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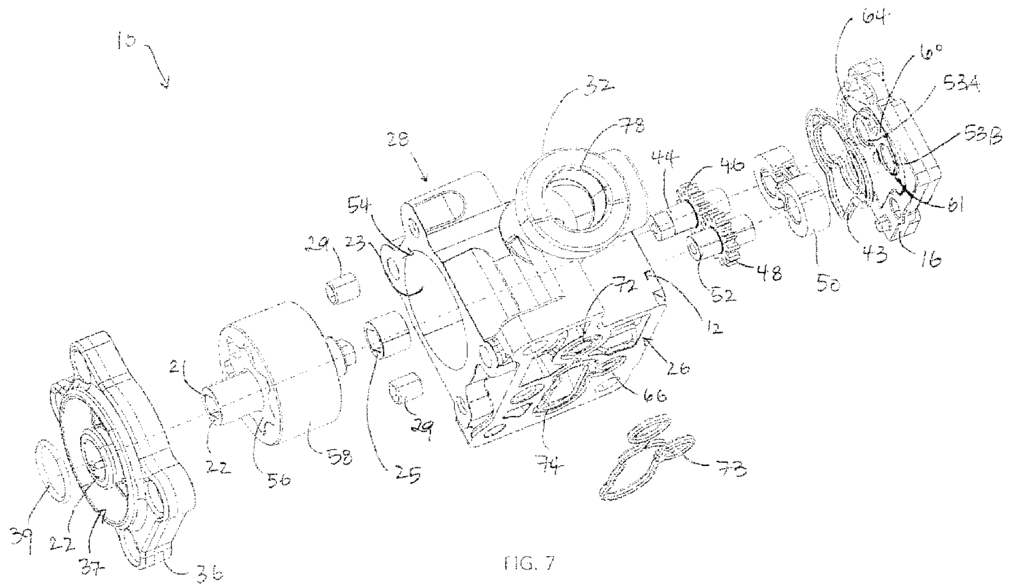

FIG. 7

(57) Abrégé/Abstract:
A pump assembly that has a first pump and a second pump for pumping lubricant, both pumps being integrated into a single housing. A drive shaft is provided that drives both pumps. Both the first pump and the second pump have a gear or rotor that is rotated by the drive shaft. Each of the pumps have an inlet provided on the housing to receive input from a source outside the housing and an outlet. The housing has a wall that is common to both pumps. The first pump is provided on a first side of the wall and the second pump is provided on the second, opposite side. The gears or rotors of the pumps may be provided in pockets provided on the first and second sides of the wall. The drive shaft extends through the wall and connects to each of the drive gears or rotors.

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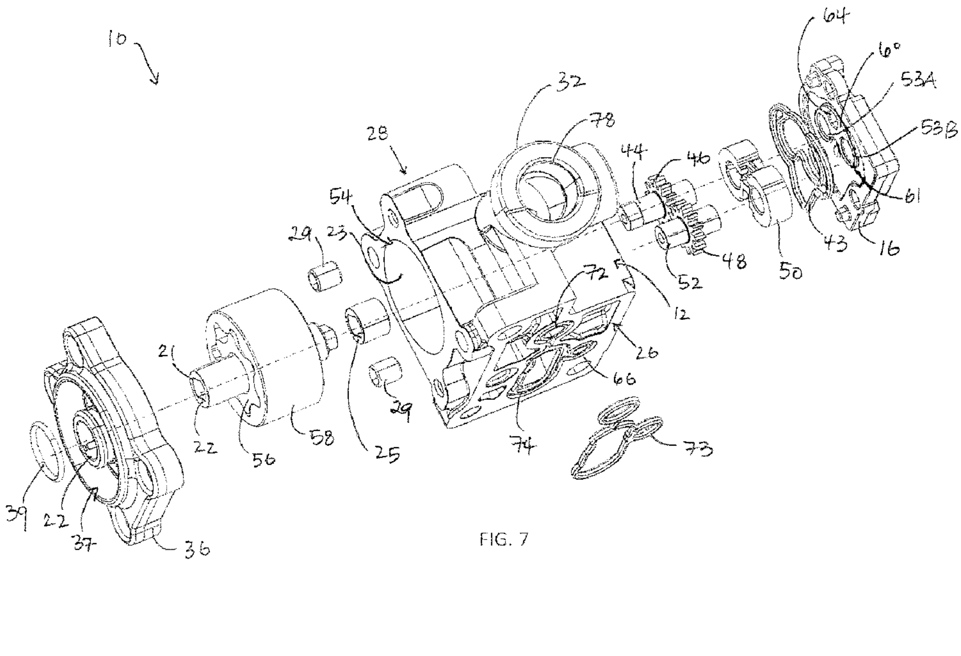

FIG. 7

(57) Abstract: A pump assembly that has a first pump and a second pump for pumping lubricant, both pumps being integrated into a single housing. A drive shaft is provided that drives both pumps. Both the first pump and the second pump have a gear or rotor that is rotated by the drive shaft. Each of the pumps have an inlet provided on the housing to receive input from a source outside the housing and an outlet. The housing has a wall that is common to both pumps. The first pump is provided on a first side of the wall and the second pump is provided on the second, opposite side. The gears or rotors of the pumps may be provided in pockets provided on the first and second sides of the wall. The drive shaft extends through the wall and connects to each of the drive gears or rotors.

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PUMP ASSEMBLY HAVING TWO PUMPS PROVIDED IN A SINGLE HOUSING

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Patent Application No. 62/786,961, filed December 31, 2018, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

Field

[0002] The present disclosure is generally related to a two stage pump assembly that includes a first pump and a second pump containing in a single housing.

Description of Related Art

[0003] Dual pump systems that include more than one pump are generally known in the art. In some cases, these systems are designed to use one pump in certain circumstances, and another, different pump in other circumstances. U.S. Publication No. 20170058895 and U.S. Patent No. 4,519,755 provide examples of these type of systems that use a second pump for pumping in certain circumstances. In some cases, the output of the pump is variable. See, e.g., U.S. Publication Nos. 20090041593 and 20110129359 for such examples of varying output from a pump.

SUMMARY

[0004] It is an aspect of this disclosure to provide a two stage pump assembly. The assembly includes: a first pump and a second pump for pumping lubricant, both the first pump and the second pump being integrated into a single housing and each configured to pressurize lubricant input into the housing. A drive shaft is provided in the housing configured to rotate about a drive axis and drive both the first pump and the second pump. The drive shaft is driven by a single input device. Both the first pump and the second pump have at least one gear configured and arranged to be rotated by the drive shaft. The first pump has a first inlet provided on the housing for receiving lubricant from a source outside the housing and a first outlet for directing lubricant that is pressurized out of the housing. The second pump has a second inlet provided on the housing for receiving lubricant from the source outside the housing and a second outlet for directing lubricant that is pressurized out of the housing. The second inlet and the second outlet are different than the first inlet and the first outlet, respectively. The housing further includes a wall that is common (or common wall) to both the first pump and the second pump, the first pump being provided on a first side of the wall and the second pump being provided on a second side of the wall that is opposite to the first side. The drive shaft extends through the wall and connects to each of the at least one gears of both the first pump and the second pump.

[0005] Another aspect of this disclosure provides the above noted two stage pump assembly with a transmission (or other system designed to receive pressurized lubricant from the pump assembly). The second pump is configured to continuously pump the lubricant to the transmission / system. In an embodiment, the transmission comprises a clutch system that selectively receives lubricant pumped from the first pump. A control valve may be provided for limiting the lubricant that is output from the first pump to the clutch system of the transmission.

[0006] Other features, improvements, and advantages of the present disclosure will become apparent from the following detailed description, the accompanying drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a perspective view of a pump assembly from a first side thereof in accordance with an embodiment of the present disclosure.

[0008] FIG. 2 is a perspective view of the pump assembly of FIG. 1 from a second side thereof.

[0009] FIG. 3 is an alternate perspective view of the pump assembly of FIG. 2 with a second cover removed therefrom, showing a portion of a second pump in the assembly, in accordance with an embodiment.

[0010] FIG. 4A is a cross sectional view through line 4—4 of FIG. 3, showing parts of the housing, the second pump and a first pump contained in the pump assembly, in accordance with an embodiment.

[0011] FIG. 4B is an alternate cross sectional view through the housing shown in FIG. 3, showing another view of parts within the housing.

[0012] FIG. 4C is a cross sectional view through the first pump showing an inlet and outlet thereof, in accordance with an embodiment.

[0013] FIG. 5 shows a connection and drive shaft of the first and second pumps, and a first cover, of the pump assembly in accordance with an embodiment.

[0014] FIG. 6 shows an exploded view of the parts shown in FIG. 5, without the first cover.

[0015] FIG. 7 shows an exploded view of the pump assembly of FIG. 1.

[0016] FIGS. 8 and 9 show perspective views of the pump assembly of FIG. 1 connected with a driver in accordance with an embodiment.

[0017] FIG. 10 shows an exploded view of the parts shown in FIGS. 8 and 9.

[0018] FIG. 11A shows a cross sectional view of the pump assembly and driver as shown in FIGS. 8 and 9, in accordance with an embodiment.

[0019] FIGS. 11B and 11C show a front perspective view and a back perspective view, respectively, of the driver including cooling fins, in accordance with an embodiment.

[0020] FIG. 12 is a schematic drawing showing options for operating the herein disclosed pump assembly for pumping lubricant to a transmission.

[0021] FIG. 13 is a is a schematic drawing of a system including the pump assembly as disclosed herein.

[0022] FIG. 14 is an underside view of a cover of one of the pumps in the pump assembly disclosed herein, including a seal.

[0023] FIG. 15 is a cross sectional view through a housing of a pump assembly, in accordance with another embodiment of this disclosure, having a first pump and a second pump therein.

[0024] FIGS. 16 and 17 show exploded, perspective views of parts of the pump assembly of FIG. 15 from a first side and a second side, respectively.

[0025] FIG. 18 is a perspective view of a pump assembly from a first side thereof in accordance with yet another embodiment of the present disclosure, having a first pump and a second pump therein.

[0026] FIG. 19 is a perspective view of the pump assembly of FIG. 18 from a second side thereof.

[0027] FIG. 20 is a top view of the pump assembly of FIG. 18.

[0028] FIG. 21 is a bottom view of the pump assembly of FIG. 18.

[0029] FIG. 22 is a first side view of the pump assembly of FIG. 18.

[0030] FIG. 23 is a second side view of the pump assembly of FIG. 18.

[0031] FIG. 24 is an alternate perspective view of the pump assembly of FIG. 18 with a second cover removed therefrom, showing a portion of a second pump in the assembly, in accordance with an embodiment.

[0032] FIG. 25 is an alternate perspective view from the second side of the pump assembly of FIG. 19 with a first cover removed therefrom, showing a portion of a first pump in the assembly, in accordance with an embodiment.

[0033] FIG. 26 shows an exploded view of parts of the pump assembly as shown in FIGS. 18 and 19.

[0034] FIG. 27A is a cross sectional view of the pump assembly as shown in FIGS. 18 and 19, in accordance with an embodiment, and FIG. 27B is an alternate view of FIG. 27A showing details of the drive shaft of the pump assembly.

[0035] FIG. 28 is a full side view of the second pump in the assembly as shown in FIG. 24, with the second cover removed therefrom, in accordance with an embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0036] The pump assembly described herein contains multiple pumps within in a single housing or block. Each pump is provided with distinct inlets and outlets that allow for selective output from one of the pumps, while the other pump regularly or continuously supplies / outputs pressurized lubricant to a system (e.g., transmission or engine) during operation. A common wall is provided in the housing, between parts of the two pumps, and forms part of the internal chambers for each pump.

[0037] In accordance with an embodiment, the herein disclosed pump assembly includes a low pressure pump and high pressure pump (that is, two stages of pressure) that are configured to be driven off the same drive shaft. In accordance with one embodiment, the herein disclosed pump assembly includes a low pressure gerotor pump and a pressure-compensated, high pressure external gear pump that are paired together and configured to be driven off the same drive shaft.

[0038] While there are parts and features of the pump assembly 10 herein referenced as top, bottom, left, right, upper, lower, first, second, etc., it should be noted that such terms are not at all intended to be limiting with respect to direction, mounting, or positioning of the housing 12 and/or pump assembly 10 described herein. Such terms are provided for reference only.

[0039] FIGS. 1 and 2 illustrate perspective views from two sides of a two-stage pump assembly 10 in accordance with this disclosure. The pump assembly 10 is used to pressurize and pump lubricant to an outside system such as a transmission (e.g., see transmission 102 of FIG. 13) or an engine. In this disclosure, “lubricant” refers to fluids such as transmission fluid or (engine) oil that may be pressurized and directed to a system, e.g., for cooling and lubrication purposes. For explanatory purposes only, this disclosure describes the fluid as transmission fluid used with a transmission. However, this design may be used with engine oil and an engine as well.

[0040] In accordance with an embodiment, the “two-stages” addressed by the disclosed pump assembly refer to the pump assembly 10 being able to provide two stages of pressure levels, i.e., a first, higher pressure and a second, lower pressure. That is, in some embodiments, a first pump 20 and a second pump 30 are provided for pumping lubricant (e.g., oil); each pump is configured to pressurize lubricant input into the housing. In the illustrated embodiments, the first pump 20 and the second pump 30 are co-axially aligned and driven using a driver (e.g., a motor or engine).

[0041] More specifically, in accordance with an embodiment, the disclosed assembly 10 includes, integrated into a single housing 12, the first pump 20 (see FIG. 4A) that is a “high pressure” pump designed for selective output operation, i.e., when higher pressurized lubricant is required by the outside system, and the second pump 30 (also shown in FIG. 4A) that is a “low pressure” pump designed for continuously pumping lower pressurized lubricant to the system. Generally the second pump 30 continuously outputs pressurized lubricant as the pump assembly 10 is operated, while the output from the first pump 20 is limited. Further details regarding the high and low pressure ranges addressed by the pump assembly 100 are described later. In another embodiment, the pump assembly 10B comprises a tandem pump assembly having, integrated into a single housing 12 and with a common drive shaft and common wall (see FIGS. 27A-B), a first pump 20B (see FIGS. 20 and 26) for pumping air and a second pump 30B (also shown in FIGS. 20 and 26) for pumping lubricant or fluid to a system. Further details regarding the tandem pump assembly 10B are also described further below.

[0042] A drive shaft 24 is provided in the housing 12 and is configured to rotate about a drive axis A—A. The drive shaft 24 drives both the first pump 20 and the second pump 30.

Both the first pump 20 and the second pump 30 have at least one gear that is configured and arranged to be rotated by the drive shaft 24. The drive shaft 24 may directly or indirectly rotate each of these gears about axis A—A. In the illustrated embodiment, as shown and described later with reference to FIG. 4A, for example, gear 46 of first pump 20 and gear 56 of second pump 30 may be the gears that are driven by the drive shaft 24.

[0043] The housing 12 of the pump assembly 10 includes a first side 14 (see FIG. 1) with a (first) cover plate 16 (covering parts of one of the pumps therein) and a second side 18 (see FIG. 2) with a (second) cover plate 36 (covering parts of the other pump therein). In one embodiment, first cover plate 16 is associated with the first pump 20 is a fixed cover plate designed for axial clearance pressure using pump pressure. The first cover plate 16 may be secured to the housing 12, and thus is not floating. The cover plate 16 may be removably secured to first side 14 of housing 12 via one or more fasteners 38 (e.g., bolts, that extend through corresponding openings within the housing) (see FIG. 1), in accordance with an embodiment. In an embodiment, a pressure compensation plate or spacer 50 inside the cover is configured to float in the housing 12 and is loaded into a gearset (e.g., gears 46, 48, which are described later below) by a seal (e.g., seal 43), and then by pressure on the cover side of the plate. The cover plate 36 may be removably secured to second side 18 of housing 12 via one or more fasteners 40 (e.g., bolts, that extend through corresponding openings within the housing) (see FIG. 2).

[0044] Optionally, in an embodiment, the housing 12 may include openings or cutouts therein, such as indicated at 27 in FIGS. 1 and 2, which act as weight saving areas within the housing. That is, the weight saving cutout portions 27 in housing 12 are designed to reduce the overall weight of the pump assembly 10. Optionally, in an embodiment, the housing 12 may include locating dowels 29 that are inserted into corresponding openings in the housing 12 and covers 36 and/or 16, in order to assist in placement and securement of the covers to the housing. The dowels 29 may be cylindrically shaped and hollow, in accordance with one embodiment. Further, one or more bolt holes 31 may be provided in the housing for receipt of fasteners/bolts therein, in order to secure the covers and/or additional parts to the housing 12.

[0045] The housing 12 further includes a top side 26 (shown on top in FIGS. 1, 2, and 8), a bottom side 28 (shown on bottom in FIGS. 4A and 8), a front side 32 (shown on the right in FIG. 1) and a back side 34 (shown on the right in FIG. 2). In the illustrated embodiment, the first side 14, the top side 26, and the front side 32 may include inlet and outlet openings for each of the pumps 20, 30 contained in the housing 12. For example, in one embodiment, the first pump 20 may include a first inlet 60 (see FIG. 4C) provided in or on the housing 12 for receiving lubricant from a source outside the housing (e.g., see lubricant source 110 of FIG. 13) and a first outlet 62 (see FIG. 4C) for directing lubricant that is pressurized (by the first pump) out of the housing 12. A first inlet opening 64 (see FIG. 1) may be provided on the housing 12 and connects to the first inlet 60, and a first outlet opening 66 may be provided on the housing 12 and connects to the outlet 62. The first inlet opening 64 may be an external connection point on the housing 12 for receiving the lubricant from the source outside the housing 12. In an embodiment, the first inlet opening 64 may be provided on a plane that is perpendicular to the drive axis A—A of the drive shaft 24. Lubricant may be directed into the housing 12 through the first inlet opening 64 in a generally parallel manner relative to the drive axis A—A. In one embodiment, such as shown in FIG. 1, the first inlet opening 64 may be provided in and through the first cover plate 16. As shown in FIG. 4A, a path that may be provided on or in an underside of the cover plate 16 to first inlet 60. In another embodiment, the first inlet 60 may include a path that is formed in the housing 12.

[0046] The first outlet opening 66 may be an external connection point on the housing 12 to direct pressurized lubricant from the first outlet 62 of the first pump 20, outside of the housing 12, and to a system (e.g., transmission 102). In an embodiment, the first outlet opening 66 may be provided on a plane that is parallel to the drive axis A—A of the drive shaft 24. Lubricant may be directed out the housing 12 through the first outlet opening 66 in a generally perpendicular manner relative to the drive axis A—A. In one embodiment, the first outlet opening 66 may be provided on the top side 26 of the housing 12. As shown in FIG. 4A, the first outlet 62 may be a path or channel that is provided in a common wall (described in greater detail later) of the housing 12 and near a driven gear 48 and driven drive shaft 52 of the first pump 20. In another embodiment, the first outlet 62 may include a path that may be provided on or in an underside of the cover plate 16.

[0047] Also, in one embodiment, the second pump 30 includes a second inlet 68 (see FIG. 4B) provided in the housing 12 for receiving lubricant from the source outside the housing and a second outlet 70 (shown in FIG. 4A) for directing lubricant that is pressurized (by the second pump) out of the housing 12. The second inlet 68 and the second outlet 70 are different than the first inlet 60 and the first outlet 62. That is, the pump assembly 10 includes at least two distinct inlets 60, 68 and two distinct outlets 62, 70.

[0048] A second inlet opening 72 (see FIG. 1) may be provided on the housing 12 and connects to the second inlet 68, and a second outlet opening 74 may be provided on the housing 12 and connects to the second outlet 70. The second inlet opening 72 may be an external connection point on the housing 12 for receiving the lubricant from the source outside the housing 12. In an embodiment, the second inlet opening 72 may be provided on a plane that is parallel to the drive axis A—A of the drive shaft 24. Lubricant may be directed into the housing 12 through the second inlet opening 72 in a generally perpendicular manner relative to the drive axis A—A. In one embodiment, such as shown in FIG. 1, the second inlet opening 72 may be provided top side 26 of the housing 12. As shown in FIG. 4B, the second inlet 68 of the second pump 30 may receive input lubricant from an inlet path 65 connected to the inlet opening 72. As described in greater detail below, the housing 12 may include a main inlet with an opening 76 provided in the housing 12 for receiving lubricant, that connects to this inlet path 65 for delivery to one or more of the pump inlets 60, 68 (e.g., shown as being connected to the second inlet 68).

[0049] The second outlet opening 74 may be an external connection point on the housing 12 to direct pressurized lubricant from the second outlet 70 of the second pump 30, outside of the housing 12, and to a system (e.g., transmission 102). In an embodiment, the second outlet opening 74 may be provided on a plane that is parallel to the drive axis A—A of the drive shaft 24. Lubricant may be directed out the housing 12 through the second outlet opening 74 in a generally perpendicular manner relative to the drive axis A—A. In one embodiment, the second outlet opening 74 may be provided on the top side 26 of the housing 12. As shown in FIG. 4A, the first outlet 70 may be a path or channel that is provided in a common wall (described in greater detail later) of the housing 12 and near a driven gear 58 of the second pump 30. In an embodiment, the first outlet 70 may include a path that may be provided on or in an underside of the cover plate 36.

[0050] In an embodiment, the first outlet opening 66 and the second inlet opening 72 may be both provided on a plane that is parallel to the drive axis A—A of the drive shaft 24. In an embodiment, the first outlet opening 66 and the second inlet opening 72 may be provided on the same side of the housing 12. In one embodiment, the first outlet opening 66 and the second inlet opening 72 may be provided on the top side 26 of the housing 12. In yet another embodiment, the second outlet opening 74 may be provided on the same side of the housing 12 as the first outlet opening 66 and the second inlet opening 72. That is, in accordance with an embodiment, such as shown in the Figures, the openings 66, 72, and 74 may be provided on the top side 26 of the pump assembly 10.

[0051] One or more seals 73 may be provided around or near the openings 66, 72, 74 to assist in sealing and securement. In an embodiment, such as shown in FIG. 7, the seal 73 is a singularly molded seal with multiple openings designed for placement in a groove formed around the openings 66, 72, and 74.

[0052] The pump assembly 10 may also include in its housing 12 one or more openings therein that connect to the previously noted inlet path 65. In an embodiment, a main inlet may be provided in the housing 12 that directs input lubricant (e.g., from a source) into one or more of the pumps 20 and/or 30. That is, this main inlet may fluidly connect to first inlet 60 and/or second inlet 68. The main inlet has an inlet opening 76 provided in the housing 12, such as shown in FIGS. 1, 4A, and 4B. In an embodiment, the inlet opening 76 is provided on a plane that is perpendicular to the drive axis A—A of the drive shaft 24. In one embodiment, the inlet opening 76 is positioned on another side of the housing 12 that is traverse to the side of the housing containing the first outlet opening 66, the second inlet opening 72, and the second outlet opening 74. In an embodiment, the first inlet opening 64 and the inlet opening 76 are provided on the same side of the housing. In an embodiment, the inlet opening 76 is positioned on the first side 14 of the pump assembly 10. In a similar manner to the first inlet opening 64, lubricant may be directed into the housing 12 through the inlet opening 76 in a generally parallel manner relative to the drive axis A—A.

[0053] In an embodiment, illustrated in FIG. 1, a passage or path 65 may be provided in housing 12 for feeding lubricant to the second inlet 68 via an opening 76 in the housing 12. This inlet path 65 may be a formed or drilled path in the housing 12 that leads to the second inlet opening 72 and second inlet 68 of the second pump 30, for example. In an embodiment, although not explicitly illustrated in the Figures, the inlet path 65 is also or alternatively connected to the inlet 60 of the first pump 20. In an embodiment, illustrated in the cross sectional view of FIG. 4B, there may be another opening 78 connected to inlet path 65. This opening 78 may be provide for manufacturing purposes, for example. As shown in FIGS. 4A and 4B, the opening 78 may include a plug 33 (e.g., made of steel) that is pressed therein to seal part of the inlet path 65 or passage within the housing 12, when the assembly 10 is ready for use.

[0054] Referring now more specifically to each of the pumps, in one embodiment, the first pump 20 of the pump assembly 10 may be an external gear pump comprising a gearset of two externally toothed and intermeshed gears 46, 48 provided on two parallel axes. In an embodiment, the first gear 46 is a driving gear that is driven by the drive shaft 24. The first gear 46 is configured and arranged to rotate about drive axis A—A. In one embodiment, the first gear 46 may be connected to the second pump 30 via drive shaft 24 and configured to rotate with the drive shaft 24. In another embodiment, the first gear 46 may be provided on its own shaft 44 that is connected to drive shaft 24 (with or without coupling 25) (further described below). In an embodiment, the second gear 48 a driven gear coupled to a rotatable shaft 52 provided on a driven axis B—B (see FIGS. 4A and 5). Driven axis B—B is parallel to drive axis A—A. The output from the first pump 20 may be selectively activated for pressurizing and pumping lubricant to the outside system (see, e.g., FIGS. 12-13). In an embodiment, a valve (such as valve 114 shown in FIG. 12) may be provided to limit or selectively provide lubricant to the system. In another embodiment, the system may be designed to combine its outlet with a second pump (not shown). Alternatively, in an embodiment, the outlet from the pump may be used just for lubrication as part of a lubrication circuit or just for cooling as part of a cooling circuit.

