(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
03 October 2024 (03.10.2024)

WIPO | PCT

(10) **International Publication Number**
WO 2024/206026 A1

(51) **International Patent Classification:**
F04C 2/10 (2006.01) ***F04D 29/60*** (2006.01)
F04C 15/06 (2006.01)

(21) **International Application Number:** PCT/US2024/020742

(22) **International Filing Date:** 20 March 2024 (20.03.2024)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
18/128,531 30 March 2023 (30.03.2023) US

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO,

(54) **Title:** ELECTRONIC POSITIVE DISPLACEMENT FLUID PUMP WITH PUMPING RING ALIGNMENT

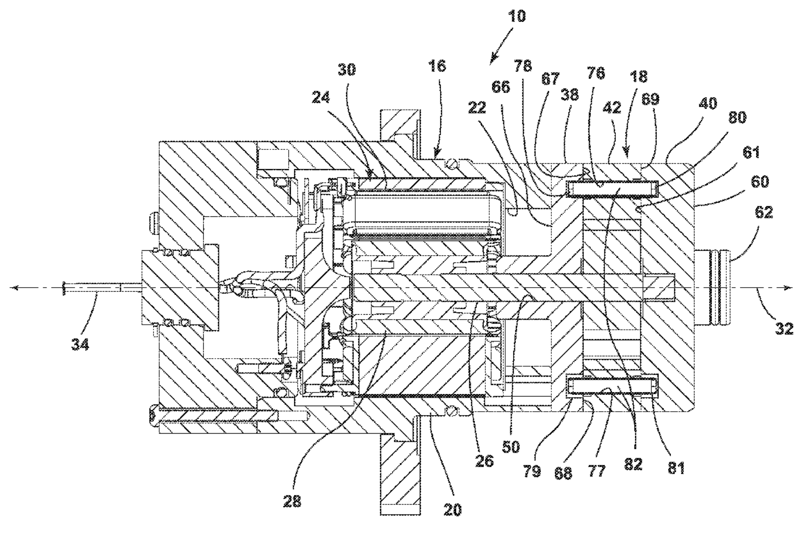

FIG. 3

(57) **Abstract:** A positive displacement fluid pump (10) is provided. The fluid pump includes a motor (24) and a pumping portion (18) driven by the motor. The pumping portion includes an internal plate (38), an external plate (40) including a fluid inlet (62) and a fluid outlet (63), a pumping ring (42) sandwiched between the internal and external plates, and a pumping arrangement (44) rotatably coupled to the motor and located within the pumping ring. The pumping ring includes at least two alignment holes (76, 77) extending through the pumping ring in an axial direction. The internal plate and the external plate each including a corresponding number of axially-extending alignment holes (78, 79, 80, 81), respectively. An alignment pin (82) is provided for each of the alignment holes of the pumping ring. The alignment holes are aligned with each other, and the alignment pins are positioned in the aligned alignment holes. A method of aligning components of a positive displacement fluid pump is also provided.

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RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

ELECTRONIC POSITIVE DISPLACEMENT FLUID PUMP WITH PUMPING RING ALIGNMENT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 18/128,531, filed March 30, 2023, the disclosure of which is incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The disclosure generally relates to positive displacement fluid pumps and, more specifically, to electronic positive displacement pumps for pumping fluids such as oil or fuel.

BACKGROUND OF THE INVENTION

[0003] Electro-hydraulic pumps are electromechanical apparatuses in which mechanical energy generated by a motor is transferred to a hydraulic pump section that moves a fluid to provide fluid flow and fluid pressure in a hydraulic circuit. Examples of these pumps used in vehicles include gear pumps such as electronic fuel pumps (EFPs) that feed fuel from the fuel delivery module (FDM) in the fuel tank to a combustion engine of the vehicle. Other examples include electronic oil pumps that move hydraulic fluid to cool and lubricate the internal mechanisms of, for example, an integrated drive module (IDM), such as the drive motor and gear box of the IDM. These electronic pumps may be directly commutated ("brush") pumps that are driven by a constant voltage signal or electronically commutated ("brushless") pumps that are driven by dedicated pump controllers. Common electronically commutated pumps include a housing assembly that houses the motor and a circuit board that operates the motor. A pumping section that is driven by the motor is also located in the housing. The pumping section may include, for example, an internal plate, a gerotor assembly that is disposed in the internal plate, and an external plate that closes the housing and includes inlet and outlet ports.

[0004] The use of electronically commutated pumps in the field of automotive vehicles has increased with the demand for greater vehicle fuel economy as well as greater drive range for electric vehicles (EVs). This demand requires that the pumps and systems that use them are more robust and efficient, while also offering these improvements at a lower cost. For example, conventional pumps typically include two cast aluminum plates in which the recess that receives the gerotor gear set is integrated directly into one of the pump plates, and the suction and delivery ports are formed in the other pump plate. However, these existing pump configurations do not allow for the addition of performance improving features or the adjustment of the volumetric displacement without increasing the size of the pump or investing in new tooling to make design changes the increase flow, pump efficiency, and/or reduce performance variation.

BRIEF SUMMARY

[0005] An improved positive displacement fluid pump is provided. The positive displacement fluid pump includes a motor having a drive shaft that rotates about an axis extending in an axial direction, and a pumping portion driven by the motor. The pumping portion includes: an internal plate including a central bore through which the drive shaft extends, an external plate including a fluid inlet and a fluid outlet, a pumping ring sandwiched between the internal and external plates, and a pumping arrangement rotatably coupled to the drive shaft such that rotation of the pumping arrangement by the drive shaft causes fluid to be pumped from the fluid inlet to the fluid outlet. The pumping arrangement is located within the pumping ring and axially between the internal plate and the external plate. The pumping ring includes at least two alignment holes extending through the pumping ring in the axial direction. The internal plate and the external plate each include a corresponding number of axially-extending alignment holes, respectively. The fluid pump further includes an alignment pin for each of the alignment holes of the pumping ring. The alignment holes of the pumping ring are aligned with the alignment holes of the internal plate and the alignment holes of the external plate, and the alignment pins are positioned in the alignment holes of the pumping ring and extend into the alignment holes of the internal and external plates to maintain the relative disposition of the pumping ring to the internal and external plates.

[0006] In specific embodiments, the alignment holes of the pumping ring include a primary alignment hole and a secondary alignment hole.

[0007] In particular embodiments, the primary alignment hole and the secondary alignment hole of the pumping ring are both circular in cross-sectional shape.

[0008] In particular embodiments, the alignment holes of the internal plate and the alignment holes of the external plate each include a primary alignment hole and a secondary alignment hole corresponding to the primary and secondary alignment holes of the pumping ring, respectively.

[0009] In certain embodiments, the primary alignment hole of the internal plate and the primary alignment hole of the external plate are each circular in cross-sectional shape.

[0010] In certain embodiments, the secondary alignment hole of the internal plate and the secondary alignment hole of the external plate have an elongated cross-sectional shape.

[0011] In certain embodiments, the secondary alignment hole of the internal plate and the secondary alignment hole of the external plate are oval in cross-sectional shape.

[0012] In specific embodiments, the pumping ring includes only two alignment holes, and the internal plate and the external plate each include only two corresponding alignment holes.

[0013] In specific embodiments, the alignment holes of the internal plate do not extend through the internal plate in the axial direction, and the alignment holes of the external plate do not extend through the external plate in the axial direction.

[0014] In specific embodiments, the alignment pins are coiled pins.

[0015] In specific embodiments, the internal plate includes an inwardly-facing face surface and an opposite, outwardly-facing face surface, the outwardly-facing face surface of the internal plate being adjacent to the pumping ring. The external plate includes an inwardly-facing face surface and an opposite, outwardly-facing face surface, the inwardly-facing face surface of the external plate being adjacent to the pumping ring.

[0016] In particular embodiments, the alignment holes of the internal plate are formed in the outwardly-facing face surface of the internal plate, and the alignment holes of the external plate are formed in the inwardly-facing face surface of the external plate.

[0017] In particular embodiments, the external plate includes a suction port formed in the inwardly-facing face surface of the external plate. The suction port of the external plate is connected to and in fluid communication with the fluid inlet.

[0018] In certain embodiments, the internal plate includes a complementary suction port formed in the outwardly-facing face surface of the internal plate. The complementary suction port is in fluid communication with the fluid inlet.

[0019] In certain embodiments, the complementary suction port of the internal plate is connected to the fluid inlet by a suction passage that extends through the pumping ring.

[0020] In particular embodiments, the external plate includes a delivery port formed in the inwardly-facing face surface of the external plate. The delivery port of the external plate is connected to and in fluid communication with the fluid outlet.

[0021] In certain embodiments, the internal plate includes a complementary delivery port formed in the outwardly-facing face surface of the internal plate.

