Oct. 9, 1956 B. H. MOSBACHER 2,765,749

FLUID PUMP OR MOTOR

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Fig. 1

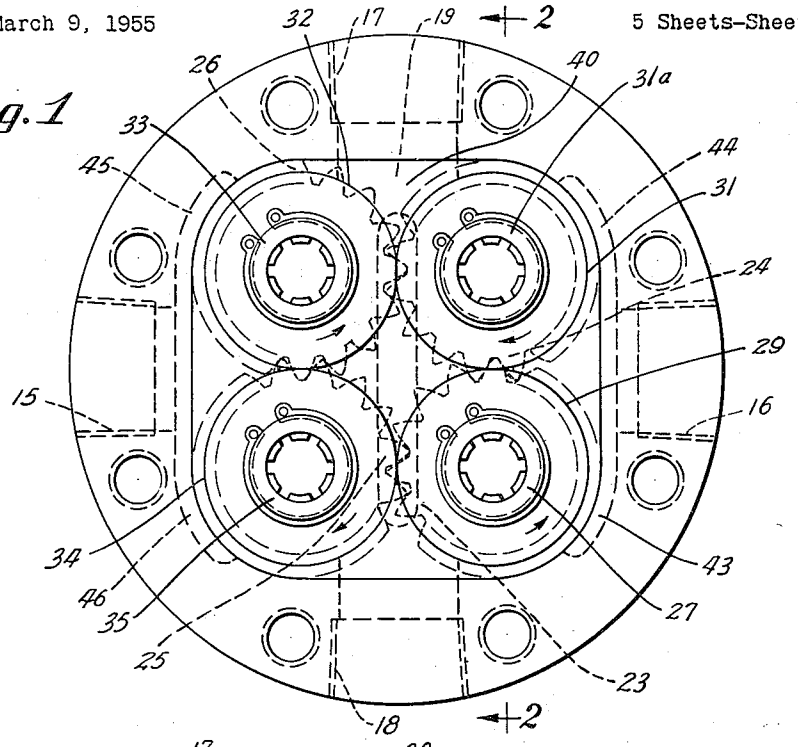
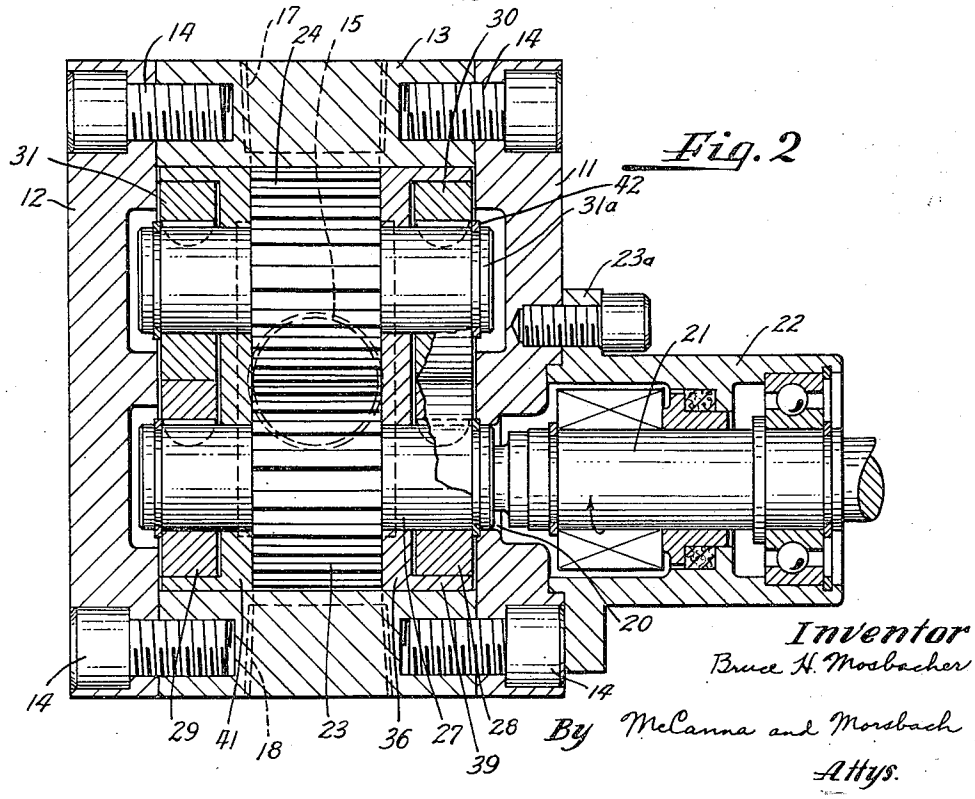


Fig. 2



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Fig. 3

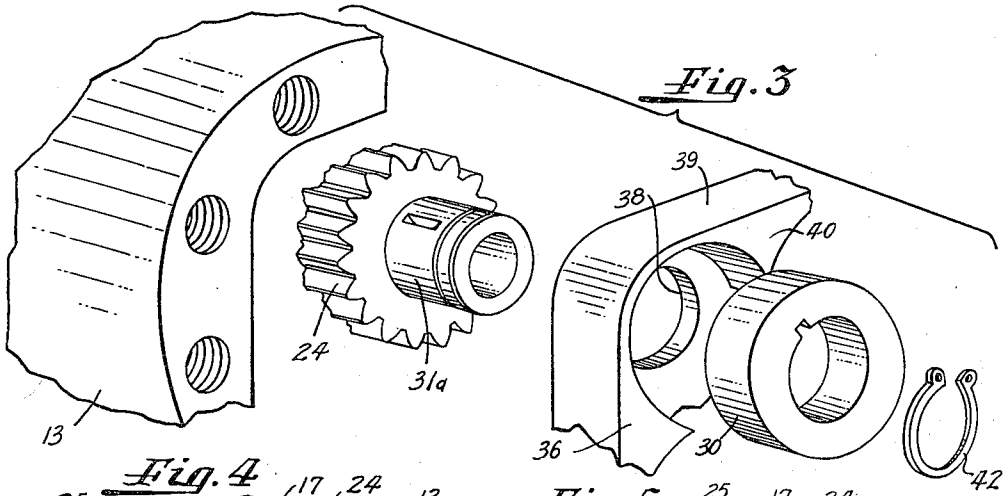


Fig. 4

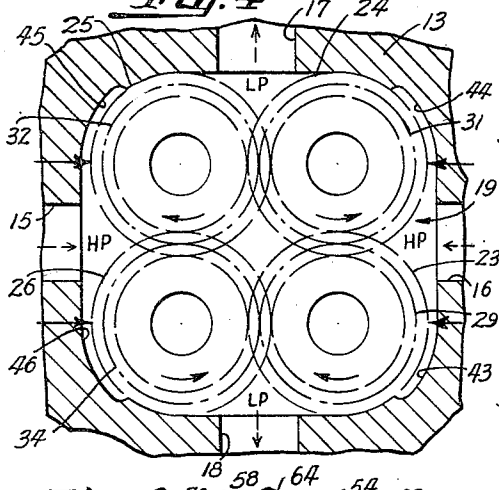


Fig. 5

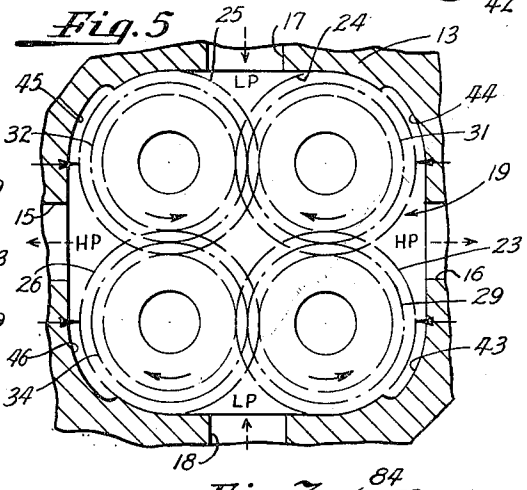


Fig. 6

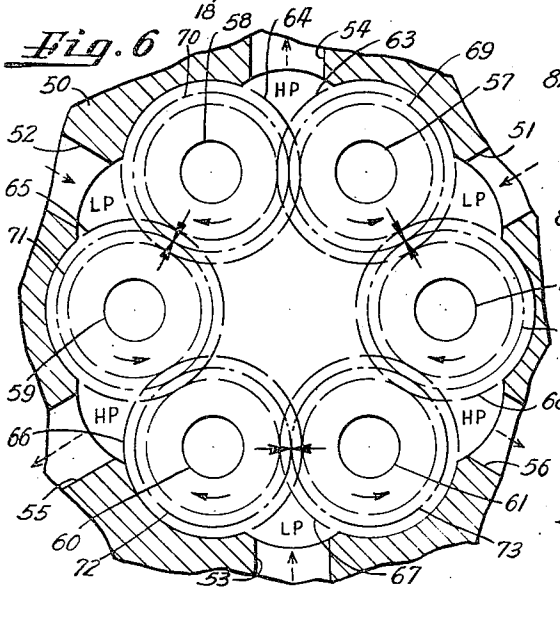
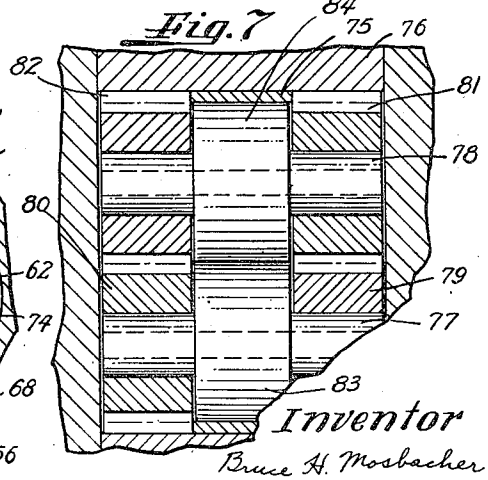


