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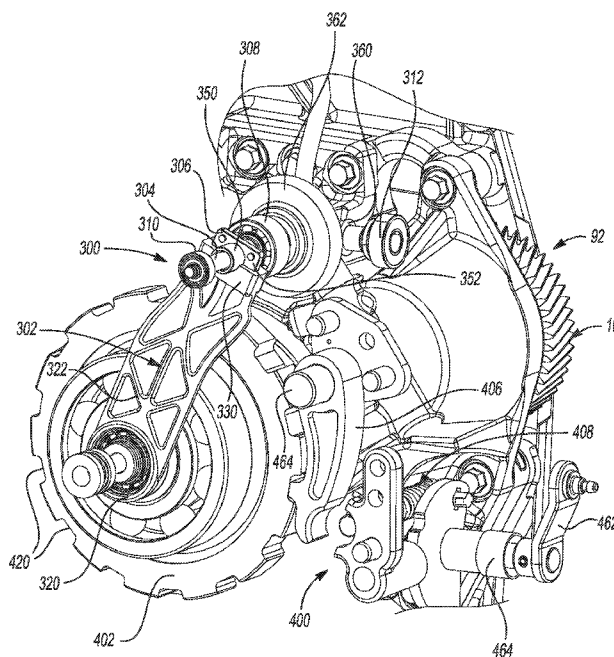


Fig-16

(57) Abstract: An actuator assembly configured to be coupled to a multi-speed electric drive axle, having an output assembly, including an axially-movably member configured to couple to a multi-speed input portion of the multi-speed electric drive axle; a ball screw having an externally-threaded portion; a coupler, attached to the axially-movable member, having an internally threaded hub that meshingly engages the externally-threaded portion of the ball screw such that rotation of the ball screw linearly moves the coupler and the axially-movable member.

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MULTI-SPEED ELECTRIC DRIVE AXLE USING MULTI-LAYSHAFT TRANSMISSION

FIELD

[0001] The present disclosure relates to a multi-speed electric drive axle that uses a multi-layshaft transmission.

BACKGROUND

[0002] The present disclosure relates to a multi-speed electric drive axle that uses a multi-layshaft transmission. The multi-speed electric drive axle can use an actuator assembly to control the selection of gears in the multi-layshaft transmission.

SUMMARY

[0003] In one implementation of the disclosure, an actuator assembly is configured to be coupled to a multi-speed electric drive axle, having an output assembly, including an axially-movably member configured to couple to a multi-speed input portion of the multi-speed electric drive axle; a ball screw having an externally-threaded portion; a coupler, attached to the axially-movable member, having an internally threaded hub that meshingly engages the externally-threaded portion of the ball screw such that rotation of the ball screw linearly moves the coupler and the axially-movable member.

[0004] In another implementation of the disclosure, an actuator assembly is configured to be coupled to a multi-speed electric drive axle, having an output

assembly, including an axially-movably member configured to couple to a multi-speed input portion of the multi-speed electric drive axle; a ball screw having an externally-threaded portion; a coupler, attached to the axially-movable member, having an internally threaded hub that meshingly engages the externally-threaded portion of the ball screw such that rotation of the ball screw linearly moves the coupler and the axially-movable member; a biasing spring configured to apply a biasing force to the multi-speed input portion of the multi-speed electric drive axle to urge the multi-speed input portion into a high-speed position.

[0005] In another implementation of the disclosure, an actuator assembly is configured to be coupled to a multi-speed electric drive axle on a vehicle, having a ball screw having an externally-threaded portion; a coupler having an internally threaded hub that meshingly engages the externally-threaded portion of the ball screw such that rotation of the ball screw linearly moves the coupler; an axially-movable member configured to couple to a multi-speed input portion of the multi-speed electric drive axle and the coupler; a pivot fork assembly comprising: a first fork member; a second fork member; at least one first pivot pin pivotably coupling a first end of the first fork member to the coupler; a second pivot pin pivotably coupling the first fork member to the second fork member; a pair of connecting pins that pivotably couple the first fork member to the second fork member; and one or more compliance springs that bias the second fork member about the second pivot pin in a first pivot direction.

DRAWINGS

[0006] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0007] Figure 1 is a perspective view of an exemplary electric drive axle constructed in accordance with the teachings of the present disclosure;

[0008] Figure 2 is a section view taken along the line 2-2 of Figure 1;

[0009] Figure 3 is an exploded perspective view of a portion of the electric drive axle of Figure 1 illustrating a gearcase of a housing assembly, a transmission and a differential assembly in more detail;

[0010] Figure 4 is a section view of a portion of the electric drive axle of Figure 1 taken through a motor axis of an electric motor;

[0011] Figure 5 is a schematic illustration of a portion of the electric drive axle of Figure 1 that illustrates the transmission in more detail;

[0012] Figure 6 is a perspective view of a portion of the electric drive axle of Figure 1 illustrating the transmission in more detail;

[0013] Figure 7 is a section view of a portion of the transmission taken along the motor axis;

[0014] Figure 8 is a perspective view of the transmission;

[0015] Figure 9 is a section view taken of a portion of the transmission taken through the motor axis and an intermediate axis of a first compound gear;

[0016] Figure 10 is an exploded perspective view of a multi-speed input portion of the transmission;

[0017] Figures 11 through 13 are enlarged portions of Figure 7 illustrating an input shaft of the multi-speed input portion of the transmission in the high-speed, neutral, and low-speed positions, respectively;

[0018] Figure 14 is a perspective view of a portion of the electric drive axle of Figure 1, illustrating a portion of the transmission that includes a mounting plate;

[0019] Figure 15 is a section view taken through a portion of the electric drive axle illustrating one of the layshafts of the transmission as mounted between the mounting plate and a portion of a housing assembly;

[0020] Figure 16 is a perspective view of a portion of the electric drive axle of Figure 1 illustrating an actuator assembly for operating the multi-speed input portion of the transmission and a park-lock mechanism in more detail;

[0021] Figure 17 is a section view of a portion of the electric drive axle of Figure 1 illustrating a connection between the actuator assembly and the input shaft;

[0022] Figure 18 is a perspective view of the electric drive axle of Figure 1 illustrating the actuator assembly in more detail;

[0023] Figure 19 is a perspective view of a portion of the electric drive axle of Figure 1 illustrating portions of the actuator assembly in more detail;

[0024] Figure 20 is a perspective view of the park-lock mechanism;

[0025] Figure 21 is a perspective view of a portion of the electric drive axle of Figure 1 illustrating the park-lock mechanism in more detail;

[0026] Figure 22 is a section view taken through a portion of the park-lock mechanism that illustrates the park-lock plunger assembly in operative association with a guide and a park pawl;

[0027] Figure 23 is a perspective view of a portion of another electric drive axle having an alternately configured actuator assembly;

[0028] Figure 24 is an end view of the electric drive axle of Figure 23;

[0029] Figure 25 is a section view taken along the line A-A of Figure 24;

[0030] Figure 26 is an exploded perspective view of a portion of the electric drive axle of Figure 23;

[0031] Figure 27 is an enlarged portion of Figure 25;

[0032] Figure 28 is a profile view of an actuator assembly.

[0033] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0034] With reference to Figures 1 and 2, an exemplary electric drive axle constructed in accordance with the teachings of the present disclosure is generally indicated by reference numeral 10. The multi-speed electric drive axle 10 includes several major assemblies or components including a housing assembly 12, an electric motor 14, a transmission 16, a differential assembly 18 and a pair of axle shafts 20.

[0035] With specific reference to Figures 2 and 3, the housing assembly 12 of the example provided includes first and second housing members 30 and 32,

respectively, and a pair of axle tubes 34 in which the axle shafts 20 are rotatably disposed. The housing assembly 12 is configured to handle beaming loads, and as such, provides the multi-speed electric drive axle 10 with a "beam" or "rigid" axle configuration. It will be appreciated, however, that the housing assembly 12 could be configured differently, for example to configure the multi-speed electric drive axle 10 for use with an independent suspension.

[0036] The first and second housing members 30 and 32 have a "clam shell" configuration and cooperate to define a gearcase that has a transmission cavity 38 and a differential cavity 40 that intersects the transmission cavity 38. Each of the first and second housing members 30 and 32 can define a coupling flange 44, a differential bearing mount 46, and an axle tube mount 48. The first housing member 30 can additionally include a motor mount 50. The coupling flanges 44 can be abutted against one another and threaded fasteners can be employed to secure the coupling flanges 44 to one another. A gasket or sealant (not shown) can be disposed between the first and second housing members 30 and 32 (e.g., contacting the adjacent faces of the coupling flanges 44) so that the first and second housing members 30 and 32 are additionally sealingly coupled to one another. Each differential bearing mount 46 is formed into an in-board side of an associated one of the first and second housing members 30 and 32 and is configured to receive a differential bearing 54 therein that supports the differential assembly 18 for rotation about an output axis 58. Each axle tube mount 48 defines an axle tube aperture that is configured to receive therein an associated one of the axle tubes 34.

[0037] Each of the axle tubes 34 can be received into an associated one of the axle tube apertures and can be fixedly coupled to an associated one of the axle tube mounts 48 in any desired manner. In the example shown, the axle tubes 34 are press-fit into the axle tube apertures and conventional weld slugs (not specifically shown) are employed to inhibit both axial and rotational movement of the axle tubes 34 along or about the output axis 58 relative to the first and second housing members 30 and 32.

[0038] With reference to Figure 4, the electric motor 14 can be configured as any type of electric motor and includes a motor housing 64, a stator 66, which is received into and fixedly coupled to the motor housing 64, a rotor 68, which is received in the stator 66 and rotatable relative to the stator 66 about a motor axis 70, and a motor output shaft 72 that is fixedly coupled to the rotor 68. The motor housing 64 can define a motor bearing mount (not specifically shown) and a seal mount. The motor output shaft 72 can extend along the motor axis 70 through the motor housing 64 and optionally into the transmission cavity 38 in the housing assembly 12. The motor output shaft 72 can be hollow and can define a plurality of first internal spline teeth 80. A motor bearing 82 can be received between the motor housing 64 and the motor output shaft 72 and can support the motor output shaft 72 for rotation about the motor axis 70 relative to the motor housing 64. A rotary shaft seal 84 can be mounted on the seal mount and can form a seal between the motor housing 64 and the motor output shaft 72 that inhibits fluid transmission through a motor shaft aperture in the motor housing 64 between the transmission cavity 38 and the interior of the motor housing 64. Fasteners (not

specifically shown) can be employed to fixedly couple the motor housing 64 to the motor mount 50 on the first housing member 30. Alternatively, the motor housing 64 could be unitarily and integrally formed with the first housing member 30. The motor output shaft 72 can extend through or be disposed in-line with the motor shaft aperture.

[0039] As shown in Figures 5 and 6, the transmission 16 in the example provided is a multi-speed transmission, but it will be understood that the transmission 16 can be any type of transmission, including a single-speed transmission. The particular transmission 16 shown includes a mounting plate 90, a multi-speed input portion 92 and a single-speed output portion 94. The mounting plate 90 will be described in more detail below, but it will suffice for now that it is received in the transmission cavity 38, that it is fixedly coupled to the first housing member 30 and that a significant portion of the multi-speed input portion 92 is disposed between the first housing member 30 and the mounting plate 90.

[0040] With reference to Figures 5 and 7, the multi-speed input portion 92 includes a first gear 100, a second gear 102, a third gear 104, a first compound gear 106, an input shaft 108 and a coupling sleeve 110. The first gear 100 can have gear teeth with a helical gear tooth form that is disposed about a first gear hub 112. The first gear hub 112 is hollow and can define a plurality of second internal spline teeth 114. A bearing 116 is mounted between the first housing member 30 and the first gear hub 112 and supports the first gear 100 for rotation about the motor output axis 58. The second gear 102 can have gear teeth with a helical gear tooth form that is disposed about a second gear hub 122. The second

gear hub 122 is hollow and can define a plurality of third internal spline teeth 124. A pair of bearings 126 are mounted between the mounting plate 90 and the second gear hub 122 and support the second gear 102 both axially along and radially about the motor output axis 58. The first gear 100 is disposed along the motor output axis 58 between the motor output shaft 72 and the second gear 102. Optionally, a portion of the first gear hub 112 can be received concentrically within a portion of the second gear hub 122.

[0041] The third gear 104 can have gear teeth with a helical gear tooth form that is disposed about a third gear hub 132. The third gear hub 132 is hollow and can define a plurality of fourth internal spline teeth 134 and a plurality of first face teeth 135 that are formed onto or into an axial end face of the third gear hub 132 that faces or is proximate the second gear 102. Bearings 136a and 136b are employed to rotationally support the third gear 104 for rotation about the motor axis 70. The bearing 136a is mounted between the mounting plate 90 and the third gear hub 132 proximate the second gear 102, while the bearing 136b is mounted between the gearcase and the third gear hub 132 on an axial end of third gear 104 that is opposite the bearing 136a.

[0042] With reference to Figures 5, 8 and 9, the first compound gear 106 includes a first layshaft 140, a first intermediate gear 142 and a second intermediate gear 144. The first layshaft 140 can be hollow and can be supported on opposite sides by first and second bearings 146a and 146b, respectively, for rotation about a respective first intermediate axis 148 that is parallel to but offset from (i.e., not coincident with) the motor axis 70. The first bearing 146a can be

disposed between a first intermediate bearing mount 150 that is formed by the first housing member 30, and a first end of the first layshaft 140, while the second bearing 148b can be disposed between a second intermediate bearing mount 152, which is formed by the mounting plate 90, and a second end of the first layshaft 140 that is opposite the first end. The first intermediate gear 142 is fixedly coupled to the first layshaft 140 for rotation therewith about the first intermediate axis 148 and includes gear teeth that are meshingly engaged with the gear teeth of the first gear 100. The second intermediate gear 144 is fixedly coupled to the first layshaft 140 for rotation therewith about the first intermediate axis 148 and includes gear teeth that are meshingly engaged with the gear teeth of the second gear 102.

[0043] With reference to Figures 7 and 10, the input shaft 108 is received concentrically through the first, second and third gear hubs 112, 122 and 132 and is rotatable about the motor axis 70. The input shaft 108 includes a plurality of first external spline teeth 160, which are disposed on a first axial end of the input shaft 108 that is disposed within the motor output shaft 72, a plurality of second external spline teeth 162, which are spaced apart from the first external spline teeth 160 along the motor axis 70, and a circumferential rib 164 that is disposed between the first and second external spline teeth 160 and 162 along the motor axis 70. A lubrication bore 166 can be formed through the input shaft 108 and a plurality of lubrication passages 168 can be formed through the input shaft 108 so as to intersect the lubrication bore 166 and extend radially through the input shaft 108 at desired locations. A lubrication nozzle can be received into the axial end of the input shaft 108 that is proximate the third gear 104 and can be configured to

dispense a flow of pressurized lubricating fluid into the lubrication bore 166. Pressurized lubricating fluid in the lubrication bore 166 can be transmitted to the lubrication passages 168 for cooling and/or lubrication of various components, such as bearings or sliding interfaces, and optionally to communicate pressurized lubricating fluid into the motor output shaft 72 where it can be employed to cool and/or lubricate various components of the electric motor 14. In the example provided, the lubrication nozzle is mounted to an auxiliary cover that is mounted to a side of the second housing member 32 that is opposite the transmission cavity 38 and the lubrication nozzle neither contacts nor is sealed to the input shaft 108.

[0044] Various bearings can be employed to provide radial support to the input shaft 108 while permitting axial movement of the input shaft 108 along the motor axis 70. In the example provided, a first needle bearing 170 is disposed between the first gear hub 112 and a first cylindrical bearing surface formed on the input shaft 108, while a second needle bearing 172 is disposed between the third gear hub 132 and a second cylindrical bearing surface formed on the input shaft 108.

[0045] The coupling sleeve 110 can be received concentrically about the input shaft 108 and is rotatable about the motor axis 70 relative to the input shaft 108. The coupling sleeve 110 can define a shoulder that can abut a first side of the circumferential rib 164 on the input shaft 108. An internal snap ring can be received in a groove formed in the coupling sleeve 110 and can abut a second side of the circumferential rib 164 on a side opposite the shoulder. As such, translation of the input shaft 108 along the motor axis 70 will cause corresponding

translation of the coupling sleeve along the motor axis 70. The coupling sleeve 110 defines a plurality of third external spline teeth 180 and a plurality of second face teeth 182. The third external spline teeth 180 are meshingly engaged with the third internal spline teeth 124 that are formed on the second gear hub 122 to thereby couple the coupling sleeve 110 to the second gear 102 in a way that inhibit relative rotation but permits axial sliding movement or translation of the coupling sleeve 110 relative to the second gear 102.

[0046] The input shaft 108 is movable along the motor axis 70 between a high-speed position (shown in Fig. 11), a neutral position (shown in Fig. 12), and a low-speed position (shown in Fig. 13). The first external spline teeth 160 on the input shaft 108 are meshingly engaged with the first internal spline teeth 80 on the motor output shaft 72 (thereby coupling the input shaft 108 to the motor output shaft 72 for rotation therewith about the motor axis 70) in each of the high-speed, neutral and low-speed positions.

[0047] When the input shaft 108 is positioned in the high-speed position as shown in Fig. 11, the first external spline teeth 160 on the input shaft 108 are engaged only to the first internal spline teeth 80 on the motor output shaft 72, the second external spline teeth 162 on the input shaft 108 are engaged to the fourth internal spline teeth 134 formed on the third gear 104, and the second face teeth 182 on the coupling sleeve 110 are spaced apart and are disengaged from the first face teeth 135 on the third gear 104. Consequently, rotary power output from the electric motor 14 (Fig. 1) through the motor output shaft 72 is input to the input

shaft 108 and transmitted to the third gear 104 to drive the third gear 104 at the rotational speed of the electric motor 14 (Fig. 1).

[0048] When the input shaft 108 is positioned in the neutral position as shown in Fig. 12, the first external spline teeth 160 on the input shaft 108 are engaged only to the first internal spline teeth 80 on the motor output shaft 72, the second external spline teeth 162 on the input shaft 108 are spaced apart and disengaged to the fourth internal spline teeth 134 formed on the third gear 104, and the second face teeth 182 on the coupling sleeve 110 are spaced apart and are disengaged from the first face teeth 135 on the third gear 104. Consequently, rotary power output from the electric motor 14 (Fig. 1) through the motor output shaft 72 is input to the input shaft 108 but is not transmitted to any of the first, second and third gears 100, 102 and 104.

[0049] When the input shaft 108 is positioned in the low-speed position as shown in Fig. 13, the first external spline teeth 160 on the input shaft 108 are engaged to both the first internal spline teeth 80 on the motor output shaft 72 and the second internal spline teeth 114 on the first gear 100, the second external spline teeth 162 on the input shaft 108 are spaced apart and disengaged from the fourth internal spline teeth 134 formed on the third gear 104, and the second face teeth 182 on the coupling sleeve 110 are engaged with the first face teeth 135 on the third gear 104. Consequently, rotary power output from the electric motor 14 (Fig. 1) through the motor output shaft 72 is input to the input shaft 108 and transmitted to the first gear 100 to drive the first intermediate gear 142 (Fig. 8) to provide a first speed reduction. The second intermediate gear 144 (Fig. 8), which

rotates with the first intermediate gear 142 (Fig. 8), drives the second gear 102 to provide a second speed reduction. As the coupling sleeve 110 is rotationally coupled with both the second gear 102 (via the mating engagement of the third external spline teeth 180 with the third internal spline teeth 124) and the third gear 104 (via mating engagement of the second face teeth 182 with the first face teeth 135), the third gear 104 rotates at the rotational speed of the second gear 102.