[0055] In one embodiment, the second pump 30 is a gerotor pump comprising an inner rotor 56 that acts as a driving gear and that is rotated relative to an outer rotor 58. The inner rotor 56 is fixedly secured to the shaft 24 (or shaft 42) for rotation about axis A—A with the drive shaft 24. The outer rotor 58 may be rotatably received in a part of the housing 12 (specifically, common wall 80, as described below), according to one embodiment. In another embodiment, the outer rotor 58 is fixed within the common wall 80. The inner rotor 56 meshes with the outer rotor 58 using teeth provided on each gear (e.g., inner rotor 56 has male teeth or external teeth provided along an outer periphery thereof, while outer rotor 58 has female receiving portions or internal teeth in an inner periphery thereof, for receipt of the male teeth of the inner rotor 56). The outer rotor 58 has greater number of teeth or portions than the inner rotor 56. The axis of the inner rotor 56 is offset from the axis of the outer rotor 58. In one embodiment, both rotors may rotate on their respective axes. Alternatively, in another embodiment, the inner rotor 56 rotates relative to the outer rotor 58. As is understood by one of ordinary skill in the art, in accordance with one embodiment, rotation of the inner rotor 56 also rotates the outer rotor 58 via their intermeshed teeth to pressurize the input fluid received in areas between the complimentary parts for output from the pump assembly 10, and thus such details are not described here. The offset of their axes creates a changing-volume space between them. During a rotation cycle, fluid may enter a suction side of the gerotor, get pressurized due to the changing-volume space, and the pressurized fluid is discharged at a discharge port of the gerotor. The drive shaft 24 may be configured to drive the inner rotor 56, for example. In an embodiment, such as shown in FIG. 3 (wherein cover 36 is removed from the housing 12 for illustrative purposes only), the outer rotor 58 may be provided (and rotated in) in a rotor pocket 54, which forms part of one rotor chamber that is provided in the housing 12.

[0056] As illustrated and described herein, the housing 12 is designed such that it provides two internal chambers therein; i.e., one internal chamber for the first (high pressure, external gear) pump 20, and one internal chamber for the second (low pressure, gerotor) pump 30. Each of these internal chambers receive and pressurize lubricant therein using respective pump parts. In particular, housing 12 includes a wall 80 that is common – also referred to as a "common wall" 80 in this disclosure – to both the first pump 20 and the second pump 30 of the pump assembly 10, that forms part of each internal chamber. The common wall 80 may be positioned in a relatively radial direction (relative to the drive axis A—A) within the pump assembly 10. The first pump 20 is provided on a first radial side 82 of the common wall 80 and the second pump 30 is provided on a second radial side 84 of the common wall 80 that is opposite to the first side. As seen in FIG. 4A, for example, the drive shaft 24 extends through the common wall 80 and connects to each of the drive gear 46 and driving gear 56 of both the first pump 20 and the second pump 30, respectively. In an embodiment, the gears 46, 48 of the first/external gear pump 20 may be provided on the first side 82 of the wall 80, and the inner and outer rotors 56, 58 of the second/gerotor pump 30 may be provided on the second side 84 of the wall 80.

[0057] In an embodiment, the common wall 80 forms at least part of each of the internal chambers provided in the pump assembly 10, and the covers – either cover plate 16 or cover plate 36 – form the other part of each of the internal chambers. For example, the common wall 80 may be a substantially flat wall that extends between the parts (e.g., gears) of the pumps 20, 30, in accordance with one embodiment. That is, each of the first and second sides of the wall 80 may be substantially flat. In this disclosure, substantially flat refers to a side of the common wall that may be positioned flush with another portion (e.g., cover) of the pump assembly 10, but that does not include pockets or chambers for receipt of pump parts therein. Such a substantially flat wall may include channels, paths, or routes that are drilled along a portion of the wall, however. In such an embodiment, the covers 16 and 36 may include pockets or openings on their inside radial walls that are sized to accommodate the gears of the pumps 20, 30 therein. When the covers 16, 36 are attached to the common wall 80, the inner radial walls of each of the covers 16, 36 may form a peripheral wall that extends around and surrounds each internal chamber (and gears of the pumps 20, 30) peripherally.

[0058] In another embodiment, the common wall 80 defines the pressurizing internal chambers in each of the pumps 20, 30, in which at least the drive gears 46, 56 are received. In the illustrated embodiment, for example, as shown in FIGS. 4A and 11A, the common wall 80 may include a first pocket 86 or first rotor chamber on the first side 82 thereof containing the at least one gear (e.g., drive gear 46) of the first pump 20 therein. A second pocket 54 or second rotor chamber may be provided on a second side 84 of the wall 80 containing the at least one gear (e.g., driving gear or inner rotor 56) of the second pump 30 therein. The common wall 80 may be positioned in a radial direction (relative to the drive axis A—A) and each of the pockets 54, 86 may extend axially into and/or towards the wall 80. The pockets 54, 86 may be sized to receive at least one of the gears associated with each of the pump 20, 30. For example, second pocket 54 may be sized in order to receive (and optionally allow rotation of) the outer rotor 58 of the gerotor pump 30 therein. In one embodiment, first pocket 86 may be sized to receive and allow rotation of both the first and second gears 46, 48 of the external gear pump 20 therein. That is, the pocket 86 may be sized such that, when the gears 46, 48 are installed in a meshing manner for rotation about their respective axes, a length of the pocket may be based on a length of the stacked or intermeshed gears.

[0059] Accordingly, the walls of the pockets 86, 54 may define axial sides of the internal chamber and include a peripheral wall 23 that extends around the gears peripherally to form the internal chambers. The covers 16, 36 may be attached to the common wall 80 to help enclose the internal chambers along with the common wall 80. The cover 36 is not shown in FIG. 3, for example, so that some of the internal components of the second pump 30 can be seen. One or more seals 43 may be provided between the common wall 80 and covers 16, 36, for example. In an embodiment, a single seal 43 is provided around any openings or connection points therebetween in cover 16, such as shown in FIG. 14. The covers 16, 36 may be made of any material, and may be formed by stamping (e.g., stamping steel or another metal), aluminum die casting, powdered metal forming, forging, or any other desired manufacturing technique.

[0060] The cover 16 may also contain, in one embodiment, one or more grooves 53A, 53B (see FIG. 7) on its inside radial wall to accommodate ends of the drive shaft 24/44 and/or driven shaft 52 therein. As shown in FIG. 7, for example, an underside or an inner radial side (pump-facing side) of the cover plate 16 may have a recessed passage 61 to house seal 43 which separates the inlet 60 from the outlet on the backside of the spacer 50 or plate. Similarly, in an embodiment, as shown in FIG. 10, an inner side (pump-facing side) of the cover plate 36 may include shadow ports for the inlet and outlet porting for the gear / gerotor set (56 and 58) of the second pump 30.

[0061] Alternatively, in another embodiment such as shown in FIG. 17, the underside or inner radial side of the cover plate 16 may be provided without a recessed passage 61. In such an embodiment, which is described in detail later with respect to pump assembly 10A, the spacer 50 or pressure compensating plate may be provided on an opposite side of the external gearset, i.e., on an inner side at or in the pocket 86, and/or at or near common wall 80.

[0062] In one embodiment, first pocket 86 may be formed in the first side 82 of the common wall 80 to accept drive gear 46 and its shaft (drive shaft 24 and/or shaft 44) and a third pocket is also formed in the first side 82 of the wall 80. The third pocket may be a separate pocket that is provided to contain the second/driven gear 48 of the first pump, and its rotating/driven shaft 52, therein. In accordance with yet another embodiment, a secondary pocket may be contained in either the first pocket 86 (when formed to contain a length of the intermeshed gears) or the third pocket for receiving an end of the driven shaft 52 of the external gear pump 20.

[0063] In yet another embodiment, the common wall 80 may have one side that is substantially flat and an opposite side with one or more pockets therein. The flat side of the common wall 80 may be connected to a cover plate that has one or more pockets therein for receipt of at least one of the gears for one of the pumps, such that when the cover is connected with the flat side of the common wall 80, the internal chamber is formed therein. On the opposite side of the common wall, the one or more pockets may be configured to receive one or more gears of the other of the pumps, and the cover plate may be attached thereto to form the additional internal chamber of the pump assembly 10.

[0064] The common wall 80 and/or housing 12 may be formed from any number of materials and manufactured in a number of ways. In one embodiment, the common wall 80 is molded, e.g., injection molded. In another embodiment, the common wall 80 may be formed via a molding process that further includes machining and/or drilling processes. For example, the pockets 54, 86 or rotor chambers may be machined into the common wall 80.

In one embodiment, the common wall 80 may be formed via a casting process (die casting), powder metal forming, forging, stamping, or any other desired manufacturing technique. Other parts of the housing 12 may be formed by similar techniques, i.e., stamping, casting, powdered metal forming, molding, etc. In accordance with embodiments, the housing 12 and its common wall 80 may be formed using a casting technique. In accordance with embodiments the housing 12 and wall 80 may be formed from die cast aluminum or cast iron. In accordance with an embodiment, common wall 80 and the walls forming the pockets may be a single, unitary and continuous part, i.e., integral.

[0065] The drive shaft 24 extends through the wall 80 and connects to each of the driving gears 56, 46 contained in the first pocket 86 and the second pocket 54, respectively. In the illustrated embodiment, the driving gear of the external gear pump 20 is gear 46, which is driven by the drive shaft 24 connected to the second pump 30, and the driven gear is gear 48, which is coupled to rotatable shaft 52.

[0066] In an embodiment, one or more spacers 50, pressure compensation plates, or collars may be provided adjacent to the first and second gears 46, 48 of the first pump 20 to substantially prevent sliding (axial) movement of the gears 46, 48 from the wall 80. For example, the gears 46, 48 may be placed such that one side is substantially flush with first side 82 of common wall 80. Spacer(s) 50, plate(s), or collar(s) may be placed on a side opposite to the first side 82 of the common wall 80, and fitted on the shafts 44, 52 between the gears 56, 58 and the inner radial side of cover 16. As shown in the exploded view of FIG. 6, which shows the parts of the drive shaft 24 (i.e., shafts 42 and 44), rotating shaft 52, and gears 46, 48 and 56, 58 of the pumps 20, 30, for example, the spacer 50 may be a part of singular construction having openings 51A, 51B extending therethrough for receipt of the shafts 44, 52 (respectively). In addition to holding the gears 46, 48 in the pocket 86 of the wall 80 in housing 12 (and aiding in reducing or preventing axial movement of the gears 46, 48 therein), the spacer(s) 50 or collar(s) limit the amount of wear and damage to the wall 80, housing 12 and/or cover 16.

[0067] As previously noted, the drive shaft 24 that drives both the first pump 20 and the second pump 30 extends through the housing 12, as shown in FIG. 4A. Accordingly, the common wall 80 may also have a receiving opening 88 that axially extends through the common wall 80, extending between the second pocket 54 and first pocket 86, for receipt of the drive shaft 24 therethrough. The size of the receiving opening 88 may be based on the diameter or size of the drive shaft 24.

[0068] In one embodiment, the drive shaft 24 is a single, common drive shaft for both pumps 20, 30 that is formed as a singular shaft (or tube) and is designed to extend through the housing 12 and into at least portion of the pumps 20, 30 for driving them as it rotates about drive axis A—A. That is, the same shaft may directly drive first pump 20 and second pump 30. The receiving opening 88 may have a substantially consistent diameter along its axial length from one end (e.g., at second pocket 54) to the other (e.g., at first pocket 86).

[0069] In another embodiment, such as shown in FIGS. 4A, 5, and 11A, the drive shaft 24 may be formed from a first drive shaft 42 and a second drive shaft 44 that are co-axially connected to one another for rotating together about the drive axis A—A. In an embodiment, the first drive shaft 42 and the second drive shaft 44 are connected via a coupling 25. In one embodiment, such as shown in the cross section of FIG. 4A, the coupling 25 has a first extension end that is inserted into an opening in the drive shaft 42, and a second end that has an opening therein for receiving an end of the first drive shaft 42 therein. In another embodiment, such as illustrated in the exploded view of FIG. 6, the coupling 25 has an opening on either of its sides. The first drive shaft may include a connector 42A on its end that is inserted (e.g., press-fit) into one opening of the coupling 25, and/or the second drive shaft may include a connector 44A on its end that is inserted (e.g., press-fit) into the other opening of the coupling 25. Such coupling 25 is optional and need not be provided. The illustrated couplings are exemplary only and not intended to be limiting. For example, the shafts may be directly connected using a receiving portion and corresponding connector portion (e.g., male and female parts), thus forming a coupling therebetween. In an embodiment, one of the drive shafts (e.g., first drive shaft) may include a connector male portion 42A1 that is inserted into a female receiving connector portion 42A2 of the other drive shaft (e.g., second drive shaft). An exemplary embodiment of such a coupling for the drive shaft(s) is shown in FIG. 27A and FIG. 27B. In some embodiments, the receiving opening 88 may include additional step portions therein to accommodate shafts 42 and 44 and/or optional coupling 25. That is, the receiving opening 88 may include multiple diameters along its axial length to accommodate parts associated with the drive shaft 24.

[0070] The drive shaft 24 is driven by a single input device or driver, which may be mechanical, electric, or electro-mechanical - e.g., an electric motor 90, such as shown in FIGS. 8-10 and 11A-11C, an engine, an internal combustion engine (ICE), or a prime mover. As shown in these Figures, in one embodiment, the pump assembly 10 is configured for assembly with an electric motor 90. As shown in the cross sectional view of FIG. 11A, the pump assembly 10 and electric motor 90 are axially aligned on drive axis A—A. The electric motor 90 is contained in a casing 91 and has motor shaft 92 configured to drive the drive shaft 24 of the pump assembly 10. In one embodiment, the motor shaft 92 and drive shaft 24 may be a single shaft that extends from the motor 90 and into the pump assembly 10. In accordance with another embodiment, such as shown in FIG. 11A, the electric motor 90 may have its own, separate motor drive shaft 92 configured to be driven about axis A—A, and still connected to the pump assembly 10, in order to drive the pumps 20, 30 in the pump assembly 10. In an embodiment, the motor shaft 92 has an end 94 that is configured connection to a connector portion 22 of the pump assembly 10. For example, the end 94 may be configured to be press-fit into an opening in the connector portion 22 for axial rotation along axis A—A.

[0071] More specifically, the connector portion 22 is provided on the second side 18 of the pump assembly 10 for connecting an input device or a driver (e.g., such a motor 90 shown in FIGS. 8-9). According to one embodiment, as shown, the connector portion 22 has a receiving area or opening 21 for receiving part of a driving shaft (motor shaft 92) of the driver therein. In one embodiment, the connector portion 22 may be integrated into an end of the drive shaft 24. That is, the drive shaft 24 may extend through the housing 12 and have one of its ends extending through (second) cover plate 36 on the second side 18 of the pump assembly 10, such that it may be connected to the driver. In another embodiment, the connector portion 22 may be a coupling that is attached to the end of the drive shaft 24, and placed in or on the cover plate 36 when assembled.

[0072] In an embodiment, the casing 91 includes a sleeve 95 (see FIG. 10) to assist in securement of the motor 90 to the pump assembly 10. As shown in the exploded view of FIG. 7, for example, the cover plate 36 provided on the second side 18 of the pump assembly 10 may include a cavity 37 on an outer radial side thereof configured to receive the sleeve 95 of the motor 90 therein when assembled together. In a particular embodiment, as shown in FIG. 11A, the connector portion 22 is aligned with and inserted into an opening 97 of the sleeve 95, while the outside of the sleeve 95 is provided in the cavity 37. One or more seals 39 or O-rings may be provided around the connector portion 22.

[0073] The electric motor 90 may include a rotor 96 and a stator 98 (see FIG. 11A) and a number of bearings 99 on provided on its motor shaft 92. The rotor 96 is connected to the motor shaft 92 which is contained within its casing 91 along with the stator 98. The motor casing 91 is generally cylindrical (see FIG. 11B) and the stator 98 may be fixed thereto. In an embodiment, shown in FIG. 11C, the motor casing 91 may include cooling fins

93 provided on outer side thereof (i.e., the side opposite to that which the pump assembly 10 is attached).

[0074] FIGS. 15-17 depict another embodiment of a pump assembly 10A that includes first and second pumps 20 and 30 therein. For purposes of clarity and brevity, like elements and components throughout FIGS. 15-17 are labeled with same designations and numbering as discussed with reference to FIGS. 1-14. Thus, although not discussed entirely in detail herein, one of ordinary skill in the art should understand that various features associated with the pump assembly 10 of FIGS. 1-14 are similar to those features previously discussed. Additionally, it should be understood that the features shown in each of the individual figures is not meant to be limited solely to the illustrated embodiments. That is, the features described throughout this disclosure may be interchanged and/or used with other embodiments than those they are shown and/or described with reference to. Pump assembly 10A may be driven by a driver such as motor 90, for example. Much like pump assembly 10, pump assembly 10A includes first pump 20 and second pump 30. Drive shaft 24 is provided in the housing configured to rotate about a drive axis A—A and drive both the first pump 20 and the second pump 30. A coupling 25 may be optionally provided to connect drive shafts 42 and 44 to form the drive shaft 24, or a single drive shaft may be provided. First pump 20 may be a high pressure external gear pump and second pump 30 may be a low pressure gerotor pump that are paired together and configured to be driven off the same drive shaft. The first pump 20 has a first inlet provided on the housing for receiving lubricant from a source outside the housing and a first outlet for directing lubricant that is pressurized out of the housing. The second pump has a second inlet provided on the housing for receiving lubricant from the source outside the housing and a second outlet for directing lubricant that is pressurized out of the housing. The second inlet and the second outlet are different than the first inlet and the first outlet, respectively. The housing further includes a common wall 80 to both the first pump 20 and the second pump 30, which may be seen in FIG. 15. The first pump 20 is provided on a first (right) side of the wall and the second pump 30 is provided on a second (left) side of the wall that is opposite to the first side. The drive shaft extends through the common wall 80 and connects to gears (e.g., gears 46 and 56) of both the first pump 20 and the second pump 30.

[0075] In this illustrated embodiment, the underside or inner radial side (pump facing side) of the cover plate 16 may include receiving openings 17 therein (see FIGS. 15 and 17) for receipt of one end of each of the shafts 44 and 52 for the gears 46 and 48 of the first pump

20. In this embodiment, the spacer 50 or pressure compensating plate may be provided on an opposite side of the external gearset. That is, rather than being provided adjacent to the cover plate 16 as shown in FIG.7, the spacer 50 is provided on an inner (opposite) side, within the pocket 86 and/or at or near common wall 80. As seen in FIG. 15, for example, the pocket 86 of common wall 80 may receive seal 43A, spacer 50 and then the gears 46, 48 therein, in accordance with an embodiment. Seal 43A may be housed in the pocket 86 to separate the side of the spacer 50 or plate from direct contact with the common wall 80 while still providing support and/or pressure with respect to the external gearset of first pump 20. Shaft 44/drive shaft 24 extends through common wall 80 and is connected to the drive shaft 42 (24) of the gerotor gearset 56, 58 which is contained in the other pocket 54 on the opposite side of the common wall 80.

[0076] FIGS. 18-28 depict yet another embodiment of a pump assembly 10B that includes a single housing 12 having a common wall 80 and drive shaft 24, and first and second pumps 20B and 30B therein. For purposes of clarity and brevity, like elements and components throughout FIGS. 18-28 are labeled with similar or same designations and numbering as discussed with reference to FIGS. 1-14. Thus, although not discussed entirely in detail herein, one of ordinary skill in the art should understand that various features associated with the pump assembly 10 of FIGS. 1-14 and/or the pump assembly 10A of FIGS. 15-17 are similar to those features previously discussed. Additionally, it should be understood that the features shown in each of the individual figures is not meant to be limited solely to the illustrated embodiments. That is, the features described throughout this disclosure may be interchanged and/or used with other embodiments than those they are shown and/or described with reference to. Pump assembly 10B may be driven by a driver such as motor 90, for example, e.g., an electric motor, an engine, or a transmission. In an embodiment, there may be a single input device for driving the drive shaft 24 of the pump assembly 10B; the input device may be an engine, a transmission, or an electric motor. Much like pump assembly 10, pump assembly 10B includes first pump 20B and second pump 30B. Drive shaft 24 is provided in the housing configured to rotate about a drive axis A—A and drive both the first pump 20B and the second pump 30B. In an embodiment, such as shown in FIG. 27A and FIG. 27B, the drive shaft 24 may be formed from a first drive shaft 42 and a second drive shaft 44 that are co-axially connected to one another for rotating together about the drive axis A—A. In an embodiment, the first drive shaft 42 and the second drive shaft 44 are connected using a receiving portion in one end of a shaft (e.g., in drive shaft 44, as shown in FIG. 27A) and corresponding connector or insertion portion in another end of a shaft (e.g., in drive shaft 42, as shown in FIG. 27A) (e.g., male and female parts), thus forming a coupling therebetween. In another embodiment, the first drive shaft 42 and the second drive shaft 44 may be connected via a separate coupling 25, such as previously described with reference to the embodiments above.

[0077] First pump 20B in the illustrative embodiment of FIGS. 18-28 may be an air pump for pressurizing air, and second pump 30B may be an oil pump or a lubricant pump configured to pressurize lubricant. The first pump 20B and second pump 30B of assembly 10B are paired together and configured to be driven via the same drive shaft 24. The first pump 20B has a first inlet 60A provided on the housing 12 and a first outlet 62A (see FIG. 21) for directing air that is pressurized out of the housing 12. The first pump 20B may be connected to a closed network (e.g., brake booster system) and configured to receive air therefrom to evacuate the connected system. The first inlet 60A has a first inlet opening 64A that is provided on a plane that is perpendicular to the drive axis A—A of the drive shaft 24, in accordance with an embodiment. The first outlet 62A has at least one first outlet opening 66A. In the exemplary illustrated embodiment, the outlet 62A includes two outlet openings 66A.

[0078] The second pump 30B has a second inlet 68 (see FIG. 27A) provided on the housing 12 for receiving lubricant from the source outside the housing and a second outlet 70 for directing lubricant that is pressurized out of the housing 12. The second inlet 68 and the second outlet 70 are different than the first inlet 60A and the first outlet 62A, respectively. The second inlet 68 has a second inlet opening 72. In accordance with an embodiment, the first outlet opening(s) 66A and the second inlet opening 72 are provided on the same side of the housing 12, i.e., on the same side of the common wall 80 or an axis extending through the common wall 80, such as shown in FIG. 23. The second outlet 70 has a second outlet opening 74. The second outlet 70 includes an outlet path 70B that directs output / pressurized fluid to the second outlet opening 74 in the housing. In an embodiment, the second outlet opening 74 is provided on the same side of the housing as the first inlet opening 64A, i.e., on the same side of the common wall 80, such as shown FIGS. 18 and 20.

[0079] In accordance with an embodiment, the first inlet opening 64A is provided on a plane that is parallel to the drive axis A—A of the drive shaft 24. In accordance with an embodiment, the second outlet opening 74 is provided on a plane that is parallel to the drive axis A—A of the drive shaft 24.

[0080] In an embodiment, illustrated in the cross sectional view of FIG. 27A, a passage or inlet path 65 may be provided in housing 12 for feeding lubricant to the second pump 30B in the housing 12. The second pump 30B may receive input lubricant via an inlet path 65 connected to the second inlet opening 72, as described in greater detail below. A lubricant source (e.g., tank, sump) fluidly connects to the second inlet opening 72 and this inlet path 65 for delivery to the second pump 30B. As shown in FIGS. 19-22, for example, the second inlet 68 and inlet opening 72 may be in fluid communication for directing input lubricant into and through the inlet path 65 or passage. This inlet path 65 may be a formed or drilled path in the housing 12 that leads to the second inlet 68 of the second pump 30, for example, as well as the pumping elements (e.g., rotor, vanes) of the second pump 30B. The inlet path 65 may be in the form of a tube, for example, in accordance with an embodiment. As shown in FIGS. 21 and 27A, a screen or filter 81 may be provided between the main inlet opening 72 and inlet path 65 or passage / second inlet 68 before any lubricant enters the inlet path 65 within the housing 12 such that any particulates may be filtered from the input lubricant before being directed to the pumping elements of second pump 30B. In an embodiment, a shape (as shown here, e.g., a cone-shape) of the housing near inlet opening 72 may be designed to slow input fluid down before the filter 81 to reduce the pressure drop over the filter 81. So the fluid is drawn in through second inlet opening 72, may expand within the (cone-shaped) housing to slow down before it passes through filter 81, and then travels through the inlet path 65 into the oil pump rotating group of second pump 30B. More specifically, in accordance with an embodiment, the inlet opening 72 and housing is configured for placement within a source (e.g., sump of the engine) such that the inlet opening 72 sits within the lubricant (oil) and is at least somewhat submerged within the source of lubricant. Accordingly, the screen or filter 81 can filter any unwanted particulates that may be recirculated within the system during operation of the pump assembly 10B.

