Aug. 6, 1957 — B. H. MOSBACHER — 2,801,593

ROTARY PUMP

Filed May 3, 1954 — 2 Sheets-Sheet 1

Fig. 1

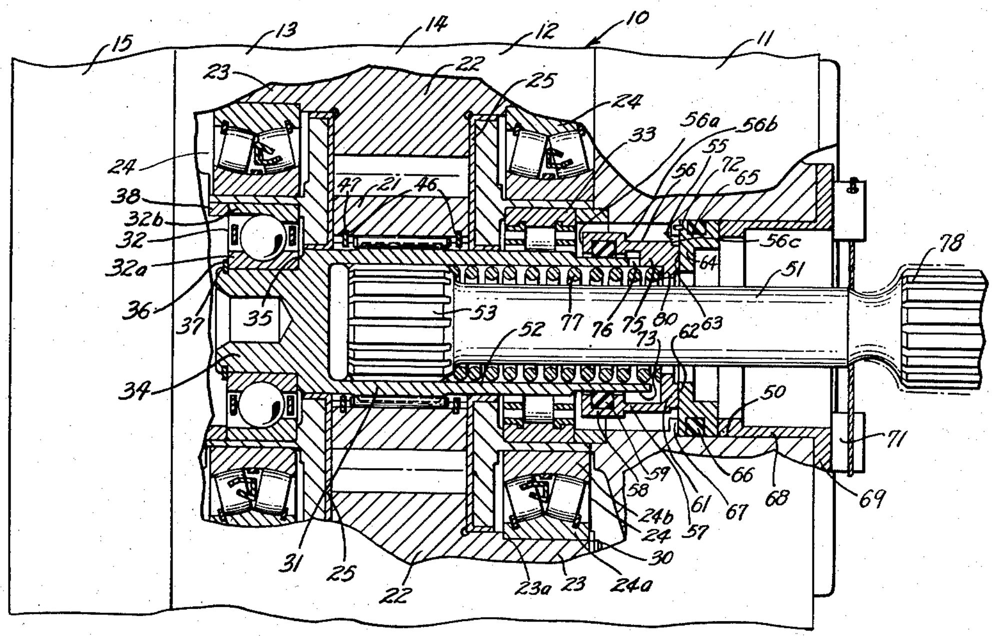

Fig. 2

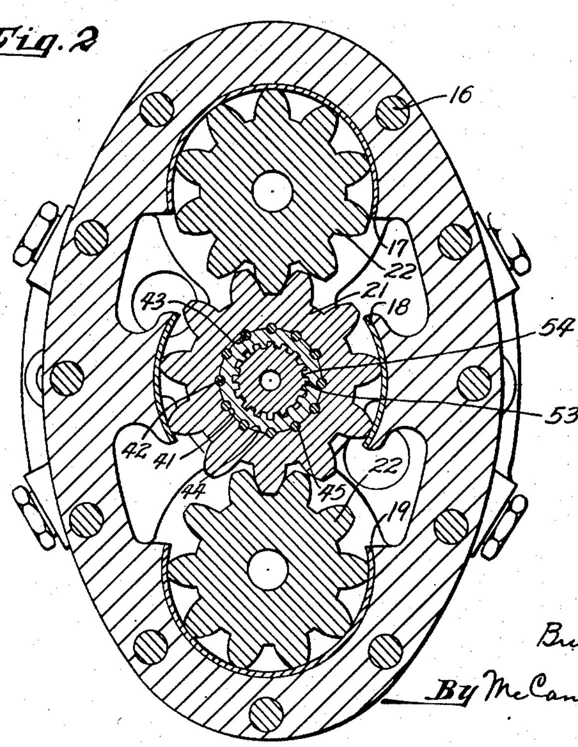

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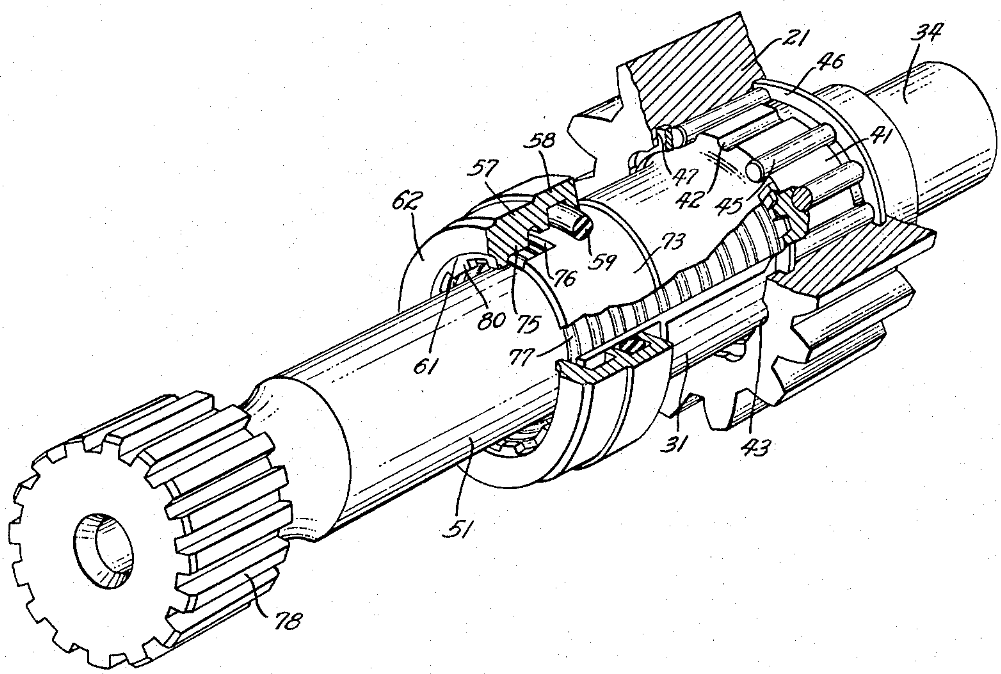
Fig. 3



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ROTARY PUMP

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13 Claims. (Cl. 103—126)

This invention relates to improvements in rotary pumps.

An important object of this invention is the provision of an improved rotary pump in which the radial and axial thrusts on the drive shaft are not transmitted to the pump gears thereby reducing wear on the pump.

Another object of this invention is the provision of a rotary pump in which the gear shaft is journaled in the pump casing and fixed against axial movement and wherein the gear is mounted on the gear shaft to float freely thereon thereby permitting the gear faces to be closely fitted between the stationary side walls of the pump chambers.

Another object of this invention is the provision of an improved drive for a rotary pump which will accommodate misalignment between the pump gear shaft and the power input shaft which drives the pump.

A further object of this invention is the provision of an improved high pressure seal for a rotary pump wherein the drive shaft is mounted so as to accommodate considerable misalignment between the pump gear shaft and the power input shaft, which seal is arranged so that the rotary seal member is mounted on the gear shaft for rotation about the axis thereof independent of the position of the drive shaft.

Still another object of this invention is the provision of an improved high pressure seal for a rotating shaft in which the rotary seal member is mounted on the shaft so as to be free to align its face with the face on the stationary seal member and which rotary seal member does not wobble as the shaft rotates.

Yet another object of this invention is the provision of a high pressure seal for a rotary shaft which is substantially hydraulically balanced so that the pressure applied to seat the rotary seal against the fixed seal remains substantially constant and is independent of the variations in the pressure which the seal must operate against.

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 a fragmentary side elevational view of the pump, parts being broken away and shown in longitudinal section;

Fig. 2 is a transverse sectional view through the pump illustrating the construction of the pump chambers and gears; and

Fig. 3 is a perspective view of the pump drive and seal assembly, parts being broken away and shown in section to illustrate details of construction.

