This invention relates to a multiple stage positive displacement pump or motor.

An important object of this invention is to provide a multiple stage positive displacement pump or motor in which the successive pump stages operate like parts to minimize the number of different parts necessary to manufacture the pump.

Another object of this invention is to provide a multiple stage pump or motor in which the successive stages are disposed axially along a shaft and wherein the successive stages are arranged so that the radial pressure unbalance on adjacent pump stages counteract each other to minimize the bearing loads on the shaft.

Another object of this invention is to provide a multiple stage pump or motor in which the successive stages are arranged in relation to each other so as to minimize the length of the flow passages between stages for improved pump efficiency.

Still another object of this invention is to provide a multiple stage pump in which the successive stages are formed by stacked pump elements and port plates and the stacked assembly is pressure loaded to force the stacked elements into close contact.

Yet another object of this invention is to provide a multiple stage positive displacement pump in which the successive stages are spaced axially along a shaft and wherein the shaft has a shaft seal at the inlet end and a labyrinth seal at the outlet end so arranged with relation to each other as to substantially counterbalance the hydraulic thrust on the shaft.

Yet another object of this invention is to provide a multiple stage pump which is compact in construction, economical to manufacture and which is adapted to deliver fluid under high pressure and has a high volumetric efficiency.

These, together with other objects and advantages of this invention will become apparent from the following description when taken in connection with the accompanying drawings wherein:

FIG. 1 is a longitudinal sectional view showing the multiple stage pump, taken on the plane 1—1 of FIG. 4; FIG. 2 is a longitudinal sectional view showing the multiple stage pump, taken on the plane 2—2 of FIG. 4, at right angles to the plane of FIG. 1; FIG. 3 is a transverse sectional view, taken on the plane 3—3 of FIG. 1 and illustrating one of the port plates; FIG. 4 is a transverse sectional view, taken on the plane 4—4 of FIG. 1, through one pump stage; FIG. 5 is a transverse sectional view, taken on the plane 5—5 of FIG. 1 illustrating a succeeding port plate; FIG. 6 is a transverse sectional view taken on the plane 6—6 of FIG. 1 illustrating a succeeding pump stage which is operated at 180° out of phase with the pump stage of FIG. 4; FIG. 7 is a fragmentary sectional view taken on the plane 7—7 of FIG. 3 and illustrating the configuration of the ports in the port plates; FIG. 8 is a transverse sectional view through a port plate taken on the plane 8—8 of FIG. 5, and illustrating the parts on a somewhat larger scale; FIG. 9 is a transverse sectional view taken on the plane 9—9 of FIG. 1; FIG. 10 is a sectional view through a modified form of multiple stage pump; FIG. 11 is an enlarged fragmentary sectional view illustrating the shaft seal arrangement used in the embodiment of FIG. 10; FIG. 12 is a fragmentary sectional view taken on the plane 12—12 of FIG. 10; and FIG. 13 is a fragmentary sectional view taken on the plane 13—13 of FIG. 10.

The apparatus disclosed herein can be used as a fluid pump or motor and, for convenience in description, is hereinafter referred to as a pump.

The multiple stage pump is enclosed in a rigid housing 10 having a cylindrical bore 11 for receiving and radially supporting the multiple stages of the pump in axial alignment of each other. A plurality of pump stages, herein shown eight in number, and designated P1—P8, are disposed in the bore 11, and are held in assembled relation therein. In the preferred embodiment illustrated, the housing 10 is formed with an integral end wall 12 which defines an irregularly extending shoulder 13 at one end of the bore 11. A removable end member 14 is mounted on the end wall 12 as by fastener 15 and is sealed to the housing as by an O-ring 16. A removable end member 17 is provided at the other end of the housing for clamping the pump stages in assembled relation, and the member is conveniently sealed to the housing by an O-ring 18. Inlet and outlet passage 21 and 22 are provided and arranged to communicate with the bore 11 adjacent opposite ends for passing fluid to and from the multiple stage pump. While the multiple stage pump is shown as being of the single stage type, the female member 17 is shown as being provided with a housing 10 increase in thickness, in a direction from the inlet to the outlet end of the pump, somewhat in accordance with the progressive increase in pressure of the fluid as it passes the successive pump stages.

The multiple stage pump includes a plurality of intermediate port plates designated as S1—S7, and an outlet port plate designated as S8. The intermediate port plates are disposed between adjacent ones of the pump stages P1—P8 to pass fluid from the outlet of one pump stage to the inlet of the next succeeding pump stage, and the outlet port plate S8 is arranged to pass the fluid from the last stage to the discharge passage 22. An inlet port plate designated S9 is also provided and, in the embodiment shown, is conveniently formed integrally with the removable end member 17, and is arranged to pass fluid from the inlet passage 21 to the first stage of the multiple stage pump. In order to simplify the number of parts which must be manufactured, each of the pump stages P1—P8 employs like parts and the several intermediate port plates are preferably of like construction. The same numerals are used to designate corresponding parts of the several pump stages and also corresponding pump parts of the several port plates.