[0081] As mentioned above, in an embodiment, the second or main inlet opening 72, such as shown in FIGS. 18, 19, and 21, may be provided in the housing 12 to direct input lubricant (e.g., from a source) into pump 30B. That is, this second inlet opening 72 may fluidly connect to inlet path 65 and thus second inlet 68. In an embodiment, the inlet opening 72 is provided on a plane that is perpendicular to the drive axis A—A of the drive shaft 24. In one embodiment, the inlet opening 72 is positioned on another side of the housing 12 as compared to the second pump 30B, i.e., it positioned on a first side (e.g., right) of the common wall 80 (on the same side as first pump 20B), while the second pump 30B is positioned on the second, opposite side (e.g., left) of the common wall 80. Accordingly, inlet path 65 connects the inlet opening 72 and second inlet 68 (such as shown in FIG. 27A). In an embodiment, the first inlet opening 64A and the second inlet opening 72 are provided on the opposite sides of the housing. In an embodiment, the second inlet opening 72 is positioned on the first side 14 of the pump assembly 10.

[0082] The housing 12 further includes a common wall 80 to both the first pump 20B and the second pump 30B, which is shown in FIG. 27A, for example. The first pump 20B is provided on a first (right) side of the wall and the second pump 30B is provided on a second (left) side of the wall that is opposite to the first side. The drive shaft 24 extends through the common wall 80 and connects to drive rotors (e.g., bearing 71 to rotor 48A and rotor 56A) of both the first pump 20B and the second pump 30B.

[0083] In an embodiment, the common wall 80 (see FIG. 27A) forms at least part of each of the internal chambers provided in the pump assembly 10, and the covers – either cover plate 16 or cover plate 36 – form the other part of each of the internal chambers. In one embodiment, the common wall 80 defines the pressurizing internal chambers in each of the pumps 20B, 30B, in which at least the rotors/gears 48A, 56A (and bearing 71) are received. In the illustrated embodiment, for example, as shown in FIGS. 24, 25, and 27A, the common wall 80 may include a first pocket 86 or first rotor chamber on the first side 82 thereof containing the bearing 71 and driven rotor 48A of the first pump 20 therein. A second pocket 54 or second rotor chamber may be provided on a second side 84 of the wall 80 containing the at least one rotor (e.g., rotor 56A) of the second pump 30 therein. The common wall 80 may be positioned in a radial direction (relative to the drive axis A—A) and each of the pockets 54, 86 may extend axially into and/or towards the wall 80. The pockets 54, 86 may be sized to receive at least one of the rotors (or gears) associated with each of the pump 20B, 30B. For example, second pocket 54 may be sized in order to receive the rotor 56A and control slide 116 of a vane pump 30 therein; i.e., sized in order to allow and accommodate movement of the slide 116 relative to the internal wall of the pocket 54. In one embodiment, first pocket 86 may be sized to receive and allow eccentric rotation of driven rotor 48A within pump 20.

[0084] Accordingly, the walls of the pockets 86, 54 may define axial sides of the internal chamber and include a peripheral wall that extends around the rotors / gears peripherally to form the internal chambers. The covers 16, 36 may be attached to the common wall 80 and/or housing 12 to help enclose the internal chambers along with the common wall

80. The cover 36 is not shown in FIG. 24, for example, so that some of the internal components of the second pump 30B can be seen. Similarly, the cover 16 is not shown in FIG. 25, for example, so that some of the internal components of the first pump 20B can be seen.

[0085] One or more seals 43 may be provided between the common wall 80 and covers 16, 36, for example. In an embodiment, a single seal 43 is provided around any openings or connection points therebetween in cover 16, such as shown in FIG. 27A.

[0086] The underside or inner radial side (pump facing side) of the cover plate 16 of the first pump 20B may include a receiving opening 17 therein (see FIG. 26) for receipt of one end of the drive shaft 44 for the gears / bearing 71 / rotor 48A of the first pump 20B. More specifically, an end of the drive shaft may be press-fit into receiving opening 17, and may or may not include a bushing. Also, as described later, the drive shaft 24 is received in a central bore of a stationary guide gear 46A or sprocket, which acts as a bearing to support the end of the drive shaft. Shaft 44/drive shaft 24 extends through common wall 80 and is connected to the drive shaft 42 (24) of the bearing 71 and thus rotor 48A, which is contained in first pocket 86 (see FIGS. 25 and 27A) on the opposite side of the common wall 80. In an embodiment, the drive shaft 24, or at least a portion thereof, is configured to extend through the cover plate 36 of the second pump 30B. More specifically, a connector portion 22 (e.g., see FIG. 18) may be provided on the second side 18 of the pump assembly 10B for connecting an input device or a driver (e.g., such a motor 90 shown in FIGS. 8-9) thereto. According to one embodiment, as previously described, the connector portion 22 may have a receiving area or opening 21 for receiving part of a driving shaft (motor shaft 92) of the driver therein.

[0087] Referring now more specifically to each of the pumps, in accordance with an embodiment, the first pump 20B of the pump assembly 10B may be an epitrochoidal vacuum pump, designed to produce epitrochoidal-like rotation of its rotor 48A within the pocket 86 and housing 12. An epitrochoid is defined as a geometric curve or plane curve that is generated by tracing motion of a fixed point on the radius (or extended radius) of a circle as it rolls on the outside/external portion of a fixed, base circle. As understood by one of ordinary skill in the art, the shape of the inner envelope of the epitrochoid (which is the basis for the shape of the housing in which the rotor rotates) determines or aids in generating the shape of the rotor (i.e., the shape of the outer edges or lobes of the rotor). In this exemplary embodiment, for illustrative purposes and without intending to be limiting, a two lobed rotor

48A is shown. Generally, such a design improves upon such principles of a Wankel engine within a vacuum pump. In accordance with an embodiment, the first pump 20 may be or include features of the epitrochoidal pump as disclosed in U.S. Patent App. No. 15/946,944, filed April 6, 2018, which is hereby incorporated by reference in its entirety. Below some of the features of such an epitrochoidal pump are described.

[0088] Generally, in an embodiment, the first side of the wall or pocket 86 of the epitrochoidal first pump 20B defines and is part of an internal space having an epitrochoidal shape. The rotor 48A of the epitrochoidal vacuum pump is rotatably received within the internal space or pocket 86. The rotor 48A is shaped with a number of edges that conjugate with the epitrochoidal shape of the internal space and has an internally toothed guide gear portion 49 (see FIG. 25). The drive shaft 24 is configured to drive the eccentric bearing 71 to thus rotate the rotor 48A eccentrically within the internal space or pocket 86. As previously noted, the externally toothed guide gear 46A (or sprocket) is connected to the drive shaft 24 for support while the rotor 48A is driven by the drive shaft 24.

[0089] In the illustrated embodiment, for example, the first pump 20B of pump assembly 10B utilizes a two lobed rotor 48A, one inlet 60A, and at least one outlet 62A provided in a housing 12. For illustrative purposes only, the vacuum / first pump 20B is illustrated with two outlet openings 66A, that connect to passageways within the pump assembly, that form a single outlet 62A of the pump 20B. The openings 66A may be positioned adjacent or next to each other to provide another channel and larger area for expulsion of air, effectively increasing the cross-sectional area of the outlet port. This may also assist in reducing resistance(s) during expulsion, for example. Reed valves 61A (see FIG. 21) may be provided on each opening 66A of the outlet 62A. Opening and closing timing of the outlet openings 66A via their associated reed valves 61A may be configured to be identical, in accordance with one embodiment, such that they act as one outlet 62A for the housing. A second inlet port or inlet 77 (e.g., see FIGS. 18-19) may be a radially positioned inlet provided along the inlet path or inlet channel, the inlet channel being connected to inlet 60A (radial relative to axis A—A) and configured to direct input air from inlet 60 to an internal inlet port within the pocket 86. The inlet port 77 may also have a reed valve 77A associated therewith. Operation of reed valves 61A and 77A is generally understood by one of ordinary skill in the art and thus not described in detail here. The inlet port 77 in the inlet path aids in preventing unwanted pressurization. The inlet port 77 is configured to provide protection against any potential consequences with regards to the pump spinning backwards or other unwelcome movement of the pump rotor or parts; that is, if the pump (i.e., rotor 48A) were to run or spin backwards, e.g., to evacuate the chamber or pocket 86, then inlet port 77 and reed valve 77A may prevent unwanted pressurization and/or back metering of lubricant or oil in the pocket 86, due to its close proximity to a check valve (e.g., associated with the engine) in the system.

[0090] Pocket 86 acts as a single epitrochoidal working chamber and has a chamber volume. For each rotor revolution, each chamber fulfills two evacuation cycles. Accordingly, the total evacuation capacity per pump shaft rotation in the disclosed vacuum pump 10A is defined as: single chamber volume x 1 (since there is one chamber) x 2 (evacuation cycles per rotor revolution) / 2 (rotor speed reduction to shaft speed); therefore, the total evacuated capacity is 1 * single chamber volume. The surrounding wall of the pocket 86 defines an internal space which is an epitrochoidally generated shape (not circular or substantially circular) and is flanked by cover 16 and common wall 80. The rotor 48A is rotatably received within the internal space of the chamber or pocket 86. As is known in the art, the chamber or pocket 86 is a single working chamber that is varied in size by the rotor 48A as it rotates and orbitally revolves therein along the surrounding wall. During rotation, each side surface of the rotor 48A is brought closer to and then away from the wall of the pocket 86, without fully contacting the wall (e.g., due to manufacturing clearances). Corners or apices of the rotor 48A are guided along the wall in a sliding contact manner (e.g., via seals 75) during rotation of the rotor 48A.

[0091] The body of the rotor 48A may have a substantially ovular shape, with two sides having convex, bow-shaped flanks (see, e.g., FIG. 25) forming its outer walls or edges, in accordance with an embodiment. Rotation of the rotor 48A is performed eccentrically about axis A—A and is implemented by an internally toothed opening or portion 49 integrated in the rotor, an externally toothed guide sprocket 46A, bearing 71, and a drive shaft 24 (44). FIG. 26 shows an exploded view parts of the first pump 20B, including bearing 71, rotor 48A, guide sprocket 46A, and shaft 44/24. The body of the rotor 48A may have an opening in its center that is internally toothed for receipt of the guide sprocket 46A therein. The central opening may be defined by a plurality of radially extending female teeth 49 on the interior thereof. The guide sprocket 46A is received within the central opening. The guide sprocket 46A may have a plurality of radially extending male teeth on the exterior thereof that mesh with and guide movement of the rotor 48A, as the drive shaft is rotated.

[0092] The drive shaft 24 (44) is designed to extend through the rotor 48A towards cover 16. An end of the drive shaft is received within a central hole of the guide sprocket 46A and secured from rotating therein by a bushing, for example. An end of the drive shaft may be placed into the receiving opening 17. To implement eccentric movement of the rotor 48A about axis A—A, an eccentric rotation bearing 71 is provided (see FIG. 26). In an embodiment, a spacer is provided to axially locate the eccentric bearing 71, e.g., during the press fitting of the pieces (i.e., drive shaft 44, bearing 71) together. The spacer may reduce the size and weight of the eccentric bearing 71 to thereby improve balancing of the bearing. Eccentric rotation bearing 71 may have its own receiving opening for positioning of the drive shaft 44 therethrough. In an embodiment, drive shaft 44 may include a stepped configuration of successively increasing diameters for assembly with the rotor 48A.

[0093] The aforementioned inlet 60A may thus be a vacuum inlet for inputting air into the housing. The vacuum inlet 60A includes an input channel or passageway that winds within the housing and receives (pulls via vacuum) air through. Air is communicated and drawn through the passageway and into at least one radial inlet port (not shown) provided in the surrounding wall of the pocket 86. Accordingly, the inlet port 64A fluidly connects to the inside of the chamber or pocket 86. Inlet 60A and its port 64A selectively draws and delivers air under negative pressure (vacuum), dependent upon the position of the rotor 48B.

[0094] In one embodiment, the second pump 30B is a vane pump comprising an inner rotor 56A and a control slide 116 (see FIGS. 24 and 28) having a rotor receiving space 118 communicated to the second inlet 68 and the second outlet 70. The control slide 116 (also referred to as a control ring in the art) is mounted in the housing 12 for pivotal movement in opposing displacement increasing and displacement decreasing directions. As illustrated in FIGS. 24 and 28, the control slide 116 has a pivotal connection established by a pivot pin 122. The control slide 116 pivots about that pivotal connection/pin 122 in the displacement increasing and displacement decreasing directions, dependent upon the pressurized fluid therein, during operation of the pump. The rotor receiving space 118 may be an essentially cylindrical bore extending through the thickness of the control slide body, as illustrated; i.e., the control slide 116 has an inside or inner surface defining rotor receiving space 118. This rotor receiving space 118 communicates directly with the inlet and outlet 65, 70 for drawing in oil, lubricant, or another fluid under negative intake pressure through the inlet 65, and expelling the same under positive discharge pressure out the outlet 70.

[0095] The rotor 56A of the second pump 30B is provided in the rotor receiving space 118, as shown in FIG. 28. The rotor 56A is configured for rotation within and relative to the control slide 116. The rotor 56A has a central axis that is typically eccentric to a central axis of the control slide 116 (and/or rotor receiving space 118). The rotor 56A is fixedly secured to the shaft 24 (or shaft 42) for rotation about axis A—A with the drive shaft 24. The rotor 56A comprises a plurality of vanes 120. The vanes 120 may be retractable and optionally have springs or other features (e.g., fluid channels) for biasing the vanes 120 radially outwardly for contact with the inner surface of the rotor receiving space 118. The rotor 56A is rotatably mounted in the rotor receiving space 118 (clockwise in the orientation shown in FIG. 28) to draw lubricant (e.g., from a source, such as a lubricant sump (e.g., an oil sump) or from generally within an enclosed space (e.g., from within a transmission housing) under negative pressure into the rotor receiving space 118 via the inlet 68 and discharge the lubricant from the rotor receiving space 118 via the outlet 70 under positive pressure. The outlet 70 generally expels the lubricant under positive pressure to the device requiring lubrication, such as to the oil gallery of an engine.

[0096] As generally understood in the art, movement of the control slide 116 in the displacement increasing direction increases eccentricity between the rotor 56A and the control slide 116 for increasing a pressure differential between the inlet 68 and outlet 70. Conversely, movement of control slide 116 in the opposite displacement decreasing direction decreases that eccentricity for decreasing the pressure differential. The principle of operation creating the pressure differential between the low pressure side of the rotor receiving space 118 and the high pressure side thereof based on the change in volume of the pockets between the individual vanes as regulated by the eccentricity between the control slide 116 and the rotor 56A is well-known and need not be described in detail.

[0097] The rotor 56A may be powered in any manner. For example, in engine applications, the rotor 56A is often coupled to a gear or pulley driven by a belt or chain, or may be directly driven by another element of the drive train. As another example, the pump 30B may be driven by an electric motor (particularly in electrically powered vehicles) or have two input connections so as to be driven by both an engine driven element and/or an electric motor (particularly in hybrid vehicles). The manner in which the rotor 56A is driven is not limiting and may occur in any manner.

[0098] A resilient structure 124 is positioned between the housing 12 or pocket 54 and the control slide 116 to bias the control slide 116 in the displacement increasing direction. In the illustrated embodiment, the resilient structure 124 is a compression spring, but it may have any structure or configuration. The control slide 116 includes a radial projection 126 (or radially extending bearing structure) opposite the pivotal connection, e.g., pin 122, of the control slide 116 to the housing 12. The radial projection 126 has a bearing surface 128 that is engaged by the resilient structure 124. In the illustrated embodiment, one end of the spring / structure 124 engages that surface 128, and an opposite end thereof engages against an opposing surface provided in the pocket 54 or housing 12. The spring 124, as illustrated is, held in compression between those surfaces thus applying a reaction force biasing the control slide 116 in the displacement increasing direction.

[0099] The control slide 116 may have one or more seals 132 which define a control chamber 130 between the control slide 116 and the pocket 54 / housing 12. The control chamber 130 is communicated with a source of the pressurized lubricant to move the control slide 116 in the displacement decreasing direction. In the illustrated embodiment, lubricant is fed into the control chamber 130 via inlet path 65 and a pocket / chamber inlet port 65A. The inlet and outlet 30, 40 are disposed on opposing radial sides of the rotational axis of the rotor 65A. The housing 12 has at least one inlet port 65A for intaking fluid to be pumped from inlet 65, and at least one outlet port 70A for discharging the fluid to outlet 70. The inlet port 65A and outlet port 70A each may have a crescent shape, and may be formed through the same wall located on one axial side or both axial sides of the housing (with regard to the rotational axis of the rotor). The inlet and outlet ports 65A, 70A may be disposed on opposing radial sides of the rotational axis of the rotor 16. These structures are conventional, and need not be described in detail. The shape of the inlet and/or outlet is not intended to be limiting. Other configurations may be used, such as differently shaped or numbered ports, etc. Further, it should be understood that more than one inlet or outlet may be provided (e.g., via multiple ports). The chamber inlet port 65A may be communicated (directly or indirectly) to chamber outlet port 70A, through outlet path 70B and to second outlet 70 of the housing 12, and thus the source of pressurized lubricant for the control chamber 130 is the lubricant discharged from the outlet 70. This is a known feedback approach wherein the pressure from the outlet 70 is used to help regulate the pump's displacement and pressure. As the pressure fed back from the outlet 70 increases, that will result in a pressure increase in the control chamber 130, which in turn moves the control slide 116 in the displacement decreasing direction against the bias of the resilient structure 124 (and that in turn will also decrease the pressure differential generated by vanes 120 and thus the pressure of the lubricant discharged from the outlet 70).

Conversely, as the pressure fed back from the outlet 70 decreases, that will result in a pressure decrease in the control chamber 130, which in turn allows the resilient structure to move the control slide 116 in the displacement increasing direction (and that in turn will also increase the pressure differential generated by the rotor 56A and thus the pressure of the lubricant discharged from the outlet 70). This technique may be used to maintain a pump's output pressure and/or volumetric displacement at or near equilibrium levels.

[00100] The second pump 30B may have multiple control chambers for providing different levels of control over the operation of the pump assembly 10B, in accordance with embodiments. In other embodiments, the pump 30B may have only one control chamber.

[00101] The second pump 30B may also include several safety features associated therewith. For example, one or more fail-safe pressure relief valves 140 (e.g., ball valves, check valves, panic valves) may be provided in the housing 12 (see FIGS. 26 and 27A-B). Such valves may be positioned in the inlet path or outlet path of the pump assembly 10B. In accordance with an embodiment, the second pump 30B may include one or more valves as disclosed in U.S. Patent Nos. 9,534,519, 9,771,935, 10,030,656, and 10,247,187, and U.S. Provisional Serial No. 62/799,449 filed Jan. 31, 2019, each of which is hereby incorporated by reference in its entirety.

[00102] Also, while the above exemplary embodiments with respect to FIGS. 18-28 describe use of a vane pump as second pump 30B along with epitrochoidal pump 20B, in another embodiment, second pump 30B may be a gerotor pump (such as shown and described previously with reference to FIG. 3) provided in the same housing and pump assembly as epitrochoidal pump 20B.

[00103] As such, the exemplary embodiment as shown in FIGS. 18-28 provides a more compact packaging option for including air and lubricant pumps in a single housing assembly. Such a design reduces connection parts required to connect to the engine. It also allows for use of a common drive shaft to operate said pumps therein.

[00104] The operation of the pump assembly 10 and/or 10A is further described with reference to FIGS. 12 and 13. Although FIGS. 12 and 13 are described with reference to pump assembly 10, it should be understood that pump assembly 10A may operate and be used in a similar manner as pump assembly 10. As shown in the schematic diagram of FIG. 12, for example, the second (low pressure, gerotor) pump 30 is configured to always provide lubrication to a transmission (see transmission 102 in FIG. 13) as the motor 90 is turning. A flow restrictor may optionally be provided (e.g., outside of the pump assembly, or built into the pump assembly or well, if desired) to restrict the amount of lubricant to the transmission. A controller 104 (shown in FIG. 13) is configured to operate or drive the electric motor 90 (e.g., control a magnetic field of the stator 98 of the motor 90), to thus control and drive the pump assembly 10. Optionally, the second pump 30 may also be configured to selectively flow lubricant through to a cooling system of the transmission, e.g., if cooling is required, via operation of a control valve 112. The controller 104 may control movement of the valve 112 to an open position for feeding to the cooling system, for example. Optionally, a flow restrictor may also (or alternatively) be provided (e.g., outside of the pump assembly) to restrict the amount of lubricant to the cooling system. In some instances, the same flow restrictor may be provided before the inlets for lubricating and cooling the transmission. In an embodiment, the operating pressure for the second pump 30 may be up to approximately 3.0 bar.

[00105] Even though the second pump 30 is configured to continuously pump lubricant to the transmission, the first (high pressure, external gear) pump 20 is not stationary. In accordance with an embodiment, the first pump 20 is also configured to rotate with operation of the motor 90, due to the connecting drive shaft 24 between the two pumps 20 and 30. However, output from the first pump 20 is generally limited in operating conditions, e.g., at approximately 3.0 bar. In some embodiments, e.g., when higher pressurized lubricant is needed by the transmission, such as when lubricant is needed in by a clutch 108 in order for a shift operation to occur, there are instances wherein the first pump 20 is selectively activated. That is, first pump 20 may be activated to output higher pressurized lubricant to the transmission. In accordance with an embodiment, the first pump 20 is configured for use to output lubricant to the clutch 108/transmission when a desired operational pressure of the lubricant is greater than approximately 20 bar. In one embodiment, the first pump 20 is configured to operate when the desired pressure for the outside system/transmission 102 is in a range of approximately 20 bar to approximately 60 bar (both inclusive).

[00106] In accordance with an embodiment, control valve 114, shown schematically in FIG. 12, is provided to selectively limit (or selectively allow) output from the first pump 20 to the clutch 108/transmission 102. For example, in its first position, the valve 114 may be configured to direct output pressurized fluid from first outlet opening 62 to the clutch 108. Otherwise, at lower pressures (i.e., less than 20 bar), the valve 114 may be configured to be provided in a second position, such that the first pump 20 recirculates the lubricant back to the tank 106, as shown in FIG. 12. Alternatively, in some embodiments, the output from the first pump 20 may be designed to assist the second pump 30 in lubricating the transmission at the low pressure.

[00107] The controller 104 is further configured to control the selective activation of the valve 114 and thus use of the output from the first pump 20.

[00108] The first epitrochoidal pump 20B may be used provide a vacuum, i.e., negative pressure or air, to any number of systems in a vehicle, e.g., a brake booster system, pneumatic actuators, and/or valves. The second vane pump 30B may be used as an oil pump to supply pressurized lubricant to another system, e.g., to act as a booster for a circuit to an engine or transmission, to provide lubricant and/or cooling to a gearbox, to assist in clutch operation, and/or another smaller pump within a vehicle.

[00109] Accordingly, the pump assemblies 10 and 10A and 10B as disclosed herein provides several features and improvements, including that both pumps (20, 30) provided in the assemblies 10 and 10A and 10B are integrated and contained in one housing and share a common wall 80 in that housing, thereby allowing for a more compact configuration and construction. As such, a larger space needed for mounting the disclosed pump assembly is not necessary. Further, fabrication and machining costs for forming the housing 12 are reduced. Additionally, both pumps (20, 30) are driven via the same shaft 24 (whether of singular or connected construction) in the housing 12.

[00110] When used in a system with a control valve, the output from the first pump may be limited. As such, the pump assembly 10 and/or 10A and/or 10B may operate under a range of operating conditions or stages, including selective use of a high pressure / first pump when required.

[00111] While the principles of the disclosure have been made clear in the illustrative embodiments set forth above, it will be apparent to those skilled in the art that various modifications may be made to the structure, arrangement, proportion, elements, materials, and components used in the practice of the disclosure.

[00112] It will thus be seen that the features of this disclosure have been fully and effectively accomplished. It will be realized, however, that the foregoing preferred specific embodiments have been shown and described for the purpose of illustrating the functional and structural principles of this disclosure and are subject to change without departure from such principles. Therefore, this disclosure includes all modifications encompassed within the spirit and scope of the following claims.

