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(54) **SCROLL PUMP WITH AXIAL LOAD CONTROL SYSTEM**

(57) A scroll pump includes a first scroll member (12) and a second scroll member (14). An electromagnet (112) is fixedly connected to one of the first scroll member and a second scroll member, and a magnetic target (116) is fixedly connected to the other of the first scroll member and the second scroll member. The electromagnet is operable to generate a magnetic field between the electromagnet and the magnetic target, thereby establishing an axially-directed magnetic biasing force between the first scroll member and the second scroll member.

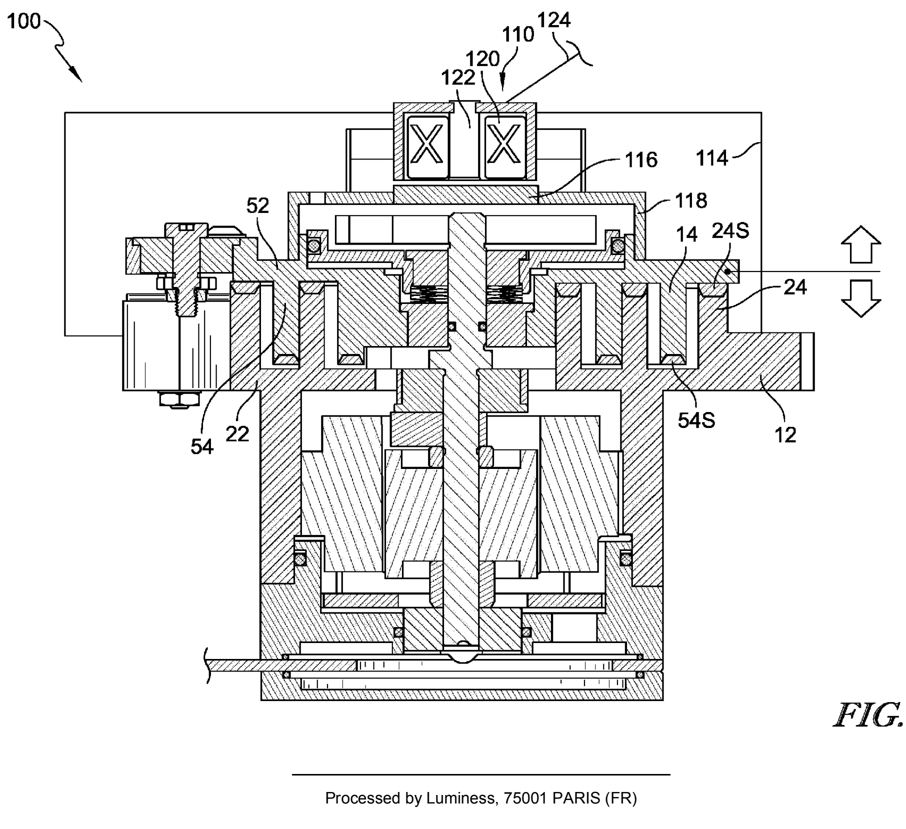

FIG. 10

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Description

BACKGROUND AND SUMMARY OF THE DISCLOSURE

[0001] A scroll pump includes a fixed scroll member operably associated with a moving scroll member. The fixed scroll member includes a fixed scroll extending axially from a fixed end plate to a fixed tip. Similarly, the moving scroll member includes a moving scroll extending from a moving end plate to a moving tip. The moving scroll is interleaved with the fixed scroll and configured to orbit with respect to the fixed scroll, so that the fixed tip engages with the moving end plate (either directly or through an intervening tip seal or gasket), and the moving tip engages with the fixed end plate (either directly or through an intervening tip seal or gasket). The fixed and moving scrolls thereby define a variable working volume therebetween. A fluid inlet port is provided in a peripheral region of the fixed and moving scrolls. A fluid discharge port is provided in a central region of the fixed and moving scrolls.

[0002] In operation, the moving scroll is driven by a motor or other prime mover so that the moving scroll orbits with respect to the fixed scroll. This orbiting causes fluid to be drawn through the fluid inlet port at a fluid inlet pressure, compressed to a discharge pressure, and discharged through the discharge port.

[0003] One skilled in the art would recognize that the increase in fluid pressure between the fixed and moving scrolls places an axial force on the fixed and moving scrolls, which axial force tends to force the moving scroll away from the fixed scroll. Consequently, this pressure tends to displace the tips of the fixed and moving scrolls away from the corresponding end plates of the moving and fixed scrolls. This phenomenon can result in undesired separation of the scroll tips from the corresponding end plates can result in the working fluid leaking between the scroll tips and the corresponding end plates. Such leakage can adversely affect the efficiency of the pump.

[0004] In some applications, it may be desirable to operate a scroll pump to provide a variable pressure output. Typically, varying the pressure output of a scroll pump is accomplished by varying the speed of the motor driving the scroll pump. One consequence of varying motor speed is variation in motor noise, which can be undesirable.

[0005] The present disclosure is directed to a system configured to control the axial force between the fixed and moving scroll members of a scroll pump. The system may use one or more of a preload force control system using a spring or other biasing member to permanently preload the moving scroll member axially toward the fixed scroll member, a fluid pressure-based axial force control system configured to bias the moving scroll member axially toward the fixed scroll member during operation of the scroll pump, and an electromagnetic axial force control system configured to selectively bias the moving scroll member axially toward or away from the fixed scroll member.

[0006] An electromagnetic axial force control system according to the present disclosure includes an electromagnet associated with one of the fixed scroll member and the moving scroll member and a magnetic target associated with the other of the fixed scroll member and the moving scroll member. The magnetic target could be a ferrous target made of ferromagnetic material. Alternatively, the magnetic target could be a permanent magnet. In embodiments wherein the ferrous target is a ferromagnetic material, the electromagnet is operable to selectively generate a force tending to bias the fixed and moving scrolls toward each other or away from each other. In embodiments wherein the ferrous target is a permanent magnet, the electromagnet is operable to selectively generate a force tending to bias the fixed and moving scrolls toward each other, away from each other, or both.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

Fig. 1	is an upper perspective view of an illustrative scroll pump having a preload and fluid pressure-based axial force control systems according to the pre-sent disclosure;
Fig. 2	is a top plan view of the scroll pump of Fig. 1;
Fig. 3	is a front cross-sectional elevation view of the scroll pump of Fig. 1 taken through section A-A;
Fig. 4	is an enlarged cross-sectional front elevation view of a portion of the scroll pump of Fig. 1 taken through section B-B;
Fig. 5A	is a perspective view of a first side of an orbiting scroll member of the scroll pump of Fig. 1;
Fig. 5B	is a perspective view of a second side of an orbiting scroll member of the scroll pump of Fig. 1;
Fig. 6	is a perspective view of a first side of a fixed scroll member of the scroll pump of Fig. 1;
Fig. 7	is a first exploded perspective view of the scroll pump of Fig. 1;
Fig. 8	is a second exploded perspective view of the scroll pump of Fig. 1;
Fig. 9	is a schematic representation of forces acting on fixed and moving scroll members of the scroll pump of Fig. 1 during operation thereof.

Fig. 10 is a front cross-sectional view of the scroll pump of Fig. 1 further including an electromagnetic axial force control system according to the present disclosure;

Fig. 11 is a schematic representation of forces acting on fixed and moving scroll members of the scroll pump of Fig. 10 during operation thereof;

Fig. 12 is a front cross-sectional view of the scroll pump of Fig. 10 with an alternative electromagnetic axial force control system according to the present disclosure;

Fig. 13 is a schematic representation of forces acting on fixed and moving scroll members of the scroll pump of Fig. 12 during operation thereof;

Fig. 14 is a front cross-sectional view of an illustrative scroll pump according to the present disclosure, which is similar to the scroll pump of Fig. 10 with the fluid pressure-based axial force control system omitted;

Fig. 15 is an upper perspective view of the scroll pump of Fig. 14;

Fig. 16 is a top plan view of the scroll pump of Fig. 14;

Fig. 17 is a first exploded perspective view of the scroll pump of Fig. 14;

Fig. 18 is a second exploded perspective view of the scroll pump of Fig. 14; and

Fig. 19 is a schematic representation of forces acting on fixed and moving scroll members of the scroll pump of Fig. 14 during operation thereof.

DETAILED DESCRIPTION OF THE DRAWINGS

[0008] Figs. 1-8 show an illustrative embodiment of a scroll pump 10 having a preload axial force control system and a fluid-pressure-based axial force control system according to the present disclosure. The scroll pump 10 includes: a first (or fixed) scroll member 12; a second (or orbiting) scroll member 14; a camshaft 16 having a first shaft portion 16A and a second shaft portion 16B connected to, spaced from, and parallel to the first shaft portion 16A; a link 18; and a prime mover 20, for example, an electric motor. The first scroll member 12 is in orbiting engagement with the second scroll member 14. The first shaft portion 16A of the camshaft 16 is rotatably connected to the first scroll member 12. The second shaft portion 16B of the camshaft 16 is rotatably connected to the second scroll member 14. A first end 18A of the link 18 is pivotably connected to the first scroll member 12, and a second end 18B of the link 18 is pivotably connected to the second scroll member 14. The motor 20 is configured to rotate the camshaft 16 with respect to the first scroll member 12 and the second scroll member 14. The link 18 substantially precludes rotation of the second scroll member 14 with respect to the first scroll member 12 when the camshaft 16 is rotating, so that rotation of the camshaft 16 causes the second scroll member 14 to orbit with respect to the first scroll member 12.

[0009] The first scroll member 12 includes a first end plate 22 and a first involute 24 extending axially from a first side of the first end plate 22. The first end plate 22 defines a first shaft-receiving aperture 26 configured to receive the first shaft portion 16A of the camshaft 16. The first end plate 22 also defines a bearing pocket 28 extending into the first end plate 22. In the embodiment shown, the bearing pocket 28 extends toward the first side of the first end plate 22 from a second side of the first end plate 22 opposite the first side of the first end plate 22. A first bearing 30 is received within the first bearing pocket 28, for example, in press-fit engagement. A land 32 at the bottom of the bearing pocket precludes the bearing 30 from being inserted into and removed from the bearing pocket 28 from the first side of the first end plate 22. The first bearing 30 may abut the land 32.

[0010] Alternatively, the bearing pocket 28 may extend into the first end plate 22 from the first side of the first end plate 22 toward the second side of the first end plate 22. In such an embodiment (not shown), the land 32 would preclude the bearing 30 from being inserted into and removed from the bearing pocket 28 from the second side of the first end plate 22.

[0011] In other embodiments, the first aperture 26 and the bearing pocket 28 may be combined into a single feature and the land 32 may be omitted. In such embodiments, the first bearing 32 could be inserted into and removed from the bearing pocket 28 from the first side of the first end plate 22 or the second side of the first end plate 22.

[0012] The first bearing 30 is configured to receive the first shaft portion 16A of the camshaft 16 in rotating, bearing engagement. The first bearing 30 may be a sealed bearing, and the interfaces among the first end plate 22, the first bearing 30, and the first shaft portion 16A of the camshaft 16 may be substantially sealed interfaces so that the first bearing 32 and the foregoing interfaces are substantially airtight.

[0013] As suggested above, the first involute 24 extends axially from the first side of the first end plate 22 in a direction perpendicular to the first end plate 22. A first end 24A of the first involute 24 proximate a periphery of the first involute 24 closes upon an intermediate portion of the first involute 24. A second end 24B of the first involute 24 proximate a center of the first involute 24 is free. As such, the first end plate 22 and the first involute 24 cooperate to define a space configured to receive a second involute, as will be discussed further below. A first tip seal 24S is provided at a free surface of the first involute 24 opposite the first end plate 22. The free end of the first involute 24 may define a recess or groove 24G configured to receive and retain the tip seal 24S.

[0014] The first scroll member 12 defines a fluid inlet aperture or port 34 proximate a periphery of the first end 24A of the first involute 24. The fluid inlet aperture 34 is configured to admit air or another fluid into the scroll pump 10 for pressurizing thereby. The fluid inlet port 34 may extend through one or both of the first end plate 22 and the first involute 24. The first scroll member 12 also defines a fluid outlet aperture or port 36 extending through the first end plate 22 proximate the second end 24B of the first involute 24. The fluid outlet port 36 is configured to discharge fluid pressurized by the scroll pump 10.