The port plates designated S1—S7 are formed with axial openings 25 which define bearings for rotatably supporting the drive shaft 26. The port plates may be either formed of a material which is suitable to function as a bearing for the shaft 26, or the openings 25 may be lined with a suitable bearing material for this purpose. The port plates S1—S7 have a cylindrical outer peripheral wall 27 disposed concentric with the axis of the openings 25, and which outer peripheral wall is squarely received in the bore 11 so that the port plates are radially centered by the bore and support the shaft 26 coaxially with the axis of the bore 11. The shaft 26 is thus radially supported between each of the successive pump stages and, preferably, the outlet port plate S8 is similarly formed with a bore designated 25′ for rotatably supporting the shaft and an
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outer peripheral wall designated 27 which is snugly received in the bore 11 in the housing. The pump stages P1–P8 are of the eccentric rotor type and are so arranged that the discharges of the successive pump stages are at relatively opposite sides of the centerline of the shaft so that the radial hydraulic thrust on adjacent rotors along the shaft counteract each other. In addition, this arrangement also simplifies the porting and reduces the overall length of the passages for conveying fluids from the outlet of one stage to the inlet of the next succeeding stage. The pump stages each include a ring member designated 31 having a cylindrical outer wall 32 which is snugly received in the bore 11 in the housing, to be radially located thereby, coaxial with the axis of the bore 11 and shaft 26. For convenience in describing the invention, the axis of the shaft 26 and bore 11 is designated by the letter A in FIGS. 4 and 6. The ring member 31 also includes an internal wall 33 which is eccentric to the shaft and bore. The pump means of each stage also includes a rotor 36 which is non-rotatably attached to the shaft 26 for rotation therewith about the axis of each rotor. As best shown in FIG. 1, the rotors 36 are individually keyed to the shaft 26 in such a manner as to provide continuous bearing surface on the shaft between each pump stage, for reception in the openings 25 of the intermediate port plates. For this purpose, this shaft 26 is formed with a plurality of longitudinally spaced key slots 38 which are spaced apart along the shaft in alignment with the successive pump stages and a key 39 extends into the slot 38 and into a corresponding slot 41 in the rotor. As will be seen, the key 39 can be inserted into the key slot 38 and the rotors then moved axially into position with the keys 39 extending into the slots 41 in the rotors.

The pump means of each stage is of the “Gerotor” type and includes an outer rotor or ring gear 41 which is rotatably supported on the internal wall 33 of the ring member 31, and which has a plurality of inwardly extending teeth or lobes 41’. The rotor 36 has a plurality of outwardly extending teeth or lobes designated 36’, and the teeth on the inner and outer rotors are shaped so that the tips of the teeth or lobes on the inner rotor maintain a close running fit with the lobes on the outer rotor, as the inner and outer rotors rotate about their respective eccentric axes designated A and B. With this arrangement, the teeth on the inner and outer rotors form segmented compartments therebetween which progressively expand on one side of the plane through the axes A and B of the inner and outer rotors, hereinafter referred to as the plane of eccentricity, and progressively contract on the other side of that plane.

If the axis B of the outer rotors of each pump stage were offset to the same side of the axis A of the shaft and bore 11, then the discharge sectors of all of the pump stages would be located at the same side of the plane of eccentricity and the inlet sectors of the pump stages would all be located at the other side of the plane of eccentricity. There is, however, a high radial pressure unbalance on each rotor, due to the difference of pressure between the inlet and discharge sides of each pump stage, and which pressure unbalance extends generally transverse to the plane of eccentricity in a direction away from the pump discharge. In accordance with the present invention, the pump stages are arranged so that the discharge sectors of alternate pump stages are located on one side of the plane of eccentricity, with the discharge sectors of the other pump stages located at the opposite side of the plane of eccentricity, so that the pressure unbalance exerted by the rotor of each stage on the shaft 26 is substantially counteracted by the opposing thrust of an adjacent stage. This reduces the radial bearing loads on the shaft.

Alternating the discharge sectors of successive pump stages is conveniently effected in the present pump construction by positioning the rings 31 of successive pump stages so that the eccentric internal walls 33 have their axes B offset to relatively opposite sides of the shaft axis A. The rings 31 can all be of like construction to minimize the number of parts which must be made, and the rings merely formed with a locating means which enables positioning of the same ring in two positions with the eccentric axes B offset 180° from each other. The pump stages each include a single locating hole 43 formed in the rings 31 at a position such as shown in FIG. 6. Thus, as shown in FIG. 1, alternate pump stages P1, P3, P5 and P7 have their discharge sectors located at the top of the pump, as shown in that view, while the other pump stages P2, P4, P6 and P8 have their discharge sectors located at the bottom of the pump in that figure.

