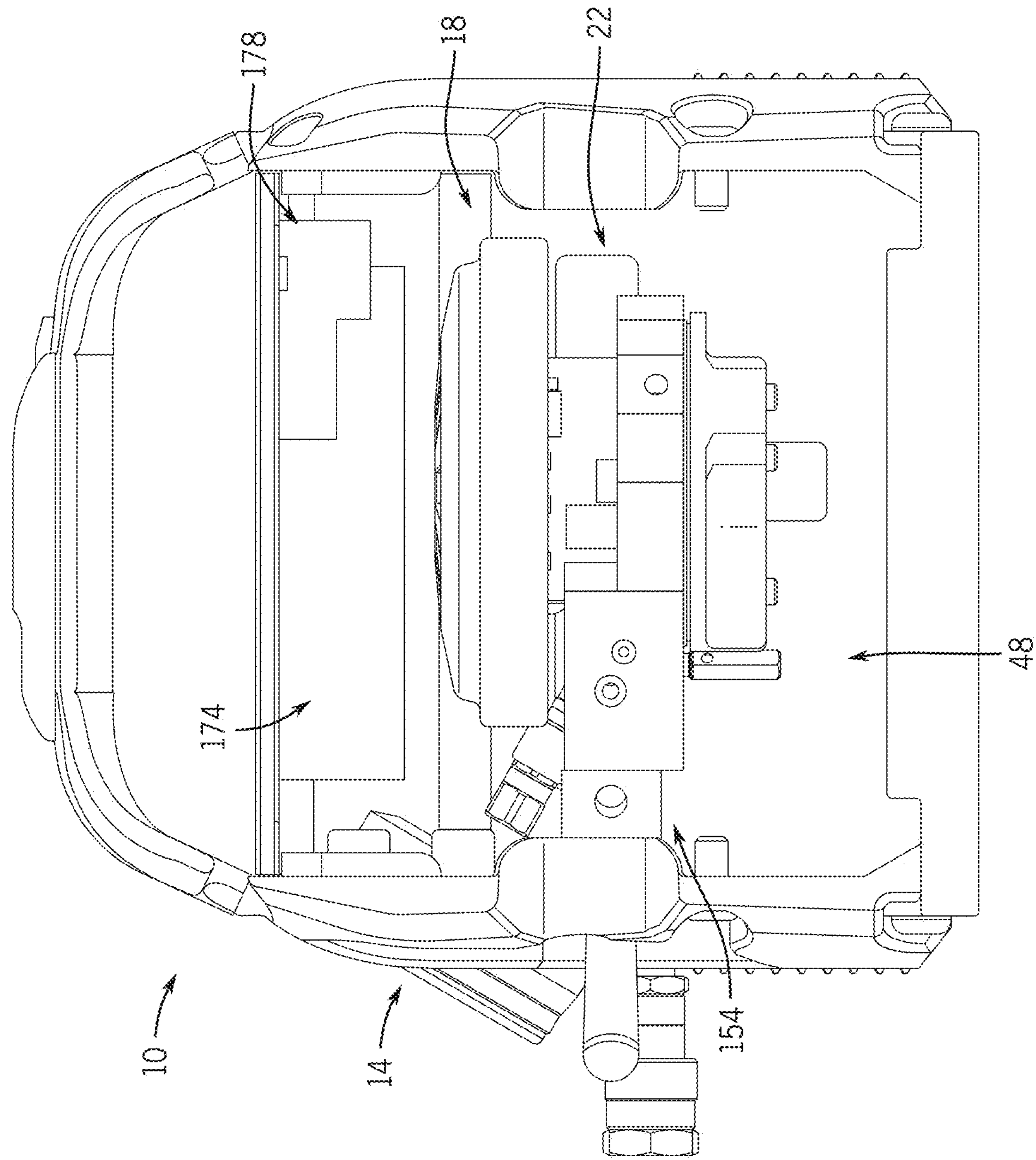


FIG. 6

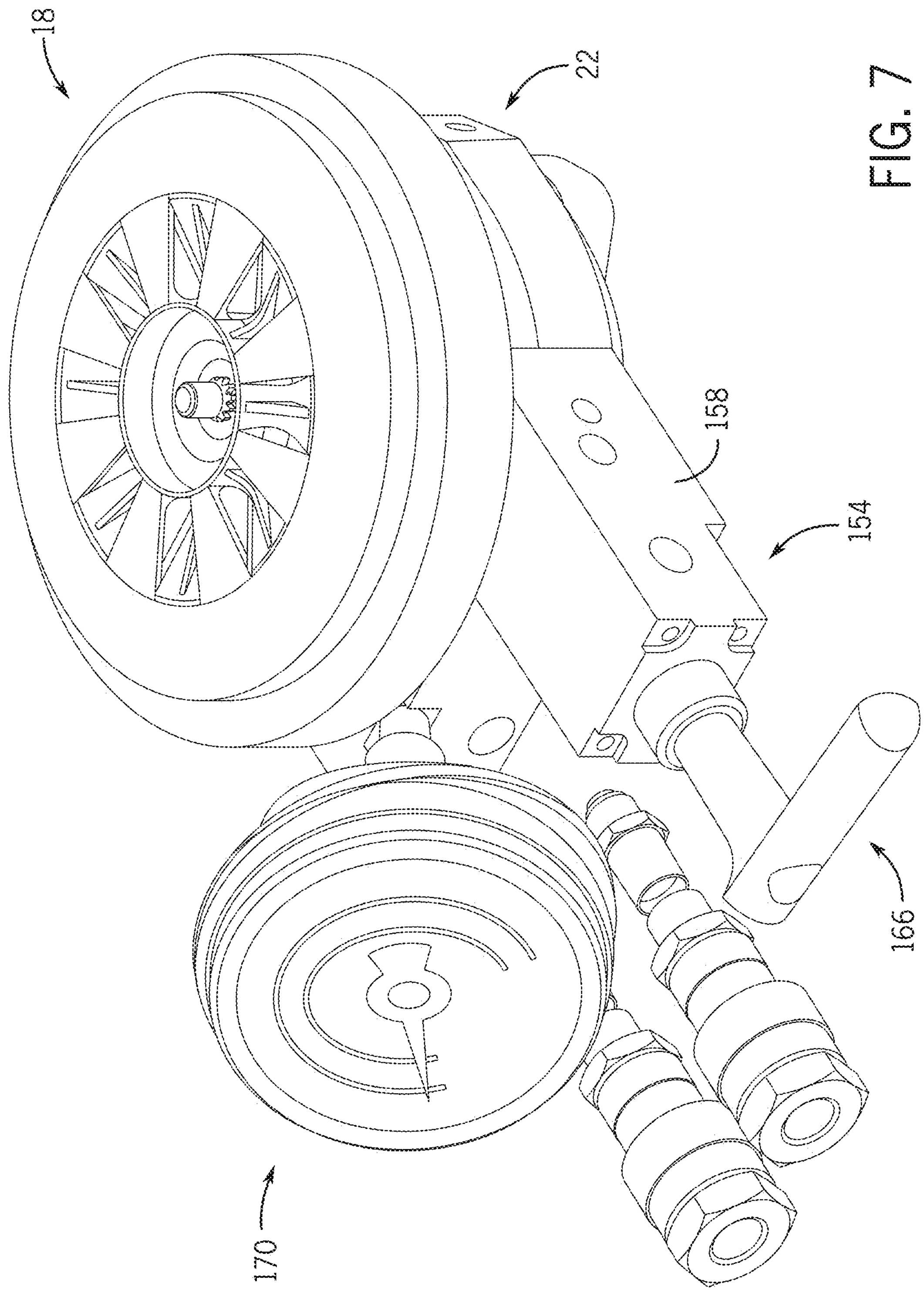


FIG. 7

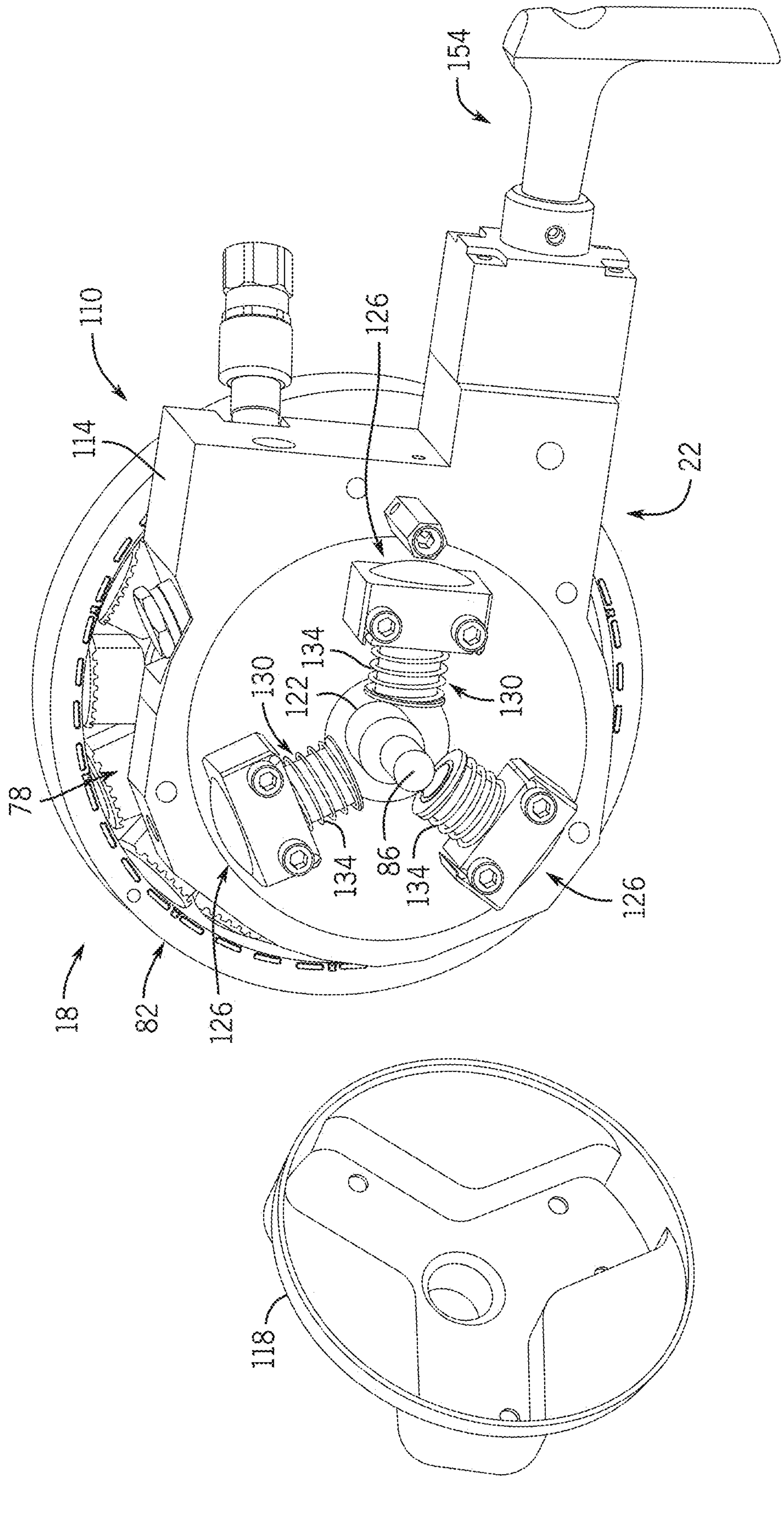

154
110
126
114
22
134
130
122
130
134
78
86
134
126
134
126
18
82
126
118

FIG. 8

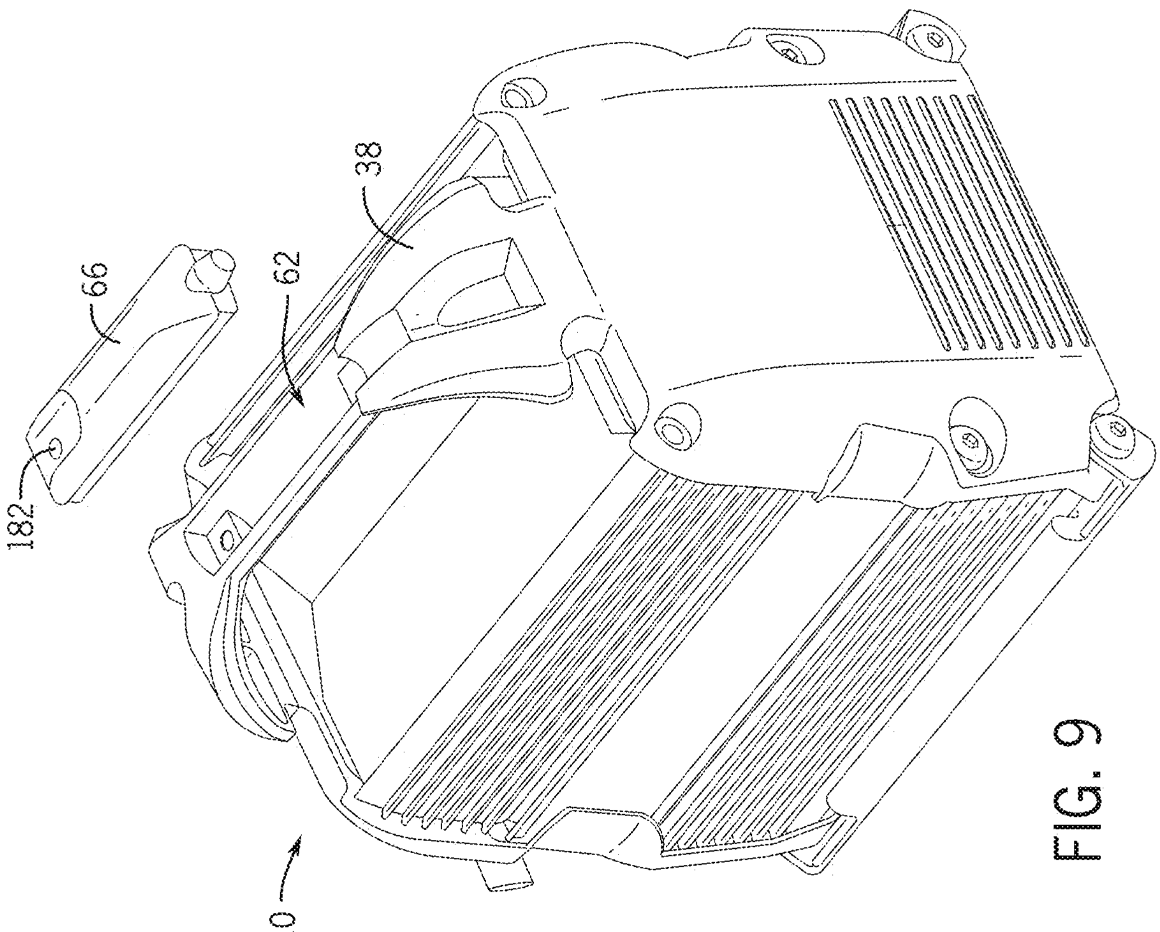


FIG. 9

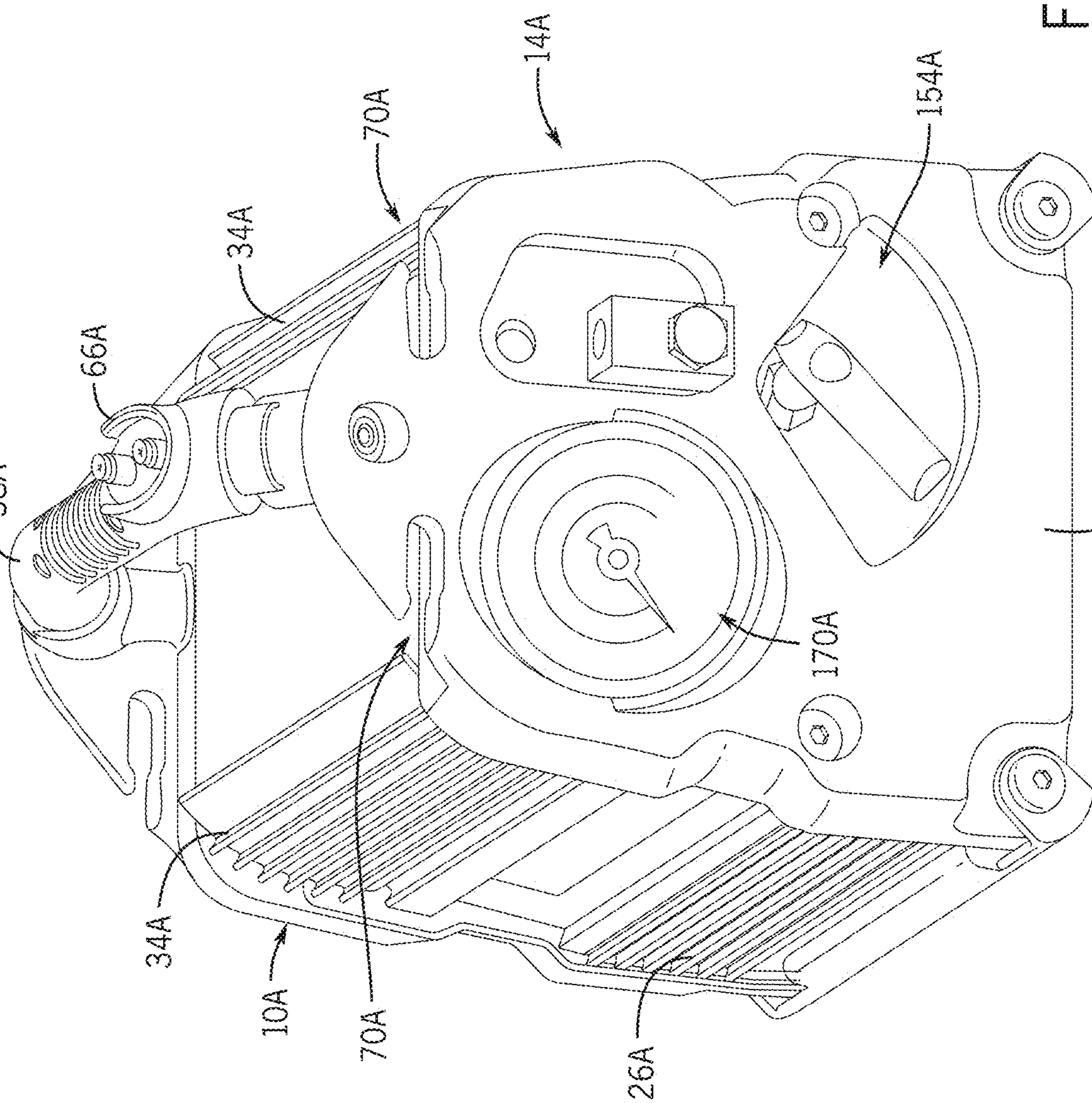


FIG. 10

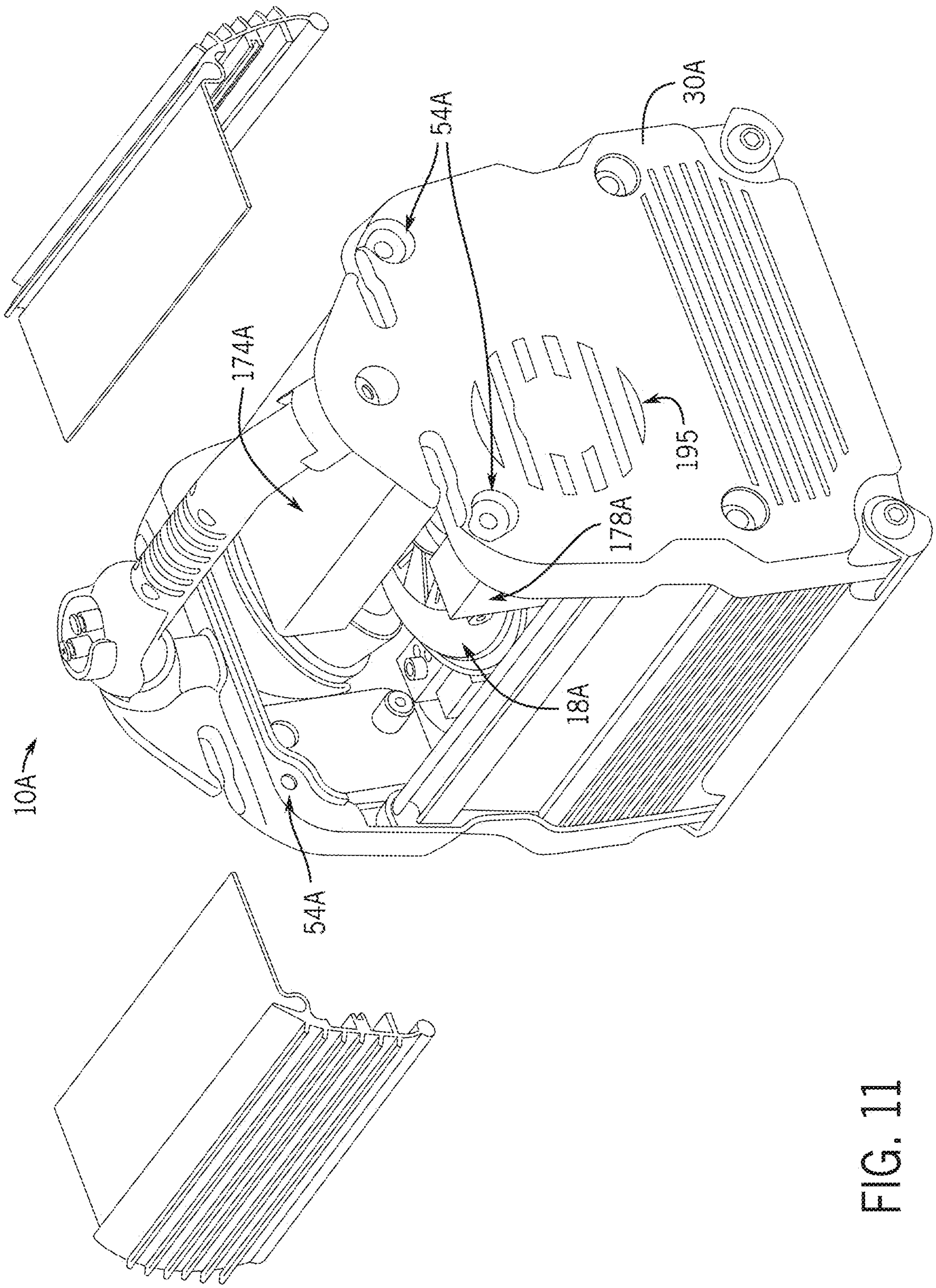


FIG. 11

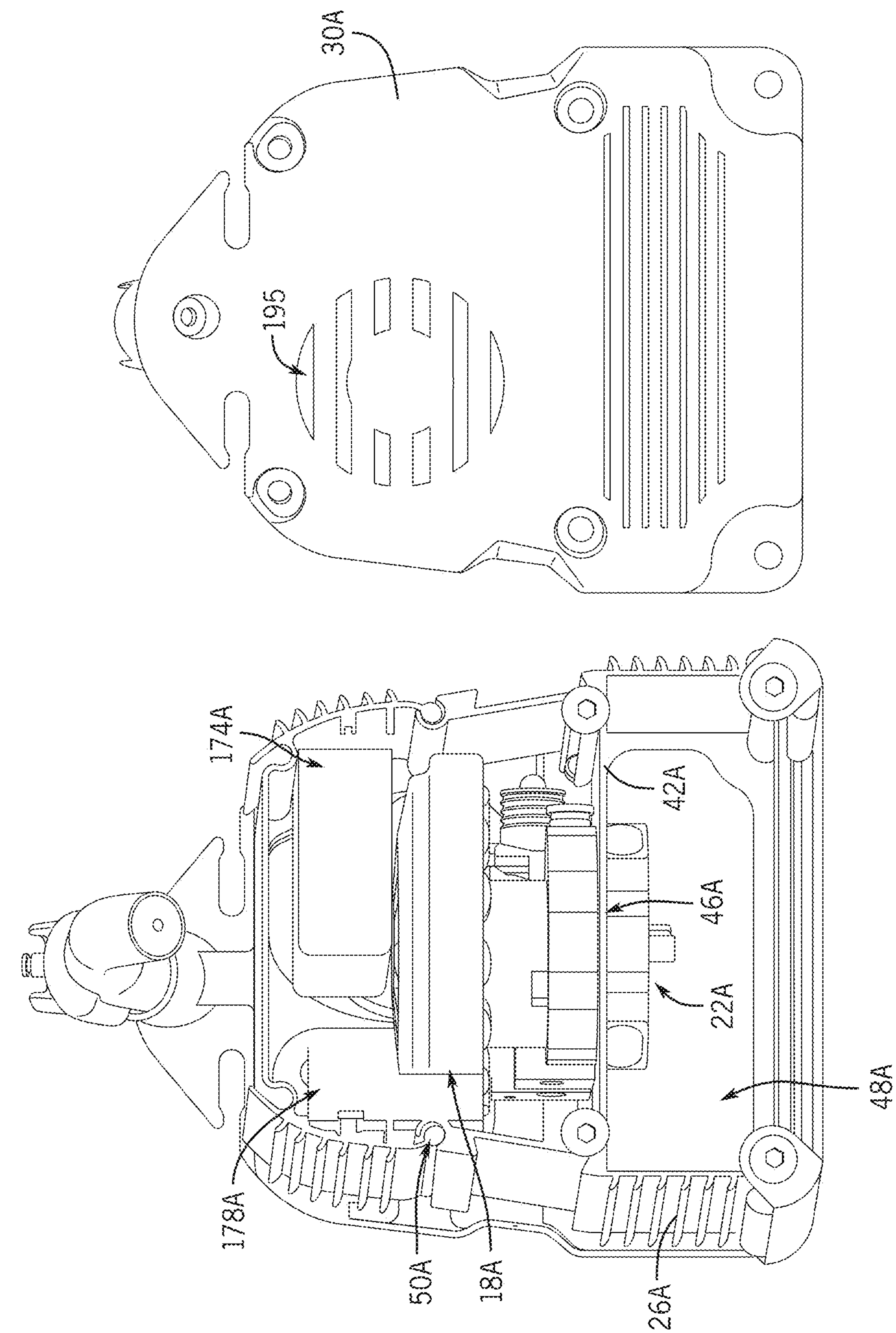


FIG. 12

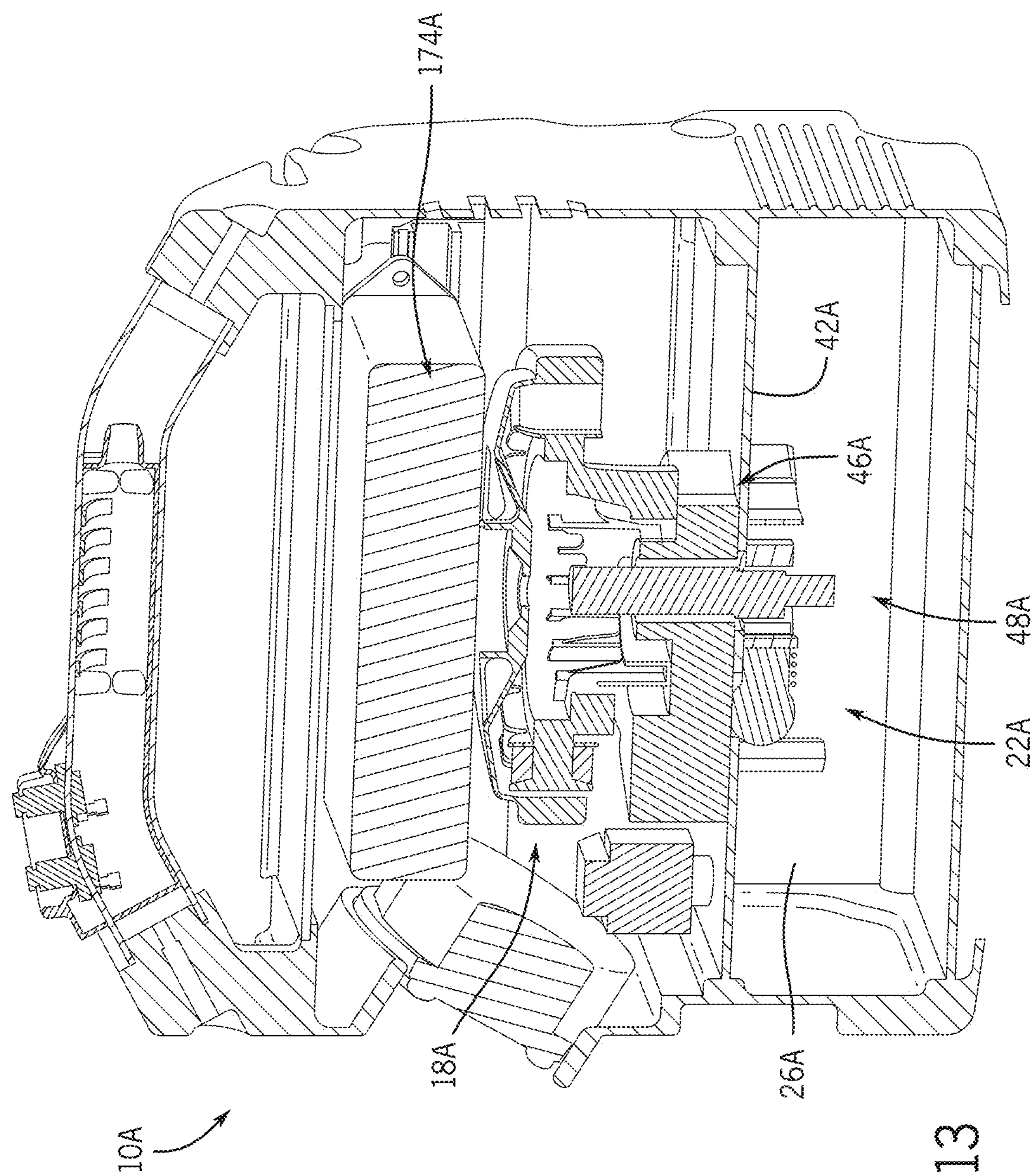
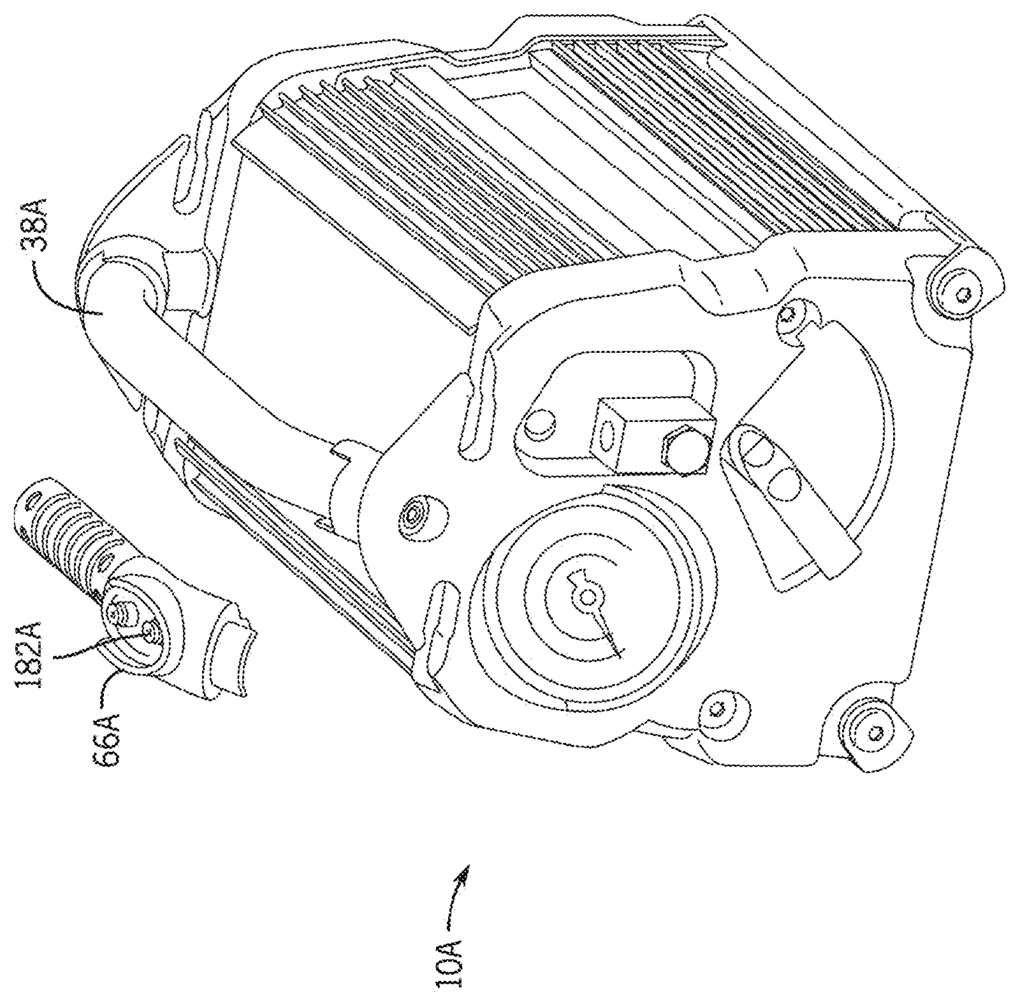