[0015] The first scroll member 12 further defines a first pivot point 38 configured to receive an axle or pin 40 connecting the first end 18A of the link 18 to the first scroll member 12 in pivoting engagement therewith. As shown, the first pivot point 38 may be embodied as a boss proximate the periphery of the first end plate 22 and/or radially outboard of the first involute 24.

[0016] The first scroll member 12 also may include one or mounting bosses 42 configured to receive fasteners (not shown) for connecting the first scroll member 12 to another structure (not shown).

[0017] A sidewall 44 extends axially from the second side of the first end plate 22. The sidewall 44 cooperates with the first end plate 22 to define a housing configured to receive the prime mover 20, in this case an electric motor. As shown, the sidewall 44 is monolithically formed or integral with the first end plate 22. An end cap 46 covers the open end of the sidewall 44. A seal 48, for example, an O-ring, may be provided between the housing wall and the end cap so that the interior of the housing is substantially air-tight.

[0018] The second scroll member 14 includes a second end plate 52 and a second involute 54 extending from a first side of the second end plate 52. The second end plate 52 defines a second shaft-receiving aperture 56 extending from the first side thereof to a second side thereof opposite the first side. The second shaft-receiving aperture 56 is configured to receive a second bearing 58 therein, for example, in press-fit engagement. The second end plate 52 also defines one or more vent holes 60 extending therethrough, proximate the center of the second end plate 52, as will be discussed further below. An annular sidewall 62 extends axially from the second side of the second end plate 52, thereby defining a cavity 64 extending axially from the second side of the second end plate. The cavity 64 is configured to receive a piston 66, as will be discussed further below. The cavity 64 may be cylindrical.

[0019] As suggested above, the second involute 54 extends from a first side of the second end plate 52 in a direction perpendicular thereto. A second tip seal 54S is provided at a free end of the second involute 54. The free end of the second involute 54 may define a recess or groove 54G configured to receive and retain the second tip seal 54S.

[0020] The second scroll member 52 further defines a second pivot point 68 configured to receive a second axle or pin 70 connecting the second end 18B of the link 18 to the second scroll member 14 in pivoting engagement therewith. As shown, the second pivot point 68 may be embodied as a boss proximate the periphery of the second end plate 52.

[0021] As mentioned above, the camshaft 16 includes a first shaft portion 16A and a second shaft portion 16B. The first shaft portion 16A defines a first axis of rotation. The first axis of rotation is perpendicular to the first end plate 22 and parallel to the first involute 24. The second shaft portion 16B defines a second axis of rotation. The second axis of rotation is perpendicular to the second end plate 52 and parallel to the second involute 54. The second axis of rotation is radially offset from and parallel to the first axis of rotation. The first shaft portion 16A is configured for connection to a drive shaft of the prime mover 20 for rotation therewith. In embodiments, the camshaft 16 may be integrated and/or monolithically formed with the drive shaft of the prime mover 20.

[0022] The second shaft portion 16B defines a circumferential groove 72 configured to receive a shaft seal 74, for example, an O-ring. The shaft seal 74 is engaged between the second shaft portion 16B and an inner race of the second bearing 58. A free end of the second shaft portion 16B may define a threaded bore 76 configured to receive a fastener 78, as will be discussed further below.

[0023] The first shaft portion 16A is received within the first bearing 30 in rotating bearing engagement therewith. The second shaft portion 16B is received within the second bearing 58 in rotating bearing engagement therewith. The first scroll member 12 is axially fixed to the first shaft portion 16A. The second scroll member 14 axially floats with respect to the second shaft portion 16B.

[0024] The first scroll member 12 is engaged with the second scroll member 14 so that the first involute 24 is interleaved with the second involute 54. The first tip seal 24S of the first scroll member 12 engages with the first side of the second end plate 52 of the second scroll member 14 in sealing engagement therewith. Similarly, the second tip seal 54S of the second scroll member 14 engages with the first side of the first end plate 22 of the first scroll member 12 in sealing engagement therewith. So assembled, the first and second scroll members 12, 14 define a working volume V substantially bounded by the first and second end plates 22, 52 and the first and second involutes 24, 54.

[0025] With the first and second scroll members 12, 14 so assembled together, a first exposed surface area of the second end plate 52 is exposed to fluid pressure within the working volume V. The first exposed surface area is defined by the surface area of the first side of the second end plate 52 normal to the second axis of rotation and radially inboard of the first involute 24, minus the surface area of the first side of the second end plate 52 normal to the second axis of rotation occupied by the second involute 54 and covered by the first involute 24/first tip seal 24S. Put another way, the first exposed surface area is the surface area of the first side of the second end plate 52 that projects against the first side of the first end plate 22, minus the surface area of the free end of the second involute 54 engaging the first side of the first end plate. A second exposed surface area of the second end plate 52 is exposed to fluid pressure within the cavity 64. The second exposed surface area is defined by the surface area of the second side of the second end plate 52 normal to the second axis of rotation within the confines of the cavity 64. The second exposed surface area is greater than the first exposed surface area so that when both sides of the second end plate 52 are subjected to the same fluid pressure, the net force on the second end plate 52 parallel to the second axis of rotation tends to bias the second scroll member 14 toward the first scroll member 12, thereby compressing the first and second tip seals 24S, 54S against the respective second and first end plates 52, 22.

[0026] As mentioned above, the link 18 is pivotably connected to both the first and second scroll members 12, 14. More specifically, a first portion of the link 18, which may be proximate a first end 18A thereof, is pivotably connected to the first scroll member 12. Similarly, a second portion of the link 18, which may be proximate a second end 18B thereof, is pivotably connected to the second scroll member 14. So connected to the first and second scroll members 12, 14, the link 18 allows the second scroll member 14 to orbit with respect to the first scroll member 12, while substantially precluding rotation of the second scroll member 14 with respect to the first scroll member 12. As shown in the drawings, the camshaft 16 and the link 18 are the only structures constraining the radial position of the second scroll member 14 with respect to the first scroll member 12.

[0027] As suggested above, the piston 66 is received within the cavity 64 defined by the second scroll member 14. The piston 66 defines a third bearing-receiving aperture 80 at the center thereof. A third bearing 82 is received in the third bearing-receiving aperture 80. The third bearing 82 is shown as a flanged bearing received in the third bearing-receiving aperture from a side of the piston 66 facing away from the second scroll member 14. The third bearing 82 may be a sealed bearing that substantially precludes fluid flow therethrough. The piston 66 also defines a groove 84 about the perimeter thereof. The groove 84 is configured to receive a piston seal 86, for example, an O-ring. The piston seal 86 substantially precludes fluid flow between the piston 66 and the cavity 64.

[0028] As shown, the piston 66 is axially retained to the camshaft 16 by a snap ring 50 received within a snap ring groove 51 defined by the cam shaft 16. More specifically, the piston 66 and the third bearing 82 received therein are disposed between the snap ring 50 and the second scroll member 14. As such, the snap ring 50 limits the axial travel of the third bearing 82 and, therefore, the piston 66, in a direction away from the second scroll member 14. The free end of the second shaft portion 16B of the camshaft 16 may be received within the center of the third bearing 82. The third bearing 82 is configured to allow the camshaft 16 to rotate with respect to the second scroll member 14, while the piston 66 remains rotationally fixed with respect to the second scroll member 14.

[0029] As shown, a first counter weight 88 may be proximate the base of the second shaft portion 16B of the camshaft 16, where the first shaft portion 16A of the camshaft is connected to the second portion 16B of the camshaft 16. As shown, the first counterweight 88 is disposed within the interior confines of the first involute 24. A second counterweight 90 may be provided proximate the free end of the second shaft portion 16B of the camshaft 16. The second counterweight 90 may be connected to the end of the camshaft 16 by a fastener 78, for example, a threaded fastener, extending into the threaded bore 76 defined by the free end of the second shaft portion 16B of the camshaft 16. As shown, the second counterweight 90 is disposed within the confines of a cavity 67 defined by the piston 66 on the side of the piston 66 opposite the second end plate 52. Each of the first and second counterweights 88, 90 is rotationally fixed to the camshaft 16 and may axially fixed thereto, as well.

[0030] A biasing spring 92 is disposed between the second side of the second end plate 52 and the piston 66. As shown, the biasing spring 92 is an assembly of a plurality of wave washers. In embodiments, the biasing spring 92 could be a plurality of distinct wave washers, a single wave washer, an elastomer, or any other suitable biasing member. The biasing spring 92 preloads the second scroll member 14 away from the piston 66 and toward the first scroll member 12, thereby engaging the first and second tip seals 24S, 54S with the respective, opposing second and first end plates 52, 22. As shown, the biasing spring 92 is disposed between the second end plate 52 and the second counterweight 90. In embodiments, the biasing spring 92 could be disposed between the piston 66 and the second counterweight 90.

[0031] An end cap 94 covers the cavity 67 and the piston 66 and second counterweight 90 received therein. An end cap seal 96, for example, an O-ring, may be provided between the end cap 94 and the second scroll member 14.

[0032] In use, the biasing spring 92 preloads the second scroll member 14 toward the first scroll member 12, thereby engaging the first and second tip seals 24S, 54S with the respective, opposing second and first end plates 52, 22. The prime mover 20 rotates the camshaft 16. The rotating camshaft 16 causes the second scroll member 14 to orbit with respect to the first scroll member 12. The orbiting of the second scroll member 14 with respect to the first scroll member 12 causes the air or another fluid to be drawn into the working volume V through the fluid inlet port 34 and pumped toward the fluid outlet port 36, thereby increasing the pressure of the fluid from the fluid inlet port 34 to the fluid outlet port 36.

[0033] In the absence of the vent holes 60 defined by the second end plate 52, the foregoing increase in fluid pressure acting against the first end plate 22 and the first exposed surface of the second end plate 52 would tend to force the first and second scroll members 12, 14 apart from each other axially. Axial displacement of the second scroll member 14 away from the first scroll member 12 resulting from such force could lessen the effect of the first and second tip seals 24S, 54S, thereby decreasing the efficiency of the scroll pump 10.

[0034] The vent holes 60 mitigate this phenomenon by equalizing the fluid pressure on the first and second opposed sides of the second end plate 52 and by applying this equalized pressure to the surface of the piston 66 facing the second end plate 52 (and to the piston seal 86) in a first embodiment or to the end cap 94 (and to the end cap seal 96) in a second embodiment.

[0035] In the first embodiment, the equalized pressure is applied against the piston 66. Because force equals pressure times area, because the second exposed surface area on the second side of the second end plate 52 is greater than the first exposed surface area on the first side of the second end plate 52, and because the piston 66 is fixed axially with respect to the first scroll member 12, the net axial force acting on the second end plate 52 due to the fluid pressure within the working volume V and the cavity 64 tends to bias the second end plate 52, and therefore the second scroll member 14, toward the first scroll member 12. This net axial force tends to increase as a function of increasing fluid pressure within the working volume V and the cavity 64. Also, because the second scroll member 14 floats on the second shaft portion 16B of the camshaft 16, the second scroll member 14 may be displaced slightly toward the first scroll member 12 in response to the foregoing axial biasing force, thereby compressing the first and second tip seals 24S, 54S against the respective, opposing second and first end plates 52, 22, and thereby promoting operational efficiency of the scroll pump 10.

[0036] In the second embodiment, as shown in Fig. 7, the piston 66 may be provided with an optional vent hole 98 similar to vent hole(s) 60 (the optional vent hole 98 is absent in the first embodiment). This may be desirable where the third bearing 82 is not a sealed a bearing. In applications where the third bearing 82 is not a sealed bearing, pressure differential across first and second sides of the third bearing 82 could force grease out of the third bearing 82, potentially leading to premature wear and failure of the third bearing 82. Providing the vent hole 98 in the piston 66 allows for pressure equalization across the piston 66, thereby mitigating against forcing grease out of the third bearing 82 due to pressure differential across the third bearing 82. In such embodiments, the equalized pressure across the second end plate 52 and the piston 66 bears against the end cap 94 and the end cap seal 96. In such embodiments, in use, the second scroll member 14 is biased toward the first scroll member 12 in a manner similar to that described above.

[0037] In any of the foregoing embodiments, cooperation of the piston 66 with the cavity 64 may provide radial support for the second shaft portion 16B of the camshaft.