With the above described arrangement wherein the discharge sectors of successive pump stages are located at relatively opposite sides of the plane of eccentricity, it will be seen that the discharge sector of one stage is in alignment with the inlet sector of the next succeeding stage. This simplifies the port and passage arrangement for passing fluid from one stage to the next succeeding stage. The inlet port plate 59 has a generally crescent shaped inlet port 51 located at one side of the plane of eccentricity and which communicates through a passage 52 with the inlet passages 51. The intermediate port plates S1–S7 each have port means designated 54 having a generally crescent configuration and disposed at one side of the plane of eccentricity to communicate the outlet of one pump stage with the inlet of the next succeeding pump stage.

As previously described, the inlet and discharge sectors of the pump are disposed at relatively opposite sides of the plane of eccentricity. As best shown in FIGS. 4 and 6, the teeth on the inner and outer eccentrically related rotors are in full meshing engagement at a cutoff point designated C and the volume of the chambers is at a minimum at that point. At the point designated T, hereinafter generally referred to as the transfer point, the volume of the chambers is at a maximum. It is necessary to shape the port means 54 with respect to the transfer and cutoff points of their respective pump stages so as to maintain at least one tooth seat within the inlet and discharge ports, as the teeth move past the plane of eccentricity, while yet preventing trapping of fluid in this area.

As best shown in FIGS. 3, 5, 7 and 9, the port means 54 defines a generally crescent shaped opening 55 at the point of intersection of the port means with the plane of the port plate adjacent the preceding pump stage. The opening 55 is arranged to prevent trapping of the discharge from the preceding stage, while maintaining a proper seal between the inlet and discharge sectors and has one end 55’ spaced relatively closer to the plane of eccentricity, adjacent the cutoff point C of the pump stage, and the other end designated 55’’ spaced relatively farther from the plane of eccentricity, adjacent the transfer point T. The port means 54 also defines an opening 56 at the point of intersection with the other side of the port plate adjacent the inlet of the next succeeding pump stage. As previously noted, however, the opening stages are operated 180° out of phase with each other, so that the cutoff and transfer points to the succeeding stage are 180° out of phase with the respective points of the preceding stage. The opening 56 must therefore be angularly offset as best shown in FIGS. 3, 5, 7 and 9 from the opening 55 so that the end 56’ of the opening 56 is spaced relatively closer to the plane of eccentricity, and the end 56’’ is spaced relatively farther from the plane of eccentricity. Thus, the port means 54 is shaped so as to avoid trapping at either the discharge of one stage.
or the inlet of the next succeeding stage. The inlet port 51 in the port plate S9 is shaped and arranged similar to the opening 56 in the intermediate port plates. The outlet port plate S8 has an outlet opening S8 which communicates with the discharge sector of the last pump stage, and which outlet opening is shaped similar to the openings 55 in the intermediate port plate. As shown in FIG. 1, the outlet opening of the several pump stages and through the intervening port plates and has end portions which extend through sockets 61 and 62 in the end wall 12 and in the removable end member 17, respectively.

With the above described arrangement, the inlet opening of one stage is located at one side of the gear set and the discharge opening for that stage is located at a relatively opposite side of the gear set. The fluid pressures acting on the ends of the gear sets tend to produce an axial thrust on the gears, and pressure distribution grooves are advantageously provided in the port plates to substantially equalize the pressure unbalance at opposite sides of the gear sets. The pressure distribution grooves in the port plates are located at the side of the plane of eccentricity opposite the side of which the port means 54 is located. As shown in FIGS. 3, 5, 8, and 9, one pressure distribution groove designated 64 is provided in one side face of each port plate, and is shaped and positioned to register with the inlet port opening of the preceding stage. For example, the groove 64 in the port plate S1 is shaped and positioned to register with the opening 51 in the port plate S9, and the groove 64 in the port plate S2 is shaped and positioned to register with the opening 56 of the preceding port plate S1. These port plates are also provided with grooves 65 at the other side, positioned to the right as viewed in FIG. 1, and which openings are shaped and positioned to register with the discharge opening 55 in the next succeeding port plate. Thus, the groove 65 in the port plate S1 is shaped and positioned to register with the discharge opening 55 in the port plate S2 and which is similarly positioned and shaped to register with the discharge opening 55 in the port plate S3.

In order to facilitate the lubrication of the bearings formed in the openings 25 of the port plate, lubrication grooves 71 and 72 are formed in opposite faces of the port plate around the periphery of the passages are provided to extend between the port openings and the distribution grooves to the lubrication grooves to pass fluid to the bearings. As best shown in FIG. 8, the port means 54 communicates through passage 73 with one of the grooves 71 and one of the pressure distribution groove 74 with other lubrication grooves 72. The fluid pressure in the lubrication grooves of each port plate is different from the fluid pressure in the port means 54 so that there is a pressure differential between the grooves 71 and 72 which is effective to pass fluid through the bearings means to provide lubrication.