Reference is now made more specifically to the accompanying drawings wherein there is illustrated a rotary pump having the improved drive and seal assembly incorporated therein. The pump comprises a casing **10** formed in a plurality of sections and including a face plate **11**, a pair of bearing support sections **12** and **13**, a pump chamber section **14** interposed between the bearing support sections and a back plate **15**. The sections are secured together by means of bolts **16** which extend therethrough. As shown in the drawings, the pump casing is formed with a plurality of intersecting bores **17**, **18** and **19** and having a drive gear **21** and driven gears **22** disposed thereat and in meshing engagement with each other. The three gear pump illustrated in the drawings is advantageous in that the resultant hydraulic pressure acting on the central drive gear, due to the differential between the pump inlet and discharge pressures, is substantially zero. Consequently, the bearing load on the drive gear shaft is low. However, it is to be understood that the improved drive and seal assembly of the present invention may be employed with equal facility on other types of pumps.

The driven gears **22** have integral trunnions **23** formed thereon, which trunnions are rotatably supported in the self-aligning anti-friction bearing assemblies **24** carried by the bearing support sections **12** and **13**. The inner bearing race **24*a*** of each of the bearing assemblies **24** is locked against axial movement between the shoulder **23*a*** and the locking ring **30** on the trunnion **23**, and the outer bearing race **24*b*** is mounted for limited axial movement to accommodate expansion and contraction of the gears and trunnions. In this manner, the driven gears are rigidly supported radially and mounted for limited axial float so that the end faces of the driven gears may become aligned between the registering faces of the wear plates **25**.

The drive gear **21** is mounted on a hollow gear shaft **31**, which gear shaft is rotatably journaled at one end by means of an anti-friction bearing assembly **32** carried by the bearing support section **13** and is journaled adjacent its other end by means of an anti-friction bearing assembly **33** carried by the bearing support section **12**. The differential between the hydraulic pressure acting on the inner end of the shaft **31** and the atmospheric pressure acting on the other end of this shaft produces an hydraulic unbalance which forces the shaft **31** to the right, as viewed in Fig. 1. In accordance with the present invention, the shaft **31** is mounted in the pump housing so as to positively prevent axial movement in the direction in which the shaft is forced by the hydraulic pressure unbalance. As shown in Fig. 1, the anti-friction bearing assembly **32** is a combined radial and thrust bearing and is arranged to take the thrust produced by the hydraulic pressure unbalance. The hollow shaft **31** has a reduced end **34** which is received in the inner bearing race **32*a*** of the anti-friction bearing assembly **32**, which reduced section defines an annular shoulder **35** on the shaft that engages the edge of the inner bearing race **32*a***. A locking ring **36** is mounted in a groove **37** on the reduced end of the gear shaft and engages the opposed edge of the inner bearing race **32*a*** to thereby lock the gear shaft against axial movement relative to the inner bearing race. The outer bearing race **32*b*** is locked against axial movement by a sleeve **38** which engages the edge thereof and which is retained in position by engagement with the back plate **15**. Thus, the gear shaft **31** is rotatably journaled in the pump casing and fixed against axial movement relative thereto.

The driven gear **21** is mounted on the gear shaft **31** for free axial movement relative thereto so that the driven gear is free to align its end faces with the faces of the wear plates **25**. In accordance with the present invention, the gear shaft **31** is provided with an enlarged cylindrical portion **41** having a plurality of semi-cylindrical slots **42** formed therein and which are adapted to register with corresponding semi-cylindrical slots **43** formed in the internal passage **44** in the drive gear. A plurality of pins **45** are disposed in the registering slots, which pins are retained in position by means of retainer rings **46** disposed in the annular slots **47** in the drive gear. The drive gear thus floats freely on the gear shaft. Since the gear shaft 31 is fixed against axial movement, and the drive gear 21 is mounted on the shaft 32 for free axial float, the end thrusts on the shaft, due to hydraulic and mechanical pressures applied thereto, are not transmitted to the drive gear, thereby reducing wear on that gear and on the wear plates 25 in the pump casing. Further, since the gear is mounted for free axial float, it may be closely fitted between the side walls of the pump chamber thereby providing improved pump performance.