[0022] In specific embodiments, the pumping arrangement includes a rotating element that is an inner gear rotor mounted on the drive shaft, and the pumping arrangement further includes an outer gear rotor engaged and driven by the inner gear rotor. The inner gear rotor and outer gear rotor together define a plurality of variable volume pumping chambers in fluid communication with the inlet and the outlet. Additionally, the pumping ring is an eccentric ring having a circular gear rotor bore that is offset from the axis of the drive shaft.

[0023] In particular embodiments, the eccentric ring and the inner and outer gear rotors of the pumping arrangement are made of materials having a similar coefficient of thermal expansion (CTE).

[0024] A method of aligning components of a positive displacement fluid pump is also provided. The method includes the step of providing a motor having a drive shaft that rotates about an axis extending in an axial direction. The method further includes the step of providing a pumping portion including: an internal plate including a central bore through which the drive shaft extends, an external plate including a fluid inlet and a fluid outlet, a pumping ring sandwiched between the internal and external plates, and a pumping arrangement rotatably coupled to the drive shaft. The pumping arrangement is located within the pumping ring and axially between the internal plate and the external plate. The method further includes the step of forming at least two alignment holes that extend through the pumping ring in the axial direction. The method further includes the step of forming a corresponding number of axially-extending alignment holes in each of the internal plate and the external plate. The method further includes the step of providing an alignment pin for each of the alignment holes of the pumping ring. The method further includes the step of positioning the alignment pins in the alignment holes of the pumping ring. The method further includes the step of aligning the alignment holes of the pumping ring with the alignment holes of the internal plate and the alignment holes of the external plate, whereby the alignment pins also extend into the alignment holes of the internal and external plates to maintain the relative disposition of the pumping ring to the internal and external plates.

[0025] In specific embodiments of the method, the pumping ring includes only two alignment holes, and the internal plate and the external plate each include only two corresponding alignment holes.

[0026] In specific embodiments of the method, the alignment holes of the internal plate do not extend through the internal plate in the axial direction, and the alignment holes of the external plate do not extend through the external plate in the axial direction.

[0027] In specific embodiments of the method, the internal plate includes an inwardly-facing face surface and an opposite, outwardly-facing face surface, the outwardly-facing face surface of the internal plate being adjacent to the pumping ring. The external plate includes an inwardly-facing face surface and an opposite, outwardly-facing face surface, the inwardly-facing face surface of the external plate being adjacent to the pumping ring. The alignment holes of the internal plate are formed in the outwardly-facing face surface of the internal plate, and the alignment holes of the external plate are formed in the inwardly-facing face surface of the external plate.

[0028] In specific embodiments of the method, the alignment pins are coiled pins.

DESCRIPTION OF THE DRAWINGS

[0029] Various advantages and aspects of this disclosure may be understood in view of the following detailed description when considered in connection with the accompanying drawings, wherein:

[0030] Figure 1 is a schematic view of an integrated drive module including a positive displacement fluid pump in accordance with embodiments of the disclosure;

[0031] Figure 2 is a perspective view of a positive displacement fluid pump in accordance with some embodiments of the disclosure, with certain components of the pump shown partially transparent to reveal internal features;

[0032] Figure 3 is a sectional view of the positive displacement fluid pump of Figure 2;

[0033] Figure 4 is another sectional view of the positive displacement fluid pump of Figure 2;

[0034] Figure 5 is a perspective view of a pumping section of the positive displacement fluid pump with certain components of the pumping section shown partially transparent to reveal internal features;

[0035] Figure 6 is another perspective view of a pumping section of the positive displacement fluid pump with certain components of the pumping section shown partially transparent to reveal internal features;

[0036] Figure 7 is a cross-sectional view of the positive displacement fluid pump taken along the line 7-7 in Figure 2;

[0037] Figure 8 is a cross-sectional view of the positive displacement fluid pump taken along the line 8-8 in Figure 2; and

[0038] Figure 9 is a cross-sectional view of the positive displacement fluid pump taken along the line 9-9 in Figure 2.

DETAILED DESCRIPTION OF THE INVENTION

[0039] A positive displacement fluid pump is provided. Referring to Figures 1-9, wherein like numerals indicate corresponding parts throughout the several views, the positive displacement fluid pump (also referred to as the fluid pump herein) is illustrated and generally designated as an oil pump 10 for pumping liquid oil from a reservoir 12 to an integrated drive module (IDM) of an electric or hybrid vehicle to cool and lubricate the internal working mechanisms of the IDM including the IDM drive motor 13 and gear box 14. While the fluid pump is illustrated as oil pump 10 for an IDM, it should be understood that the invention is not limited to an oil pump, but could also be applied to fluid pumps for pumping fluids other than oil, such as but not limited to fuel, and in other applications other than for an IDM. The oil pump 10 provides for improved modularity and flexibility. Particularly, the oil pump 10 has a pumping section that includes a pumping ring that is separate from the plates of the pumping section. Separation of the plates from the pumping ring allows for easier adjustment and control of the pump displacement and eccentricity. Separation of the plates from the pumping ring also allows for additional ports and passages to be molded in the plates. Certain features of the oil pump 10 are functional, but can be implemented in different aesthetic configurations.

[0040] With reference to Figures 2-4, the oil pump 10 generally includes a motor section 16, and a pumping section 18 adjacent to motor section 16. A housing 20 of the oil pump 10 includes an internal motor cavity 22 in which the motor section 16 is retained. Low pressure oil enters oil pump 10 at pumping section 18, a portion of which is rotated by the motor section 16 as will be described in more detail below, and is pumped out of the pumping section 18 at a higher pressure than the inlet pressure.

[0041] Motor section 16 includes an electric motor 24 which is disposed within the motor cavity 22 of the housing 20. The electric motor 24 may be, for example, an electronically commutated (EC) brushless motor. Electric motor 24 includes a shaft 26 extending therefrom into the pumping section 18. A permanent magnet rotor 28 is attached at an opposite end of the shaft 26, and the rotor 28 is surrounded by a stator 30. Shaft 26 rotates about a first axis 32 when an electric current is applied to the stator 30 of the electric motor 24. The electric motor 24 is connected to a supply of power and an external controller by wires 34 connected to a wire harness 36. Electric motors and their operation are well known, consequently, electric motor 24 will not be discussed further herein.

[0042] With continued reference to Figures 2-4 and now with additional reference to Figures 4-9, the pumping section 18 forms a head that generally closes the motor cavity 22 and includes an internal plate 38, an external plate 40, a pumping ring 42 sandwiched between the internal plate 38 and the external plate 40, and a pumping arrangement 44 rotatably coupled to the drive shaft 26. By way of non-limiting example, the pumping arrangement 44 is shown as a gerotor. The pumping arrangement 44 thus includes a rotating drive element that is illustrated as an inner gear rotor 46. The pumping arrangement 44 is also illustrated as including an outer gear rotor 48 that is a rotating driven element. Collectively, inner gear rotor 46 and outer gear rotor 48 will be referred to herein as pumping arrangement 44. External plate 40 is disposed at an end of pumping section 18 that is distal from motor section 16 while internal plate 38 is disposed at an end of pumping section 18 that is proximal to the motor section 16 and the internal cavity 22 of the housing 20. The drive shaft 26 extends through a central bore 50 in the internal plate 38 and is connected to the pumping arrangement 44. Pumping arrangement 44 is rotatably disposed within a circular gear rotor bore 52 formed within the pumping ring 42, and the pumping arrangement 44 is located axially between the internal plate 38 and the external plate 40. Gear rotor bore 52 is centered about a second axis (not shown) which is parallel and laterally offset relative to drive shaft axis 32. In this manner, the pumping ring 42 is in the form of an eccentric ring. Gear rotor bore 52 is diametrically sized to allow the outer gear rotor 48 to rotate freely therein while substantially preventing radial movement of outer gear rotor 48. The inner gear rotor 46 includes a plurality of external teeth 54 on the outer perimeter thereof which engage complementary internal tooth recesses 56 of the outer gear rotor 48, thereby defining a plurality of variable volume pumping chambers 58 between the inner gear rotor 46 and the outer gear rotor 48 that increase and decrease in size to suck and pressurize fluid such as the oil pumped by the pump 10. It should be noted that only representative external teeth 54, internal tooth recesses 56 and pumping chambers 58 have been labeled in the drawings. As shown, the inner gear rotor 46 has seven external teeth 54 while the outer gear rotor 48 has eight internal tooth recesses 56; however, it should be understood that inner gear rotor 46 may have any number n external teeth 54 while outer gear rotor 48 has n+1 internal tooth recesses 56.