While the above described multiple stage pump is so arranged as to effectively counterbalance the radial hydraulic thrusts exerted on the shaft 26, the shaft is subjected to a very relative high axial pressure unbalance, due to the difference in pressure between the outlet and inlet. Accordingly, thrust bearings are advantageously provided to take up the axial thrust on the shaft. As shown in FIG. 1, a plurality of anti-friction type thrust bearings designated 81, 82 and 83 are mounted in the pump housing adjacent the inlet of the pump housing. The axial thrust on the shaft is transmitted through a collar 56 secured to the shaft and through the bearings to the housing. A shaft seal, including a rotary and stationary sealed members 88 and 89, is conveniently provided between the shaft and casing to prevent the leakage of fluid along the shaft. In order to enable the use of a low pressure seal, it is preferable to arrange the drive end 26 of the shaft adjacent the inlet of the pump.

From the foregoing it is thought that the construction and operation of the multiple stage pump will be readily understood. Assuming that the pump is rotating in a direction to draw fluid into the inlet passage 21, the fluid will be carried around in the intertotooth spaces of the pump stage P1 to the discharge sector at the opposite side of the plane of eccentricity and discharged through the opening 55 of port 54 in the first port plate S1. The fluid from the port plate S1 passes into the inlet of the next succeeding stage pump which carries it around in the intertotooth spaces to the discharge sector at the lower side of the pump, as viewed in FIG. 1. Thus, each pump stage discharges substantially directly into the inlet of the next succeeding pump stage so as to simplify the passage arrangement and to minimize the length of the passages necessary to communicate adjacent pump stages. Moreover, since the discharge zones of successive pump stages are located at relatively opposite sides of the plane of eccentricity, the radial hydraulic thrusts exerted on the shaft by one stage are substantially counteracted by the next succeeding stage, to thereby minimize the overall radial loads on the shaft and to simplify the problem of providing adequate radial bearings. The pressure distribution grooves in the port plates are shaped to register with the port openings at the relatively opposite side of each gear set, so as to substantially equalize the axial hydraulic thrusts on each gear set. As will be seen, the end of the port openings 55' and 56' adjacent the transfer point T are spaced from the ends of the adjacent pressure distribution grooves a distance approximately corresponding to the spacing between the teeth on the inner rotor at the points of contact with the outer rotor, and the other ends 55' and 56' of the port openings adjacent the cut-off point C are spaced relatively closer to the ends of the adjacent pressure distribution grooves, and preferably corresponding to the width of one tooth on the inner gear at the point of contact with the outer gear.

Since the pump stages each uses like parts and as the port plates are also of similar construction, the number of different pieces which must be formed is minimized. Moreover, the number of stages in a pump can be readily increased or decreased, merely by suitably selecting the length of the housing 10. The latter functions to radially center successive pump stages. The port plates in proper alignment and has a close fit with the outer periphery of the port plates and ring members to inhibit leakage of fluid from the pump outlet to the pump inlet along the pump stages.

The embodiment of the multiple stage pump illustrated in FIGS. 10–13 is generally similar to that shown in FIGS. 1–9 and includes a housing 110 having a bore 111 therein and an end wall 112 at one end of the bore. An
end member 113 closes the other end of the bore and inlet passage 121 communicates with the bore adjacent one end and an outlet passage 122 communicates with the bore adjacent the relatively opposite end. The pump includes a plurality of port plates including an inlet port plate X1, intermediate port plates X2-X4 and outlet port plate X5. A plurality of pump stages designated X1-X4 are disposed between adjacent port plates. As in the preceding embodiment, the port plates each have a central opening 125 which forms a bearing to slidably and rotatably support the shaft 126. The pump stages each include an outer ring member 131 which is guidedly received within the bore 111 and has an eccentric inner wall 133 that rotatably supports an outer rotor 141. The inner rotor 136 of each pump stage is non-rotatably keyed to the shaft as by a key means 139. The ring members 131 are held against rotation relative to the housing by a common locating rod 144 that can extend through either of two openings 159a or 159b, and the ring members of adjacent stages are positioned so as to operate adjacent pump stages 180° out of phase with each other. The port plates also have port means 154 arranged to communicate the outlet of one stage with the inlet of the next succeeding stage and, since adjacent pump stages are operated 180° out of phase with each other, the succeeding port plates are also positioned so that the port means 154 of adjacent stages are located at relatively opposite sides of the plane of eccentricity through the axes of the inner and outer rotors. The intermediate port plates are also provided with pressure balancing grooves 164 and 165 which correspond generally to the pressure balancing grooves 64 and 65 described in the previous embodiment. The inlet port 151 of the inlet pump stage communicates with the inlet passage 21 and, preferably, the pressure balancing grooves 164 of the intermediate port plate X2 is also preferably communicated through a passage 121 with the inlet passage, to aid in filling the tooth spaces of the inlet pump stage. The outlet port plate X5 has an outlet passage 158 wherein discharges the fluid from the pump into the bore at the outer face of the plate X5 to thereby pressure load the outlet plate X5 toward the inlet and thereby press all of the port plates and ring members into close face to face contact. A spring, herein shown in the form of a dashed washer 116 is conveniently provided and interposed between the housing and the outlet port plate to hold the pump stages together during shipment and until the discharge pressure of the pump is operative to pressure load the pump stages together. The arrangement of the several pump stages and the port plates as well as the configuration of the ports is similar to that previously described in connection with the embodiment of FIGS. 1-9, and further detailed description is deemed unnecessary.