The pump is arranged to be driven from a drive pad or power input shaft (not shown) and it is a feature of the present invention that the pump drive shaft 51 is arranged to accommodate misalignment between the power input shaft and the gear shaft 31. For this purpose, the drive shaft 51 has one end thereof extending loosely into the passage 52 in the hollow gear shaft and is provided with an enlarged externally splined portion 53 which cooperated with the internal splines 54 formed on the gear shaft to drivingly interconnect the inner end of the drive shaft thereto. The enlarged spline portion 53 on the drive shaft is loosely received in the splines in the gear shaft so that axial and angular movement of the drive shaft relative to the gear shaft about the splined connection therebetween may be effected. Since the gear shaft 31 is fixed axially and radially, it is apparent that the axial and radial thrusts produced by the movement of the drive shaft 51 are not imparted to the drive gear 21.

A high pressure seal assembly 55 is provided to prevent the pump fluid from leaking through the passage 50 in the face plate 11 through which the drive shaft 51 extends. The rotary seal member 56 of the fluid seal assembly is mounted on the gear shaft for rotation therewith independent of the position of the drive shaft 51 relative to the gear shaft. As best seen in Fig. 1, the rotary seal member 56 includes an annular body 57 having an annular channel-shaped portion 58 on one end thereof and opening inwardly for the reception of an O-ring 59. An inwardly extending flange 61 is formed on the other end of the rotary seal member and is provided with a flat annular sealing face 62 which is adapted to register with the sealing face 63 on the stationary seal member 64. The latter is also annular in form and has a peripheral groove 65 formed therein for the reception of an O-ring 66. The stationary seal member 64 is received in the passage 50 in the face plate 11 and the inner face of the seal member abuts an annular shoulder 67 formed in the passage, the stationary seal member being retained against the shoulder by the retaining sleeve 68. The latter has a flanged end 69 which is secured to the face plate 11 as by fasteners 71. As shown in Fig. 1, the stationary seal member is positively locked against rotation by means of a pin or pins 72.

The channel-shaped portion 58 on the rotary seal member is loosely received on the reduced end 73 of the gear shaft, and is supported thereon by the O-ring 59 for limited axial and angular movement relative to the gear shaft. The rotary seal member is therefore free to move angularly about the gear shaft so that the sealing face 62 thereon may align itself with the sealing face 63 on the stationary member. When thus aligned with the sealing face on the stationary member, the rotary member will rotate about the axis of the gear shaft without wobble relative to the stationary seal member, as occurs when the rotary seal member is fixed to the shaft and the sealing face thereof is not exactly normal to the axis of the shaft. Thus, if the sealing face 62 of the rotary seal member is not exactly normal to its axis or if the sealing face 63 of the stationary seal member is not exactly normal to the axis of the shaft 31, the rotary seal will pivot relative to the shaft 31 about the O-ring 59 until the rotary seal face mates properly with the stationary seal face 63. As the shaft 31 rotates, the rotary seal member rotates therewith but with its axis inclined to the axis of the shaft. However, after the rotary seal member has become tilted relative to the shaft 31 so that its seal face 62 registers with the stationary seal face 63, the mass of the rotary seal member does not have to move in an axial direction relative to the stationary seal member, as the rotary seal member rotates, in order to maintain the rotary seal face against the stationary seal face. Consequently, there is no inertial force tending to prevent the rotary seal face from maintaining a proper seal with the stationary seal face. Contrarywise, in those shaft seal constructions employing a rotary seal member which is fixed to the shaft, the mass of the stationary seal member must move in a direction axially of the rotating shaft, if the sealing face of the rotary seal member is not exactly normal to its shaft, in order to maintain a proper seal thereat. At high shaft speeds, the inertia of the stationary seal member prevents the latter from closely following the undulations of the sealing face of the rotary seal member thereby impairing the effectiveness of the seal.