WHAT IS CLAIMED IS:

1. A two-stage pump assembly comprising:

a first pump and a second pump for pumping lubricant to a system, both the first pump and the second pump being integrated into a single housing and each configured to pressurize lubricant input into the housing;

a drive shaft provided in the housing configured to rotate about a drive axis and drive both the first pump and the second pump, the drive shaft being driven by a single input device;

both the first pump and the second pump comprising at least one gear configured and arranged to be rotated by the drive shaft;

the first pump comprising a first inlet provided on the housing for receiving lubricant from a source outside the housing and a first outlet for directing lubricant that is pressurized out of the housing;

the second pump comprising a second inlet provided on the housing for receiving lubricant from the source outside the housing and a second outlet for directing lubricant that is pressurized out of the housing, the second inlet and the second outlet being different than the first inlet and the first outlet, respectively;

the housing further comprising a wall that is common to both the first pump and the second pump, the first pump being provided on a first side of the wall and the second pump being provided on a second side of the wall that is opposite to the first side, and wherein the drive shaft extends through the wall and connects to each of the at least one gears of both the first pump and the second pump.

2. The pump assembly of claim 1, wherein the wall includes a first pocket on the first side thereof containing the at least one gear of the first pump therein and a second pocket on a second side thereof, the second pocket containing the at least one gear of the second pump therein, and wherein the drive shaft extends through the wall and connects to each of the at least one gears contained in the first pocket and the second pocket.

3. The pump assembly of claim 1, wherein the single input device for driving the drive shaft of the pump assembly is an engine, a transmission, or an electric motor.

4. The pump assembly of claim 1, wherein the first pump is an external gear pump comprising two gears provided on two parallel axes, the first gear being a driving gear that is driven by the drive shaft connected to the second pump, and the second gear being a driven gear coupled to a rotatable shaft.

5. The pump assembly of claim 2, wherein the wall further comprises a third pocket therein, the third pocket being provided on the first side of the wall, wherein the first pump is an external gear pump comprising first and second gears provided on two parallel axes, and wherein the second gear of the first pump is contained in the third pocket.

6. The pump assembly of claim 4, wherein the second pump is a gerotor pump comprising an inner rotor that acts as a driving gear and that is rotated relative to an outer rotor, and wherein the outer rotor of the second pump is provided on the second side of the wall.

7. The pump assembly of claim 1, wherein the drive shaft is a single, common drive shaft.

8. The pump assembly of claim 1, wherein the drive shaft comprises a first drive shaft and a second drive shaft co-axially connected to one another for rotating together about the drive axis.

9. The pump assembly of claim 7, wherein the first drive shaft and the second drive shaft are connected via a coupling.

10. The pump assembly of claim 1, further comprising a first cover plate connected to the housing and covering at least the at least one gear of the first pump and a second cover plate connected to the housing and covering at least the at least one gear of the second pump.

11. The pump assembly of claim 10, wherein the first cover plate of the first pump comprises a floating cover plate.

12. The pump assembly of claim 10, wherein the first cover plate of the first pump comprises a fixed cover plate.

13. The pump assembly of claim 10, wherein the first inlet of the first pump comprises a first inlet opening provided in the first cover plate, the first inlet opening receiving the lubricant from the source outside the housing, and wherein the first inlet opening is provided on a plane that is perpendicular to the drive axis of the drive shaft.

14. The pump assembly of claim 13, wherein the first outlet comprises a first outlet opening, wherein the second inlet comprises a second inlet opening, and wherein the first outlet opening and the second inlet opening are provided on the same side of the housing.

15. The pump assembly of claim 14, wherein the first outlet opening and the second inlet opening are provided on a plane that is parallel to the drive axis of the drive shaft.

16. The pump assembly of claim 14, wherein the second outlet comprises a second outlet opening, and wherein the second outlet opening is provided on the same side of the housing as the first outlet opening and the second inlet opening.

17. The pump assembly of claim 16, wherein the second outlet opening is provided on a plane that is parallel to the drive axis of the drive shaft.

18. The pump assembly of claim 15, wherein the second pump further comprises a third inlet, the third inlet comprising a third inlet opening, and wherein the third inlet opening is positioned on another side of the housing that is traverse to the side of the housing containing the first outlet opening, the second inlet opening, and the second outlet opening.

19. The pump assembly of claim 18, wherein the third inlet opening is provided on a plane that is perpendicular to the drive axis of the drive shaft.

20. The pump assembly of claim 16, wherein the first inlet opening and the third inlet opening are provided on the same side of the housing.

21. A system comprising the two stage pump assembly of claim 1 and a transmission, wherein the second pump is configured to continuously pump the lubricant to the transmission, and wherein the transmission comprises a clutch system that selectively receiving lubricant pumped from the first pump, the system further comprising a control valve for limiting the lubricant that is output from the first pump to the clutch system of the transmission.

22. A system comprising the two stage pump assembly of claim 1 and a driver connected to the pump assembly, wherein the driver is configured to rotate the drive shaft of the pump assembly for pumping the lubricant to the transmission or engine.

23. A pump assembly comprising:

a first pump for pumping air and a second pump for pumping lubricant to a system, both the first pump and the second pump being integrated into a single housing;

a drive shaft provided in the housing configured to rotate about a drive axis and drive both the first pump and the second pump, the drive shaft being driven by a single input device;

both the first pump and the second pump comprising a rotor configured and arranged to be rotated by the drive shaft;

the first pump comprising a first inlet provided on the housing for receiving air from outside the housing and a first outlet for directing air that is pressurized out of the housing;

the second pump comprising a second inlet provided on the housing for receiving lubricant from a source outside the housing and a second outlet for directing lubricant that is pressurized out of the housing, the second inlet and the second outlet being different than the first inlet and the first outlet, respectively;

the housing further comprising a wall that is common to both the first pump and the second pump, the first pump being provided on a first side of the wall and the second pump being provided on a second side of the wall that is opposite to the first side, and wherein the drive shaft extends through the wall and connects to each of the rotors of both the first pump and the second pump.

24. The pump assembly of claim 23, wherein the wall includes a first pocket on the first side thereof containing the rotor of the first pump therein and a second pocket on a second side thereof, the second pocket containing the rotor of the second pump therein, and wherein the drive shaft extends through the wall and connects to each of the rotors contained in the first pocket and the second pocket.

25. The pump assembly of claim 23, wherein the single input device for driving the drive shaft of the pump assembly is an engine, a transmission, or an electric motor.

26. The pump assembly of claim 23, wherein the first pump is an epitrochoidal vacuum pump, wherein the first side of the wall defines and is part of an internal space having an epitrochoidal shape, wherein the rotor of the epitrochoidal vacuum pump is rotatably received within the internal space, the rotor being shaped with a number of edges that conjugate with the epitrochoidal shape of the internal space and comprising an internally toothed guide gear; the drive shaft being configured to rotate the rotor eccentrically within the internal space; and wherein the epitrochoidal vacuum pump comprises an externally toothed guide sprocket for meshing with and guiding movement of the guide gear of the rotor as it is driven by the drive shaft.

27. The pump assembly of claim 26, wherein the second pump is a vane pump comprising a control slide having a rotor receiving space communicated to the first inlet and the first outlet, the rotor of the second pump being provided in the rotor receiving space, the rotor comprising a plurality of vanes 26, the vanes being movable within the rotor receiving space, and the rotor being rotatable in the rotor receiving space to draw lubricant under negative pressure into the rotor receiving space via the second inlet for pressurization and discharge pressurized lubricant from the rotor receiving space via the second outlet under positive pressure.

28. The pump assembly of claim 23, wherein the drive shaft is a single, common drive shaft.

29. The pump assembly of claim 23, wherein the drive shaft comprises a first drive shaft and a second drive shaft co-axially connected to one another for rotating together about the drive axis.

30. The pump assembly of claim 23, wherein the first inlet of the first pump comprises a first inlet opening for receiving the air from outside the housing, and wherein the first inlet opening is provided on a plane that is perpendicular to the drive axis of the drive shaft.

31. The pump assembly of claim 30, wherein the rotor of the first pump is provided on a first side of a plane parallel to the common wall and wherein the first inlet opening is provided on a second side of the plane that is parallel to the common wall.

32. The pump assembly of claim 30, wherein the first outlet comprises a first outlet opening, wherein the second inlet comprises a second inlet opening, and wherein the first outlet opening and the second inlet opening are provided on the same side of the housing.

33. The pump assembly of claim 30, wherein the second outlet comprises a second outlet opening, and wherein the second outlet opening is provided on the same side of the housing as the first inlet opening.

34. The pump assembly of claim 33, wherein the second outlet opening is provided on a plane that is parallel to the drive axis of the drive shaft.

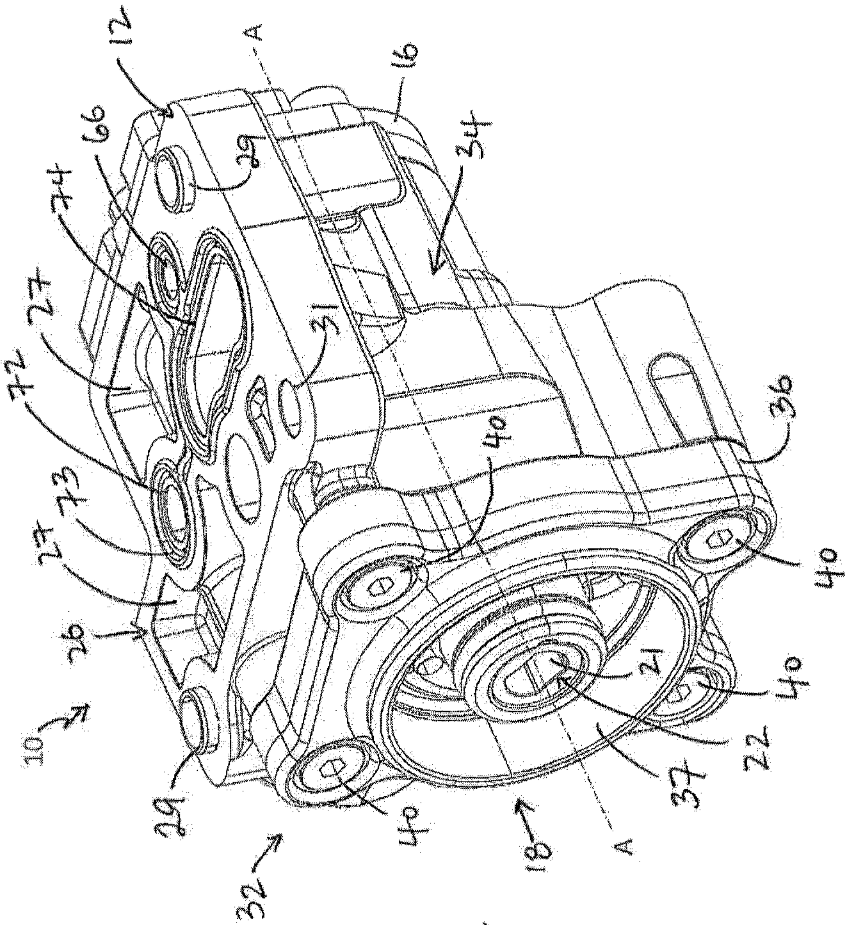

FIG. 2

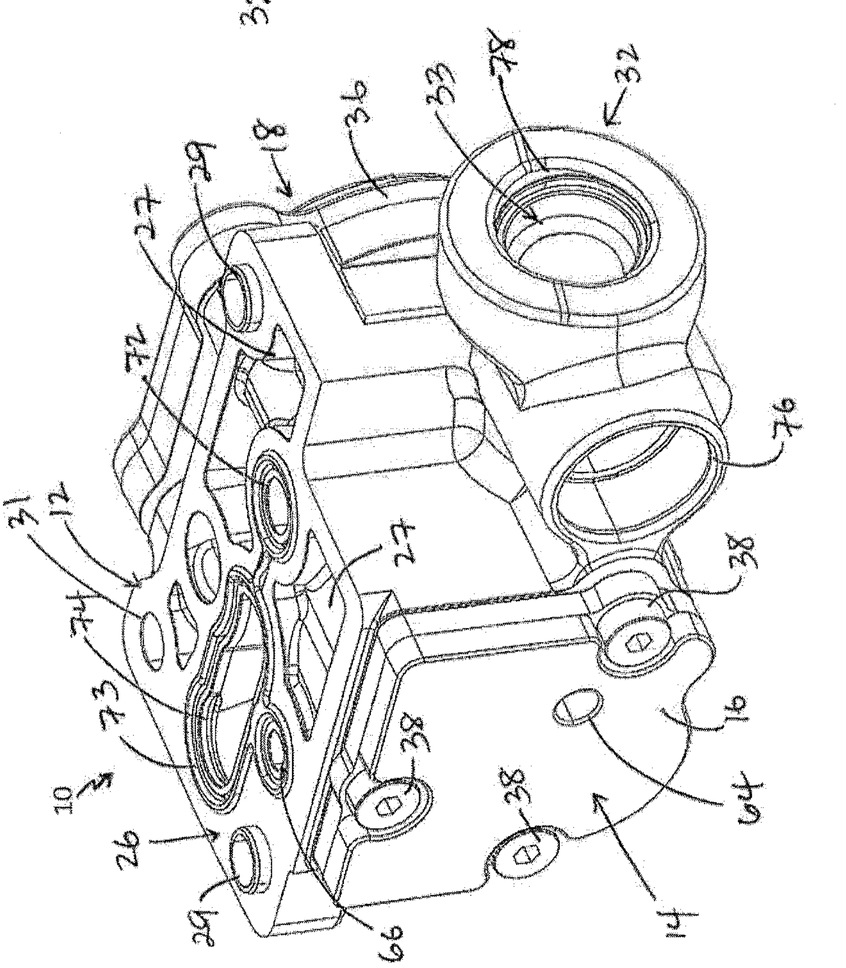

FIG. 1

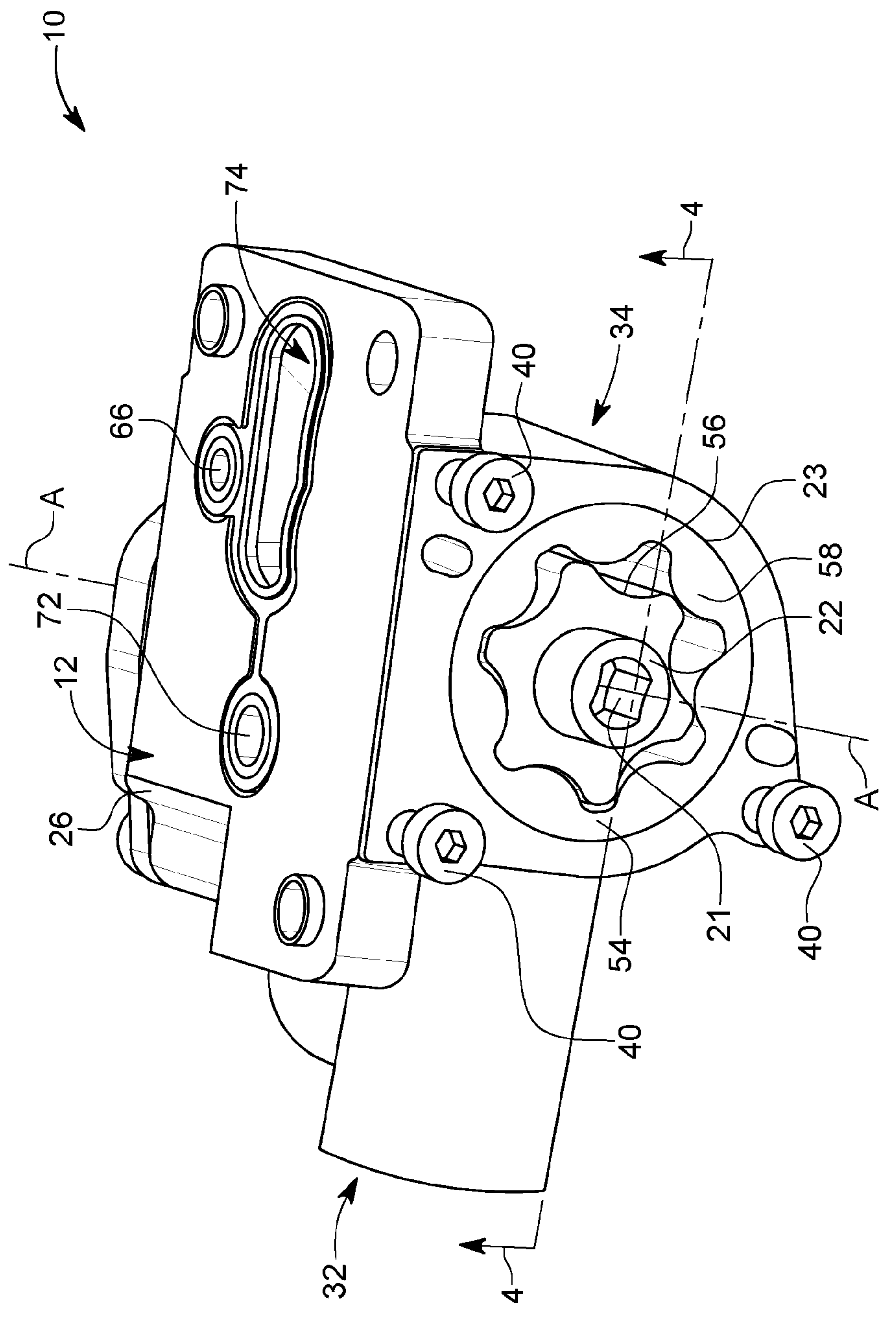

FIG. 3

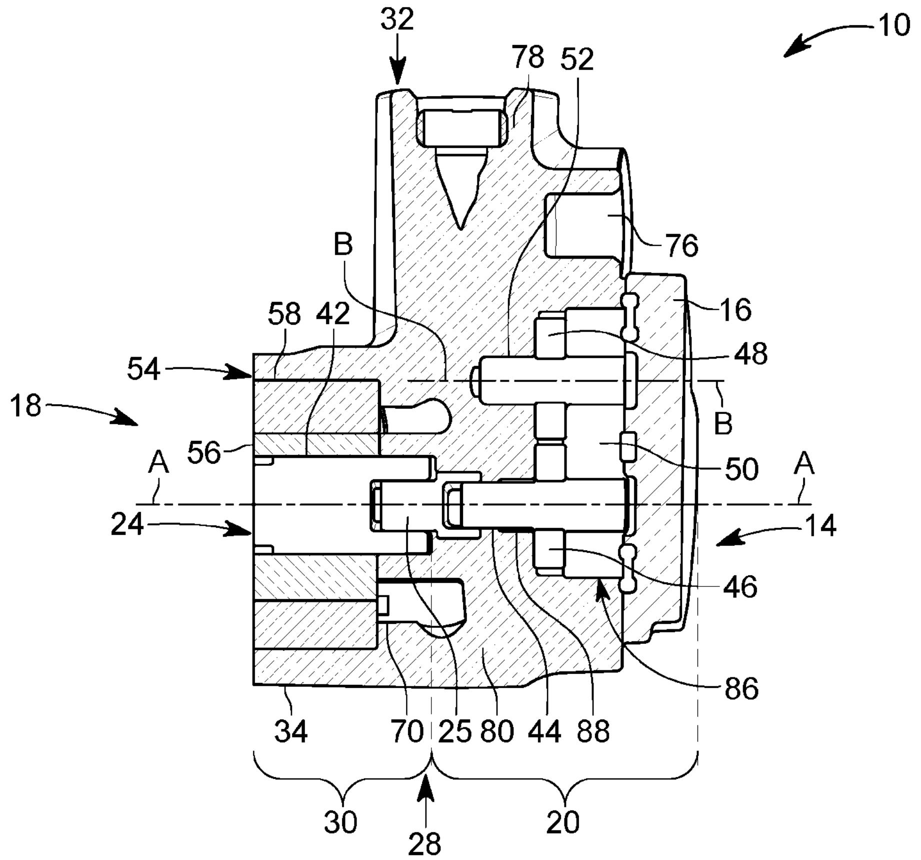
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FIG. 4A

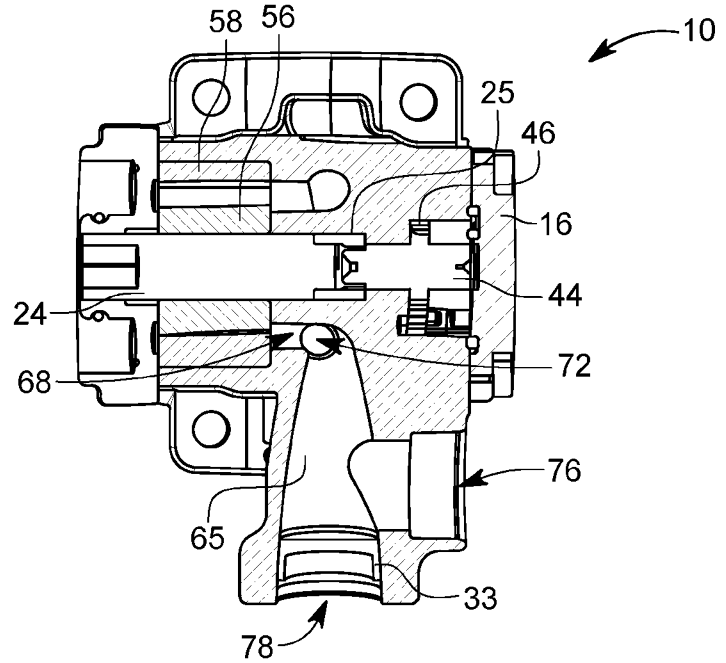
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FIG. 4B