Fig. 7



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Fig. 8

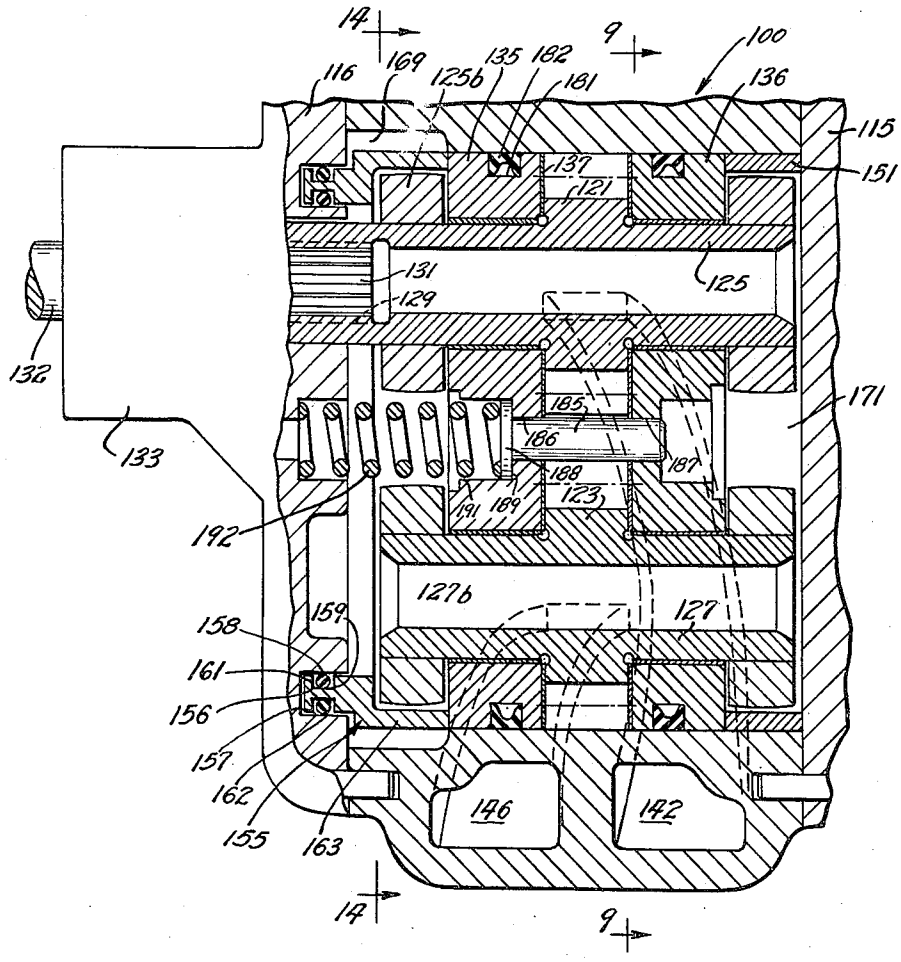
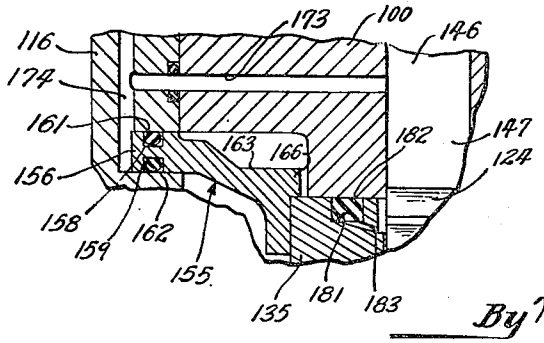


Fig. 11



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Fig. 9

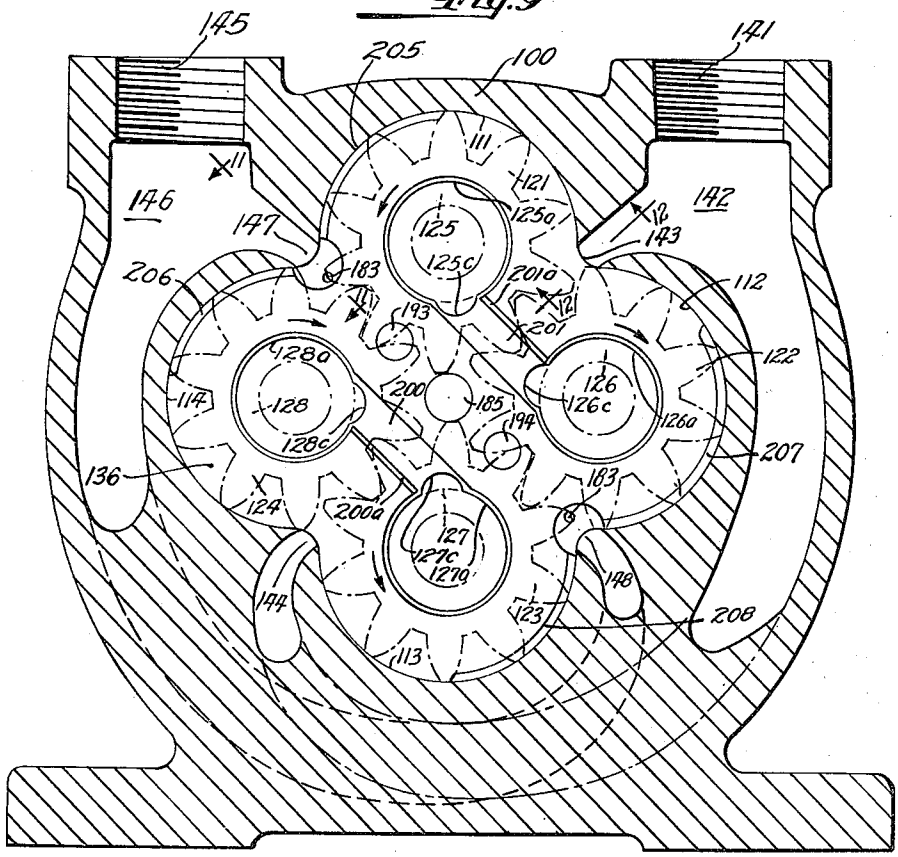


Fig. 10

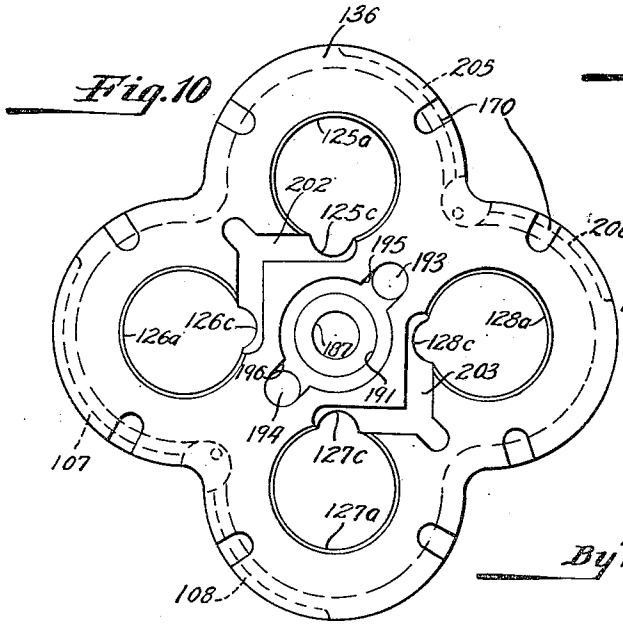
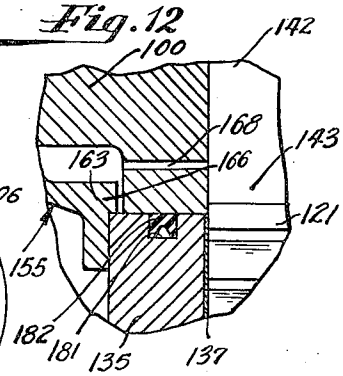


Fig. 12



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Fig. 13

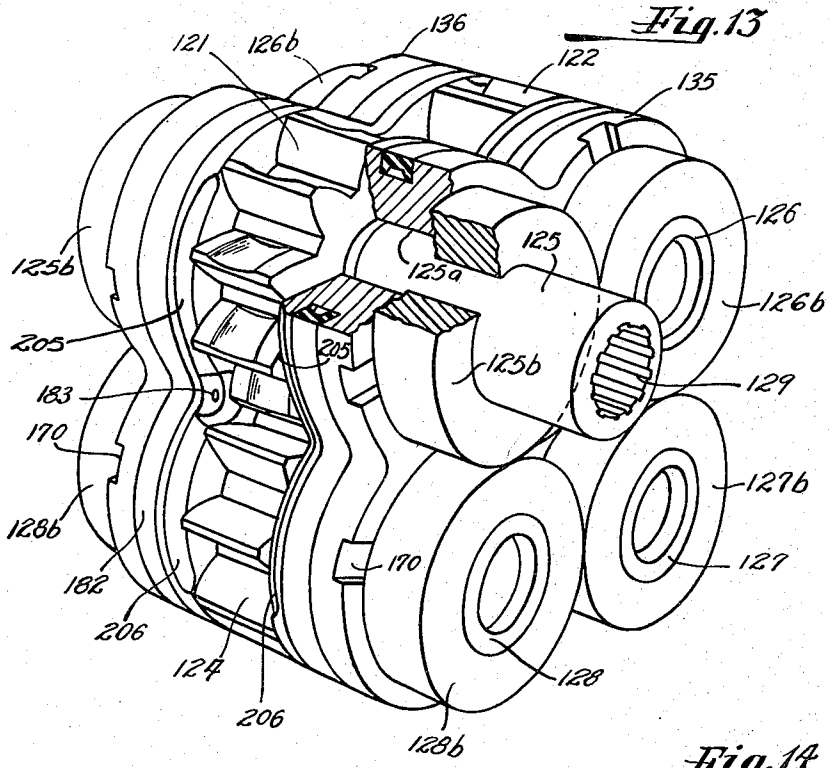
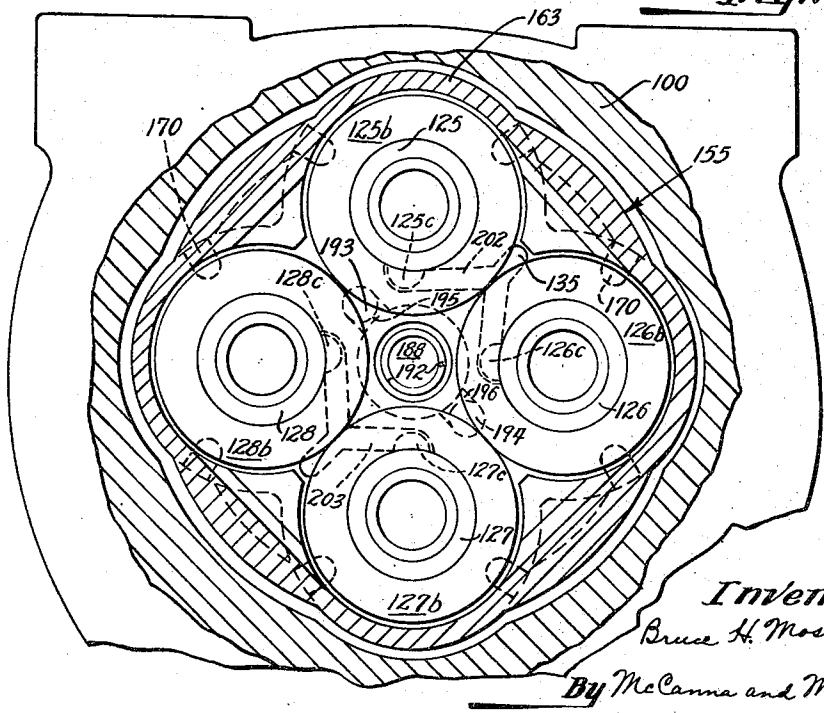


Fig. 14



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FLUID PUMP OR MOTOR

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Application March 9, 1955, Serial No. 493,216

27 Claims. (Cl. 103—126)

This invention relates to fluid pumps or motors and more particularly to a multiple gear pump of the type having a plurality of pairs of meshing gears.

This is a continuation-in-part application of my co-pending application for a "Rotary Pump or Motor," Serial No. 269,399, filed February 1, 1952, now abandoned.