[0050] Returning to Figures 5 and 8, the single-speed output portion 94 receives rotary power from the third gear 104 and includes an output gear 200 that is rotatable about the output axis 58. Optionally, the single-speed output portion 94 can include one or more speed reductions between the third gear 104 and the output gear 200. In the example provided, the single-speed output portion 94 includes a pair of second compound gears 210 that provide the single-speed output portion 94 with two gear reductions between the third gear 104 and the output gear 200.

[0051] Each of the second compound gears 210 includes a second layshaft 212, a third intermediate gear 214 and a fourth intermediate gear 216. The second layshaft 212 can be hollow and can be supported on opposite sides by first and second bearings 220a and 220, respectively, for rotation about a respective second intermediate axis 222 that is parallel to but offset from (i.e., not coincident with) both the motor axis 70 and the output axis 58. The first bearing 220a can be disposed between a first intermediate bearing mount that is formed by the first housing member 30, and a first end of the second layshaft 212, while the second bearing 220b can be disposed between a second intermediate bearing mount,

which is formed by the second housing member 32, and a second end of the second layshaft 212 that is opposite the first end. The third intermediate gear 214 is fixedly coupled to the second layshaft 212 for rotation therewith about the second intermediate axis 222 and includes gear teeth that are meshingly engaged with the gear teeth of the third gear 104. The fourth intermediate gear 216 is fixedly coupled to the second layshaft 212 for rotation therewith about the second intermediate axis 222 and includes gear teeth that are meshingly engaged with gear teeth of the output gear 200. In the example provided, the second compound gears 210 are arranged along the second intermediate axes 222 so that the third intermediate gears 214 are disposed farther away from the first gear 100 than the fourth intermediate gears 216. Configuration in this manner permits the transmission 16 to be relatively compact in an axial direction (e.g., along the output axis 58).

[0052] With reference to Figures 5 and 8, the differential assembly 18 can include a differential input member 230, which is coupled to the output gear 200 for rotation therewith, and a pair of differential output members 232 that are rotatable relative to the differential input member 230 about the output axis 58. The differential assembly 18 can be configured in any desired manner. For example, the differential assembly 18 could be configured with a bevel gearset having (straight) bevel side gears and differential pinions, and the differential input member 230 could be a differential case that houses the side gears and the differential pinions. In the example provided, the differential assembly 18 is configured as a planetary or epicyclic differential assembly having an internal gear

(not specifically shown), a sun gear (not specifically shown), a planet carrier (not specifically shown) and a plurality of sets of planet gears (not specifically shown). The internal gear can be fixedly coupled to (e.g., unitarily and integrally formed with) the output gear 200 of the transmission 16. The sun gear is disposed concentrically within the internal gear and is rotatable about the output axis 58. The planet carrier is rotatable about the output axis 58. Each of the sets of planet gears is meshed with both the internal gear and the sun gear and includes one or more planet gears that are journally supported by the planet carrier. In situations where the sets of planet gears comprise two or more planet gears, each of the planet gears is meshed with another one of the planet gears, one of the planet gears is meshed with the internal gear, and a different one of the planet gears is meshed with the sun gear. In the example shown, each set of planet gears comprises a first planet gear, which is meshingly engaged to the internal gear and journally supported by the planet carrier, and a second planet gear that is meshingly engaged to both the first planet gear and the sun gear and which is also journally supported by the planet carrier. In this configuration, the sun gear and the planet carrier are the differential output members 232 of the differential assembly 18. The differential bearings 54 can be mounted radially between the gearcase and hubs (not specifically shown) formed on the planet carrier to support the differential input member 230 for rotation about the output axis 58. In the example shown, the differential bearings 54 are tapered roller bearings that additionally provide support to the differential assembly 18 in an axial direction along the output axis 58.

[0053] With reference to Figures 2 and 5, each of the axle shafts 20 is received through a corresponding one of the axle tubes 34 and is coupled for rotation with a corresponding one of the differential output members 232. Various bearings (not specifically shown) can be employed to support the axle shafts 20 relative to the housing assembly 12. In the example provided, the multi-speed electric drive axle 10 has a "full floating" axle configuration in which the axle shafts 20 are rotationally coupled to wheel hubs 250 that are supported (axially and rotationally) on the axle tubes 34 so that the axle shafts 20 transmit rotational torque between the differential assembly 18 and an associated vehicle wheel (not shown) but do not carry the weight of the vehicle. It will be appreciated, however, that the multi-speed electric drive axle 10 could be configured differently and that it could have any desired configuration (e.g., semi-floating, three-quarters floating, independent).

[0054] With reference to Figures 3, 9 and 14, the mounting plate 90 includes a mounting plate body 260, flange member 262, a plurality of bearing mounts (a bearing mount 264a, a bearing mount 264b and the second intermediate bearing mount 152), and a lubrication gallery 266. The flange member 262 is fixedly coupled to and extends about the mounting plate body 260. The flange member 262 is configured to abut an interior or inboard surface of the first housing member 30. A plurality of threaded fasteners can be received through the flange member 262 and can be threadably engaged to corresponding threaded holes (not specifically shown) in the first housing member 30 to secure the mounting plate 90 to the first housing member 30. A locating means, such as one or more dowel pins

or a pair of roll pins, can be employed to position or locate the mounting plate 90 relative to the first housing member 30. The mounting plate body 260 can be contoured to form a space or cavity that can accommodate the gear teeth of the third gear 104 and the first intermediate gear 142.

[0055] The bearing mount 264a is disposed on a first side of the mounting plate body 260 (i.e., a side that faces the first housing member 30) and is configured to receive one of the bearings 126 that supports the second gear 102. The bearing mount 164b is disposed on a second, opposite side of the mounting plate body 260 (i.e., a side that faces the second housing member 32) and is configured to receive one of bearings (i.e., bearing 136a) that supports the third gear 104. The second intermediate bearing mount 152 is formed on the first side of the mounting plate body 260 and is configured to receive the bearing 146b that supports the first layshaft 140 of the first compound gear 106.

[0056] With reference to Figures 14 and 15, the lubrication gallery 266 includes an inlet port 270, one or more fluid passages (e.g., fluid passages 272, 274 and 276), and one or more fluid outlets (e.g., an outlet nozzle 278, and/or one or more outlet orifices (not specifically shown)). The inlet port 270 is configured to be coupled in fluid communication to a source or flow of pressurized lubricating fluid. In the example provided, the inlet port 270 is coupled in fluid communication to a hose 280 that provides pressurized lubricating fluid to the lubrication gallery 266. The fluid passages are generally configured to route the pressurized lubricating fluid through the mounting plate 90 between the inlet port 270 and the fluid outlets. In the example provided, a first fluid passage 272 receives

pressurized lubricating fluid from the inlet port 270 and transmits the pressurized lubricating fluid to second and third fluid passages 274 and 276, respectively, and to the outlet nozzle 278. The outlet nozzle 278 supplies pressurized lubricating fluid to both the second intermediate bearing mount 152 (for lubrication of both the second bearing 146b and the teeth of the second intermediate gear 144), as well as to the hollow interior of the first layshaft 140. Pressurized lubricating fluid that travels through the first layshaft 140 can be transmitted into the first intermediate bearing mount 150 and employed to lubricate both the first bearing 146a and the teeth of the first intermediate gear 142. The outlet orifices can be located and sized to provide lubrication in desired areas, such as the bearing 146b and/or the teeth of the third gear 104. Additionally or alternatively, one or more of the fluid passages in the mounting plate 90 could transmit pressurized lubricating fluid into the first housing member 30, for example for lubrication of various bearings (e.g., the bearings that are mounted in the first housing member 30 and support the second compound gears 210), and/or gear meshes.

[0057] With reference to Figures 16 through 19, the multi-speed input portion 92 of the transmission 16 can further include an actuator assembly 300 that is configured to move the input shaft 108 between the high-speed, neutral and low-speed positions. The actuator assembly 300 can be configured in any manner desired, but in the particular example provided, includes an output assembly 302, a lead screw 304, a coupler 306, first and second actuator bearings 308 and 310, and an actuator motor 312.

[0058] The output assembly 302 can include a bearing 320 and an axially movable member 322. The bearing 320 can be received over the input shaft 108 and can be abutted against a shoulder that is formed on the input shaft 108. The axially movable member 322 can extend between the motor axis 70 and a rotational axis of the lead screw 304 and can define a bearing aperture and a coupler mount 330 that are disposed on its opposite ends. The bearing 320 is received in the bearing aperture and can be fixedly coupled to the axially movable member 322 in any desired manner. In the example provided, an internal snap ring is mounted into a snap-ring groove that is formed into the axially movable member 322 concentric with the bearing aperture b4 and on an axial end of the bearing 320 that is opposite the axial end of the bearing 320 that abuts the shoulder on the input shaft 108. Accordingly, the axially movable member 322 is coupled to the input shaft 108 in a manner that inhibits relative axial movement between the axially movable member 322 and the input shaft 108 but which permits rotation of the input shaft 108 relative to the axially movable member 322.

[0059] The lead screw 304 is rotatably disposed about a lead screw axis and includes a lead screw input 340 and an externally threaded portion 342.

[0060] The coupler 306 can have an internally threaded hub 350 and a mounting flange 352 that can be mounted to the coupler mount 330. The internally threaded hub 350 can be threaded onto the externally threaded portion 342 of the lead screw 304. It will be appreciated that the mounting flange 352 and the coupler mount 330 can be configured in any desired manner. In the example provided, the mounting flange 352 has a non-circular cross-sectional area (taken perpendicular

to the longitudinal axis of the internally threaded hub 350) and the coupler mount 330 defines a slot into which a portion of the mounting flange 352 is received so that the mounting flange 352 is axially and non-rotatably coupled to the coupler mount 330. Accordingly, rotation of the lead screw 304 causes corresponding translation of both the coupler 306 and the output assembly 300.

[0061] The first and second bearings 308 and 310 can be mounted to the gearcase and can support the lead screw 304 for rotation about the lead screw axis.

[0062] The actuator motor 312 is configured to provide rotary power to drive the lead screw 304 about the lead screw axis. The actuator motor 312 can be directly coupled to the lead screw input or a speed reduction, such as a reduction gearset, can be disposed between the actuator motor 312 and the lead screw input. In the example provided, a reduction gearset that utilizes bevel gearing is employed. More specifically, the reduction gearset comprises an actuator input gear 360, which is directly driven by the actuator motor 312 about an axis that is perpendicular to the lead screw axis, and an actuator output gear 362 that is meshingly engaged with the actuator input gear 360 and rotatable about the lead screw axis. It will be appreciated that the reduction gearset could be configured differently and need not utilize bevel gearing. The actuator output gear 362 can be coupled to the lead screw input in any desired manner. For example, the actuator output gear 362 can be directly coupled to the lead screw input so that the lead screw 304 rotates directly with the actuator output gear 362. Alternatively, a torsionally resilient coupling could be employed between the actuator output gear

362 and the lead screw input 340 to provide compliance in one or both rotational directions between the actuator output gear 362 and the lead screw 304. In the example provided, a torsionally resilient coupling permits the actuator output gear 362 to rotate in instances where the input shaft 108 is not able to translate (e.g., due to: 1) tooth-on-tooth contact between one of the sets of external splines on the input shaft and one of the sets of internal splines on one of the first or third gears or between the first and second face teeth; or 2) the magnitude of the torque that is exerted through the input shaft 108, i.e., torque loading).

[0063] With reference to Figures 16 and 19 through 22, a park-lock mechanism 400 can be incorporated into the multi-speed electric drive axle 10 (Fig. 1). In the example provided, the park-lock mechanism 400 is configured to inhibit rotation of the third gear 104 to inhibit rotation of the differential input member 230 (Fig. 5) and thereby inhibit rotation of the differential output members 232 (Fig. 5). The park-lock mechanism 400 can include a park-lock gear 402, a pivot pin 404, a park pawl 406, and a park-lock plunger assembly 408.

[0064] The park-lock gear 402 can be fixedly coupled to the third gear 104 and can define a plurality of park-lock teeth and a plurality of valleys 420 that are each disposed circumferentially between an associated pair of the park-lock teeth. The pivot pin 404 can be fixedly coupled to the second housing member 32. In the example provided, the pivot pin 404 is mounted on a bracket 424 that is in turn mounted to the second housing member 32. Any desired means can be employed to control the position and orientation of the bracket 424 relative to the second housing member 32. In the example provided, a pair of pins 426 are mounted to

the bracket 424 and are received into corresponding holes in the second housing member to both position the pivot pin 404 at a desired location and to inhibit rotation of the bracket 424 relative to the second housing member 32. One or more threaded fasteners can be employed to secure the bracket 424 to the second housing member 32.

[0065] The park pawl 406 includes a pawl body 430 which is pivotally mounted on the pivot pin 404, and a pawl member 432 that is fixedly coupled to the pawl body 430. The pawl body 430 can pivot relative to the park-lock gear 402 between a first or locked position, in which the park pawl 406 is received into a valley 420 to thereby inhibit rotation of both the park-lock gear 402 and the third gear 104 about the motor axis 70, and a second or unlocked position in which the park pawl 406 is disengaged from the park-lock gear 402 and does not inhibit rotation of the park-lock gear 402 about the motor axis 70. The park-pawl 406 can optionally include a guide structure 438 that can be mounted to the second housing member 32. The guide structure 438 can have a guide member that can guide the pawl body 430 as it moves between the first and second positions. Movement of the guide structure 438 caused by corresponding movement of the plunger 450 can cause corresponding pivoting motion of the pawl body 430 about the pivot pin 404.

[0066] A biasing spring, such as a torsion spring 440, can be employed to bias the pawl body 430 into the second position. In the example provided, the torsion spring 440 has a helically coiled portion that is received over the pivot pin 404 and disposed between two arms. An end of a first one of the arms is mounted

to the bracket 424, while an end of the other one of the arms is mounted to the pawl body 430. A feature, such as a head or a washer, can be formed on or coupled to the pivot pin 404 to trap the helically coiled portion of the torsion spring 440 on the pivot pin 404 on a side of the bracket 424 that is opposite the park pawl 406.

[0067] The park-lock plunger assembly 408 can include a plunger 450, an input member 452 and a compliance spring 454. The plunger 450 is movable along an axis that is parallel to the motor axis 70 and has a generally cylindrical first plunger portion, a generally cylindrical second plunger portion and a transition portion that tapers between the first and second plunger portions. The first plunger portion has a first diameter, the second plunger portion is spaced apart from the first plunger portion and has a second, larger diameter, and the transition portion is disposed and tapers between the first and second plunger portions so that the transition portion has a frustoconical exterior surface. The plunger 450 can be translated between a first plunger position, in which the first plunger portion is in contact with the park pawl 406, and a second plunger position in which either the transition portion or the second plunger portion is in contact with the park pawl 406. The first plunger portion is sized so that the pawl body 430 of the park pawl 406 is disposed in the second position when the first plunger portion is engaged to (directly contacts) the pawl body 430. Translation of the plunger 450 from the first plunger position to the second plunger position causes relatively larger portions of the plunger 450 to contact the pawl body 430, which pivots the pawl body 430 toward the second pawl position.

[0068] The input member 452 is movable about the translation axis of the plunger 450 and can be moved in any desired manner. In the example provided, an electric park-lock motor 460 and a manual park-lock input lever 462 are provided as alternative or redundant inputs for the operation of the park-lock mechanism 400, while an output lever 464 is employed to coordinate movement of the input member 452. More specifically, the output lever 464 is coupled to the input member 452 and is pivotably coupled to the second housing member 32 for movement between a first input position and a second input position. The manual park-lock input lever 462 is fixedly coupled to a portion of the output lever 464 that extends through the second housing member 32 (i.e., so that the manual park-lock input lever 462 is disposed outside the gearcase). Pivoting motion of the manual park-lock input lever 462 about the pivot axis of the output lever 464 causes corresponding pivoting motion of the output lever 464 about the pivot axis of the output lever 464. The electric park-lock motor 460 is mounted to an exterior surface of the second housing member 32 and includes an output shaft 470 that extends into the transmission cavity 38. An intermediate lever 472 is coupled to the output shaft 470 of the electric park-lock motor 460 and can be moved by the electric park-lock motor 460 about the rotational axis of the output shaft 470 between a first intermediate lever position and a second intermediate lever position. An end of the intermediate lever 472 that is opposite the output shaft 470 includes a pin that is received into a slotted aperture in the output lever 464. Movement of the intermediate lever 472 from the first intermediate lever position to the second intermediate lever position (in response to rotation of the output shaft

470) causes pivoting motion of the output lever 464 about its pivot axis from the first input position to the second input position. The slotted aperture in the output lever 464 permits the output lever 464 to be moved about its pivot axis from the first input position to the second input position without corresponding motion of the intermediate lever 472.

[0069] The compliance spring 454 is disposed between the input member 452 and the plunger 450 and permits the pawl body 430 to push the plunger 450 away from the pawl body 430 when the output lever 464 is disposed in the second input position. It will be appreciated that placement of the output lever 464 in the second input position places the input member 452 into a position that would ordinarily position the plunger 450 in the second plunger position. However, in situations where the pawl member 432 is not able to drop into a valley 420 or remain in a valley 420, the park pawl 406 can translate the plunger 450 toward the compliance spring 454 to compress the compliance spring 454 so that the park-lock gear 402 is able to rotate.

[0070] Significant portions of both the actuator assembly 300 and the park-lock mechanism 400 can be assembled to the second housing member 32 before it is assembled to the first housing member 30 to close the transmission cavity 38 and the differential cavity 40. In this regard, all or portions of the reduction gearset (e.g., the actuator input gear 360 and the actuator output gear 362 in the example provided), the bearings 308 and 310, the lead screw 304, the torsionally resilient coupling (if included) and optionally the coupler 306 and/or the actuator motor 312 of the actuator assembly 300 can be installed to the second housing member 32

prior to the mounting of the second housing member 32 to the first housing member 30. Additionally or alternatively, all of the components of the park-lock mechanism 400 except for the park-lock gear 402 can be assembled to the second housing member 32 prior to the mounting of the second housing member 32 to the first housing member 30.

[0071] With reference to Figures 23 through 27, an alternative actuator assembly 300a is illustrated. The actuator assembly 300a is configured to move the input shaft 108 between the high-speed, neutral and low-speed positions, but is configured to provide a modicum of compliance in shifting, as will be explained in more detail below, and to permit the input shaft 108 to be biased toward the high-speed position in situations where electrical power to the actuator assembly 300a has been interrupted. The actuator assembly 300a can include an output assembly 302a, a ball screw 304a, a coupler 306a, first and second actuator bearings 308 and 310, and an actuator motor (not specifically shown). Except as described below, the ball screw 304a and the coupler 306a can be generally similar to the lead screw 304 and the coupler 306 described above. It will be appreciated, however, that the ball screw 304a and the coupler 306a define external and internal tracks, respectively, between which a plurality of spherical balls are disposed and that rotation of the ball screw 304a will cause commensurate linear movement of the coupler 306a along the axis of the ball screw 304a.