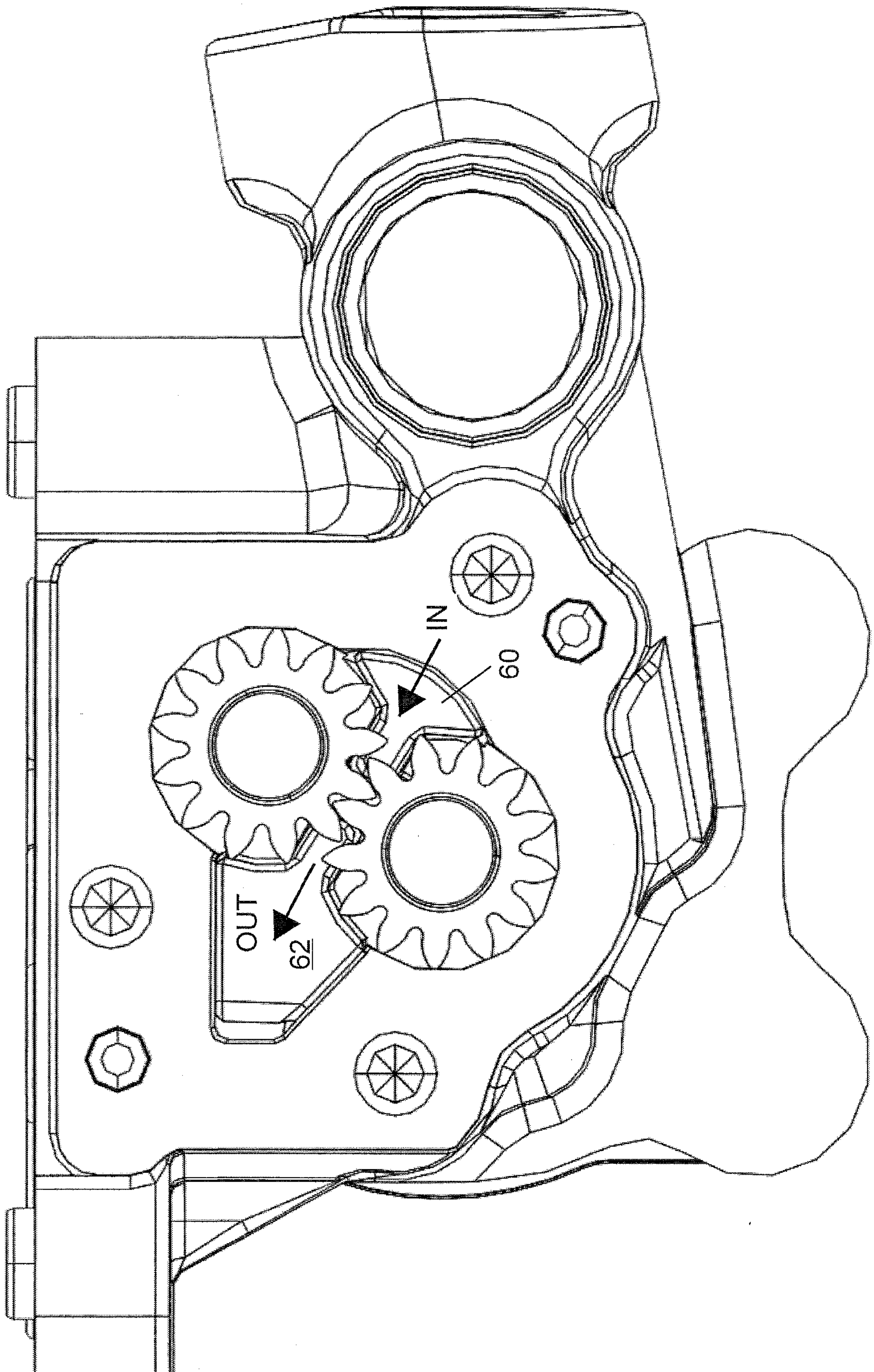

FIG. 4C

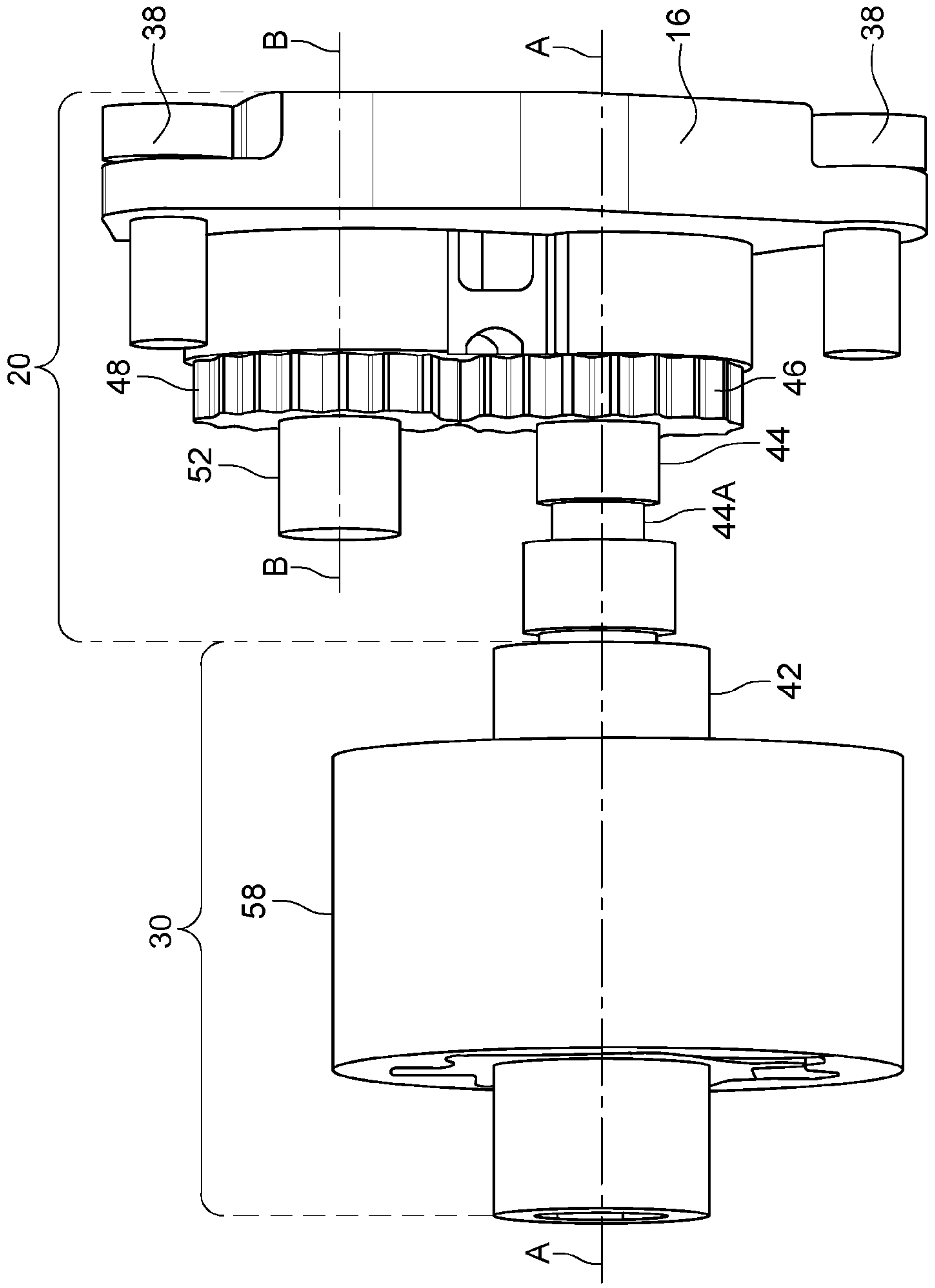

FIG. 5

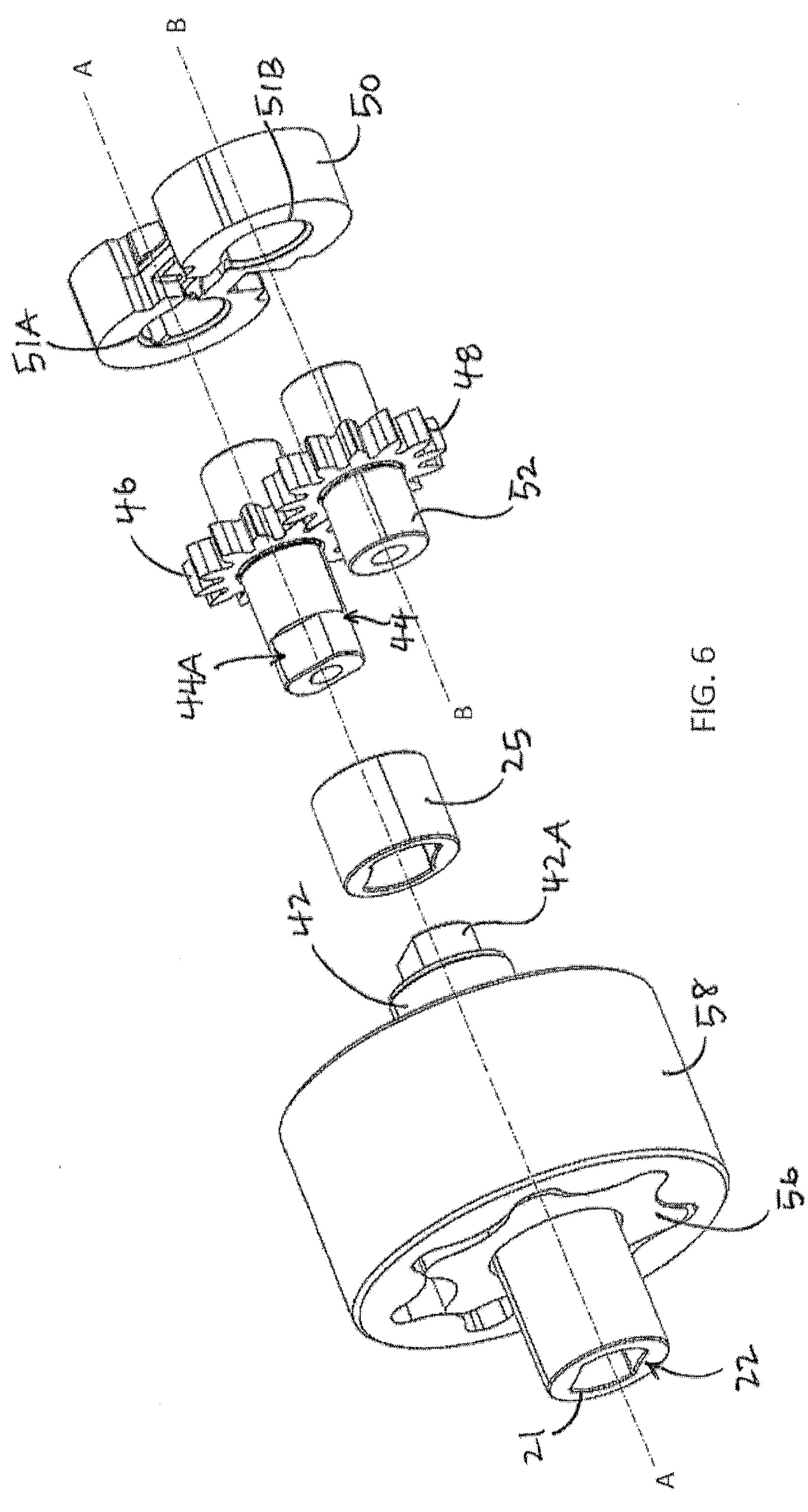

FIG. 6

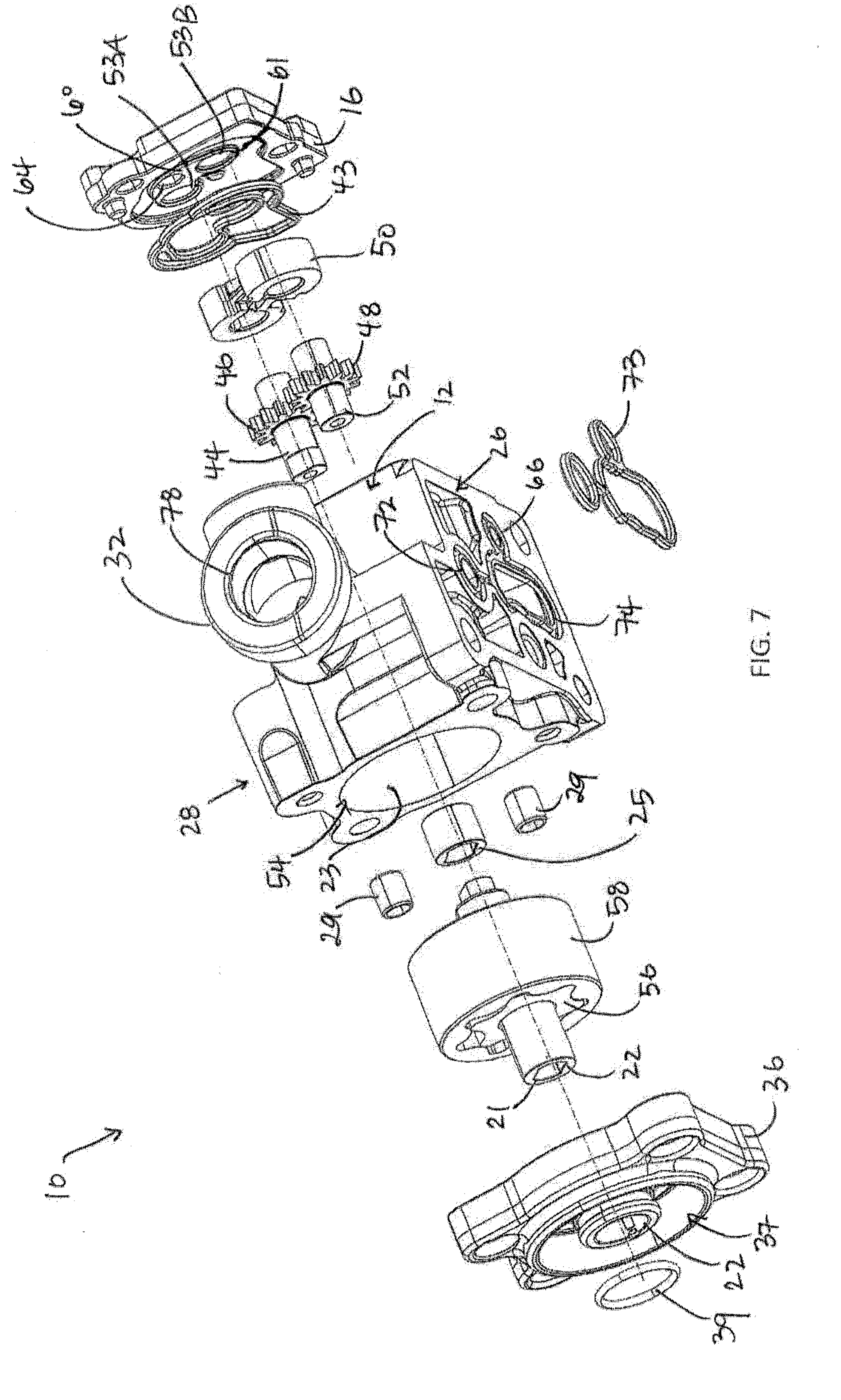
64
60
53A
53B
61
16
43
50
46
48
52
44
12
26
66
73
32
78
72
74
28
29
25
54
23
29
58
56
22
21
36
37
22
39
10

FIG. 7

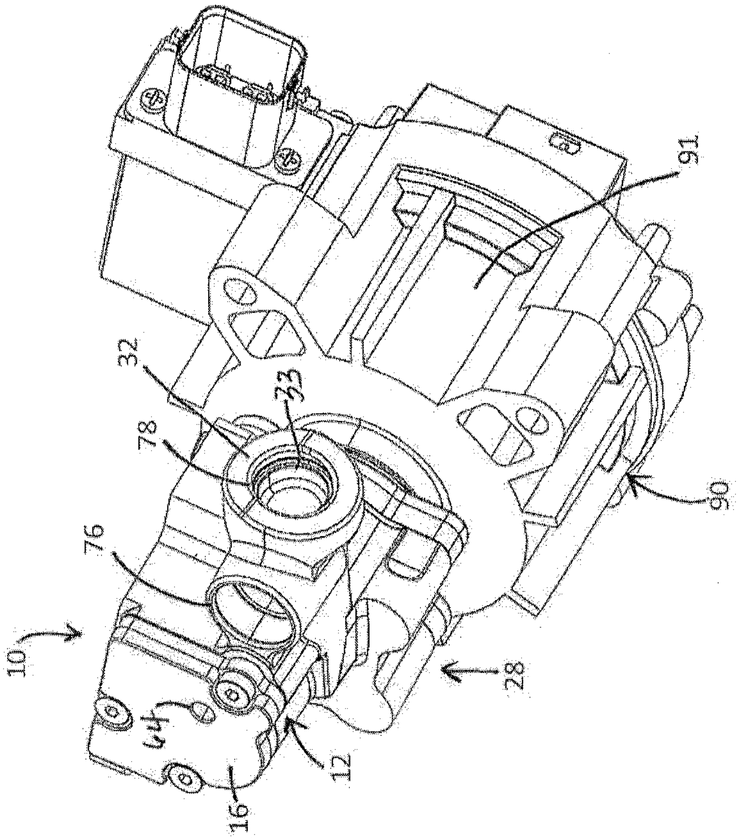
10
76
78
32
33
91
90
28
12
16
44

FIG. 9

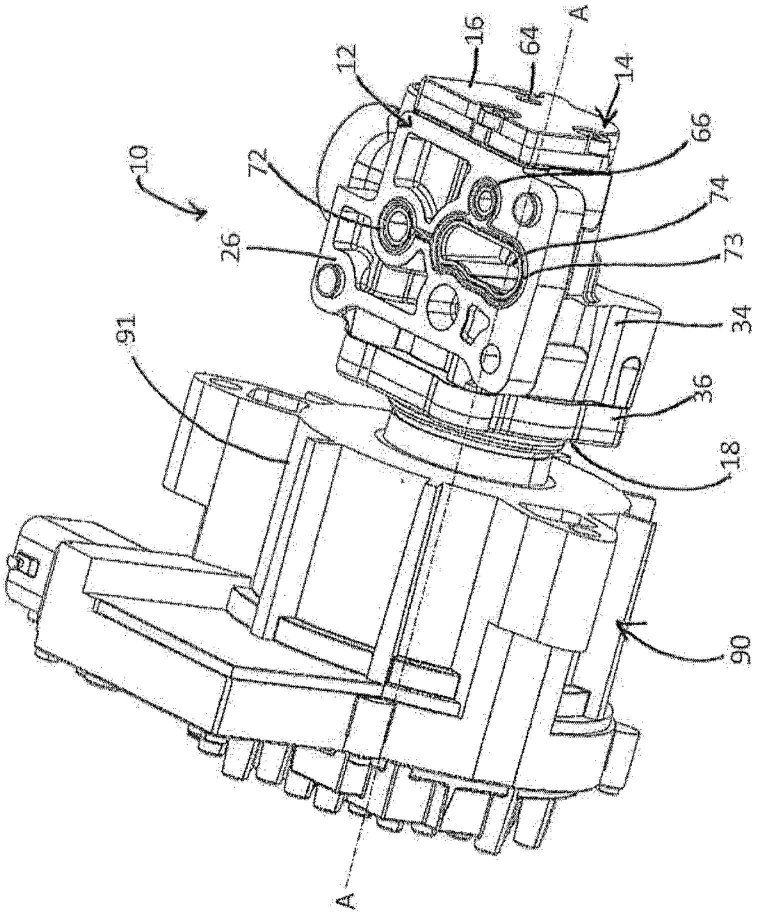
10
72
26
91
12
16
64
A
14
66
74
73
34
36
18
90
A

FIG. 8

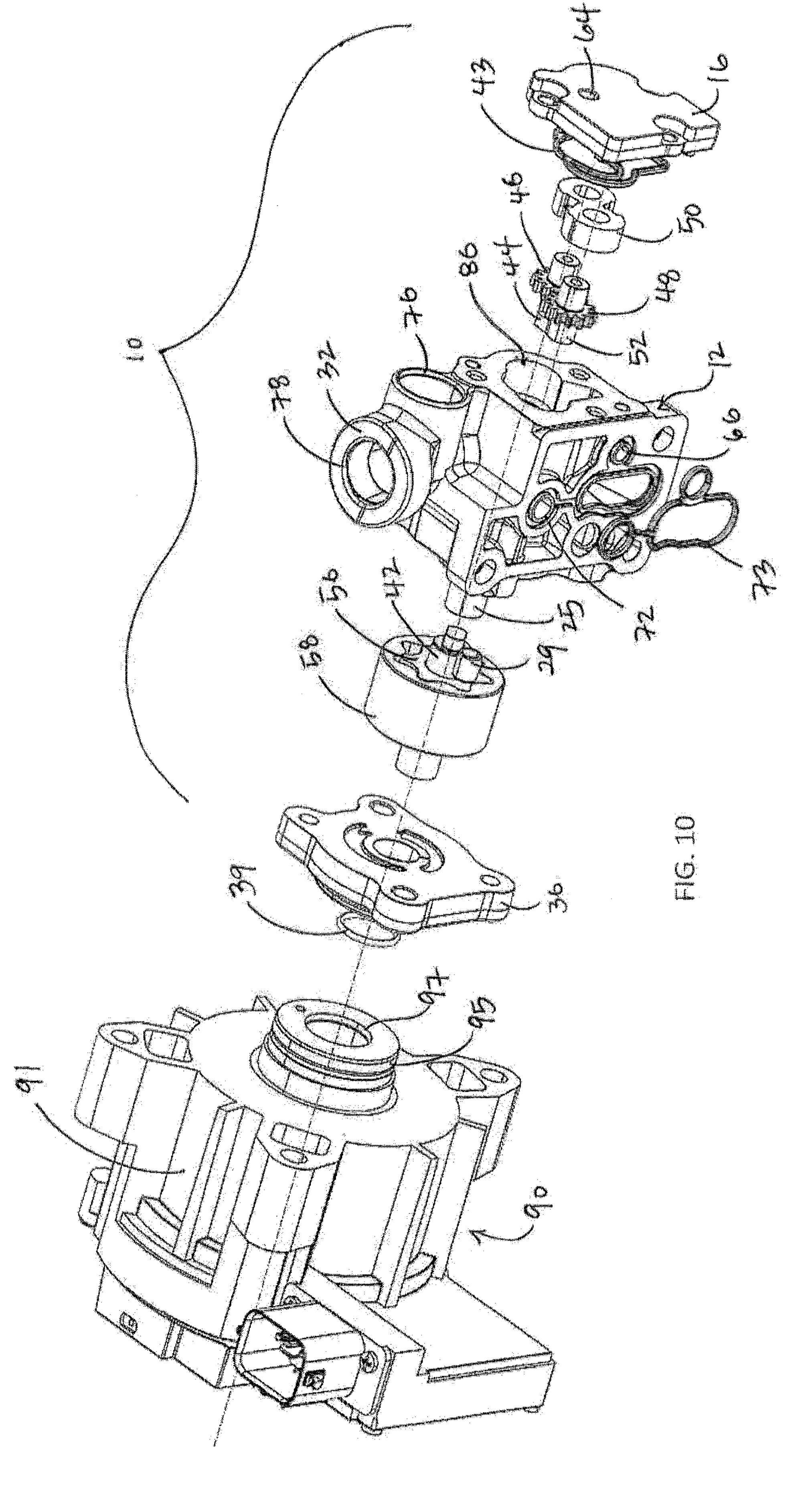
10
64
43
16
46
50
44
48
52
86
76
32
78
12
66
73
72
25
29
42
56
58
39
36
97
95
91
90

FIG. 10

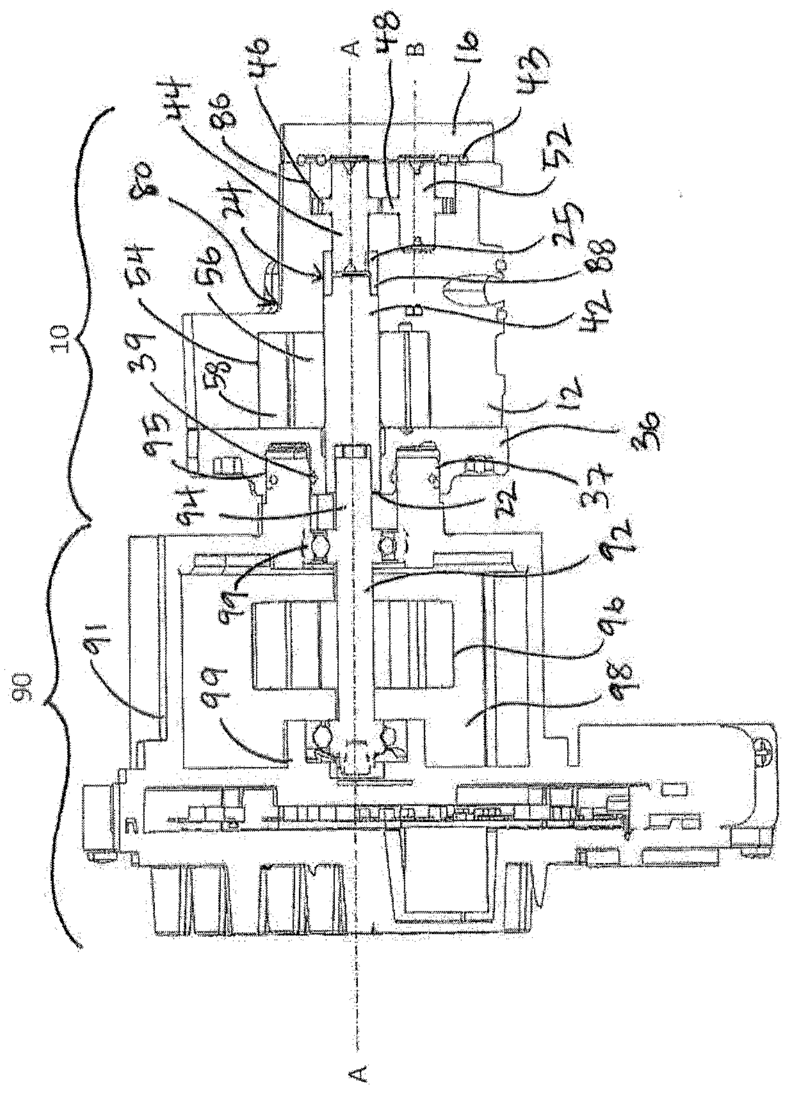
10
90
A
A
B
B
46
48
16
43
44
86
80
52
25
88
42
24
54
56
58
39
95
94
12
36
37
22
92
99
96
98
91
99