Various problems are presented in making a rotary gear type pump for operation at high pressures. As the operating pressure is increased, so is the tendency of the fluid to leak between the gear end faces and around the gear peripheries and thereby reduce the efficiency of the pump. Further, the higher the operating pressures, the greater the radial bearing loads which cause wear on the gear shaft bearings and abrading of the gear housing by the gears.

In order to reduce leakage past the gear end faces, it has heretofore been proposed in some two-gear type pumps to provide movable wear plates or bushings at the gear end faces, which wear plates are urged against the gear end faces to form a running seal thereat. In these pumps, the inlet and discharge passages are necessarily arranged at opposite sides of the mesh point of the gears so that the high and low pressure areas on the gear face sides of the wear plates are not symmetrically located. There is, consequently, an hydraulic force acting on the wear plates, in a direction parallel to the axes of the gears, which tends to urge the wear plates, adjacent the high pressure passage, away from the gear end faces and causes the wear plates to tilt. This prevents forming a close running fit with the gear end faces and to a large extent nullifies the usefulness of the wear plates. Various modifications in the wear plate construction and the manner of applying pressure to the side of the gears remote from the wear plates have been made in the two gear pumps in an attempt to overcome tilting of the wear plates, which modifications have greatly increased the expense of manufacturing the pumps and have, in general, not been completely satisfactory.

In addition to the axial hydraulic thrust on the wear plates which tends to cause tilting of the latter, there is also a radial hydraulic thrust acting on the gears and wear plates. This radial hydraulic thrust urges the gears and wear plates in a direction away from the high pressure passage and against the opposed wall of the pump housing causing the wear plate to bind on the housing and prevent free floating movement of the wear plate against the gear end faces. Further, the radial pressure on the gears produces high bearing loads on the gear shafts which causes excessive bearing wear.

It is an important object of this invention to provide a novel rotary pump capable of operating at high fluid pressure.

Another object of this invention is to provide a rotary pump or fluid motor having a plurality of rotary fluid displacement members in which the radial loads on the fluid displacement members is taken up by novel bearing members in such a manner as to minimize wear on the journals for the displacement members.

Another object of this invention is the provision of a novel rotary pump or motor having wear plates for forming a running seal with the gear end faces in which tilting of the wear plates away from the gear end faces is prevented.

A further object of this invention is the provision of a rotary pump or motor having wear plates for forming a running seal with the gear end faces in which the assembly of the gears and wear plates is substantially hydraulically balanced in a radial direction so that the wear plates are not forced radially against the pump housing and therefore are free to float axially of the pump housing to form a proper running seal with the gear end faces.

A more particular object of this invention is the provision of a rotary pump or motor having a plurality of gears each meshing with a pair of adjacent gears, with rollers on the gear shafts and means for adjusting the direction of the resultant radial load on the gears so that the rollers are fully effective to take up the radial thrust on the gears and minimize or eliminate bearing wear on the gear journals.

A further object of this invention is the provision of a rotary pump or motor having a plurality of gears each meshing with a pair of adjacent gears and providing alternate inlet and discharge passages around the external periphery of the gear assembly between each pair of meshing gears, with movable wear plates at opposite ends of the gears.

Still another object of this invention is the provision of a gear pump or motor in accordance with the foregoing object in which the gear shafts have rollers thereon for taking up the radial thrust on the gears whereby there is substantially no radial thrust between the gear shafts and the wear plates which can cause wear on the journals in the wear plates or cause binding of the wear plates on the gear shafts and prevent free axial float of the wear plates.

Yet another object of this invention is the provision of a pump or motor in accordance with the foregoing object having an improved arrangement for applying pressure to the wear plates.

An additional object of this invention is the provision of a pump or motor having a novel lubrication system which provides positive circulation of fluid across the gear end faces and through the gear trunnions to lubricate and cool the same and which lubrication system does not affect the volumetric efficiency of the pump.

A still further object of this invention is the provision of a multiple gear pump or motor in which the fluid which leaks from the pump chamber into other cavities in the pump is recirculated across the gear end faces and through the gear shaft journals whereby only fluid which has been effectively filtered by passage through confined leakage paths is circulated.

These together with various ancillary objects and advantages of this invention will be more readily appreciated as the same becomes better understood by reference to the following detailed description when taken in connection with the accompanying drawings wherein:

Figure 1 is an end view of a four-gear pump or fluid motor according to the present invention, with an end plate removed to better show the construction of the device;

Fig. 2 is a longitudinal section of the Fig. 1 device, taken along the line 2—2 of Fig. 1;

Fig. 3 is an enlarged exploded perspective view showing the mounting for one of the gears in the Fig. 1 device at one end thereof;

Fig. 4 is a schematic transverse sectional view of the Fig. 1 device operating as a fluid motor;

Fig. 5 is a view similar to Fig. 4 showing the four-gear fluid displacement mechanism of Fig. 1 operating as a pump;

Fig. 6 is a schematic transverse sectional view of an alternative embodiment of the present invention having six gears;

Fig. 7 is a fragmentary longitudinal section through another embodiment of the invention having two sets of four gears each;

Fig. 8 is a longitudinal sectional view through a further modified form of the gear pump constituting the preferred embodiment thereof;

Fig. 9 is a transverse sectional view taken on the plane 9—9 of Fig. 8;

Fig. 10 is a side view of one of the wear plates of the embodiment of Fig. 8;

Fig. 11 is a fragmentary longitudinal sectional view taken on the plane 11—11 of Fig. 9;

Fig. 12 is a fragmentary longitudinal sectional view taken on the plane 12—12 of Fig. 9;

Fig. 13 is a perspective view of the gear and wear plate assembly, with parts broken away and shown in section to illustrate details of construction; and

Fig. 14 is a fragmentary transverse sectional view taken on the plane 14—14 of Fig. 8.

The hydraulic apparatus of the present invention is adaptable for operation as either a fluid pump or motor, but for convenience will be described and referred to herein as a pump.

Referring to the particular construction shown in Figs. 1–3 and assuming that the device is operating as a pump, the pump is provided with a pair of spaced end plates **11** and **12** and an annular housing **13** located between the end plates, being suitably attached thereby by threaded bolts **14**. The housing **13** is formed at opposite sides with a pair of discharge passages **15** and **16**, spaced 180° apart around the circumference of the housing, and with a pair of inlet passages **17** and **18**, located midway between the discharge passages **15**, **16** and 180° apart from one another around the circumference of the housing. The suction and discharge passages communicate with the pumping chamber, indicated generally at **19**, which is enclosed by the spaced end plates **11** and **12** and the annular housing **13**.

As best seen in Fig. 2, the end plate **11** is formed with a passage **20** permitting the driving shaft **21** to extend into the pump chamber **19**. A sleeve **22** formed with a transverse annular end flange **23***a* abutting against the end plate **11** is bolted to the end plate **11** and surrounds the drive shaft **21** beyond the pump. The drive shaft is suitably sealed in fluid tight relation and supported for rotation, in the direction indicated by the arrow in Fig. 2, in sleeve **22** and is coupled to a prime mover, such as an electric motor, for driving the pump.

Within the pump chamber **19**, the drive shaft is coupled to a shaft **27** which carries a driving gear **23**, which meshes with a pair of identical gears **24** and **25**, which are spaced 90° apart around the circumference of the driving gear **23**. A fourth gear **26**, identical to the others, meshes with the gears **24** and **25** at locations thereon spaced 90° apart from their respective interengagements with the driving gear **23**. From the arrows in Fig. 1, it will be noted that the driving gear **23** rotates counterclockwise in this view and drives the gears **24** and **25** to rotate clockwise. Both of the gears **24** and **25** drive the fourth gear **26** counterclockwise in Fig. 1. With this arrangement, a portion of the fluid entering through the inlet passage **17** is carried in the spaces between the teeth on gear **26** (rotating counterclockwise in Fig. 1) around to the discharge passage **15**; the rest of the fluid entering through the inlet passage **17** is carried in the spaces between the teeth on gear **24** (rotating clockwise in Fig. 1) around to the other discharge passage **16**; a portion of the fluid entering through the inlet passage **18** is carried in the spaces between the teeth on driving gear **23** (rotating counterclockwise in Fig. 1) around to the discharge passage **16**; and the rest of the fluid entering through the inlet passage **18** is carried in the spaces between the teeth on gear **25** (rotating clockwise in Fig. 1) around to the discharge passage **15**.

Since the fluid at the suction or inlet passages **17** and **18** is at low pressure and the fluid at the discharge passages **15** and **16** is at high pressure, the fluid at the discharge passages exerts a thrust on the gears **23** and **24** tending to force them inwardly, to the left in Fig. 1, and a thrust on the gears **25** and **26** tending to force them inwardly, to the right in Fig. 1. Thus, the meshing gears **24** and **26** are forced toward each other, and the meshing gears **23** and **25** are forced toward each other. In the prior art pumps, the output pressure in such pumps having practical gear proportions was limited by the load capacity of the radial bearings for the gear shafts. The present invention incorporates novel bearings for taking up the described fluid thrusts on the gears, which enable the pump to discharge fluid under increased pressure. Conversely, when operated as a fluid motor, the present invention is able to operate at higher intake fluid pressures. Also, the present invention includes means for causing the thrusts on each gear to be directed substantially in alignment with the axis of the adjacent meshing gear toward which it is being thrust.

Referring to Figs. 2 and 3, the driving gear **23** is mounted on a hollow shaft **27** which is coupled to the driving shaft **21**. Cylindrical steel rollers **28** and **29** are keyed to the shaft **27** at opposite sides of the gear **23** in spaced relation therefrom. A pair of identical rollers **30** and **31** is similarly keyed to the shaft **31***a* to which the gear **24** is attached. Likewise a pair of rollers, one of which is shown at **32** in Fig. 1, is similarly attached to the rotary shaft **33** on which gear **26** is mounted, at opposite sides of the gear **26** in spaced relation therefrom, and a pair of rollers, one of which appears at **34** in Fig. 1, is mounted in like manner on the rotary shaft **35** for the gear **25**. Each of the rollers has an outside diameter equal to the pitch diameter of the corresponding gear.

A bearing plate or wear plate **36** is snugly received within the annular housing member **13** and abuts against one end of each of the gears **23**—**26**. The bearing plate **36** is formed with four holes, one of which is shown at **38** in Fig. 3, properly spaced and dimensioned to pass the gear shafts **27**, **31***a*, **33** and **35** without impairing the free rotation of these shafts. The bearing plate **36** is formed at its periphery with an integral transverse flange **39** which is shaped to conform snugly to the interior wall of the housing member **13** and which at its outer face is spaced slightly from the inner face of the end plate **11** (see Fig. 2). The bearing plate **36** along with its flange **39** defines with the end plate **11** a chamber in which the rollers **28** and **30** for the gears **23** and **24** and the corresponding rollers (not shown) for the gears **25** and **26** are located. As indicated in Fig. 3, the bearing plate flange **39** with its inwardly protruding portions **40** between its corners defines a plurality of intersecting substantially cylindrical recesses for receiving the rollers, the protrusions **40** being located between the adjacent outer peripheral portions of adjacent rollers. These recesses are shaped complementary to the rollers for properly locating the same and providing bearing surfaces for the rollers, while at the same time permitting the rollers to engage one another at their respective inner peripheral portions where the respective recesses in the bearing plate intersect.