The rotary seal member 56 has a plurality of circumferentially spaced inwardly extending keys 75 which are loosely received in a notch 76 in the gear shaft whereby the rotary seal member is positively driven by the gear shaft and wear on the gasket member 59 due to slippage between the rotary seal and the shaft is prevented. The rotary seal member is yieldably urged against the stationary seal member by means of a coil spring 77, which coil spring is disposed loosely around the drive shaft 51 and within the passage 52 in the gear shaft 31. The inner end of the spring 77 abuts the internal splines 54 on the gear shaft 31 and the outer end of the spring abuts the portion 80 of the flange 61 on the rotary seal member which extend inwardly of the gear shaft. As best shown in Fig. 3, the portion 80 is formed with notches therein so that the externally splined end 53 of the drive shaft 51 may pass therethrough when assembling the pump. The drive shaft 51 may thus freely move within the gear shaft 31, inward movement of the drive shaft being limited by engagement of the inner end of the drive shaft with the inner end of the gear shaft and outward movement of the drive shaft being limited by engagement of the internally splined end 53 on the drive shaft with the inner end of the spring 77. The spring 77 which urges the rotary seal member against the stationary seal thus also yieldingly retains the drive shaft 51 within the gear shaft, inward movement of the inner end of the spring being limited by engagement with the internal splines 54 on the gear shaft. As shown in Figs. 1 and 3, the outer end of the drive shaft 51 is provided with an enlarged externally splined portion 78 which is adapted to be received in a drive pad or an internally splined power input shaft (not shown) in such a manner as to permit relative axial and angular movement therebetween. Since the splined ends 53 and 78 on the drive shaft are larger in diameter than the spring, the latter must be formed by first winding the spring on the drive shaft and thereafter heat treating the spring to obtain the desired characteristics.

In order to provide a uniform pressure on the rotary seal member notwithstanding variations in the pump discharge pressure, the rotary seal member is preferably hydraulically balanced. Some of the fluid passing through the pump leaks past the bearing assembly 33 into the passage 50 and fills the latter. This fluid is under pressure, hereinafter referred to as an intermediate pressure, which is less than the pump discharge pressure and greater than the atmospheric pressure outside the pump. The fluid in the passage 50 acting on the rotary seal member produces a predetermined end thrust thereon tending to urge the rotary seal against the stationary seal. The magnitude of this thrust is determined by the area of the rotary seal member 56 which is directly exposed to this pressure, hereinafter referred to as the effective area of the rotary seal. In the rotary seal illustrated in the drawings, the effective area of the rotary seal is the area of the inner end 56a of the rotary seal member 56 between the gear shaft **31** and the outer periphery of the rotary seal member less the areas of the faces of the steps **56***b* and **56***c*. Thus, the axial thrust produced by the intermediate pressure acting on the effective area of the rotary seal is equal to the thrust produced by the intermediate pressure acting on an area equal to the face area of an annular disk having an outer diameter equal to the outer diameter of the rotary seal face **62** and an inner diameter equal to the outer diameter of the shaft **31**.

The hydraulic pressure acting on the seal face **62** of the rotary member decreases from a maximum adjacent the outer edge thereof to zero adjacent the inner end. This pressure gradient acting on the sealing face will tend to counteract the axial thrust due to the hydraulic pressures acting on the areas of the rotary seal member which are directly exposed to the intermediate pressure. In accordance with the present invention, the area of the sealing face is proportioned to the effective area on the sealing member which is exposed to intermediate pressure so that the total hydraulic force acting on the sealing face of the rotary member will substantially counterbalance the resultant hydraulic force acting on the areas of the rotary seal which are directly exposed to the intermediate fluid pressure. Thus, the spring **77** provides a substantially constant pressure for urging the rotatary member against the stationary seal member and, since the rotary seal member is substantially hydraulically balanced, this pressure does not materially increase or decrease with variations in the intermediate pressure produced by changes in pump discharge pressure. In practice, the relative areas are so proportioned that there is a slight excess hydraulic pressure acting on the rotary seal which aids the spring **77** in retaining the latter in sealing engagement with the stationary seal **64** to avoid the possibility that the hydraulic forces acting on the rotary seal would oppose the sealing pressure applied by the spring and thereby cause leakage past the seal.