FIG. 13

FIG. 14



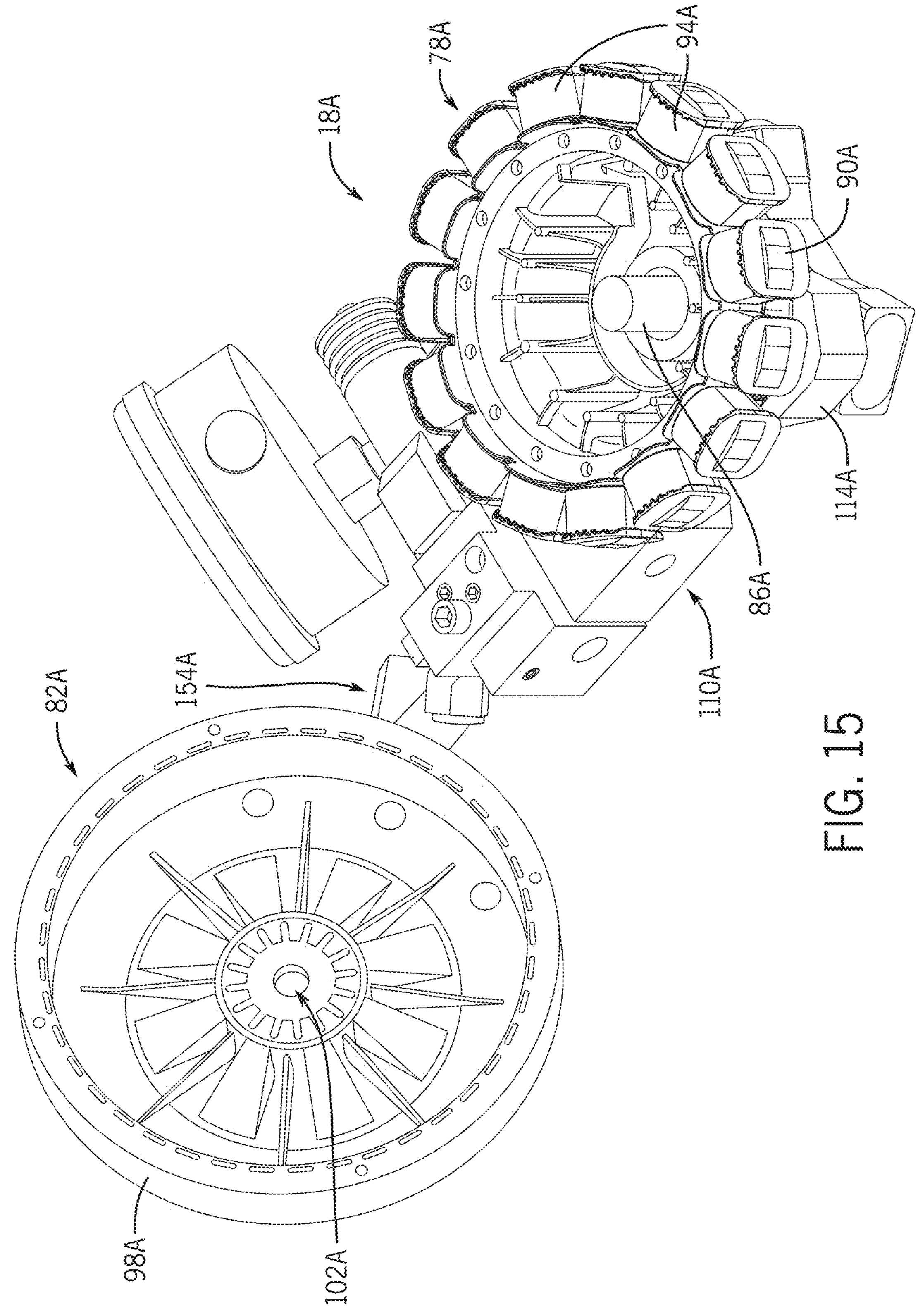


FIG. 15

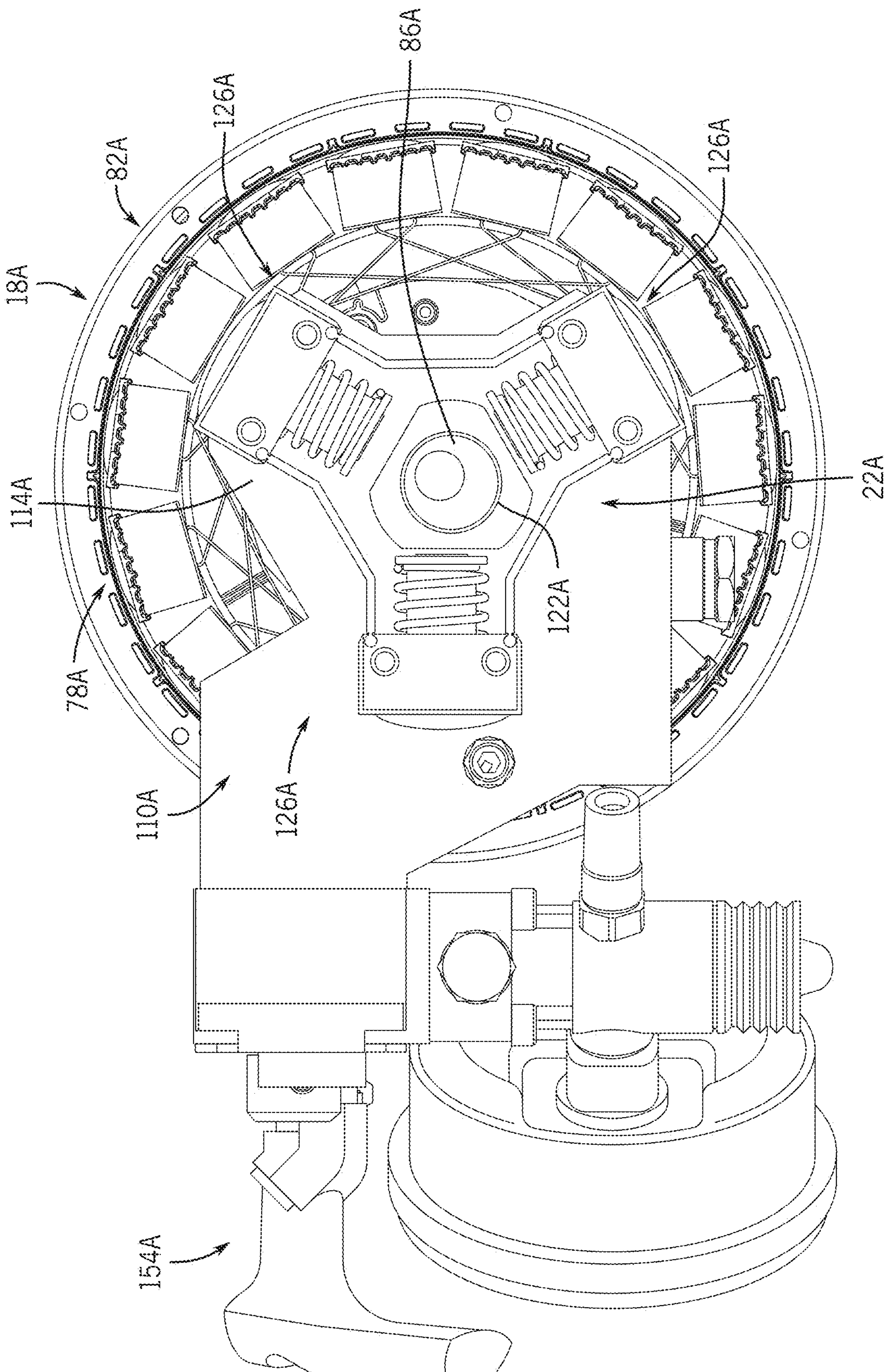


FIG. 16

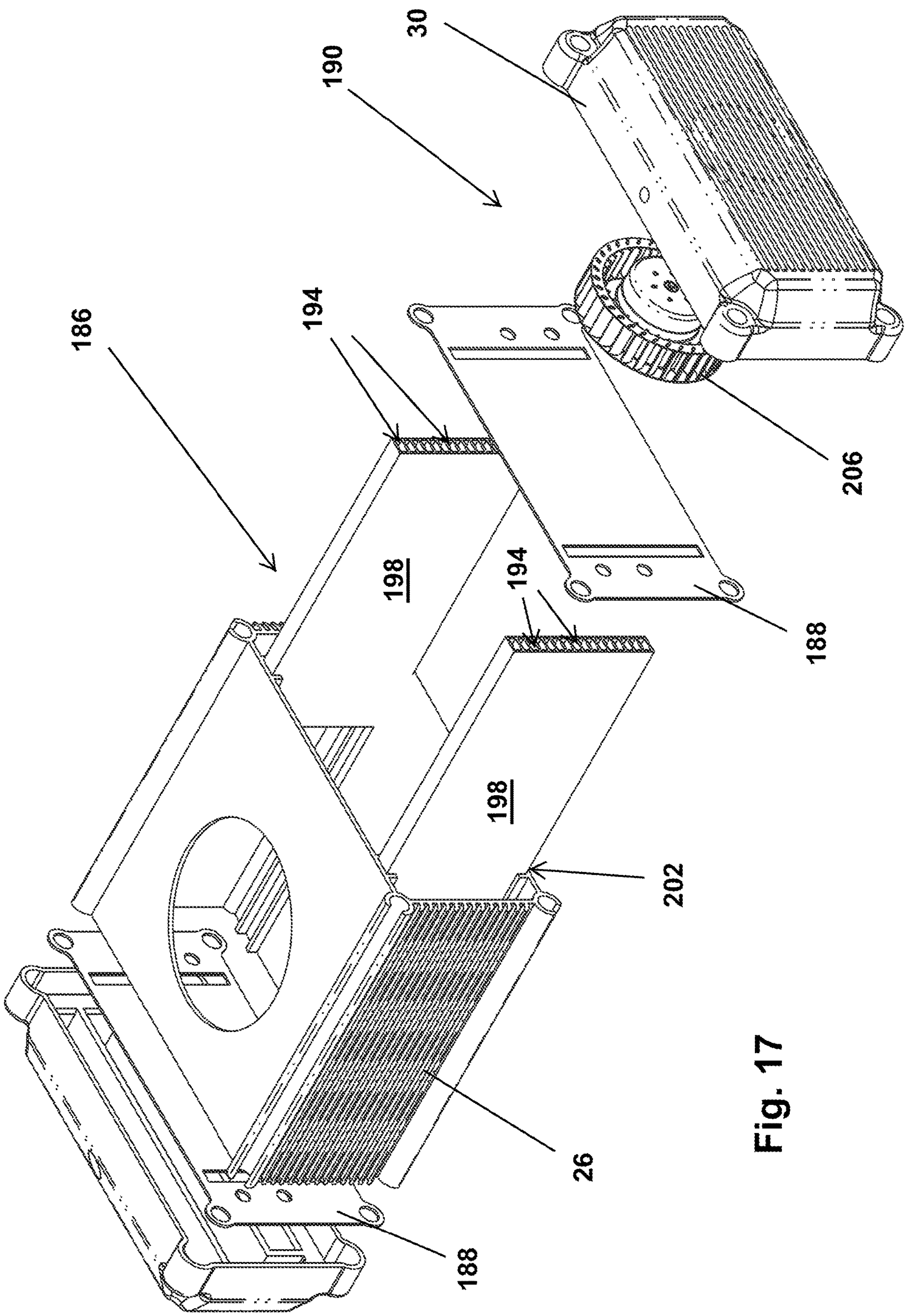


Fig. 17

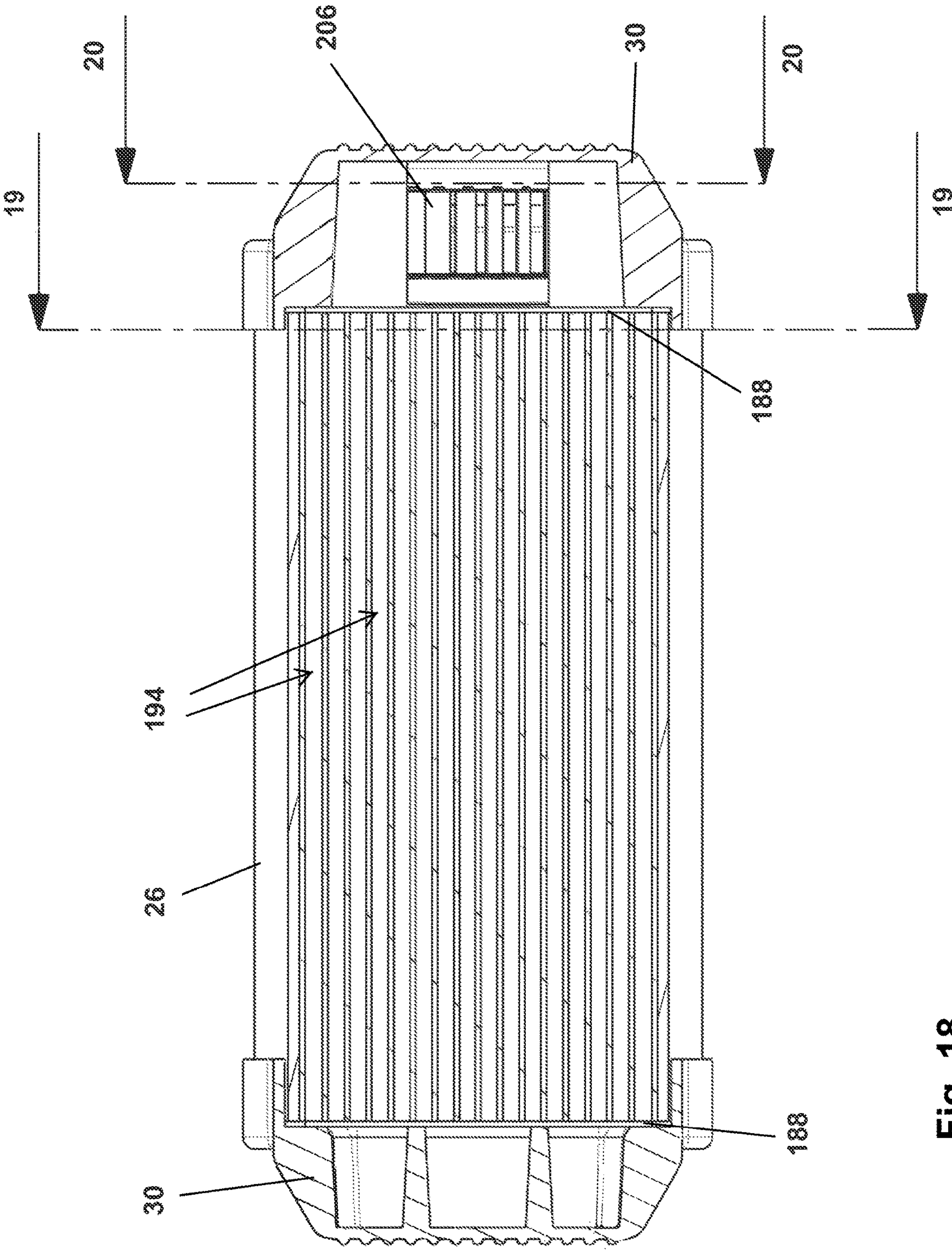


Fig. 18

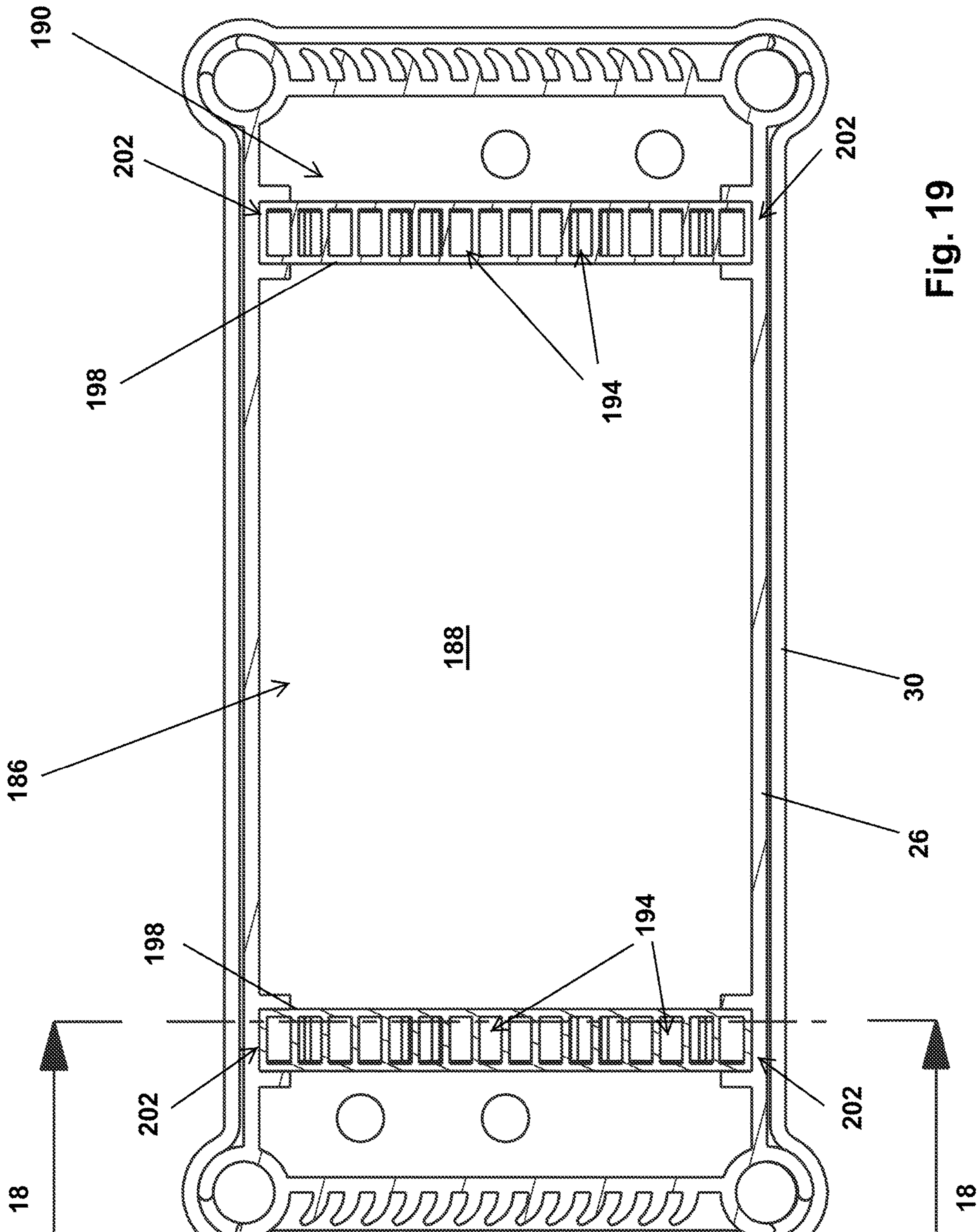


Fig. 19

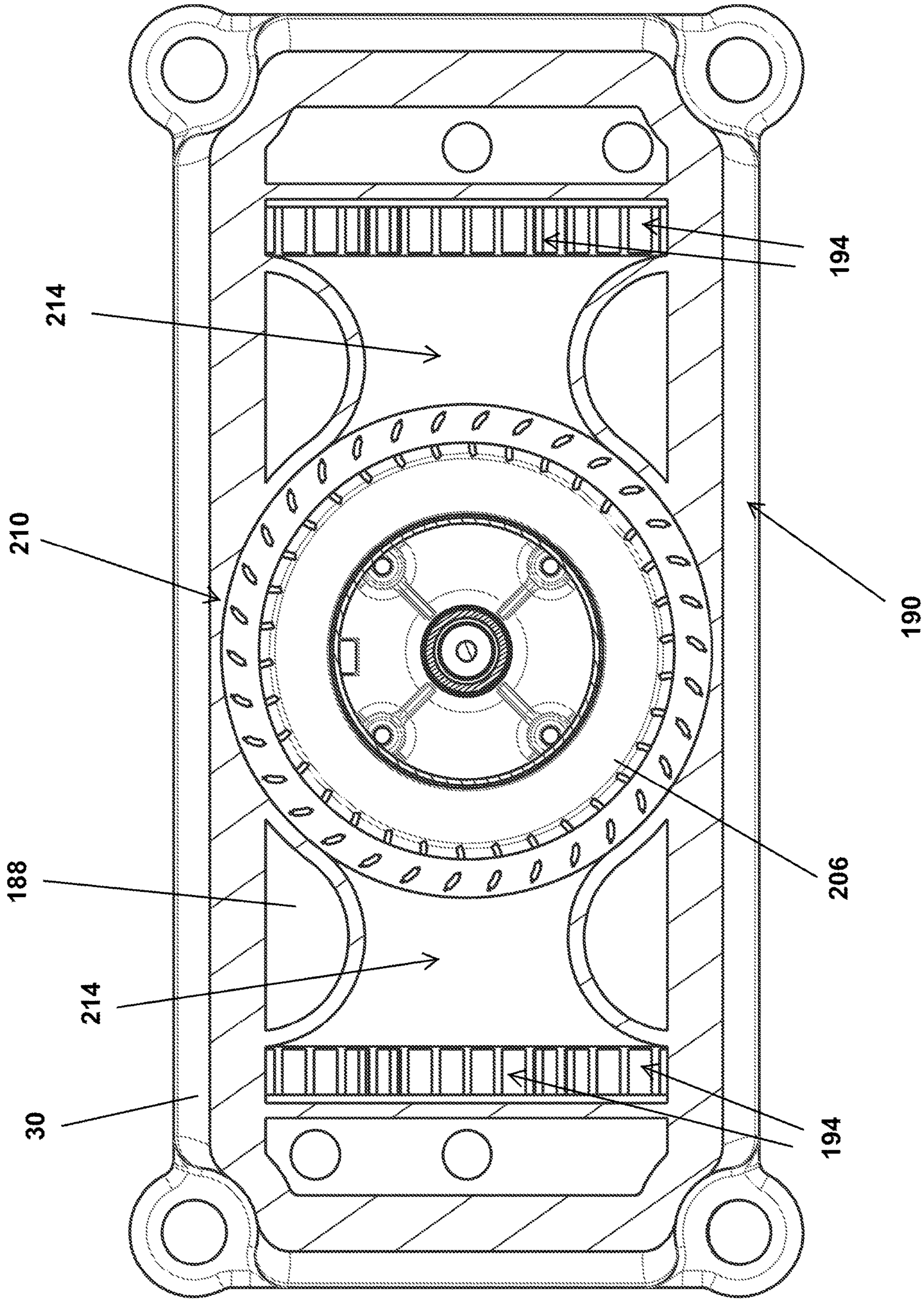


Fig. 20

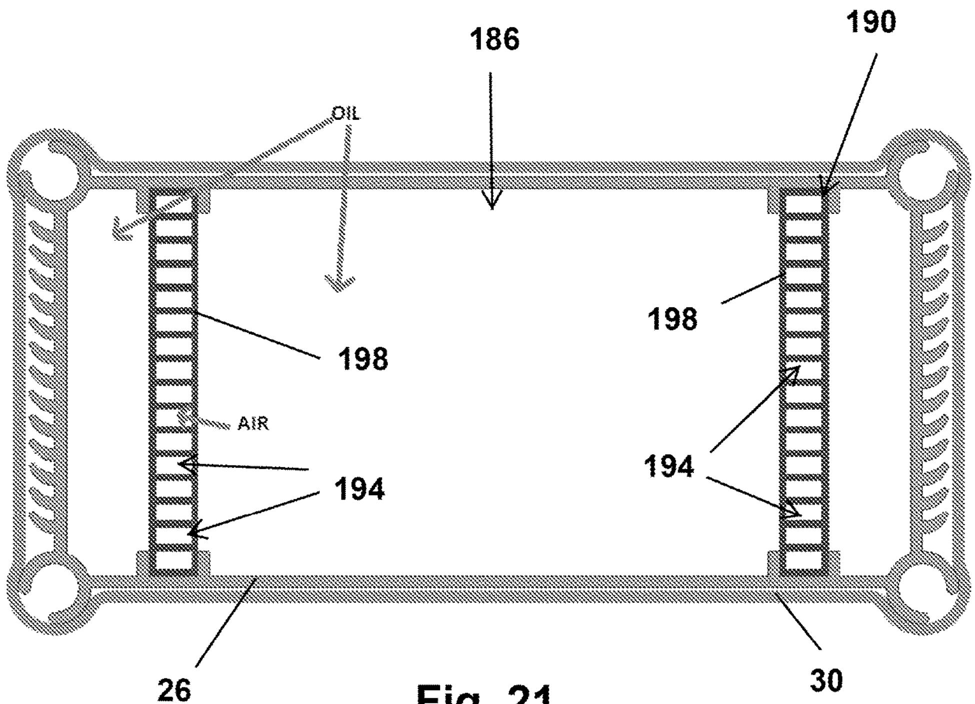

186
190
OIL
198
198
AIR
194
194
26
30

Fig. 21

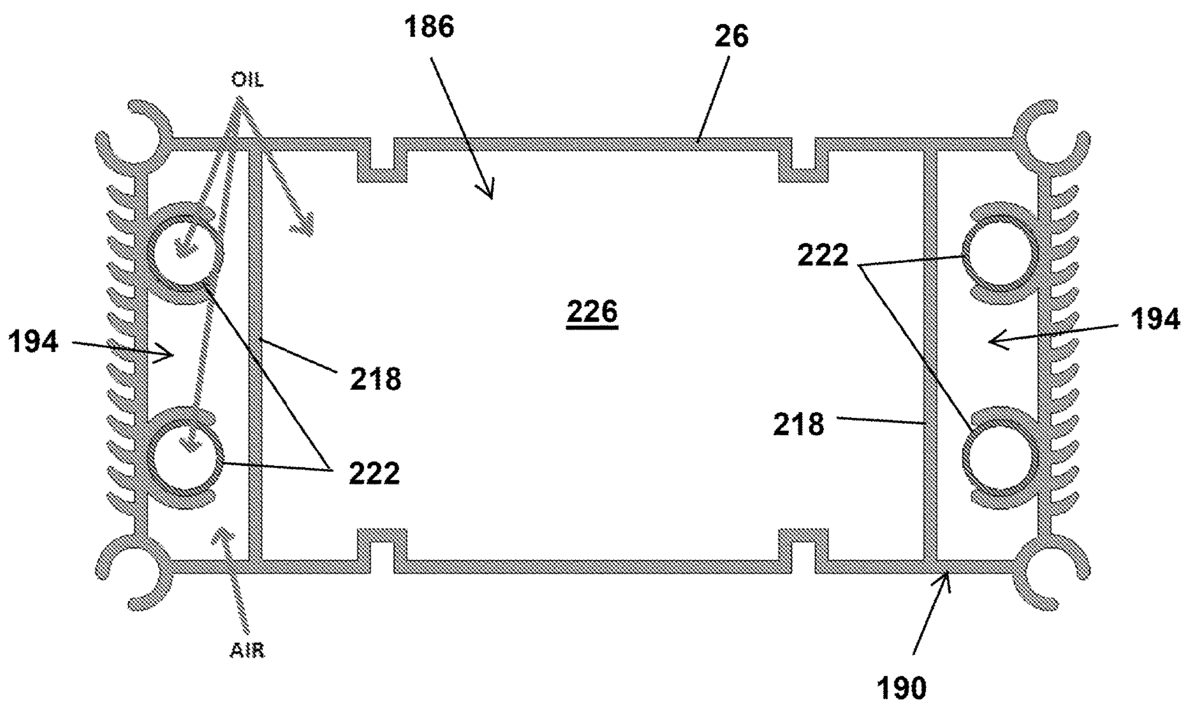

186
26
OIL
222
226
194
194
218
218
222
AIR
190

Fig. 22

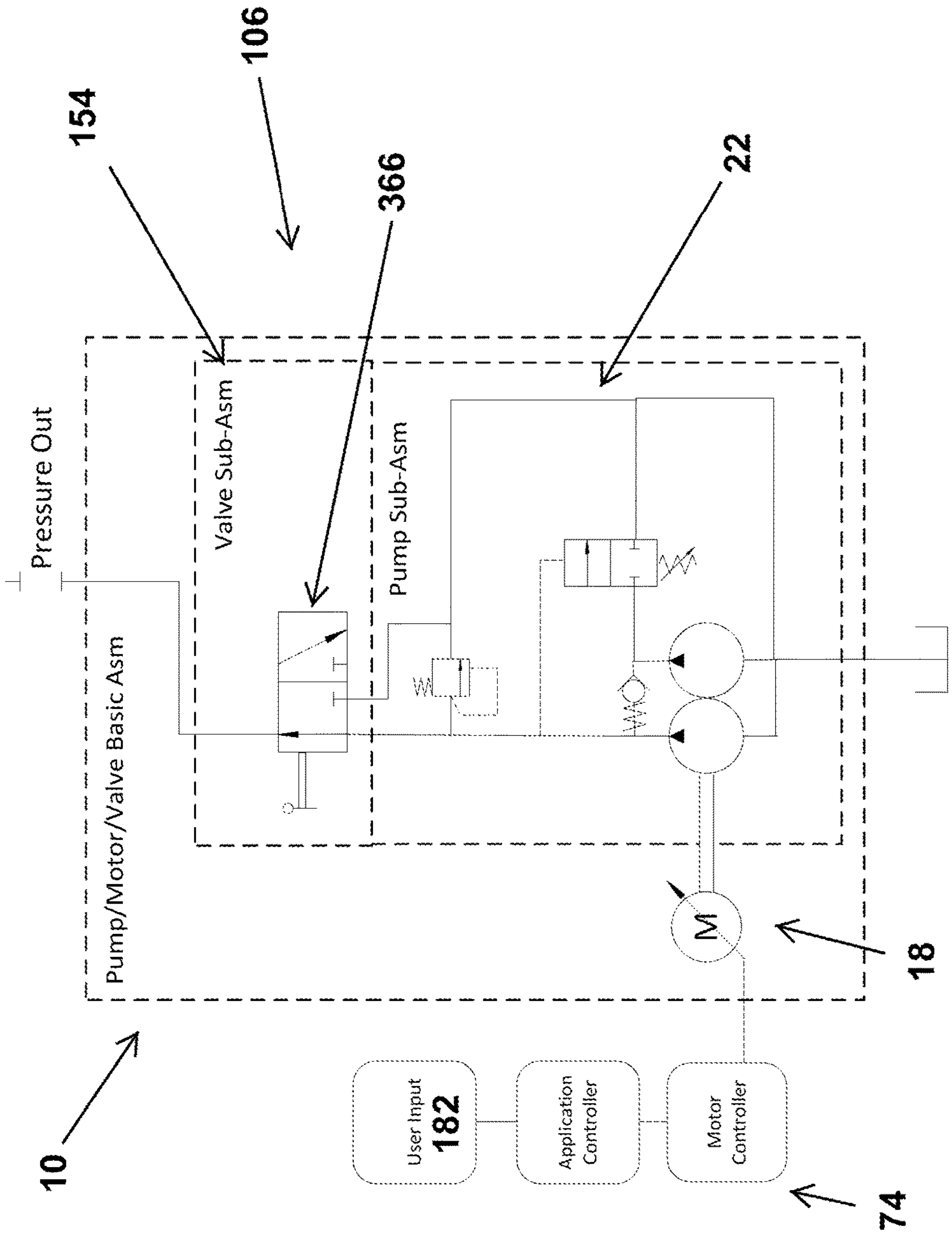

106
154
366
22
Pressure Out
Valve Sub-Asm
Pump Sub-Asm
Pump/Motor/Valve Basic Asm
M
18
10
User Input
182
Application Controller
Motor Controller
174

Fig. 23

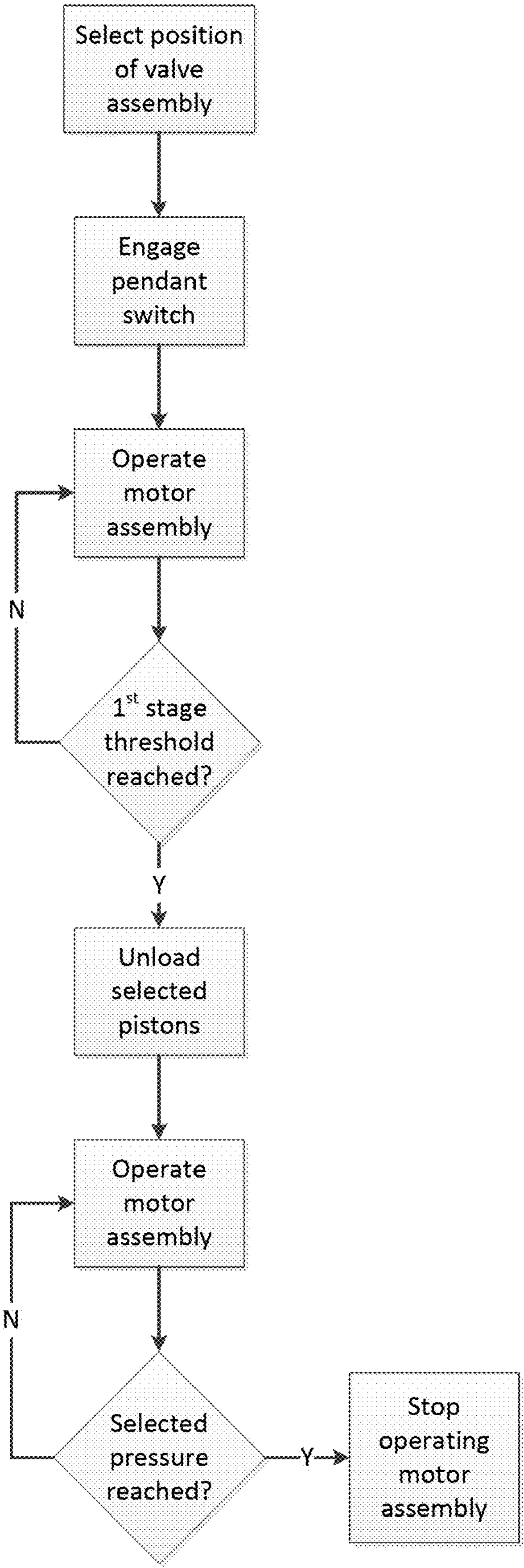

Select position of valve assembly
Engage pendant switch
Operate motor assembly
N
1st stage threshold reached?
Y
Unload selected pistons
Operate motor assembly
N
Selected pressure reached?
Y
Stop operating motor assembly