[0043] Since the eccentric pumping ring 42 is separate from both the internal plate 38 and the external plate 40, it is possible to construct the pumping ring 42 from a material that has a similar coefficient of thermal expansion (CTE) as the pumping arrangement 44 (i.e., inner and outer gear rotors 46, 48). This provides for reduced axial clearance variation between the pumping ring 42 and the pumping arrangement 44 within the operating temperature range of the oil pump 10, which is typically in the range of -40°C and 150°C. In certain embodiments, the pumping ring 42 and the pumping arrangement 44 may be constructed of the same or similar material. For example, the gears 46, 48 of the pumping arrangement 44 may be made of powdered metal or plastic (e.g., phenolic polymer or polyetheretherketone (PEEK)), while the eccentric pumping ring 42 may be made of aluminum or a phenolic polymer. In contrast, conventionally the pumping ring is integrated into one of the internal or external plates, which are made of cast aluminum, and the gear rotors are made of a material such as nickel steel powdered metal, which has half the CTE of aluminum.

[0044] The external plate 40 is disposed at the outer end of the oil pump 10 and includes outwardly-facing face surface 60 on the outside of the pump 10 and an inwardly-facing face surface 61 adjacent the pumping ring 42. A low-pressure inlet 62 and a high-pressure outlet 63 are formed in the outwardly-facing face surface 60 of the external plate 40. The inlet 62 and outlet 63 may include a conduit that extends outwardly beyond the outwardly-facing face surface 60 of the external plate 40. The inlet 62 is connected to and in fluid communication with (fluidly connected to) a suction port 64 formed in the inwardly-facing face surface 61 of the external plate 40. The outlet 63 is connected to and in fluid communication with a delivery port 65 formed in the inwardly-facing face surface 61 of the external plate 40. The inlet 62 and outlet 63 both face and extend in the axial direction (direction of drive shaft axis 32). However, it should be understood that the outlet could instead face in the radial direction. The inlet 62 of the external plate 40 is aligned with a portion of gear rotor bore 52 within which the geometry between external teeth 54 and internal tooth recesses 56 create pumping chambers 58 of relatively large size while the outlet 63 of the external plate 40 is aligned with a portion of gear rotor bore 52 within which the geometry between external teeth 54 and internal tooth recesses 56 create pumping chambers 58 of relatively small size. When the electric motor 24 is rotated by application of an electric current, inner gear rotor 46 rotates about drive shaft axis 32. By virtue of external teeth 54 engaging internal tooth recesses 56, rotation of inner gear rotor 46 causes outer gear rotor 48 to rotate about the second axis. In this way, the volume of pumping chambers 58 decreases as each pumping chamber 58 rotates from being in communication with the inlet 62 (and suction port 64) to being in communication with the outlet 63 (and delivery port 65), thereby causing oil to be pressurized and pumped from the inlet 62 to the outlet 63.

[0045] The internal plate 38 is adjacent the electric motor 24 and includes an inwardly-facing face surface 66 that faces the internal cavity 22, an opposite outwardly-facing face surface 67 that is adjacent the pumping ring 42. The pumping ring 42 includes an inwardly-facing face surface 68 adjacent the outwardly-facing face surface 67 of the internal plate 38, and an opposite, outwardly-facing face surface 69 adjacent the inwardly-facing face surface 61 of the external plate 40. A complementary suction port 70 is formed in the outwardly-facing face surface 67 of the internal plate 38. Similarly, a complementary delivery port 71 is also formed in the outwardly-facing face surface 67 of the internal plate 38. The complementary delivery port 71 is in fluid communication with the pumping chambers 58 of the pumping arrangement 44 that are intermediate the delivery port 65 and the complementary delivery port 71. The complementary suction port 70 is in fluid communication with the pumping chambers 58 of the pumping arrangement 44 that are intermediate the suction port 64 and the complementary suction port 70. The complementary suction port 70 is also connected to and in fluid communication with the inlet 62 via a suction passage 72 that extends between the inlet 62 and the complementary suction port 70. More specifically, the suction passage 72 includes a first portion 73 that extends from the inlet 62 to the inwardly-facing face surface 61 of the external plate 40, a second portion 74 continuous with the first portion 73 that extends through the pumping ring 42 from the outwardly-facing face surface 69 to the inwardly-facing face surface 68, and a third portion 75 continuous with the second portion 74. The third portion 75 is formed in the outwardly-facing face surface 67 of the internal plate 38 and connects the second portion 74 of the suction passage 72 to the complementary suction port 70. The suction passage 72 provides for the suction of fluid from the inlet 62 to the complementary suction port 70. The suction port 64 and complementary suction port 70 are thereby dual suction ports for the pumping section 18.

[0046] In operation, electricity is applied to the electric motor 24 which causes pumping arrangement 44 to rotate via rotation of the drive shaft 26, thereby drawing oil in through inlet

62 into the suction port 64 as well as the complementary suction port 70 via the suction passage 72, and subsequently to the pumping chambers 58 at an initial pressure which may be by way of non-limiting example only, 0 kPa. Rotation of pumping arrangement 44 further causes the volume of pumping chambers 58 to decrease as each pumping chamber 58 rotates from being in communication with suction port 64 and complementary suction port 70 to being in communication with the delivery port 65 and complementary delivery port 71, thereby causing oil to be pressurized to a final pressure which is much greater than the initial pressure, and pumped from the delivery port 65 to the outlet 63.

[0047] The oil pump 10 also has an alignment/assembly feature for aligning and assembling the plates 38, 40 and pumping ring 42 of the pumping section 18. The alignment/assembly feature allows for the facile assembly and interchange of the component plates and pumping ring of the pumping section 18 to quickly and easily adjust the eccentricity and/or capacity of the pumping section 18. The alignment/assembly feature includes a set of alignment holes in the pumping ring 42 and internal and external plates 38, 40, as well as alignment pins that are inserted into the set of alignment holes. Particularly, the pumping ring 42 includes at least two alignment holes extending in an axial direction through the pumping ring 42 from the outwardly-facing face surface 69 to the inwardly-facing face surface 68, the internal plate 38 includes a corresponding number of axially-extending alignment holes, and the external plate 40 likewise includes a corresponding number of axially-extending alignment holes. While the oil pump 10 may include more than two sets of alignment holes, in the embodiment shown in the drawings the oil pump 10 has only two sets of alignment holes. More specifically, in the illustrated embodiment the alignment holes of the pumping ring 42 include a primary alignment hole 76 and a secondary alignment hole 77. The primary alignment hole 76 and the secondary alignment hole 77 of the pumping ring 42 are both cylindrically shaped through-holes and are circular in cross-sectional shape. As such, the primary and secondary alignment holes 76, 77 of the pumping ring 42 extend all the way through the pumping ring in the axial direction. The alignment holes of the internal plate 38 include a primary alignment hole 78 and a secondary alignment hole 79 that correspond to the primary and secondary alignment holes 76, 77 of the pumping ring 42, respectively. The alignment holes of the external plate 40 include a primary alignment hole 80 and a secondary alignment hole 81 that also correspond to the primary and secondary alignment holes 76, 77 of the pumping ring 42, respectively. The primary alignment hole 78 of the internal plate 38 and the primary alignment hole 80 of the external plate 40 are each cylindrically-shaped bores and are circular in cross-sectional shape. In contrast, the secondary alignment hole 79 of the internal plate 38 and the secondary alignment hole 81 of the external plate 40 are bores that have an elongated cross-sectional shape, such as an oval (e.g., long oval) or stadium shape (i.e., rounded semi-circular ends and slightly elongated center). The primary alignment holes 78, 80 and the secondary alignment holes 79, 81 of the internal and external plates 38, 40 do not extend all the way through the internal and external plates 38, 40, respectively. Instead, the primary and secondary alignment holes 78, 79 of the internal plate 38 are bores formed in the outwardly-facing face surface 67 of the internal plate 38, and the primary and secondary alignment holes 80, 81 of the external plate 40 are bores formed in the inwardly-facing face surface 61 of the external plate 40.

[0048] An alignment pin 82 is provided for each of the alignment holes 76, 77 of the pumping ring 42. More particularly, one alignment pin 82 corresponds to the set of the primary alignment holes 78, 76, 80 in the internal plate 38, the pumping ring 42, and the external plate 40, while another alignment pin 82 corresponds to the set of the secondary alignment holes 79, 77, 81 in the internal plate 38, the pumping ring 42, and the external plate 40. Hence, in the illustrated embodiment there are two alignment pins 82. The alignment pins 82 may be cylindrical in shape. The alignment pins also may be solid. However, in certain embodiments, as illustrated the alignment pins 82 are coiled pins (i.e., elongated coiled springs) formed by rolling a planar sheet of metal into a tubular coil. One such coiled pin is a light duty coiled pin described in ASME B18.8.2, which is incorporated herein by reference in its entirety. The coiled pins allow for generous tolerance when press-fit into the alignment holes.