It has been found that movement of the rotary seal member eccentrically relative to the stationary seal member greatly reduces the effectiveness of the seal. However, such movement is prevented in the present seal, even when the drive shaft is angularly displaced relative to the gear shaft, since the rotary seal is supported on the gear shaft, independent of transaxial movement of the drive shaft. Moreover, the rotary seal member is mounted on the gear shaft for axial and angular movement relative thereto whereby the rotary seal member is free to align its face with the face on the stationary seal member, and when thus aligned, the rotary seal will rotate with the gear shaft without wobble relative to the stationary seal member. It is also to be noted that the interface between the rotary and the stationary seal extends radially of the gear shaft so that the centrifugal force will aid in preventing the leakage of liquid between the rotary and stationary seals.

I claim:

1. In a device of the character described comprising a casing, a hollow shaft mounted for rotation in said casing, a rotary seal member mounted on one end of said hollow shaft for axial and angular movement relative thereto, said rotary seal member having a flat annular sealing face on one end thereof, a stationary seal member mounted on said casing and having a flat sealing face cooperating with the sealing face on said rotary member, a drive shaft extending into said hollow shaft and drivingly connected thereto internally of said hollow shaft, said drive shaft having an enlarged portion on the inner end thereof, and a spring disposed in said hollow shaft around said drive shaft and having one end thereof in engagement with said enlarged portion on the drive shaft and the other end engaging said rotary seal member to yieldably urge the latter into sealing engagement with the stationary seal member.

2. In a device of the character described comprising a casing, a hollow shaft mounted for rotation in said casing, a rotary seal member mounted on one end of said hollow shaft for axial and angular movement relative thereto, said rotary seal member having a flat annular sealing face on one end thereof, a stationary seal member mounted on said casing and having a flat sealing face cooperating with the sealing face on said rotary member, a drive shaft extending into said hollow shaft and drivingly connected thereto internally of said hollow shaft, said drive shaft having an enlarged portion on the inner end thereof, and a spring disposed in said hollow shaft around said drive shaft and having one end thereof in engagement with said enlarged portion on the drive shaft and the other end engaging said rotary seal member to yieldably urge the latter into sealing engagement with the stationary seal member, and means providing a positive drive connection between the rotary seal member and the hollow shaft.

3. In a device of the character described comprising a casing, a hollow shaft member mounted for rotation in said casing, a rotary seal member mounted on one end of said hollow shaft for axial and angular movement relative thereto, said rotary seal member having a flat annular sealing face on one end thereof, a stationary sealing member mounted on said casing and having an annular sealing face cooperating with the sealing face on the rotary member, a drive shaft having one end extending loosely into said hollow shaft, means drivingly connecting said one end of said drive shaft to the hollow shaft internally of the latter for limited axial and angular movement relative to the hollow shaft about said connecting means, and spring means disposed within said hollow shaft and engaging said rotary seal member to yieldably urge the latter into sealing engagement with the stationary seal member.

4. In a device of the character described comprising a casing, a hollow shaft member mounted for rotation in said casing, a rotary seal member mounted on one end of said hollow shaft for axial and angular movement relative thereto, said rotary seal member having a flat annular sealing face on one end thereof, a stationary sealing member mounted on said casing and having an annular sealing face cooperating with the sealing face on the rotary member, a drive shaft having one end extending loosely into said hollow shaft, means drivingly connecting said one end of said drive shaft to the hollow shaft internally of the latter for limited axial and angular movement relative to the hollow shaft about said connecting means, and spring means disposed within said hollow shaft and engaging said rotary seal member to yieldably urge the latter into sealing engagement with the stationary seal member, said drive shaft having an enlargement on the inner end thereof, the other end of said spring means engaging said enlargement to yieldably urge said drive shaft inwardly of said hollow shaft.