Fig. 24

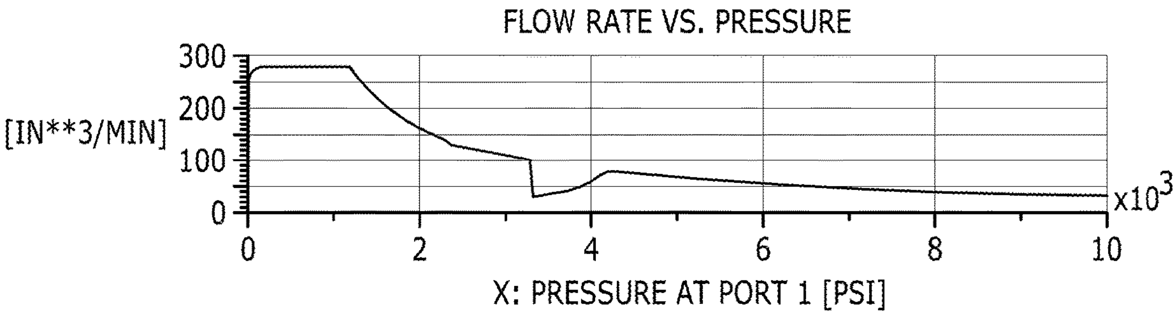


FIG. 25

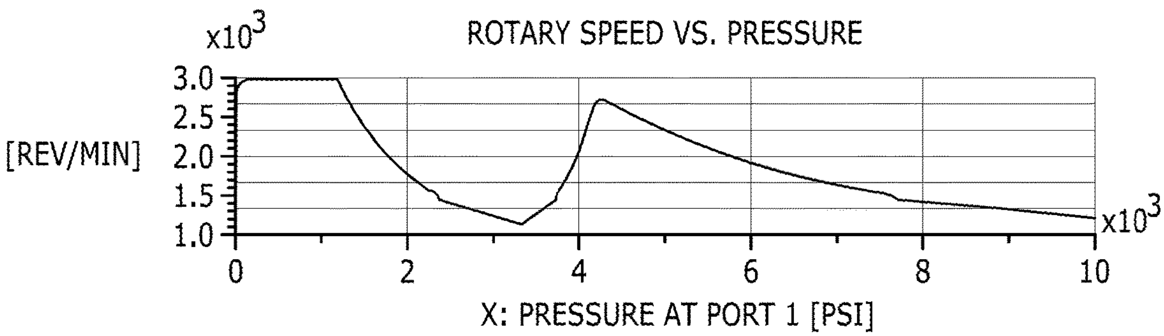


FIG. 26

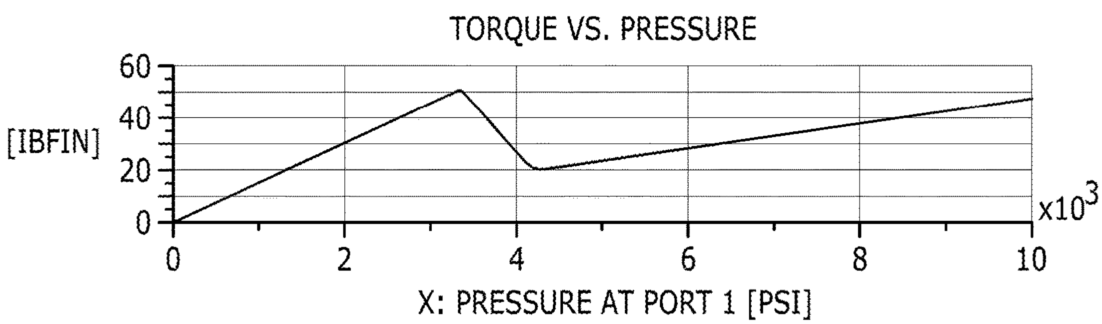


FIG. 27

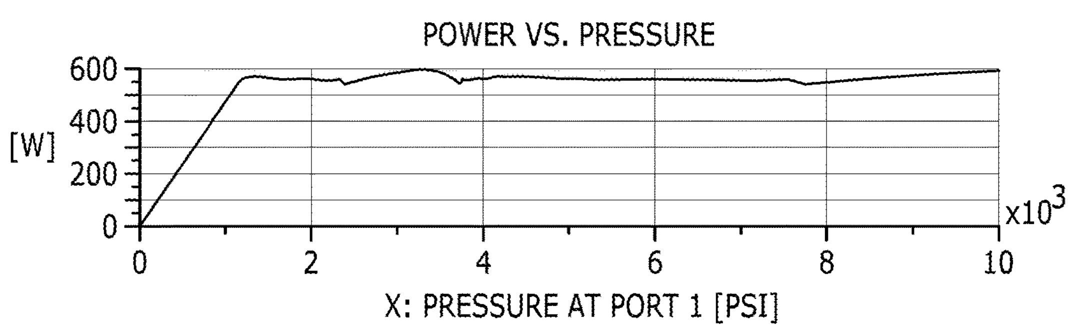


FIG. 28

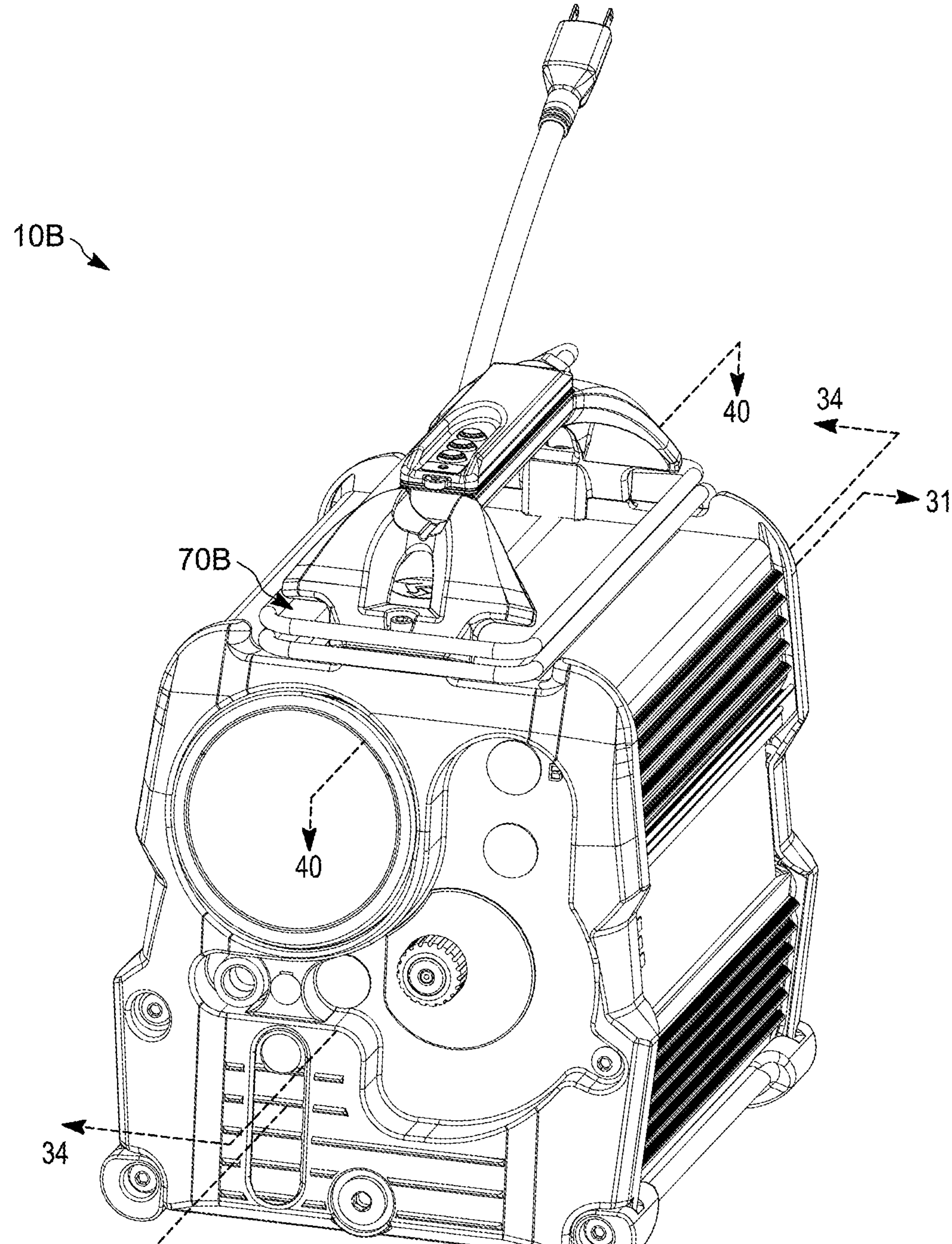


FIG. 29

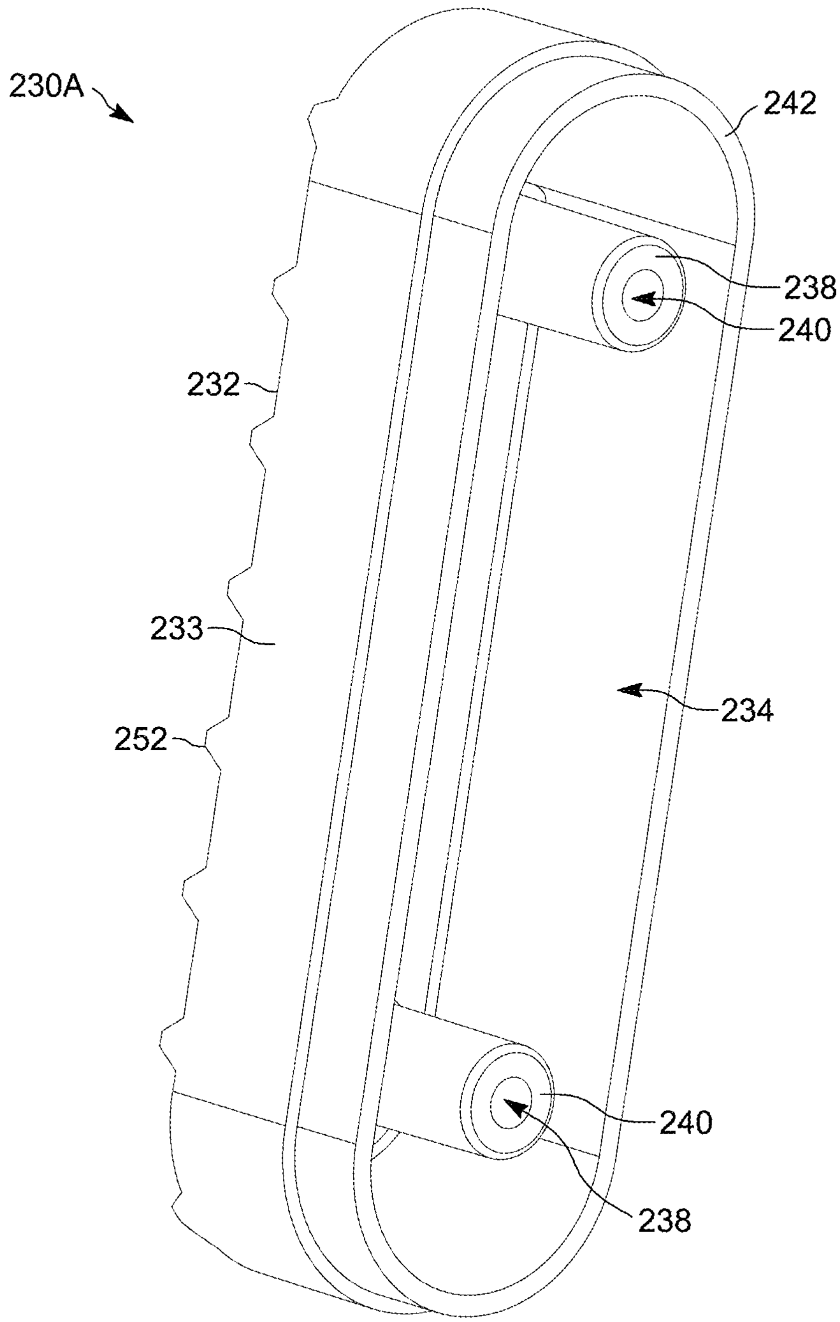


FIG. 30A

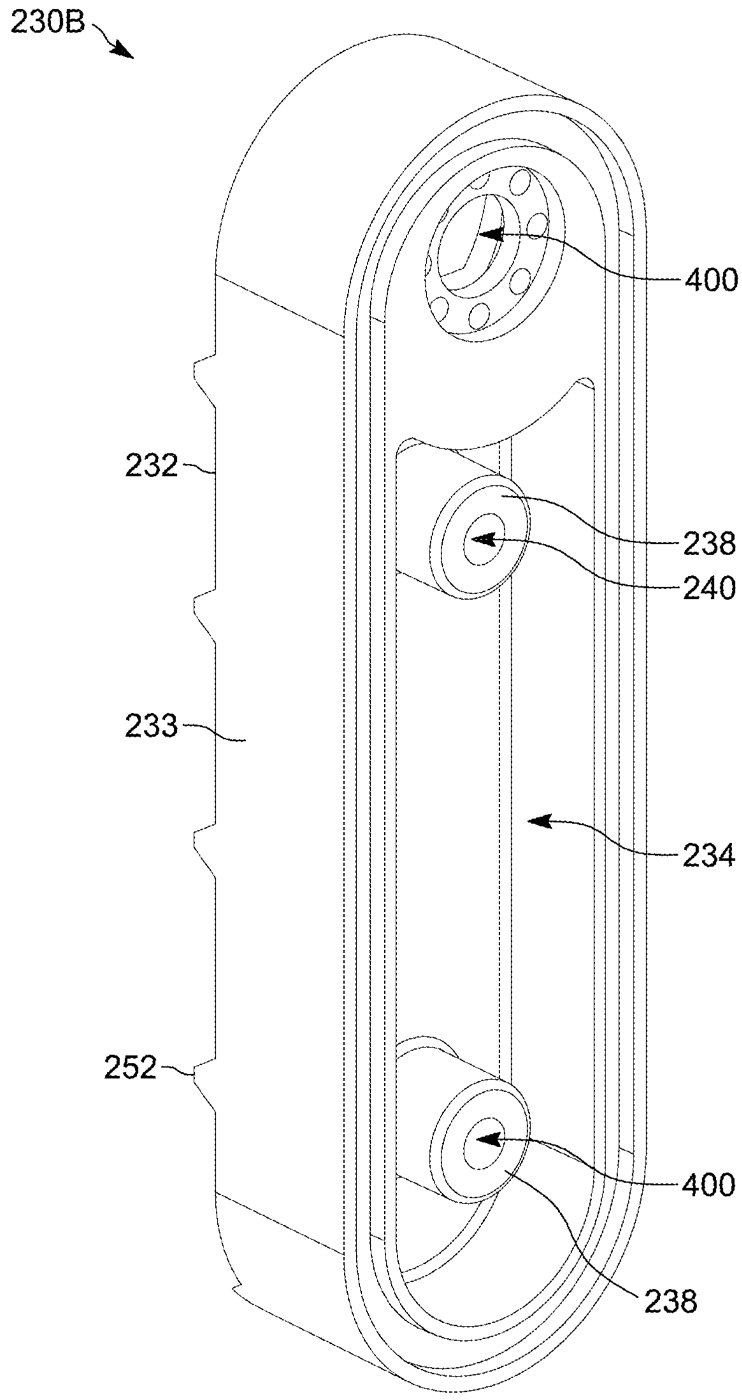


FIG. 30B

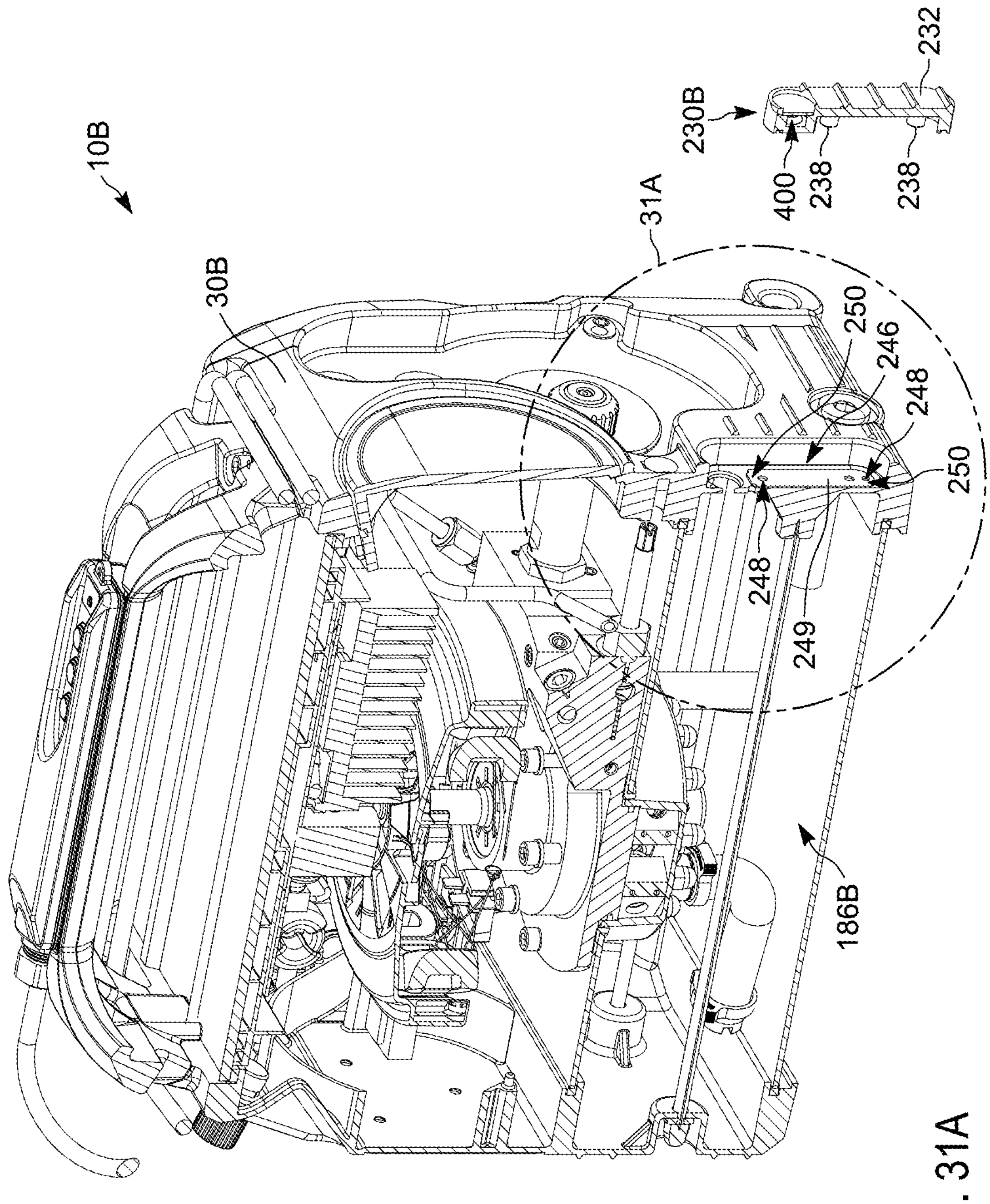

10B
30B
31A
230B
232
400
238
238
250
246
248
248
250
248
249
186B

FIG. 31A

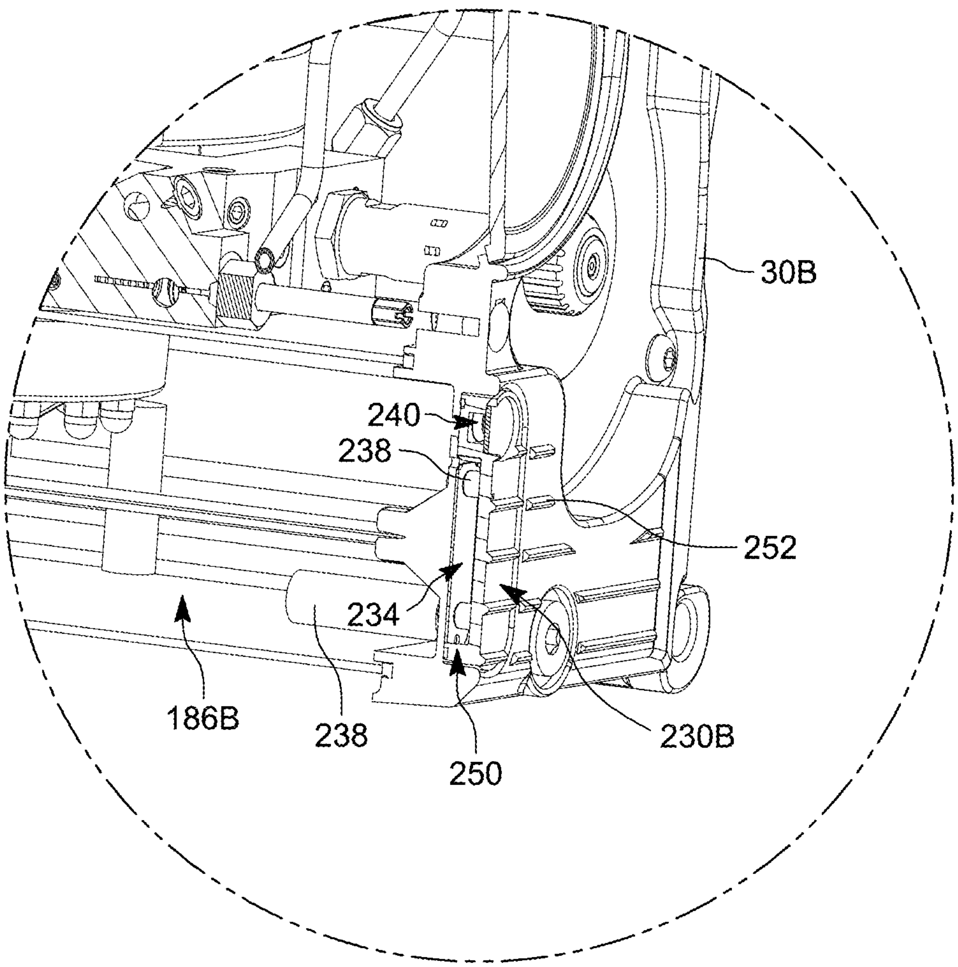