[0038] Fig. 9 is a schematic representation of forces acting on fixed and moving scroll members 12, 14 of the scroll pump 10 during operation thereof. In Fig. 9, F_{PI} represents the axial force applied between the fixed end plate 22 and the moving end plate 52 by the fluid being pumped or compressed by the scroll pump 10 and tending to bias the moving scroll member 14 away from the fixed scroll member 12, as discussed above. Fs represents the axial preload force applied between the fixed and moving scroll members 12, 14 and tending to bias the moving scroll member 14 toward the fixed scroll member 12, as discussed above. F_{PE} represents the axial force applied between the piston 66 or the end cap 94 and the moving end plate 52 and tending to bias the moving scroll member 14 toward the fixed scroll member 12, as discussed above. F_{NET} represents the net axial force acting between the fixed scroll member 12 and the moving scroll member 14 as a result of the forces F_{PI}, F_S, and F_{PE}. That is, F_{NET} represents the algebraic sum of the forces F_{PI}, Fs, and F_{PE}. The symbol + represents a force direction tending to bias the moving scroll member 14 away from the fixed scroll member 12, and the symbol - represents a force direction tending to bias the moving scroll member 14 toward the fixed scroll member 12. As suggested in Fig. 9, F_{NET} may be neutral, tending to bias the moving scroll member 14 toward the fixed scroll member 12, or tending to bias the moving scroll member 14 away from the fixed scroll member 12.

[0039] In embodiments, the preload axial force control system including the spring 92 may be eliminated from scroll pump 10. In such embodiments, the axial preload force Fs would be absent from the schematic representation of forces shown in Fig. 9.

[0040] Fig. 10 shows an illustrative embodiment of a scroll pump 100 generally identical to the scroll pump 10 but further including an electromagnetic axial force control system 110 according to the present disclosure. The electromagnetic axial force control system 110 of the scroll pump 100 includes an electromagnet 112 fixedly connected to the fixed scroll member 12 via a mounting bracket 114, and a magnetic target in the form of a permanent magnet 116 fixedly connected to the moving scroll member 14 via a mounting bracket 118. Fig. 10 shows the electromagnet 112 as a coil 120 (wound about a bobbin, not shown) surrounding a ferromagnetic core 122. Fig. 10 shows the coil 120 and the permanent magnet 116 as having respective outer diameters. In embodiments, the outer diameter of the permanent magnet 116 is sufficiently larger than the outer diameter of the coil 120 so that the radial bounds of the permanent magnet 116 overlap the radial bounds of the coil 120 at all times as the second scroll member 14 orbits with respect to the first scroll member 14 during operation of the scroll pump 100. This arrangement of relative diameters promotes consistent magnetic coupling between the electromagnet 112 and the permanent magnet 116 during operation of the scroll pump 100.

[0041] A wiring harness 124 connects the electromagnet 112 to a source of electrical current (not shown). A controller (not shown), for example, an electronic controller, may be provided to selectively control the supply of electrical current to the electromagnet 112 and thereby control a magnetic electric field generated by the electromagnet 112. The controller (not shown) may be configured to vary the magnitude of electrical current provided to the electromagnet 112 to thereby vary the strength of the magnetic field generated by the electromagnet 112.

[0042] In use, the biasing spring 92 preloads the second scroll member 14 toward the first scroll member 12, thereby engaging the first and second tip seals 24S, 54S with the respective, opposing second and first end plates 52, 22. Also, the permanent magnet 116 magnetically couples with the fixed scroll member 12 and thereby biases the second scroll member 14 away from the first scroll member 12.

[0043] The electromagnet 112 may be selectively energized and thereby generate a magnetic force that couples to the permanent magnet 116. As would be understood by one skilled in the art, the electromagnet 112 may be selectively energized to generate an attractive magnetic force between the electromagnet 112 and the permanent magnet 116, thereby biasing the moving scroll member 14 away from the fixed scroll member 12. As also would be understood by one skilled in the art, the electromagnet 112 also may be selectively energized to generate a repulsive magnetic force between the electromagnet 112 and the permanent magnet 116, thereby biasing the moving scroll member 14 toward the fixed scroll member 12.

[0044] During operation of the scroll pump 100, a net axial biasing force axially biasing the moving scroll member 14 away from the fixed scroll member 12 may lessen the seal between the fixed and moving scroll tips 24, 54 and/or between the fixed and moving tip seals 24S, 54S and the corresponding end plates 52, 22. The lessening of the foregoing seal may induce fluid leakage between the fixed and moving scroll tips 24, 54 and/or between the fixed and moving tip seals 24S, 54S and the corresponding end plates 52, 22. Such induced fluid leakage may be used to control the output flow rate and/or output pressure of the scroll pump 10 without varying its speed. Controlling the output flow rate and/or output pressure of the scroll pump 10 by inducing leakage in this manner may allow the scroll pump to operate within a predetermined range of output flow rate and/or output pressure with less noise or variation in noise than operating the scroll pump 10 at varying speeds to accomplish similar variation in output flow rate and/or output pressure.

[0045] Fig. 11 is a schematic representation of forces acting on the fixed and moving scroll members 12, 14 of the scroll pump 100 during operation thereof. In Fig. 11, F_{PI} represents the axial force applied between the fixed end plate 22 and the moving end plate 52 by the fluid being pumped or compressed by the scroll pump 100 and tending to bias the moving scroll member 14 away from the fixed scroll member 12, as discussed above. F_{PE} represents the axial force applied between the piston 66 or the end cap 94 and the moving end plate 52 and tending to bias the moving scroll member 14 toward the fixed scroll member 12, as discussed above. Fs represents the axial preload force applied between the fixed and moving scroll members 12, 14 and tending to bias the moving scroll member 14 toward the fixed scroll member 12, as discussed above. F_M represents the axial magnetic force applied by the permanent magnet 116 of the magnetic target between the permanent magnet of the magnetic target and the fixed scroll member and tending to bias the moving scroll member 14 away from the fixed scroll member 12. F_E represents the magnetic force selectively applied by the electromagnet 112 between the electromagnet 112 and the permanent magnet 116 of the magnetic target and tending to selectively bias the moving scroll member 14 toward or away from the fixed scroll member 12. F_{NET} represents the net axial force acting between the fixed scroll member 12 and the moving scroll member 14 as a result of the forces F_{PI}, F_{PE}, Fs, F_M, and F_E. That is, F_{NET} represents the algebraic sum of the forces F_{PI}, F_{PE}, Fs, F_M, and F_E. The symbol + represents a force direction tending to bias the moving scroll member 14 away from the fixed scroll member 12, and the symbol - represents a force direction tending to bias the moving scroll member 14 toward the fixed scroll member 12. As suggested in Fig. 9, F_{NET} may be neutral, tending to bias the moving scroll member 14 toward the fixed scroll member 12, or tending to bias the moving scroll member 14 away from the fixed scroll member 12.

[0046] In the foregoing embodiment of the scroll pump 100, the electromagnet 112 is located opposite the moving scroll member 14 from the fixed scroll member 12. In an alternative embodiment, the electromagnet 112 could be located on the same side of the moving scroll member 14 as the fixed scroll member 12. For example, the electromagnet 112 may be integrated into the fixed scroll member 12. In such an embodiment, the magnetic force vector F_M shown in Fig. 11 would point in the opposite direction, and the magnetic force applied by the permanent magnet 116 of the magnetic target would tend to bias the moving scroll member 14 toward the fixed scroll member 12, rather than away from the fixed scroll member 12. In such an embodiment, the preload axial force control system could be configured to bias the moving scroll member 14 away from the fixed scroll member 12, rather than toward the fixed scroll member 12. In such an embodiment, the axial preload force vector Fs shown in Fig. 11 would point in the opposite direction.

[0047] In embodiments, the axial preload system including the spring 92 could be omitted from the scroll pump 100. In such embodiments, axial force Fs would be omitted from the force diagram of Fig. 11.

[0048] Fig. 12 shows an alternative embodiment of the scroll pump 100' wherein the permanent magnet 116 is omitted and a ferrous element 117 is provided in its place. Functionally, the scroll pump 100' is similar to the scroll pump 100. Functionally, the scroll pump 100' differs from the scroll pump 100 in that the electromagnet 112 of the scroll pump 100' is operable only to generate an attractive force between itself and the ferrous element 117, whereas the electromagnet 112 of the scroll pump 100 is operable to generate both attractive and repulsive forces between itself and the permanent magnet 116. As such, the electromagnet 112 of the scroll pump 100' is operable to effect an attractive axial biasing force between the fixed scroll member 12 and the moving scroll member 14, but not a repulsive biasing force between the fixed scroll member 12 and the moving scroll member 14. Accordingly, the electromagnet 112 of the scroll pump 100' is operable to bias the fixed scroll member 12 and the moving scroll member 14 away from each other, but not toward each other.

[0049] Fig. 13 is a schematic representation of forces acting on fixed and moving scroll members 12, 14 of the scroll pump 100' during operation thereof. In Fig. 13, F_{PI} represents the axial force applied between the fixed end plate 22 and the moving end plate 52 by the fluid being pumped or compressed by the scroll pump 100' and tending to bias the moving scroll member 14 away from the fixed scroll member 12, as discussed above. F_{PE} represents the axial force applied between the piston 66 or the end cap 94 and the moving end plate 52 and tending to bias the moving scroll member 14 toward the fixed scroll member 12, as discussed above. Fs represents the axial preload force applied between the fixed and moving scroll members 12, 14 and tending to bias the moving scroll member 14 toward the fixed scroll member 12, as discussed above. F_E represents the magnetic force selectively applied by the electromagnet 112 between the electromagnet 112 and the ferrous element 117 of the magnetic target and tending to selectively bias the moving scroll member 14 toward or away from the fixed scroll member 12. F_{NET} represents the net axial force acting between the fixed scroll member 12 and the moving scroll member 14 as a result of the forces F_{PI}, F_{PE}, F_S, and F_E. That is, F_{NET} represents the algebraic sum of the forces F_{PI}, F_{PE}, F_S, and F_E. The symbol + represents a force direction tending to bias the moving scroll member 14 away from the fixed scroll member 12, and the symbol - represents a force direction tending to bias the moving scroll member 14 toward the fixed scroll member 12. As suggested in Fig. 9, F_{NET} may be neutral, tending to bias the moving scroll member 14 toward the fixed scroll member 12, or tending to bias the moving scroll member 14 away from the fixed scroll member 12.

[0050] In the foregoing embodiment of the scroll pump 100', the electromagnet 112 is located opposite the moving scroll member 14 from the fixed scroll member 12. In an alternative embodiment, the electromagnet 112 could be located on the same side of the moving scroll member 14 as the fixed scroll member 12. For example, the electromagnet 112 may be integrated into the fixed scroll member 12.

[0051] In embodiments, the axial preload system including the spring 92 could be omitted from the scroll pump 100'. In such embodiments, axial force Fs would be omitted from the force diagram of Fig. 11.

[0052] Figs. 14-18 show an illustrative embodiment of a scroll pump 200 including an electromagnetic axial force control system according to the present disclosure. The scroll pump 200 is in most respects similar to the scroll pump 100. The scroll pump 200 differs from the scroll pump 100 primarily in that the preload-based axial force control system and the fluid pressure-based axial force control system of the scroll pump 100 are omitted from the scroll pump 200.

[0053] As such, the electromagnetic axial force control system 110 of the scroll pump 200 as shown in Figs. 14-18 includes the electromagnet 112 fixedly connected to the fixed scroll member 12 via the intervening mounting bracket 114, and the magnetic target in the form of the permanent magnet 116 fixedly connected to the moving scroll member 14. Figs. 14-18 show the electromagnet as the coil 120 (wound about a bobbin, not shown) surrounding the ferromagnetic core 122. Fig. 14 shows the coil 120 and the permanent magnet 116 as having respective outer diameters. In embodiments, the outer diameter of the permanent magnet 116 is sufficiently larger than the outer diameter of the coil 120 so that the radial bounds of the permanent magnet 116 overlap the radial bounds of the coil 120 at all times as the second scroll member 14 orbits with respect to the first scroll member 14 during operation of the scroll pump 200. This arrangement of relative diameters promotes consistent magnetic coupling between the electromagnet 112 and the permanent magnet 116 during operation of the scroll pump 200.

[0054] The wiring harness 124 connects the electromagnet 112 to a source of electrical current (not shown). A controller (not shown), for example, an electronic controller, may be provided to selectively control the supply of electrical current to the electromagnet 112 and thereby control a magnetic electric field generated by the electromagnet 112. The controller (not shown) may be configured to vary the magnitude of electrical current provided to the electromagnet 112 to thereby vary the strength of the magnetic field generated by the electromagnet 112.