5. In a fluid pump or motor comprising a pump casing having a pump chamber therein, a hollow gear shaft sealed at one end thereof and mounted for rotation in said casing, thrust means engaging said hollow shaft for preventing axial movement thereof out of said casing, a pump gear disposed in said pump chamber and having a spline connection to said gear shaft for rotation therewith and for free axial movement relative thereto, a drive shaft having one end extending loosely into said gear shaft and adapted for connection at the other end to a power shaft, said one end of said drive shaft having a loose spline connection to said gear shaft internally of the latter drivingly connecting said shafts, said spline connection between said gear shaft and said drive shaft permitting limited axial and angular movement of the drive shaft about the connection to accommodate misalignment between the power shaft and the gear shaft.

6. The combination of claim 5 wherein the spline connection between the drive and gear shaft is located

within the spline connection between the gear shaft and the pump gear.

7. In a fluid pump or motor comprising a casing having a pump chamber therein, a hollow gear shaft mounted for rotation in said casing and sealed at one end thereof, thrust means preventing axial movement of said gear shaft, a pump gear disposed in said pump chamber and having a spline connection to said gear shaft for rotation therewith and free axial movement relative thereto, and a drive shaft having one end extending into said gear shaft, said drive shaft having a spline connection to said gear shaft for rotation therewith and for free axial movement relative thereto, an annular rotary seal member having one end loosely received on said gear shaft for axial and angular movement relative thereto, said rotary seal member having a flat annular sealing face on one end thereof, a stationary seal member mounted on said casing and having a flat sealing face cooperating with the face on the rotary member, and means yieldably urging said rotary seal member into sealing engagement with said stationary member.

8. In a fluid pump or motor comprising a casing having a pump chamber therein, a hollow gear shaft mounted for rotation in said casing, thrust means preventing axial movement of said gear shaft, a pump gear disposed in said pump chamber and having a spline connection to said gear shaft for rotation therewith and free axial movement relative thereto, and a drive shaft having one end extending into said gear shaft, said drive shaft having a spline connection to said gear shaft for rotation therewith and for free axial movement relative thereto, an annular rotary seal member having one end loosely received on said gear shaft for axial and angular movement relative thereto, said rotary member having a flat annular sealing face on one end thereof, a stationary seal member mounted on said casing and having a flat sealing face cooperating with the face on the rotary member, a spring disposed in said gear shaft around said drive shaft, one end of said spring engaging the spline connection between the drive shaft and the gear shaft, the other end of said spring engaging said rotary seal member to yieldably urge the latter into sealing engagement with the stationary member.

9. The combination of claim 8 including means providing a positive drive connection between said rotary seal member and said gear shaft.

10. In a fluid pump or motor including a casing, a shaft member in said casing, means for sealing the interface between said shaft member and the casing comprising a rigid annular rotary seal member loosely surrounding said shaft member, thrust means separate from said seal member engageable with said shaft member for preventing axial movement of the latter outwardly of the casing, an annular resilient gasket interposed between said members to floatingly support said seal member on the shaft member, a collar on one of said members engageable with the side of the gasket opposed to the side exposed to the fluid pressure in the casing, said gasket engaging the other of said members to form a slidable liquid seal at the point of engagement therewith, an annular seal face on said rotary seal member spaced axially from said gasket and extending radially inwardly and outwardly from the point of engagement of said gasket with said other member, a stationary seal having a face opposed to the seal face on said rotary member, means yieldably urging said rotary member towards said stationary seal to form a running seal thereat, the area of the seal face on the rotary seal member being greater than the effective area on the other end of the rotary seal member which is exposed to the fluid pressure in the casing to effect substantial hydraulic balance of the rotary seal member.