FIG. 31B

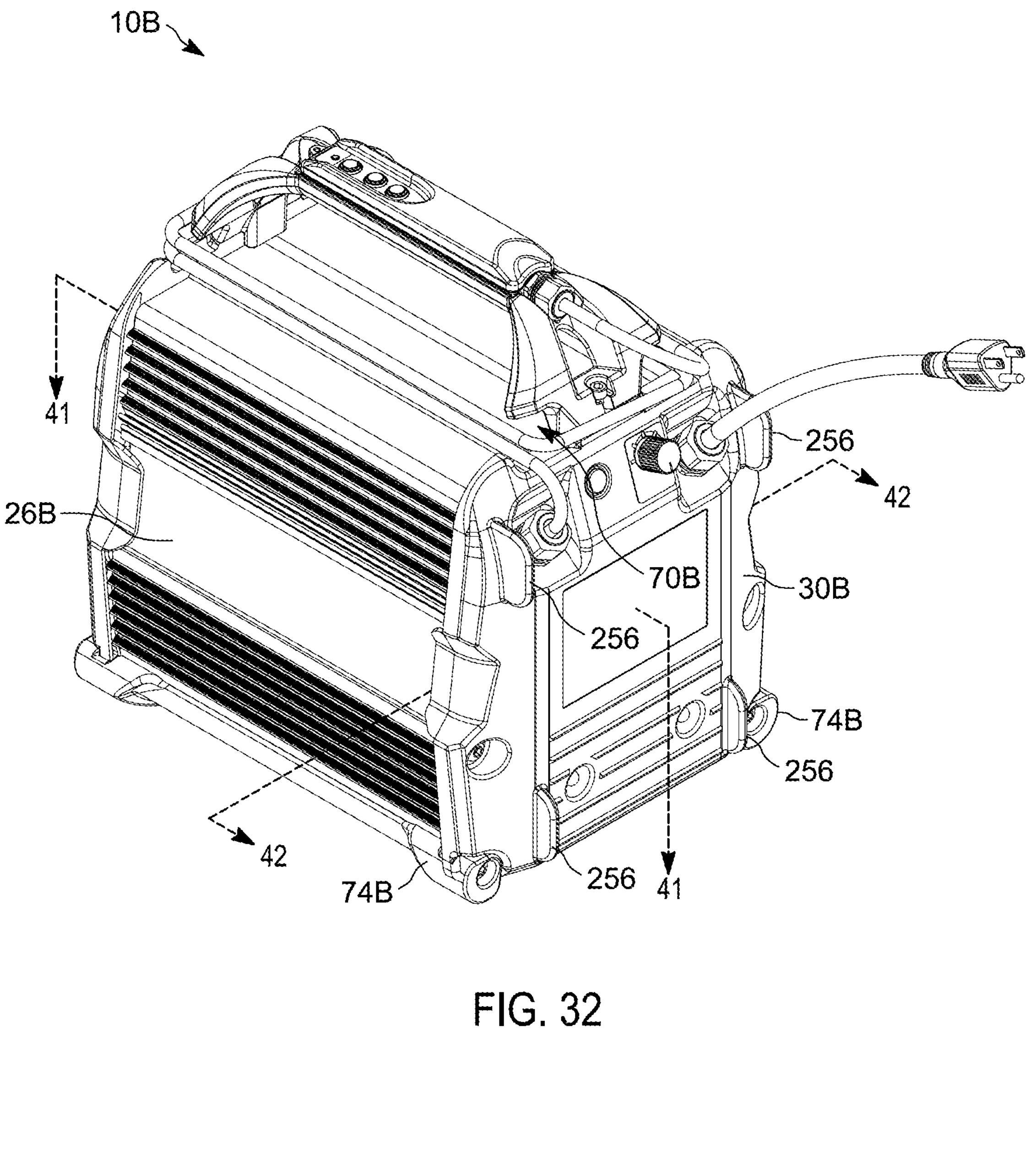


FIG. 32

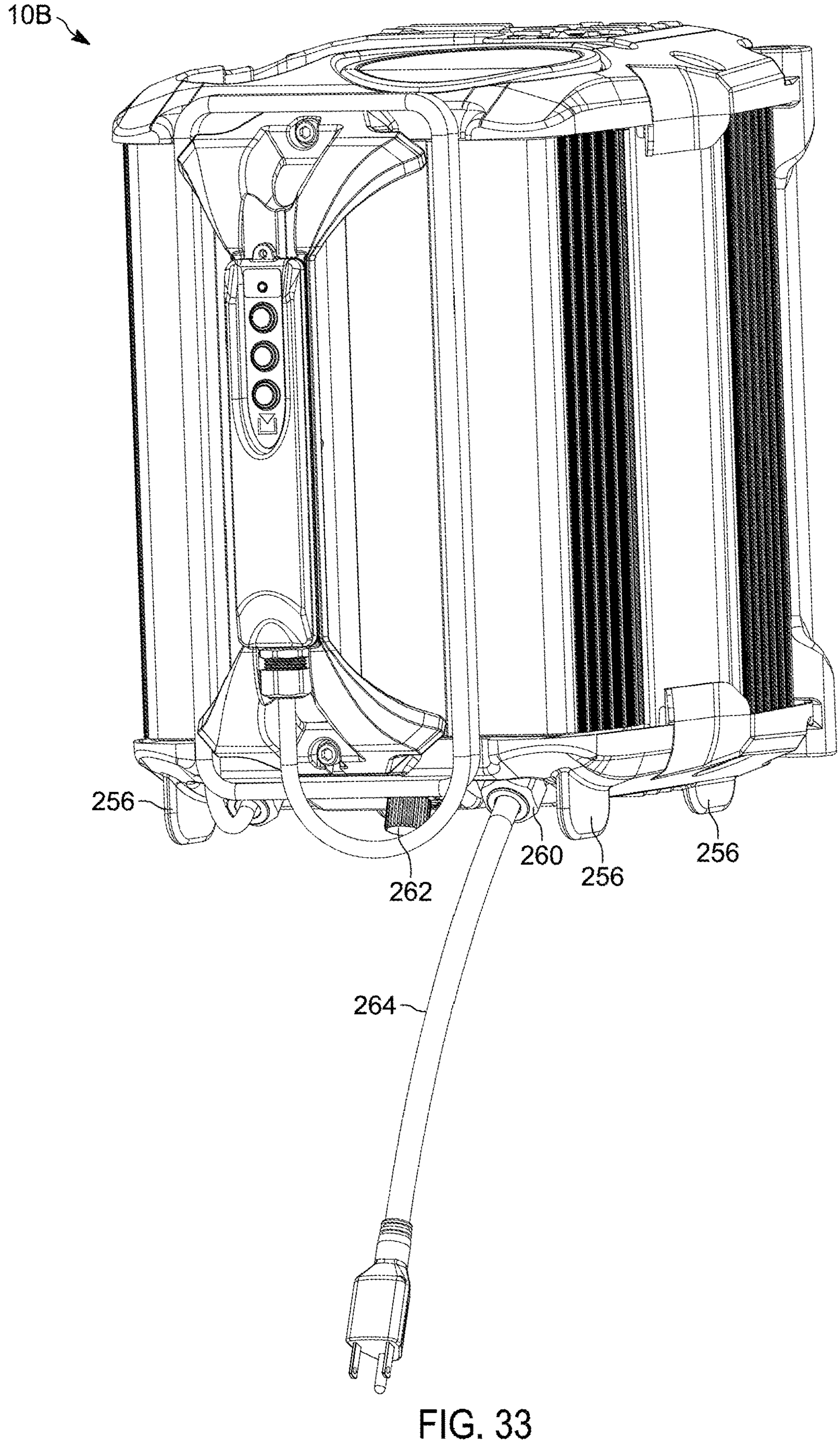


FIG. 33

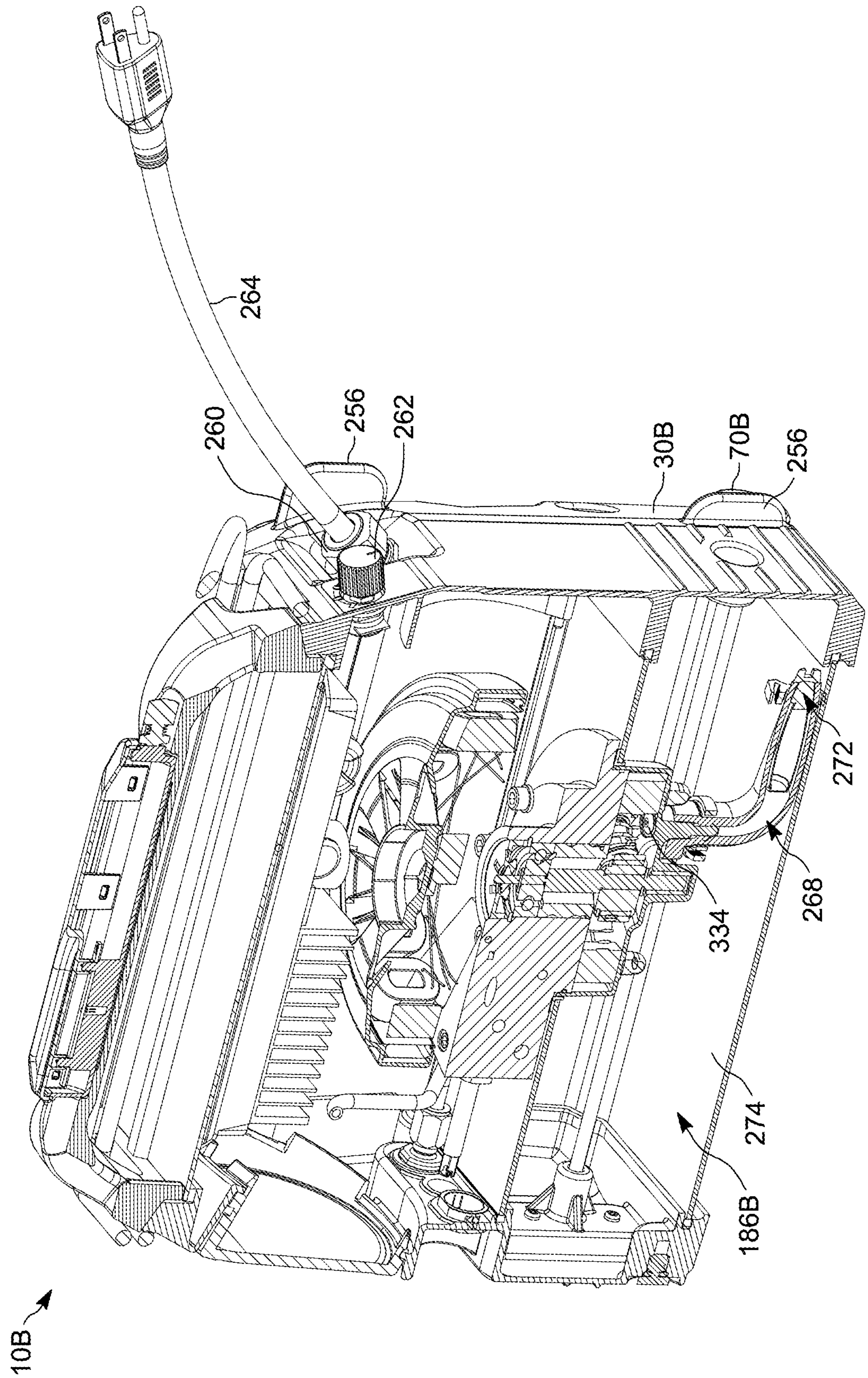


FIG. 34

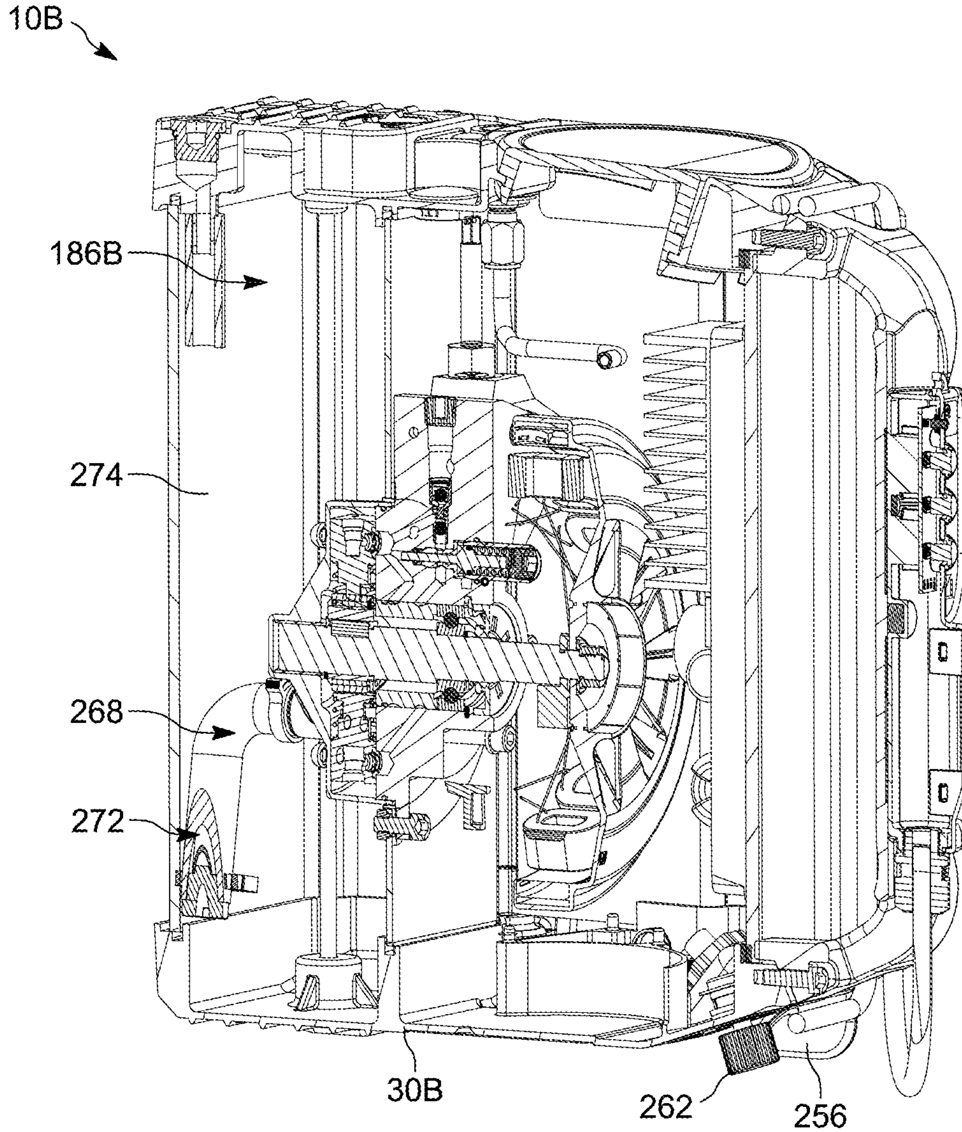


FIG. 35

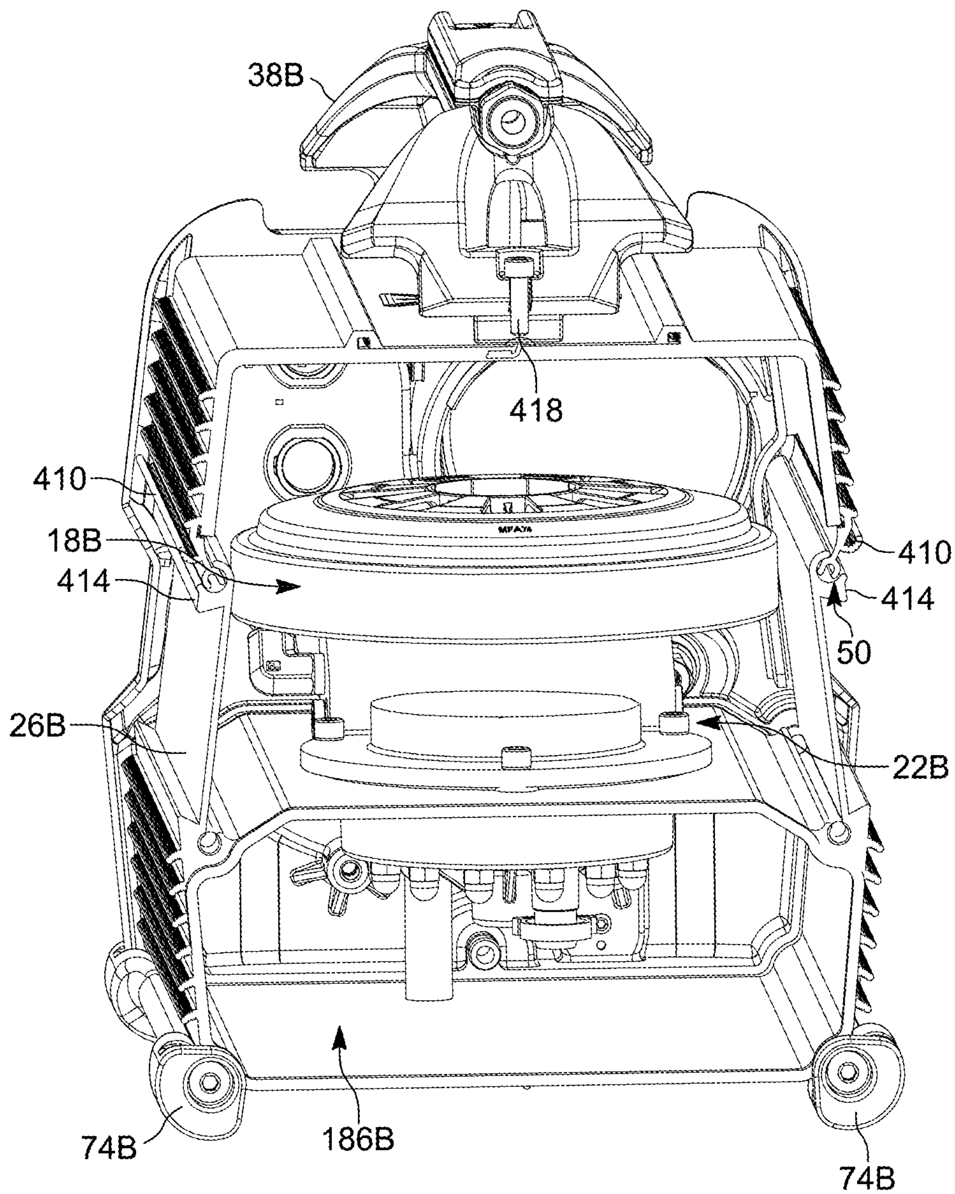


FIG. 36

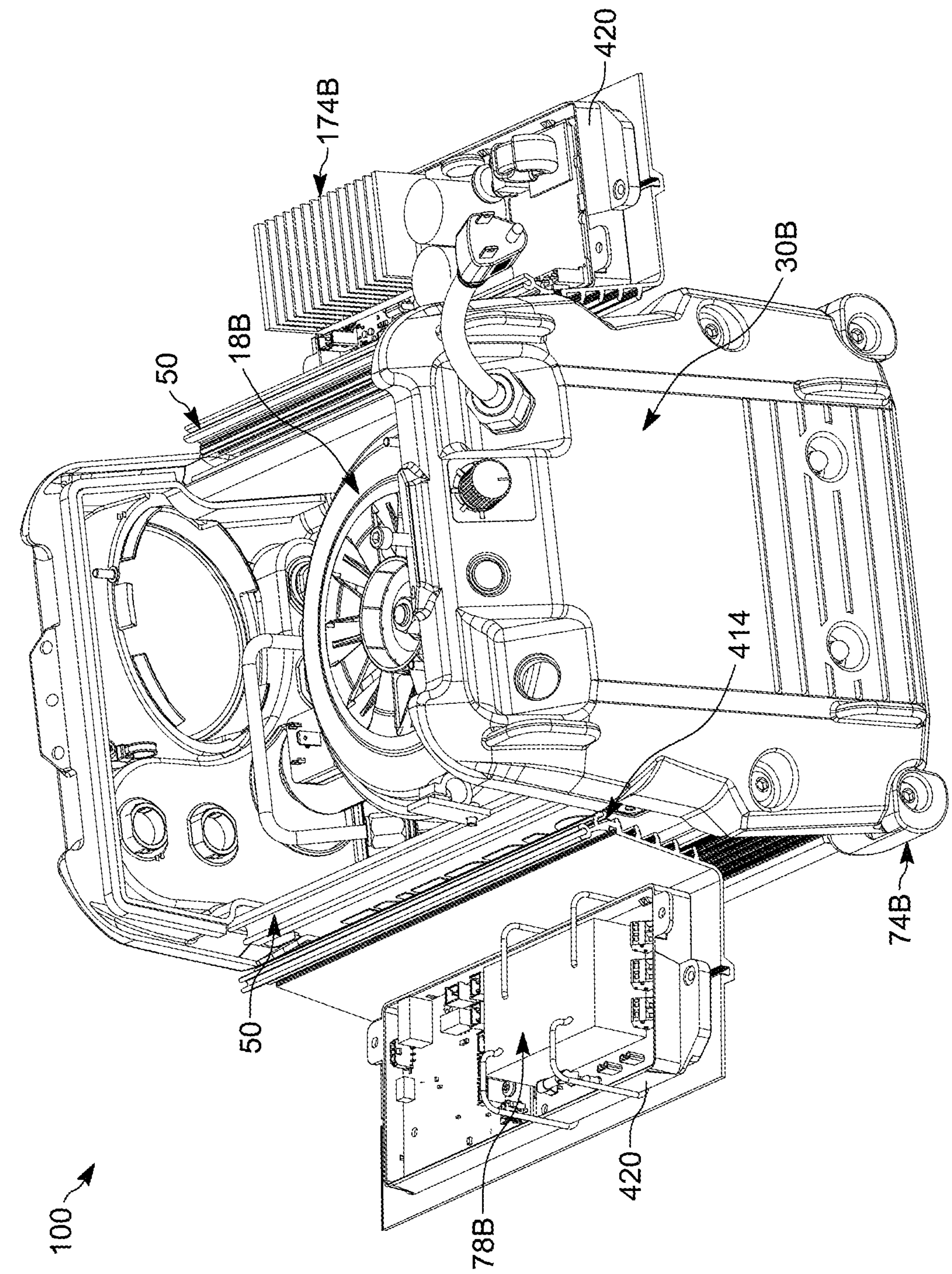


FIG. 37

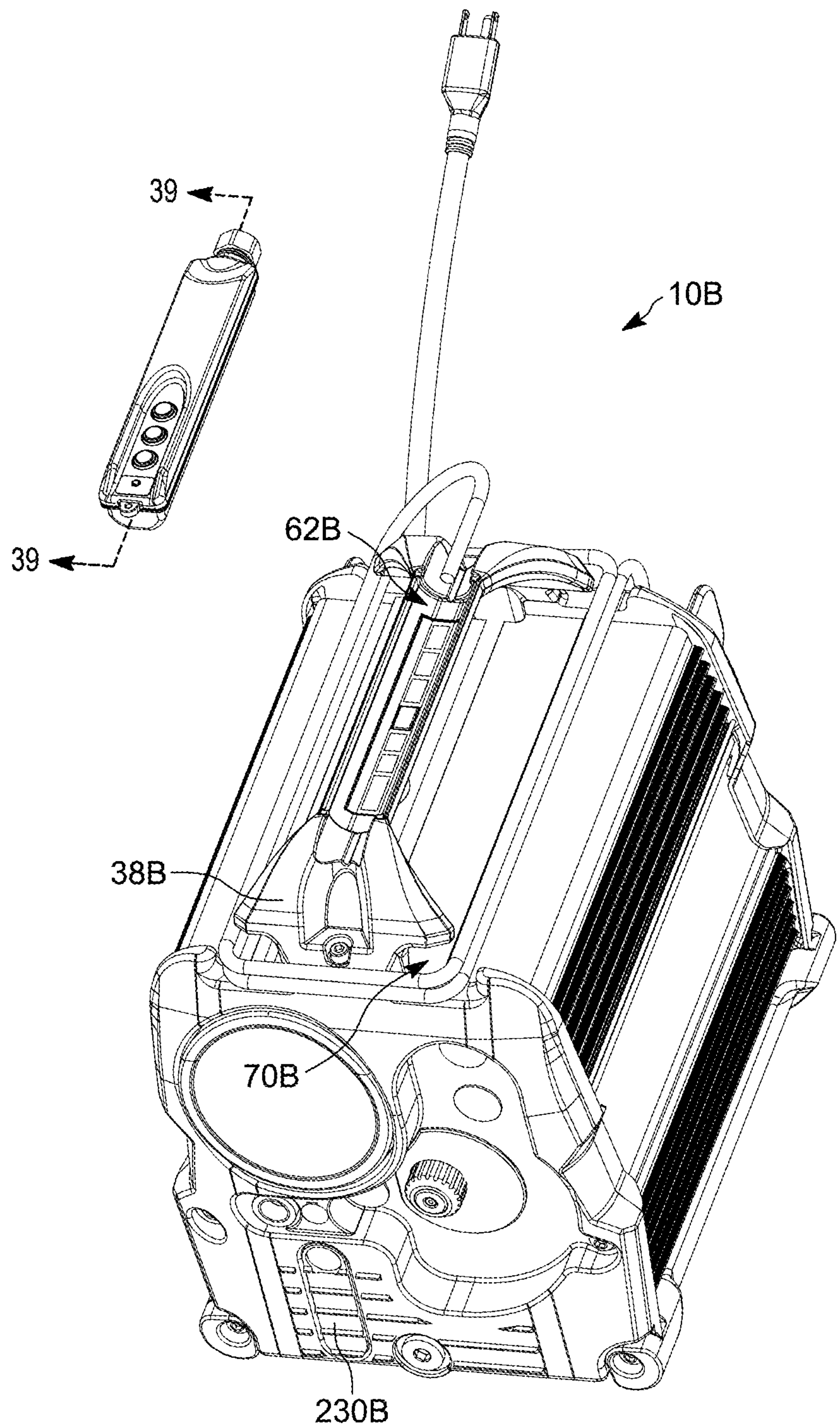


FIG. 38

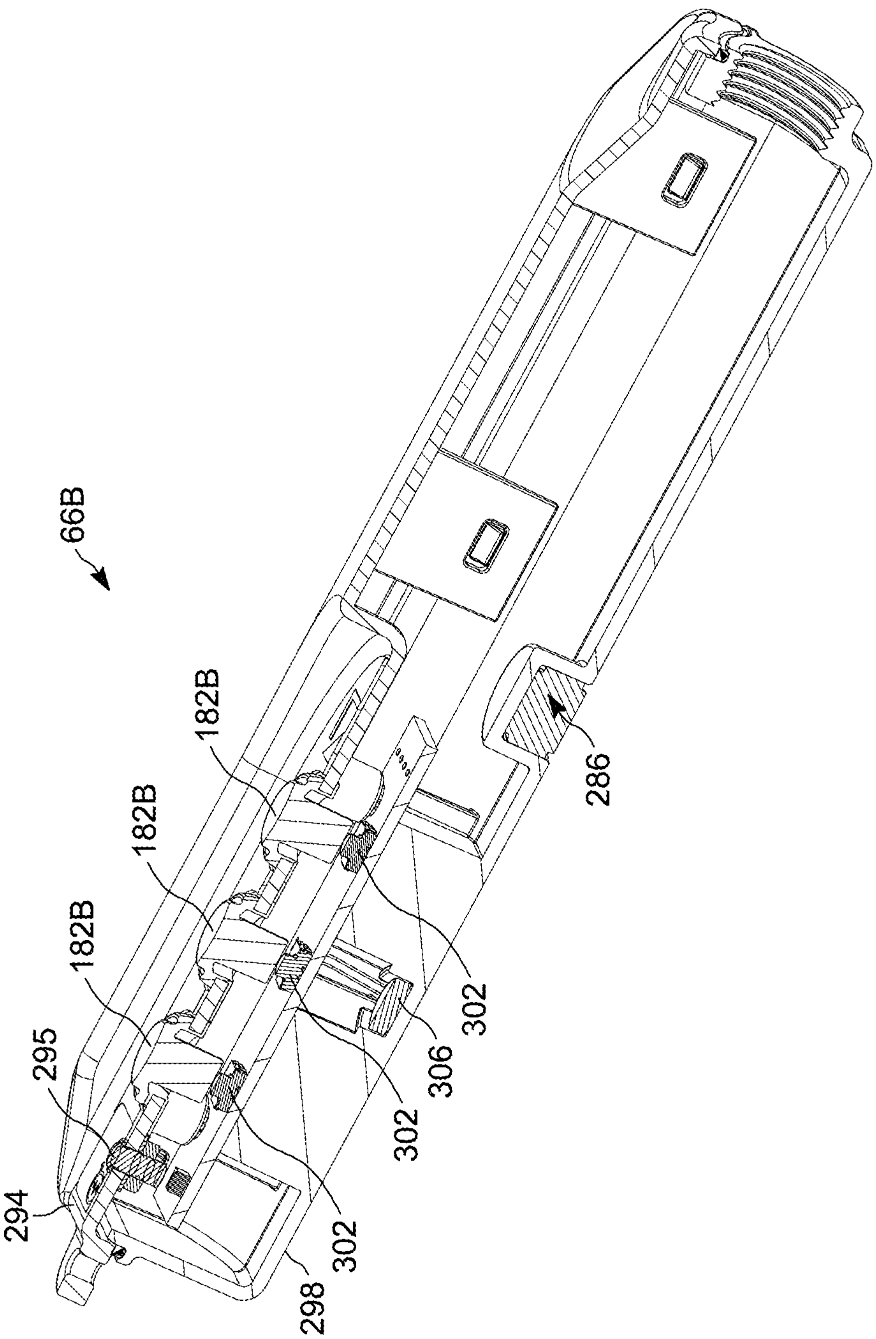


FIG. 39

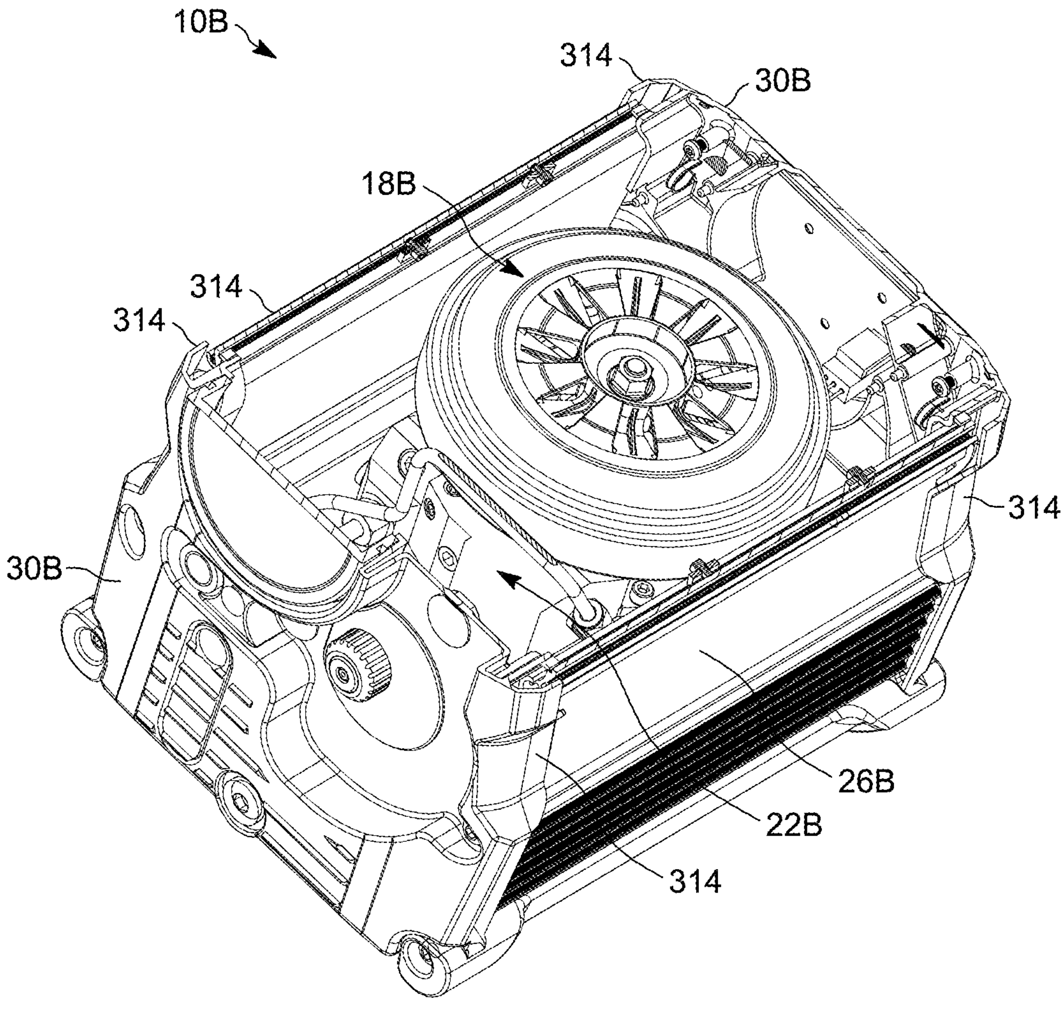


FIG. 40

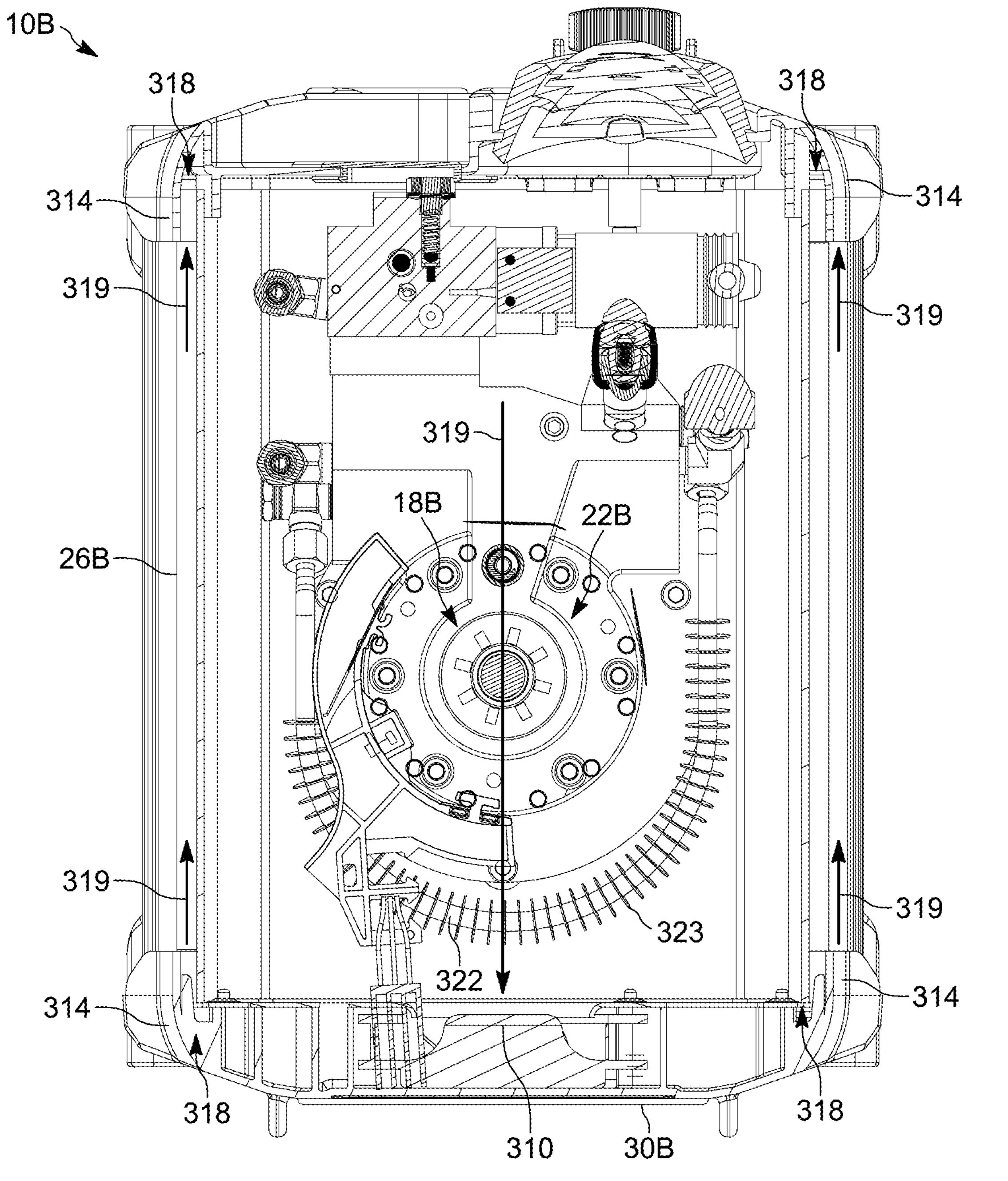

10B
318
318