[0049] To align the plates 38, 40 and the pumping ring 42, an alignment pin 82 is inserted into the primary alignment hole 78 of the internal plate 38, and an alignment pin 82 is inserted into the secondary alignment hole 79 of the internal plate 38 such that the alignment pins 82 extend into the two alignment holes 78, 79. The pumping ring 42 may then be installed adjacent the internal plate 38 by inserting the primary and secondary alignment holes 76, 77 of the pumping ring 42 onto the two alignment pins 82 so that the alignment pins become positioned in the primary and secondary alignment holes 76, 77 of the pumping ring 42. In this arrangement, the inwardly-facing face surface 68 of the pumping ring 42 is positioned to contact the outwardly-facing face surface 67 of the internal plate 38. Next, the external plate 40 is installed adjacent the pumping ring 42 by inserting the primary and secondary alignment holes 79, 80 of the external plate 40 onto the two alignment pins 82 so that the alignment pins are inserted and extend into the two alignment holes 79, 80. The inwardly-facing face surface 61 of the external plate 40 is positioned to contact the outwardly-facing face surface of the pumping ring 42.

[0050] In this disposition, the primary alignment hole 76 of the pumping ring 42 is aligned with the primary alignment holes 78, 80 of the internal and external plates 38, 40, respectively, and likewise the secondary alignment hole 77 of the pumping ring 42 is aligned with the secondary alignment holes 79, 81 of the internal and external plates 38, 40. The alignment holes are formed in each of the internal plate 38, external plate 40, and pumping ring 42 in an arrangement such that when aligned, the suction port 64 and delivery port 65 in the external plate 40 are aligned with the complementary suction port 70 and complementary delivery port 71, respectively, and likewise the first portion 73 of the suction passage 72 formed in the external plate 40 is aligned with the second portion 74 of the suction passage 72 formed in the pumping ring 42 and the third portion 75 of the suction passage 72 formed in the internal plate 38. Also, the alignment pins 82 maintain this relative disposition of the pumping ring 42 to the internal and external plates 38, 40. Particularly, the coiled alignment pin 82 inserted into the circular shaped primary alignment holes 76, 78, 80 restricts relative movement of the plates 38, 40 and pumping ring 42, while the oval shaped secondary alignment holes 79, 81 of the internal and external plates 38, 40, respectively, prevent an over-constrained condition by allowing some relative movement of the pin 82 and the alignment holes 79, 81. At the same time, the spring-like coiled structure of the alignment pins 82 allows for generous tolerances for the shape of alignment holes 76, 77, 78, 79, 80, 81 when the pins 82 are press-fit into the alignment holes.

[0051] The internal plate 38 may also be mounted to the housing 20 by a plurality of fasteners 83, such as two bolts or similar, that extend through the internal plate 38 and into the sidewall of the housing 20. In this arrangement, the internal plate 38 may be first bolted to the housing 20 by the fasteners 83, and then the pumping ring 42 and external plate 40 may be installed onto the pumping section 18 using the alignment pins 82 as described above. Further, the internal plate 38, the pumping ring 42, and the external plate 40 may be secured together by a plurality of fasteners 84, such as four bolts or similar, that extend through the plates 38, 40 and pumping ring 42, and also beyond the internal plate 38 and into the sidewall of the housing 20. These fasteners 84 may be installed after the alignment of the pumping ring 42 and external plate 40 with the alignment pins 82 as described above.

[0052] While the oil pump 10 has been described by example as being a gerotor-type fluid pump, the oil pump may be another type of positive displacement pump such as an impeller-type pump or a vane-type pump, such that the rotating element of the pumping arrangement may take other forms which may include, by way of non-limiting example, an impeller.

[0053] It is to be understood that the appended claims are not limited to express and particular compounds, compositions, or methods described in the detailed description, which may vary between particular embodiments which fall within the scope of the appended claims. With respect to any Markush groups relied upon herein for describing particular features or aspects of various embodiments, different, special, and/or unexpected results may be obtained from each member of the respective Markush group independent from all other Markush members. Each member of a Markush group may be relied upon individually and or in combination and provides adequate support for specific embodiments within the scope of the appended claims.

[0054] Further, any ranges and subranges relied upon in describing various embodiments of the present invention independently and collectively fall within the scope of the appended claims, and are understood to describe and contemplate all ranges including whole and/or fractional values therein, even if such values are not expressly written herein. One of skill in the art readily recognizes that the enumerated ranges and subranges sufficiently describe and enable various embodiments of the present invention, and such ranges and subranges may be further delineated into relevant halves, thirds, quarters, fifths, and so on. As just one example, a range "of from 0.1 to 0.9" may be further delineated into a lower third, i.e., from 0.1 to 0.3, a middle third, i.e., from 0.4 to 0.6, and an upper third, i.e., from 0.7 to 0.9, which individually and collectively are within the scope of the appended claims, and may be relied upon individually and/or collectively and provide adequate support for specific embodiments within the scope of the appended claims. In addition, with respect to the language which defines or modifies a range, such as "at least," "greater than," "less than," "no more than," and the like, it is to be understood that such language includes subranges and/or an upper or lower limit. As another example, a range of "at least 10" inherently includes a subrange of from at least 10 to 35, a subrange of from at least 10 to 25, a subrange of from 25 to 35, and so on, and each subrange may be relied upon individually and/or collectively and provides adequate support for specific embodiments within the scope of the appended claims. Finally, an individual number within a disclosed range may be relied upon and provides adequate support for specific embodiments within the scope of the appended claims. For example, a range "of from 1 to 9" includes various individual integers, such as 3, as well as individual numbers including a decimal point (or fraction), such as 4.1, which may be relied upon and provide adequate support for specific embodiments within the scope of the appended claims.

[0055] The above description is that of current embodiments of the invention. Various alterations and changes can be made without departing from the spirit and broader aspects of the invention as defined in the appended claims, which are to be interpreted in accordance with the principles of patent law including the doctrine of equivalents. This disclosure is presented for illustrative purposes and should not be interpreted as an exhaustive description of all embodiments of the invention or to limit the scope of the claims to the specific elements illustrated or described in connection with these embodiments. For example, and without limitation, any individual element(s) of the described invention may be replaced by alternative elements that provide substantially similar functionality or otherwise provide adequate operation. This includes, for example, presently known alternative elements, such as those that might be currently known to one skilled in the art, and alternative elements that may be developed in the future, such as those that one skilled in the art might, upon development, recognize as an alternative. Further, the disclosed embodiments include a plurality of features that are described in concert and that might cooperatively provide a collection of benefits. The present invention is not limited to only those embodiments that include all of these features or that provide all of the stated benefits, except to the extent otherwise expressly set forth in the issued claims. Any reference to claim elements by ordinal terms, for example “first,” “second,” and “third,” are used for clarity, and are not to be construed as limiting the order in which the claim elements appear. Any reference to claim elements in the singular, for example, using the articles “a,” “an,” “the” or “said,” is not to be construed as limiting the element to the singular.

CLAIMS

1. A positive displacement fluid pump comprising:

a motor (24) having a drive shaft (26) that rotates about an axis (32) extending in an axial direction;

a pumping portion (18) driven by the motor;

the pumping portion (18) including:

an internal plate (38) including a central bore (50) through which the drive shaft extends;

an external plate (40) including a fluid inlet (62) and a fluid outlet (63);

a pumping ring (42) sandwiched between the internal and external plates; and

a pumping arrangement (44) rotatably coupled to the drive shaft such that rotation of the pumping arrangement by the drive shaft causes fluid to be pumped from the fluid inlet to the fluid outlet, the pumping arrangement being located within the pumping ring and axially between the internal plate and the external plate;

the pumping ring including at least two alignment holes (76, 77) extending through the pumping ring in the axial direction;

the internal plate and the external plate each including a corresponding number of axially-extending alignment holes (78, 79, 80, 81), respectively; and

an alignment pin (82) for each of the alignment holes (76, 77) of the pumping ring;

wherein the alignment holes (76, 77) of the pumping ring are aligned with the alignment holes (78, 79) of the internal plate and the alignment holes (80, 81) of the external plate, and the alignment pins (82) are positioned in the alignment holes of the pumping ring and extend into the alignment holes of the internal and external plates to maintain the relative disposition of the pumping ring to the internal and external plates.

2. The positive displacement fluid pump of claim 1, wherein the alignment holes of the pumping ring include a primary alignment hole (76) and a secondary alignment hole (77).

3. The positive displacement fluid pump of claim 2, wherein the primary alignment hole (76) and the secondary alignment hole (77) of the pumping ring are both circular in cross-sectional shape.