Provision is made for substantially balancing the axial hydraulic thrusts on the shaft 126 so as to eliminate the necessity of the heavy duty thrust bearings used in the preceding embodiment. The shaft 126 is adapted for connection, as by a splined end 126', to a drive shaft (not shown). A rotary shaft seal 165 is provided at the inlet end of the pump to form a running seal between the housing and the shaft. As best shown in FIG. 11, the shaft seal includes a rotary seal member 166 which is mounted as by a seal ring 167 on the shaft for rotation therewith, and a stationary seal member extending seal face 168. A shoulder or collar 169 is provided on the shaft and engages the outer end of the rotary seal member to transmit the axial thrust on the seal member directly to the shaft. A stationary seal member 171 is non-rotatably connected to the housing as by key connections 172, and the stationary seal member seal face 173 disposed in running engagement with the rotary seal face 168. The stationary seal member is thus supported for limited axial movement relative to the housing and is sealed to the housing as by a diaphragm 175. A spring 176 is provided to apply a light pressure on the stationary seal member in a direction to yieldably urge the stationary seal member against the rotary seal member. As will be seen from FIG. 11, the stationary seal face 173 engages the rotary seal face in an annular area spaced radially outwardly from the center of the shaft. The inner side of the shaft seal is vested to substantially inlet pressure, as is apparent from the face 168 of the rotary seal member is subjected to inlet pressure. This inlet pressure acting on the rotary seal member produces an axial hydraulic thrust on the seal member which is transmitted to the shaft, and which tends to urge the shaft to the left as viewed in FIGS. 10 and 11. The pressure of the spring 176 supplements this inlet pressure and also produces a force which tends to urge the shaft to the left.

The other end of the shaft 126 is effectively sealed from the discharge pressure of the pump, in order to avoid the high axial pressure unbalance on the shaft which would occur if discharge pressure were applied to the outlet end of the shaft. As shown, the end of the shaft 126 extends through the end wall 112 of the housing and into a chamber 120, which chamber is vested through a passage 188 to the inlet 121. The shaft is rotatably supported and sealed at the end thereof by a sleeve 191 which extends through the end wall and is sealed to the end wall by an O-ring 192. The shaft 126 slidably and rotatably extends through the sleeve and has a sufficiently close fit therewith so that there is a gradient pressure drop in the fluid which tends to leak from the discharge side of the pump between the shaft and sleeve to the chamber 120. Preferably, either the shaft or sleeve is formed with spaced grooves indicated at 195 which forms spaced chambers along the shaft to distribute the flows more uniformly around the shaft. A collar 196 is connected to the shaft and held against movement as by a split ring 197. The inner face 198 of the collar engages the sleeve to form a radial seal and pressure applying area. As will be appreciated, the pressure across the face 198 of the collar is a gradient pressure which varies from inlet pressure adjacent the outer periphery of the collar to a relatively higher intermediate pressure, which intermediate pressure is the difference between pump discharge pressure and the pressure drop in the fluid as it flows between the shaft and sleeve. The gradient pressure, acting across the area of the collar face 198, tends to urge the shaft to the right, and to oppose the axial hydraulic thrust due to the aforementioned inlet pressure acting on the seal face 168. In order to enable substantial axial balance of the axial thrusts on the shaft, the diameter of the seal face 198 on the collar 196 is made smaller than the diameter of the seal face 173. With this arrangement, the inlet pressure acting through the rotary seal member 165 will tend to urge the shaft 126 to the left as viewed in FIGS. 10 and 11. This will force the collar 196 more firmly against the end of the sleeve and decrease the leakage between the face 198 on the collar 196 and the end face 199 on the sleeve. This decrease in flow between the shaft and sleeve allows the intermediate pressure adjacent the inner periphery of the face 198 on the collar 196 to build up to a value such that it will counter-balance the opposing end thrust on the shaft produced by the seal 165. If the gradient pressure at the seal area 198 is insufficient, the opposing axial thrust on the shaft will urge the collar 196 more has a generally radial extending seal face 168. A shoulder or collar 169 is provided on the shaft and engages the outer end of the rotary seal member to transmit the axial thrust on the seal member directly to the shaft. A stationary seal member 171 is non-rotatably connected to the housing as by key connections 172, and the stationary seal member seal face 173 disposed in running engagement with the rotary seal face 168. The stationary seal member is thus supported for limited axial movement relative to the housing and is sealed to the housing as by a diaphragm 175. A spring 176 is provided to apply a light pressure on the
seal member. Substantial axial hydraulic balance of the shaft is accordingly achieved and maintained.