An identical bearing plate **41** is provided at the opposite side of the gears **23**—**26**, and defines with the end plate **12** a chamber having recesses which intersect for receiving and locating the rollers **29**, **31**, **32** and **34** (Fig. 1) for these gears.

Because of the leakage of fluid through the hole **38** in the bearing plate **36** into the space between the main body of bearing plate **36** and the roller **30**, which would build up pressure against the roller **30** tending to force the latter outwardly against the inner face of the end plate **11**, there is provided a snap ring **42** mounted in a groove in shaft

31*a* at the outer side of roller **30** for maintaining the roller **30** in its proper axial location on shaft **31***a*. Similar provision is made for each of the other rollers in the assembly. Alternatively, axial holes may be drilled through the rollers to insure equal pressures at opposite axial ends thereof to prevent axial displacement of the rollers.

As best seen in Fig. 1, the pump chamber **19** defined by the housing **13** is approximately square in configuration, with rounded corners permitting the free rotation of the gears. The gear teeth are disposed in close running fit with the rounded corners of the pump chamber to limit or prevent leakage of fluid from the high pressure passages, around the gear peripheries to the low pressure passage. There is, accordingly, a pressure gradient around the gear peripheries, the pressure on the gear peripheries varying from discharge pressure at the discharge passages to inlet pressure at the inlet passages. The resultant radial hydraulic thrust on each gear would normally extend in a direction away from high pressure passage and toward the low pressure passage. However, only that component of the radial thrust on each gear which extends in a direction through the axis of an adjacent roller would be transmitted to the adjacent roller. In accordance with the present invention, provision is made for adjusting the radial thrusts on each gear so that the resultant thrust extends in a direction through the axis of an adjacent gear whereby the rollers are effective to take up substantially all of the radial thrust on the gears. Under these conditions, the radial thrust on the gears will not be transmitted to the wear plates so that there is substantially no wear on the shaft journals formed in the wear plates and there is no radial pressure acting between the wear plates and the shafts which would impede free floating movement of the wear plates into engagement with the adjacent gear side faces.

As best shown in Figs. 1, 4 and 5, between the bearing plates **36** and **41**, the housing is cut away above and below the discharge passages **15** and **16** to provide the pressure distributing channels **43**, **44**, **45** and **46**, located respectively at the discharge side of the gears **23**, **24**, **25** and **26**. By virtue of these channels and the pressure gradient around each gear from the end of each channel to the adjacent suction inlet, the resultant fluid pressure unbalance forces on the gears, instead of being concentrated adjacent the discharge openings, are spaced over substantial area on the gears at their respective discharge sides. The lengths of these channels is made such that the resultant of the various increments of pressure on each of the gears is directed substantially directly toward the axis of an adjacent gear.

The fluid thrusts on the gears thus force the gears **23** and **25** toward each other and force the gears **24** and **26** toward each other. The rollers take up these various fluid thrusts and form the bearings needed for taking up the radial forces on the gear shafts. The rollers limit the displacement of the gears to the meshing position at which they operate most efficiently. Also these rollers have a considerably greater load carrying capacity than would a plurality of conventional roller bearings at the same location.

At substantial fluid pressures at the discharge side of the gears it has been found that, instead of one gear driving an adjacent gear, it is the driving roller which through friction drives the roller associated with the driven gear toward which the driving gear is thrust. This friction drive through the rollers results in a substantial reduction in gear noise in the pump.

The bearing or wear plates **36** and **41** are urged into engagement with the adjacent end faces of the gears and are preferably urged towards the gears by fluid pressure from the pump or motor in such a manner that the pressure urging the wear plates towards the gears bears a preselected relation to the pump discharge pressure acting on a portion of the gear face side of the wear plates.

In an embodiment of Figs. 1–4, pressure loading of the wear plates is effected by the slippage of fluid around the gear shafts and through the shaft holes in the bearing plates to the outer sides of the bearing plates for forcing them inwardly against the gears. The fluid pressure at the outer sides of the wear plates is effected by the slippage of fluid around the gear shafts and through the shaft holes in the bearing plates to the outer sides of the wear plates is therefore a pressure intermediate the discharge pressure and inlet pressure, which intermediate pressure varies with the discharge pressure.

The provision of the evenly spaced alternate fluid and discharge passages located symmetrically with respect to the bearing plates **36** and **41** enable them to operate more effectively in pressure loading. At the inner side of these bearing plates at the high pressure areas thereon the fluid tends to force them away from the gears to thereby increase slippage past the gears and decrease the pump efficiency. At the outer side of each plate there is a uniform fluid pressure, due to the pressure loading, which forces the plates inwardly toward the gears to decrease the slip path at the ends of the gears and thereby increase the pump efficiency. Since the spaced high pressure areas on the bearing plates at the inner sides thereof are located symmetrically about the plates there is no tilting of these plates, and the slip path at the ends of the gears is the same at the high pressure areas as at the low pressure areas. As contrasted with this desirable arrangement, in conventional two-gear pumps having pressure loading, with high pressure at one end of the wear plates and low pressure at the other end, the plates tend to be tilted by this pressure unbalance at their inner sides to have a greater slip path around the ends of the gears at the high pressure area, which is precisely where it is desired to minimize the slippage. The present invention avoids such difficulties by providing symmetrically located high pressure areas on the wear plates at their inner sides, so that the latter do not tilt and the pressure loading is effective at the high pressure areas in the pump.

For operating the device of Figs. 1–3 as a fluid motor (Fig. 4) rather than as a pump (Fig. 5), the connection to the prime mover is eliminated and the direction of rotation of each gear is reversed. Fluid under pressure at the inlet passages **15** and **16** drives the gears for rotation in the direction indicated and is discharged at low pressure through the outlet passages **17** and **18**. The thrust on the gears due to the pressure differential between the inlet and outlet sides is taken up by the rollers in the same manner as during the operation of the device as a pump.

Figure 6 shows schematically a six-gear form of the present invention. The annular pump housing **50** is formed with three low pressure passages **51**, **52** and **53**, which are evenly spaced around the circumference of the housing, and three evenly spaced high pressure passages **54**, **55** and **56**, located midway between the inlet passages around the circumference of the housing. The circularly arranged, evenly spaced shafts **57–62** carry identical gears **63–68**, each meshing with the two adjacent gears. Rollers **69–74** are mounted on the respective shafts at one side of the respective gears, with similar rollers (not shown) being provided at the opposite side of the gears. Each of the rollers has a diameter equal to the pitch diameter of its gear, and the rollers perform the same function as in the described four-gear embodiment of the invention. Bearing plates (not shown) similar to those in the embodiment of Figs. 1–3, but formed with six holes for receiving the gear shafts **57–62** and six intersecting recesses shaped complementary to the rollers for receiving the rollers, are snugly received within the pump housing **50**. These bearing plates serve to properly locate the gears and to provide bearing surfaces for the rollers, as well as to provide pressure loading on the gears, as in the first-described embodiment of the invention.

Assuming that the Fig. 6 assembly is operating as a pump, the high pressure passages 54, 55 and 56 are discharge passages at which the fluid is under pressure. The pressure unbalance in the system between the high and low pressure passages exerts forces against the gears tending to force the gears 63 and 68, 64 and 65, and 66 and 67 toward one another. In the six-gear pump, the rollers on each shaft contact the roller on an adjacent gear shaft at a point angularly spaced 120° from the mesh point of the gear at the high pressure passage, whereas in the four-gear pump, the roller on each gear shaft contacts the roller on an adjacent gear shaft at a point angularly spaced 90° from the mesh point of the gear at the high pressure passage. Consequently, the area on the gear periphery which need be exposed to the high pressure to adjust the direction of the resultant hydraulic thrust to extend through the axis of an adjacent gear, is smaller for the six-gear pump than for the four-gear pump. In the embodiment of Fig. 6, the high pressure passages 54, 55 and 56 are preferably proportioned to expose a peripheral area on each gear to the high pressure such that the resultant hydraulic thrust on each gear extends in a direction through the axis of an adjacent gear.

In the embodiment of the present invention which is shown in Fig. 7 there are provided two gear sets of four gears each. Figure 7 is a view similar to Fig. 2, with only two of the shafts, 77 and 78, appearing, these shafts carrying spaced pairs of gears 79 and 80, and 81 and 82, respectively, and single rollers 83 and 84.

Each roller serves as the radial bearing for its shaft. For locating the rollers and providing bearing surfaces therefor, there is provided the plate member 75 snugly disposed within the annular housing member 76 between the gears on each shaft. The annular member 75 is formed with four intersecting cylindrical recesses which provide curved interior surfaces shaped complementary to the rollers for properly locating the same and defining bearing surfaces therefor. Preferably pressure distributing channels are provided at the high pressure areas on the gears, as in the other four gear embodiment of the invention shown in Figs. 1–3.

Reference is now made to Figs. 8–14 wherein there is illustrated another embodiment of the pump of the present invention. The pump includes a pump housing 100 formed with an even numbered plurality of intersecting bores, here shown four in number and designated 111, 112, 113 and 114. End plates 115 and 116 are secured to opposite ends of the pump housing and close the ends of the pump bores therein. A plurality of pump gears 121—124 are disposed in the pump chambers 111—114, respectively, with each pump gear in meshing engagement with the pair of gears disposed in the adjacent pump bores to provide alternate inlet and discharge ports around the outer periphery of the gear assembly. The gears are supported on shafts 125–128 inclusive and, as shown in Fig. 8, the gear shafts may conveniently be formed integrally with the gears to extend from opposite sides thereof. One of the gear shafts designated 125 in Fig. 8 extends through the end wall 116 of the pump housing and is internally splined as at 129 for connection to the splined end 131 of the input shaft 132. As is conventional, a shaft seal (not shown) is disposed within the seal housing 133 on the end plate 116 to prevent leakage of fluid from the pump and along the input shaft.

A pair of bearing or wear plates 135 and 136 having the external periphery thereof formed complementary to the pump bores are slidably disposed in the latter in engagement with opposed end faces of the gears. In the form of the invention illustrated, the wear plates are mirror images of each other and accordingly like numerals are used to designate the same parts on the several wear plates. The wear plates have bores 125*a*—128*a* formed therein for rotatively receiving the gear shafts 125—128 respectively and advantageously, a wear lining 137 may be provided on the gear face side of the wear plates and also in the bores 125*a*—128*a*.