[0055] In use, the electromagnet 112 may be selectively energized and thereby generate a magnetic force that couples to the permanent magnet 116. As would be understood by one skilled in the art, the electromagnet 112 may be selectively energized to generate an attractive magnetic force between the electromagnet 112 and the permanent magnet 116, thereby biasing the moving scroll member 14 away from the fixed scroll member 12. As also would be understood by one skilled in the art, the electromagnet 112 also may be selectively energized to generate a repulsive magnetic force between the electromagnet 112 and the permanent magnet 116, thereby biasing the moving scroll member 14 toward the fixed scroll member 12.

[0056] During operation of the scroll pump 200, a net axial biasing force axially biasing the moving scroll member 14 away from the fixed scroll member 12 may lessen the seal between the fixed and moving scroll tips 24, 54 and/or between the fixed and moving tip seals 24S, 54S and the corresponding end plates 52, 22. The lessening of the foregoing seal may induce fluid leakage between the fixed and moving scroll tips 24, 54 and/or between the fixed and moving tip seals 24S, 54S and the corresponding end plates 52, 22. Such induced fluid leakage may be used to control the output flow rate and/or output pressure of the scroll pump 200 without varying its speed. Controlling the output flow rate and/or output pressure of the scroll pump 200 by inducing leakage in this manner may allow the scroll pump to operate within a predetermined range of output flow rate and/or output pressure with less noise or variation in noise than operating the scroll pump 200 at varying speeds to accomplish similar variation in output flow rate and/or output pressure.

[0057] Fig. 19 is a schematic representation of forces acting on fixed and moving scroll members 12, 14 of the scroll pump 200 during operation thereof. In Fig. 19, F_{PI} represents the axial force applied between the fixed end plate 22 and the moving end plate 52 by the fluid being pumped or compressed by the scroll pump 200 and tending to bias the moving scroll member 14 away from the fixed scroll member 12, as discussed above. F_M represents the axial magnetic force applied by the permanent magnet 116 of the magnetic target between the permanent magnet 116 of the magnetic target and the fixed scroll member 12 and tending to bias the moving scroll member 14 toward the fixed scroll member 12. F_E represents the magnetic force selectively applied by the electromagnet 112 between the electromagnet 112 and the permanent magnet 116 of the magnetic target and tending to selectively bias the moving scroll member 14 toward or away from the fixed scroll member 12. F_{NET} represents the net axial force acting between the fixed scroll member 12 and the moving scroll member 14 as a result of the forces F_{PI}, F_M, and F_E. That is, F_{NET} represents the algebraic sum of the forces F_{PI}, F_M, and F_E. The symbol + represents a force direction tending to bias the moving scroll member 14 away from the fixed scroll member 12, and the symbol - represents a force direction tending to bias the moving scroll member 14 toward the fixed scroll member 12. As suggested in Fig. 19, F_{NET} may be neutral, tending to bias the moving scroll member 14 toward the fixed scroll member 12, or tending to bias the moving scroll member 14 away from the fixed scroll member 12.

[0058] In embodiments, the permanent magnet 116 of the scroll pump 200 could be replaced with the ferrous target 117 of the scroll pump 100'. In such embodiments, the electromagnet 112 would be operable to generate an attractive force, but not a repulsive force, between the fixed scroll member 12 and the moving scroll member 14. As such, the axial force F_{E-} would be absent from the force diagram of Fig. 19.

[0059] In the foregoing embodiment of the scroll pump 200, the electromagnet 112 is located opposite the moving scroll member 14 from the fixed scroll member 12. In an alternative embodiment, the electromagnet 112 could be located on the same side of the moving scroll member 14 as the fixed scroll member 12. For example, the electromagnet 112 may be integrated into the fixed scroll member 12. In such an embodiment, the magnetic force vector F_M shown in Fig. 11 would point in the opposite direction, and the magnetic force applied by the permanent magnet 116 of the magnetic target would tend to bias the moving scroll member 14 toward the fixed scroll member 12, rather than away from the fixed scroll member 12.

[0060] In embodiments, the axial preload system including the spring 92 could be added to the scroll pump 200. In such embodiments, the axial force Fs would be added to the force diagram of Fig. 19 in a manner similar to the force Fs shown in Figs. 9, 11, and 13.

[0061] In all of the foregoing embodiments, the axial control forces F_{PE}, Fs, and F_M may be predetermined and the axial control force F_E may be predetermined or adjusted as desired to achieve the desired net axial force F_{NET} tending to bias the moving scroll member 14 toward or away from the fixed scroll member 12, as desired.

[0062] The embodiments shown and described herein are illustrative and may be modified as would be understood by one skilled in the art without departing from the scope of the appended claims.

Claims

1. A scroll pump comprising:

a first scroll member, the first scroll member comprising:

a first end plate; and
a first scroll extending in an axial direction from the first end plate to a first scroll tip;

a second scroll member, the second scroll member comprising:

a second end plate; and
a second scroll extending in the axial direction from the second end plate to a second scroll tip, wherein the second scroll is intermeshed with the first scroll, wherein the first scroll member and the second scroll member define a working volume therebetween, and wherein the second scroll is

movable in the axial direction with the respect to the first scroll; and

an electromagnet fixedly connected to the fixed scroll member, wherein the electromagnet is operable to selectively bias the second scroll member axially with respect to the first scroll member.

2. The scroll pump of claim 1 wherein the electromagnet comprises a coil.

3. The scroll pump of claim 2 wherein the electromagnet further comprises a ferromagnetic core.

4. The scroll pump of any preceding claim further comprising a magnetic target fixed to the other of the first scroll member and the second scroll member.

5. The scroll pump of claim 4 wherein the magnetic target comprises a ferrous target made of ferromagnetic material.

6. The scroll pump of claim 4 wherein the magnetic target comprises a permanent magnet.

7. The scroll pump of any preceding claim further comprising a spring associated with the first scroll member and the second scroll member and operable to bias the second scroll member toward the first scroll member.

8. The scroll pump of any of any preceding claim further comprising a controller operable to selectively energize and de-energize the coil and thereby selectively cause the electromagnet to bias the second scroll member axially with respect to the first scroll member.

9. The scroll pump of claim 8 wherein the controller is operable to selectively cause the electromagnet to bias the second scroll member away from the first scroll member.

10. The scroll pump of claim 8 wherein the controller is operable to selectively cause the electromagnet to bias the second scroll member toward the first scroll member.

11. The scroll pump of claim 8 wherein the controller is operable to selectively cause the electromagnet to bias the second scroll member toward the first scroll member to mitigate leakage of a working fluid between the first scroll and the second scroll.

12. The scroll pump of claim 8 wherein the controller is operable to selectively cause the electromagnet to bias the second scroll member away from the first scroll member to induce leakage of a working fluid between the first scroll and the second scroll.

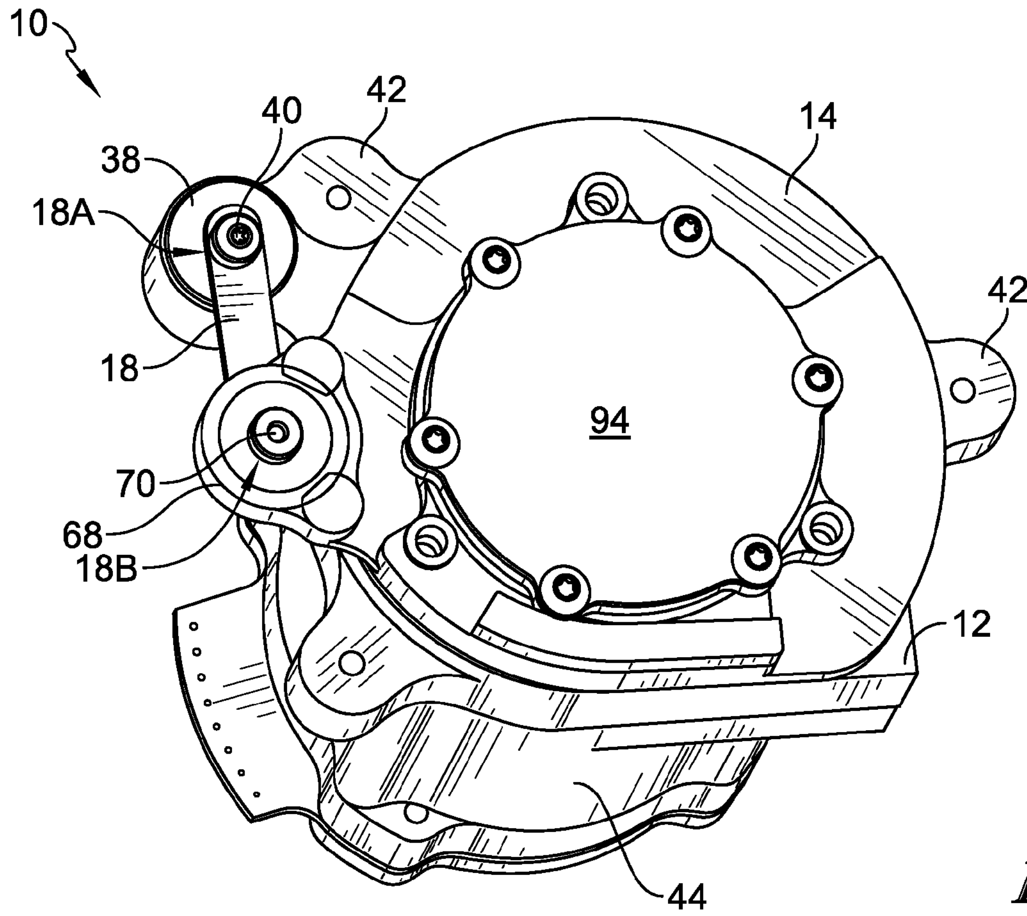
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FIG. 1

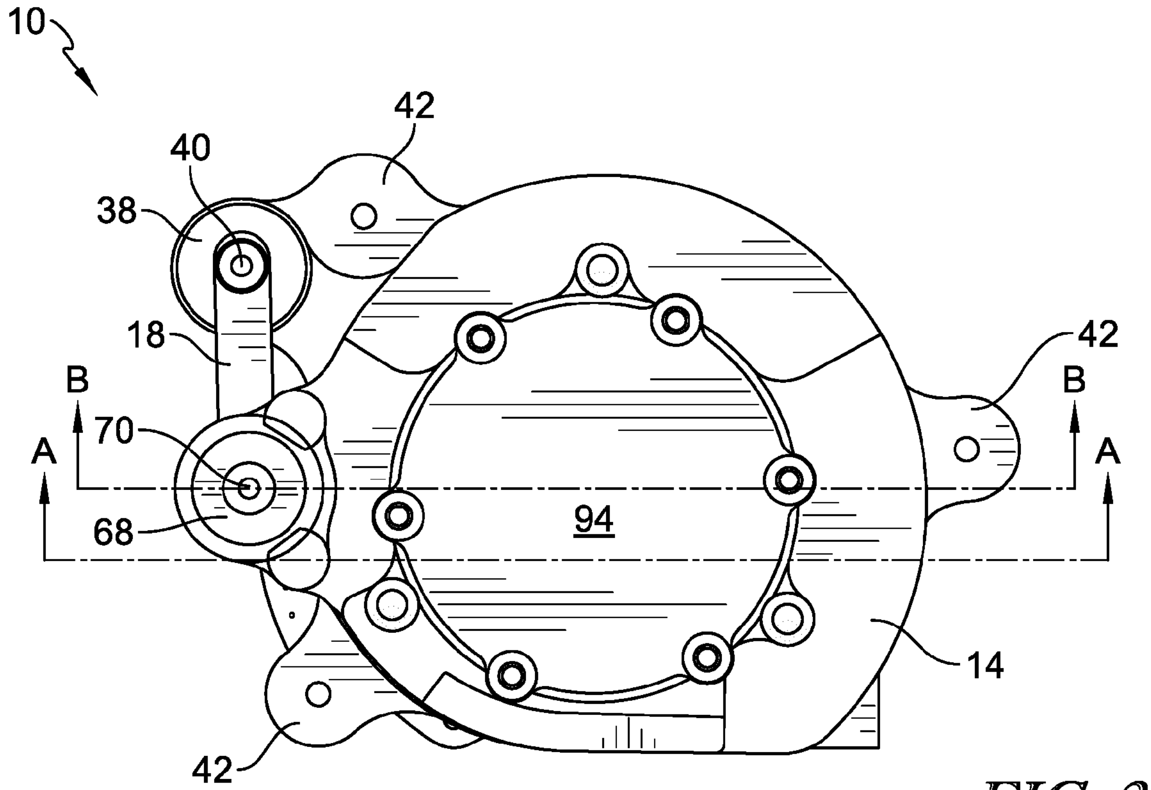
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FIG. 2