[0072] The output assembly 302a can include a bearing 320, an axially movable member 322a, and a pivot fork assembly 500. The bearing 320 can be received over (i.e., mounted on) the input shaft 108 and can be abutted against a

shoulder that is formed on the input shaft 108. The axially movable member 322a can include a sleeve member 322a-1, which can be mounted to the outer bearing race of the bearing 320 and can be disposed concentrically about the input shaft 108, and one or more connecting elements (not specifically shown) that couple the sleeve member 322a-1 to the input shaft 108 in a manner that permits relative rotation but limits or inhibits relative axial movement along the motor axis 70. In the example provided, the connecting element(s) are formed of wire with a circular cross-sectional shape and includes a semi-circular body (not specifically shown), which is received into a circumferentially-extending groove in the input shaft 108, and a pair of ears (not specifically shown) that extend radially outwardly from the opposite ends of the semi-circular body through first connecting element apertures formed through the circumferential wall of the sleeve member 322a-1.

[0073] The pivot fork assembly 500 can include a first fork member 510, a second fork member 512, a plurality of first pivot pins 514, a second pivot pin 516, a pair of connecting pins 518, and one or more compliance springs 520. The first fork member 510 can define a pair of first pivot pin mounts 530, a second pivot pin mount 532, a pair of first connecting pin apertures 534 and a first compliance spring mount 536. The second fork member 512 can define a third pivot pin mount 540, a pair of second connecting pin apertures 542, a pair of second connecting element apertures 544, and a second compliance spring mount 546.

[0074] Each of the first pivot pins 514 can be received through a corresponding one of the first pivot pin mounts 530 and into a respective first pivot pin aperture (not specifically shown) formed in the coupler 306a to pivotally couple

a first end of the first fork member 510 to the coupler 306a for pivoting movement about the rotational axis of the ball screw 304a.

[0075] The second pivot pin 516 can be received through apertures (not specifically shown) in the second pivot pin mount 532 and the third pivot pin mount 540 to pivotally couple the first and second fork members 510 and 512 to one another for pivoting movement about a longitudinal axis of the second pivot pin 516.

[0076] Each of the connecting pins 518 can be disposed through an associated set of the first and second connecting pin apertures 534 and 542. The connecting pins 518 and the first and second connecting pin apertures 534 and 542 can cooperate to control and limit pivoting motion of the second fork member 512 about the second pivot pin 516 relative to the first fork member 510 in first and second pivot directions. In the example provided, the first connecting pin apertures 534 in the first fork member 510 are round in shape and are configured to engage the connecting pins 518 in an interference fit (e.g., press-fit) manner, while the second connecting pin apertures 542 in the second fork member 512 are slotted. Accordingly, the connecting pins 518 are able to travel within the slots of the second connecting pin apertures 542 when the second fork member 512 pivots about the second pivot pin 516 relative to the first fork member 510.

[0077] The second connecting element apertures 544 can be positioned on opposite sides of the sleeve member 322a-1 and can have a slotted shape. The ears of each connecting element can be received through a corresponding one of the second connecting element apertures 544. The slotted shape of the second

connecting element apertures 544 permits the second fork member 512 to move relative to the ears of the connecting element when the second fork member 512 is pivoted about the second pivot pin 516 and exert a force to the ears that is directed along the motor axis 70.

[0078] The compliance spring(s) 520 can be mounted on the first and second compliance spring mounts 536 and 546 and can bias the second fork member 512 about the second pivot pin 516 in the first pivot direction. Engagement between the connecting pins 518 and an (upper) end of the slots of the second connecting pin apertures 542 can limit the extent to which the second fork member 512 pivots about the second pivot pin 516 relative to the first fork member 510.

[0079] In operation, the ball screw 304a can be rotated (i.e., through rotation of the actuator motor and if included, a reduction gearset) to cause translation of the coupler 306a along the ball screw 304a. Translation of the coupler 306a causes corresponding pivoting motion of the first fork member 510 about the first pivot pins 514 relative to the coupler 304a. In instances where tooth-on-tooth contact does not occur so that the input shaft 108 is able to translate freely along the motor axis 70, the second fork member 512 moves with the first fork member 510 about the first pivot pins 514, which causes corresponding translation of the compliance springs 520 which tends to cause corresponding translation of the connecting element along the motor axis 70 to thereby move the sleeve member 322a-1 and the input shaft 108 along the motor axis 70. In instances where the input shaft 108 is not able to move freely along the motor axis 70 (e.g., due to tooth-on-tooth contact or torque-lock), the second fork member 512 will not be able

to fully pivot with the first fork member 510 about the first pivot pins 514. In such cases, relative pivoting motion about the second pivot pin 516 will occur between the first and second fork members 510 and 512, causing corresponding compression of the compliance spring(s) 520. The compression of the compliance spring(s) 520 generates a force that is applied through the second fork member 512 and the axially movable member 322a to the input shaft 108. This force is maintained until such time that the input shaft 108 is able to translate along the motor axis 70 to a desired one of the high-speed, neutral and low speed positions associated with the positioning of the coupler 306a along the ball screw 304a. It will be appreciated that movement of the input shaft 108 caused by the force exerted by the compliance spring(s) 520 will cause pivoting motion of the second fork member 512 about the second pivot pin 516 to return the second fork member 512 to its "normal" position relative to the first fork member 510.

[0080] A biasing spring 550 can be provided to generate a biasing force that can be applied, either directly or indirectly, to the input shaft 108 to urge the input shaft 108 into the high-speed position. In the example provided, the biasing spring 550 is a compression spring that is disposed between the ball screw 304a and the coupler 306a. If desired, a thrust washer or bearing 552 can be disposed between an end of the biasing spring 550 and an associated one of the ball screw 304a and the coupler 306a. Due to the relatively low friction of the connection between the ball screw 304a and the coupler 306a, the force exerted by the biasing spring 550 onto the ball screw 304a and the coupler 306a causes corresponding rotation of the ball screw 304a relative to the coupler 306 that positions the coupler 306a

along the ball screw 304a in a location that is associated with the placement of the input shaft 108 in the high-speed position.

[0081] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

IN THE CLAIMS:

1. An actuator assembly configured to be coupled to a multi-speed electric drive axle, comprising:
 - an output assembly, including an axially-movably member configured to couple to a multi-speed input portion of the multi-speed electric drive axle;
 - a ball screw having an externally-threaded portion;
 - a coupler, attached to the axially-movable member, having an internally threaded hub that meshingly engages the externally-threaded portion of the ball screw such that rotation of the ball screw linearly moves the coupler and the axially-movable member.
2. The actuator assembly recited in claim 1, wherein the axially-movable member moves the multi-speed input portion of the multi-speed electric drive axle parallel to a motor axis of an electric motor propelling a vehicle.
3. The actuator assembly recited in claim 1, wherein the multi-speed input portion of the multi-speed electric drive axle includes a first gear and a second gear.
4. The actuator assembly recited in claim 1, wherein the multi-speed input portion of the multi-speed electric drive axle is a motor axis of an electric motor propelling a vehicle.
5. The actuator assembly recited in claim 1, wherein the axially-movable member moves the multi-speed input portion of the multi-speed electric drive axle parallel to a motor axis of an electric motor propelling a vehicle.
6. The actuator assembly recited in claim 1, wherein the multi-speed input portion of the multi-speed electric drive axle includes a first gear and a second gear.

7. The actuator assembly recited in claim 1, wherein the multi-speed input portion of the multi-speed electric drive axle is a motor axis of an electric motor propelling a vehicle.
8. An actuator assembly configured to be coupled to a multi-speed electric drive axle, comprising:
- an output assembly, including an axially-movably member configured to couple to a multi-speed input portion of the multi-speed electric drive axle;
 - a ball screw having an externally-threaded portion;
 - a coupler, attached to the axially-movable member, having an internally threaded hub that meshingly engages the externally-threaded portion of the ball screw such that rotation of the ball screw linearly moves the coupler and the axially-movable member;
 - a biasing spring configured to apply a biasing force to the multi-speed input portion of the multi-speed electric drive axle to urge the multi-speed input portion into a high-speed position.
9. The actuator assembly recited in claim 8, wherein the biasing spring is disposed between the ball screw and the coupler.
10. The actuator assembly recited in claim 8, wherein the biasing spring causes rotation of the ball screw relative to coupler.
11. An actuator assembly configured to be coupled to a multi-speed electric drive axle on a vehicle, comprising:
- a ball screw having an externally-threaded portion;
 - a coupler having an internally threaded hub that meshingly engages the externally-threaded portion of the ball screw such that rotation of the ball screw linearly moves the coupler;

- an axially-movable member configured to couple to a multi-speed input portion of the multi-speed electric drive axle and the coupler;
- a pivot fork assembly comprising:
- a first fork member;
 - a second fork member;
 - at least one first pivot pin pivotably coupling a first end of the first fork member to the coupler;
 - a second pivot pin pivotably coupling the first fork member to the second fork member;
 - a pair of connecting pins that pivotably couple the first fork member to the second fork member; and
 - one or more compliance springs that bias the second fork member about the second pivot pin in a first pivot direction.
12. The actuator assembly recited in claim 11, wherein the pair of connecting pins limits pivoting motion of the first fork member relative to the second fork member.
13. The actuator assembly recited in claim 11, further comprising a first connecting pin aperture receiving one of the connecting pins.
14. The actuator assembly recited in claim 13, wherein the first connecting pin aperture is round.
15. The actuator assembly recited in claim 11, further comprising a second connecting pin aperture receiving the connecting pins.
16. The actuator assembly recited in claim 15, wherein the second connecting pin aperture is slotted.

17. The actuator assembly recited in claim 11, further comprising a biasing spring configured to apply a biasing force to the multi-speed input portion of the multi-speed electric drive axle to urge the multi-speed electric drive axle into a high-speed position.

18. The actuator assembly recited in claim 17, wherein the biasing spring is disposed between the ball screw and the coupler.

19. The actuator assembly recited in claim 17, wherein the biasing spring causes rotation of the ball screw relative to coupler.