FIG. 11A

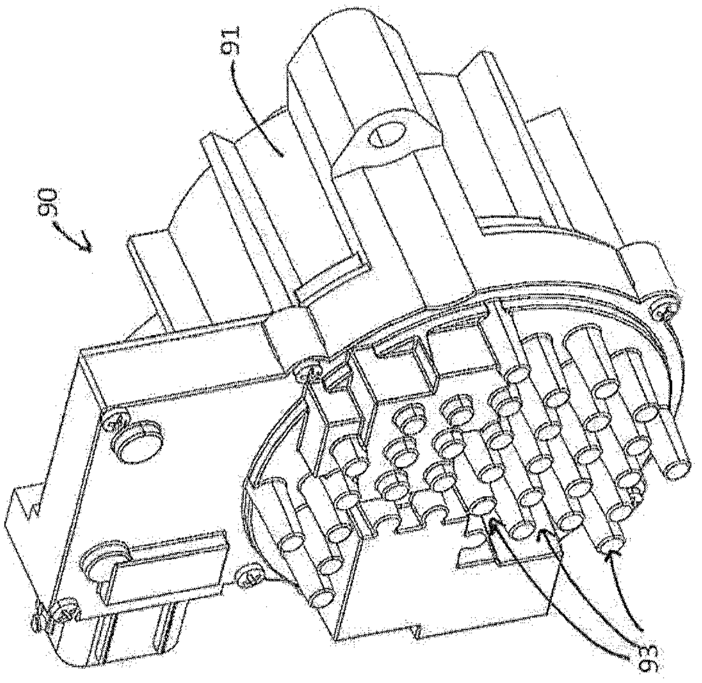

FIG. 11C

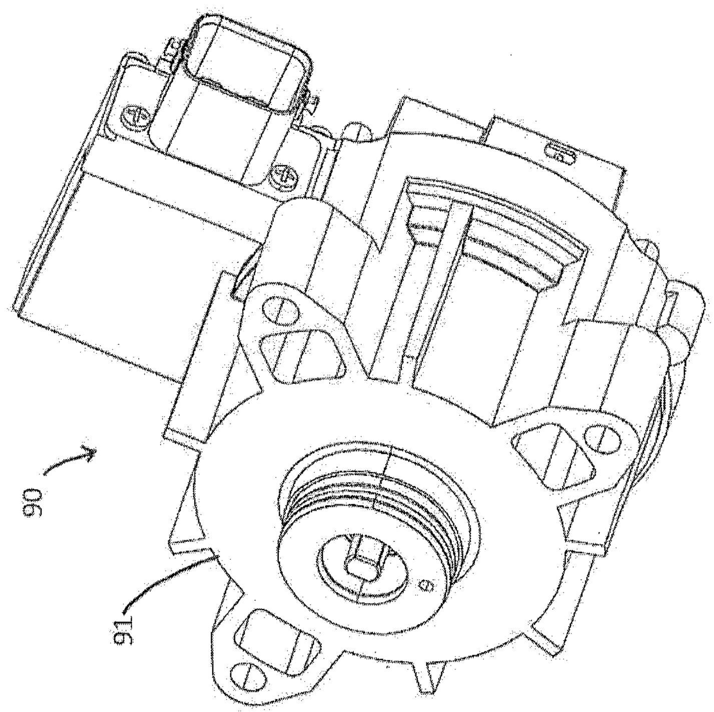

FIG. 11B

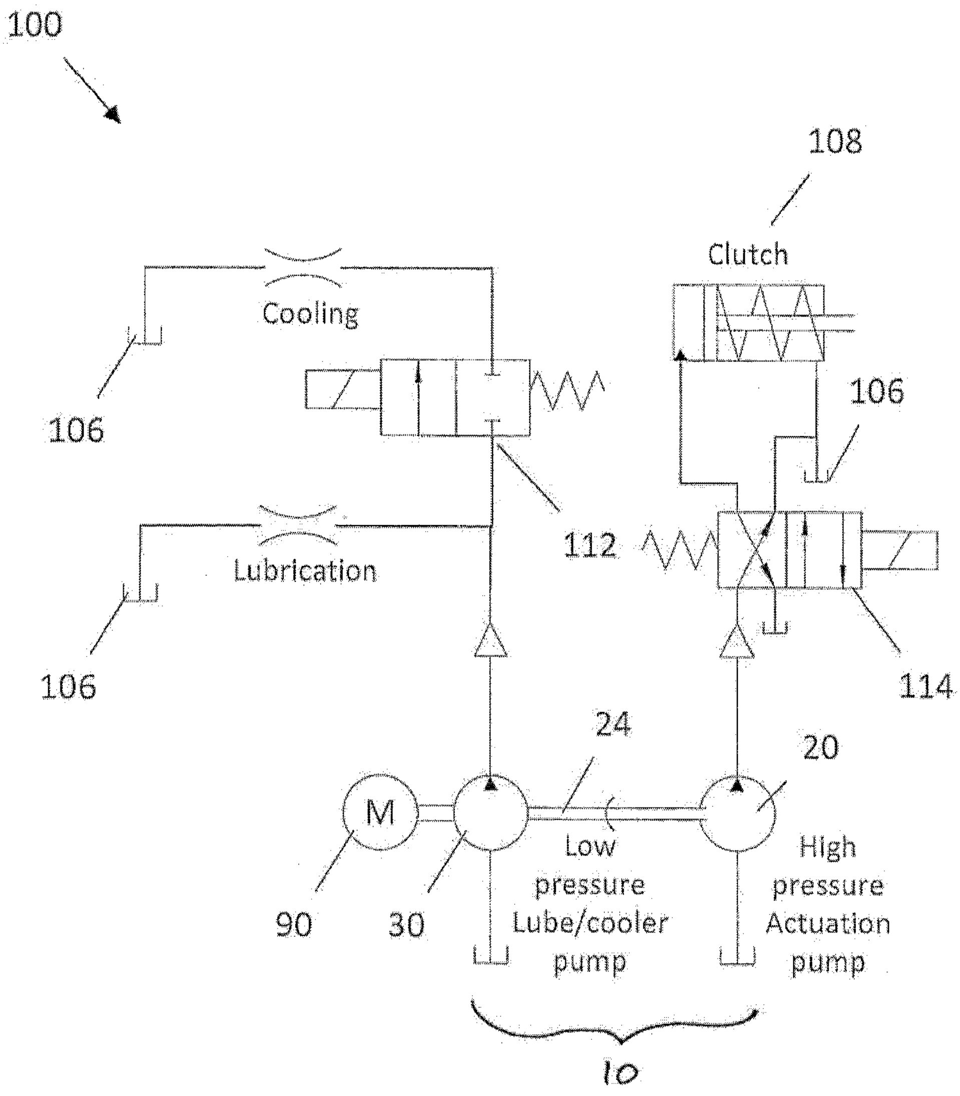
100
108
Clutch
Cooling
106
106
112
Lubrication
106
114
24
20
M
Low
pressure
Lube/cooler
pump
High
pressure
Actuation
pump
90
30
10

FIG. 12

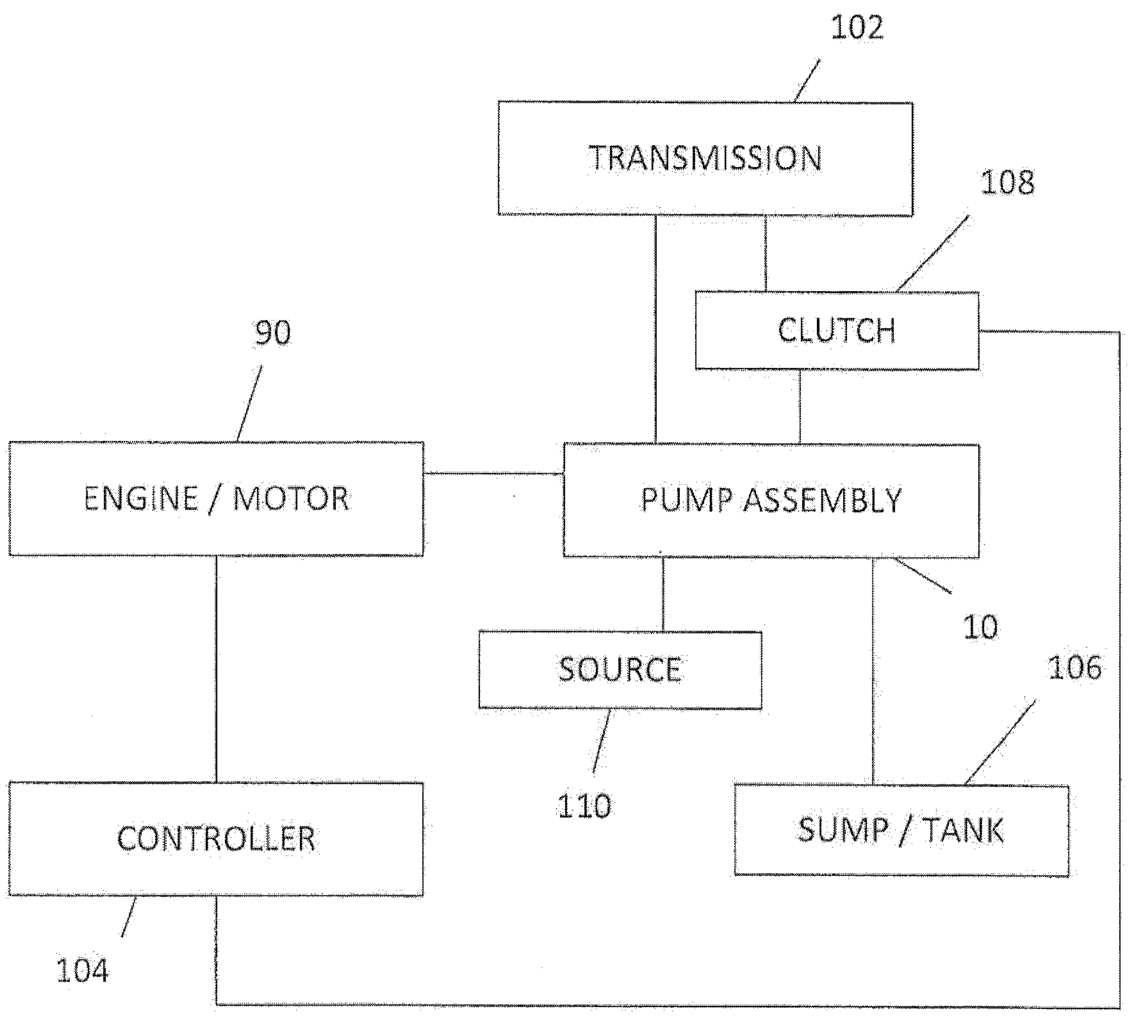
102
TRANSMISSION
108
CLUTCH
90
ENGINE / MOTOR
PUMP ASSEMBLY
10
SOURCE
106
110
SUMP / TANK
CONTROLLER
104

FIG. 13

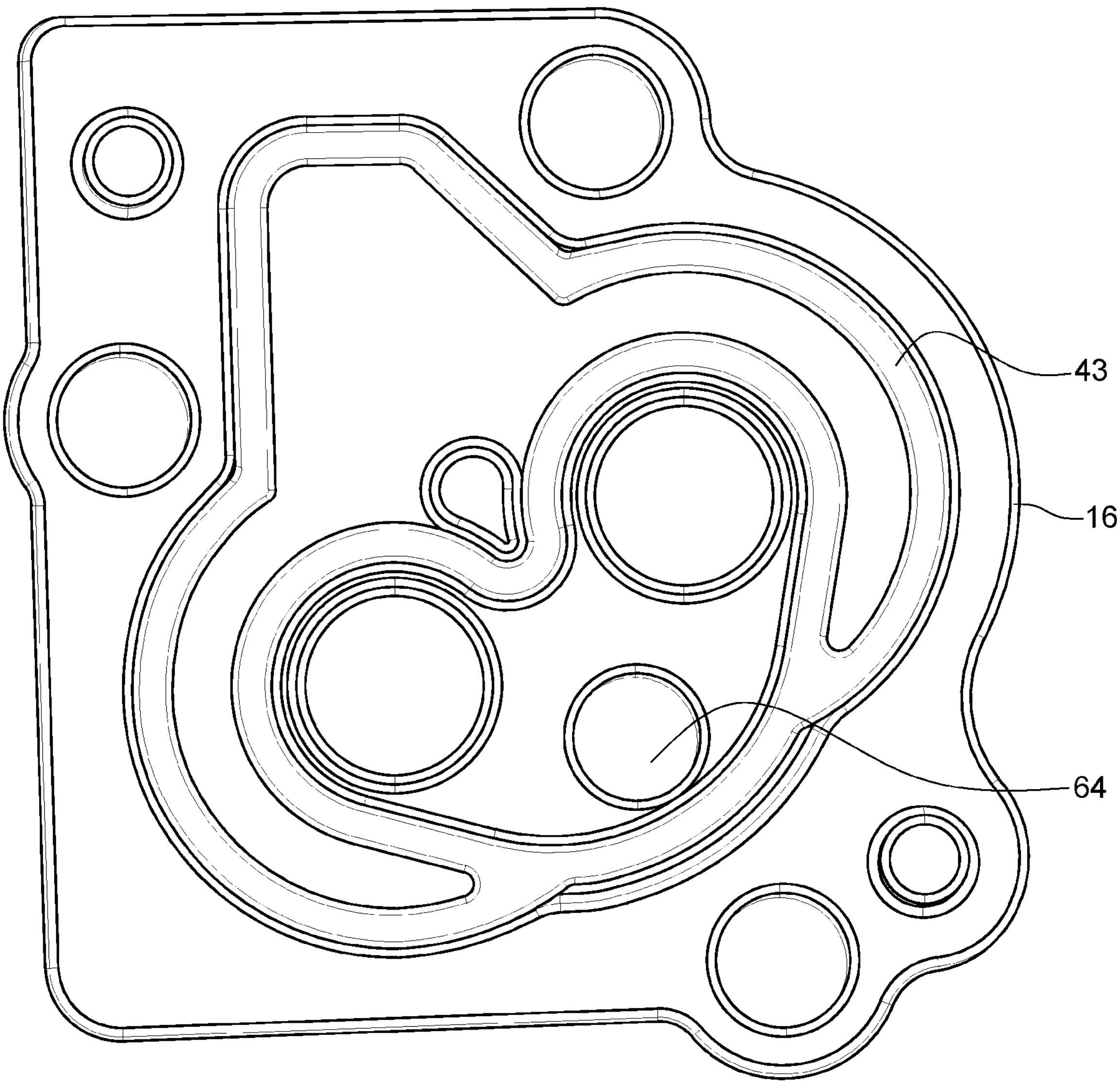

FIG. 14

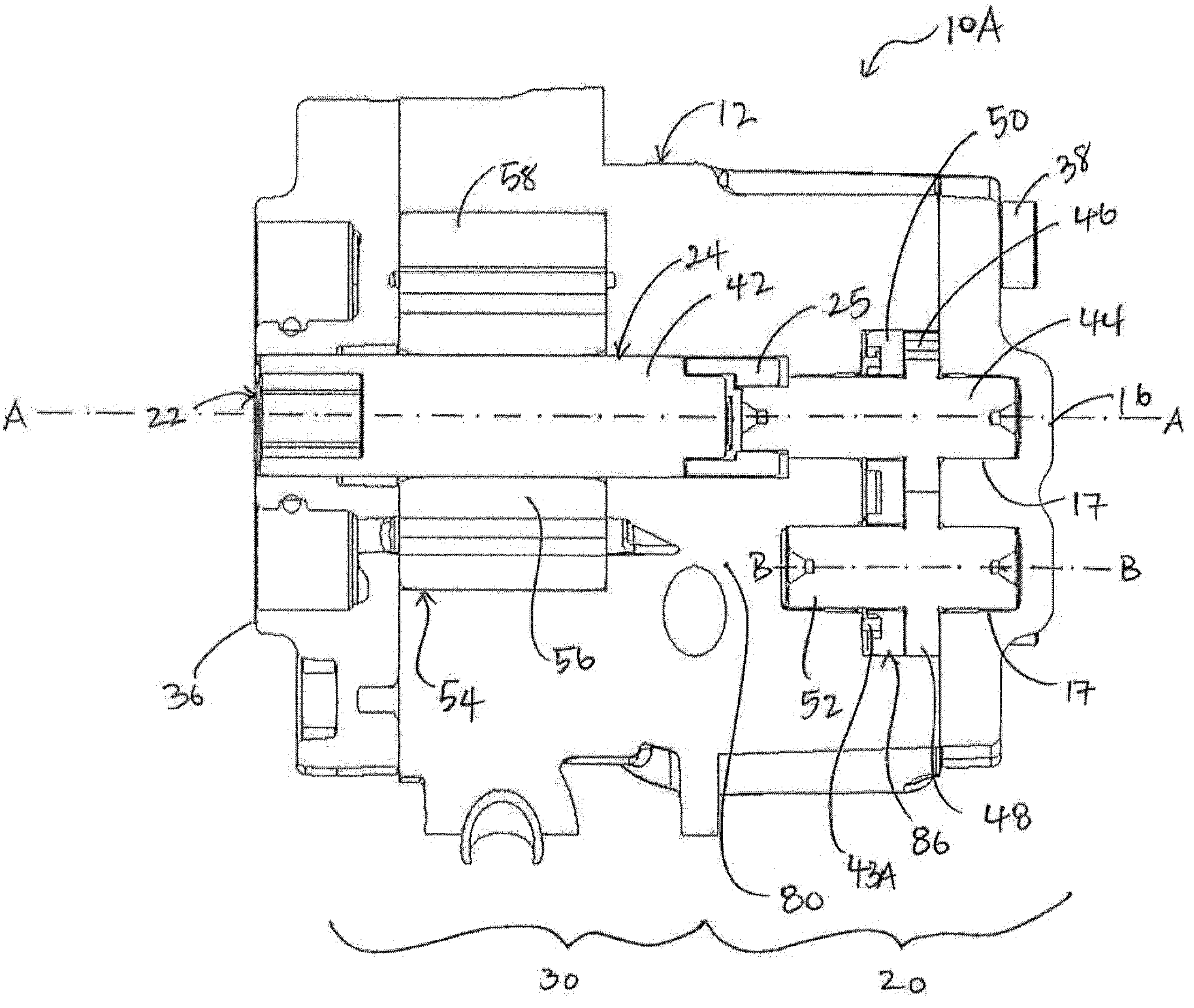
10A
12
50
38
46
58
24
42
25
44
A
22
16
A
17
B
B
17
36
54
56
52
80
43A
86
48
30
20

FIG. 15

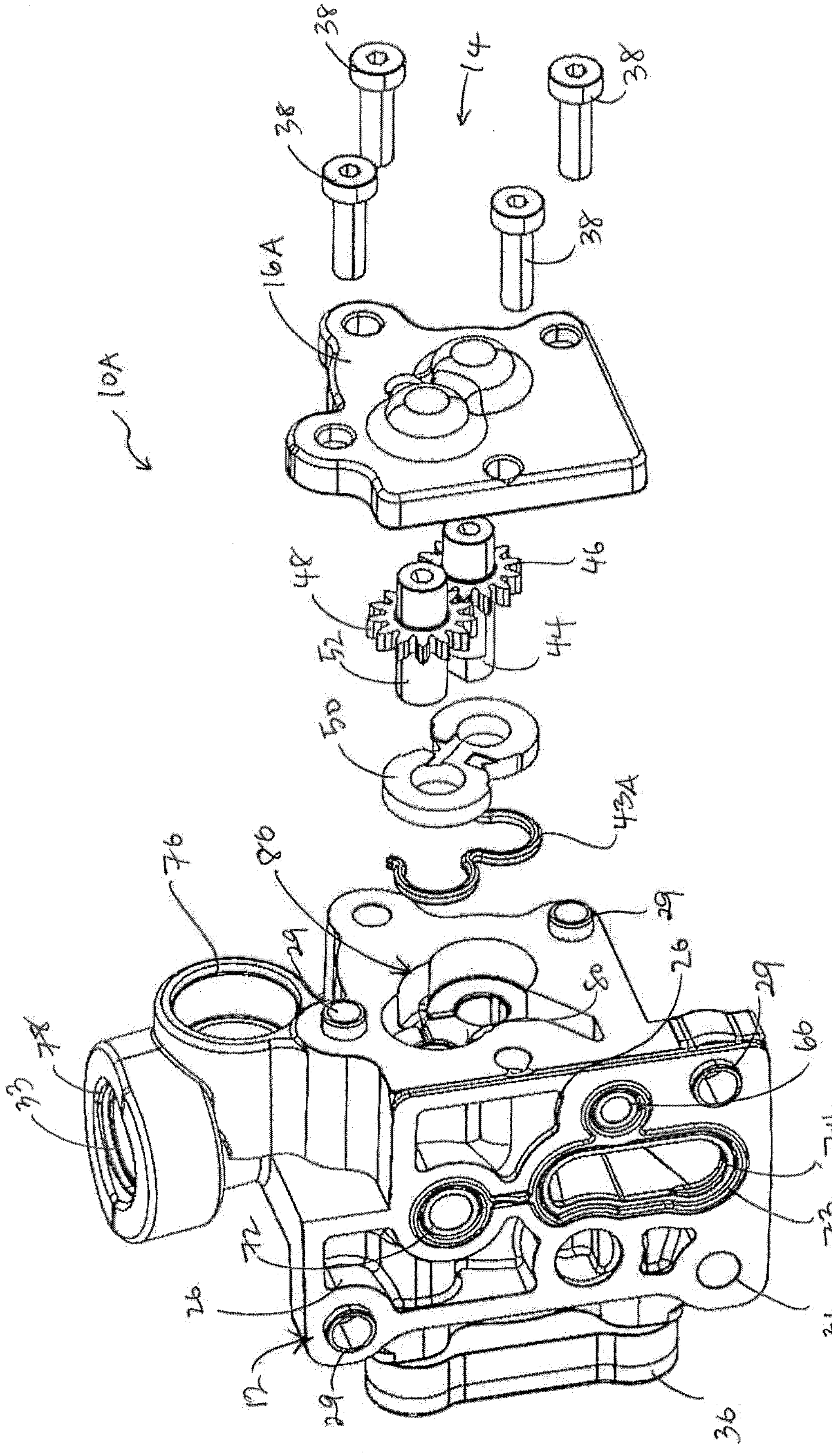
38
14
38
38
38
16A
10A
48
46
52
44
50
43A
76
80
29
29
26
58
29
66
33
78
74
73
72
26
31
12
29
36

FIG. 16

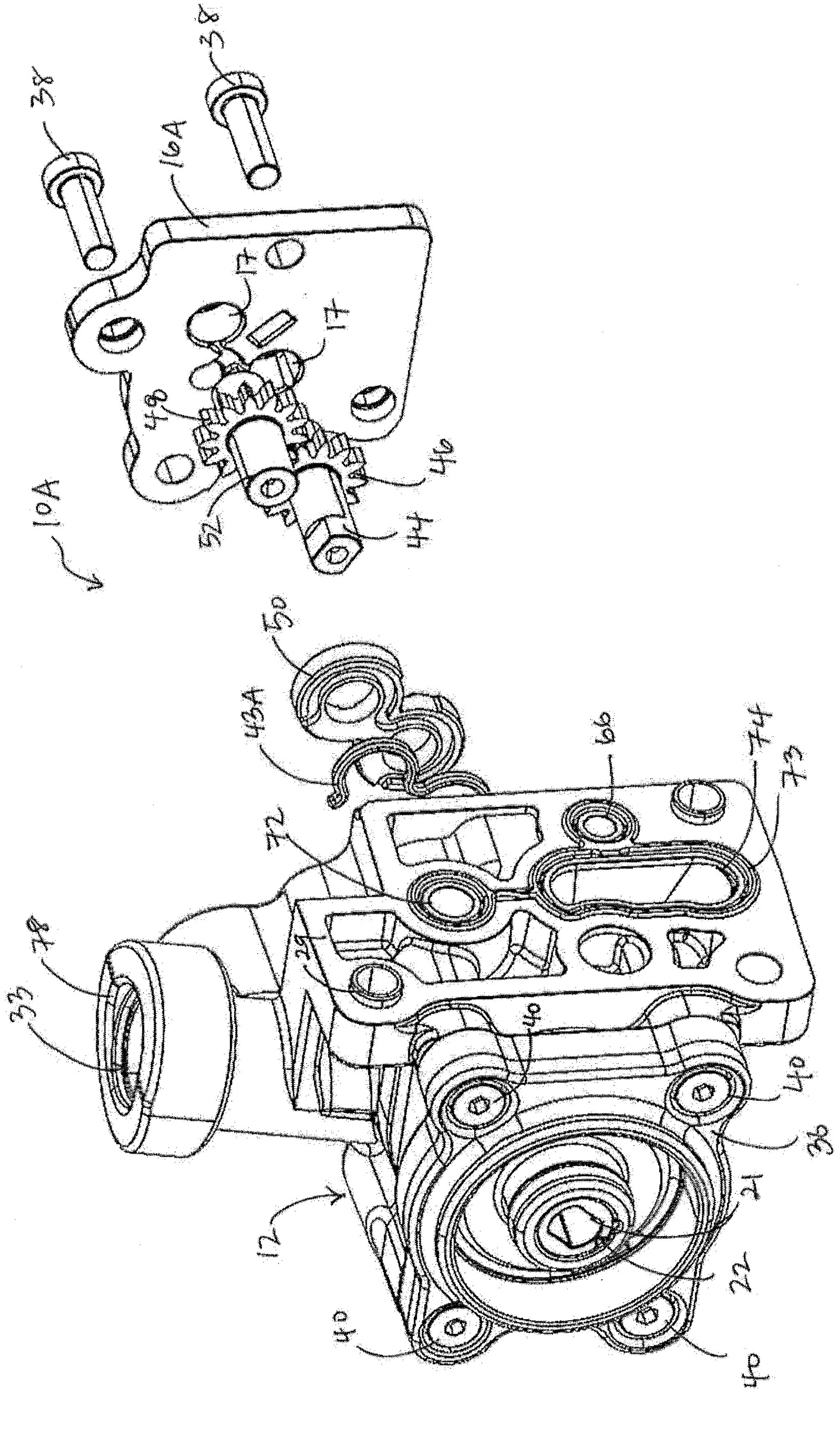
38
38
16A
17
17
17
48
46
44
52
10A
50
43A
66
74
73
72
29
78
33
40
40
36
12
21
22
40
40