314
314
319
319
319
18B
22B
26B
319
319
323
322
314
314
318
318
310
30B

FIG. 41

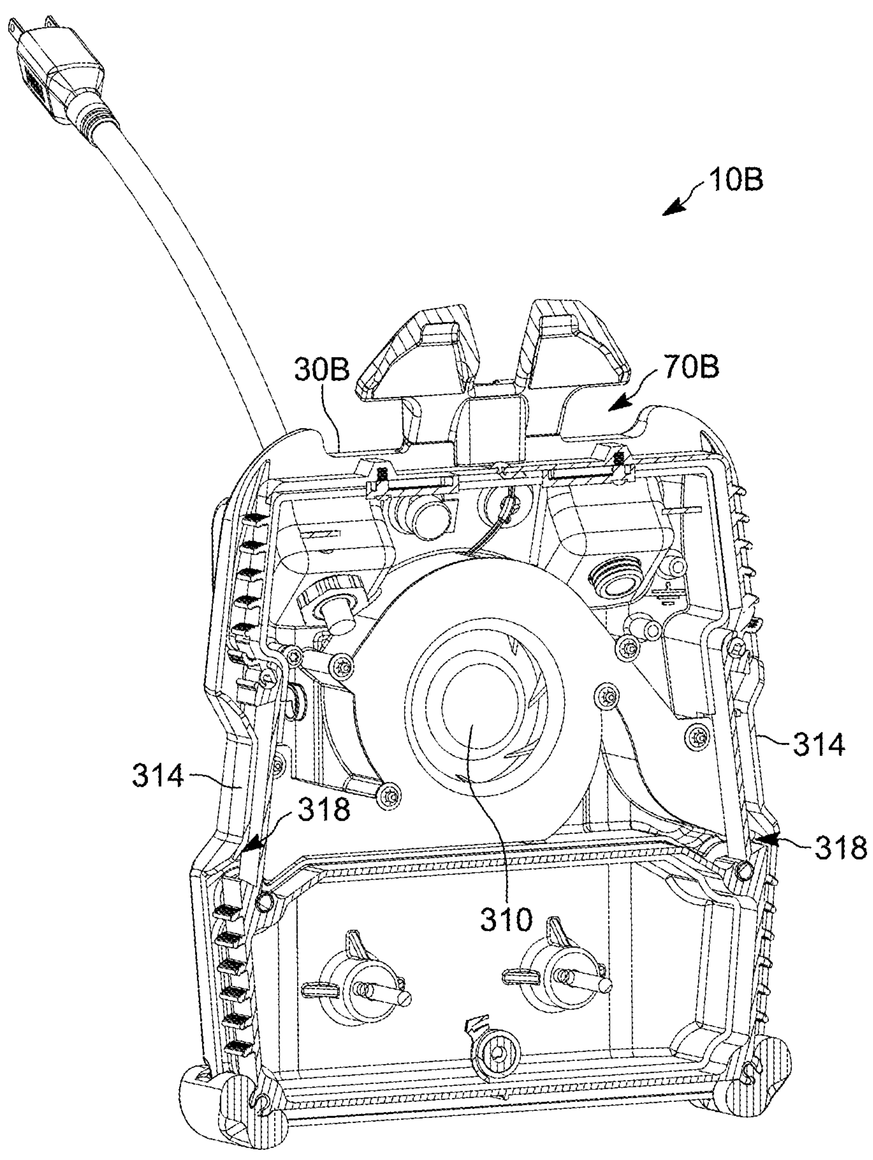


FIG. 42

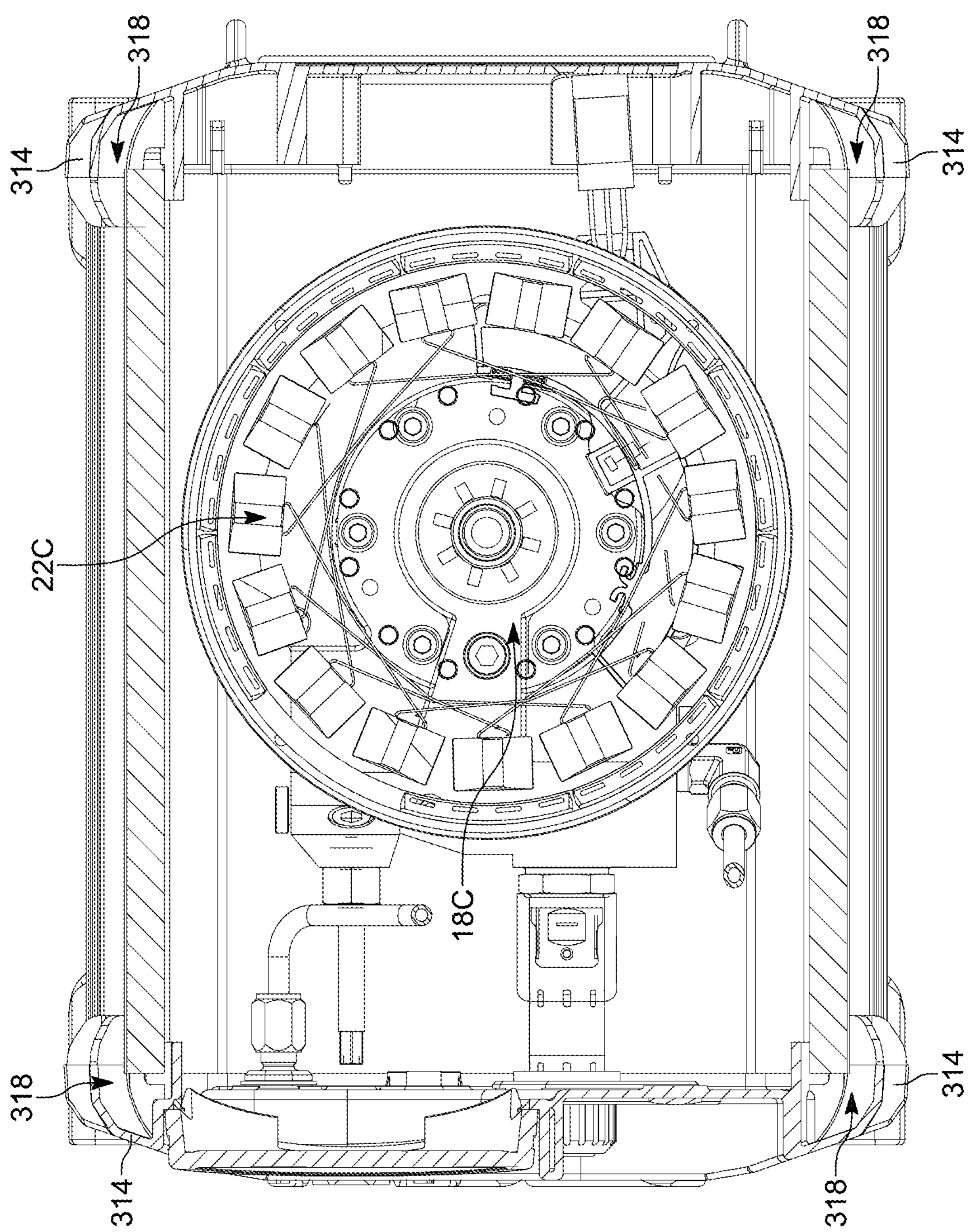


FIG. 43

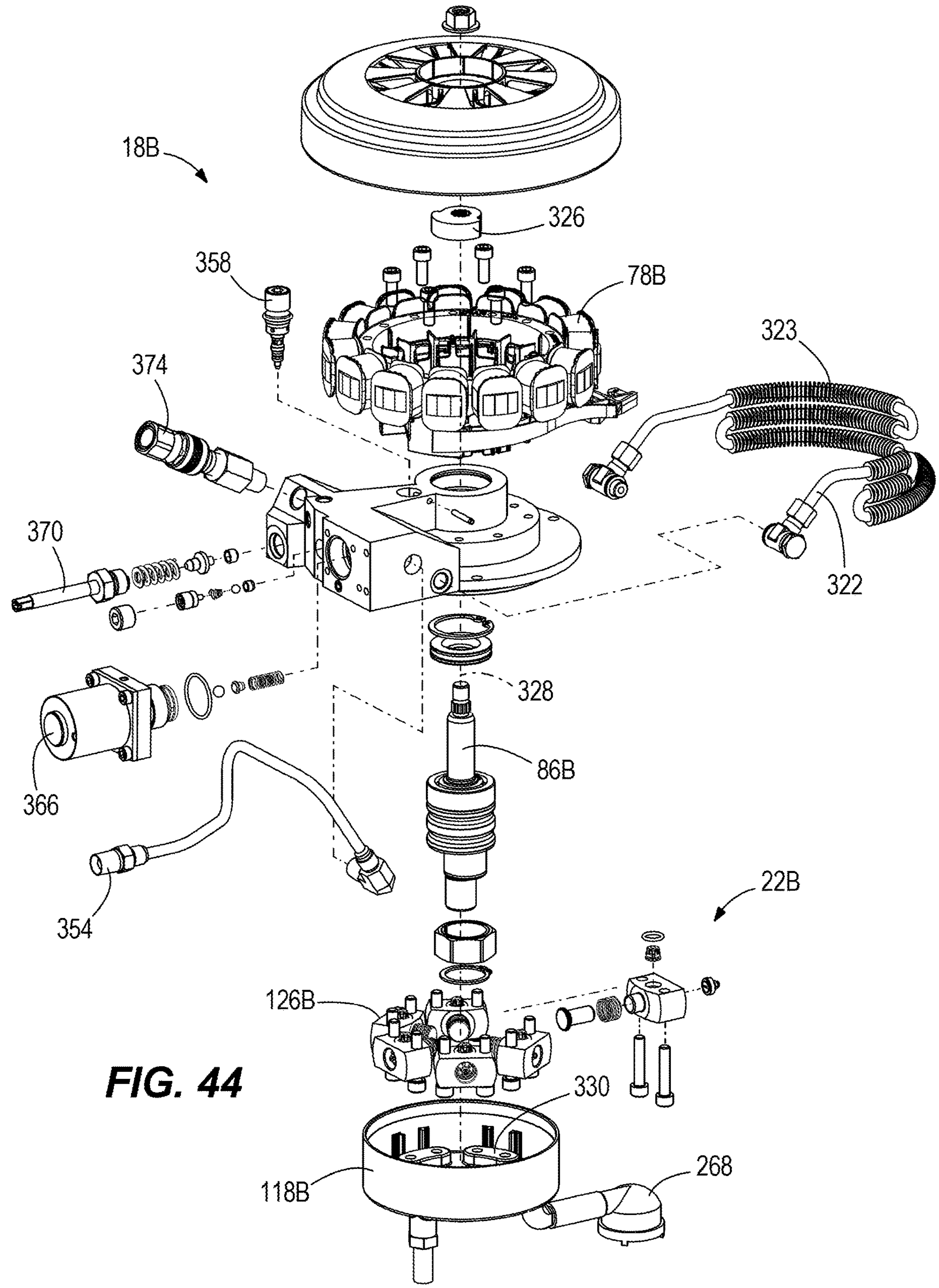

18B
326
358
78B
323
374
370
322
328
86B
366
22B
354
126B
330
268
118B

FIG. 44

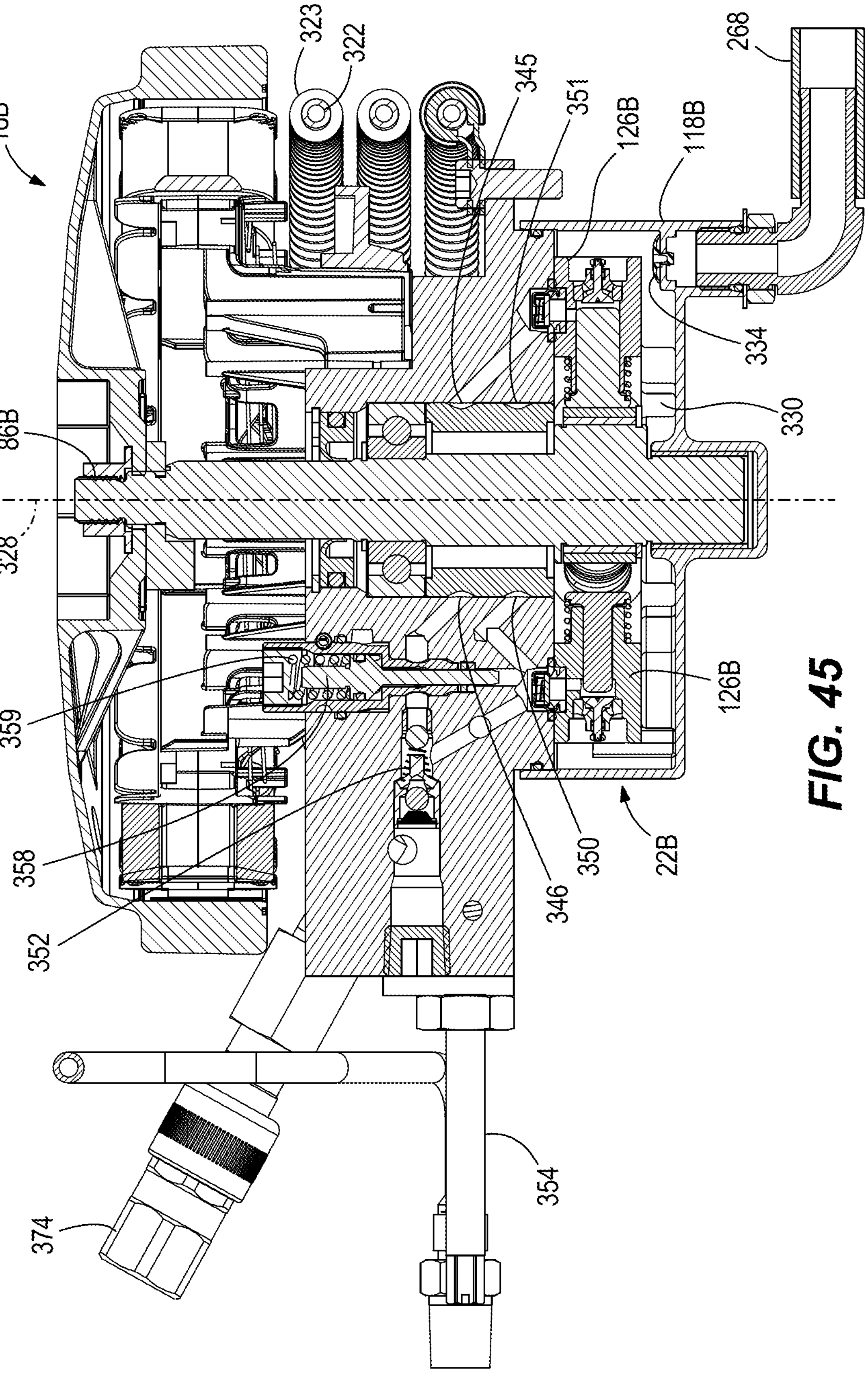

18B
323
322
345
351
126B
118B
268
334
330
86B
328
359
358
352
346
350
22B
126B
354
374

FIG. 45

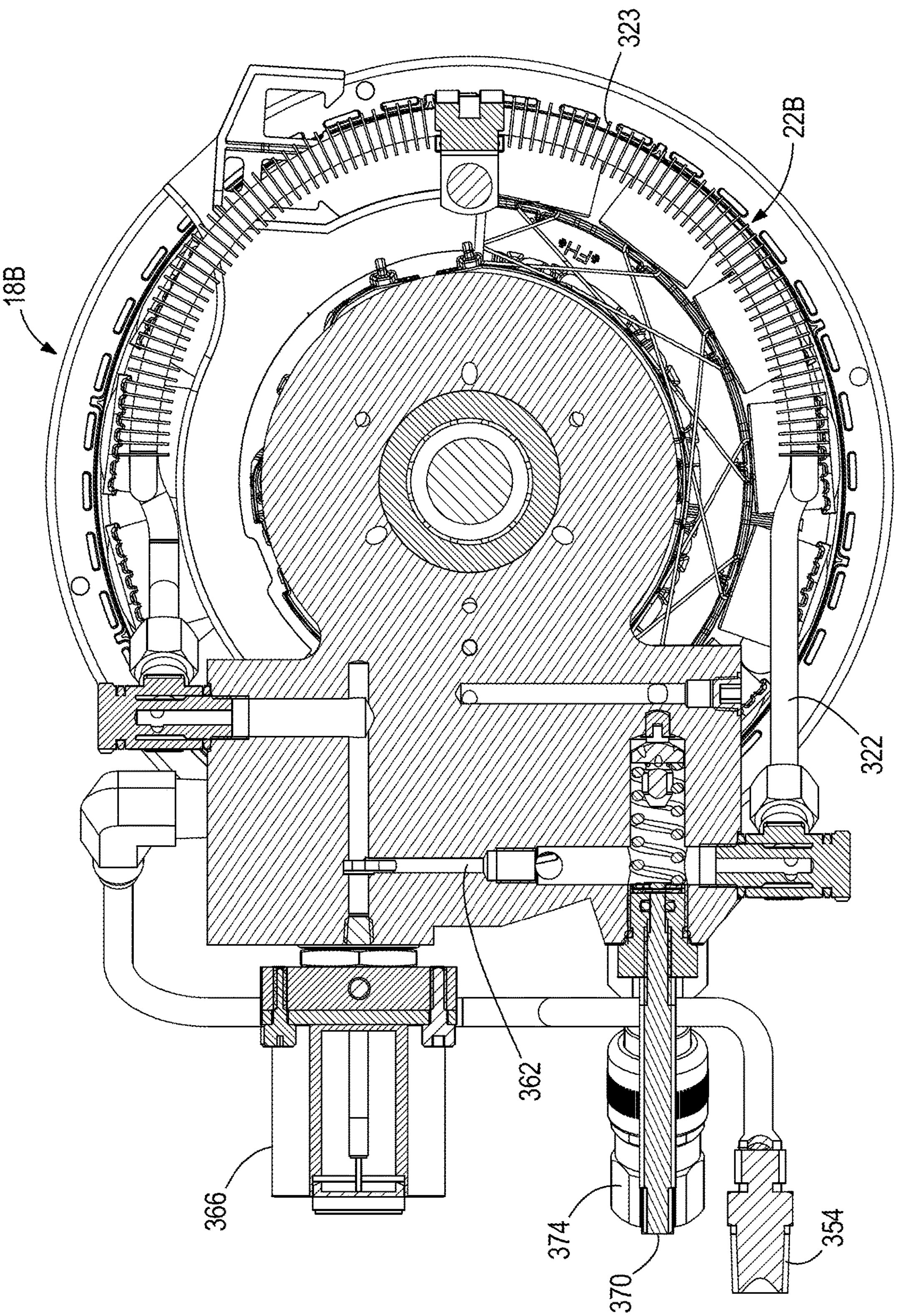


FIG. 46

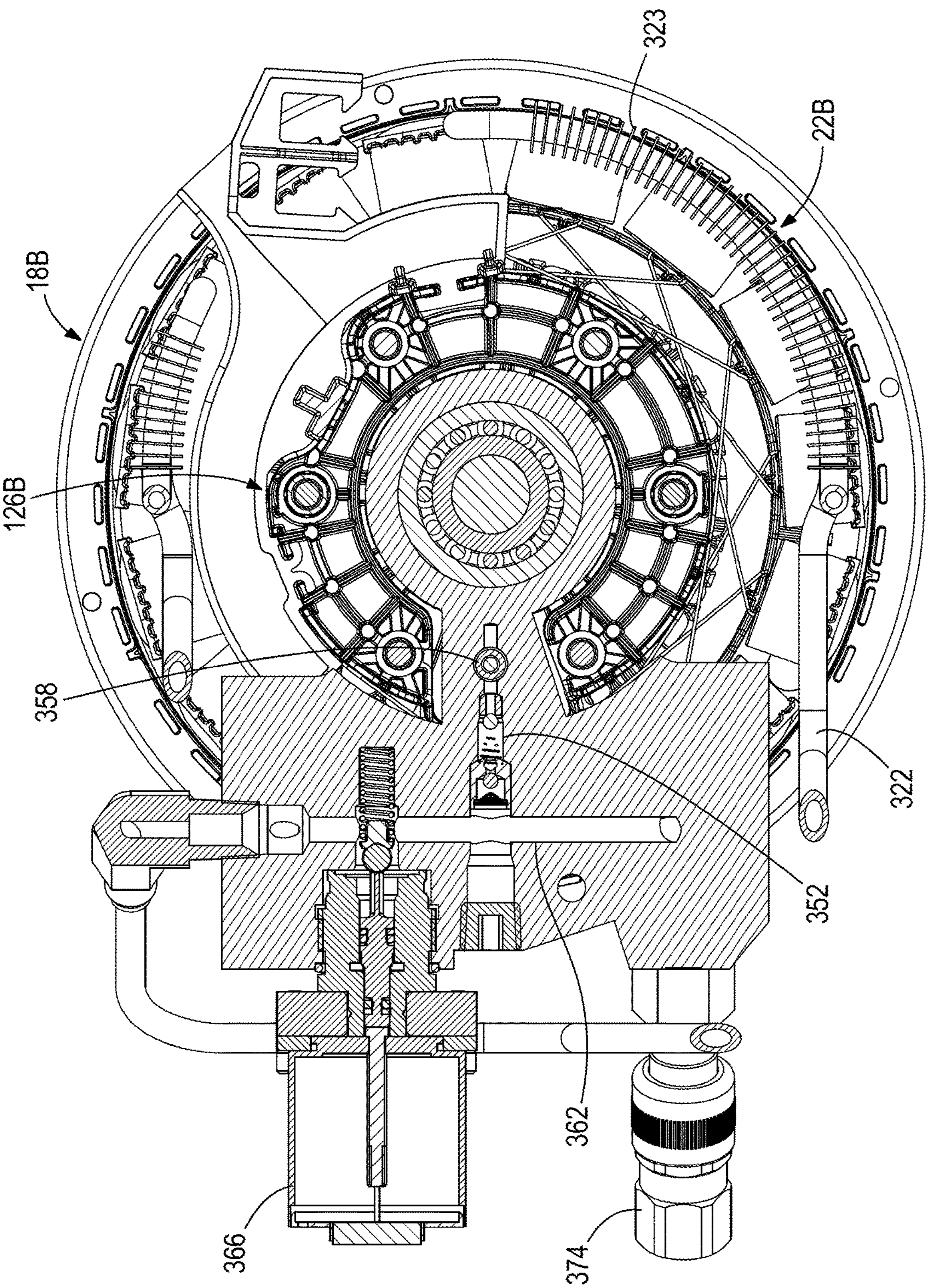