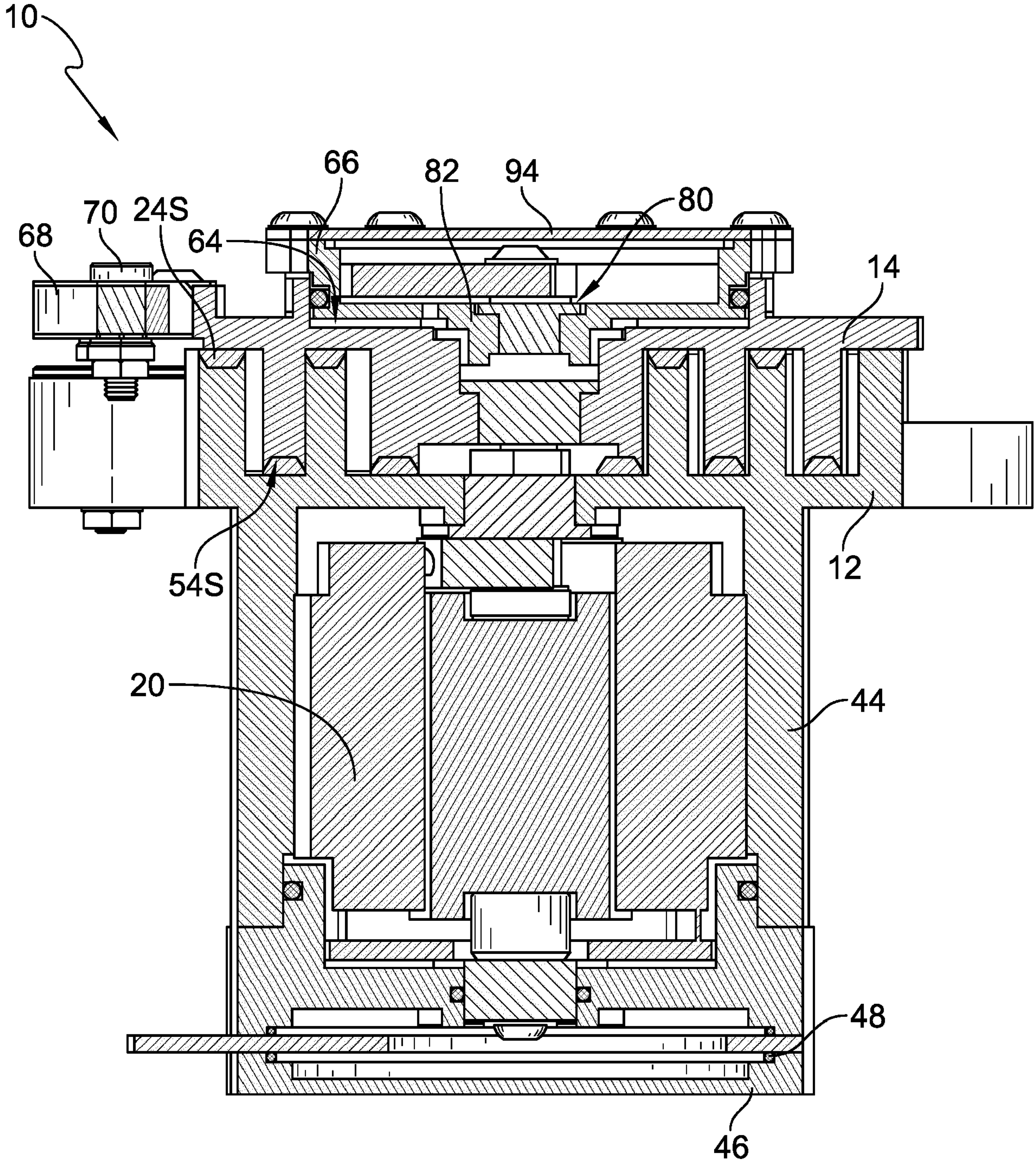

FIG. 3

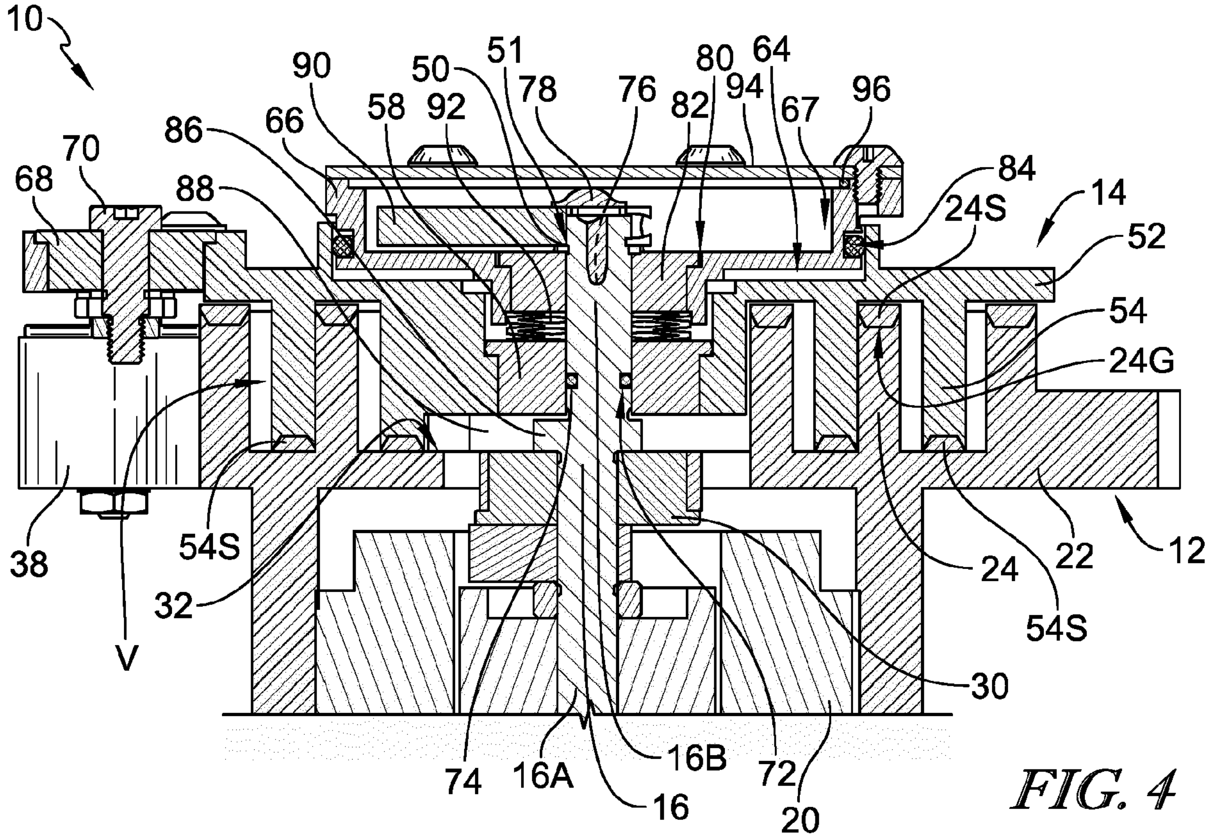

FIG. 4

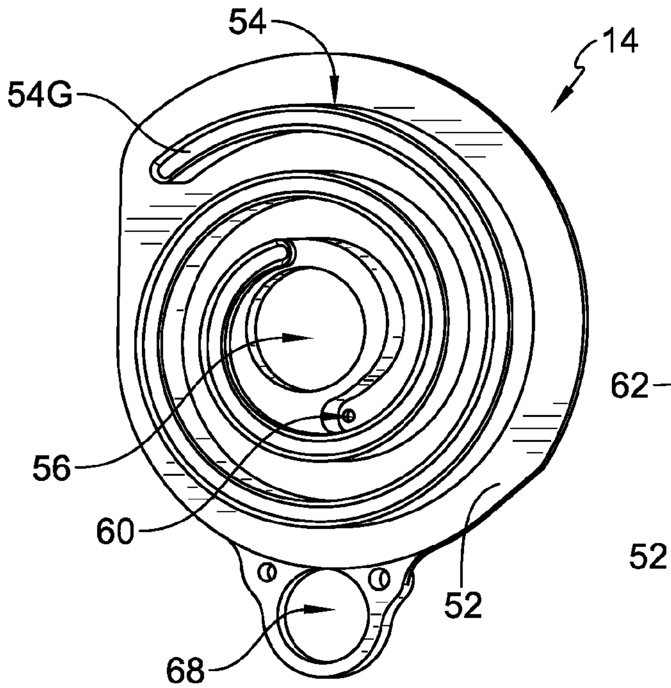

FIG. 5A

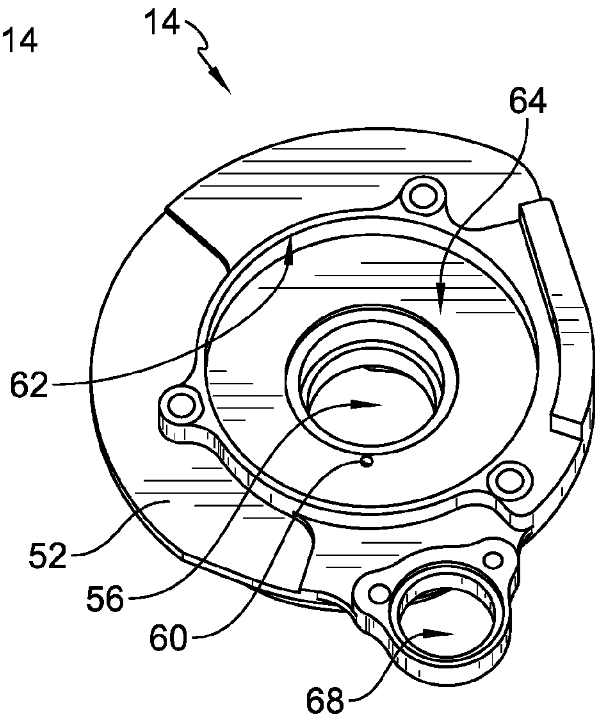

FIG. 5B

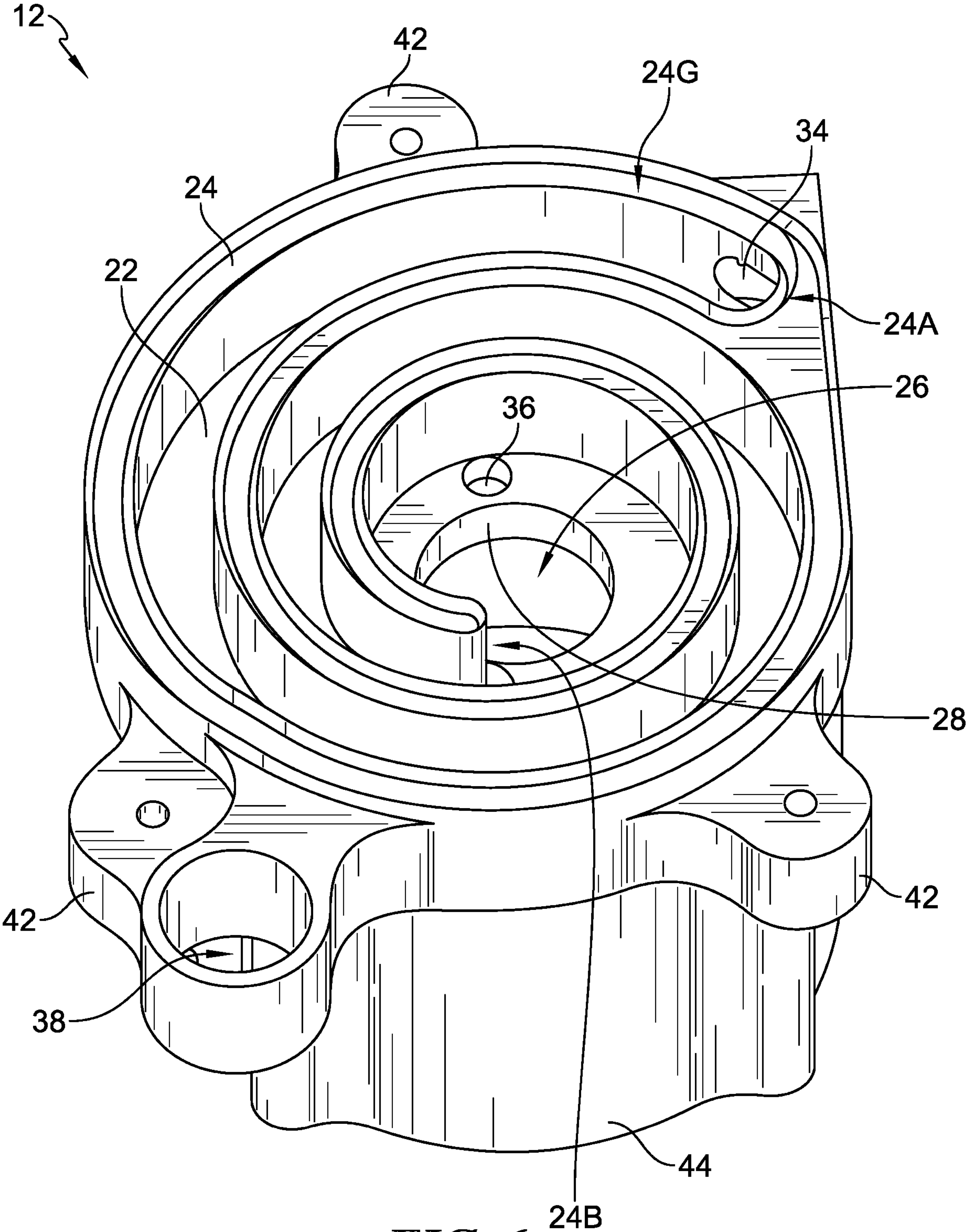