I claim:

1. A multiple stage positive displacement pump or motor comprising, a plurality of ring members and a plurality of port plates separate from the ring members as assembled in a stack with one port plate interleaved between adjacent ones of said ring members, said port plates having axial shaft extensions therefrom at opposite sides thereof, a shaft extending through said openings in said plates and rotatably supported by said bearings, said ring members each having an internal wall, pump means disposed in each ring member, said pump means each including a rotor non-rotatably attached to said shaft for rotating therewith about an axis eccentric to the axis of the inner wall of the respective ring member and defining a plurality of segregated pumping chambers which progressively expand in an inlet sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having port means extending therefrom at each side of said plate of eccentricity and arranged to communicate the outlet sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having pressure distribution grooves in opposite faces thereof at the side of said plate of eccentricity opposite the port means disposed in the respective port plate, the pressure distribution groove in one face of the port plate being shaped generally complementary to the port means of the preceding stage and the pressure distribution groove in the other face of the port plate being shaped generally complementary to the port means in the next succeeding stage.

2. The combination of claim 1 including lubrication grooves in opposite faces of the port plate around said axially extending openings therein, a first passage means communicating the port means in the respective plate with one of said lubrication grooves, and a second passage means communicating one of said pressure distribution grooves in the respective plate with the other of said lubrication grooves for lubricating the bearings.

3. A multiple stage positive displacement pump or motor comprising, a rigid housing having a cylindrical bore therein and means defining inlet and outlet passages adjacent one end of the bore, a plurality of ring members and a plurality of port plates separate from the ring members stacked in said bore and having port means thereon disposed in opposite sides of said plate of eccentricity and arranged to communicate the outlet sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having pressure distribution grooves in opposite faces thereof at the side of said plate of eccentricity opposite the port means in the respective port plate, the pressure distribution groove in one face of the port plate being shaped generally complementary to the port means of the preceding stage and the pressure distribution groove in the other face of the port plate being shaped generally complementary to the port means in the next succeeding stage.

4. A multiple stage positive displacement pump or motor comprising, a rigid housing having a cylindrical bore therein and means defining inlet and outlet passages adjacent one end of the bore, a plurality of ring members and a plurality of port plates separate from the ring members stacked in said bore and having port means thereon disposed in opposite sides of said plate of eccentricity and arranged to communicate the outlet sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having pressure distribution grooves in opposite faces thereof at the side of said plate of eccentricity opposite the port means in the respective port plate, the pressure distribution groove in one face of the port plate being shaped generally complementary to the port means of the preceding stage and the pressure distribution groove in the other face of the port plate being shaped generally complementary to the port means in the next succeeding stage.

5. A multiple stage positive displacement pump or motor comprising, a plurality of ring members and a plurality of port plates separate from the ring members as assembled in a stack with a port plate interleaved between adjacent ones of said ring members, said port plates having axial shaft extensions therefrom at opposite sides thereof, a shaft extending through said openings in said plates and rotatably supported by said bearings, said ring members each having a cylindrical internal wall, pump means disposed in each ring member, said pump means each including a rotor non-rotatably attached to said shaft for rotating therewith about an axis eccentric to the axis of the inner wall of the respective ring member and defining a plurality of segregated pumping chambers which progressively expand in an inlet sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having port means extending therefrom at each side of said plate of eccentricity and arranged to communicate the outlet sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having port means extending therefrom at each side of said plate of eccentricity and arranged to communicate the outlet sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having pressure distribution grooves in opposite faces thereof at the side of said plate of eccentricity opposite the port means disposed in the respective port plate, the pressure distribution groove in one face of the port plate being shaped generally complementary to the port means of the preceding stage and the pressure distribution groove in the other face of the port plate being shaped generally complementary to the port means in the next succeeding stage.
including an outer ring gear rotatably supported on the internal wall of the respective ring member and an inner gear non-rotatably attached to the shaft for rotation therewith about an axis eccentric to the outer gear, said inner and outer gears defining pumping chambers which expand in an inlet sector at one side of a plane of eccentricity through the axes of the inner and outer gears and contract in an outlet sector at the other side of said plane, said ring members being positioned with the axes of the internal walls of successive ring members offset to relatively opposite sides of the axis of the shaft whereby the discharge sectors of alternate pump stages are disposed on relatively opposite sides of said plane of eccentricity to have the radial pressure unbalance on adjacent inner gears counteract each other and to position the discharge sector of one pump stage adjacent the inlet sector of next succeeding stage, said port plates having port means extending therethrough with the port means in successive port plates being located at opposite sides of said plane of eccentricity and arranged to communicate the outlet sector of one stage with the inlet sector of the next succeeding stage, said port means defining a crescent shaped opening in each face of the port plate, the ends of the crescent shaped openings in opposite sides of the port plate being angularly offset from each other, the opposite ends of said each crescent shaped opening being spaced unequal distances from said plane of eccentricity.