The pump gear assembly is arranged to have alternate inlet and discharge passages between adjacent pairs of meshing gears around the external periphery of the gear assembly. As best shown in Fig. 9, an inlet port 141 is formed in the pump housing in communication with a low pressure passage 142. The low pressure passage communicates through an inlet passage 143 with the pump chamber between the meshing gears 121 and 122 and extends around the gear assembly to the inlet passage 144 which communicates with the pump chamber between the meshing gears 123 and 124. An outlet port 145 communicates with a high pressure passage 146 in the pump housing, which high pressure passage communicates through the discharge passage 147 with the pump chamber between the meshing gears 121 and 124, the high pressure passage also communicating with the pump chamber between the meshing gears 122 and 123 through an opposed discharge passage 148. There are thus provided alternate high and low pressure passages symmetrically located around the periphery of the gear assembly, which alternate high and low pressure passages communicate with the pump chamber between adjacent pairs of meshing gears so that the assembly of the gears and the wear plates is substantially radially hydraulically balanced within the housing 100. There is consequently substantially no radial thrust between the housing and assembly of the gears and the wear plates so that the wear plates may freely move axially within the pump bores. Additionally, the high pressure areas on the gear face side of the wear plates are symmetrically located and, in the four-gear pump illustrated, are diametrically opposed so that the alternate high and low pressure areas on the wear plates do not tend to tilt the wear plates away from the adjacent gear end faces.

In order to reduce the wear on the bearings formed in the wear plates, a plurality of rollers 125*b*–128*b* are nonrotatably mounted on the shafts 125–128 respectively at the sides of the wear plates remote from the gears. The rollers are formed with an external diameter at least equal to the pitch diameter of the gears and are each disposed in rolling engagement with the adjacent pair of rollers. Preferably, the diameter of the rollers is made slightly greater than the pitch diameter of the gears so that when the gears are subjected to radial pressure and the shafts deflect slightly under this pressure, the gears will mesh properly. Advantageously, the rollers are provided with a small crown so that the rollers will not have only line contact along the edge, when the shafts deflect under pressure.

There is a radial hydraulic pressure acting on each of the gears, which hydraulic pressure varies from discharge pressure at the mesh point of the gears at the discharge passages 147 and 148 to inlet pressure adjacent the passages 143 and 144. This gradient pressure produces a resultant hydraulic thrust on each of the gears which extends in a direction away from the high pressure passages at an angle of greater than 90°, in the direction of rotation of the gears, from the mesh point of adjacent gears at the high pressure passages. In the four-gear pump, the rollers on each of the gear shafts contact the roller on an adjacent gear shaft at a point angularly spaced 90° from the mesh point of the gears at the high pressure passages. In the previously described embodiment, provision was made for adjusting the peripheral area on the gear which was exposed to high pressure so that the direction of the resultant hydraulic thrust on each gear extended in a direction through the axis of an adjacent gear so that the rollers would be effective to take up the radial hydraulic thrust.

In addition to the radial hydraulic forces on each gear, there are also radial mechanical thrusts on each gear produced as a consequence of the meshing inter-engagement of the gears and the transmission of power from

the drive gear to the several idler gears, which mechanical thrusts are commonly referred to as the tangential and separating forces on the gears. These mechanical forces produce radial mechanical thrusts on the gears which are appreciable at high pump pressures and, if not compensated, would tend to cause bearing wear.

Adjustment of the radial hydraulic loads, in the manner previously described materially reduces bearing wear since the rollers are effective to take up the radial hydraulic thrust on the gears. However, it has been found that the radial mechanical thrusts on the gears, superimposed on the radial hydraulic thrusts, change the direction and magnitude of the total resultant radial thrust on the gears. It is therefore preferred to adjust the radial hydraulic thrusts on the gears so that the total resultant radial thrust on each gear, including the radial hydraulic thrust and the radial mechanical thrust, is in a direction such that the rollers are effective to take up the full radial thrust on the gears. It is to be noted that the rollers are effective to take up the radial thrust on the gears whenever the radial gear loads are adjusted so that resultant radial thrust on each gear extends inwardly of the gear assembly, that is, in a direction between the points on each gear where it meshes with the adjacent pair of gears. In the four-gear pump illustrated, the resultant radial thrust must therefore extend at an angle of 90° or less measured in the direction of gear rotation from the mesh point of each gear at the high pressure passages. When the radial loads on the gears of the four-gear pump are adjusted to extend at an angle of 90° from the mesh point of the gears at the high pressure passage, the radial thrust on each gear will be transmitted through the rollers to the rollers on one of the adjacent gear shafts and when the radial thrust is adjusted to extend at at angle of less than 90°, the radial thrust on each gear will be transmitted to the rollers on both adjacent gear shafts. The rollers are thus effective to take up the total resultant radial thrust on the gears including the radial hydraulic thrust and the radial mechanical thrust, when the direction of the total resultant radial thrust is adjusted to extend inwardly of the gear assembly at the same angle, that is, whenever the direction of the total resultant radial thrust extends inwardly of the gear assembly between the mesh points of each gear with the adjacent pair of gears. In a four gear pump, the total resultant radial thrust on each gear should extend at the same angle of 90° or less from the mesh point of the gears at the high pressure passages.

The necessity of providing sufficient area of contact between the gear peripheries and the housing to form a seal thereat limits the area of the gear peripheries which can be exposed to high pressure to obtain the aforementioned adjustment of the direction of the resultant radial thrust on the gears. In practice it has been found sufficient to adjust the total radial thrusts in a four-gear pump to extend at an angle of 90° or slightly less than 90° from the mesh point of the gears at the high pressure passage.

Since the tangential and separating forces on the gears which make up the mechanical loads vary depending on which is the drive and driven gear and on the direction of rotation of the gears, the magnitude and direction of the radial mechanical loads on the gears vary for each of the pump gears. In order to adjust the total radial loads on the gears to extend inwardly of the gear assembly at the same angle from the mesh point of the gears at the high pressure passage, it is necessary to apply high pressure to different areas on each of the gears.

As best shown in Figs. 9 and 10, the peripheries of one and preferably both of the wear plates, at the gear face side thereof, are chamfered, as indicated at **205** and **206** from a point adjacent the discharge passage **147** part way around the peripheries of the gears **121** and **124** and are also chamfered as indicated at **207** and **208** from a point adjacent the discharge passage **148** part way around the peripheries of the gears **122** and **123**. Fluid at discharge pressure is thus applied part way around the peripheries of the gears adjacent the discharge passages, the length of the chamfers **205—208** being made such that the total resultant radial thrust on each of the gears extends in a direction inwardly of the gear assembly. In the embodiment illustrated, the length of the chamfers **205—208** is made such that the direction of the resultant radial thrust on gear **121** extends in a direction through the axis of the shaft **126** and the resultant radial thrust on the gear **122**, carried on the shaft **126**, extends through the axis of the shaft **125** as indicated by the arrows in Fig. 14. Similarly, the resultant radial thrust on gear **124** extends through the axis of shaft **127** and the radial thrust on the gear **123** extends through the axis of shaft **128**. These radial thrusts are substantially equal and opposite and, as previously described, are transmitted through the rollers **125*b*—128*b***.

Provision is made for applying pressure to the wear plates to urge the latter into engagement with opposite sides of the gear end faces and in accordance with the present invention, there is provided a clover-leaf shaped ring member **151** which surrounds the rollers at one end of the gear assembly. The ring member is snugly received within the pump chambers and has one end thereof disposed in engagement with the end wall **115** of the housing and the other end thereof disposed in engagement with the side of the adjacent wear plate **136** remote from the gear end faces. The length of the ring member is made greater than the length of the rollers and normally supports the wear plate **136** in spaced relation to the end wall **115** a distance such that the rollers and shafts are spaced from this end plate. An annular pressure member **155** is provided at the other end of the housing and includes a piston portion **156** which is slidably received in an annular groove **157** in the end plate **116** of the housing. For reasons set forth more fully hereinafter, the piston portion is sealed to the end plate by means of a pair of O-rings **158** and **159** disposed in grooves **161** and **162**. A clover-leaf shaped portion **163** is formed integrally with the piston portion and surrounds the rollers on shafts **125—128**, the end of the clover-leaf shaped portion **163** remote from the piston portion thereof being disposed in engagement with the end face of the wear plate **135** remote from the gears to thereby apply pressure around the entire periphery of the wear plate **135**. Since the pressure is applied around the entire periphery of the wear plates, distortion of the wear plates, at areas where there is a high pressure unbalance on opposite sides of the plates, is minimized. A plurality of tabs **166** (see Figs. 11 and 12) are provided on the portion **163** of the pressure member and engage the periphery of the wear plate **135** to center the pressure member thereon.

In accordance with the present invention the chamber formed within the housing between the wear plate **135** and the end wall **116** is communicated through one or more passages **168** (Fig. 12) with the low pressure passage **142** in the housing to thereby return the fluid, which leaks from the pump chambers past the wear plates, to the inlet side of the pump. The gear shafts **125—128** are preferably made hollow so that the pressure within the reservoir **169**, formed between the wear plate **135** and the end plate **116**, and the pressure in the reservoir **171**, formed at the other side of the gear assembly between the wear plate **136** and the end plate **115**, are equalized. A plurality of notches **170** (see Figs. 10 and 13) are formed in the sides of the wear plates **135** and **136** remote from the gears and provide free fluid flow between the pressure members **151** and **155** and the adjacent wear plates **136** and **135**, respectively. These notches are conveniently arranged at spaced intervals around the roller periphery to permit insertion of a tool into the notches for removal of the rollers. The pressures acting on the sides of the wear plates remote from the gears are thus substantially equal to inlet pressure while the pressure acting on the gear face side of the wear plates varies from inlet pressure adjacent the inlet

passages 143 and 144 to discharge pressure adjacent the ends of the grooves in the wear plates, full discharge pressure being applied across those portions of the wear plates in direct communication with the grooves therein. The pressure gradient on the gear face side of the wear plates also varies radially from discharge pressure adjacent the peripheries thereof to an intermediate pressure at the grinding relief grooves formed adjacent the gear trunnions.

The resultant hydraulic thrust on the gear face side of the wear plates is thus in a direction to urge the latter axially away from the adjacent gear end faces. In order to counterbalance the axial hydraulic thrust on the wear plates, discharge pressure is applied from the high pressure passage 146 through passages 173 and 174 (see Fig. 11) to the end of the piston portion 156 of the pressure member to urge the latter against the wear plate 135. The area of the inner end of the piston portion 156 is made such that discharge pressure acting thereon applies an axial thrust on the wear plate 135 which slightly overbalances the axial hydraulic unbalance on this wear plate whereby the latter is urged into engagement with the adjacent end faces of the gears. The pressure applied to wear plate 135 is transmitted through the gears which move axially into engagement with the wear plate 136, which last-mentioned wear plate is held against axial movement by the clover-leaf ring member 151, as previously described. In this manner, a preselected pressure unbalance is applied to urge the wear plates into engagement with the adjacent end faces of the gears and maintain a pumping seal thereat.

In order to reduce leakage from the pump chambers past the wear plates, sealing rings are provided to seal the interface between the wear plates and pump housing. As best shown in Fig. 8, the wear plates are formed with grooves 181 in the periphery thereof, which grooves have sealing rings 182 disposed therein to extend around the peripheries of the wear plates. The sealing rings are preferably formed with a central relieved area at the underside thereof to form a pressure chamber at the bottom of the groove, which pressure chamber is communicated through passages 183 (see Figs. 9 and 11) with the high pressure passages 147 and 148. Thus, fluid at discharge pressure is applied to the underside of the sealing rings to urge the latter outwardly into sealing engagement with the pump housing, and prevent leakage of fluid from the high pressure passages across the wear plate peripheries to the reservoirs 169 and 171. Preferably, the sealing rings 182 are located closely adjacent the gear face side of the wear plates so as to minimize the peripheral area around the wear plates through which fluid may leak from the high pressure passages 147 and 148 to the low pressure passages 143 and 144.