FIG. 6

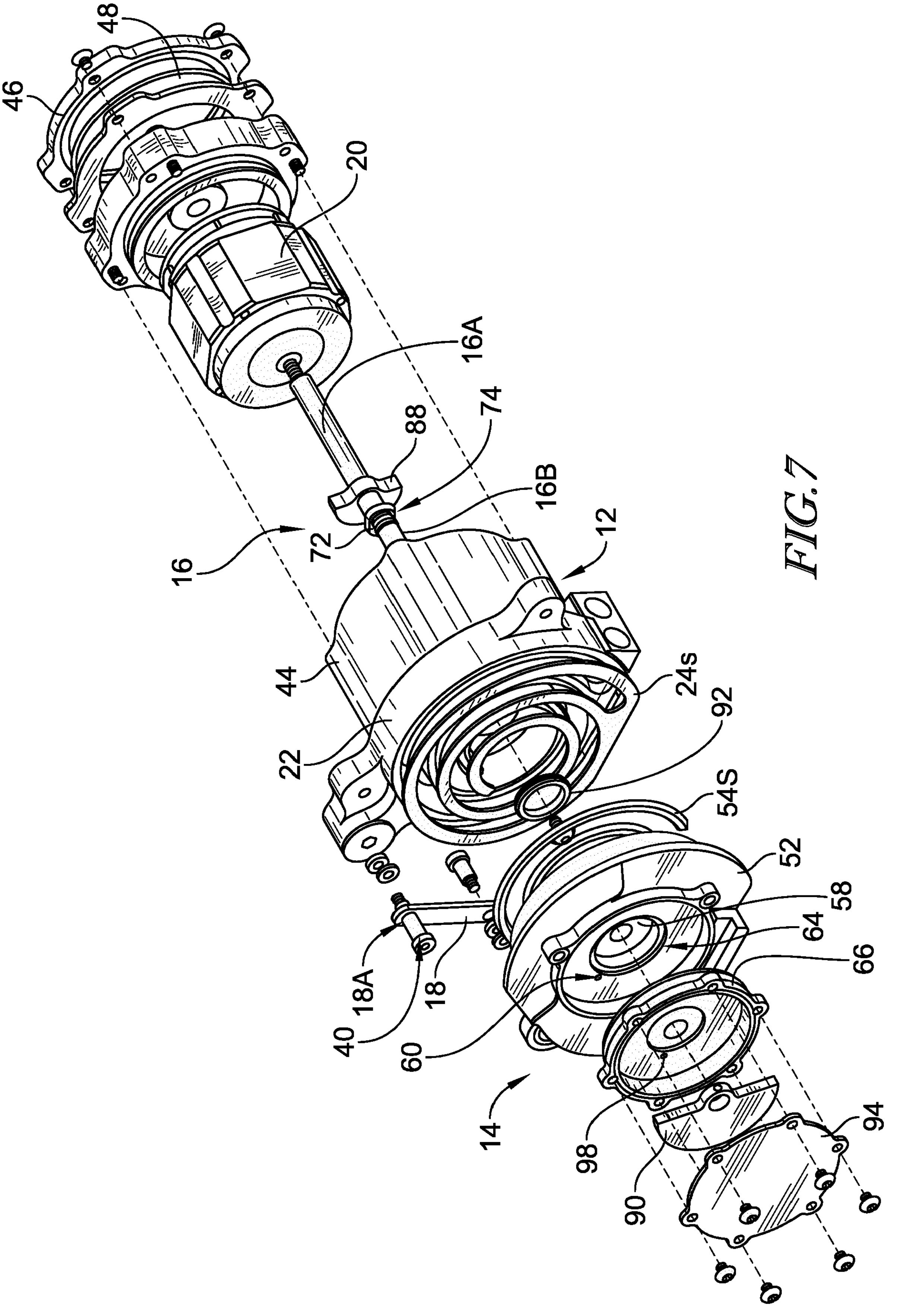
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FIG.7

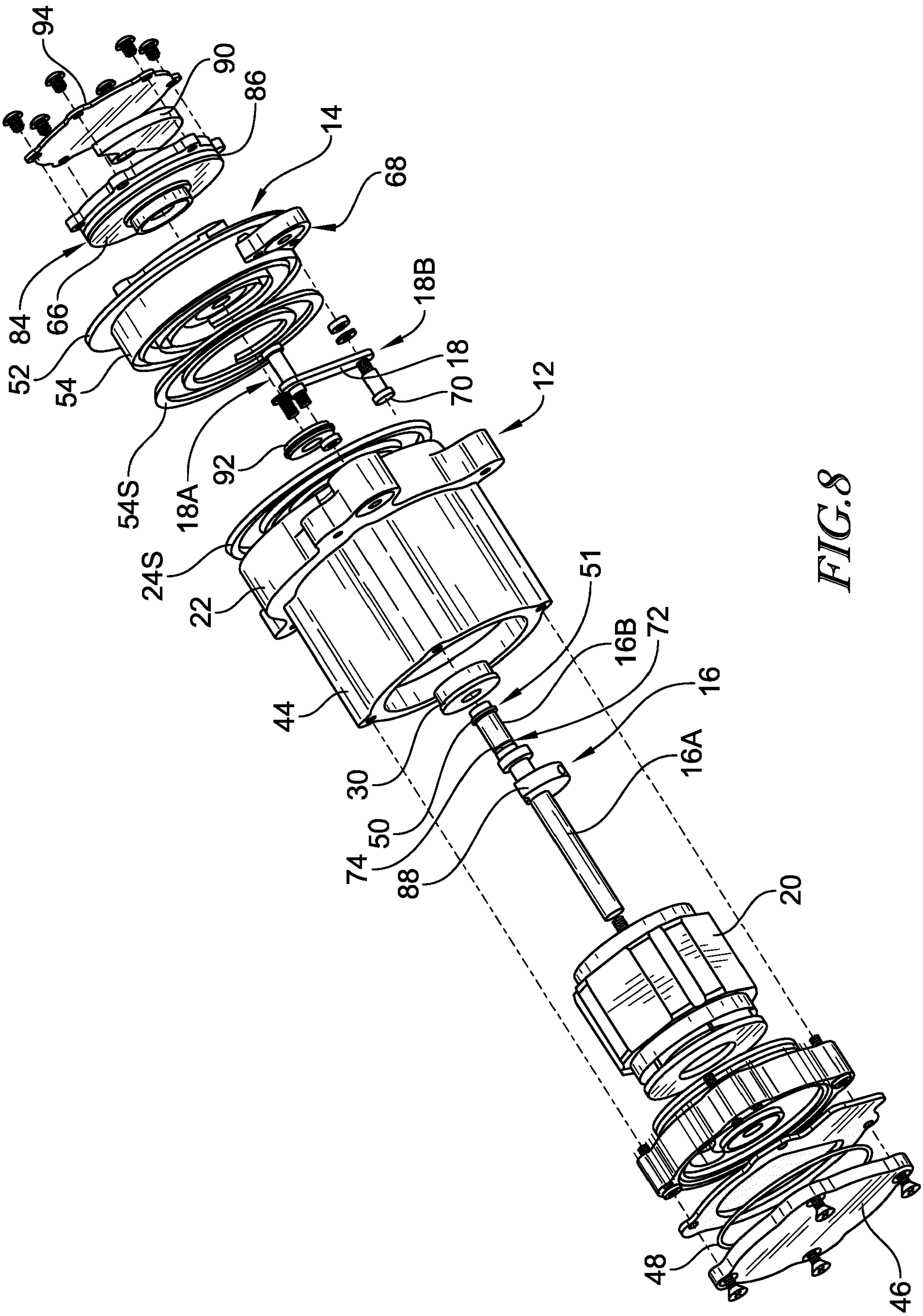
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FIG.8