6. A multiple stage positive displacement pump or motor comprising, a rigid housing having a cylindrical bore therein and means defining inlet and outlet passages adjacent opposite ends of the bore, a plurality of ring members and a plurality of port plates separate from said ring members stacked in said bore with a port plate interleaved between adjacent ones of said ring members, said port plates and ring members having outer peripheral walls of like diameter and means defining inlet and outlet passages through the axes of the internal walls of successive ring members offset to relatively opposite sides of the axis of the shaft whereby the discharge sectors of alternate pump stages are disposed on relatively opposite sides of said plane of eccentricity to have the radial pressure unbalance on adjacent inner gears counteract each other and to position the discharge sector of one pump stage adjacent the inlet sector of next succeeding stage, said port plates having port means extending therethrough with the port means in successive port plates being located at opposite sides of said plane of eccentricity and arranged to communicate the outlet sector of one stage with the inlet sector of the next succeeding stage, said port means defining a crescent shaped opening in each face of the port plate, the ends of the crescent shaped openings in opposite sides of the port plate being angularly offset from each other, the opposite ends of said each crescent shaped opening being spaced unequal distances from said plane of eccentricity.

8. A multiple stage positive displacement pump or motor comprising, a rigid housing having a cylindrical bore therein and means defining inlet and outlet passages adjacent opposite ends of the bore, a plurality of ring members and a plurality of port plates separate from said ring members stacked in said bore with a port plate interleaved between adjacent ones of said ring members, said port plates and ring members having outer peripheral walls of like diameter and means defining inlet and outlet passages through the axes of the inner and outer gears and contract in an outlet sector at the other side of said plane, said ring members being positioned with the axes of the internal walls of successive ring members offset to relatively opposite sides of the axis of the shaft whereby the discharge sectors of alternate pump stages are disposed on relatively opposite sides of said plane of eccentricity to have the radial pressure unbalance on adjacent inner gears counteract each other and to position the discharge sector of one pump stage adjacent the inlet sector of next succeeding stage, said port plates having port means extending therethrough with the port means in successive port plates being located at opposite sides of said plane of eccentricity and arranged to communicate the outlet sector of one stage with the inlet sector of the next succeeding stage, said port plates having pressure distributing grooves in opposite faces at the side of said plane of eccentricity opposed to the port means in the respective port plate, the pressure distributing groove in one face of the port plate registering with the port means of the preceding stage and the pressure distributing groove in the other face of the port plate registering with the port means in the next succeeding stage.
adjacent inner gears counteract each other and to position the discharge sector of one pump stage adjacent the inlet sector of next succeeding stage, said port plates having port means extending therethrough with the port means in successive port plates being located at opposite sides of said plane of eccentricity and arranged to communicate the outlet sector of one stage with the inlet sector of the next succeeding stage, said port plates having pressure distribution grooves in opposite faces at the side of the plane of eccentricity opposite the port means in the respective port plate, lubrication grooves in opposite faces of the port plates around said axially extending openings therein, a first passage means communicating the port means in the respective plate with one of said lubrication grooves, and a second passage means communicating one of said pressure distribution grooves with the other of said lubrication grooves for lubricating the bearings.

9. A multiple stage positive displacement pump or motor comprising, a rigid housing having a cylindrical bore therein and means defining inlet and outlet passages adjacent opposite ends of the bore, a plurality of ring members each having an internal wall eccentric to its outer peripheral wall, pump means disposed in each ring member, said pump means each including a rotor non-rotatably attached to said shaft for rotation therewith about an axis eccentric to the axis of the inner wall of the respective ring member and defining a plurality of segregated pumping chambers which progressively expand in an inlet sector at one side of a plane of eccentricity through the axis of said shaft whereby the discharge sectors of alternate pump stages are disposed on relatively opposite sides of said plane of eccentricity to have the radial pressure imbalance on adjacent rotors counteract each other and to position the discharge sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having port means extending therethrough with the port means in successive port plates being located at opposite sides of said plane of eccentricity and arranged to communicate the outlet sector of one stage with the inlet sector of the next succeeding stage, a shaft seal at the inlet end of the pump including a rotary seal member connected to the shaft for rotation therewith and a stationary seal member connected to the housing, said rotary and stationary seal members having interengaging seal faces spaced radially outwardly from the axis of the shaft a preselected distance to form a running seal between the housing and the shaft, a labyrinth seal at the outlet end of the pump including a sleeve mounted on the housing and extending out of said bore, said sleeve slidably and rotatably supporting said shaft, and a collar engaged on the outer end of said sleeve along an area spaced radially from the axis of said shaft a distance less than said preselected distance.