In accordance with the present invention, provision is made for positively forcing fluid through the bores in the wear plates to lubricate and cool the gear end faces and the gear shafts which are rotatively supported therein. As shown in Figs. 9, 10 and 14, the wear plates are formed with axially extending grooves 125*c*–128*c* which form lubrication passages. Provision is made for circulating the fluid which leaks from the pump chamber into the reservoirs 169 and 171 through these lubrication grooves. For this purpose the gear pump is arranged to provide a lubrication pump within the gear assembly and, as shown in Figs. 8 and 9, a plug member 185 is mounted on the wear plates to extend within the gear assembly in closely spaced adjacency to the gear peripheries thereat. In the form shown in the drawings, the plug member 185 is cylindrical in shape although it is to be understood that the plug member may be formed with a different cross sectional configuration and may be provided with cusps on the periphery thereof if additional pumping action is desired. The cylindrical plug member 185 extends through aligned axially disposed bores 186 and 187 in the wear plates 135 and 136, and has a head 188 on one end thereof which seats on the shoulder 189 formed by the counterbore 191. A spring 192 is interposed between the head 188 and the end plate 116 of the housing to retain the plug member in position, the spring 192 also providing a preselected constant pressure for urging the wear plates into engagement with the adjacent gear end faces to form a pumping seal thereat when the pump is not in operation and to thereby assure proper operation of the pump when the latter is put into operation. When operated as a pump, the gears 125–128 rotate in one direction as indicated by the arrows in Fig. 9 and thus provide alternate low pressure passages and high pressure passages within the gear assembly. More specifically, a low pressure passage is formed within the gear assembly between the gears 121 and 124 and a similar low pressure passage is formed between the gears 122 and 123, high pressure passages being formed within the gear assembly between gears 121 and 122 and also between gears 123 and 124 within the gear assembly. Lubrication pump inlet passages 193 and 194 extend through each of the wear plates from a point at the gear face side thereof adjacent the mesh point of the gears to the other side of the wear plates. Passages 193 and 194 communicate at the ends thereof remote from the gears through radial channels 195 and 196 with the reservoirs on the outer side of the wear plates and within the roller assembly so as to permit drawing of fluid from the reservoirs through the passages 193 to the pump chamber within the gear assembly. Channels 200 and 201 (see Fig. 9) are formed in the gear face side of the wear plates and communicate the high pressure passages formed between gears 123 and 124 and between gears 121 and 122 with the inner ends of the lubrication grooves 125*c*—128*c*. Preferably, the channels 200 and 201 are chamfered as indicated at 200*a* and 201*a* to reduce the wiping action of the groove edges on the gear end faces so that a film of liquid will remain on the gear end faces to lubricate the same. The outer ends of these lubrication grooves communicate through channels 202 and 203 with the reservoirs 169 and 171 around the roller assembly. In this manner, fluid from the reservoirs is drawn in through passages 193 and discharged under pressure through channels 200 and 201 to the lubrication grooves 125*c*—128*c*, the fluid passing from the other ends of these lubrication grooves through channels 202 and 203 back to the respective reservoirs.

The lubrication pump is thus separate from the main fluid pump and positively forces fluid through the lubrication grooves in the bearings without any decrease in volumetric efficiency of the pump. Moreover, since the lubrication pump draws fluid from the reservoirs on the outer side of the wear plates, which reservoirs are filled with fluid which leaks past the wear plates from the pump chambers, it is apparent that only fluid which has been effectively filtered by leakage past the wear plates is utilized to lubricate the pump. Consequently, any abrasive particles in the fluid being pumped will not pass into the reservoirs at the outer sides of the wear plates so that no abrasive material is circulated through the shaft bearings. Moreover, since the reservoirs are communicated to inlet, the fluid in these reservoirs is changed at a rate determined by the leakage past the wear plates and thus permits replenishing of the fluid within the chamber with relatively cooler fluid.

From the foregoing it is thought that the operation of the gear pump of Figs. 8–14 will be readily understood. As the gears rotate in the directions indicated by the arrows in Fig. 9, fluid is drawn in through the inlet passages 143 and 144 from the low pressure passage 142 and is carried around the peripheries of the gears to the high pressure or discharge passages 147 and 148 from which it flows through the high pressure passage 146 to the discharge port 145. The high pressure passages and the low pressure passages are symmetrically arranged around the peripheries of the gear assembly and consequently the

high pressure areas on the gear side of the wear plates are symmetrically located and do not cause the wear plates to tilt and produce uneven spacing between the wear plates and the gear end faces at the high pressure areas where proper seal is required. The chambers **205** and **206**, on the gear side of the wear plates, communicate the discharge passage **147** with portions of the peripheries of the gears **121** and **124** adjacent the discharge passages and produce a radial hydraulic unbalance on the gears **121** and **124** which, together with the radial mechanical forces acting on the respective gears, produces a total radial thrust on the respective gears to urge those gears in a direction in alignment with the axes of the adjacent meshing gears **122** and **123** respectively. The latter gears also have an hydraulic pressure unbalance applied thereto through chamfers **207** and **208** to thereby produce a radial hydraulic unbalance on the gears **122** and **123** which, together with the mechanical radial forces on these gears, produces a total radial thrust on the gears which is directed through the axes of gears **121** and **124** and opposes the radial thrust on the gears **121** and **124**. These radial thrusts are transmitted through the rollers and since the radial thrusts on the rollers **125***b* and **126***b* and the radial thrusts on the rollers **127***b* and **128***b* are substantially equal and opposite, wear on the bearings is minimized and in practice has been found to be negligible when the radial forces on the gears are adjusted to cancel, as previously described.

The reservoirs **169** and **171** are communicated with the inlet passages **142** so that a low pressure is applied across the outer faces of the wear plates and pressurized fluid from the discharge passage **146** is applied to the inner end of the pressure member to urge the latter against the wear plate **135** to thereby, in turn, urge the wear plate against the adjacent end faces of the gears. The pressure member extends around the roller assembly and engages the wear plate adjacent the periphery thereof so as to thereby uniformly distribute the pressure around the outer edge of the wear plate. This materially minimizes the tendency of the wear plate to deform under high pressure unbalance conditions, and thereby improves the overall efficiency of the pump.

The lubrication pump formed within the gear assembly draws the fluid which leaks into the reservoirs **169** and **171** in through the intake passages **193** and **194** and discharges fluid under pressure through the grooves **200** and **201** into the lubrication passages **125***c*—**128***c* inclusive. The fluid flows through the lubrication grooves and out through the channels **202** and **203** at the outer side of the wear plates back into the reservoir and is cooled therein by contact with the housing. In this manner, fluid is positively pumped across the gear end faces and through the lubrication passages in the bearings to lubricate and cool the same without diverting a part of the pump output through these passages, which practice results in a reduction in the volumetric efficiency of the pump. Moreover, drawing of fluid from these reservoirs results in the circulation of only filtered fluid through the bearings, the fluid being filtered by passage through the small leakage paths between the pump chamber and the reservoirs.

While in the foregoing description there have been disclosed specific preferred forms of the present invention, it is to be understood that various changes, modifications, omissions and refinements may be adopted which depart from the described forms of the invention without departing from the spirit and scope of my invention. For example, the passages for adjusting the radial pressures on the gears may be formed in either the pump housing or in the wear plates and may be located otherwise than as specifically shown.

I claim:

1. A rotary pump or fluid motor comprising an annular housing defining a fluid displacement chamber, a gear assembly including an even numbered plurality of gears disposed in said housing, each of said gears being mounted for rotation on separate shafts with each gear meshing with two adjacent gears, a cylindrical roller on each shaft in rolling engagement with the rollers on the adjacent pair of shafts, said housing having passages extending therethrough and each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others of said passages being discharge passages providing alternate high pressure areas around the gear assembly exerting a thrust on each gear, means at each of the high pressure areas extending over substantial areas of the peripheries of the gears for applying fluid pressure on the gear peripheries to direct the thrust against each gear in a direction toward the axis of one of the adjacent meshing gears whereby said rollers are effective to take up the radial thrust on the gears, and power transmission means connected to one of said shafts and extending out of the said housing.

2. A rotary pump or fluid motor comprising an annular housing defining a fluid displacement chamber, a gear assembly including an even numbered plurality of gears disposed in said housing, each of said gears being mounted for rotation on separate shafts with each gear meshing with two adjacent gears, a cylindrical roller on each shaft in rolling engagement with the rollers on the adjacent pair of shafts, said housing having passages extending therethrough and each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others of said passages being discharge passages providing alternate high pressure areas around the gear assembly exerting a thrust on each gear, fluid pressure distribution passages each communicating with said high pressure passages and extending part way around the peripheries of the gears, the lengths of said fluid distribution passages being made such that the direction of the radial thrust on each of the gears extends in a direction inwardly of the gear assembly between the mesh points of each gear with the adjacent pair of gears whereby the radial thrusts on the gears are transmitted through the rollers on the gear shafts to the rollers on the adjacent gear shafts, and power transmission means connected to one of said gear shafts and extending outwardly of said housing.

3. A rotary pump or fluid motor comprising an annular housing defining a fluid displacement chamber, a gear assembly including an even numbered plurality of gears disposed in said housing, each of said gears being mounted for rotation on separate shafts with each gear meshing with two adjacent gears, a cylindrical roller on each shaft in rolling engagement with the rollers on the adjacent pair of shafts, said housing having passages extending therethrough and each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others of said passages being discharge passages providing alternate high pressure areas around the gear assembly exerting a thrust on each gear, said gears having radial hydraulic and mechanical thrusts exerted thereon, fluid pressure distribution passages at each of the high pressure passages for applying fluid pressure to a portion of the gear peripheries, said fluid distribution passages having relatively different lengths on each gear such that the total radial mechanical and hydraulic thrust on each gear extends inwardly of the gear assembly at substantially the same angle measured from the mesh point of the gears at the high pressure passages whereby the radial thrusts on adjacent gears are equal and opposite and are transmitted radially through the rollers to cancel each other.

4. A gear pump or fluid motor comprising an annular housing defining a fluid displacement chamber, four evenly spaced shafts disposed within said chamber in a square pattern, four aligned identical gears each mounted on a separate one of said shafts and each meshing with

the gears on two adjacent shafts, power transmission means connected to one of said shafts and extending out of said housing, said housing being provided with a plurality of alternate fluid inlet and discharge passages disposed around the external periphery of the gear assembly and each communicating with the peripheries of the gears between adjacent pairs of meshing gears and providing alternate high and low pressure areas adjacent the mesh points of adjacent pairs of gears externally of the gear assembly, a roller on each of said shafts having a diameter equal to the pitch diameter of said gears, and fluid pressure distribution passages for applying fluid pressure from the high pressure areas around substantial areas at the gear peripheries, said passages applying high fluid pressure to an area on each gear such that the direction of the resultant thrust on each gear extends in a direction towards the axis of an adjacent gear whereby said rollers are effective to take up the radial thrusts on the gears.