FIG. 47

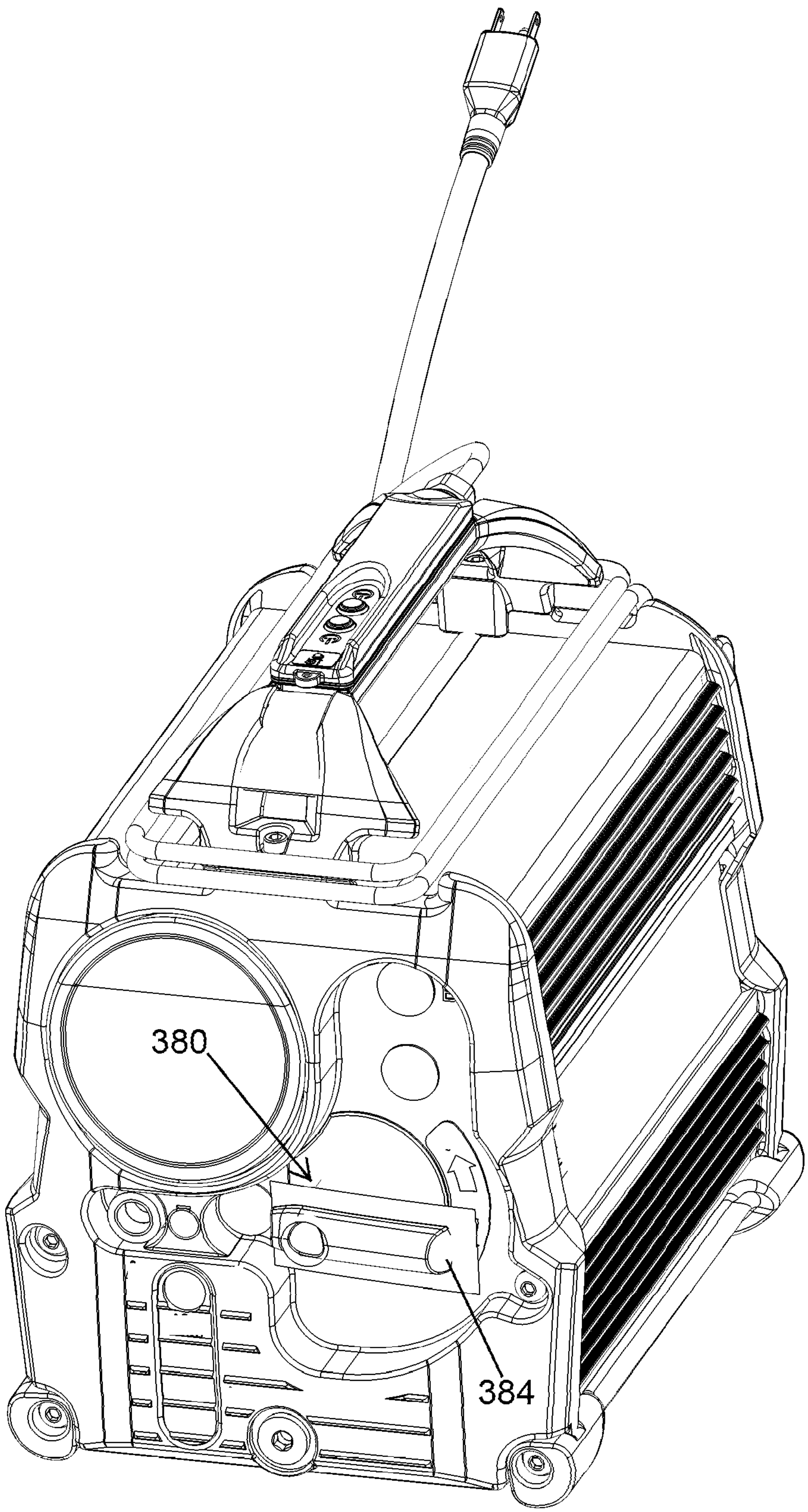


Fig. 48

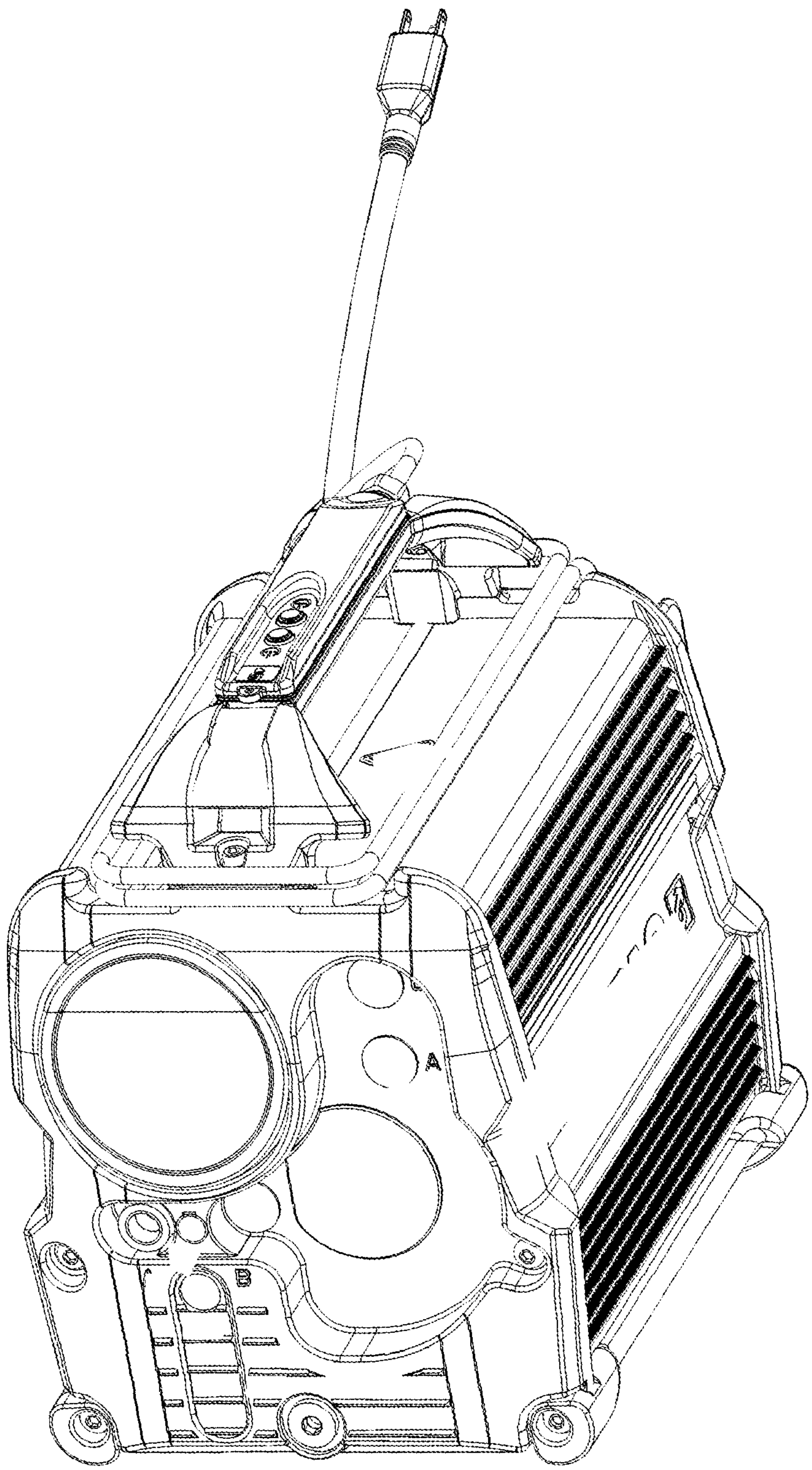


Fig. 49

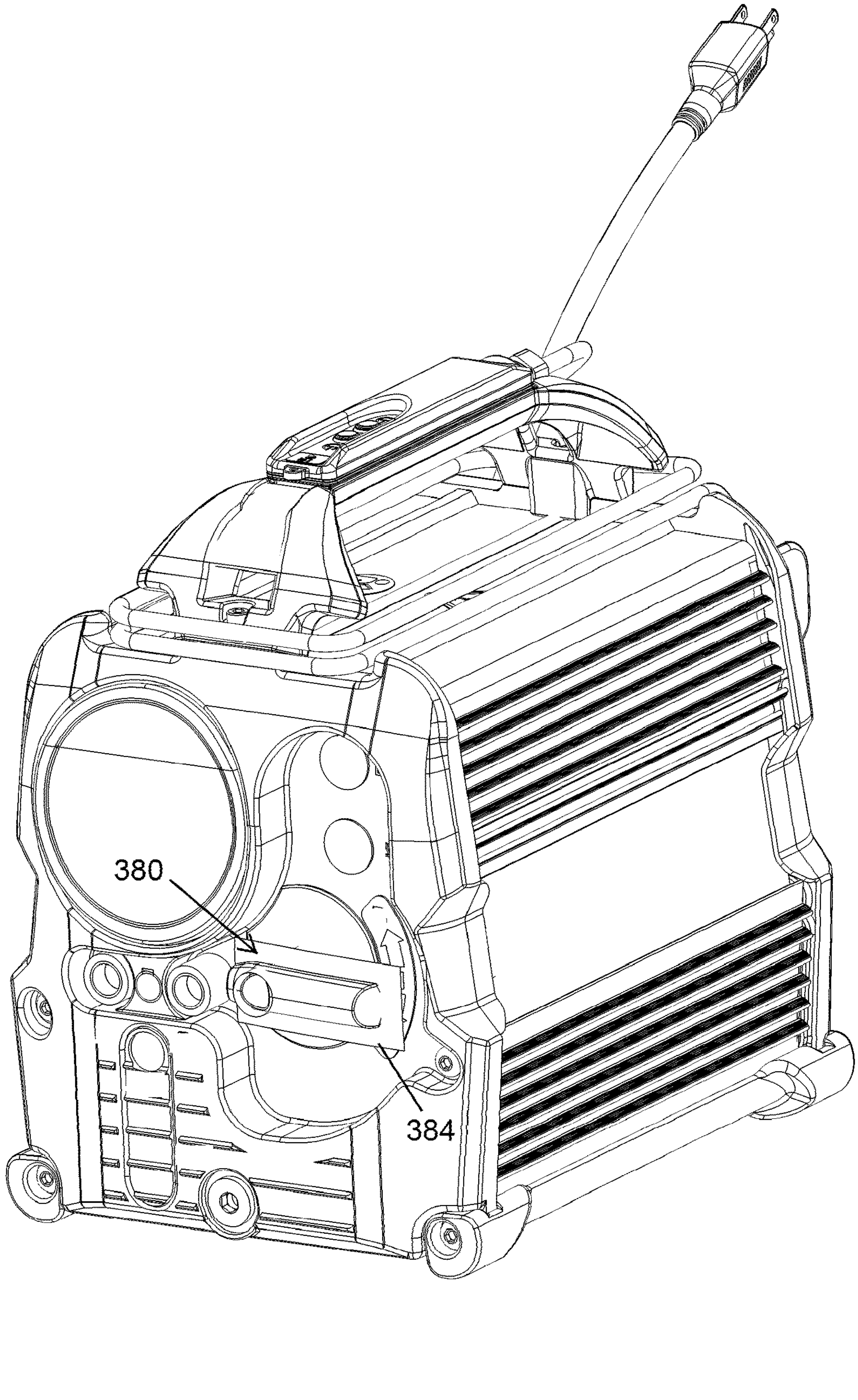


Fig. 50

HYDRAULIC PUMP WITH TWO-STAGE OPERATION

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation of U.S. Non-Provisional patent application Ser. No. 15/981,869, filed on May 16, 2018, which claims the benefit of U.S. Provisional Patent Application No. 62/507,130, filed May 16, 2017, the entire contents of each of which are hereby incorporated by reference.