FIG. 17

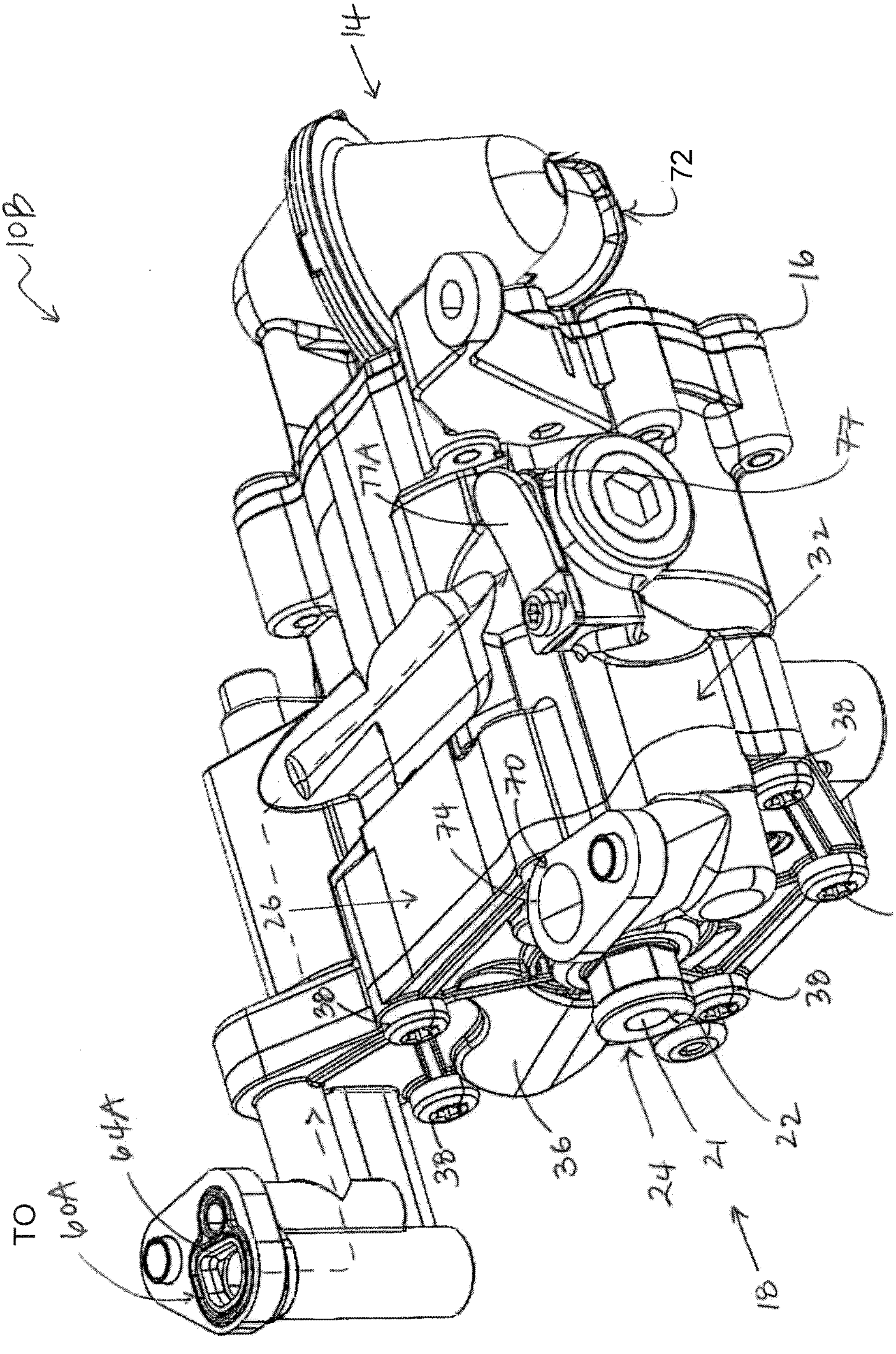
10B
14
72
16
77
77A
32
38
70
74
26
38
38
38
36
24
21
22
38
TO
60A
64A
18

FIG. 18

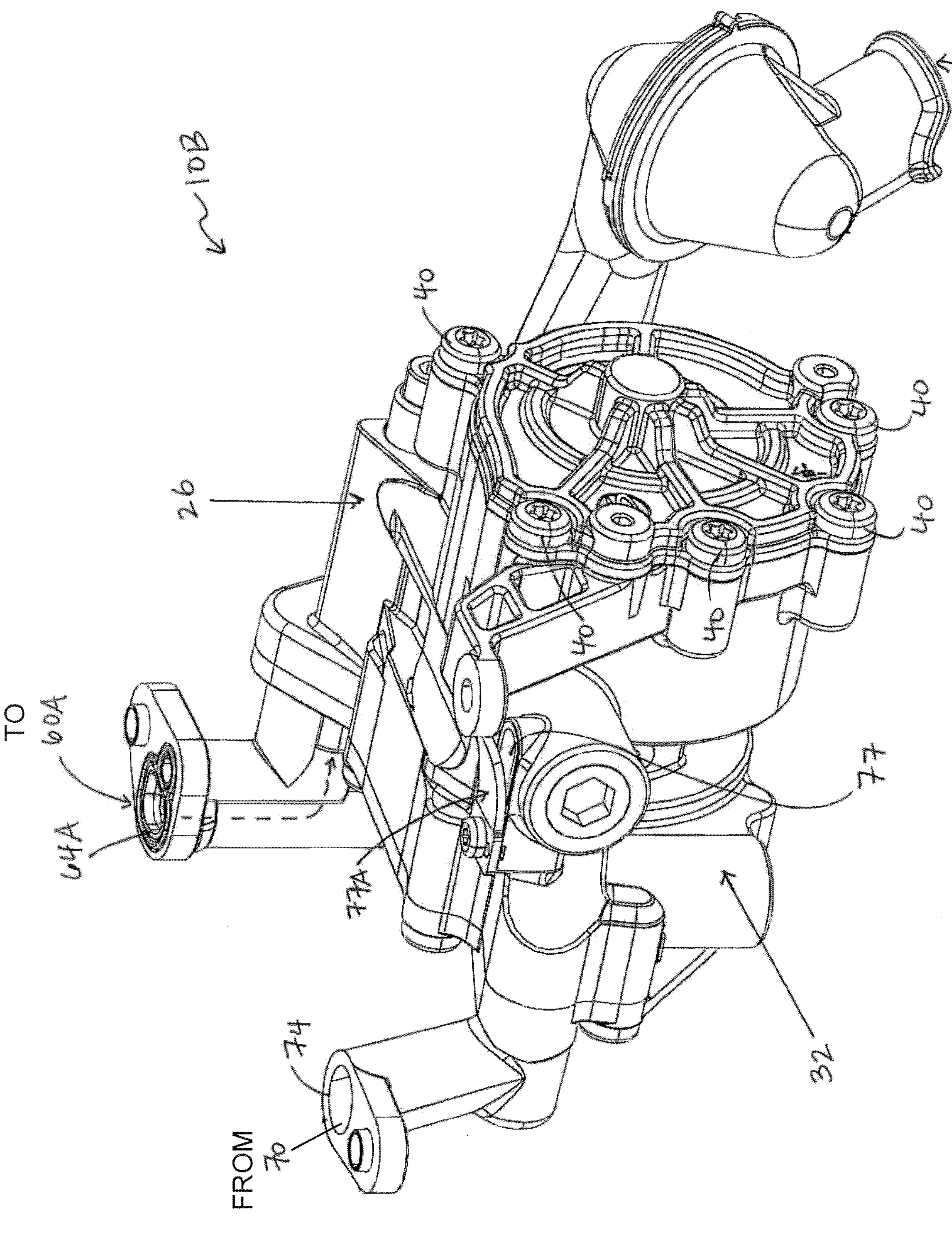

FIG. 19

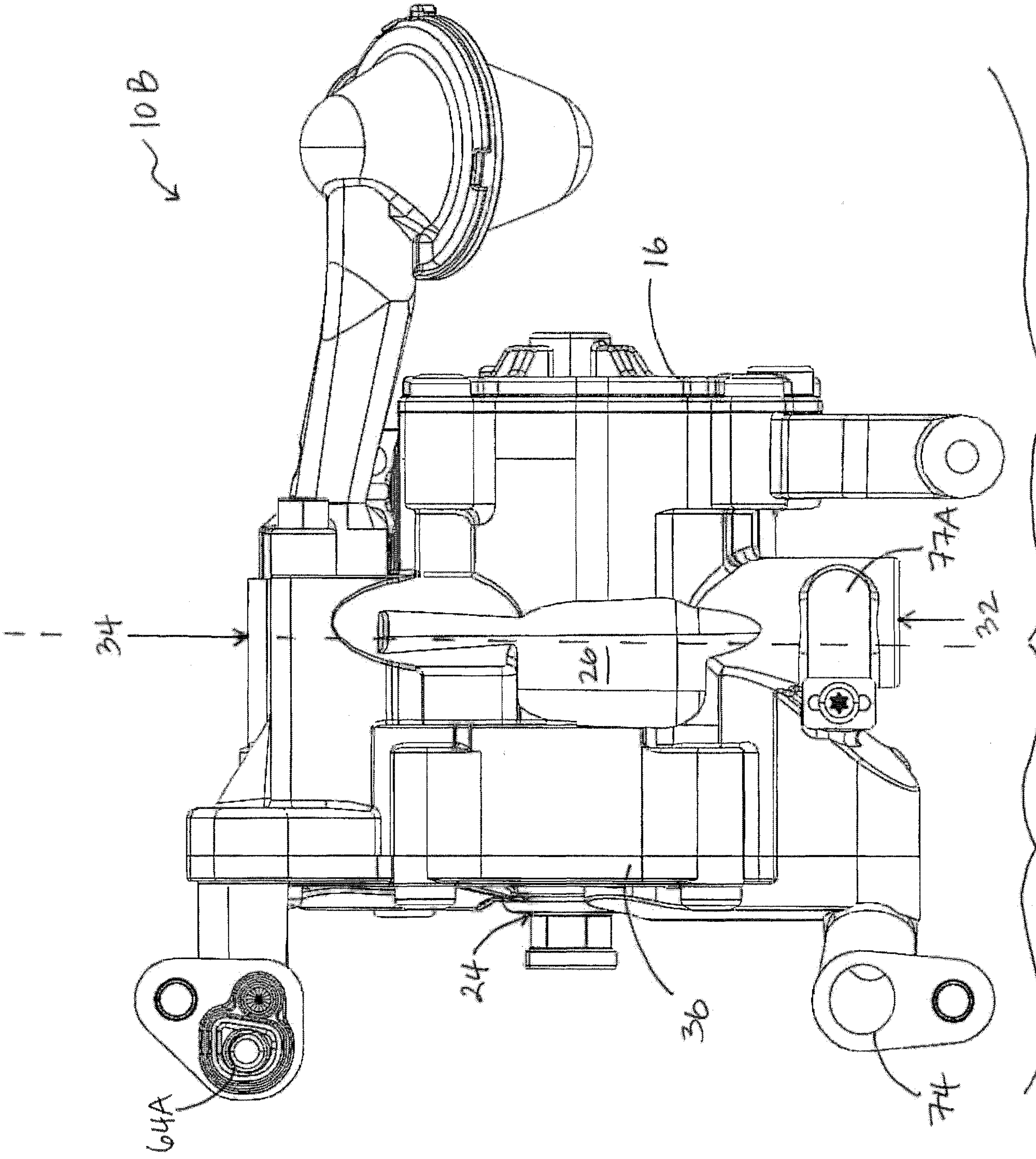

FIG. 20

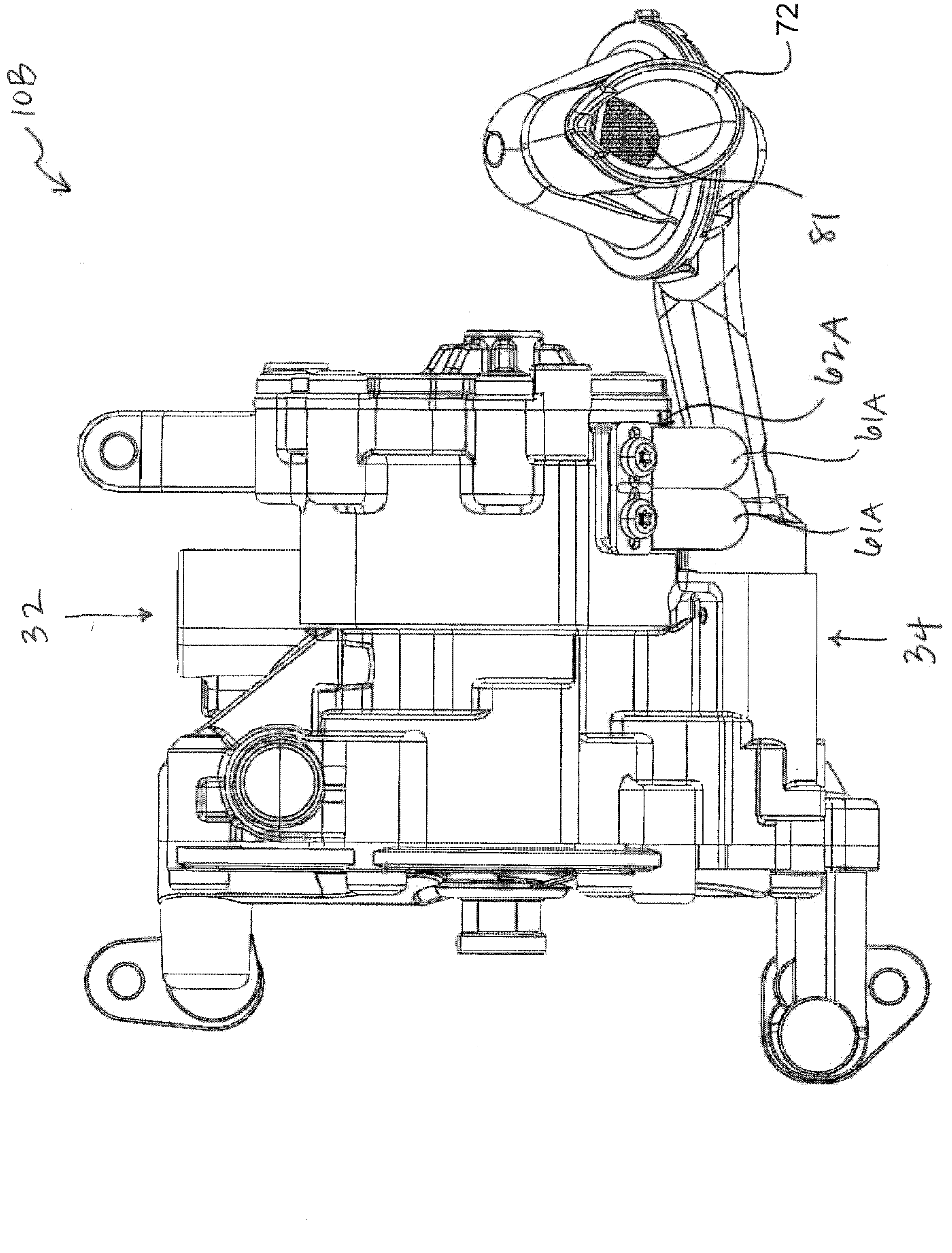

FIG. 21

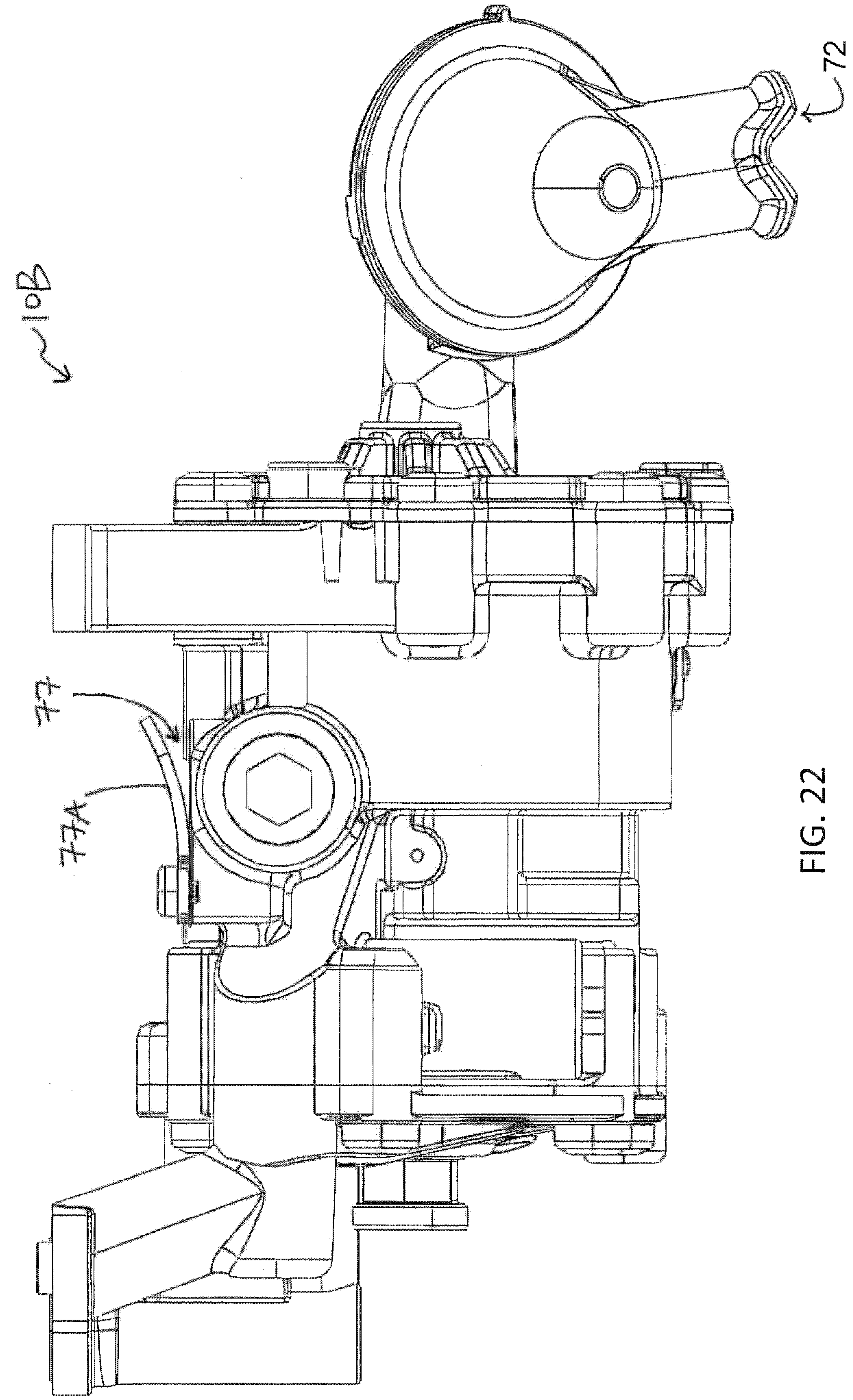

FIG. 22

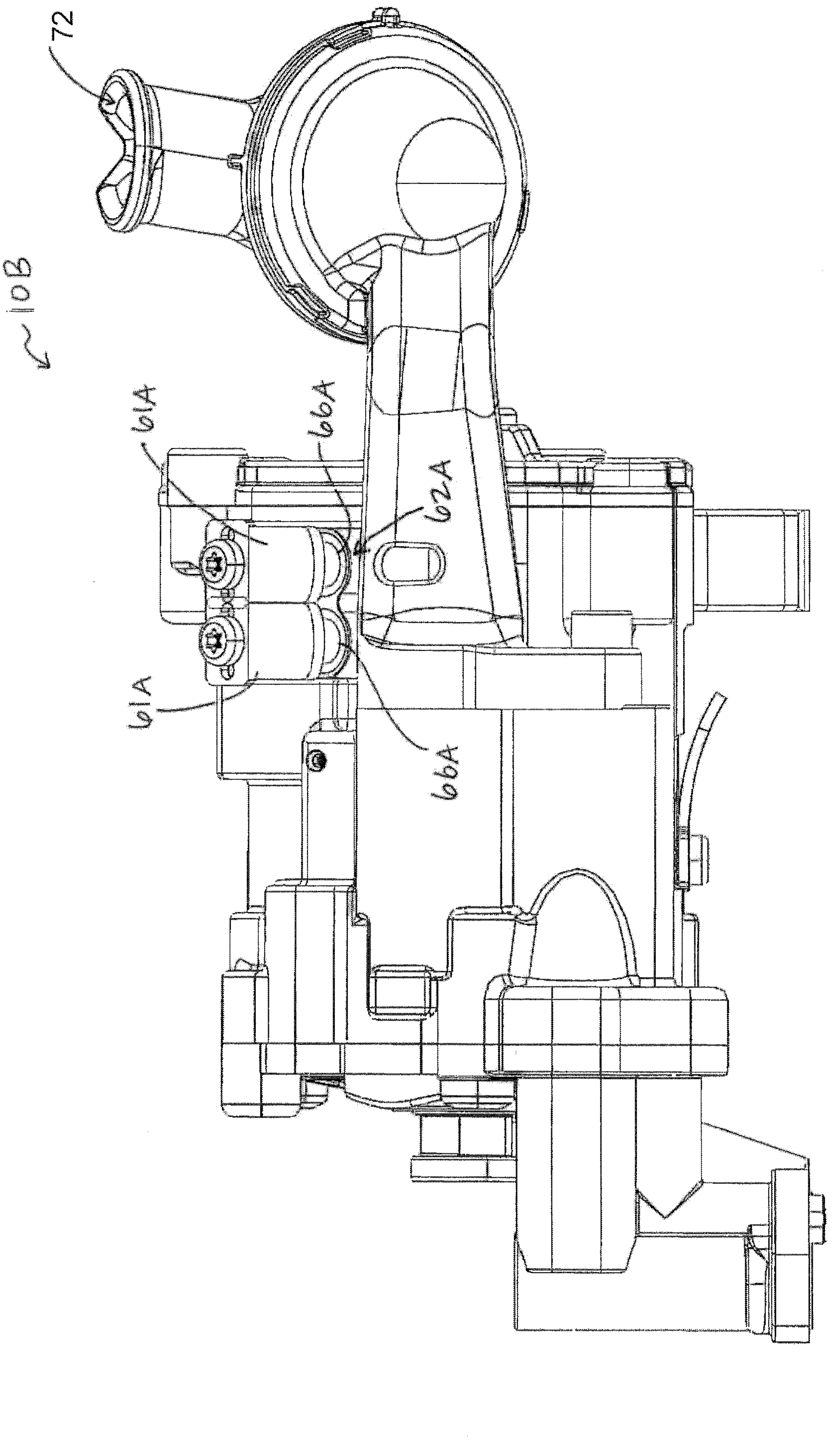

FIG. 23

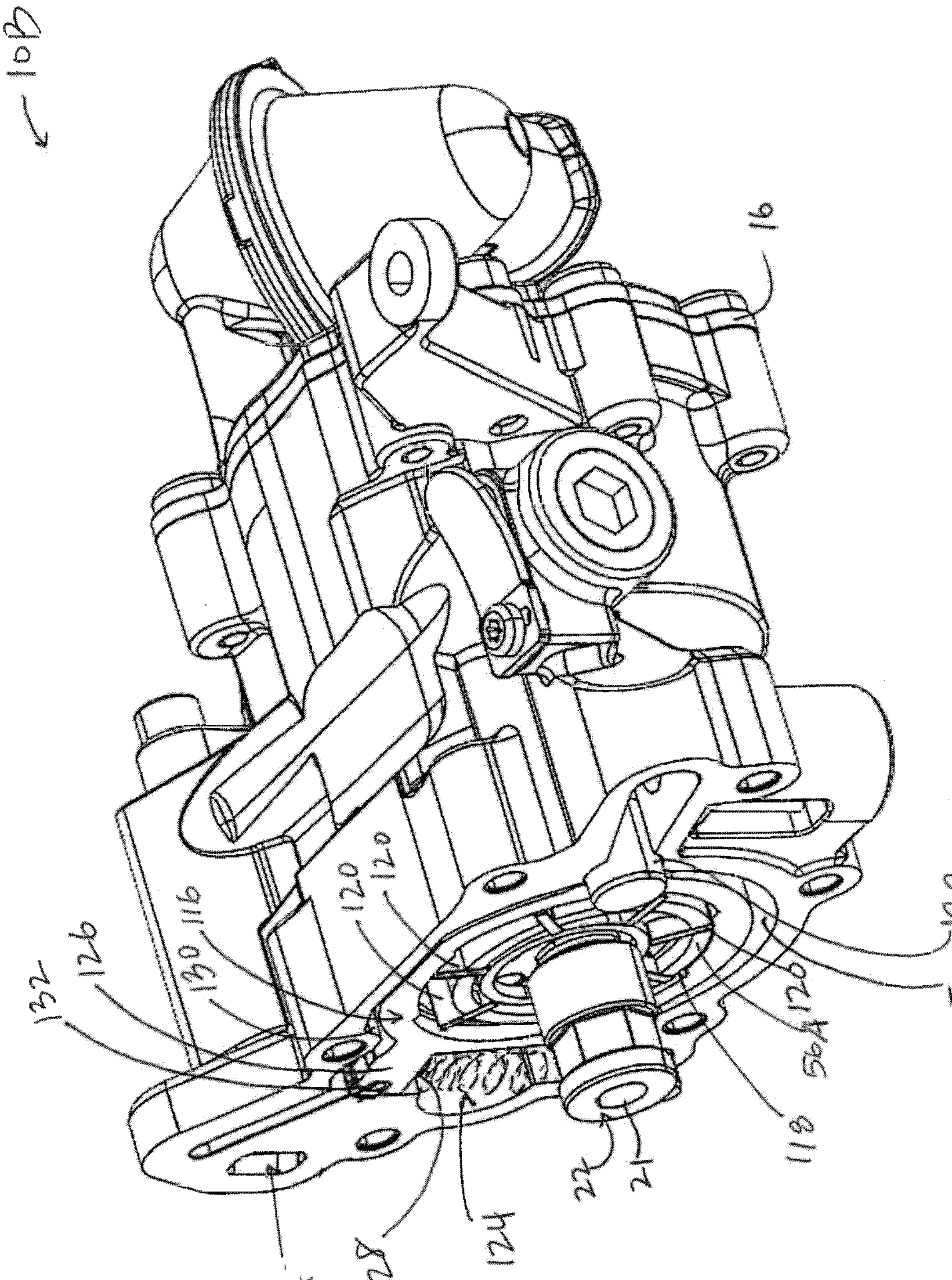
10B
16
132
126
130
116
120
120
122
54
120
56A
118
22
21
124
128
40A