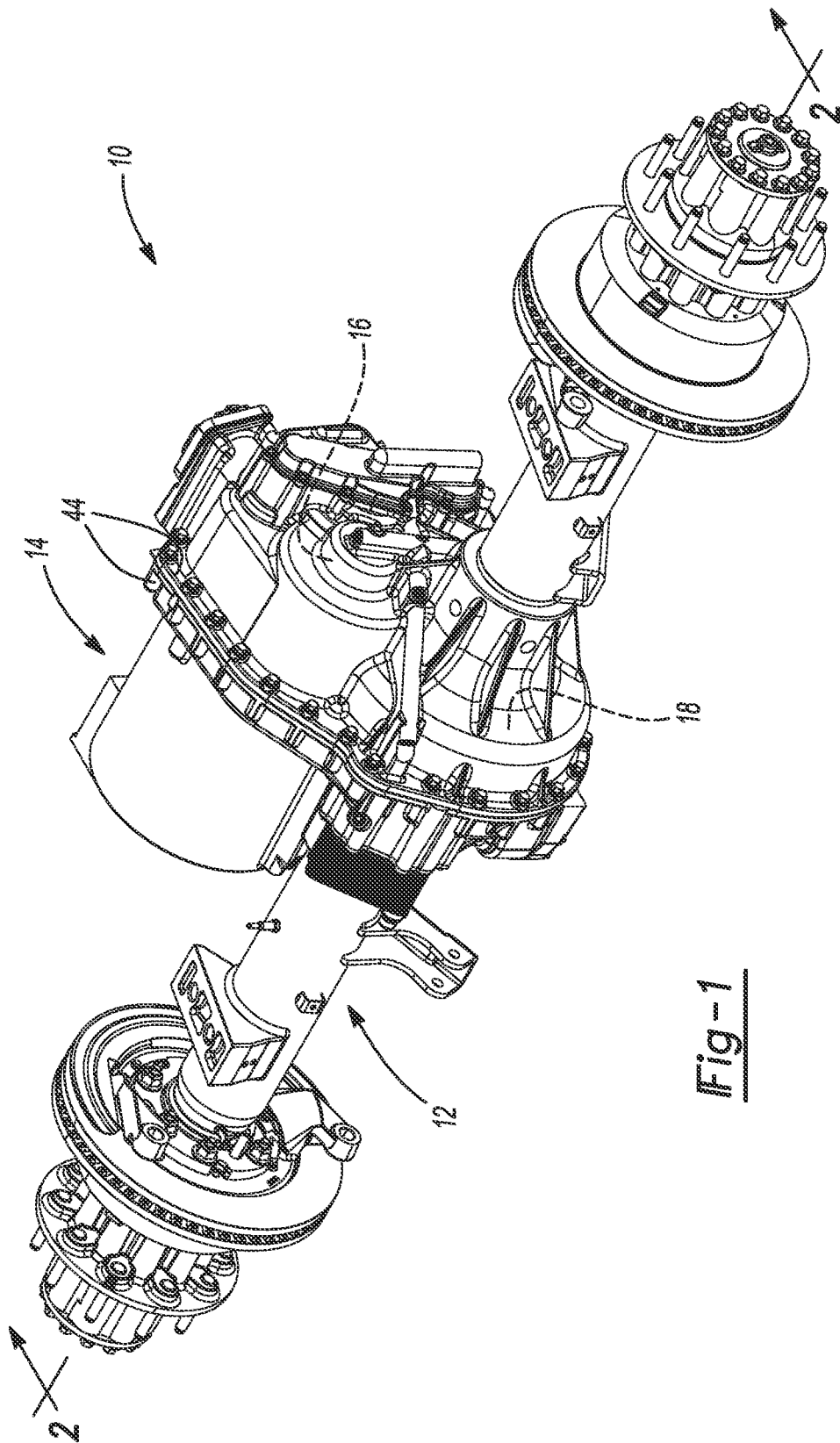


Fig-1

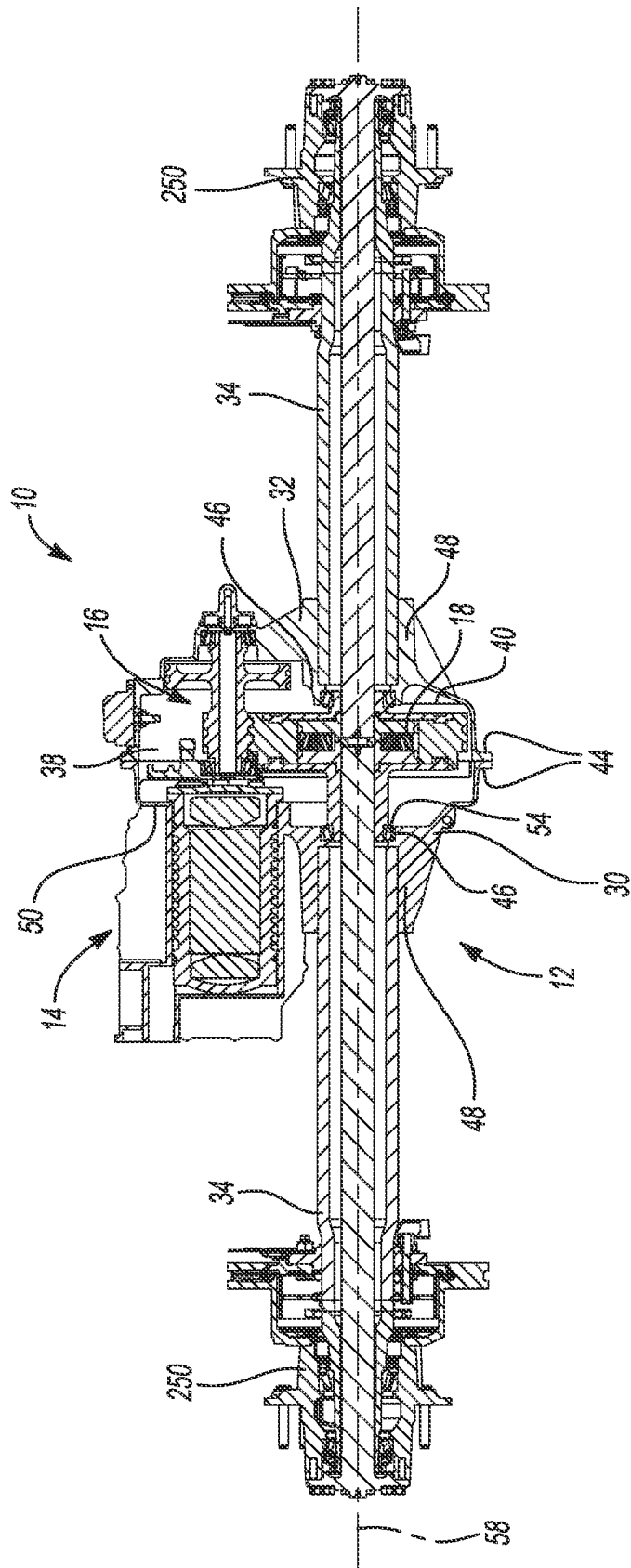


Fig-2

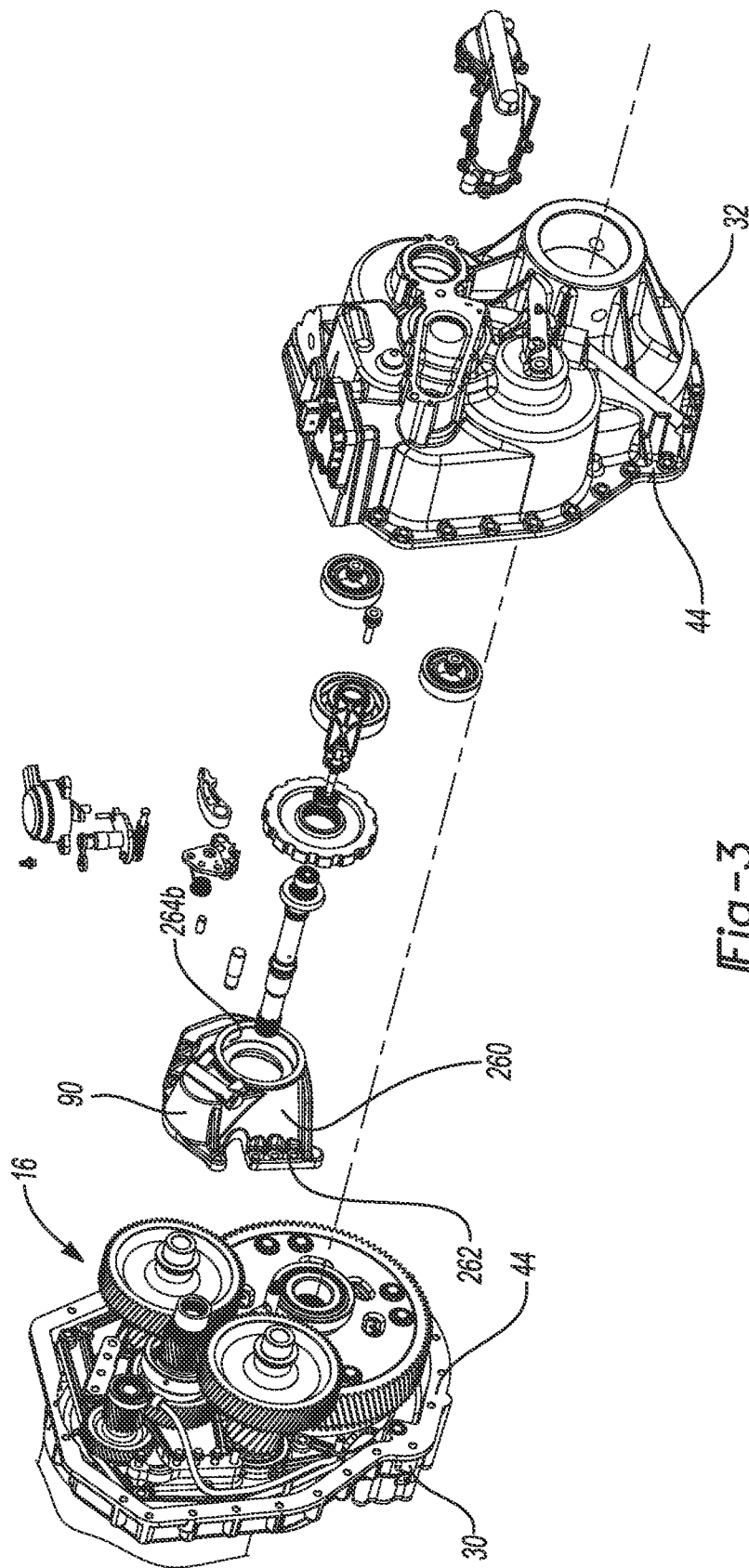


Fig-3

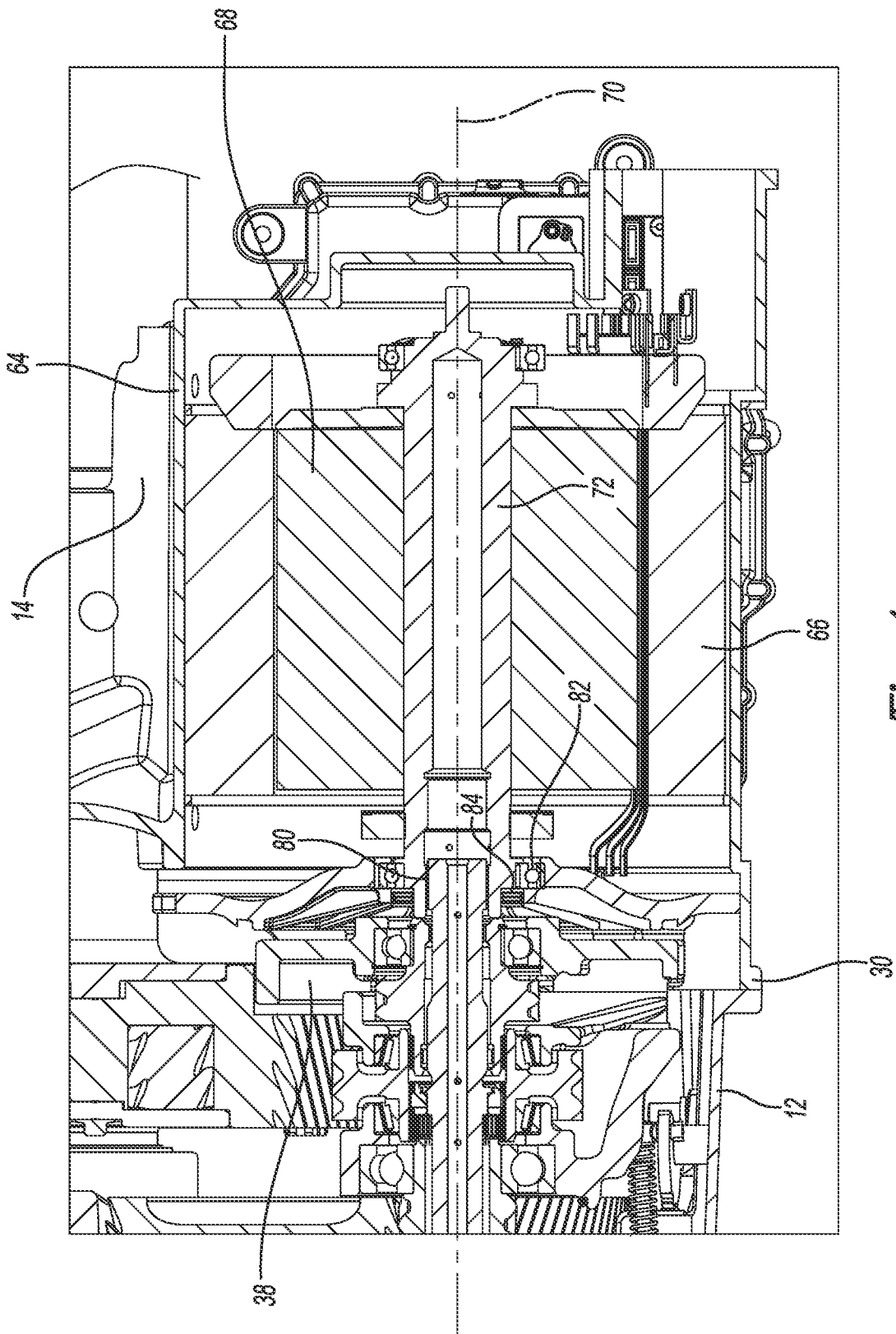
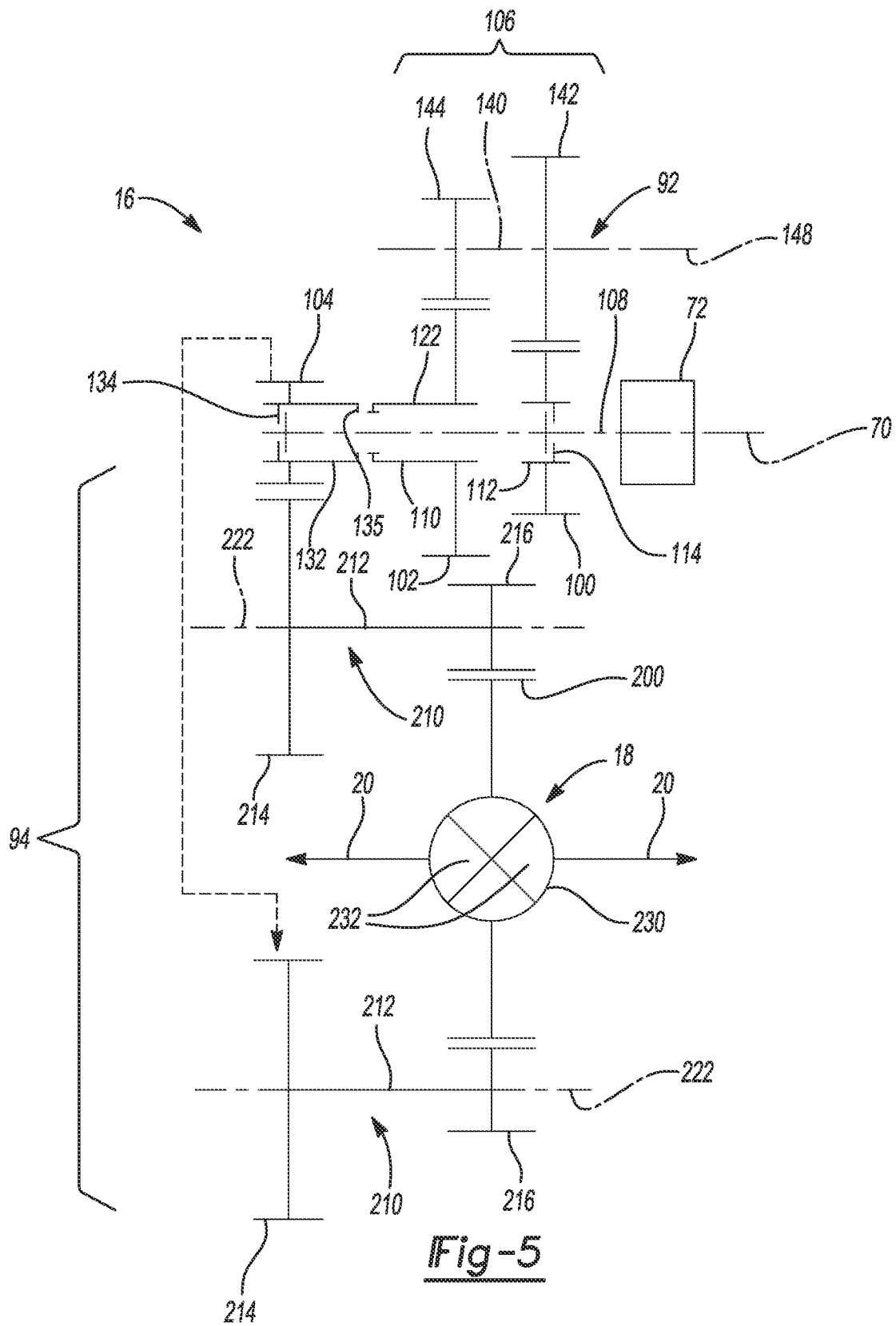


Fig -4



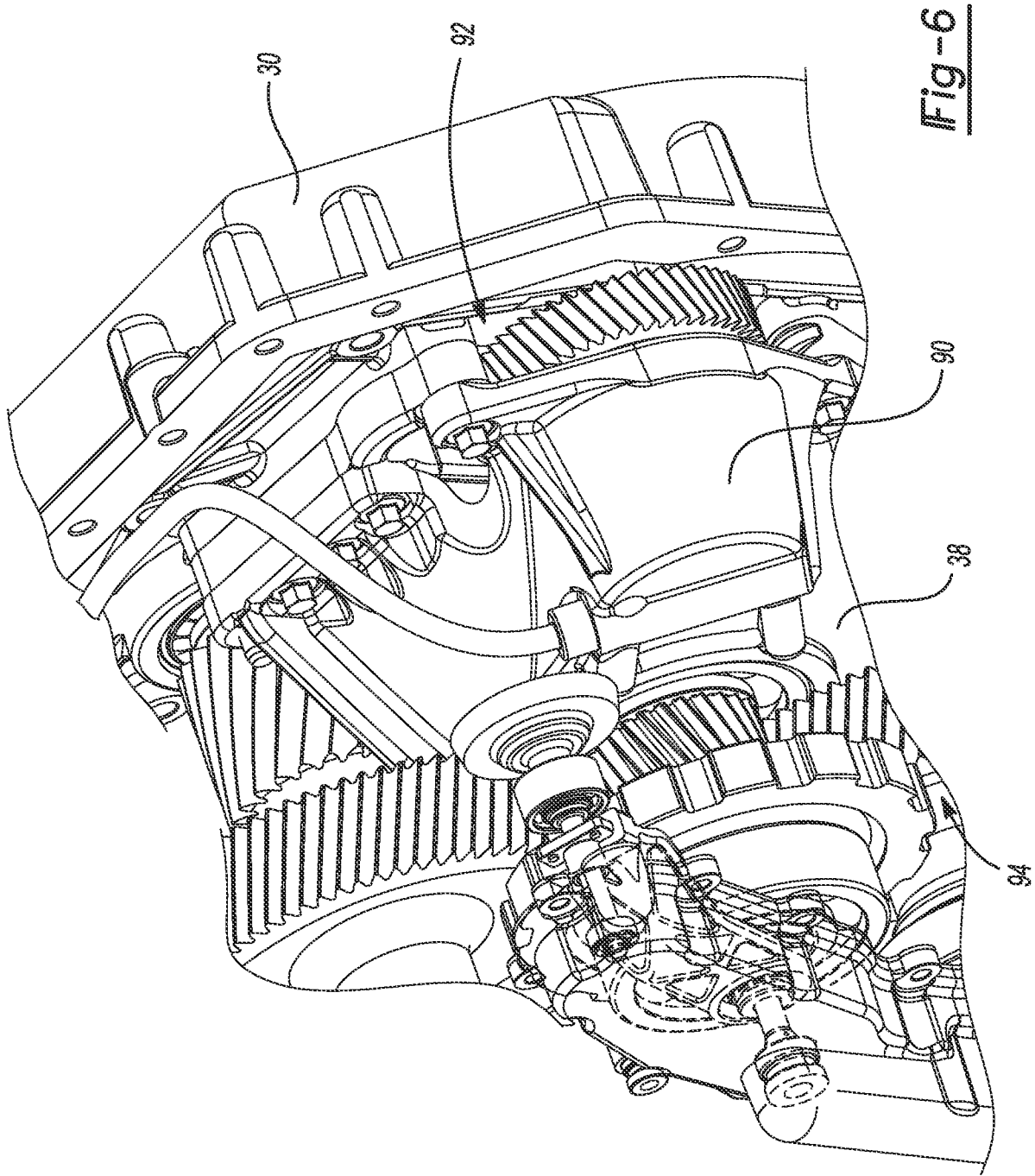


Fig-6

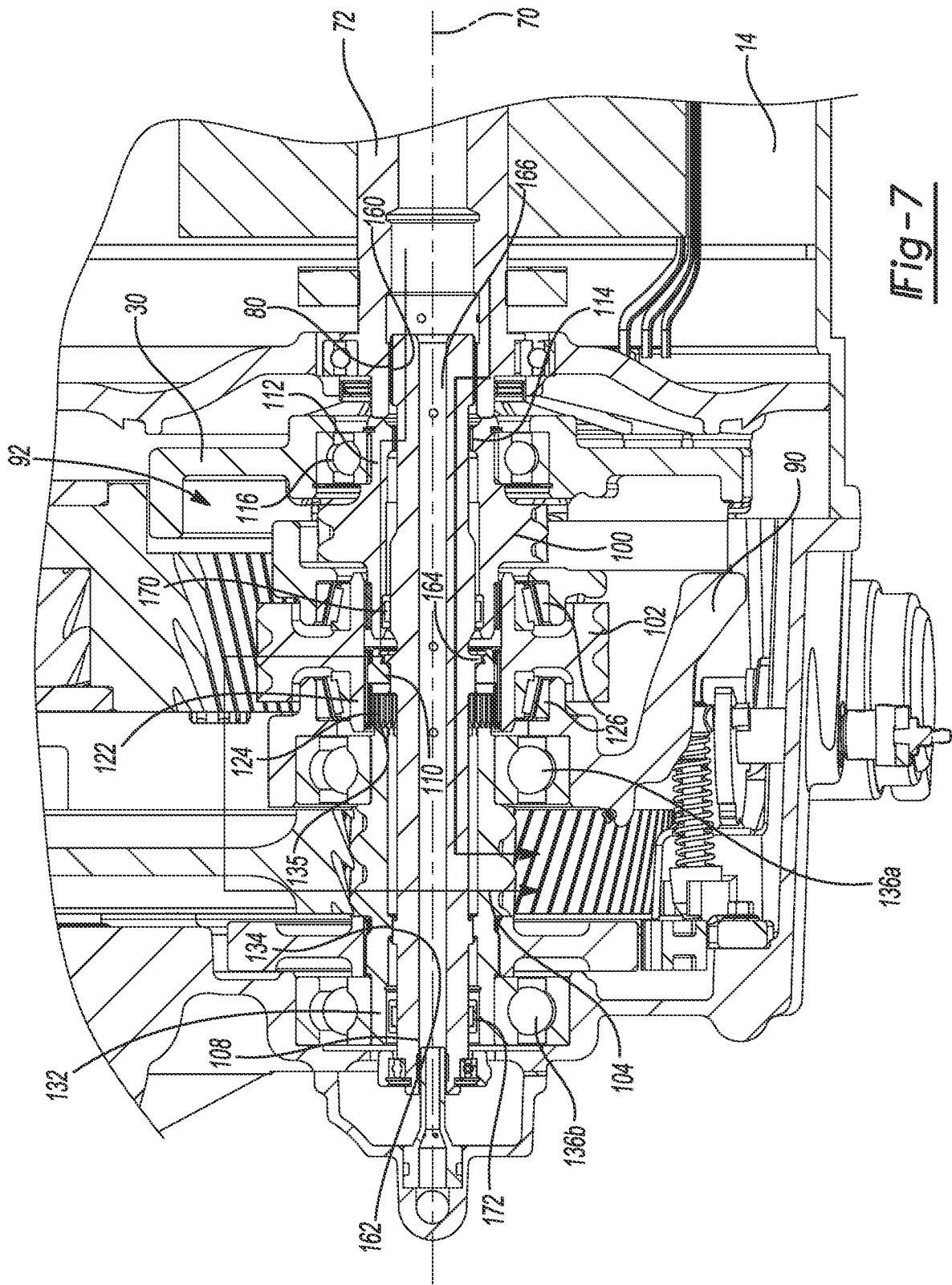
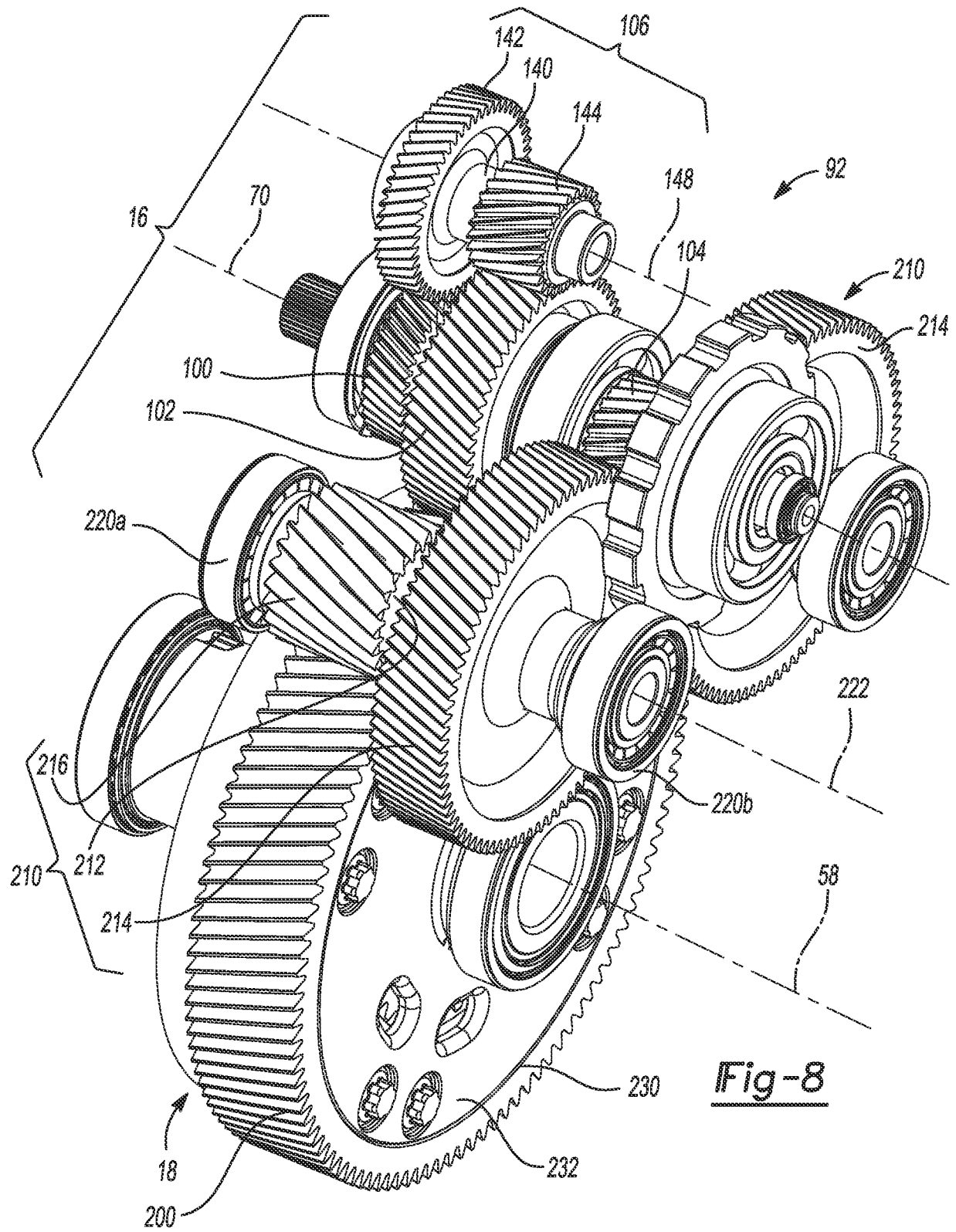