FIELD

The present disclosure generally relates to hydraulic pumps, and particularly to a variable displacement pump for providing substantially constant power output.

SUMMARY

In some independent aspects, a constant power and variable displacement hydraulic pump may be provided. In some existing pumps, variable displacement of a pump assembly may be provided by mechanical features or components to change the stroke of a pumping piston, for example, by varying the offset of an eccentric cam driving the piston.

Another existing pump uses a single-stage pump and a variable speed motor. In such a pump, a gear pump pre-charged the single-stage pump, and the motor speed was varied manually to attempt to maintain a constant power output. However, practical differences in flow rates for high flow versus high pressure cannot be achieved with variable speed on a single stage alone.

In one independent aspect, a pump may generally include a two-stage pump assembly operable to dispense fluid under pressure; and a brushless motor assembly operable to drive the motor assembly, the motor assembly being controlled to operate at a substantially constant power as fluid pressure increases in each stage of the pump assembly.

In another independent aspect, a pump may generally include a pump assembly operable to dispense fluid, the pump assembly including a pump housing supporting a rotating pump member; a motor operable to drive the pump assembly, the motor including a stator and a rotor supported for rotation relative to the stator; and a shaft connected directly to each of the rotor to the pump member and being operable to transmit power from the rotor to the pump member.

In yet another independent aspect, a pump may generally include a pump assembly operable to dispense fluid, the pump assembly including a pump housing supporting a pump mechanism; and a motor operable to drive the pump assembly, the motor including a stator connected directly to the pump housing, a rotor supported for rotation relative to the stator, and a shaft connected to the rotor and operable to transmit power to the pump assembly.

In a further independent aspect, a pump may generally include a pump assembly operable to dispense fluid, the pump assembly including a pump housing supporting a pump mechanism; and a motor operable to drive the pump assembly, the motor including a stator including a plurality of laminations encapsulated in electrically-insulating material and connected directly to the pump housing and windings wound on the encapsulated lamintations, a rotor including a plurality of permanent magnets encapsulated in electrically-insulating material and supported for rotation relative to the stator, and a shaft connected to the encapsulated rotor and operable to transmit power to the pump assembly.

In another independent aspect, a pump may generally include a pump assembly operable to dispense fluid; a reservoir including a housing defining a container for storing fluid, the housing defining a plurality of channels passing through the container, each channel having an inlet and an outlet; and a fan operable to cause air flow through the channels to cool fluid in the reservoir.

In yet another independent aspect, a pump may generally include a housing, a pump assembly supported by the housing and operable to dispense fluid, a pendant operable to control the pump assembly to dispense fluid; and retainer assembly operable to selectively removably retain the pendant on the housing. In some constructions, the housing may include a handle engageable by a user to transport the pump, the handle defining a receptacle to selectively removably retain the pendant.

In a further independent aspect, a pump may generally include an electric motor connectable to a power source by a cord, a pump assembly driven by the motor assembly to dispense fluid, and a housing supporting the motor assembly and the pump assembly, the housing including a cord wrap formed integrally with a portion of the housing. The housing may have a base and define an outer periphery extending in a vertical direction, the cord wrap being within the outer periphery.

In another independent aspect, a method of operating a pump may be provided. The pump may include a housing, a motor assembly supported by the housing, and a pump assembly supported by the housing, the pump assembly including a plurality of pistons. The method may generally include operating the motor assembly to drive the pump assembly; dispensing fluid under pressure with the plurality of pistons; after a pressure threshold is reached, unloading fewer than all of the plurality of pistons; after unloading, operating the motor assembly to drive the pump assembly; dispensing fluid under pressure with remaining pistons of the plurality of pistons until a selected pressure is reached.

In another independent aspect, a pump may generally include a frame including a reservoir. The reservoir stores a hydraulic fluid. The pump may also include a motor assembly supported by the frame and a pump assembly operably driven by the motor assembly. The pump assembly is in fluid communication with the reservoir and configured to dispense the hydraulic fluid out of the frame. The pump assembly includes a first piston and a second piston, wherein the first piston dispenses hydraulic fluid out of the frame between a first pressure and a second pressure greater than the first pressure, and the second piston dispenses hydraulic fluid out of the frame between the first pressure and a third pressure, the third pressure being greater than the second pressure.

In another independent aspect, a pump may generally include a frame with a first side, a second side, and an end positioned between the first side and the second side, wherein the frame defines a compartment. A motor assembly and a pump assembly are positioned within the compartment. The pump may also include a radial fan positioned within the compartment and adjacent the end of the frame, an inlet positioned on one of the first side and the second side of the frame, and an outlet positioned on one of the first side or the second side of the frame, wherein the outlet is spaced apart from the inlet. The radial fan is configured to force air over the motor assembly and the pump assembly in order to reduce a temperature of the motor assembly and a temperature of the pump assembly. The radial fan draws air through the inlet and exhausting air through the outlet.

In another independent aspect, a pump may generally include a frame with a compartment, a motor assembly and a pump assembly positioned within the compartment. A handle is positioned adjacent the frame and a control device removably coupled to the handle. The control device has at least one switch and is in communication with a controller supported by the frame, wherein actuating the switch sends a signal to the controller. The control device includes a motor, wherein actuating the switch actuates the motor, the motor providing an output configured to be sensed by a user.

In another independent aspect, a pump may generally include a frame with a reservoir and an internal compartment, where a motor assembly and a pump assembly are positioned within the internal compartment. The pump includes an external cavity, an aperture, and a viewing lens. A surface of the frame separates the compartment from the cavity. The aperture provides fluid communication from the reservoir to the cavity. The viewing lens covers the cavity and the viewing lens is flush with the surface of the frame. Measurement markings are positioned on a surface of the viewing lens, wherein the measurement markings allows a user to determine a level of fluid in the reservoir.

In another independent aspect, a pump may generally include a frame housing a reservoir and a pump assembly. A fluid inlet provides fluid communication between the reservoir and the pump assembly. First feet are positioned on a first surface of the frame and second feet positioned on a second surface of the frame, the second surface is adjacent to the first surface. The fluid inlet is positioned proximate an edge of the frame at which the first surface and the second surface intersect, wherein the pump is operable when supported by either the first feet or the second feet.

The method may include operating the motor assembly to produce a substantially constant power output as pressure increases. Operating the motor assembly may include reducing the motor speed as pressure increases. Reducing the motor speed may include employing field weakening.

Independent features and independent advantages may become apparent to those skilled in the art upon review of the detailed description, drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front perspective view of a pump.

FIG. **2** is a front perspective view of the pump shown in FIG. **1** with the doors open.

FIG. **3** is a partial exploded view of the pump of FIG. **1**, illustrating a locking arrangement.

FIG. **4** is a rear perspective view of the pump shown in FIG. **1** with the doors removed.

FIG. **5** is a rear perspective view of the pump shown in FIG. **1** with the rear end cap removed.

FIG. **6** is a right side view of the pump shown in FIG. **1** with portions of the housing assembly removed.

FIG. **7** is a front perspective view of a portion of the pump shown in FIG. **1**.

FIG. **8** is a bottom perspective view of the portion of the pump shown in FIG. **1** with the lower housing removed.

FIG. **9** is a rear perspective view of the pump shown in FIG. **1** with the pendant removed.

FIG. **10** is a front perspective view of a further alternative construction of a pump.

FIG. **11** is a rear perspective view of the pump shown in FIG. **10** with the doors removed.

FIG. **12** is a rear perspective view of the pump shown in FIG. **10** with the rear end cap removed.

FIG. **13** is a right side cross-sectional view of the pump shown in FIG. **10**.

FIG. **14** is a front perspective view of the pump shown in FIG. **10** with the pendant removed.

FIG. **15** is a top perspective view of the portion of the pump shown in FIG. **10** with the rotor removed.

FIG. **16** is a bottom view of the portion of the pump shown in FIG. **10** with the lower housing removed.

FIG. **17** is an exploded view of an alternative construction of a reservoir including an integrated heat exchanger.

FIG. **18** is a cross-sectional view of the reservoir shown in FIG. **17** taken generally along line **18-18** in FIG. **19**.

FIG. **19** is a cross-sectional view of the reservoir shown in FIG. **17** taken generally along line **19-19** in FIG. **18**.

FIG. **20** is a cross-sectional view of the reservoir shown in FIG. **17** taken generally along line **20-20** in FIG. **18**.

FIG. **21** is another cross-sectional view of the reservoir shown in FIG. **17** similar to FIG. **19**.

FIG. **22** is a cross-sectional view of an alternative construction of a reservoir including an integrated heat exchanger.

FIG. **23** is a schematic diagram of a circuit of the pump shown in FIG. **1**.

FIG. **24** is a flowchart illustrating a method of operating the pump shown in FIG. **1**.

FIG. **25** is a graph of simulated flow (CIM) versus pressure (psi) for the pump of FIG. **1**.

FIG. **26** is a graph of simulated torque (Nm) versus pressure (psi) for the pump of FIG. **1**.

FIG. **27** is a graph of the simulated speed (rpm) versus pressure (psi) for the pump of FIG. **1**.

FIG. **28** is a graph of simulated power (W) versus pressure (psi) for the pump of FIG. **1**.

FIG. **29** is a front perspective view of another alternative construction of a pump.

FIG. **30**A is a rear perspective view of a viewing lens.

FIG. **30**B is a rear perspective view of an alternate construction of a viewing lens.

FIG. **31**A is a cross-sectional view of the pump shown in FIG. **29** taken generally along line **31-31**.

FIG. **31**B is an enlarged view of the pump shown in FIG. **31** taken generally along **31**B.

FIG. **32** is a rear perspective view of the pump of FIG. **29**.

FIG. **33** is a rear perspective view of the pump of FIG. **29**, in a second orientation.

FIG. **34** is a cross-sectional view of the pump shown in FIG. **29** taken generally along line **34-34**.

FIG. **35** is a cross-sectional view of the pump shown in FIG. **29** in a second orientation, taken generally along line **34-34**.

FIG. **36** is an end view of the pump shown in FIG. **29**, with an end plate removed.

FIG. **37** is a perspective view of the pump shown in FIG. **29**, with doors of the pump open.

FIG. **38** is a partial exploded view of the pump of FIG. **29**, illustrating a controller.

FIG. **39** is a cross-sectional view of the controller shown in FIG. **38** taken generally along line **39-39**.

FIG. **40** is a cross-sectional view of the pump shown in FIG. **29** taken generally along line **40-40**.

FIG. **41** is a cross-sectional view of the pump shown in FIG. **32** taken generally along line **41-41**.

FIG. **42** is a cross-sectional view of the pump shown in FIG. **32** taken generally along line **42-42**.

FIG. **43** is a cross-sectional view of the pump shown in FIG. **32** without a fan and a heat exchanger, taken generally along line **42**-**42**.

FIG. **44** is an exploded view of a pump assembly and a motor assembly.

FIG. **45** is a cross-sectional view of the pump assembly and the motor assembly shown in FIG. **44**.

FIG. **46** is a cross-sectional view of the pump assembly and the motor assembly shown in FIG. **44**.

FIG. **47** is a cross-sectional view of the pump assembly and the motor assembly shown in FIG. **44**.

FIG. **48** is a perspective view of another alternate construction of a pump.

FIG. **49** is a perspective view of another alternate construction of a pump.

FIG. **50** is a perspective view of another alternate construction of a pump.

DETAILED DESCRIPTION

Before any independent embodiments are explained in detail, it is to be understood that the disclosure is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The disclosure is capable of other independent embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

Use of "including" and "comprising" and variations thereof as used herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Use of "consisting of" and variations thereof as used herein is meant to encompass only the items listed thereafter and equivalents thereof.

Also, the functionality described herein as being performed by one component may be performed by multiple components in a distributed manner. Likewise, functionality performed by multiple components may be consolidated and performed by a single component. Similarly, a component described as performing particular functionality may also perform additional functionality not described herein. For example, a device or structure that is "configured" in a certain way is configured in at least that way but may also be configured in ways that are not listed.

Furthermore, some embodiments described herein may include one or more electronic processors configured to perform the described functionality by executing instructions stored in non-transitory, computer-readable medium. Similarly, embodiments described herein may be implemented as non-transitory, computer-readable medium storing instructions executable by one or more electronic processors to perform the described functionality. As used in the present application, "non-transitory computer-readable medium" comprises all computer-readable media but does not consist of a transitory, propagating signal. Accordingly, non-transitory computer-readable medium may include, for example, a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a ROM (Read Only Memory), a RAM (Random Access Memory), register memory, a processor cache, or any combination thereof.

Many of the modules and logical structures described are capable of being implemented in software executed by a microprocessor or a similar device or of being implemented in hardware using a variety of components including, for example, application specific integrated circuits ("ASICs"). Terms like "controller" and "module" may include or refer to both hardware and/or software. Capitalized terms conform to common practices and help correlate the description with the coding examples, equations, and/or drawings. However, no specific meaning is implied or should be inferred simply due to the use of capitalization. Thus, the claims should not be limited to the specific examples or terminology or to any specific hardware or software implementation or combination of software or hardware.

FIGS. **1**-**9** illustrate a pump **10** embodying several independent aspects of the disclosure. The pump **10** generally includes (see FIGS. **1**-**7**) a package or frame assembly **14** supporting (see FIGS. **5**-**7**) a motor **18** operable to drive a pump assembly **22**.

In the illustrated construction, the motor **18** includes a brushless permanent magnet synchronous motor (PMSM), a permanent magnet AC motor (PMAC), an electrically-commutated motor (EC), or a brushless DC motor (BLDC). The illustrated pump assembly **22** includes a two-stage hydraulic pump assembly driven by the motor **18** controlled to provide (substantially) constant power and variable displacement for each stage. During operation, the motor speed is adjusted to maintain peak power based motor load/current for improved flow rate throughout the pressure range.

The frame assembly **14** includes (see FIG. **5**) a support frame **26**, end caps **30** and lids/doors **34** connected and cooperating to define a compartment for the motor assembly **18** and the pump assembly **22**. The support frame **26** includes a partition wall **42** defining an opening **46** receiving a portion of the pump assembly **22**. A fluid reservoir **48** is defined in the lower section of the support frame **26** below the partition wall.

In the illustrated construction (see FIGS. **2**-**4**), each door **34** is movably supported (e.g., pivotable) about (see FIGS. **4** and **5**) a pivot **50** defined between the door **34** and a portion of the support frame **26**. A locking assembly **275** is provided to selectively retain each door **34** in a closed position. In the illustrated construction, tie rods or pins **276** are engageable through openings **54** in the rear end cap **30** and into a groove **58** in the door **34**. The front end cap **30** may also define a recess (not shown) for receiving the end of the pins **276**.

As shown in FIG. **3**, the pins **276** are engageable through openings **54** in the rear end cap **30**B, and each pin **276** into a respective groove **58** in an associated door **34**. To open the door **34** (FIG. **2**), the pins **276** may be removed from the groove **58**B. Additionally, pins **278** and fasteners **280** may be inserted through openings **282** in order to secure the rear end cap **30**B to the support frame **26**B.

To open the door **34**, the pin **276** is removed from the front recess, if provided, and from the door groove **58**. In the open position, the pin may be retained in the opening **54** (e.g., by an enlarged head on the pin) or may be removed from the opening **54**.

A cord wrap **70** (FIG. **1**) is provided on the frame assembly **14** (e.g., between each end of the handle **38** and the associated end cap **30**) for the power cord (not shown) of the pump **10** and/or for a cable (not shown) of the pendant **66**. Feet **74** are attached to the support frame **26** for supporting the pump **10** on a work surface S. In the illustrated construction, the feet **74** are formed of elastomeric material, such as synthetic rubber (e.g., thermoplastic polyurethane (TPU)), to increase friction with the surface S, absorb impacts on the pump **10**, etc. The feet **74** are coupled to the support frame **26** via a snap-fit. Washers are molded onto the feet **74** and assist in transmitting loads from the support frame **26** to the feet **74**. The snap-fit allows the feet **74** to be removed from the support frame **26** without having to remove other components (e.g., end caps **30**).

As mentioned above, the motor assembly **18** includes a brushless permanent magnet synchronous motor (PMSM), a permanent magnet AC motor (PMAC), an electrically-commutated motor (EC), or a brushless DC motor (BLDC). In the illustrated construction, the electrical components of the motor assembly **18** are electrically isolated from other components of the pump **10**, for example, by electrically-insulating material, such as plastic. No metal components of the motor assembly **18** are electrically connected to the controller. The "plastic" motor assembly **18** does not need a ground connector, does not have leakage and is usuable with a GFCI outlet (not shown).

The motor assembly **18** generally includes (see FIGS. **5**-**8**) a stator **78** and a rotor **82** connected to a drive shaft **86**. The stator **78** includes (see FIGS. **8** and **15**) laminations **90** encapsulated in electrically-insulating material, such as glass-filled polypropylene or other plastic, supporting windings **94**. As discussed below, the stator **78** is fixed directly to the housing of the pump assembly **22**. The rotor **82** includes permanent magnets (not shown) encapsulated in a housing **98** formed of electrically-insulating material, such as glass-filled polypropylene or other plastic. A spline **102** is molded into the housing **98** and drivingly engages an end of the shaft **86**.

As shown in FIGS. **5**-**8**, the pump assembly **22** is connected to a hydraulic circuit **106** (FIG. **23**) and includes a housing assembly **110** formed by a body **114** and a lower housing **118**. As mentioned above, the stator **78** is fixed directly to the pump housing assembly **110** (e.g., the pump body **114**). The shaft **86** is a common shaft for the motor assembly **18** and the pump assembly **22** and is rotatably supported by the housing assembly **110**. The shaft **86** extends through an opening in the stator **78**, and, as mentioned above, the rotor **82** connects directly to the shaft **86**.

An eccentric member **122** is on the shaft **86** and, during rotation, selectively activates one or more piston and cylinder assemblies (three illustrated) to dispense hydraulic fluid with a desired flow and pressure. Each piston and cylinder assembly incudes a piston **126** supported in a chamber or cylinder **130** defined by the housing assembly **110** (e.g., by the lower housing **118**). A return spring **134** is provided for each piston **126** to return the piston **126** to the initial position from an activated position.

As mentioned above, the pump assembly **22** includes a two-stage pump assembly. In the first stage, the eccentric member **122** drives all of the pistons **126** to dispense fluid at a relatively high flow rate (e.g., about 200 in^3/min) and relatively low pressure (up to about 3,000 psi to about 4,000 psi). In the second stage, the eccentric member **122** continues to drive all of the pistons **126**, but the hydraulic circuit **106** is controlled to unload (e.g., dump to atmosphere) a number of pistons **126** (e.g., two of the three pistons **126**). The remaining piston(s) **126** (e.g., the remaining one piston **126**) dispense fluid at a lower flow rate (e.g., initially, about 60 in^3/min to about 70 in^3/min, decreasing to about 30 in^3/min as pressure increases) and higher pressure (e.g., from about 3,000 to about 4,000 psi up to about 10,000 psi). In the illustrated construction, the pump assembly **22** thus uses common pistons **126** in both stages.

The circuit **106** includes (see FIGS. **1** and **23**) an inlet **138** and an outlet **142** with connectors **146**, **150**. A valve assembly **154** (see FIGS. **1** and **6**-**8**) is operable to control flow through the circuit **106**. The valve assembly **154** includes a valve block **158** with passages (not shown) and an adjustable valve member **162**. In the illustrated construction, the valve assembly **154** (FIG. **6**) is manually actuated and includes an actuator **166** (e.g., a lever, handle, button, etc.) to direct flow through the valve assembly **154**. The illustrated valve assembly **154** is a 4-way, 3-position valve operable between a first "advance" position, a second "retract" position and a neutral position. In the illustrated construction, a gage **170** is connected to the circuit **106** and displays conditions in the circuit **106** (e.g., the pressure).

As shown in FIGS. **2**-**6**, a motor controller **174**, an application controller **178**, and a power board are each supported in an electronics package mounted, in the illustrated construction, on a pivoting door **34** separate and spaced from the motor assembly **18** and the pump assembly **22**. In the illustrated embodiment, trays **420** are mounted to the doors **34**. The motor controller **174**, the application controller **178**, and the power board are potted in the trays **420**. A fan (not shown) may be provided to cause air flow through openings in the frame assembly **14** (e.g., through the end caps **30**) to cool components of the pump **10** (e.g., the controllers **174**, **178**, the power board, the motor assembly **18**, etc.).

The controllers **174**, **178** are operable to, among other things, configure and control operation of the pump **10** and/or of its components. Each controller **174**, **178** includes a processing unit (e.g., a microprocessor, a microcontroller, or another suitable programmable device), non-transitory computer-readable media, and an input/output interface. The processing unit, the media, and the input/output interface are connected by one or more control and/or data buses. The computer-readable media stores program instructions and data. The processing unit is configured to retrieve instructions from the media and execute the instructions to perform the control processes and methods described herein. The application controller **178** may also include a socket (not shown). Electronic components (not shown) are configured to be inserted into the socket and electrically connect with the application controller **178**. The electrical components provide additional functionality like Bluetooth connectivity, which may allow a user to control the pump **10** using a smartphone or other electronic device. Alternatively or in addition, the electrical component may wirelessly transmit diagnostic data to a user's smartphone or other electronic device.

The input/output interface transmits data from the controller **174**, **178** to external systems, networks, and/or devices and receives data from external systems, networks, and/or devices. The input/output interface stores data received from external sources to the media and/or provides the data to the processing unit.

In the illustrated construction, the motor controller **174** operates to control the motor assembly **18** to provide substantially constant power control of motor assembly **18**. In the illustrated method, field weakening is employed to achieve the desired speed and torque of the motor assembly **18**. The controller **174** is operable to control the motor assembly **18** accordingly. The illustrated controller **174** operates the motor assembly **18** in a sensorless configuration. However, in other constructions (not shown), the controller **174** and the motor assembly **18** would include sensors.

The controller **174** may be programmed to achieve different speeds and target peak efficiency with algorithms for substantially constant power and flow curves. Additional functions, such as, for example, pressure control with a sensor or based on instantaneous motor current and speed, may be added that utilize the "smart control" of the controller **174**.

The application controller **178** interfaces with various components of the pump **10**. The pendant **66** provides a user-held remote control device communicating with the controller **178** (e.g., via cables or hard-wired connectors such as USB, RS-232, serial or parallel link, and Ethernet cables, or using wireless interfaces such as Bluetooth or IEEE 801.11 compatible devices) to provide user inputs to control operation of the pump **10**.

As shown in FIG. **9**, the handle **38** is constructed to provide storage (e.g., a receptacle **62**) for a remote controller, such as a pendant **66**. A retainer assembly (not shown) is provided between the handle **38** and the pendant **66**. The retainer assembly may include, for example, a detent, a magnet, a strap, etc.

In the illustrated construction, the pendant **66** includes one switch **182**, providing a simple interface for the user. In other embodiments, the pendant **66** may include multiple switches **182** (FIG. **14**). Win some embodiments, when a switch **182** is depressed, the application controller **178** sends a signal to the motor controller **174** to turn on and run the motor assembly **18** and, thereby, operates the pump assembly **22** until the switch **182** is released.

The controller **178** receives information from and transmits information to the components of the pump **10** and generally controls operation of the pump **10**. For example, the controller **178** receives information regarding the status/characteristics of the components (e.g., the pressure/flow through the pump assembly **22**, temperature of the pump **10** and its components, valve position, etc.).

The application controller **178** controls operation of the pump **10** and its components. As mentioned above, based on the signal from the pendant switch **182**, the application controller **178** causes the motor controller **174** to operate the motor assembly **18**. The application controller **178** may also control, for example, the fan based on sensed temperatures, indicators (e.g., light-emitting diodes (LEDs)) to indicate pump conditions, an electrical valve assembly, etc.).

FIGS. **17**-**22** illustrate alternative constructions of a reservoir **186**. The reservoir **186** contains hydraulic fluid to be dispensed and communicates with the circuit **106** (FIG. **23**). The reservoir **186** is formed within the support frame **26** cooperating with end walls **188**. In the illustrated construction, the reservoir **186** includes an integrated heat exchanger **190** to cool the fluid.

The heat exchanger **190** includes channels **194** in the reservoir **186**. As shown in FIG. **17**-**21**, the channels **194** are provided by channel members **198** received in the reservoir **186**. The channel members **198** are supported in slots **202** in the wall of the reservoir **186**.

A radial fan **206** is supported by the end cap **30** and blows cooling air through the channels **194** to cool fluid on each side of the channel members **198**. As shown in FIG. **20**, the end cap **30** defines a chamber **210** and passages **214** to direct air flow to the channels **194**.

In an alternate construction shown in FIG. **84**, the channels **194** may be formed by partition walls **218** in the reservoir **186**. Conduits **222** carry fluid through each channel **194** and back to a main fluid section **226** of the reservoir **186**. In this construction, the fan **206** (FIG. **17**) is blows cooling air through the channels **194** to cool fluid on each side of the partition walls **218** (e.g., in the conduits **222** or in the main section **226**). As shown in FIG. **20**, the end cap **30** defines a chamber **210** and passages **214** to direct air flow to the channels **194**.

FIG. **24** illustrates a method of operating the pump **10** executed by the controller **174**. In operation, the user selects the position of the valve assembly **152** and engages the motor assembly **18** to drive the pump assembly **22** (e.g., by actuating the switch **190**). The motor assembly **18** initially operates at maximum speed for a minimum load (and a minimum pressure provided by the pump assembly **22**). As the load and the pressure increase, the motor assembly **18** slows. When the load and the pressure reach an upper threshold for the first stage, the circuit **106** is controlled to unload selected pistons **126** (again, two of the three pistons **126** dispense fluid to atmosphere).