FIG. 24

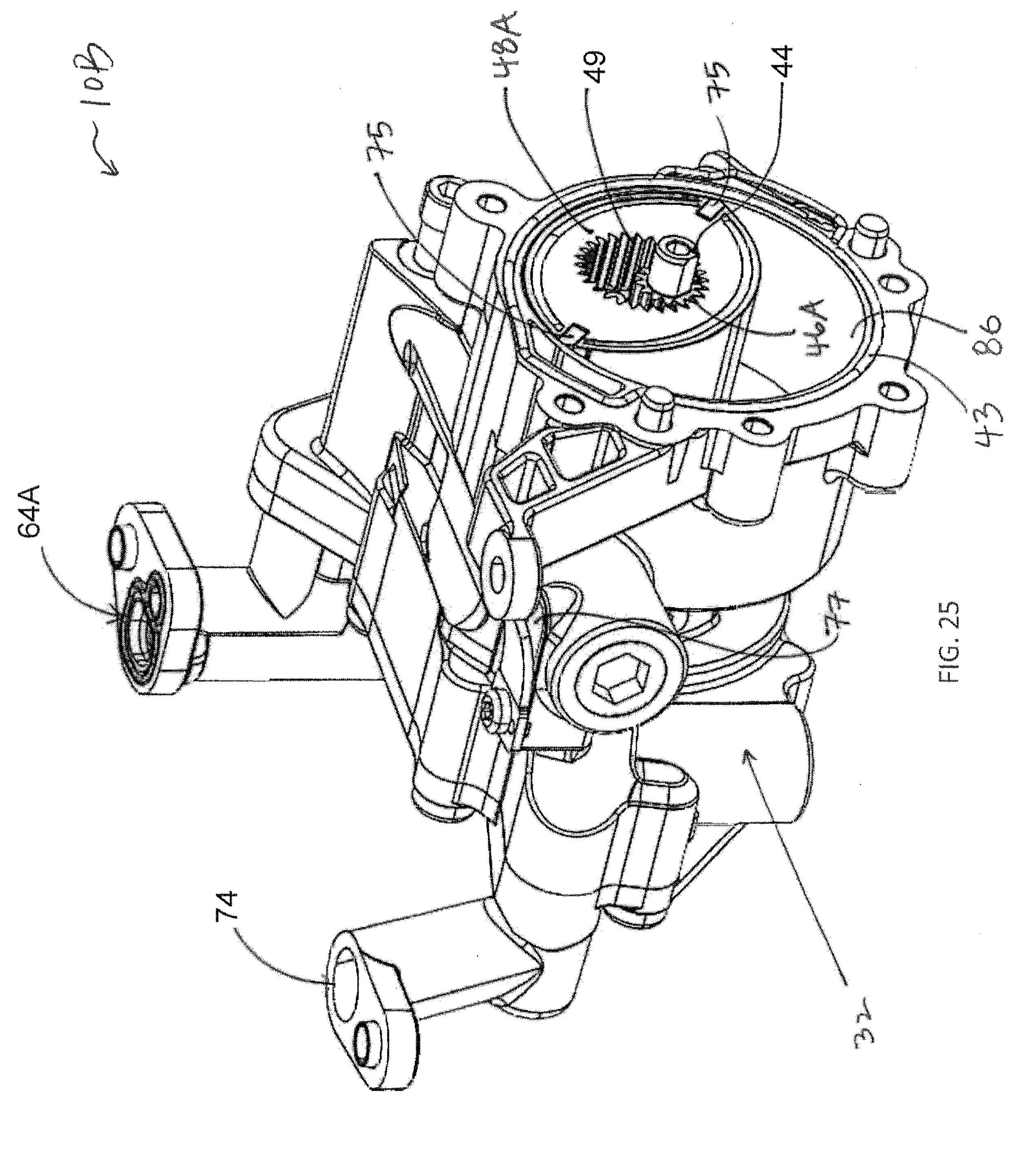

FIG. 25

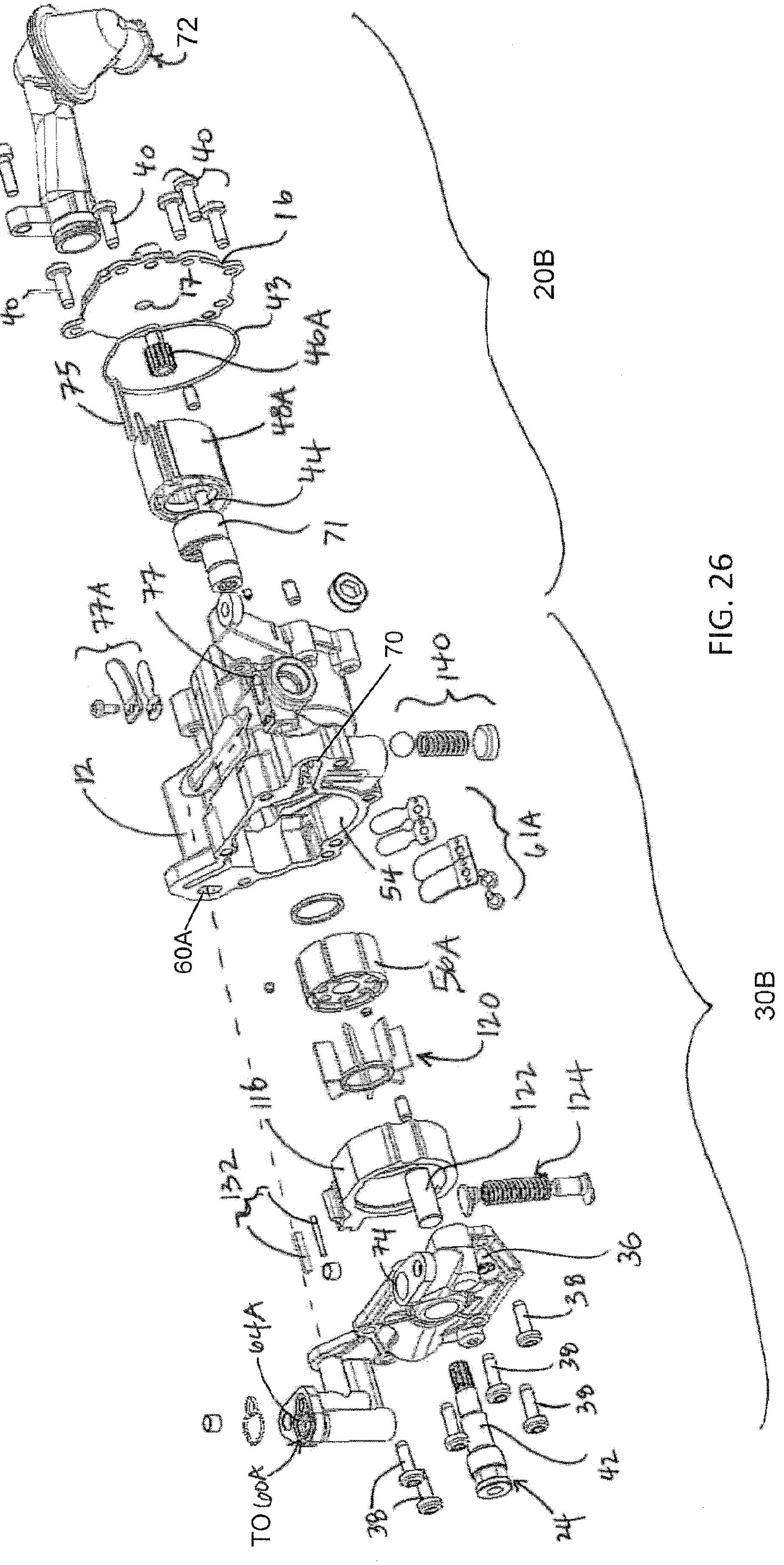
72
40
40
40
40
16
17
43
46A
75
48A
44
71
77A
77
70
140
12
54
61A
60A
56A
120
116
122
124
132
74
36
38
38
38
38
64A
TO 60A
24
42
20B
30B

FIG. 26

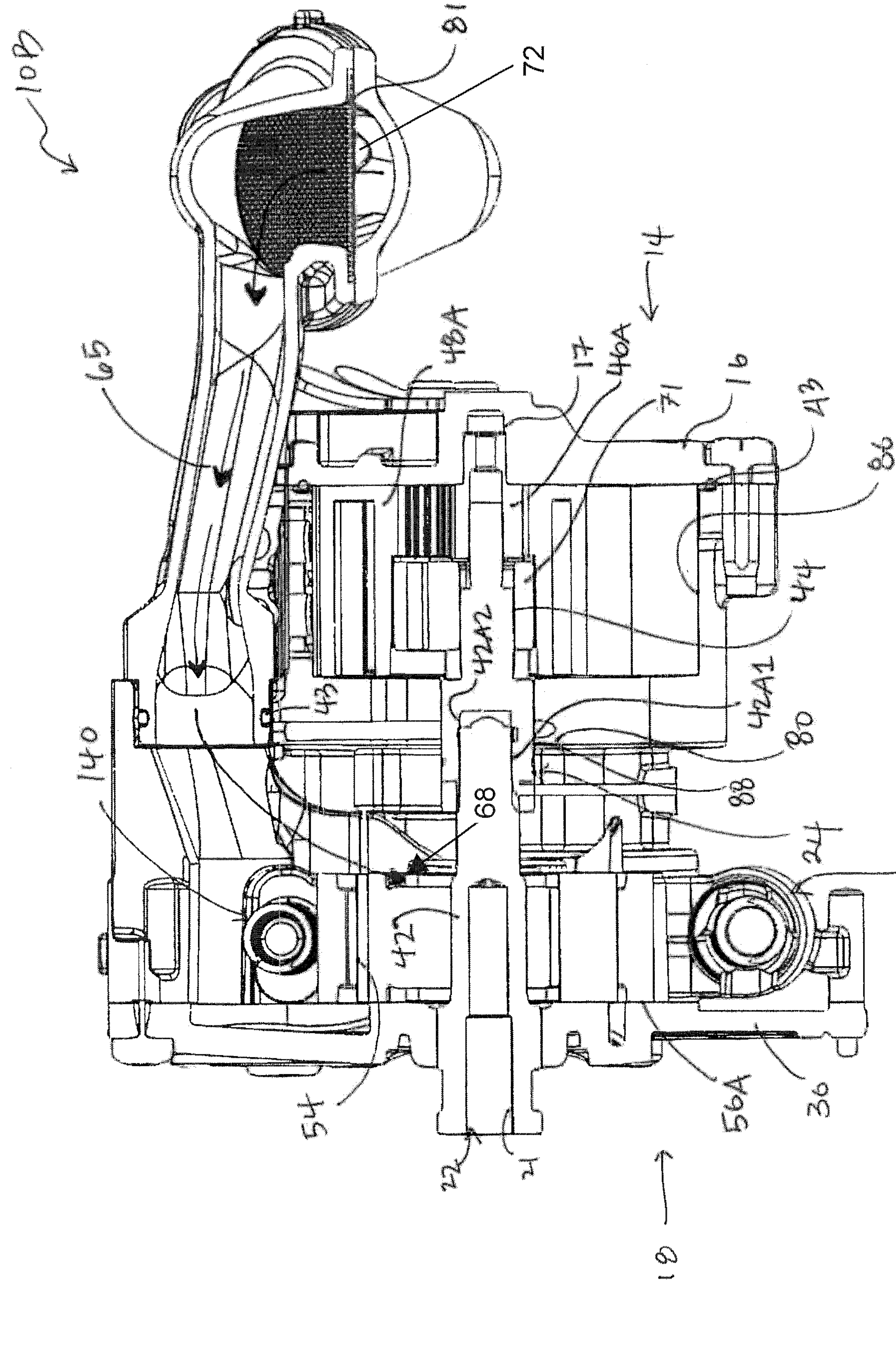
108
81
72
65
48A
14
17
46A
71
16
43
86
44
42A2
43
42A1
80
88
24
140
68
140
42
54
56A
36
22
21
18

FIG. 27A

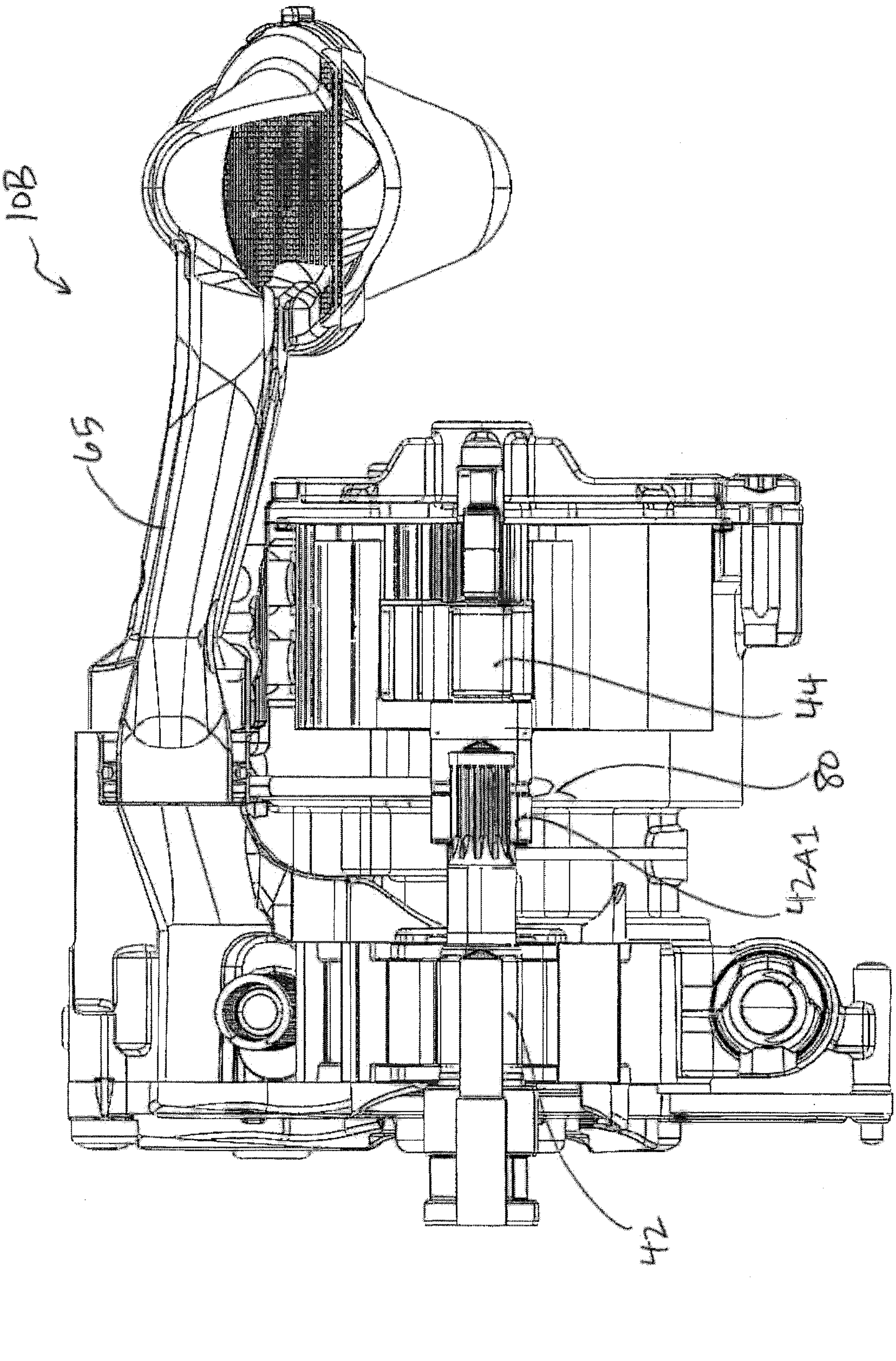

FIG. 27B

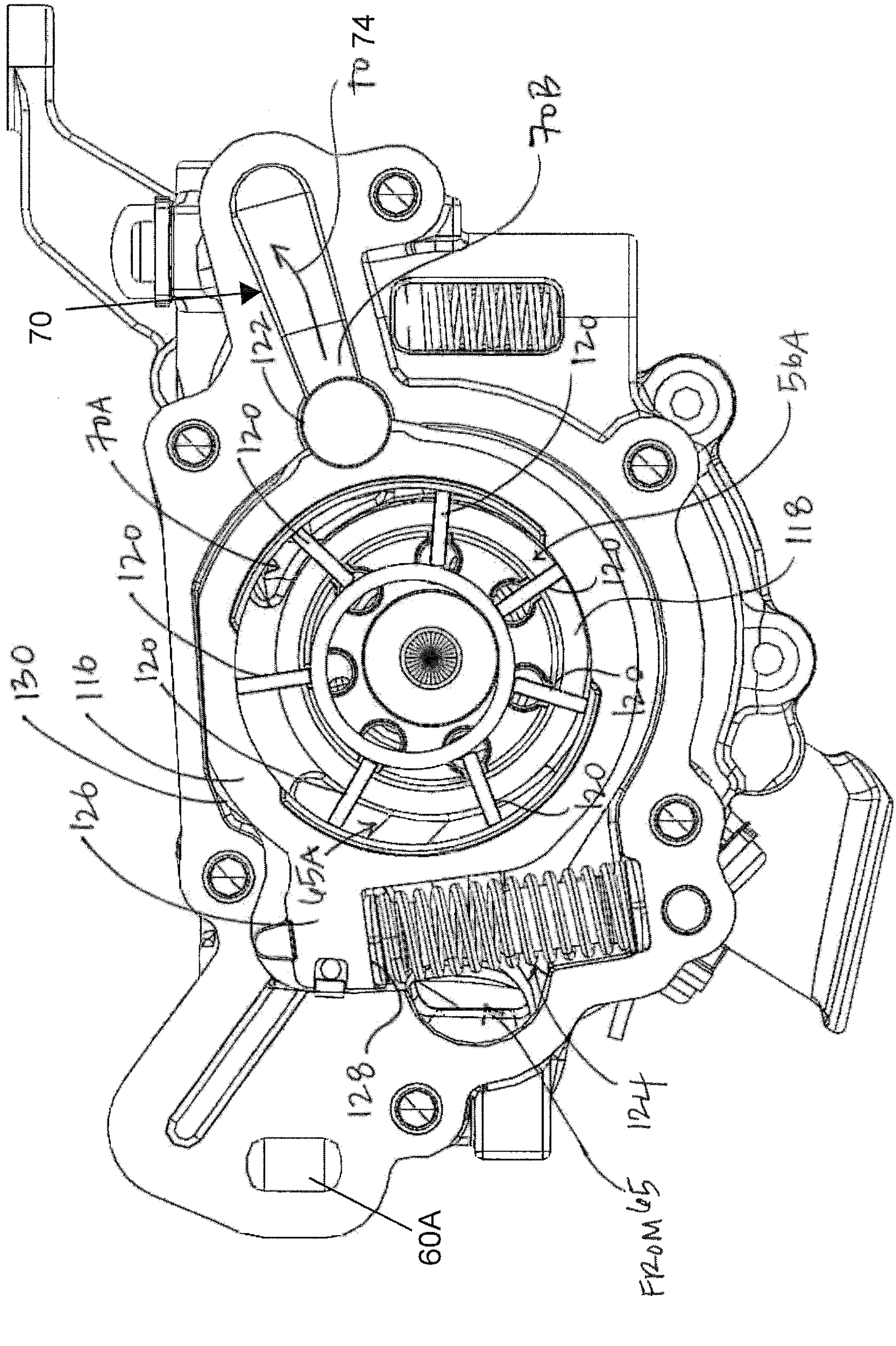
70
To 74
70B
122
120
70A
56A
118
130
116
126
65A
128
124
FROM 65
60A

FIG. 28

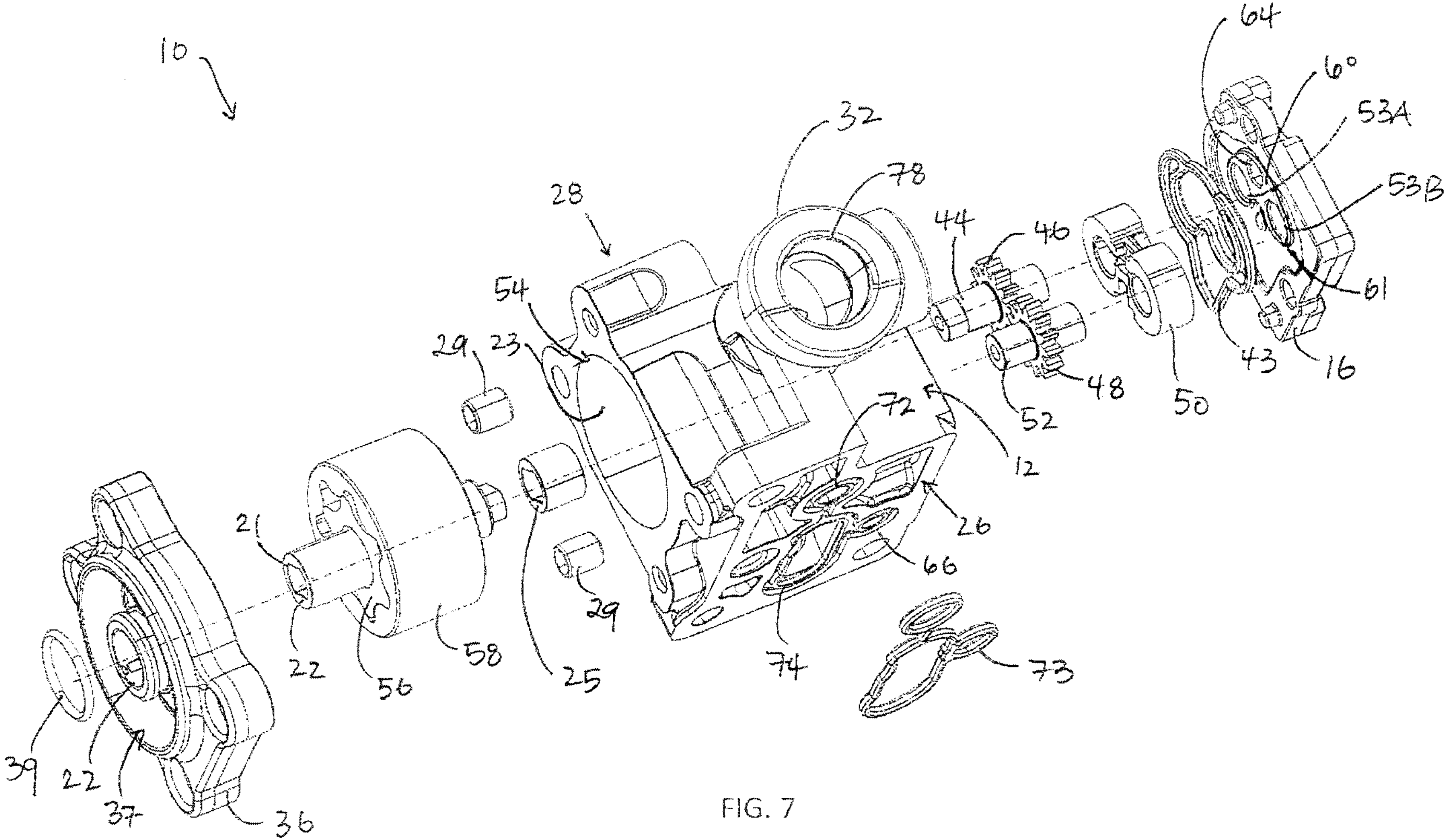
10
32
78
64
60
53A
53B
61
28
44
46
54
29
23
16
43
48
50
52
72
12
26
21
66
29
22
56
58
25
74
73
39
22
37
36

FIG. 7