Fig-7



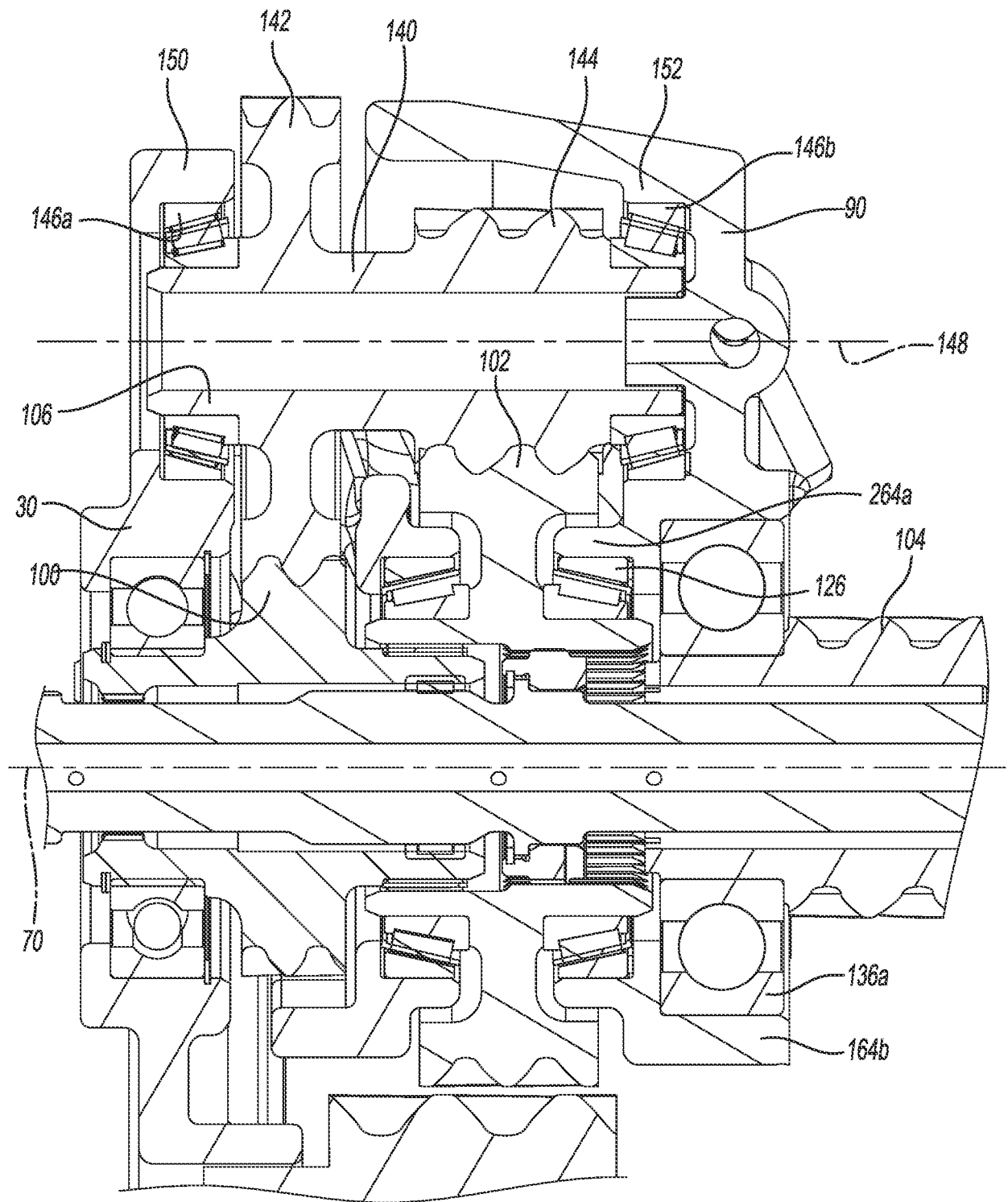
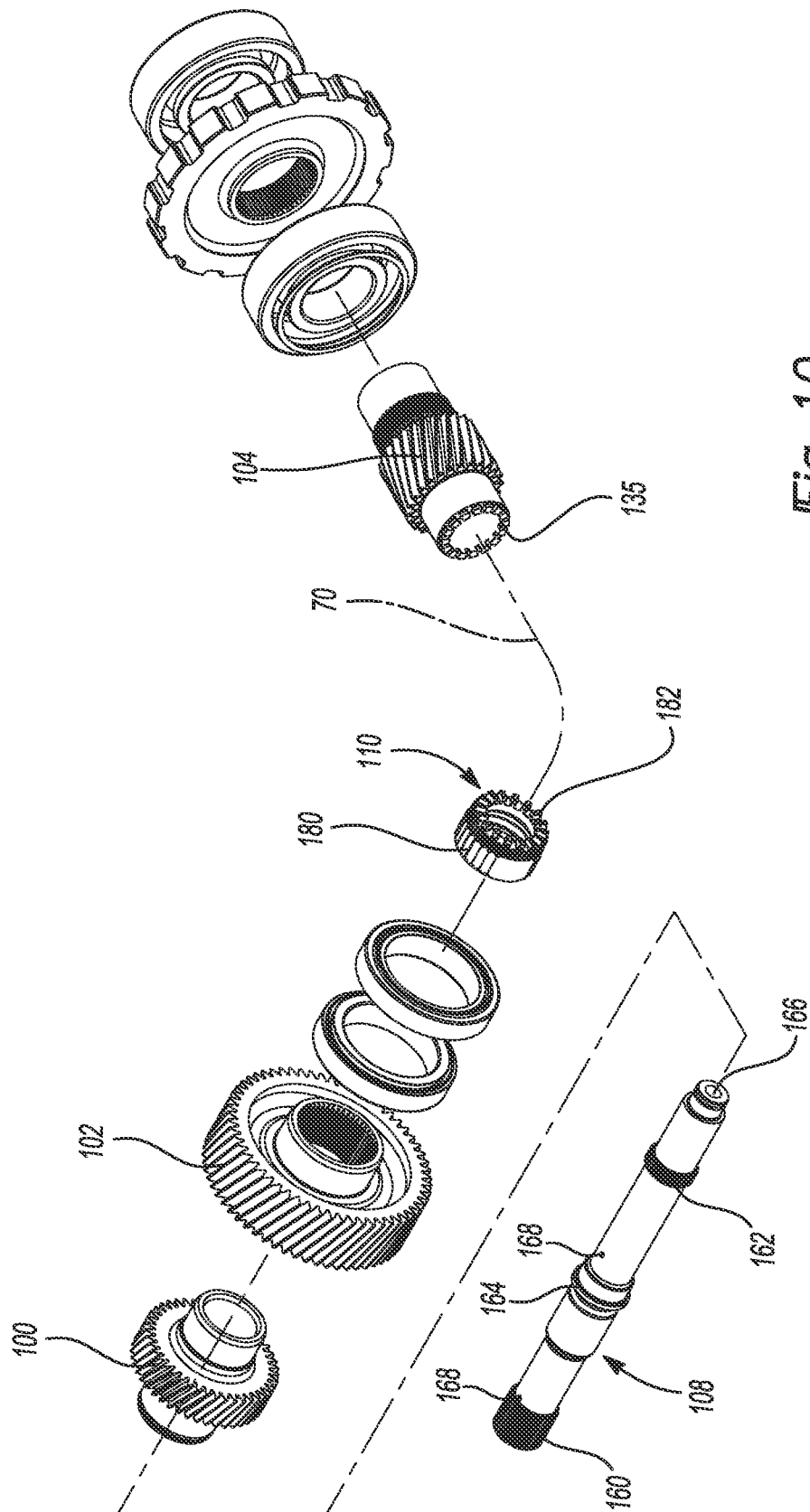