The remaining piston(s) **126** (one piston **126**) is operated to provide flow and pressure in the second stage. With pistons **126** unloaded, the speed of the motor assembly **18** ramps up to its maximum. As the load and the pressure provided by the remaining piston **126** increases, the speed of the motor assembly **18** decreases. The pump **10** is operated until the desired pressure (up to the maximum) is achieved.

FIGS. **26**-**29** illustrate simulated performance (flow, speed, torque and power versus pressure) of the pump **10** at 3,000 revolutions per minute (RPM). As illustrated in FIG. **28**, the pump has a substantially constant power output upon reaching a lower limit of its operating pressure (e.g., between 1,500 and 2,000 psi).

As discussed above, in the illustrated construction, the pump assembly **22** is a two-stage pump assembly. It should be understood that, in other constructions (not shown), this operation could be carried out for any number of stages with the pump assembly **22** being operated as or having an associated multi-stage pump assembly.

In the pump **10**, having the motor assembly **18** adjust speed to maintain peak power based on pressure (load) may allow for improved flow rate throughout the pressure range. Thus, a smaller size pump assembly **22**/motor assembly **18** may be able to achieve the same or increased performance compared to larger ones.

FIGS. **10**-**16** illustrate an alternative construction of a pump **10**A similar to the pump **10**. Common elements have the same reference number "A".

As shown in FIG. **14**, the handle **38**A is arranged to support and retain the pendant **66**A. The pendant **66**A includes a number of switches **182**A (two illustrated) for communicating with the controller **174**A.

As shown in FIG. **11**, the rear end cap **30**A defines an opening **195** for air flow for the fan **206**. As shown in FIG. **10**, each end cap **30**A includes a cord wrap portion **70**A. The opposite ends of the handle **38**A are received by the respective cord wrap portions **70**A.

In other constructions, the pump **10**, including the motor assembly **18** and the pump assembly **22**, may be similar to that described in U.S. Provisional Patent Application No. 62/491,566, filed Apr. 28, 2017, the entire contents of which are hereby incorporated by reference. In such constructions, the pump **10** is battery-powered and includes a high voltage (e.g., having a nominal voltage of 60 V or greater) DC power unit (one or more battery packs), and the pump assembly **22** may include a 3-stage hydraulic pump assembly.

FIGS. **29**-**47** illustrate a pump **10**B according to another embodiment. The pump **10**B is similar to the pump **10**. Similar features are identified with similar reference numbers, plus the letter "B".

As shown in FIGS. **29**-**31**B, the pump **10**B includes a viewing lens or sight glass **230**. In the illustrated embodiment, the sight glass **230** is formed via injection molding. The sight glass **230** is positioned adjacent the front end cap **30**B and an exterior surface **232** of the sight glass **230** may be substantially flush with a surface of the front end cap **30**B.

As shown in FIG. **30**A, the sight glass **230** is formed as an elongated member including an exterior face **232** and a peripheral wall **233** extending around a cavity **234**. When the sight glass **230** is secured to the front end cap **30**B (FIG. **31**A), the cavity **234** is enclosed between the exterior surface **232**, the peripheral wall, and the front end cap **30**B. The cavity **234** has a shape similar to the shape of the sight glass **230**. In the illustrated embodiment, the sight glass **230** includes two bosses **238** protruding from an inner surface of the exterior face **232** through the cavity **234**. The bosses **238** extend and have an end surface substantially co-planar with an edge **242** of the peripheral wall. Each boss **238** includes an opening **240** extending through the end surface.

In some embodiments, the sight glass **230** includes a double check valve **400** that is press molded into the sight glass **230** (FIG. **30**B). The double check valve **400** defines a breather system that includes an umbrella valve and a duckbill valve. Both the umbrella valve and the duckbill valve are one-way valves, and are oriented in opposite directions (i.e., the umbrella valve allows fluid flow in a first direction and the duckbill valve allows fluid flow in a second direction that is opposite the first direction).

As shown in FIGS. **31**A and **31**B, the pump **10**B has a recess **246** which receives the sight glass **230**. In the illustrated embodiment, the recess **246** of the pump **10**B is slightly larger than the sight glass **230** to allow the sight glass **230** to fit snugly within the cavity **246**. In the illustrated embodiment, the cavity **246** of the pump **10**B has two fastening apertures **248** and two fluid apertures **250**. Each boss **238** of the sight glass **230** aligns with the one of the fastening apertures **248**. A fastening member (e.g., a threaded screw—not shown) may be inserted from within the reservoir **186**B, through one of the fastening apertures **248**, and into one of the bosses **238**. The fastening member secures the edge **242** against a plate **249** positioned in the base of the recess **246** to seal the cavity **234**, thereby securing the exterior face **232** of the sight glass **230** flush with a surface of the pump **10**B.

The fluid apertures **250** allow fluid from the reservoir **186**B to flow into the cavity **234** of the sight glass **230** when the pump **10**B and sight glass **230** are coupled together. Hydraulic fluid fills the cavity **234** proportional to a fluid level in the reservoir **186**B. In the illustrated embodiment, the exterior surface **232** of the sight glass **230** is a viewing window and includes measurement markers **252** (FIG. **31**B), which may provide a visual indication to a user regarding an amount (e.g., a percentage) of fluid that is in the reservoir **186**B. In some embodiments, the plate against which the sight glass **230** is secured may include a reflective surface.

The duckbill valve and the umbrella valve provide fluid communication between the reservoir **186**B and the external environment. A fluid (e.g., air) in the external environment can flow through the duckbill valve and into the reservoir **186**B to ensure that there is sufficient air within the reservoir **186**B. Air can flow from the reservoir **186**B and through the umbrella valve to the external environment to relieve pressure within the reservoir **186**B.

FIG. **32** illustrates feet **256** of the pump **10**B positioned on the rear end cap **30**B. In the illustrated embodiment, each foot **256** is positioned proximate a corner of the rear end cap **30**B.

As shown in FIG. **33**, the pump **10**B may be oriented so that the rear end cap **30**B is positioned proximate the ground or other support surface (not shown), and the feet **256** engage the ground. The feet **256** extend away from the rear end cap **30**B so that the rear end cap **30**B is spaced apart from the ground. Electrical components like conduit couplings **260** for electrical conduit (e.g., power cords) and control knobs **262** extend away from the rear end cap **30**B and are oriented at an oblique angle (e.g., a non-parallel angle such as 45 degrees) with respect to a surface of the rear end cap **30**B. Stated another way, the features such as the conduit couplings **260** and control knobs **262** are oriented at an oblique angle relative to a plane defines by the end surface of the feet **256**. This angled orientation prevents the couplings **260** and the knobs **262** from being pressed between the pump **10**B and the ground while the pump **10**B is supported by the feet **256**. The obliquely angled conduit couplings **260** allow electrical conduit **264** to extend away from the rear end cap **30**B without bending or creasing while the feet **256** support the pump **10**B.

The positioning of a pump intake **268** allows the pump **10**B to operate in either a first or second position (e.g., while the pump **10**B is supported by **74**B, or while the pump **10**B is supported by feet **256**). As shown in FIGS. **100** and **101**, an opening **272** of the pump intake **268** is positioned within the reservoir **186**B and proximate an edge or junction between the rear end cap **30**B and a lower side **274** of the support frame **26**B (FIG. **32**). In other words, the opening **272** is positioned proximate a lower end of the reservoir **186**B when either set of feet **74**B, **256** rest on the ground. The positioning of the opening **272** facilitates fluid flow into the pump inlet **268** from the reservoir **186**B in multiple orientations of the pump **10**B. Also, the feet **74**B, **256** are formed from a polymeric or synthetic rubber material (e.g., TPU), thereby acting as vibrational isolators to reduce wear on the pump housing.

As shown in FIGS. **36** and **37** of the illustrated construction, each door **34** is movably supported (e.g., pivotable) about a pivot **50** defined between the door **34** and a portion of the support frame **26**. Each door **34** includes a rib **410** oriented toward the support frame **26**. In the illustrated embodiment, the ribs **410** are hanging ribs and are receivable within a slot **414** on the support frame **26**. The hanging ribs **410** provide a second pivot **414** and allow the doors **34** to pivot to a fully opened position (i.e., an outer surface of the doors **34** are adjacent outer surfaces of the support frame **26**).

A handle **38** is a cast piece connected between the end caps **30**. The handle **38** covers the interface between the doors **34** and may protect components of the pump **10**. In the illustrated embodiment, the handle **38** locks the doors **34** in a closed position (i.e., the doors **34** enclose the compartment for the motor assembly **18** and pump assembly **22**). The handle **38** is coupled to the end caps **30** or doors **34** by fastening members **418** (e.g., threaded screws). The doors **34** are unable to pivot open while the handle **38** is secured between the end caps **30**, thereby preventing access to components within the frame (e.g., while the pump is operated). A user can uncouple and remove the fastening members **418** and the handle **38** from the frame assembly **14** in order to pivot the doors **34**.

As shown in FIGS. **38** and **39**, a pendant **66**B is removably coupled to a receptacle **62**B positioned on the handle **38**B. In the illustrated embodiment, the pendant **66**B includes a member **286** for coupling the pendant **66**B to the handle **38**B. In some embodiments, the member **286** includes a magnet or another type of coupling member. As shown in FIG. **39**, the pendant **66**B includes the magnet **286** that is substantially flush with the surface of the pendant, and the receptacle **62**B (FIG. **38**) includes a metallic surface. When the pendant **66**B is coupled to the handle **38**B, the magnet **286** is coupled to the magnetic surface. In addition, the magnet **286** may be used for coupling the pendant to a metallic surface (e.g., a metallic frame portion) near the location of the pump **10**.

As shown in FIG. **39**, the pendant **66**B is formed from a first portion **294** and a second portion **298**. In the illustrated embodiment, the first portion **294** and the second portion **298** snap together and create a liquid resistant seal. The first portion **294** includes switches or buttons **182**B. In the illustrated embodiment, the first portion **294** includes three buttons **182**B that are made from rubber (or a similar synthetic material). The buttons **182**B are overmolded onto the first portion **294**. A user input (e.g., pushing one of the buttons **182**B) actuates an associated control switch **302**, sending a signal to a controller **170**A (FIG. **10**).

The pendant **66**B includes at least one haptic motor **306**. The haptic motor sends feedback (e.g., vibrations) when the switches **302** are actuated. The haptic motor **306** may be able to send more than one type of feedback (e.g., a different number of pulses or different intensities of vibrations). A user holding the pendant **66**B may sense the feedback and be alerted to changes in pump **22**B/motor **18**B operation. In some embodiments, the pendant may include a light-emitting device (e.g., an LED) **295** to provide visual feedback to the user.

The pump **10**B may be used for high torque applications (e.g., operating a torque wrench—not shown). The pump **10**B generates a substantial amount of heat during the high torque application, and requires cooling to maintain optimal operating conditions. FIGS. **40**-**42** illustrate a radial fan **310** positioned proximate the rear end cap **30**B. In the illustrated embodiment, the front end cap **30**B and the rear end cap **30**B each include curved portions **314** that protrude beyond the outer side surfaces of the support frame **26**B when the front end cap **30**B and the rear end cap **30**B are coupled to the support frame **26**B. In the illustrated embodiment, each of the end caps **30**B includes a first curved portion **314** proximate a first side of the support frame **26**B and a second curved portion **314** proximate a second side of the support frame **26**B. In other embodiments, each end cap may only include one curved portion **314**. As illustrated in FIG. **41**, the curved portions **314** are spaced apart from the support frame **26**B so that a gap **318** exists between the curved portion **314** and the support frame **26**B. One curved portion **314** extends over each of the gaps **318** on the support frame **26**B.

The gaps **318** provide inlet ports and exhaust ports for air to cool the motor **18**B. As illustrated in FIG. **42**, the gaps **318** proximate the radial fan **310** are outlets. As illustrated in FIG. **41**, the radial fan **310** draws air **319** (e.g., arrows illustrate airflow path) from an external environment, through inlet gaps **318** proximate the front end cap **30**B. The air **319** then travels across the motor assembly **18**B and the pump assembly **22**B and through the fan **310**. The movement of the air **319** across the motor assembly **18**B and the pump assembly **22**B lowers a motor temperature and a pump temperature through forced convection. Heat is transferred from the surface of the motor assembly **18**B and from heat fins **323** of a heat exchanger **322** of the pump assembly **22**B to the air **319**, thereby reducing the temperature of the motor assembly **18**B and the pump assembly **22**B. The air **319** passes through the compartment of the frame assembly **14**B and is exhausted through either of the outlet gaps **318** proximate the radial fan **310** and back into the external environment.

The pump **10**B may also be used in lower torque applications. In the lower torque applications, the motor assembly **18**B, the pump assembly **22**B, and the fluid within the pump assembly **22**B do not generate the same amount of heat as the pump **10**B in the high torque application, and the fan and heat exchanger are not necessary (FIG. **43**). Pumps **10**B that are intended to be used for low torque applications may still include a fan and/or a heat exchanger in order to cool the pump **10**B.

As shown in FIG. **44**, the motor shaft **86**B includes a counter-weight **326** proximate the stators **78**B. In the illustrated embodiment, the counter-weight **326** is splined to the motor shaft **86**B. Positioning the counter-weight **326** proximate the stators **78**B, rather than lower on the motor shaft **86**B (i.e., inside of the pump assembly **22**B), facilitates easier assembly and disassembly of the pump and motor.

The pump **10**B is a radial piston pump and includes six piston and cylinder assemblies. In the illustrated embodiment, the piston and cylinder assemblies are arranged in a circular orientation about a shaft axis, with each piston oriented to move in a radial direction relative to the shaft axis **328**. Similar to pump **10**, the pump assembly **22**B includes a two-stage pump assembly. In the illustrated embodiment, three of the piston and cylinder assemblies are first piston and cylinder assemblies and three of the piston and cylinder assemblies are second piston and cylinder assemblies. The piston and cylinder assemblies are positioned so that each first piston and cylinder assembly is positioned directly in between two second piston and cylinder assemblies. In other words, the piston and cylinder assemblies alternate between first pistons **126**B and second pistons **126**B around the shaft axis.

The piston and cylinder assemblies of the pump assembly **22**B rest in the lower housing **118**B. In the illustrated embodiment, the lower housing **118**B is positioned partially within the reservoir **186**B (FIG. **31**A) and is in fluid communication with the reservoir **186**B. Hydraulic fluid is drawn from the reservoir **186**B, through the fluid intake **268**, and into a plenum or bowl **330** of the lower housing **118**B so that the bowl **330** is substantially filled with hydraulic fluid. Each piston and cylinder assembly draws in the hydraulic fluid from the bowl **330** through a separate port. As hydraulic fluid leaves the bowl **330** and flows into the first and second pistons **126**B, additional hydraulic fluid is drawn into the bowl **330** from the reservoir **186**B.

A valve **334** positioned within the fluid intake. In some embodiments, the valve **334** is an umbrella check valve (FIG. **45**) positioned adjacent an opening into the bowl **330**. The umbrella check valve **334** is a one-way valve that is moveable between a first position and a second position and allows fluid to pass from the reservoir **186**B and into the bowl **334**, but prevents fluid from flowing in the reverse direction (i.e., from the bowl **334** to the reservoir **186**B). This keeps hydraulic fluid within the bowl **330**, even when the pump **10**B is not operating (i.e., after it has been powered down). When the pump **10**B is started, hydraulic fluid is already present in the bowl **330**. This keeps the pump primed and reduces the likelihood of a dry start (i.e., when the pistons **126**B intake air instead of hydraulic fluid), which helps to prolong the service life of the pump assembly **22**B and its components.

In a first stage of operation, the pump assembly **22**B drives all of the pistons **126**B of the first and second piston and cylinder assemblies to dispense fluid at a relatively high flow rate (e.g., about 220 in^3/min) and relatively low pressure (up to about 3,000 psi to about 4,000 psi). In a second stage of operation, the pump assembly **22**B continues to drive all of the pistons **126**B, but the hydraulic circuit **106** (FIG. **23**) is controlled to unload (e.g., dump to the reservoir **186**B) the three pistons **126**B of the first piston and cylinder assemblies. The three pistons **126**B of the second piston and cylinder assembly then dispense fluid at a lower flow rate (e.g., initially, about 60 in^3/min to about 70 in^3/min, decreasing to about 35 in^3/min as pressure increases) and higher pressure (e.g., from about 3,000 to about 4,000 psi up to about 10,000 psi). In the illustrated construction, the pump assembly **22**B thus uses common pistons **126**B in both stages.

As shown in FIG. **45**, each of the piston and cylinder assemblies is in fluid communication with an associated passageway. In the illustrated embodiment, each of the first piston and cylinder assemblies **126**B is in fluid communication with a first or low pressure passageway **346**. Each of the second piston and cylinder assemblies is in fluid communication with a second or high pressure passageway **350**. The first passageway **346** and the second passageway **350** are each formed on an outer surface central hub **351** extending around the shaft. In the first stage, while the pump **10**B operates at a relatively low pressure, the low pressure passageway **346** and the high pressure passageway **350** are each in fluid communication with an outlet **352** of the pump assembly **22**B. In other words, fluid dispensed by the first and second piston and cylinder assemblies flows through the outlet **352** of the pump assembly **22**B in the first stage.

In the second stage, only the pistons **126**B of the second piston and cylinder assemblies are in fluid communication with the outlet **352** of the pump assembly **22**B, and therefore, only the high pressure passageway **350** is in communication with the outlet **352** of the pump assembly **22**B. A pilot or spool valve **358** is positioned between the low pressure passageway **346** and the outlet **352**. In the illustrated embodiment, the spool valve **358** is biased by a biasing member or spring **359** toward an extended position, and an end surface of the spool valve **358** is subjected to the fluid pressure in the high pressure passageway **350**. In another embodiment, a solenoid valve (not shown) may be used instead of the spool valve **358**. The solenoid valve is configured to be in electrical communication with sensors (not shown) and is configured to be electronically actuated (i.e., opened or closed) in response to parameters measured by the sensors.

In the first stage, the spool valve **358** is in a first position and fluid leaving the first piston and cylinder assemblies may pass through the spool valve **358**, and into the outlet **352**. As the fluid pressure increases, the pressure in the high pressure passageway **350** exerts a force to the spool valve **358** to overcome the biasing force and move the spool valve **358** to a retracted position (e.g., upwardly toward the motor assembly **18**B in FIG. **45**). The spool valve **358** then blocks the flow of fluid from the low pressure passageway **346**, redirecting the fluid back into the reservoir **186**B. In other words, fluid dispensed by the pistons **126**B of the first piston and cylinder assemblies returns to the reservoir **186**B and does not leave the pump **10**B while the pump operates in the second stage. In some embodiments (e.g., pumps **10**B used in high torque applications), the fluid may also flow through the heat exchanger **322** before returning to the reservoir **186**B. Blocking the fluid flow with the spool valve **358** allows only the high pressure fluid from the pistons **126**B of the second piston and cylinder assemblies to leave the pump in the second stage of operation.

The provision of multiple second pistons **126**B (i.e., pistons of the second piston and cylinder assemblies) reduces the torque and the flow ripple.

As shown in FIGS. **46** and **47**, fluid leaving the outlet **352** may be diverted into passageway **362**, which is in communication with the outlet **352** and extends in two orthogonal directions with respect to the outlet **352**. The first side of the passageway **362** includes a first valve **366** and the second side of the passageway **362** includes a second valve **370**. In the illustrated embodiment, the first valve **366** is a three way, two position normally open solenoid valve. In other words, the first valve **366** has an open position that allows fluid to pass through the pump outlet **352** and a closed position that prevents fluid from reaching the pump outlet **352**. In the illustrated embodiment, the pendant **66**B may actuate the first valve **366** between the open and closed positions. Other embodiments may include different valves **380-382** in place of the first valve **366**. The second valve **370** is an adjustable relief valve, which allows a user to control a maximum pressure that the pump **10**B may achieve. In the illustrated embodiment, adjustable relief valve **370** opens to the heat exchanger **322** so that fluid may pass through the heat exchanger **322** before returning to the reservoir **186**B. In the illustrated embodiment, the adjustable relief valve **370** does not have a handle or knob.

While the first valve **366** is closed, fluid travels from the outlet **352** of the pump assembly **22**B to a pump outlet **354**. Alternatively, while the first valve **366** is open, toward the heat exchanger **322** and back to the reservoir **186**B. As shown in FIG. **46**, the heat exchanger **322** of the illustrated embodiment includes multiple tubes arranged in a stacked coil around a periphery of the pump and motor. The tubes include heat fins **323** for transferring heat from the fluid to the air and the heat exchanger **322** transports the fluid back to the reservoir **186**B.

As shown in FIG. **29**, in some embodiments the pump **10**B includes a pressure gauge **338**. The pump **10**B can also include a display (not shown). The display can be positioned on the front end cap **30**B and include LED indicators. The LED indicators can be configured to indicate the outputs of internal diagnostics/sensors to monitor operation of the pump **10**B. The pump **10**B also includes a pressure operated valve **342**. The pressure operated valve **342** is configured to be adjusted by a user. The pressure operated valve can be rotated in either a first direction or in a second direction in order to adjust the tolerances of the pump **10**B.

FIGS. **48-50** illustrate additional alternate constructions of a pump. The pumps shown in FIGS. **48-50** are substantially similar to pump **10**B. These pumps include alternate valves **380**, which replace the first valve **366** (FIG. **108**). Valves **380** (FIGS. **112** and **114**) are manual valves as opposed to automatic valves like the first valve **366** in the pump **10**B, although the manual valves **380** perform a substantially similar task. In various embodiments, the valves **380** may be, but are not limited to, a three way two position manual valve that may be used in single acting tools and cylinders or a four way three position tandem center manual valve that may be used in double acting tools and cylinders. Each manual valve **380** includes a handle **384**. A user may actuate the handle **384** in order to change the position of the valve **380**. Additionally, the pump may be a four way three position valve. Although not illustrated, further alternate constructions of a pump may include a three way two position normally closed pilot operated valve, which may be used in crimping tools or presses. The normally closed pilot valve automatically retracts when a motor is turned off. In a further alternate construction, a pump may include no valves. Instead valves may be externally mounted to the pump as needed. FIG. **23** illustrates a 3 way two position valve although any valve **366** will work in the valve sub-assembly **154**.

Preferred embodiments have been described in considerable detail. Many modifications and variations to the preferred embodiments described will be apparent to a person of ordinary skill in the art. Therefore, the disclosure should not be limited to the embodiments described. One or more independent features and independent advantages may be set forth in the claims.

What is claimed is:

1. A pump comprising:

a frame including a reservoir configured to store hydraulic fluid;

a motor assembly supported by the frame;

a pump assembly operably driven by the motor assembly, the pump assembly being in fluid communication with the reservoir and configured to dispense hydraulic fluid out of the frame, the pump assembly including a first piston and a second piston;

a hub having an outer surface defining a first passageway communicating with the first piston and a second passageway spaced from the first passageway and communicating with the second piston, the first passageway and the second passageway being in communication with a pump outlet; and

a first valve having a first position in which the first passageway and the second passageway each communicate with the pump outlet, and a second position in which the first passageway is prevented from communicating with the pump outlet while the second passageway is communicating with the pump outlet.

2. The pump of claim 1, wherein the first piston includes a plurality of first pistons, and the second piston includes a plurality of second pistons, and wherein each of the first pistons is positioned between two second pistons.

3. The pump of claim 1, further comprising a shaft connected to the pump assembly, the shaft being configured to be driven by the motor assembly, and wherein the hub is positioned around the shaft.

4. The pump of claim 3, further comprising an eccentric member coupled to the shaft proximate the pump assembly, the eccentric member selectively engaging at least one of the first piston and the second piston, and wherein the hub is positioned between the eccentric member and the motor assembly.

5. The pump of claim 1, wherein the hub is cylindrical and the outer surface is curved.

6. The pump of claim 5, wherein each of the first passageway and the second passageway extends around the periphery of the outer surface.

7. The pump of claim 1, wherein the first piston is configured to dispense hydraulic fluid to the pump outlet through the first passageway, and wherein the pump assembly further comprises an outlet valve positioned between the first passageway and the pump outlet, the outlet valve being configured to selectively inhibit hydraulic fluid from flowing from the first passageway to the pump outlet and to redirect hydraulic fluid from the first passageway to the reservoir.

8. The pump of claim 1, wherein the pump assembly has a one-piece shaft that is shared with the motor assembly and that is rotatable by the motor assembly and has an eccentric outer surface for driving the pump assembly.

9. The pump of claim 1, further comprising first feet positioned on a first surface of the frame and second feet positioned on a second surface of the frame, the second surface substantially orthogonal to the first surface, wherein the pump is operable when supported by either the first feet or the second feet, and

wherein the hydraulic fluid is communicated with the reservoir when the pump is supported by either the first feet or the second feet.

10. The pump of claim 1, wherein a shaft is configured to receive rotational output from the motor assembly, the shaft including an eccentric member at an end of the shaft.

11. The pump of claim 10, further comprising a bushing positioned around the eccentric member of the shaft, the bushing selectively engaging at least one of the first piston and the second piston.

12. A pump comprising:

a frame including a reservoir configured to store hydraulic fluid; a motor assembly supported by the frame;

a pump assembly operably driven by the motor assembly, the pump assembly being in fluid communication with the reservoir, the pump assembly including a first piston, a second piston, and a valve, the first piston being configured to dispense hydraulic fluid out of the frame, the second piston being configured to dispense hydraulic fluid out of the frame, the valve being configured to selectively inhibit hydraulic fluid dispensed via compression by the first piston from flowing out of an outlet of the pump assembly to thereby reduce a flow of the hydraulic fluid out of the outlet as compared to when uninhibited by the valve; and

a heat exchanger including a tube and a plurality of fins each disposed around the tube, the tube receiving hydraulic fluid dispensed by the first piston when the valve inhibits hydraulic fluid dispensed by the first piston from flowing out of the frame, the hydraulic fluid traveling through the tube to the reservoir.

13. The pump of claim 12, further comprising:

a radial fan configured to cool the motor assembly, the radial fan being positioned proximate one end of the frame;

a fan inlet positioned adjacent an opposite end of the frame; and a fan outlet positioned adjacent the one end of the frame; and

wherein air flows through the fan inlet, across the heat exchanger, through the radial fan, and radially through the fan outlet.

14. The pump of claim 12, wherein the valve is an outlet valve, and wherein the pump assembly further comprises a housing supporting the first piston and the second piston, and an inlet valve configured to allow flow from the reservoir to the housing and to prevent flow from the housing to the reservoir.

15. The pump of claim 12, wherein the frame further includes a frame valve having an open position, in which hydraulic fluid is configured to travel toward the reservoir through the heat exchanger, and a closed position, in which hydraulic fluid is configured to travel from the outlet of the pump assembly to an outlet of the frame.

16. The pump of claim 15, further comprising an actuator configured to adjust the frame valve between the open position and the closed position.

* * * * *