11. In a fluid pump or motor including a casing, a shaft member in said casing, means for sealing the interface between said shaft member and the casing comprising a rigid annular rotary seal member loosely surrounding the shaft member, thrust means separate from said seal member and engageable with said shaft member for preventing movement of the latter outwardly of said casing, an annular resilient gasket interposed between said members to floatingly support the seal member on the shaft member, a collar on one of said members engageable with the side of said gasket opposed to the side exposed to the fluid pressure in the casing, said gasket engaging the other of said members to form a slidable fluid seal at the point of engagement therewith, an annular seal face on one end of said rotary member having the inner and outer peripheries thereof respectively disposed radially inwardly and outwardly of the seal point of said gasket with said other member, a stationary seal having an annular seal face juxtaposed to the seal face on the rotary member, means yieldably urging said rotary member towards said stationary member to cause the seal face on the rotary member to align itself with the seal face on the stationary seal and form a running seal thereat, said rotary member having the fluid pressure in said housing applied thereto to an effective area equal to the radial area between the seal point of said gasket with said other member and the periphery of the seal face on the rotary member at the high pressure side of the seal face, the area of the seal face on the rotary member being greater than said effective area by an amount such that the gradient pressure on the seal face exerts a thrust on the rotary member substantially equal and opposite to the thrust of the fluid pressure in the casing acting on said effective area.

12. In a fluid pump or motor including a casing, a shaft member in said casing, means for sealing the interface between said shaft member and the casing comprising a rigid annular rotary seal member loosely surrounding the shaft member, thrust means separate from said seal member and engageable with said shaft member for preventing movement of the latter outwardly of said casing, an annular resilient gasket interposed between said members to floatingly support the seal member on the shaft member, a collar on one of said members engageable with the side of said gasket opposed to the side exposed to the fluid pressure in the casing, said gasket engaging the other of said members to form a slidable fluid seal at the point of engagement therewith, an annular seal face on one end of said rotary member having the inner and outer peripheries thereof respectively disposed radially inwardly and outwardly of the seal point of said gasket with said other member, a stationary seal having an annular seal face juxtaposed to the seal face on the rotary member, means yieldably urging said rotary member towards said stationary member to cause the seal face on the rotary member to align itself with the seal face on the stationary seal and form a running seal thereat, said rotary member having the fluid pressure in said housing applied thereto to an effective area equal to the radial area between the seal point of said gasket with said other member and the periphery of the seal face on the rotary member at the high pressure side of the seal face, the area of the seal face on the rotary member being greater than said effective area by an amount such that the gradient pressure on the seal face exerts a thrust on the rotary member substantially equal and opposite to the thrust of the fluid pressure in the casing acting on said effective area, and means on said shaft engageable with said rotary member for effecting a positive drive connection between said rotary seal member and said shaft.

13. In a fluid pump or motor including a casing a hollow shaft extending into said casing and sealed at the inner end thereof, means for sealing the interface between said shaft and said casing comprising a rigid annular rotary seal member loosely surrounding said shaft, thrust means separate from said seal member engageable with said shaft for preventing axial movement of the latter outwardly of the casing, an annular resilient gasket carried by said seal member and engageable with said shaft

to form a seal therewith, an annular seal face on said rotary member having the outer periphery thereof spaced radially outwardly from the point of engagement of said gasket with said shaft, said seal face being located beyond the end of said hollow shaft and extending radially inwardly of the point of engagement of said gasket with said shaft across the end of the latter, a stationary seal having a seal face in juxtaposition to the seal face on the rotary member, a spring disposed within said hollow shaft engaging said rotary seal member to urge the latter into a running seal with the stationary seal, the area of said seal face being greater than the effective radial area between the outer periphery of the rotary seal face and the point of engagement of the gasket with said shaft, by an amount such that the axial hydraulic thrust due to the gradient pressure on said seal face is substantially equal and opposite to the axial thrust due to the fluid pressure in said casing acting on said effective area on the rotary seal member, and a drive shaft extending into said hollow shaft and drivingly connected thereto inwardly of said spring.

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