Fig-9



10-19-19

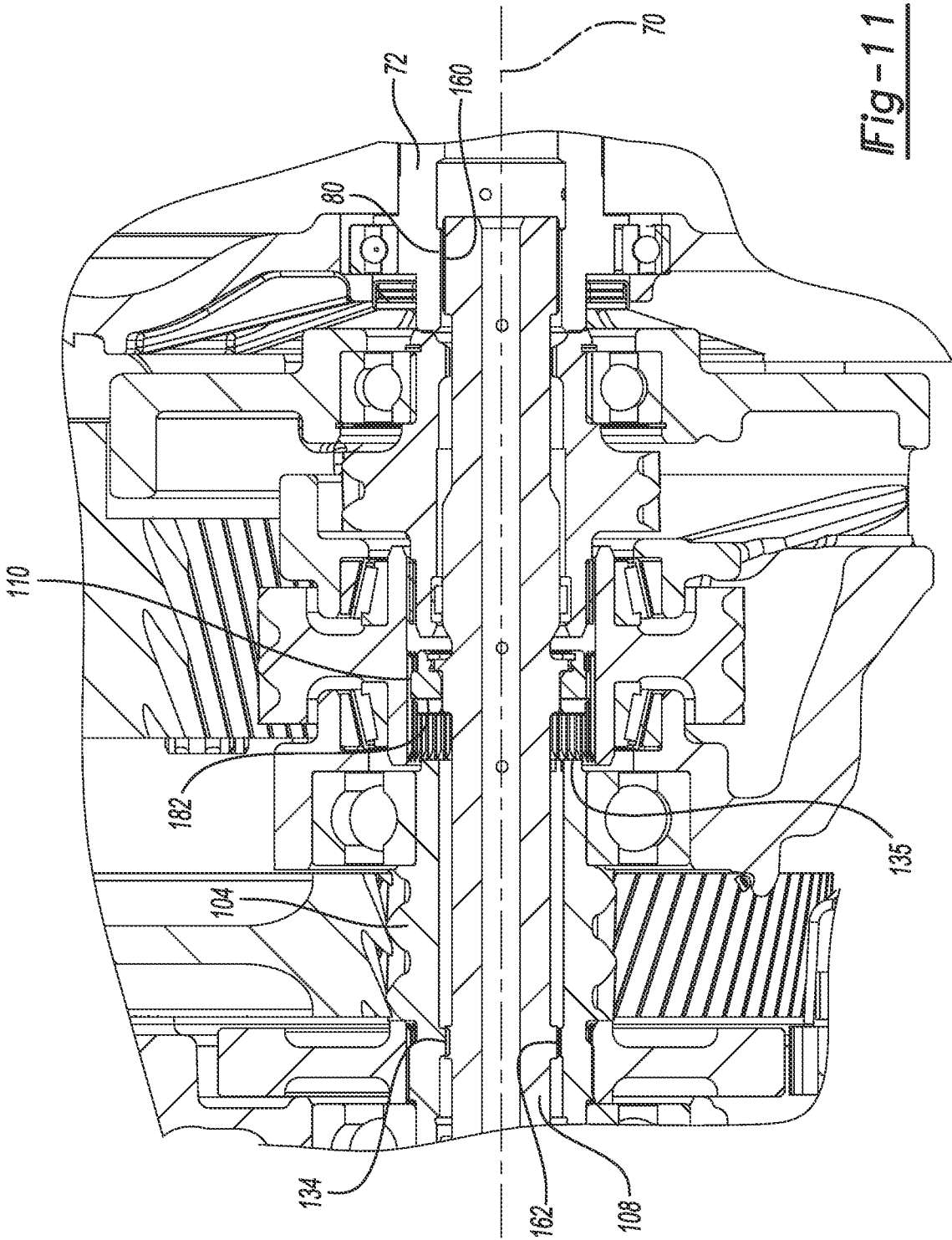


Fig-11

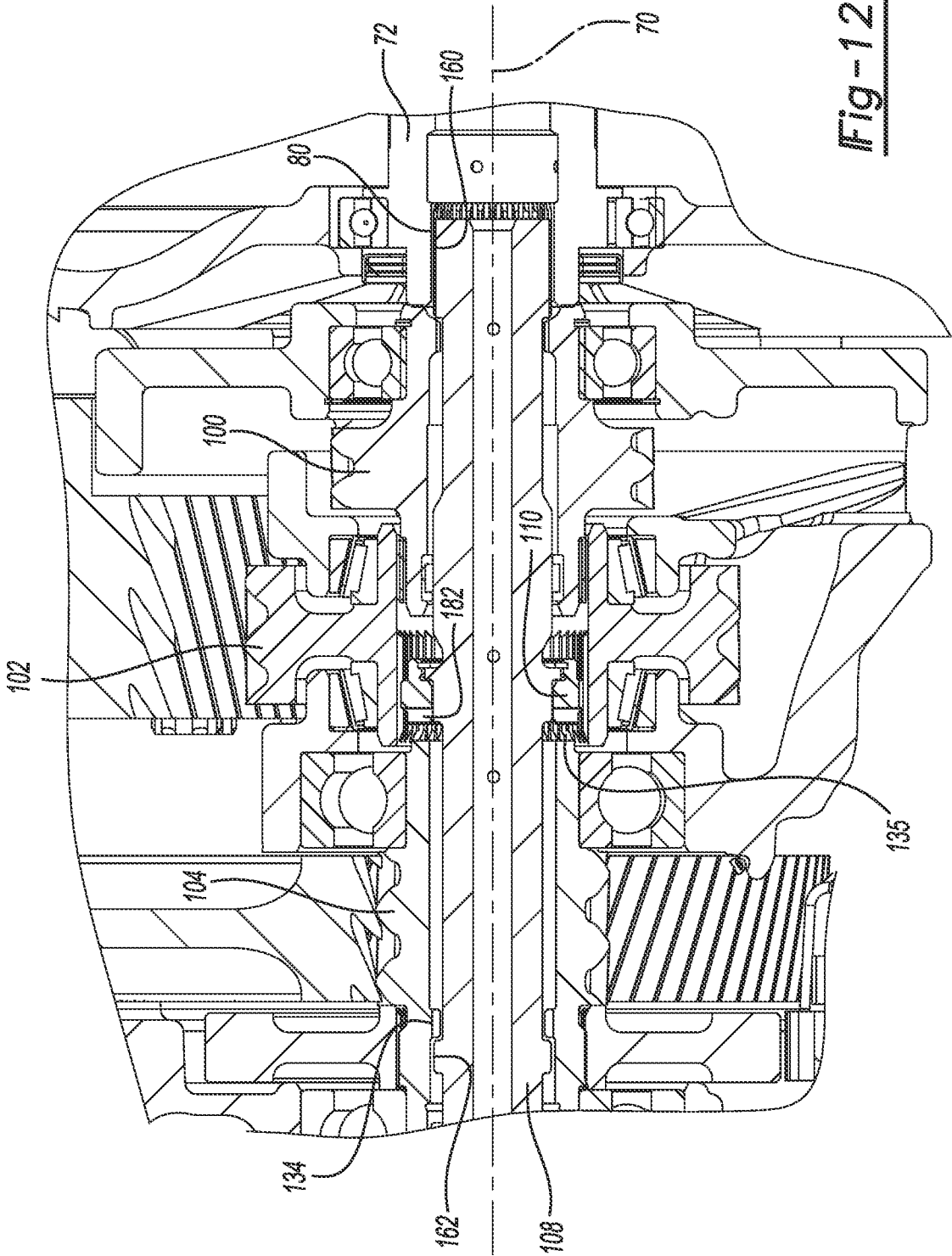


Fig-12

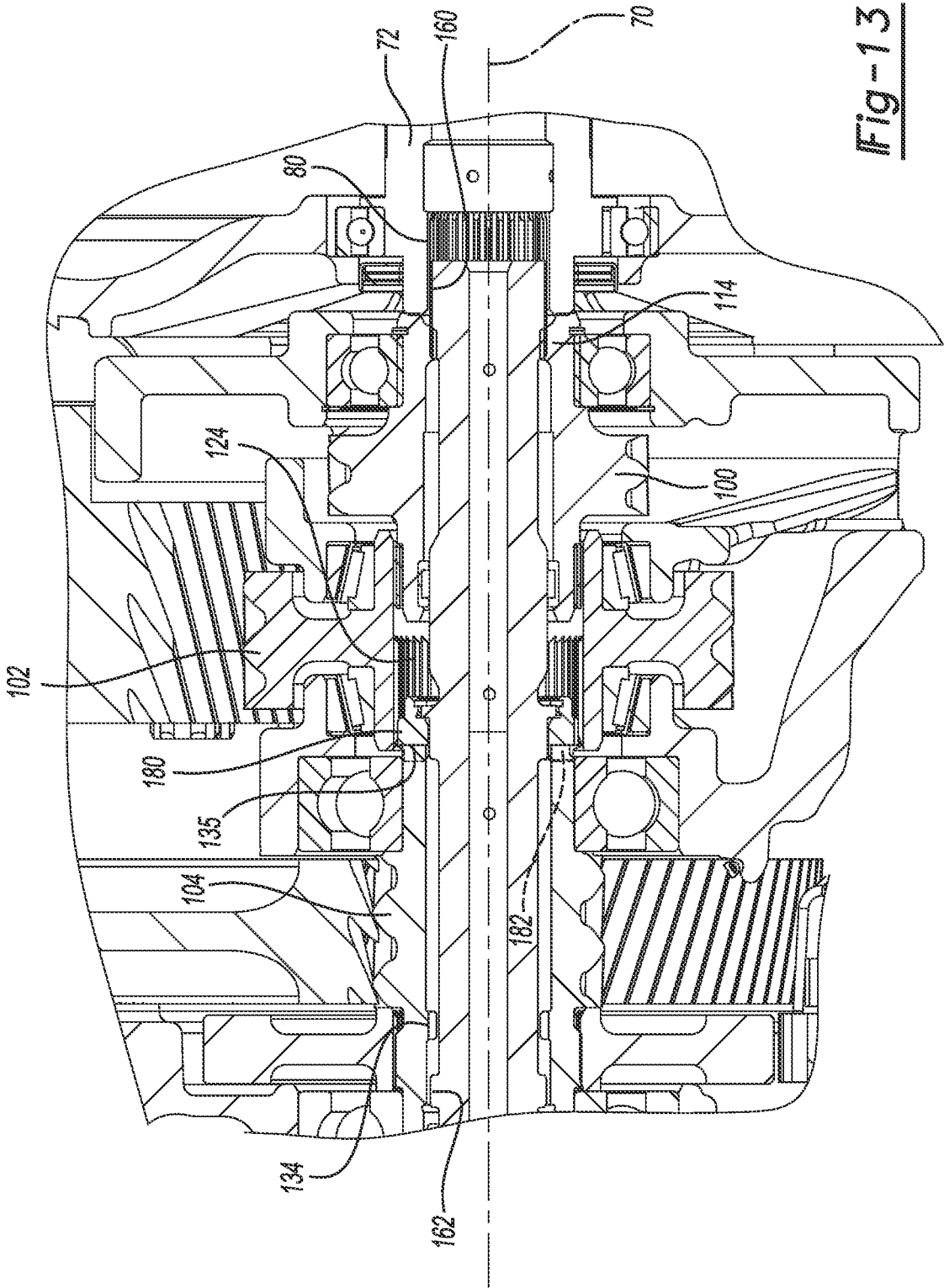


Fig-13

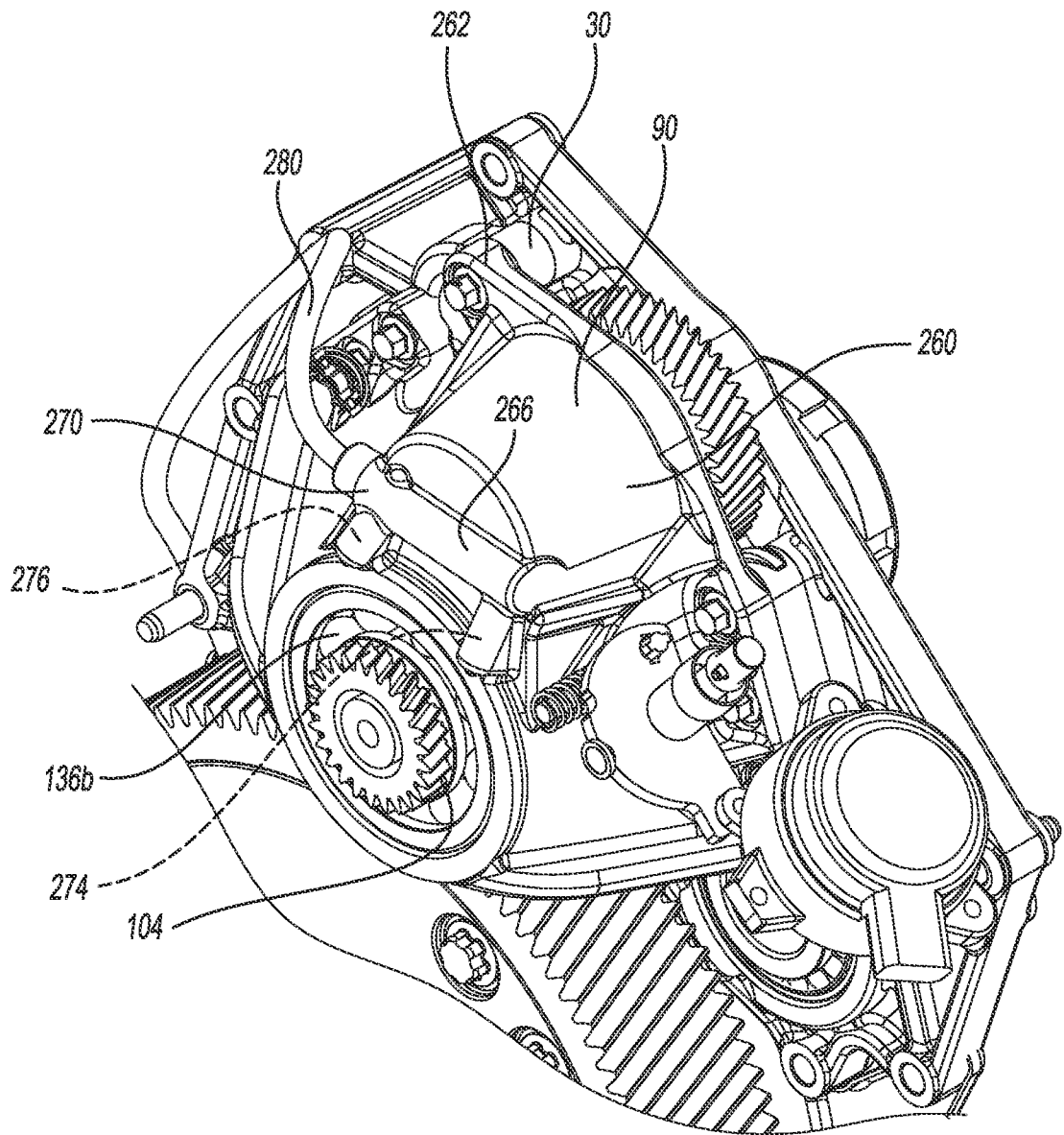
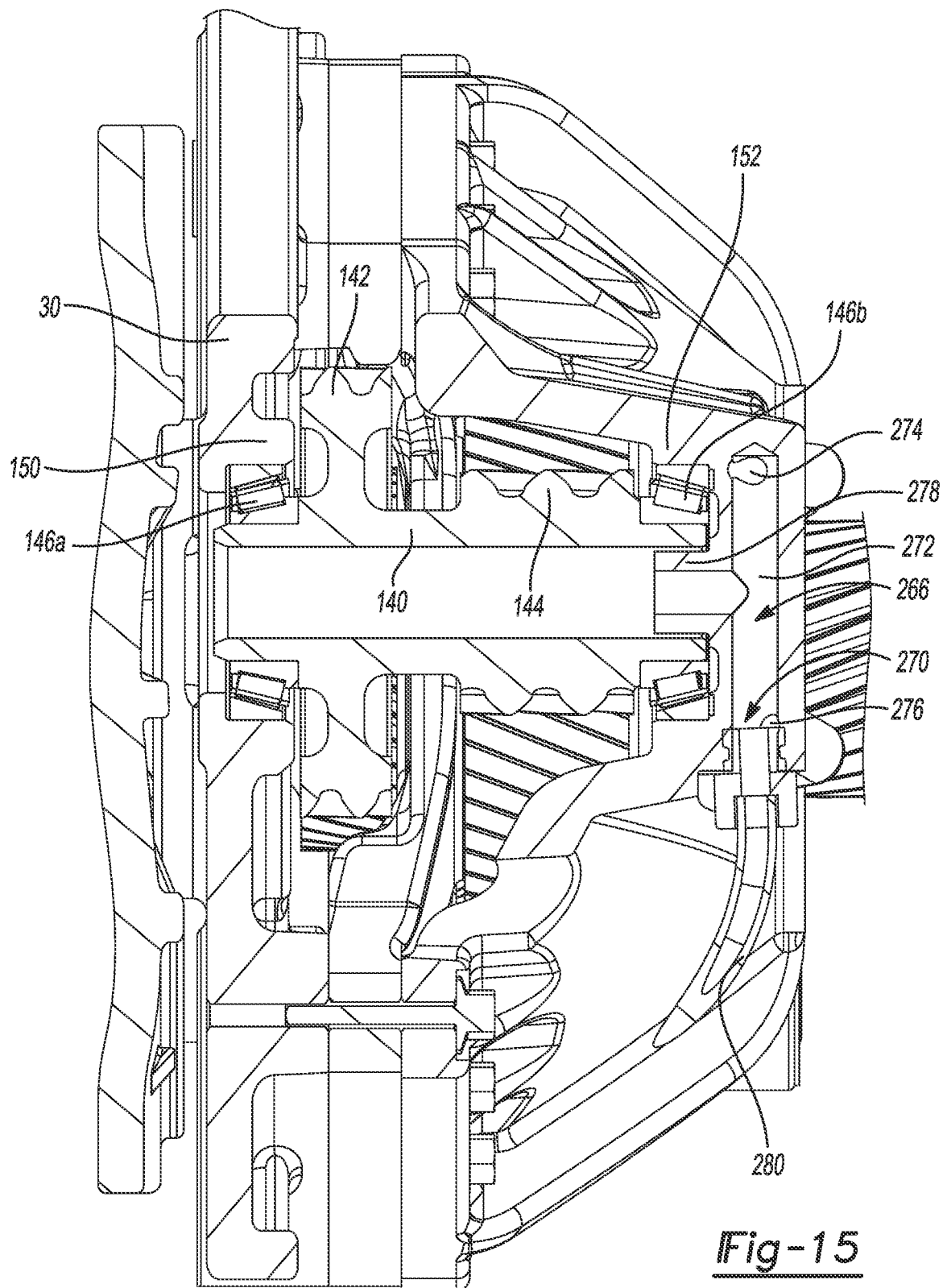


Fig-14



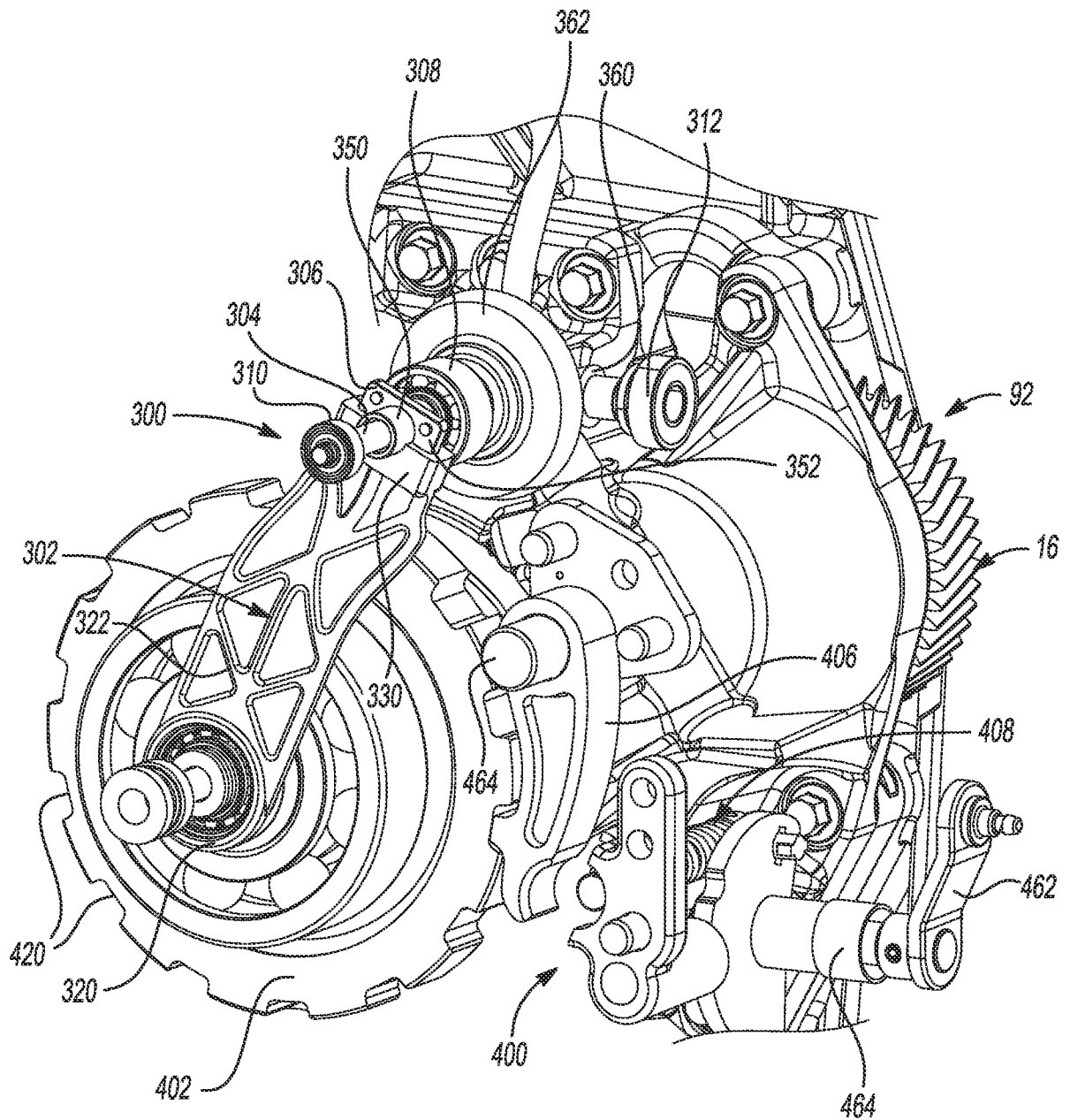


Fig-16

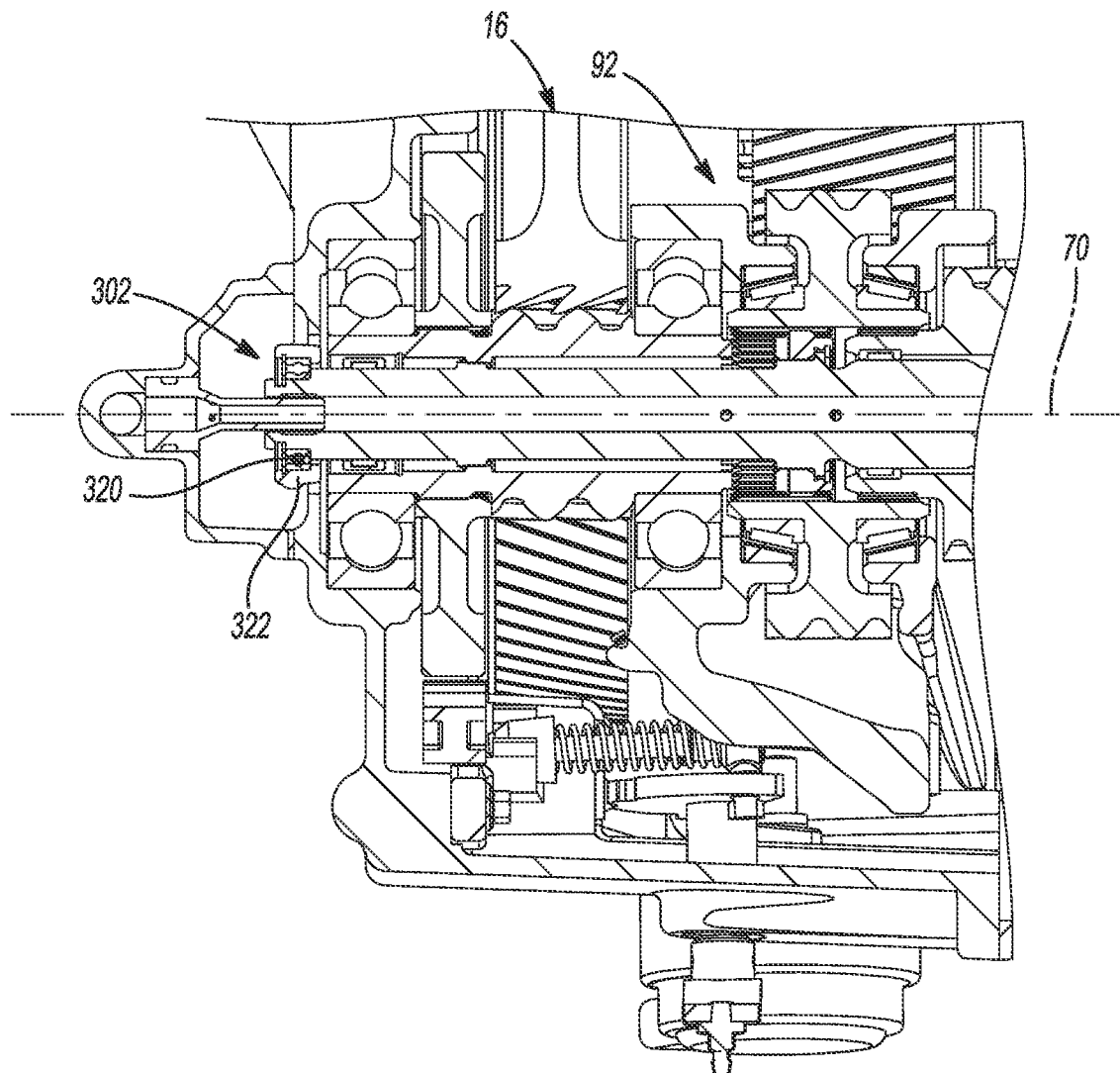
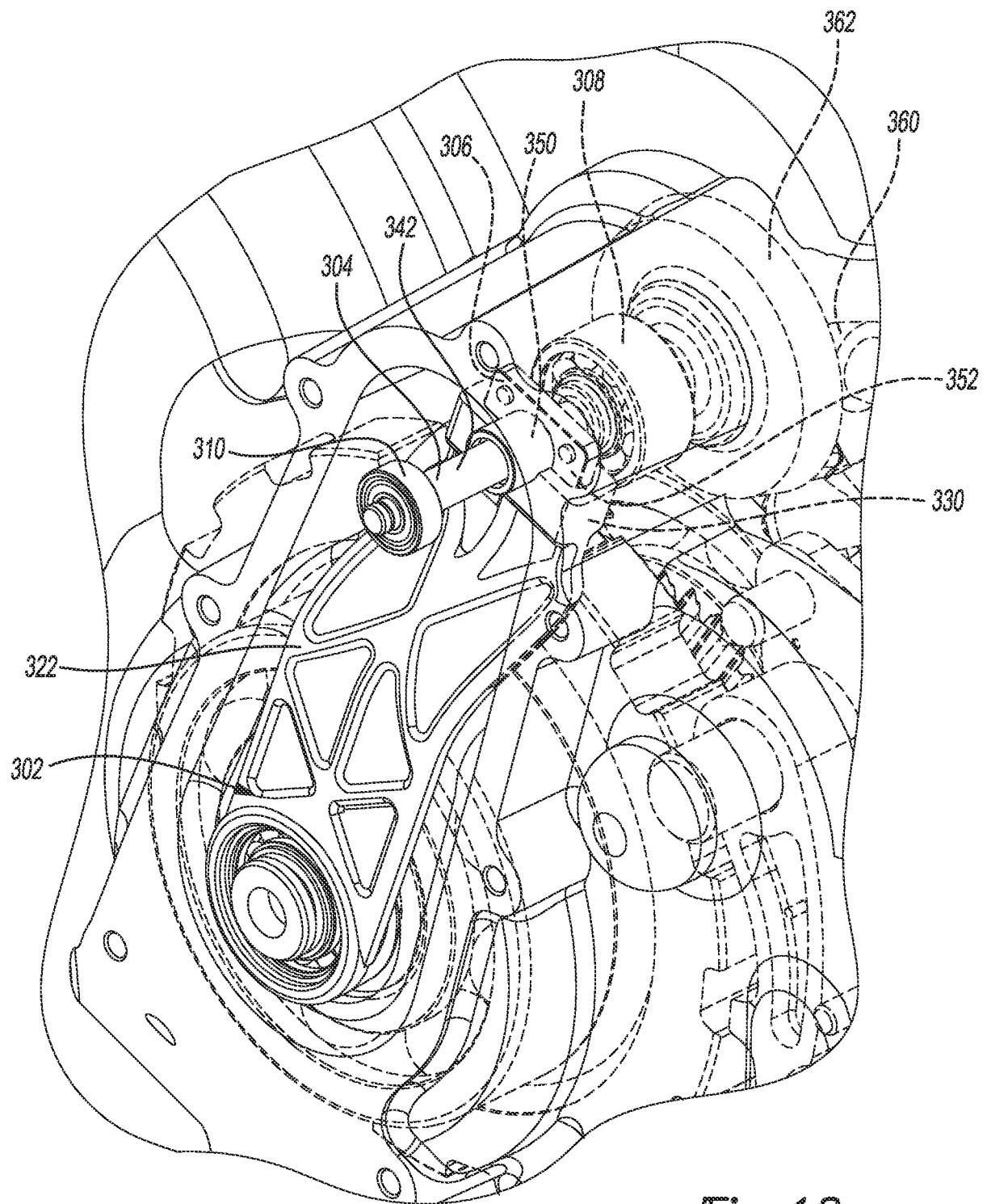