5. A gear pump or fluid motor comprising a housing defining a fluid displacement chamber, four evenly spaced shafts disposed within said chamber in a square pattern, a gear assembly comprising four gears each mounted on one of said shafts and each meshing with the gears on two adjacent shafts, the mesh points of each gear with the pair of adjacent gears being angularly spaced 90° apart, a roller on each of said shafts in rolling engagement with the rollers on an adjacent pair of shafts, said housing having flow passages therein communicating with said chamber externally of the gear assembly between each pair of meshing gears, alternate ones of said passages being inlet passages and the others of said passages being outlet passages to provide alternate high and low pressure areas around the gear assembly, fluid pressure distribution means for applying fluid pressure from the high pressure passages to substantial areas on the gear peripheries, the fluid distribution passages being arranged to apply fluid pressure from the high pressure areas to an area on the periphery of each gear such that the direction of radial thrust on each gear extends inwardly of the gear assembly at an angle of not more than 90° from the mesh point of each gear at the high pressure areas whereby the rollers are effective to take up the full radial thrust on the gears.

6. A gear pump or fluid motor comprising a housing defining a fluid displacement chamber, four evenly spaced shafts disposed within said chamber in a square pattern, a gear assembly comprising four gears each mounted on one of said shafts and each meshing with the gears on two adjacent shafts, a roller on each of said shafts in rolling engagement with the rollers on the adjacent pair of shafts, the mesh points of each gear with the pair of adjacent gears being angularly spaced 90° apart, said housing having flow passages therein communicating with said chamber externally of the gear assembly between each pair of meshing gears, alternate ones of said passages being inlet passages and the others of said passages being outlet passages to provide alternate high and low pressure areas around the gear assembly, fluid pressure distribution means for applying fluid pressure from the high pressure passages to substantial areas on the gear peripheries, the fluid pressure distribution passages being arranged to apply fluid pressure from the high pressure areas to relatively different areas on the peripheries of each gear such that the direction of the radial thrust on each gear extends inwardly of the gear assembly at the same angle of not greater than 90° from the mesh point of the gears at the high pressure areas whereby the radial thrusts on each gear are equal and opposite to the radial thrusts on adjacent gears, the radial thrusts on each gear shaft being transmitted by the rollers on that shaft to the rollers on the adjacent gear shafts to thereby provide a gear assembly which is substantially radially balanced.

7. A gear pump or fluid motor comprising a housing enclosing a fluid displacement chamber, an even numbered plurality of gears disposed within said housing and each meshing with a pair of adjacent gears, a wear plate having the periphery thereof contoured complementary to said chamber slidably disposed in said housing and located at one end of the gears to form a fluid seal there at, each of said gears being mounted on separate shafts, means rotatably mounting one end of each of said shafts in said wear plate, power transmission means connected to one of said shafts and extending out of said housing, said housing having a plurality of alternate fluid inlet and discharge passages extending therethrough and communicating with the peripheries of the gears externally of the gear assembly between pairs of meshing gears to provide alternate high fluid pressure and low fluid pressure areas around the external periphery of the gear assembly, means for applying pressure against the wear plate at the face thereof remote from the gears to pressure load the wear plate toward the gears, said high and low pressure areas being located symmetrically around the gear assembly so that the fluid pressures acting radially on the gear assembly and wear plate are substantially balanced and the axial fluid pressures acting on the face of the wear plate adjacent the gears are symmetrical of the wear plate.

8. A gear pump or fluid motor comprising a pump housing having an even numbered plurality of intersecting bores therein defining a pump chamber, end plates on said housing closing opposite ends of said chamber, a gear assembly comprising an even numbered plurality of gears in said chamber each meshing with two adjacent gears, said housing having an even numbered plurality of passages communicating with said chamber externally of the gear assembly and between meshing pairs of gears, alternate ones of said passages being inlet passages and the others being outlet passages and providing alternate high and low pressure areas around the gear assembly, each of said gears being mounted for rotation on separate shafts, wear plates contoured complementary to said pump chamber and slidably disposed therein on opposite ends of the gears, said wear plates having bores therein for rotatably receiving said shafts, means for urging the wear plates against the adjacent end faces of the gears, said high and low pressure areas being located symmetrically around the gear assembly and around the peripheries of the wear plates so that the fluid pressures acting radially on the gear assembly and wear plates are substantially radially balanced and the axial fluid pressures on the gear face side of the wear plates are symmetrically located and do not cause tilting of the wear plates, and power transmission means connected to one of said shafts and extending out of said housing.

9. A gear pump or fluid motor comprising a pump housing having an even numbered plurality of intersecting bores therein defining a pump chamber, end plates on said housing closing opposite ends of said chamber, a gear assembly comprising an even numbered plurality of gears in said chamber each meshing with two adjacent gears, said housing having an even numbered plurality of passages communicating with said chamber externally of the gear assembly and between meshing pairs of gears, alternate ones of said passages being inlet passages and the others being outlet passages and providing alternate high and low pressure areas around the gear assembly, each of said gears being mounted for rotation on separate shafts, wear plates contoured complementary to said pump chamber and slidably disposed therein on opposite ends of the gears, said wear plates having bores therein for rotatably receiving said shafts, means for urging the wear plates against the adjacent end faces of the gears, said high and low pressure areas being located symmetrically around the gear assembly and around the peripheries of the wear plates so that the fluid pressures acting radially on the gear assembly and wear plates are substantially radially balanced and the axial fluid pressures on the gear face side of the wear plates are symmetrically located and do not cause tilting of the wear

plates, power transmission means connected to one of said shafts and extending out of said housing, rollers on opposite ends of said shafts between said wear plates and the adjacent housing end plate, said rollers being disposed in rolling engagement with an adjacent pair of rollers and operative to take up the radial thrusts on the gears to limit the radial thrust which is transmitted from the gear shafts to the wear plates and thereby reduce wear on the bores in the wear plates.

10. A gear pump or fluid motor comprising a housing enclosing a fluid displacement chamber, an even numbered plurality of aligned identical gears mounted on separate shafts within said housing and each meshing with the gears on the two adjacent shafts, each of said shafts carrying a pair of cylindrical rollers located at opposite ends of the respective gear in spaced relation therefrom and having a diameter equal to the pitch diameter of the gear, the rollers at each side of the gear assembly being in alignment with one another, power transmission means connected to one of said shafts and extending out of said housing, a pair of wear plates snugly and slidably located within said housing at opposite ends of the gears and disposed between the gears and the respective rollers at opposite ends of the gears, each of said wear plates being apertured to receive said shafts, a plurality of evenly spaced fluid inlet and discharge passages disposed in alternate sequence about the assembly of gears and communicating with the meshing gears of each pair at the outer sides thereof and providing alternate high pressure and low pressure areas at alternate locations around the gear assembly, the fluid pressure unbalance between said inlet and discharge passages exerting a thrust on each gear displacing it toward an adjacent gear, said rollers being operative to engage one another to take up said fluid pressure unbalance thrusts to provide radial bearings for the shafts, and means for applying pressure against the wear plates at the respective sides thereof remote from the gears to pressure load the wear plates toward the gears, said high fluid pressure areas around the gear assembly being located symmetrically about the wear plates at the respective sides thereof adjacent the gears to maintain the wear plates evenly spaced from the respective adjacent ends of the gears at said high pressure areas and said low pressure areas.

11. A gear pump or fluid motor comprising a pump housing having an even numbered plurality of intersecting bores therein defining a pump chamber, end plates on said housing closing opposite ends of said chamber, a gear assembly comprising an even numbered plurality of gears in said chamber each meshing with two adjacent gears, said housing having an even numbered plurality of passages communicating with said chamber externally of the gear assembly and between meshing pairs of gears, alternate ones of said passages being inlet passages and the others being outlet passages and providing alternate high and low pressure areas around the gear assembly, each of said gears being mounted for rotation on separate shafts, wear plates contoured complementary to said pump chamber and slidably disposed therein on opposite ends of the gears, said wear plates having bores therein for rotatably receiving said shafts, means for urging the wear plates against the adjacent end faces of the gears, said high and low pressure areas being located symmetrically around the gear assembly and around the peripheries of the wear plates so that the fluid pressures acting radially on the gear assembly and wear plates are substantially radially balanced and the axial fluid pressures on the gear face side of the wear plates are symmetrically located and do not cause tilting of the wear plates, power transmission means connected to one of said shafts and extending out of said housing, rollers on opposite ends of said shafts between said wear plates and the adjacent housing end plate, said rollers being disposed in rolling engagement with two adjacent rollers, and pressure distribution passages for applying fluid pressure from the high pressure areas around substantial areas on the peripheries of each gear, the areas on the gear peripheries to which fluid pressure is applied being made such that the total radial thrust on each gear extends inwardly of the gear assembly at substantially the same angle measured from the mesh point of the gears at the high pressure passages.

12. A gear pump or fluid motor comprising a pair of spaced end plates and an annular housing member disposed between said end plates and defining therewith a fluid displacement chamber, four evenly spaced shafts disposed within said chamber in a square pattern, a pair of spaced gears mounted on each shaft, said gears forming two spaced sets of four aligned gears each and each of said gears meshing with the aligned gears on the two adjacent shafts, each of said shafts carrying a cylindrical roller located between the gears on that shaft and having a diameter equal to the pitch diameter of the gears, the rollers being in alignment with one another, a bearing plate member positioned within said fluid displacement chamber between said sets of gears, said bearing plate member being formed with intersecting recesses shaped complementary to the rollers for receiving and locating the rollers and forming bearing surfaces therefor, said annular housing member being provided with a plurality of alternately disposed fluid inlet and discharge passages communicating with pairs of meshing gears and providing alternate high and low pressure areas around the gear assembly, the fluid pressure unbalance between alternate ones of said locations around the gear assembly exerting a thrust on each gear displacing it toward an adjacent gear with which it meshes, and means at each of said high pressure areas extending over substantial areas of the gear peripheries thereat for applying fluid under pressure from said high pressure areas to the gear peripheries to direct the thrust against each gear in a direction substantially through the mesh point of the gears at said low pressure areas, said rollers taking up the fluid pressure unbalance thrusts on the gears to thereby form radial thrust bearings for said shafts and at substantial fluid pressure unbalances forming friction drives between adjacent shafts which are thrust toward one another.

13. A gear pump or fluid motor comprising a housing enclosing a fluid displacement chamber, an even numbered plurality of gears mounted on separate shafts within said housing and each meshing with a pair of adjacent gears, a plurality of aligned cylindrical rollers mounted respectively on each shaft and each being of a diameter equal to the pitch diameter of the gear on its shaft, power transmission means connected to one of said shafts and extending out of said housing, a wear plate snugly and slidably received within said housing and located at one end of the gears, a plurality of evenly spaced fluid inlet and discharge passages disposed in alternate sequence about the assembly of gears and communicating with the meshing gears of each pair at the outer sides thereof and providing alternate high pressure and low pressure areas around the gear assembly, the fluid pressure unbalance between said inlet and discharge passages exerting a thrust on each gear displacing it toward an adjacent gear and said rollers being operative to engage one another to take up said fluid pressure unbalance thrusts to provide radial bearings for the shafts, and means for applying pressure to the wear plate at the face thereof remote from the gears to pressure load the wear plate toward the gears, said high fluid pressure areas around the gear assembly being located symmetrically about the wear plate at the face thereof adjacent the gears to maintain the wear plate evenly spaced from the respective adjacent end of the gears at said high pressure areas and said low pressure areas.