4. The positive displacement fluid pump of claim 2 or 3, wherein the alignment holes of the internal plate and the alignment holes of the external plate each include a primary alignment hole (78, 80) and a secondary alignment hole (79, 81) corresponding to the primary and secondary alignment holes (76, 77) of the pumping ring, respectively.

5. The positive displacement fluid pump of claim 4, wherein the primary alignment hole (78) of the internal plate and the primary alignment hole (80) of the external plate are each circular in cross-sectional shape.

6. The positive displacement fluid pump of claim 4 or 5, wherein the secondary alignment hole (79) of the internal plate and the secondary alignment hole (81) of the external plate have an elongated cross-sectional shape.

7. The positive displacement fluid pump of claim 6, wherein the secondary alignment hole (79) of the internal plate and the secondary alignment hole (81) of the external plate are oval in cross-sectional shape.

8. The positive displacement fluid pump of any one of claims 1-7, wherein the pumping ring (42) includes only two alignment holes (76, 77), and the internal plate (38) and the external plate (40) each include only two corresponding alignment holes (78, 79, 80, 81).

9. The positive displacement fluid pump of any one of claims 1-8, wherein the alignment holes (78, 79) of the internal plate (38) do not extend through the internal plate in the axial direction, and the alignment holes (80, 81) of the external plate (40) do not extend through the external plate in the axial direction.

10. The positive displacement fluid pump of any one of claims 1-9, wherein the alignment pins (82) are coiled pins.

11. The positive displacement fluid pump of any one of claims 1-10, wherein the internal plate (38) includes an inwardly-facing face surface (66) and an opposite, outwardly-facing face surface (67), the outwardly-facing face surface of the internal plate being adjacent to the pumping ring (42); and

the external plate (40) includes an inwardly-facing face surface (61) and an opposite, outwardly-facing face surface (60), the inwardly-facing face surface of the external plate being adjacent to the pumping ring (42).

12. The positive displacement fluid pump of claim 11, wherein the alignment holes (78, 79) of the internal plate (38) are formed in the outwardly-facing face surface (67) of the internal plate, and the alignment holes (80, 81) of the external plate (40) are formed in the inwardly-facing face surface (61) of the external plate.

13. The positive displacement fluid pump of claim 11 or 12, wherein the external plate (40) includes a suction port (64) formed in the inwardly-facing face surface (61) of the external plate, the suction port of the external plate being connected to and in fluid communication with the fluid inlet (62).

14. The positive displacement fluid pump of claim 13, wherein the internal plate (38) includes a complementary suction port (70) formed in the outwardly-facing face surface (67) of the internal plate, the complementary suction port being in fluid communication with the fluid inlet (62).

15. The positive displacement fluid pump of claim 14, wherein the complementary suction port (70) of the internal plate (38) is connected to the fluid inlet (62) by a suction passage (72) that extends through the pumping ring (42).

16. The positive displacement fluid pump of any one of claims 11-15, wherein the external plate (40) includes a delivery port (65) formed in the inwardly-facing face surface (61) of the external plate, the delivery port of the external plate being connected to and in fluid communication with the fluid outlet (63).

17. The positive displacement fluid pump of claim 16, wherein the internal plate (38) includes a complementary delivery port (71) formed in the outwardly-facing face surface (67) of the internal plate.

18. The positive displacement fluid pump of any one of claims 1-17, wherein the pumping arrangement (44) includes a rotating element that is an inner gear rotor (46) mounted on the drive shaft (26), and the pumping arrangement further includes an outer gear rotor (48) engaged and driven by the inner gear rotor, the inner gear rotor and outer gear rotor together defining a plurality of variable volume pumping chambers (58) in fluid communication with the inlet (62) and the outlet (63); and

the pumping ring (42) is an eccentric ring having a circular gear rotor bore (52) that is offset from the axis (32) of the drive shaft (26).

19. The positive displacement fluid pump of claim 18, wherein the eccentric ring (42) and the inner and outer gear rotors (46, 48) of the pumping arrangement (44) are made of materials having a similar coefficient of thermal expansion (CTE).

20. A method of aligning components of a positive displacement fluid pump, the method comprising the steps of:

providing a motor (24) having a drive shaft (26) that rotates about an axis (32) extending in an axial direction;

providing a pumping portion (18) including:

an internal plate (38) including a central bore (50) through which the drive shaft extends;

an external plate (40) including a fluid inlet (62) and a fluid outlet (63);

a pumping ring (42) sandwiched between the internal and external plates; and

a pumping arrangement (44) rotatably coupled to the drive shaft, the pumping arrangement being located within the pumping ring and axially between the internal plate and the external plate;

forming at least two alignment holes (76, 77) that extend through the pumping ring in the axial direction;

forming a corresponding number of axially-extending alignment holes (78, 79, 80, 81) in each of the internal plate and the external plate;

providing an alignment pin (82) for each of the alignment holes (76, 77) of the pumping ring;

positioning the alignment pins in the alignment holes of the pumping ring; and

aligning the alignment holes (76, 77) of the pumping ring with the alignment holes (78, 79) of the internal plate and the alignment holes (80, 81) of the external plate, whereby the alignment pins also extend into the alignment holes of the internal and external plates to maintain the relative disposition of the pumping ring to the internal and external plates.

21. The method of claim 20, wherein the pumping ring (42) includes only two alignment holes (76, 77), and the internal plate (38) and the external plate (40) each include only two corresponding alignment holes (78, 79, 80, 81).

22. The method of claim 20 or 21, wherein the alignment holes (78, 79) of the internal plate (38) do not extend through the internal plate in the axial direction, and the alignment holes (80, 81) of the external plate (40) do not extend through the external plate in the axial direction.

23. The method of any one of claims 20-22, wherein:

the internal plate (38) includes an inwardly-facing face surface (66) and an opposite, outwardly-facing face surface (67), the outwardly-facing face surface of the internal plate being adjacent to the pumping ring (42);

the external plate (40) includes an inwardly-facing face surface (61) and an opposite, outwardly-facing face surface (60), the inwardly-facing face surface of the external plate being adjacent to the pumping ring (42); and

the alignment holes (78, 79) of the internal plate (38) are formed in the outwardly-facing face surface (67) of the internal plate, and the alignment holes (80, 81) of the external plate (40) are formed in the inwardly-facing face surface (61) of the external plate.