Fig-17

Fig-18

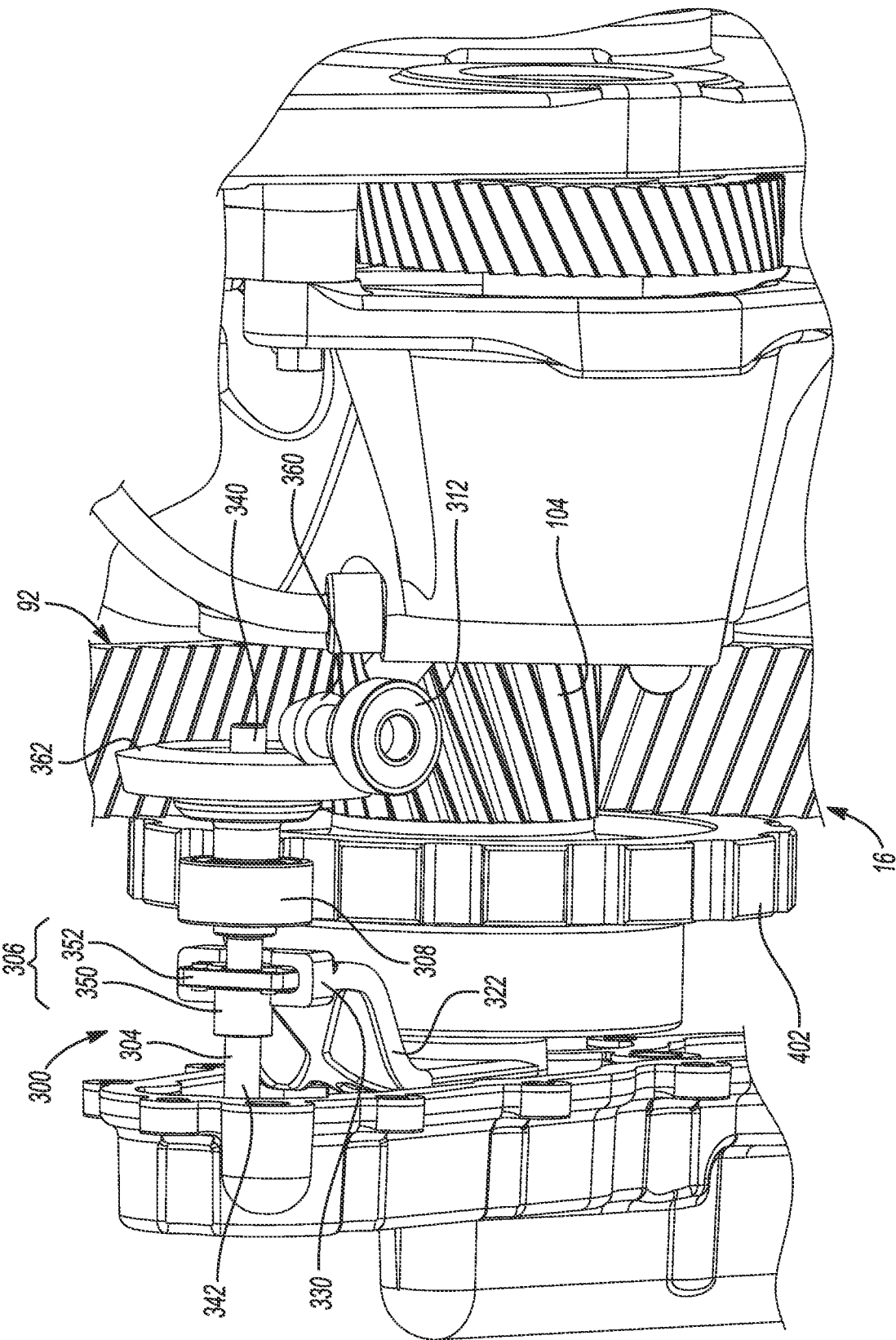


Fig-19

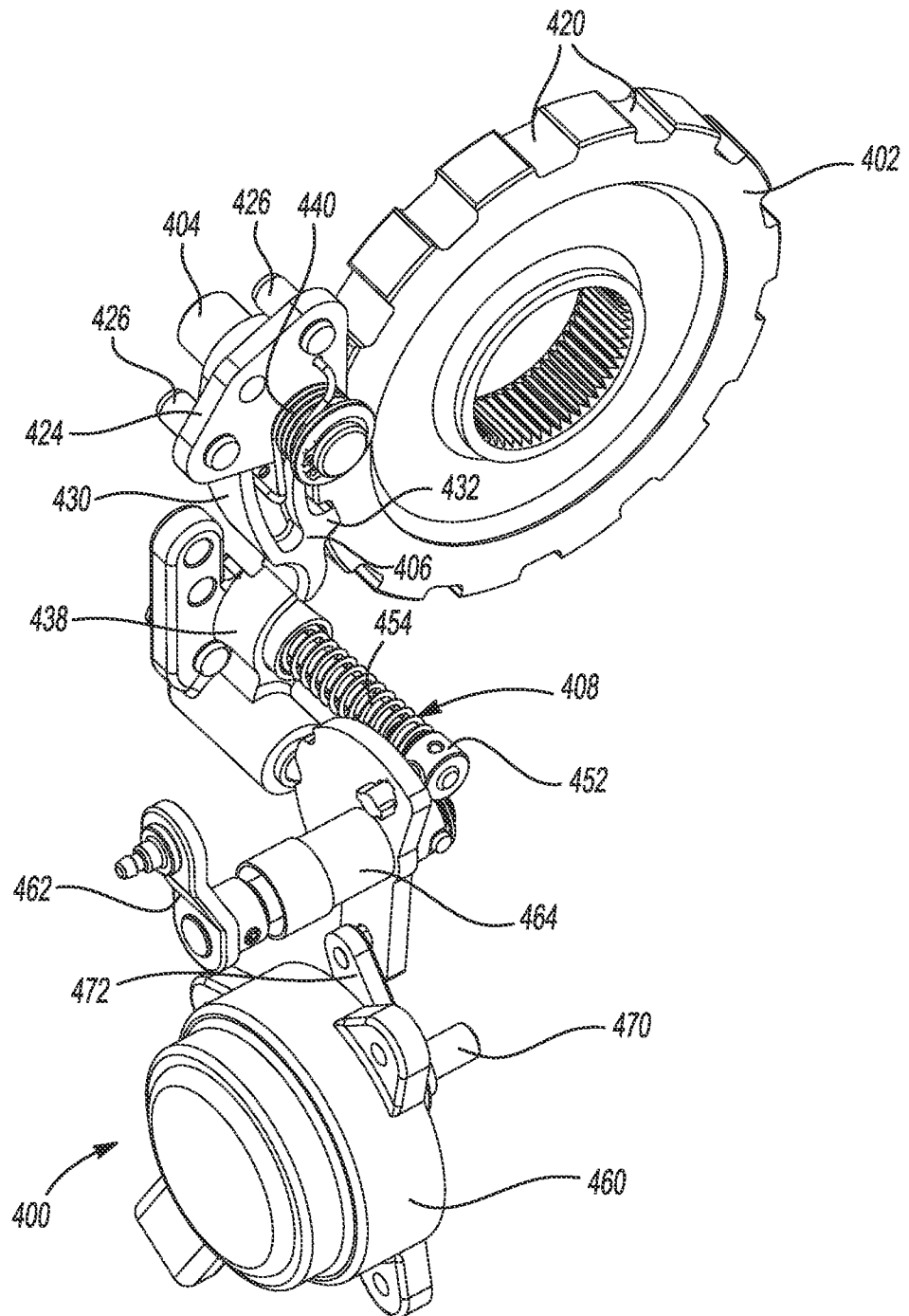
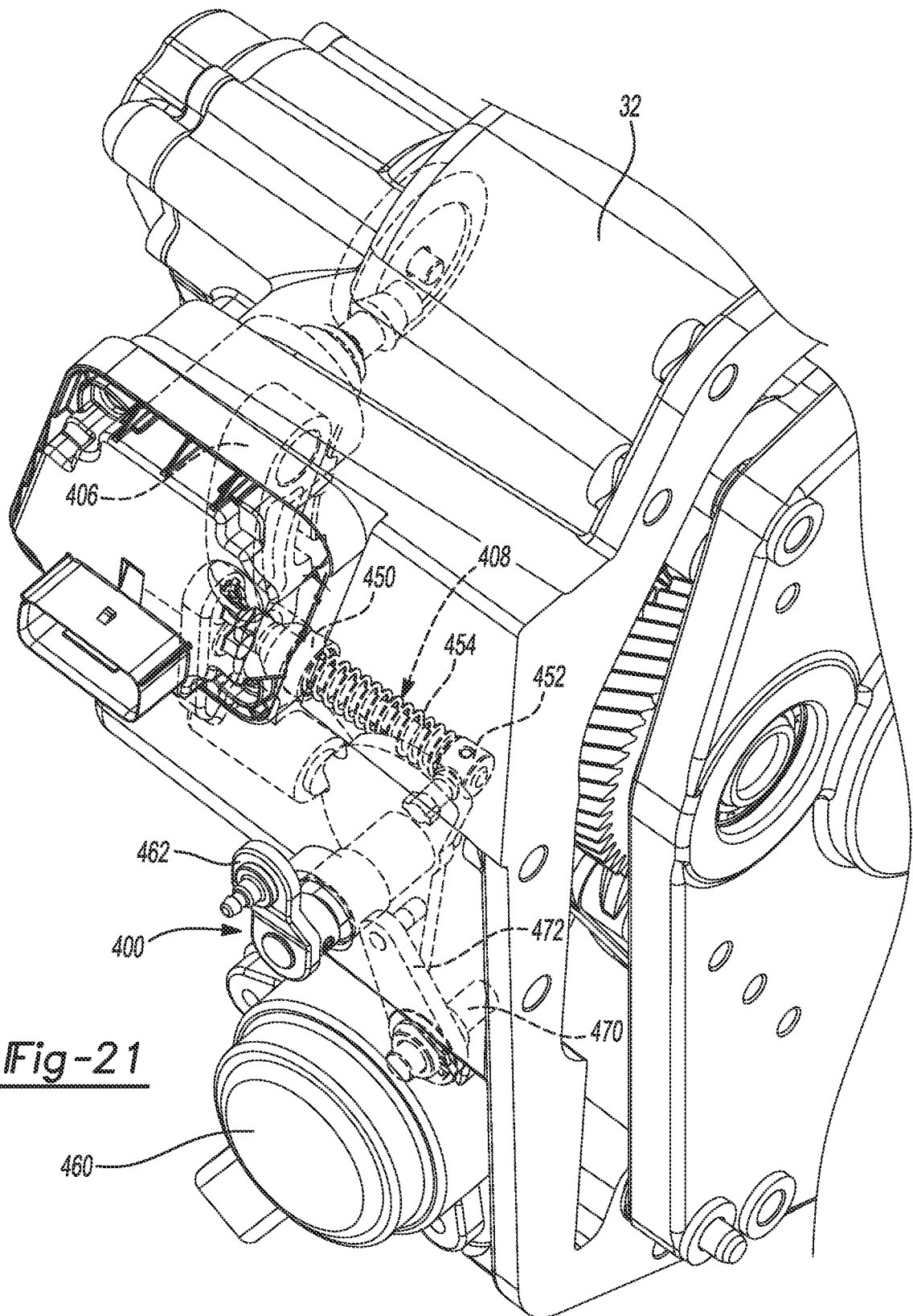


Fig-20



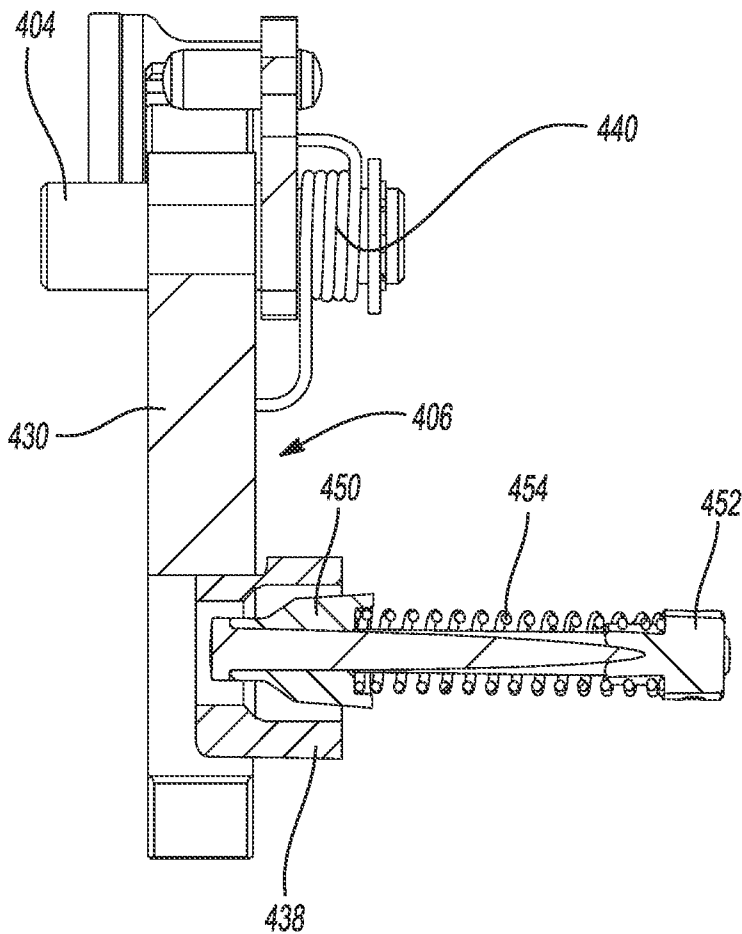
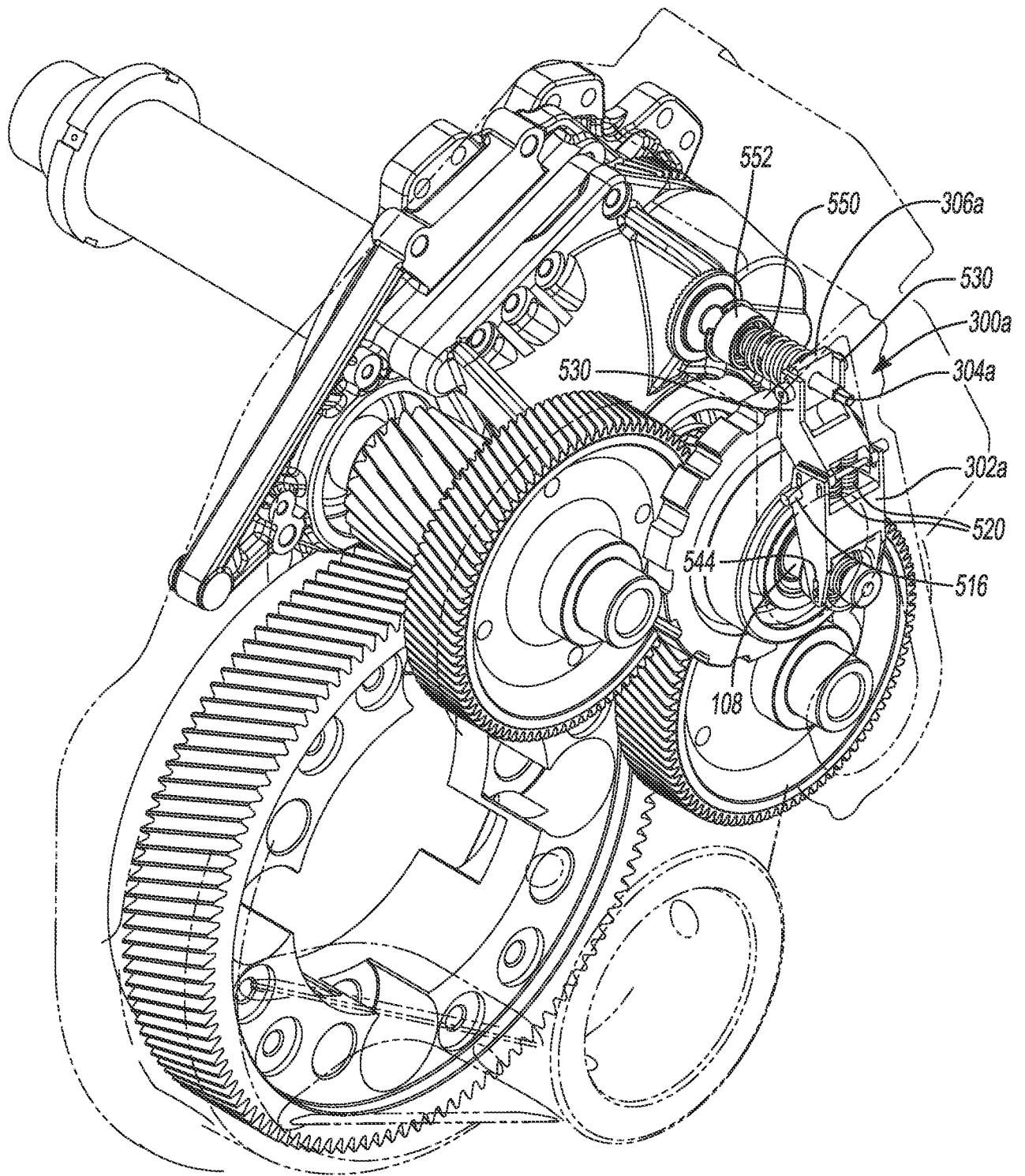