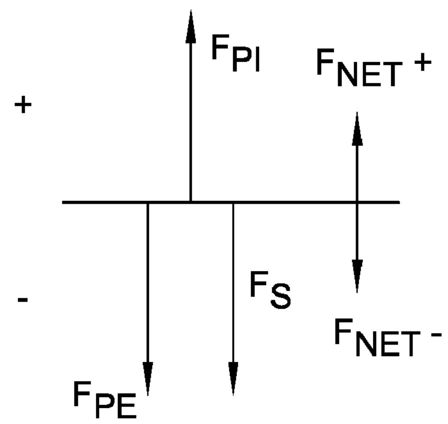

FIG. 9

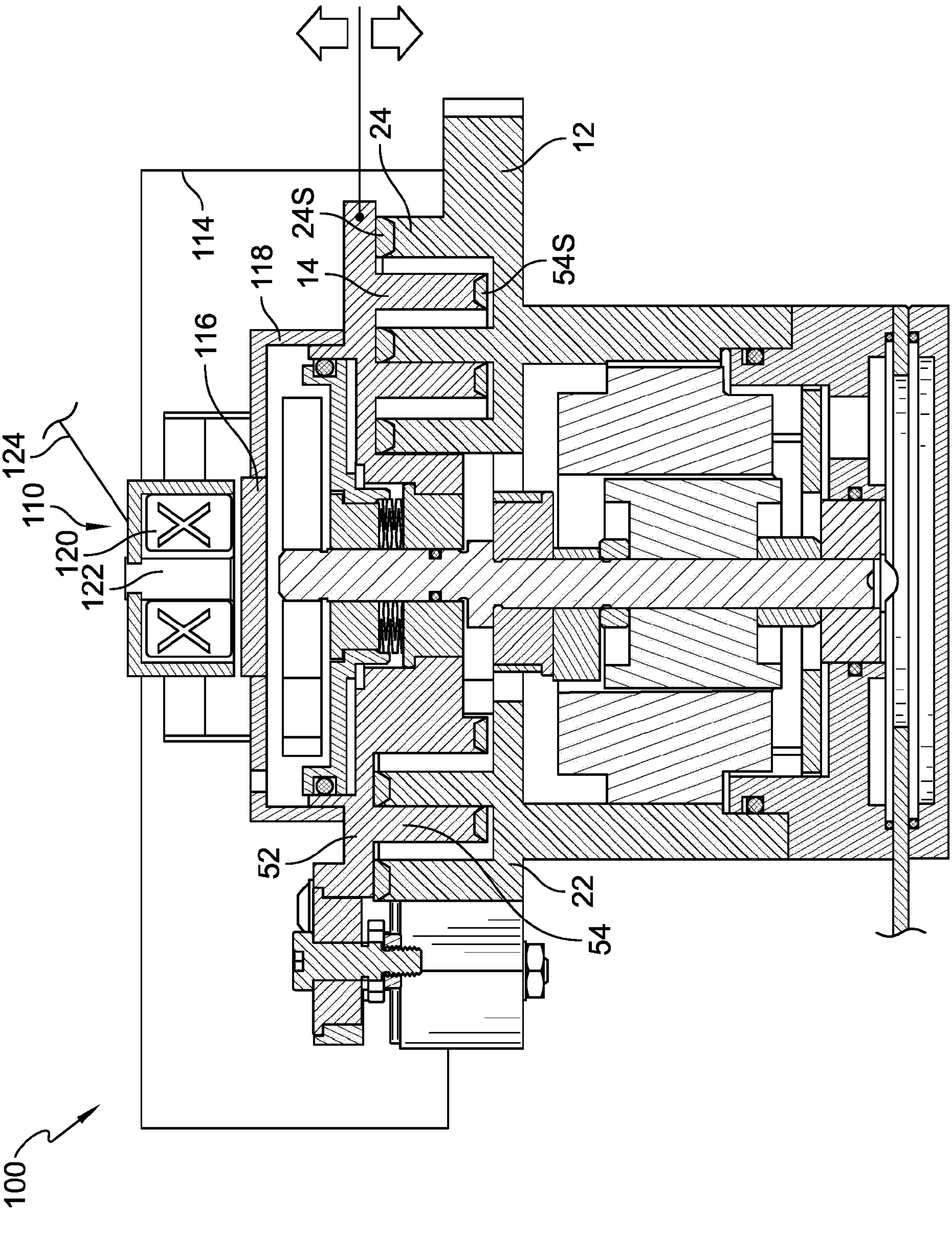

FIG. 10

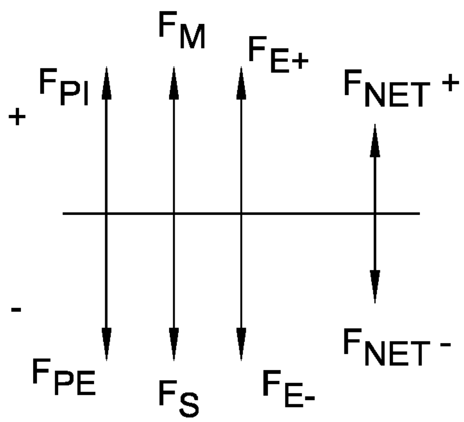

FIG. 11

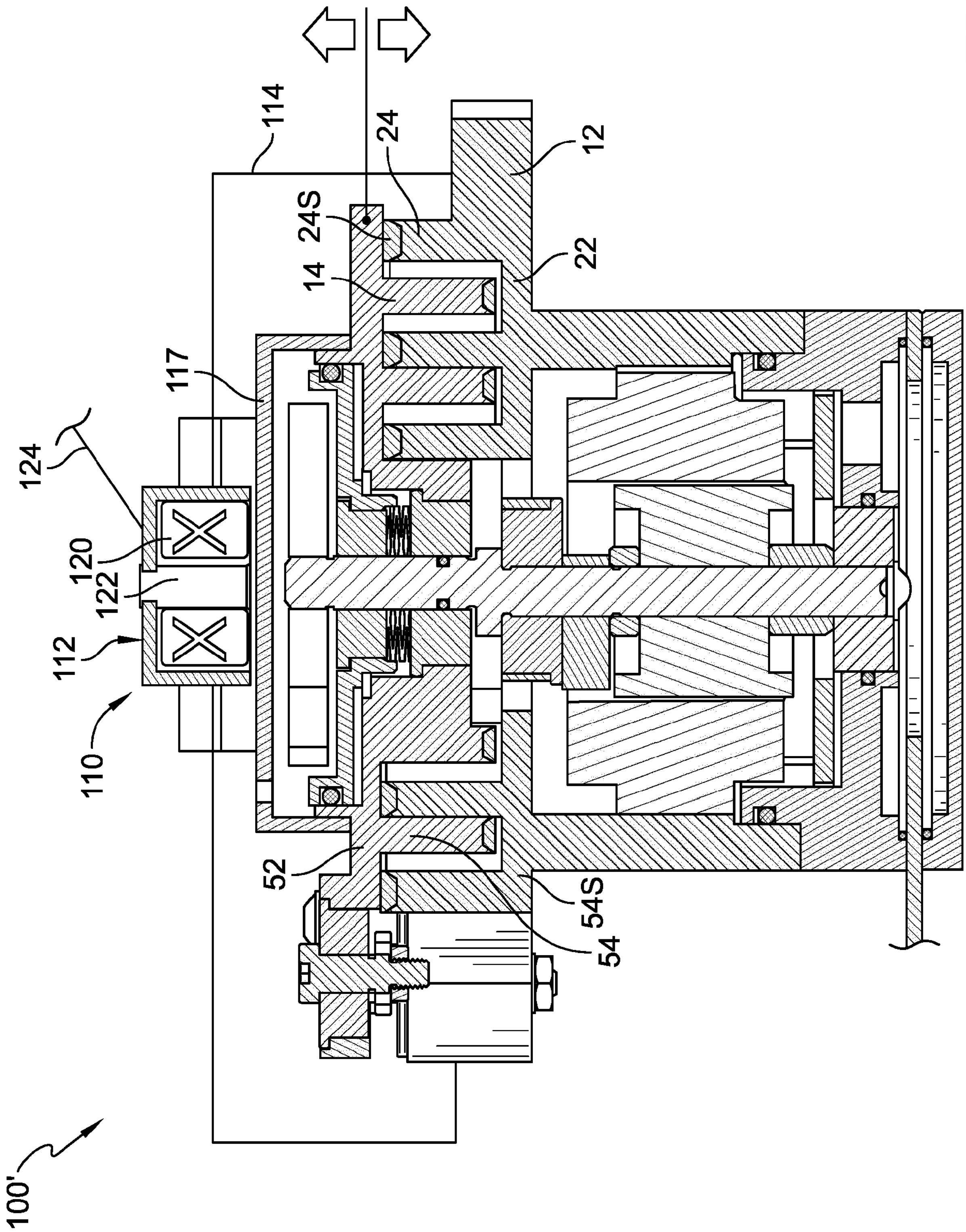

FIG. 12

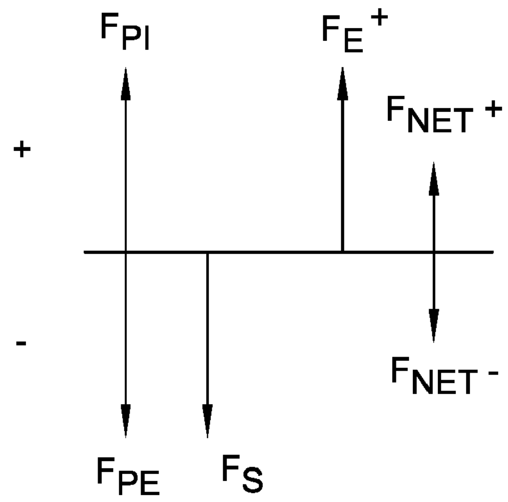

FIG. 13

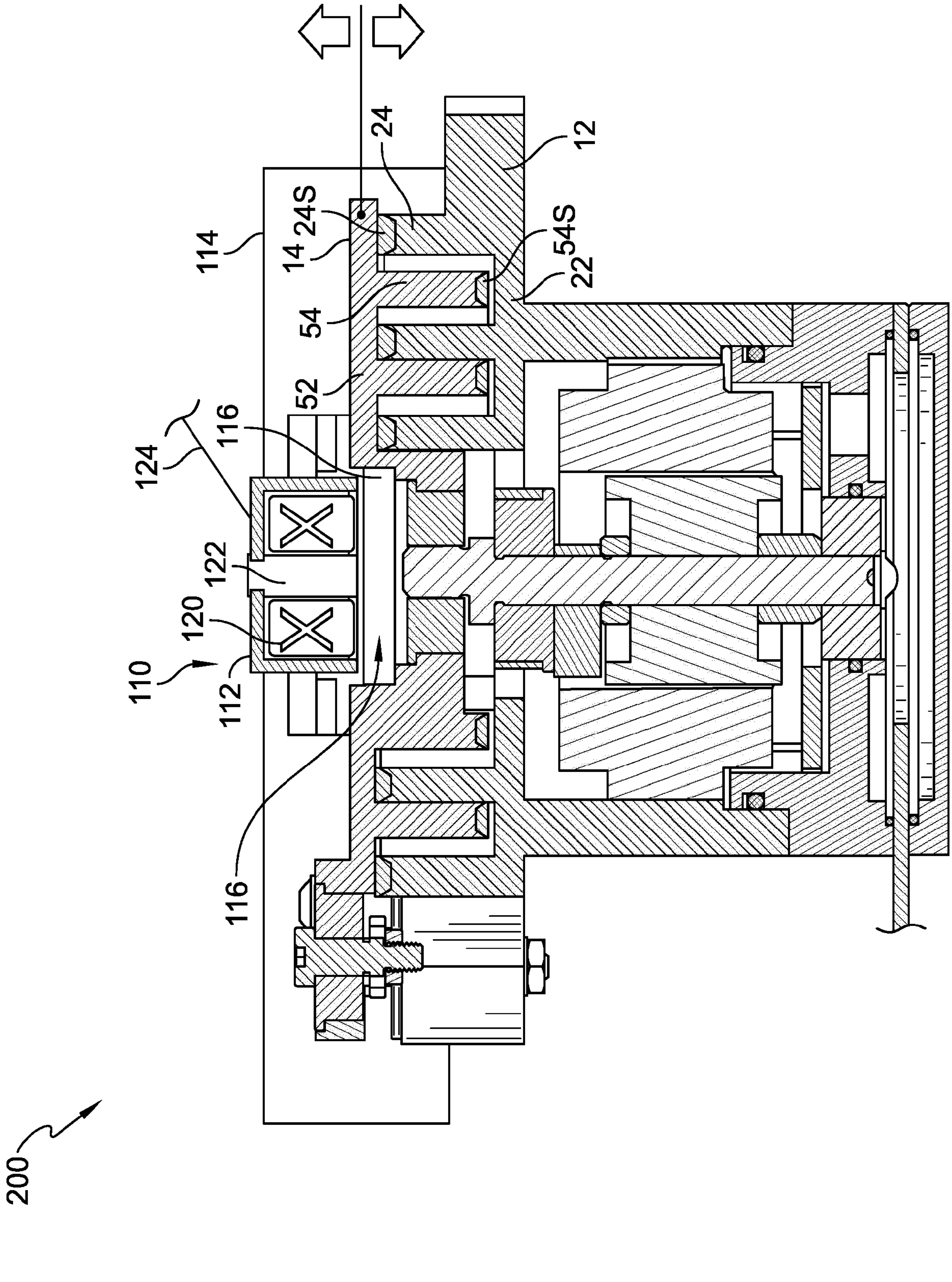

FIG. 14

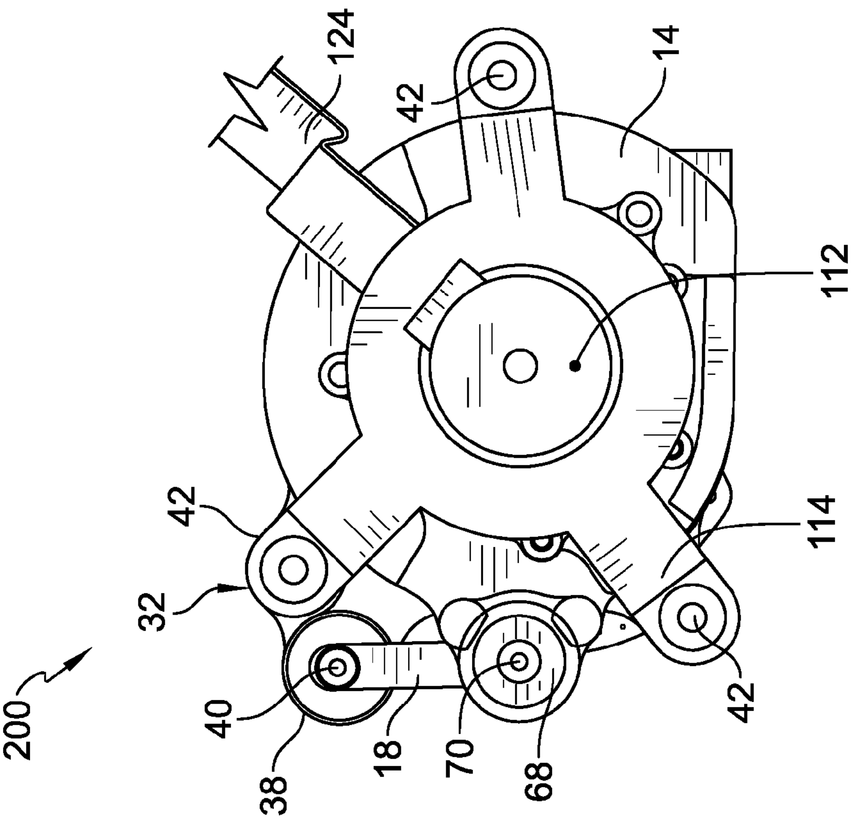
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FIG. 16