24. The method of any one of claims 20-23, wherein the alignment pins (82) are coiled pins.

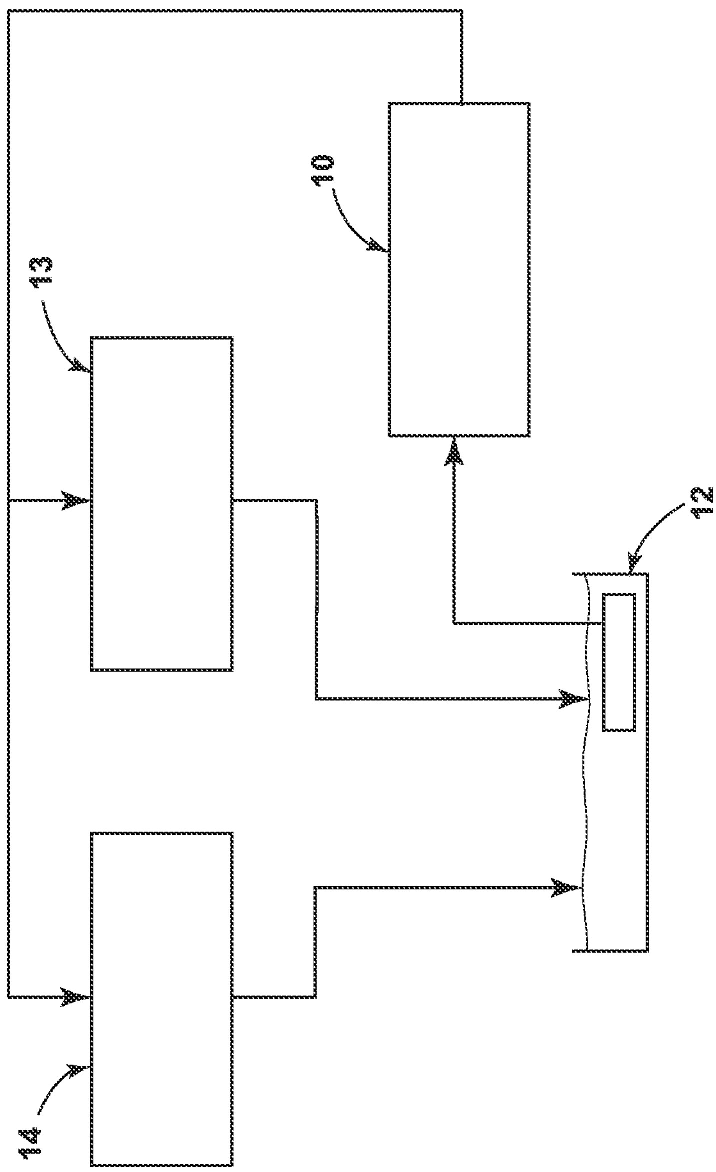

FIG. 1

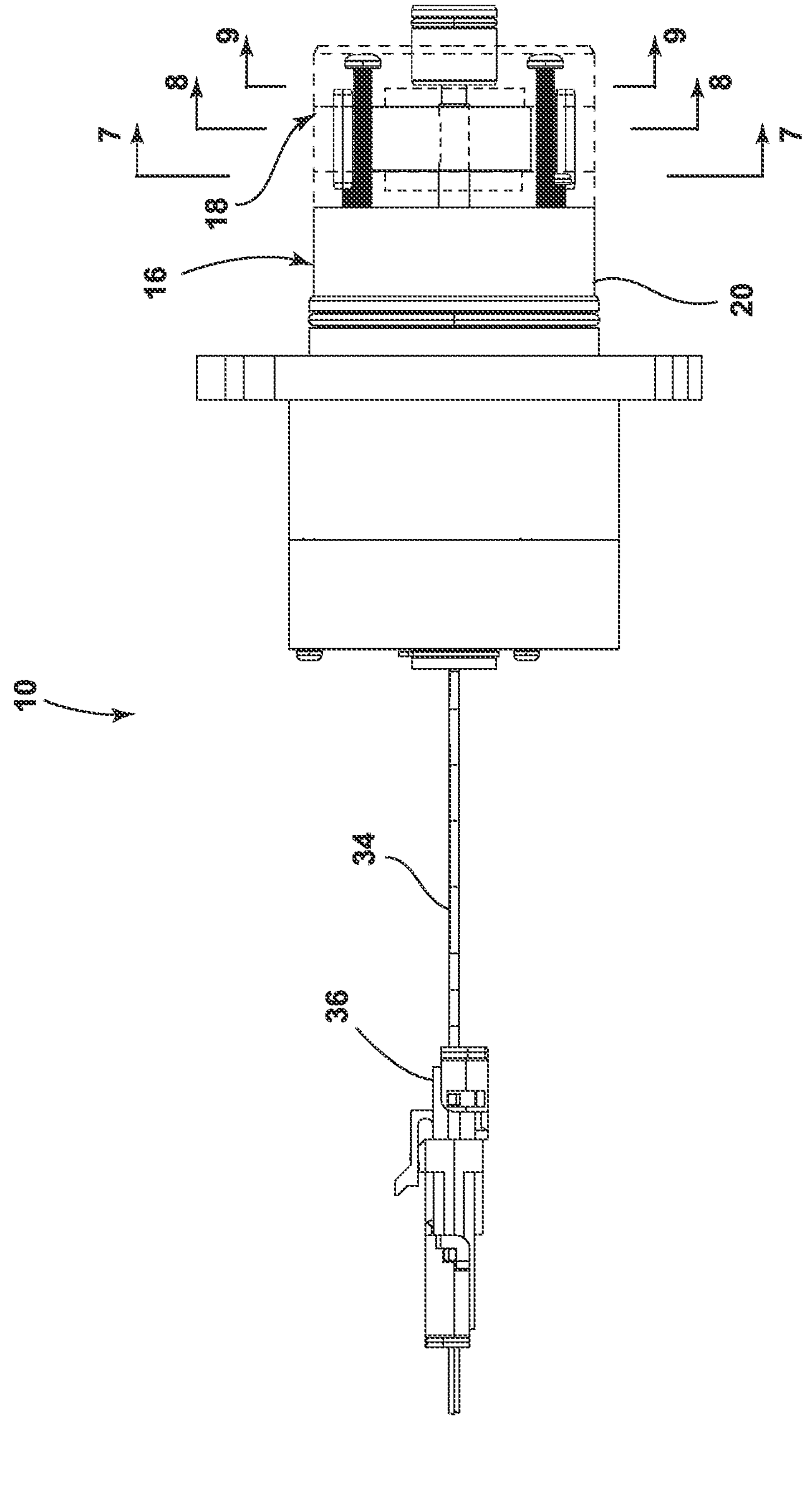

FIG. 2

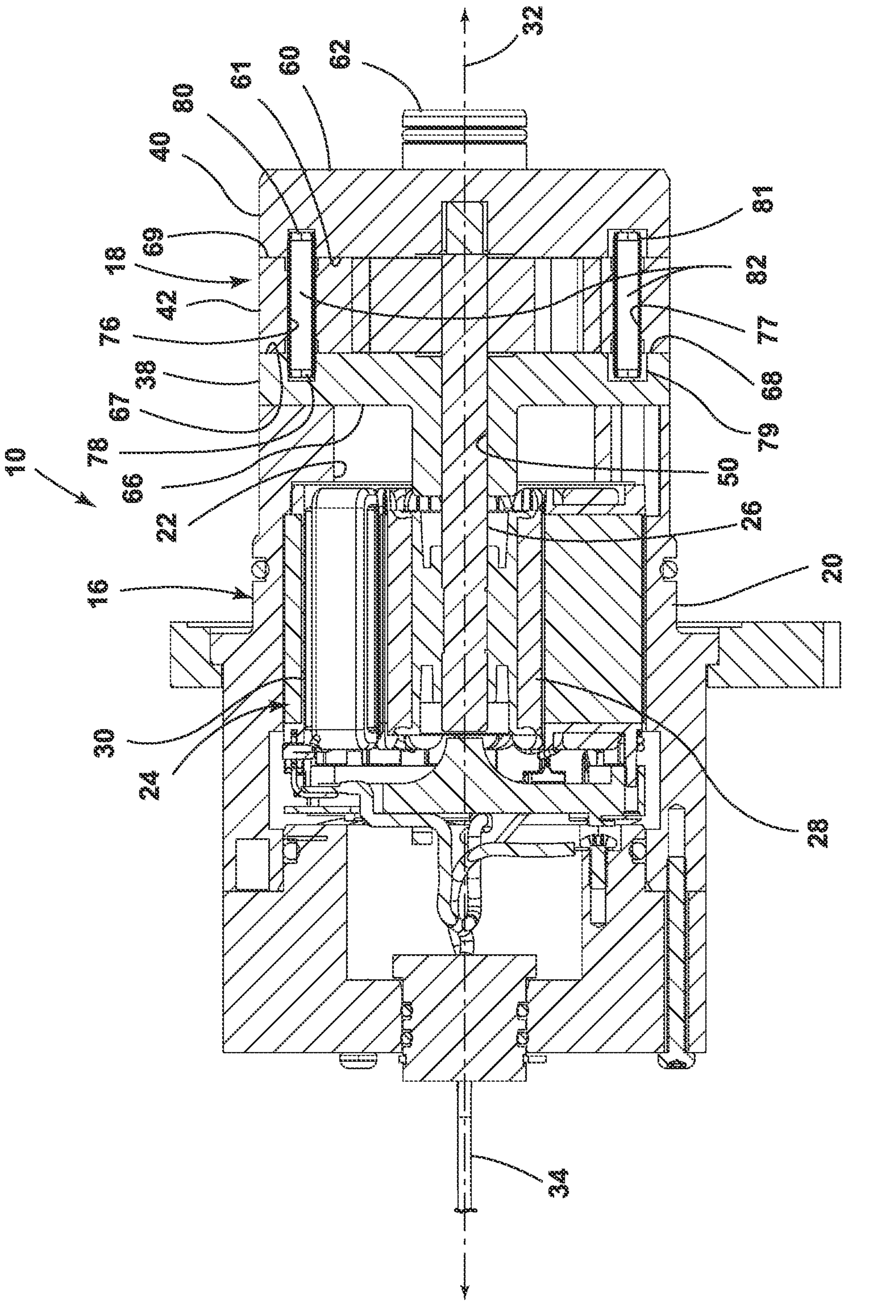
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FIG. 3