10. A multiple stage positive displacement pump or motor comprising, a rigid housing having a cylindrical bore therein and means defining inlet and outlet passages adjacent opposite ends of the bore, a plurality of ring members each having an internal wall eccentric to its outer peripheral wall, pump means disposed in each ring member, said pump means each including a rotor non-rotatably attached to said shaft for rotation therewith about an axis eccentric to the axis of the inner wall of the respective ring member and defining a plurality of segregated pumping chambers which progressively expand in an inlet sector at one side of a plane of eccentricity through the axis of said shaft whereby the discharge sectors of alternate pump stages are disposed on relatively opposite sides of said plane of eccentricity to have the radial pressure imbalance on adjacent rotors counteract each other and to position the discharge sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having port means extending therethrough with the port means in successive port plates being located at opposite sides of said plane of eccentricity and arranged to communicate the outlet sector of one stage with the inlet sector of the next succeeding stage, a shaft seal at the inlet end of the pump including a rotary seal member connected to the shaft for rotation therewith and a stationary seal member connected to the housing, said rotary and stationary seal members having interengaging seal faces spaced radially outwardly from the axis of the shaft a preselected distance to form a running seal between the housing and the shaft, a labyrinth seal at the outlet end of the pump including a sleeve mounted on the housing and extending out of said bore, said sleeve slidably and rotatably supporting said shaft, and a collar engaged on the outer end of said sleeve along an area spaced radially from the axis of said shaft a distance less than said preselected distance.

11. A multiple stage positive displacement pump or motor comprising, a rigid housing having a cylindrical bore therein and means defining inlet and outlet passages adjacent opposite ends of the bore, a plurality of ring members each having an internal wall eccentric to its outer peripheral wall, pump means disposed in each ring member, said pump means each including a rotor non-rotatably attached to said shaft for rotation therewith about an axis eccentric to the axis of the inner wall of the respective ring member and defining a plurality of segregated pumping chambers which progressively expand in an inlet sector at one side of a plane of eccentricity through the axis of said shaft whereby the discharge sectors of alternate pump stages are disposed on relatively opposite sides of said plane of eccentricity to have the radial pressure imbalance on adjacent rotors counteract each other and to position the discharge sector of one stage adjacent the inlet sector of the next succeeding stage, said port plates having port means extending therethrough with the port means in successive port plates being located at opposite sides of said plane of eccentricity and arranged to communicate the outlet sector of one stage with the inlet sector of the next succeeding stage, a shaft seal at the inlet end of the pump including a rotary seal member connected to the shaft for rotation therewith and a stationary seal member connected to the housing, said rotary and stationary seal members having interengaging seal faces spaced radially outwardly from the axis of the shaft a preselected distance to form a running seal between the housing and the shaft, a labyrinth seal at the outlet end of the pump including a sleeve mounted on the housing and extending out of said bore, said sleeve slidably and rotatably supporting said shaft, and a collar engaged on the outer end of said sleeve along an area spaced radially from the axis of said shaft a distance less than said preselected distance.

12. A multiple stage positive displacement pump or
motor comprising a rigid housing having a cylindrical bore therein and means defining inlet and outlet passages adjacent opposite ends of the bore, a plurality of ring members and a plurality of port plates separate from the ring members stacked in said bore with one port plate interleaved between adjacent ones of said ring members, said port plates and ring members having outer peripheral walls of like diameter Guideably received in said bore to be centered thereby, said port plates having axially extending openings therein defining bearings disposed coaxially of said bore, a shaft extending through said openings in said plates coaxially of said bore and rotatably supported by said bearings, said ring members each having an internal wall eccentric to its outer peripheral wall, pump means disposed in each ring member, said pump means each including a rotor non-rotatably attached to said shaft for rotation therewith about an axis eccentric to the axis of the inner wall of the respective ring member and defining a plurality of segregated pumping chambers which progressively expand in an inlet sector at one side of a plane of eccentricity through the axis of said rotor and the axis of the inner wall of the respective ring member and progressively contract in an outlet sector at the other side of said plane, said port plates having port means arranged to communicate the outlet sector of one stage with the inlet sector of the next succeeding stage, a shaft seal at the inlet end of the pump including a rotary seal member connected to the shaft for rotation therewith and a stationary seal member connected to the housing, said rotary and stationary seal members having interengaging seal faces spaced radially outwardly from the axis of the shaft a preselected distance to form a running seal between the housing and the shaft, a labyrinth seal at the outlet end of the pump including a sleeve mounted on the housing and extending out of said bore, said sleeve slidably and rotatably supporting said shaft, and a collar on said shaft engaging the outer end of said sleeve along an area spaced radially from the axis of said shaft a distance less than said preselected distance.

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