Fig-22

Fig-23

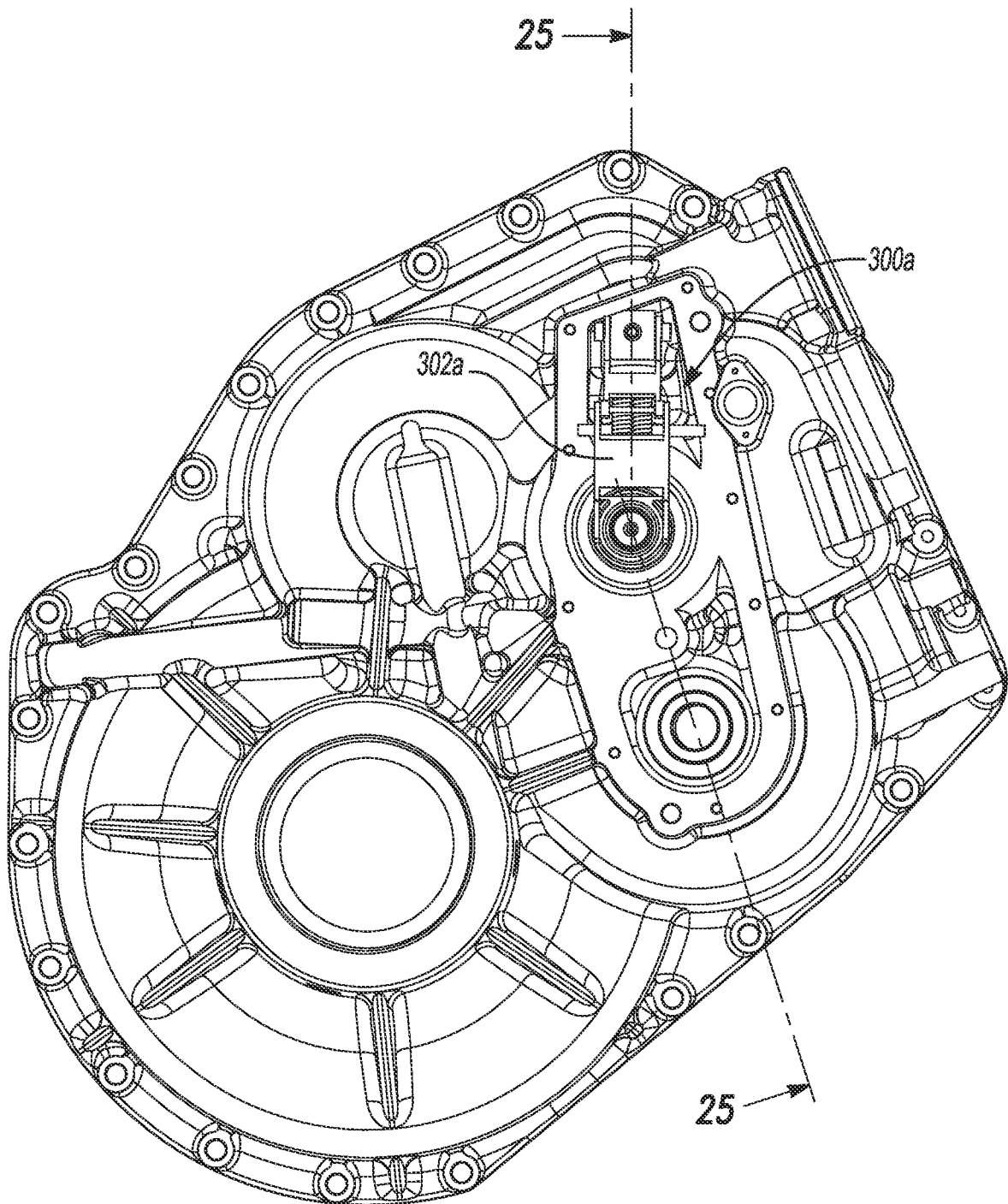


Fig-24

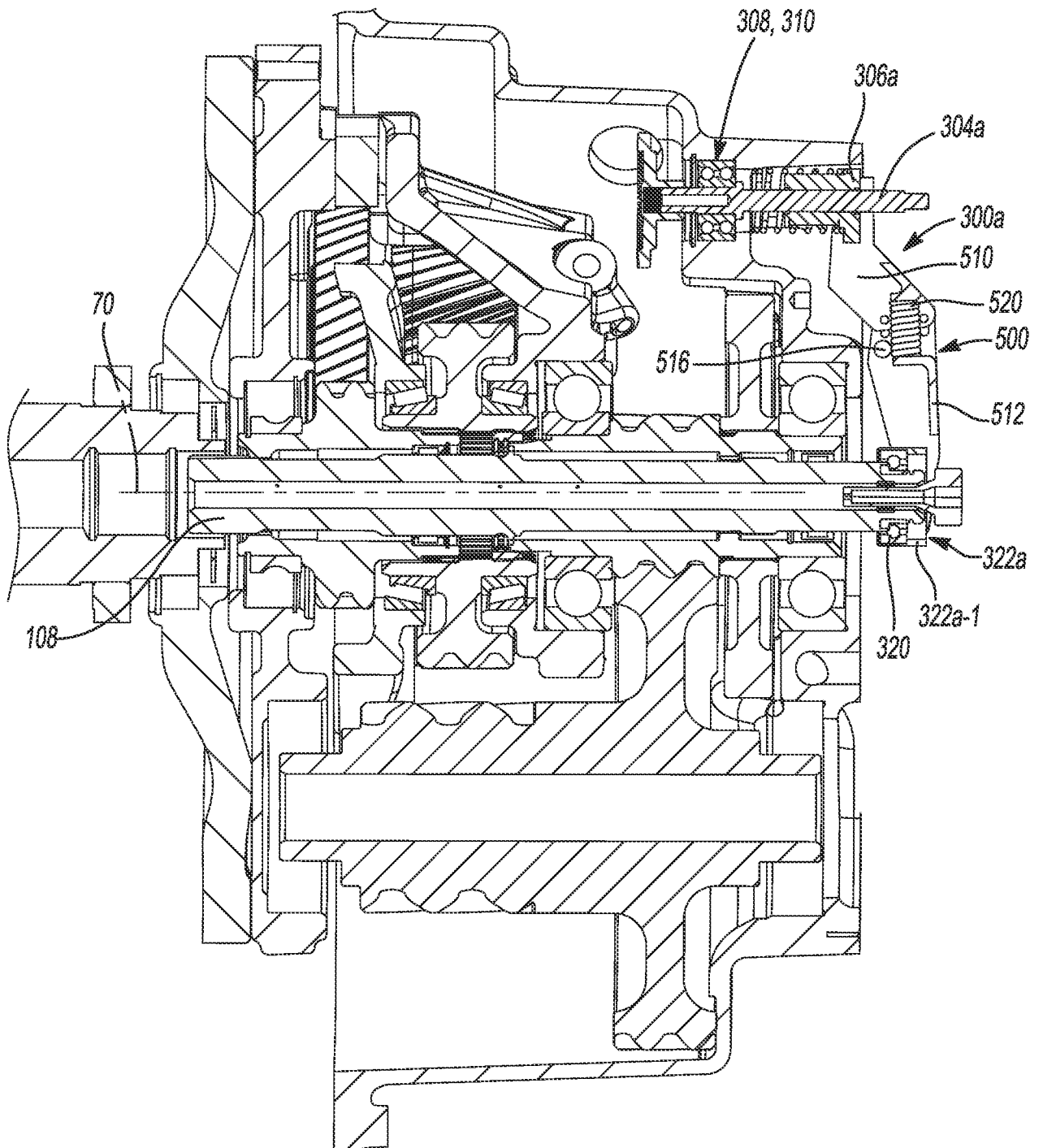
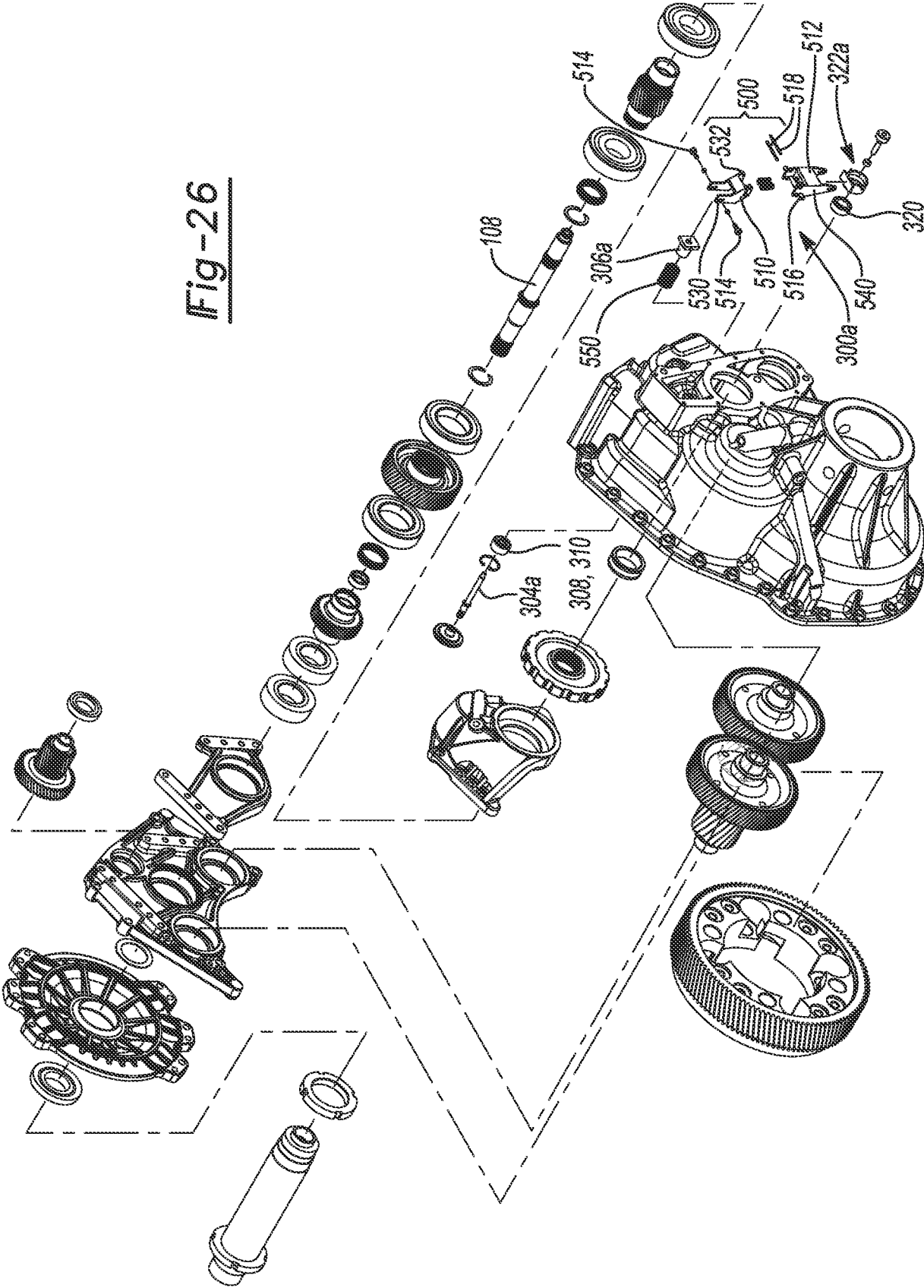
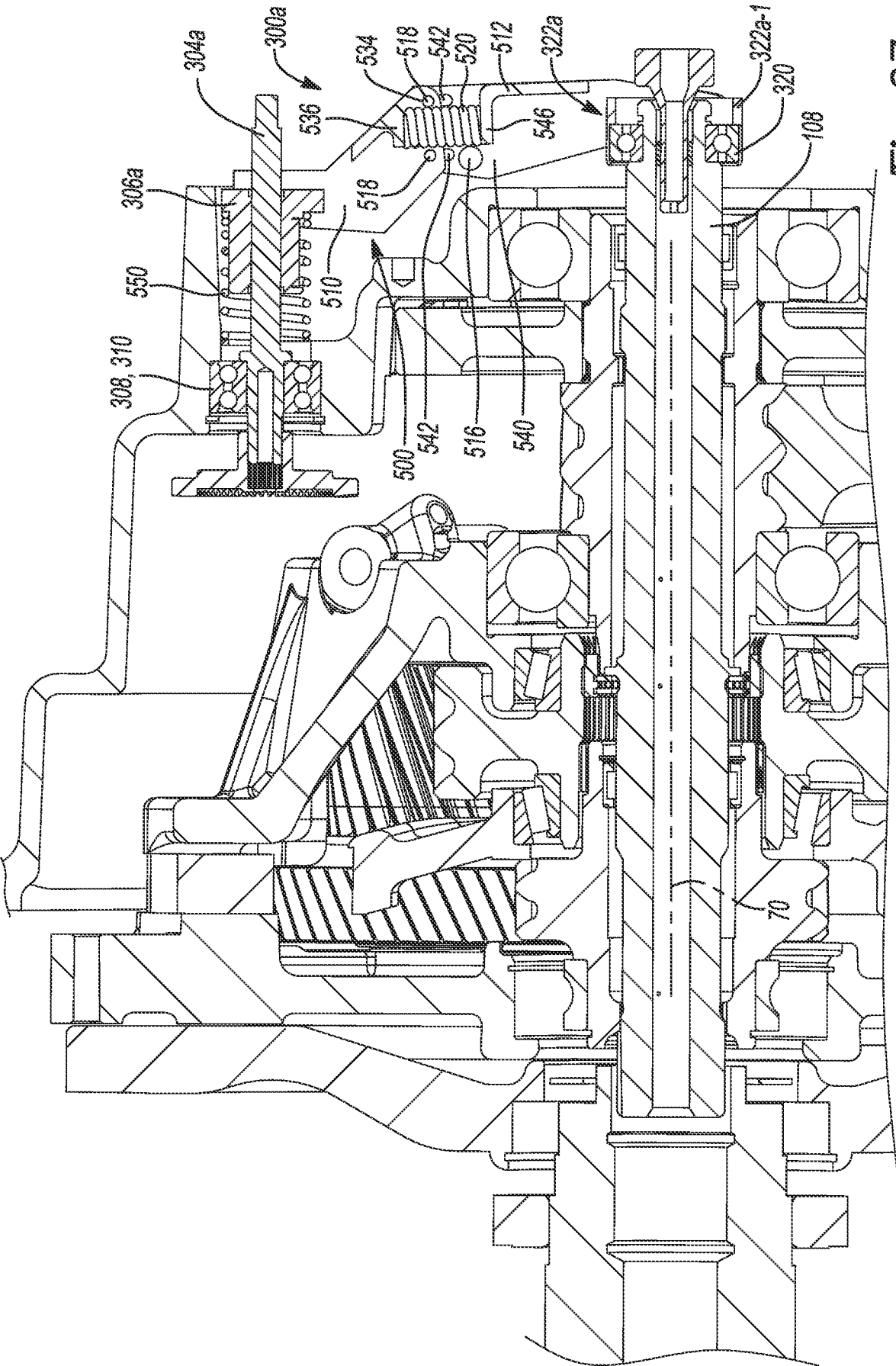
Fig-25

Fig-26





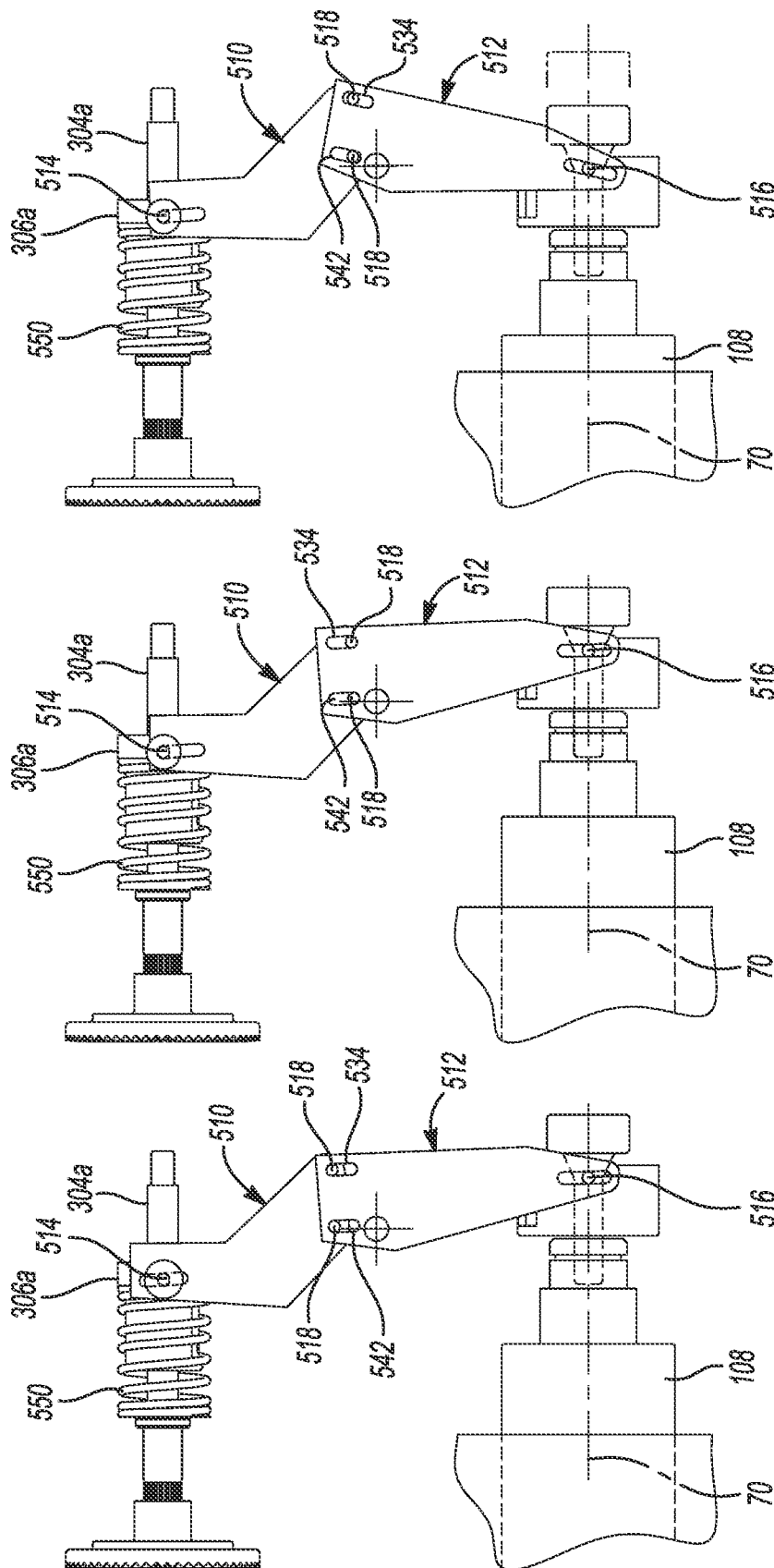


Fig-28

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/038499

A. CLASSIFICATION OF SUBJECT MATTER F16H 57/02(2006.01)i; F16H 1/22(2006.01)i; H02K 7/116(2006.01)i; B60K 1/00(2006.01)i; F16H 48/12(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) F16H 57/02(2006.01); B60L 11/18(2006.01); F16D 23/14(2006.01); F16H 61/28(2006.01); F16H 63/30(2006.01); F16H 63/32(2006.01); F16H 63/38(2006.01); F16H 63/40(2006.01); F16H 9/18(2006.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: transmission, actuator, screw, fork, and pivot		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2013-044406 A (NSK LTD.) 04 March 2013 (2013-03-04) paragraphs [0024]-[0032] and figures 1-5	1-7
Y		8-10
A		11-19
Y	JP 2014-105748 A (AISHIN SEIKI K.K.) 09 June 2014 (2014-06-09) paragraphs [0045]-[0059] and figures 1-7	8-10
A	CN 218761343 U (SANY ELECTRIC VEHICLE TECHNOLOGY CO., LTD.) 28 March 2023 (2023-03-28) paragraphs [0032]-[0038] and figures 1-4	1-19
A	WO 2017-185044 A1 (AMERICAN AXLE & MANUFACTURING, INC.) 26 October 2017 (2017-10-26) paragraphs [0030]-[0049] and figures 1-8	1-19
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search 25 October 2024		Date of mailing of the international search report 25 October 2024
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer PARK, Tae Wook Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/038499

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2014-167315 A (NTN CORP.) 11 September 2014 (2014-09-11) paragraphs [0025]-[0070] and figures 1-6	1-19

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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JP	2013-044406	A	04 March 2013	None			
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CN	218761343	U	28 March 2023	None			
WO	2017-185044	A1	26 October 2017	CN	109070725	A	21 December 2018
				CN	109070725	B	28 January 2022
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