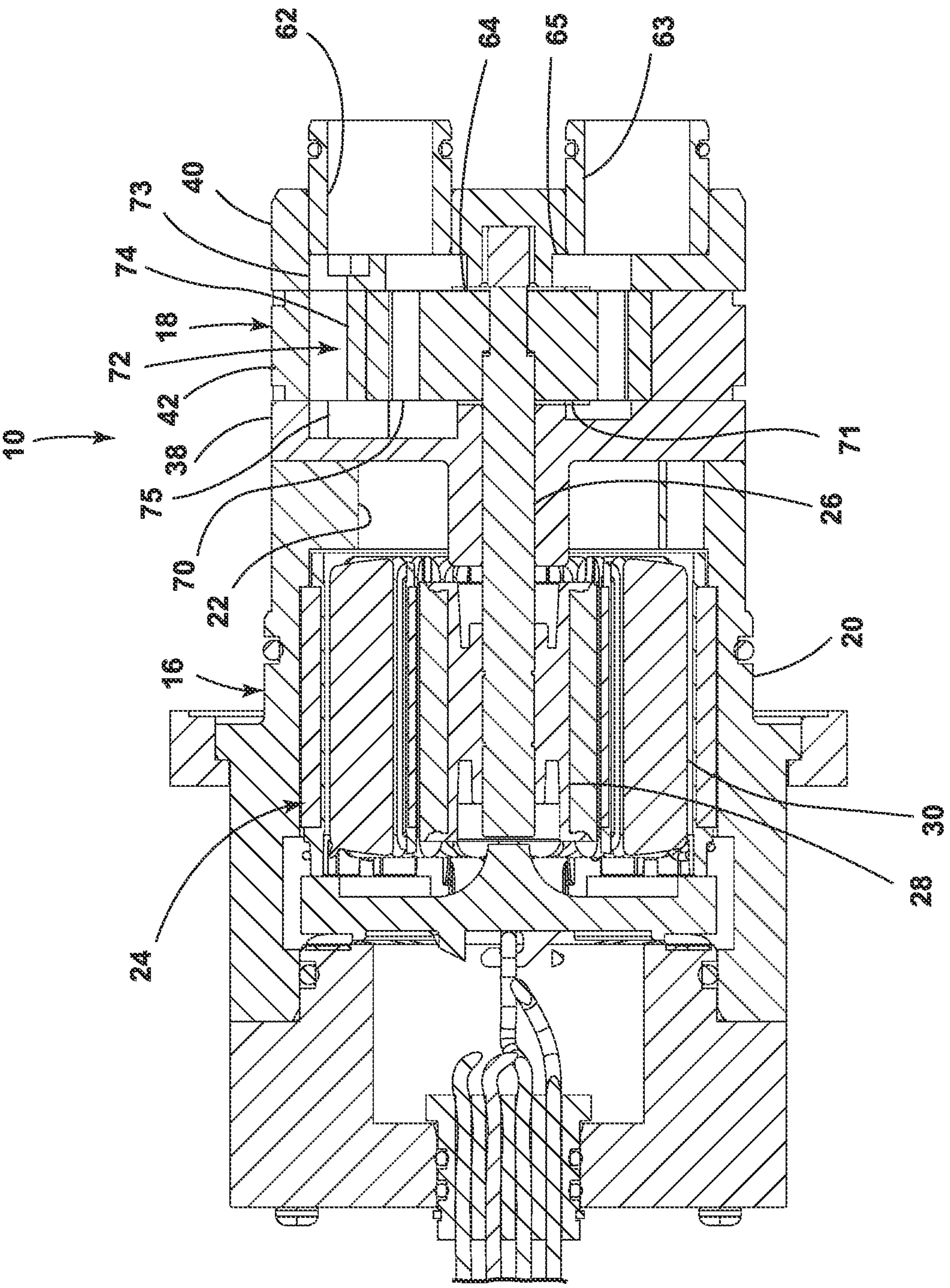

FIG. 4

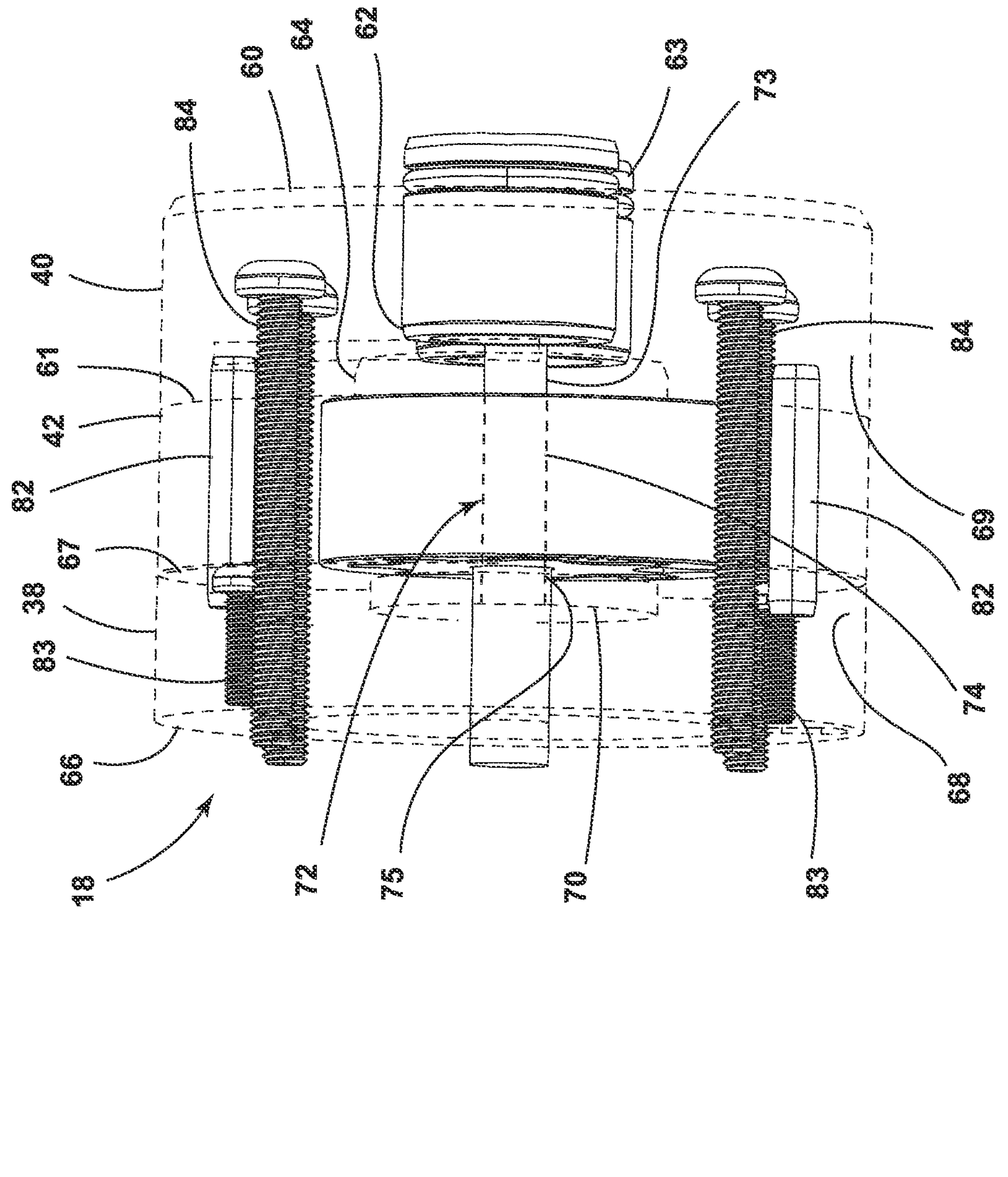

FIG. 5

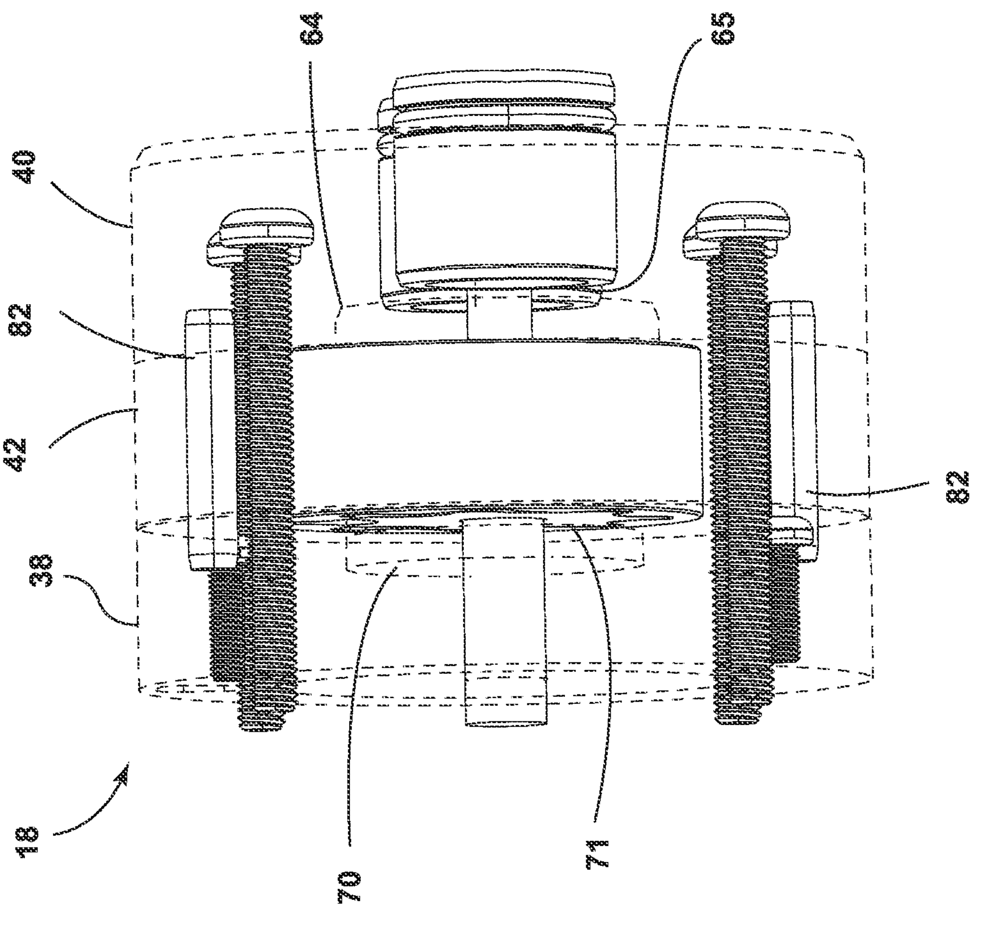

FIG. 6

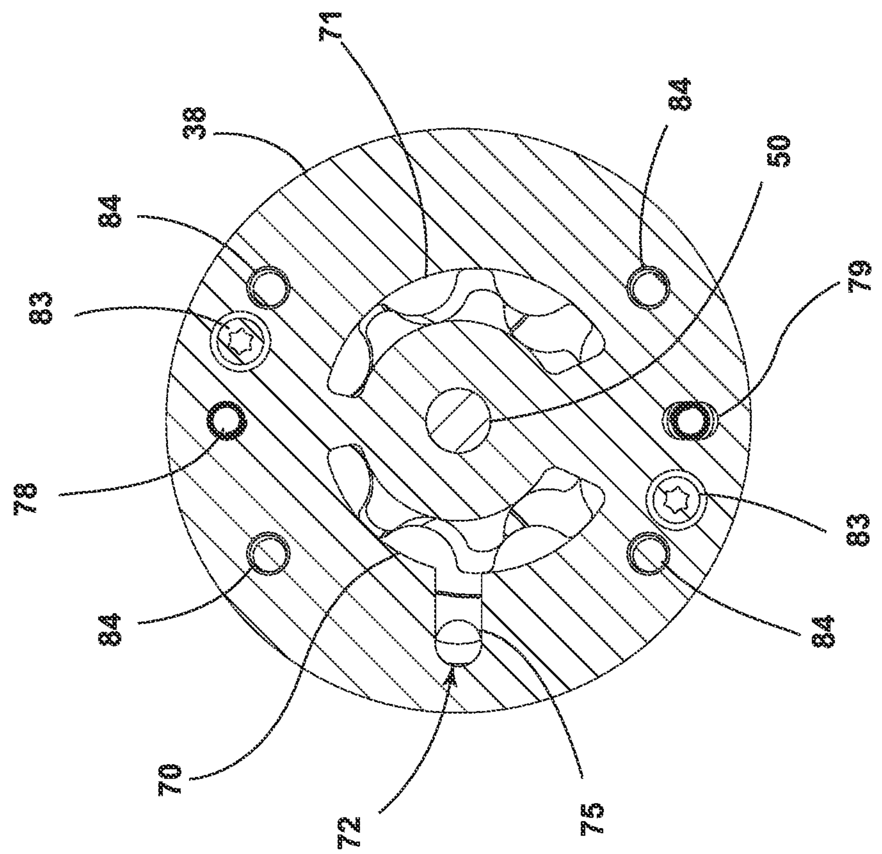

FIG. 7

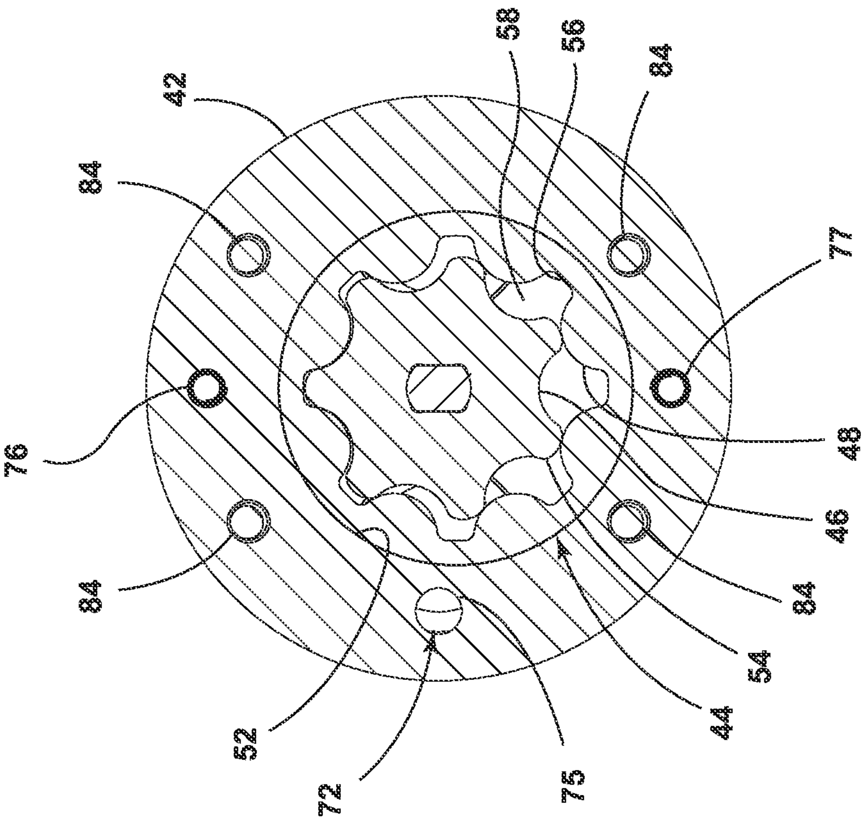

FIG. 8

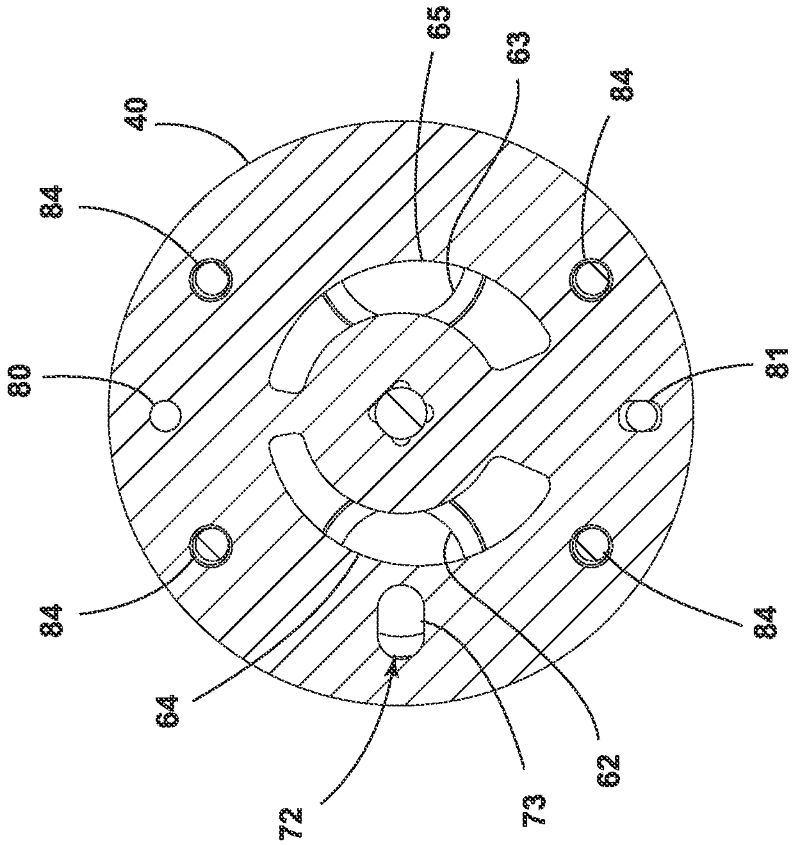

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/020742

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04C2/10 F04C15/06 F04D29/60
ADD.

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)
F04C F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 July 2024	30/07/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Durante, Andrea

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No
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