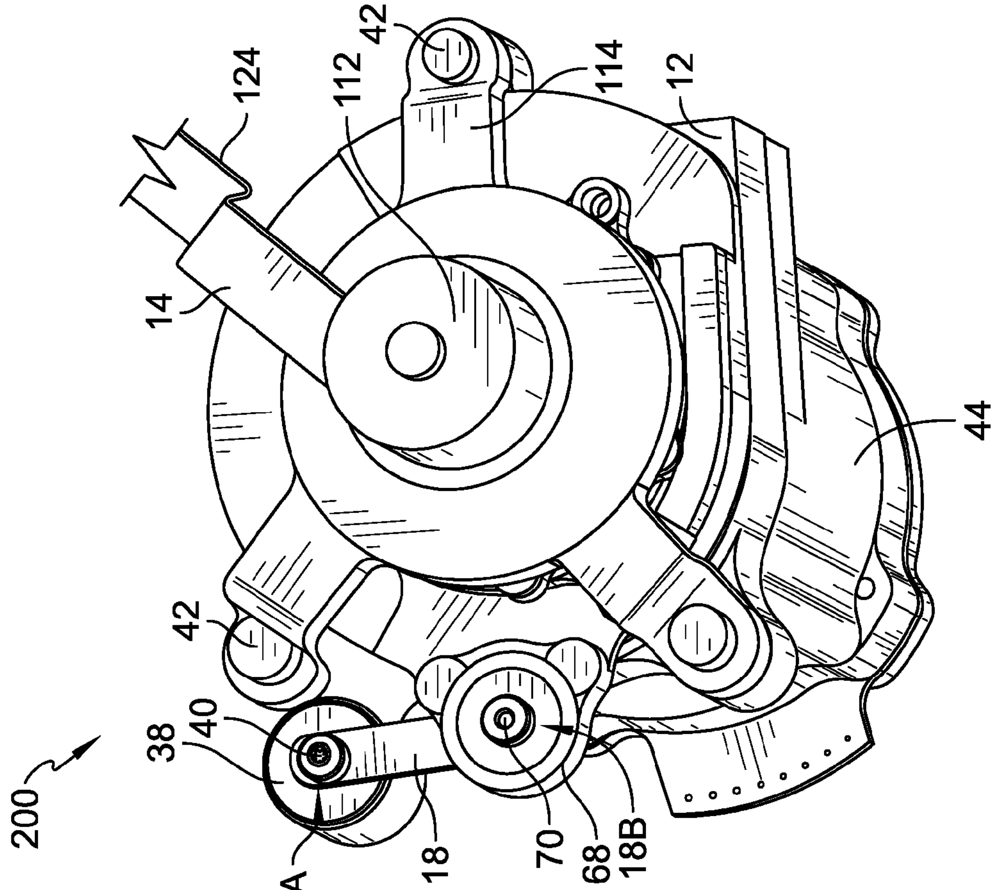
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FIG. 15

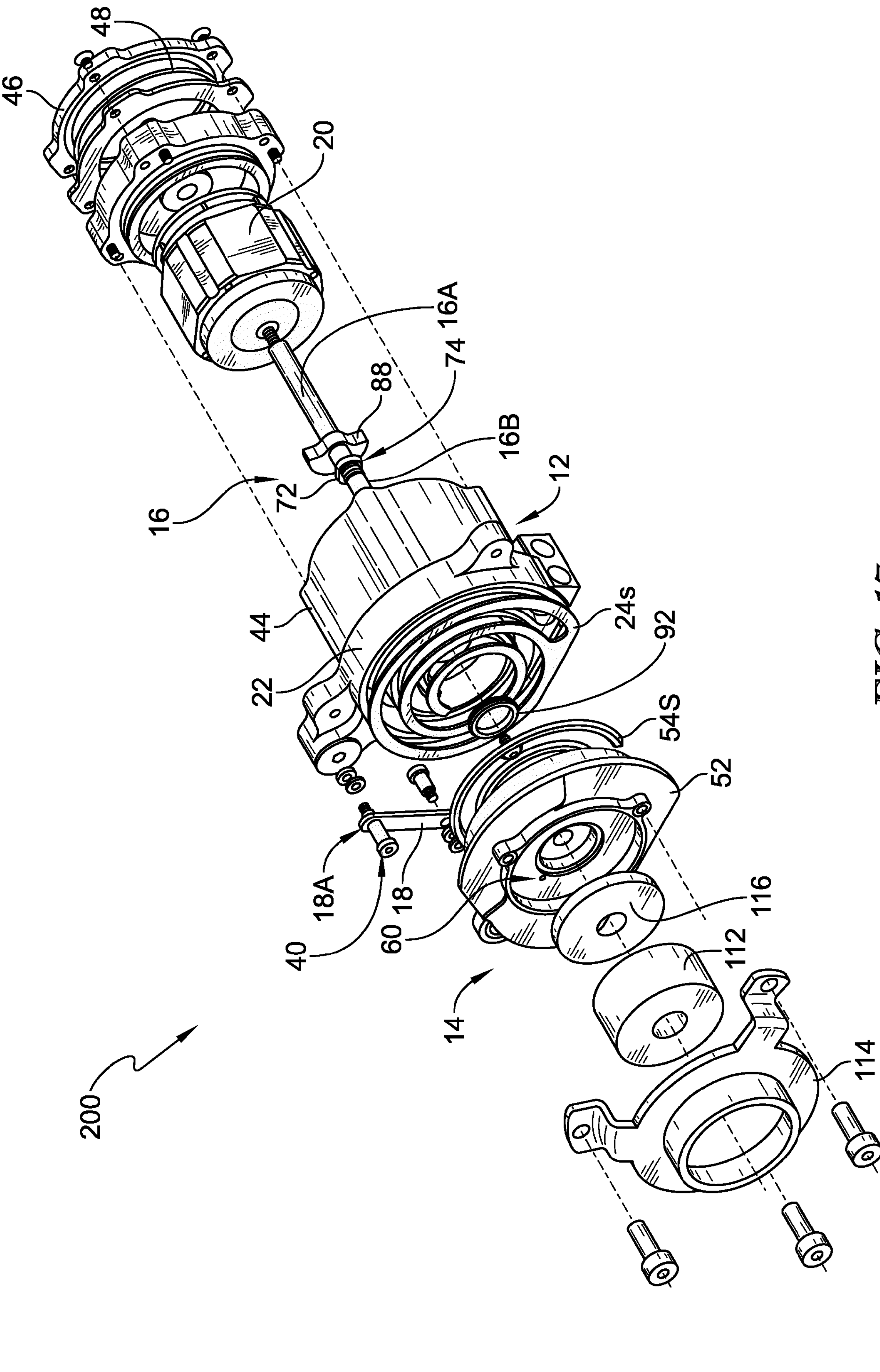
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FIG. 17

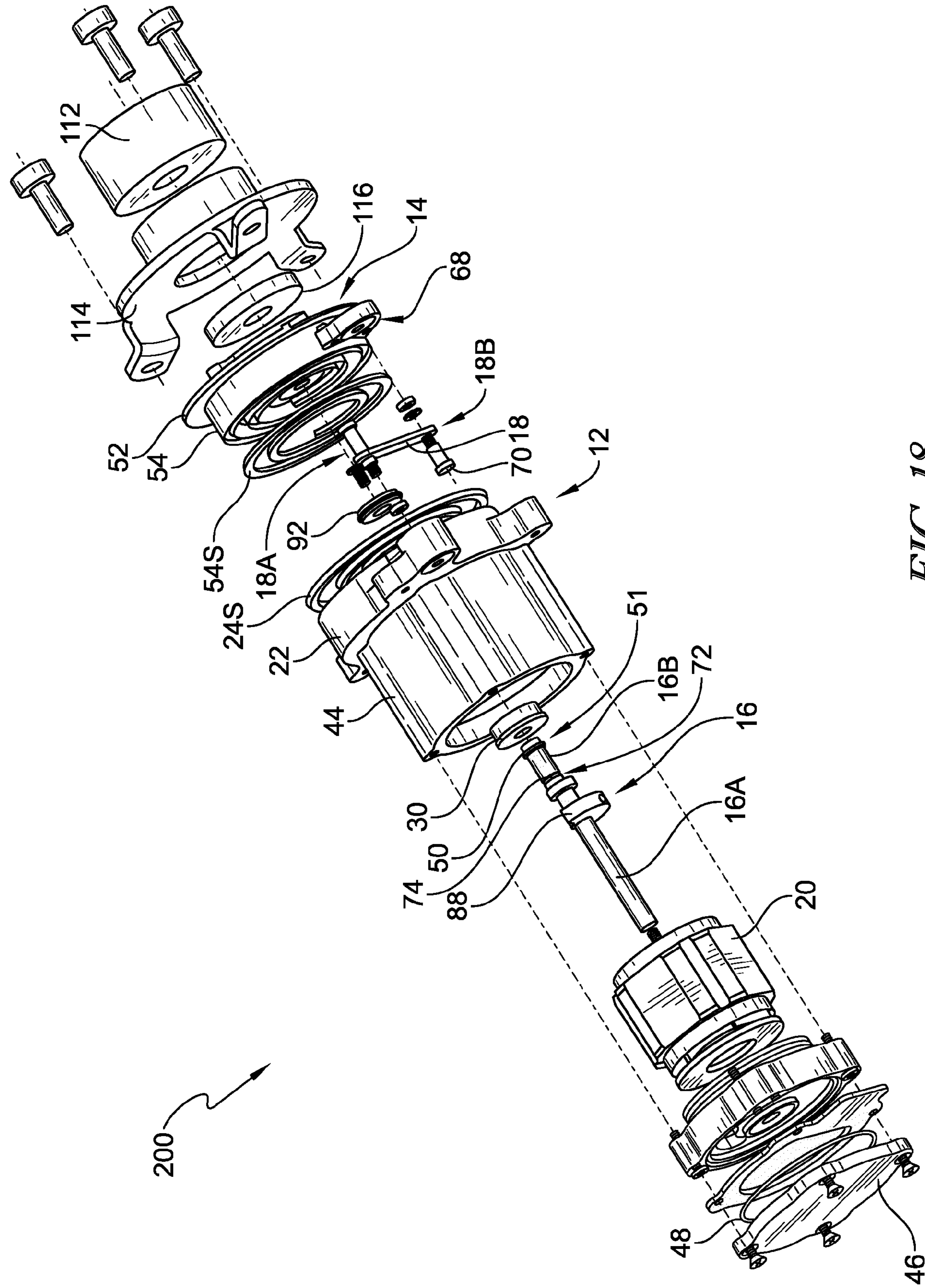
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FIG. 18

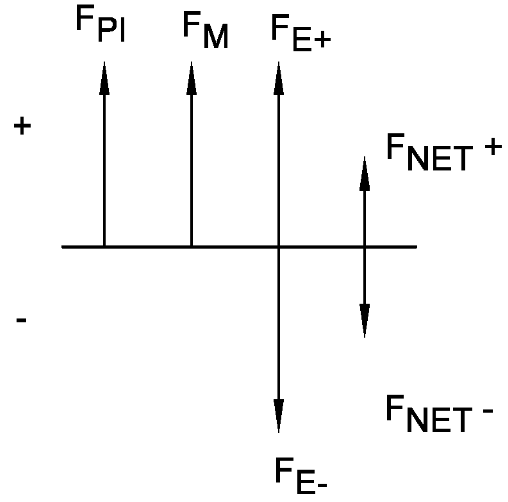

FIG. 19

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EUROPEAN SEARCH REPORT

Application Number
EP 23 17 0751

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	4 September 2023	Di Giorgio, F

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L : document cited for other reasons

& : member of the same patent family, corresponding document

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