14. In a fluid pump or motor, a pump housing having four intersecting bores defining a pump chamber, end plates on said housing closing said chamber, a gear assembly including four gears in said chamber each mounted

for rotation on separate shafts, each of said gears being disposed in meshing engagement with two adjacent gears, a roller on each of said shafts in rolling engagement with the rollers on the adjacent pair of shafts, the mesh points of each gear with the adjacent gears being angularly spaced 90° apart, wear plates slidably disposed in said housing on opposite ends of the gears and having bores therein for rotatably receiving the gear shafts, said housing having a plurality of passages communicating with the pump chamber externally of the gear assembly and between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others of said passages being discharge passages providing alternate high and low pressure areas around the gear assembly and around the wear plates, said high and low pressure areas being symmetrically located whereby the fluid pressures acting radially on the gear assembly and wear plates are substantially balanced and the axial fluid pressures on the gear face side of the wear plates are symmetrical of the plate and do not cause tilting of the wear plates, means for applying a pressure correlative with the pressure at the high pressure areas to said wear plates to urge the latter against the gear end faces, and pressure distribution passages for applying fluid from the high pressure areas to areas on the peripheries of each of the gears, the areas on the gear peripheries to which high pressure is applied being adjusted so that the total radial force on each gear extends at the same angle of 90° or less measured from the mesh point of the gears at the high pressure areas whereby the radial thrusts on the adjacent gears are equal and opposite and are transmitted through the rollers on each shaft to the rollers on the adjacent shafts to thereby cancel one another.

15. A rotary pump comprising a housing defining a fluid displacement chamber, a gear assembly including an even numbered plurality of gears disposed in said housing, each of said gears being mounted for rotation on separate shafts in meshing engagement with two adjacent gears, said housing having a plurality of passages extending therethrough and each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others of said passages being discharge passages, walls in said housing engaging opposed end faces of the gears, said walls having bores extending therethrough for rotatably supporting the gear shafts, means in said housing forming fluid reservoirs on the sides of each of said walls remote from the gears to collect the fluid which leaks from the displacement chamber past said walls, a body disposed within said gear assembly having the periphery thereof disposed adjacent the periphery of the gears of said assembly to provide alternate lubricating pump inlet and discharge chambers between adjacent pairs of meshing gears internally of the gear assembly, each of said bores in said walls having a channel therein for the passage of fluid when the shaft is disposed in the bore, and passage means in said walls for communicating said lubricating pump inlet and discharge passages with said reservoirs through said channels in the walls to circulate fluid from the reservoir through the lubrication channels.

16. A rotary pump comprising a housing defining a fluid displacement chamber, a gear assembly including an even numbered plurality of gears disposed in said housing, each of said gears being mounted for rotation on separate shafts in meshing engagement with two adjacent gears, said housing having a plurality of passages extending therethrough and each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others of said passages being discharge passages, walls in said housing engaging opposed end faces of the gears, said walls having bores extending therethrough for rotatably supporting the gear shafts, means in said housing forming fluid reservoirs on the sides of each of said walls remote from the gears to collect the fluid which leaks from the displacement chamber past said walls, a body disposed within said gear assembly having the periphery thereof disposed adjacent the periphery of the gears of said assembly to provide alternate lubricating pump inlet and discharge chambers between adjacent pairs of meshing gears internally of the gear assembly, each of said bores in said walls having a channel therein for the passage of fluid when the shaft is disposed in the bores, bores extending through said walls communicating each of said lubrication pump inlet chambers with said reservoirs, passages in said walls communicating the ends of said channels adjacent the gears with said lubrication pump discharge chambers and the other ends of said channels with said reservoirs whereby said lubrication pump circulates the fluid from said reservoirs through said channels.

17. A rotary pump comprising a housing defining a fluid displacement chamber, a gear assembly including an even numbered plurality of gears disposed in said chamber, each of said gears being mounted for rotation on separate shafts in meshing engagement with two adjacent gears, said housing having a plurality of inlet and discharge passages each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others being discharge passages, wear plates slidably disposed in said displacement chamber on opposite sides of the gears and in engagement with opposed end faces thereof, said wear plates having bores extending therethrough for rotatably supporting said gear shafts, said housing having end walls spaced from said wear plates to form fluid reservoirs on the sides of said wear plates remote from said gears to collect the fluid which leaks from said displacement chamber past said wear plates, a body carried by said plates and extending therebetween within the gear assembly and having the periphery thereof disposed adjacent the peripheries of the gears of the assembly to provide alternate lubricating pump inlet and discharge chambers internally of the wear assembly, channels in each of said bores in said wear plates, and passage means in said plates for communicating said lubricating pump inlet and discharge chambers with said reservoirs and with said channels to circulate fluid from the reservoirs through said channels.

18. A rotary pump comprising a housing defining a fluid displacement chamber, a gear assembly including an even numbered plurality of gears disposed in said chamber, each of said gears being mounted for rotation on separate shafts in meshing engagement with two adjacent gears, said housing having a plurality of inlet and discharge passages each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others being discharge passages, wear plates slidably disposed in said displacement chamber on opposite sides of the gears and in engagement with opposed end faces thereof, said wear plates having bores extending therethrough for rotatably supporting said gear shafts, said housing having end walls spaced from said wear plates to form fluid reservoirs on the sides of said wear plates remote from said gears to collect the fluid which leaks from said displacement chamber past said wear plates, a pin extending through said wear plates and having the periphery thereof disposed adjacent the peripheries of the gears to provide alternate lubricating pump inlet and discharge chambers internally of the gear assembly, channels in each of said bores in said wear plates, and passage means in said wear plates communicating said lubricating pump inlet and discharge passages with reservoirs and with said channels to circulate fluid from said reservoirs through said channels.

19. The combination of claim 18 wherein said pin has a head on one end thereof, and spring means interposed

between one end wall of the housing and the head on the pin.

20. A rotary pump comprising a housing defining a fluid displacement chamber, a gear assembly comprising an even numbered plurality of gears disposed in said chamber, each of said gears being mounted on separate shafts in meshing engagement with two adjacent gears, said housing having a plurality of inlet and discharge passages each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others being discharge passages providing alternate high and low pressure areas around the gear assembly, a wear plate slidably disposed in said displacement chamber having one face thereof adapted to engage one end face of said gears, said wear plates having bores therein for rotatably receiving said shafts, said high pressure areas being symmetrically located around the gear assembly whereby the fluid pressures acting radially of the gear assembly are substantially balanced and the axial fluid pressures on the gear face side of the wear plate are symmetrical and do not cause tilting of the wear plate, said housing having an end wall spaced from said wear plate and defining a chamber therebetween, means communicating said last mentioned chamber with one of said inlet passages, an annular pressure member slidably mounted in said end wall and engaging the said wear plate adjacent the periphery thereof, and means applying discharge pressure to the end of said pressure member remote from said wear plate to urge the latter into close running fit with the adjacent end faces of said gears.

21. The combination of claim 20 wherein the area on the end of the pressure member remote from the wear plate is proportioned so that the discharge pressure acting thereon produces an end thrust on the pressure member which slightly exceeds the thrust due to the pressure unbalance on opposite sides of the wear plate.

22. A rotary pump comprising a housing defining a fluid displacement chamber, a gear assembly comprising an even numbered plurality of gears disposed in said chamber, each of said gears being mounted on separate shafts in meshing engagement with two adjacent gears, said housing having a plurality of inlet and discharge passages each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others being discharge passages providing alternate high and low pressure areas around the gear assembly, a wear plate slidably disposed in said displacement chamber having one face thereof adapted to engage one end face of said gears, said wear plates having bores therein for rotatably receiving said shafts, said high pressure areas being symmetrically located around the gear assembly whereby the fluid pressures acting radially of the gear assembly are substantially balanced and the axial fluid pressures on the gear face side of the wear plate are symmetrical and do not cause tilting of the wear plate, said housing having an end wall spaced from said wear plate and defining a chamber therebetween, means communicating said last mentioned chamber with one of said inlet passages, rollers on one end of each of said shafts at the side of said wear plate remote from the gears, said rollers having an outer diameter equal to the pitch diameter of the gears and each disposed in rolling engagement with an adjacent pair of rollers, an annular pressure member surrounding said rollers and engaging the side of said wear plate remote from the gears adjacent the periphery thereof, the other end of said pressure member being slidably supported in said end wall, and passage means for applying pressurized fluid from the discharge passage to said last mentioned end of the pressure member to urge the wear plate against the adjacent end faces of the gears.

23. The combination of claim 22 including tabs on said pressure member engageable with the periphery of said wear plate to center said pressure member thereon.

24. A rotary pump or fluid motor comprising an annular housing defining a fluid displacement chamber, a gear assembly including an even numbered plurality of gears disposed in said chamber, each of said gears being mounted on separate shafts, a roller on each of said shafts having a diameter equal to the pitch diameter of the gear on said shaft, means including a plate contoured complementary to said chamber and slidably disposed therein for supporting said gears thereon with each gear in meshing engagement with an adjacent pair of gears, said housing having passages extending therethrough and each communicating with the gear peripheries externally of the gear assembly between the gears of each meshing pair, alternate ones of said passages being inlet passages and the others of said passages being discharge passages providing alternate high and low pressure areas around the gear assembly exerting a thrust on each gear, means at each of the high pressure areas extending over substantial areas of the peripheries of the gears for applying fluid pressure on the gear peripheries to direct the thrust against each gear in a direction toward the axis of one of the adjacent meshing gears whereby said rollers are effective to take up the radial thrust on the gears, and power transmission means connected to one of said shafts and extending out of said housing.

25. The combination of claim 24 wherein said rollers are rotatably supported in said plate.

26. The combination of claim 24 wherein said shafts are rotatably supported in said plate.

27. A gear pump or fluid motor comprising housing means defining a fluid displacement chamber, six evenly spaced shafts disposed within said chamber with each of the shafts equidistant from the two adjacent shafts, a gear mounted on each of said shafts and meshing with respective gears on the two adjacent shafts, said housing means being provided with a plurality of fluid inlet and discharge passages communicating with pairs of meshing gears and disposed alternately in evenly spaced relation around the gear assembly and providing alternate high and low pressure areas around the gear assembly, a roller mounted on each shaft having a diameter equal to the pitch diameter of the corresponding gear, said rollers being in alignment with one another, means at each of said high pressure areas for applying fluid pressure from the high pressure areas to an area on the periphery of each gear such that the radial thrust on each gear extends in a direction substantially through the mesh point of the gears at the low pressure passage whereby the fluid pressure unbalance between alternate ones of said locations around the gear assembly exerts a thrust on each gear displacing it toward an adjacent gear with which it meshes, said rollers taking up said fluid pressure unbalance thrusts on the gears to thereby form radial thrust bearings for said shafts, and power transmission means connected to one of said shafts and extending out of said housing.

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