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(54) Apparatus for liquid sealing a pump shaft

(57) An apparatus for liquid sealing a shaft (12) projecting externally of a housing (30), said housing (30) being provided with a seal chamber (38) formed adjacent said pump chamber (33), said seal chamber (38) having an external opening (38*a*) through which said shaft (12) projects and having a liquid flow outlet (32) which allows a cooling fluid to reduce the frictional heat formed in the vicinity of shaft seal (44, 52; 47, 50).

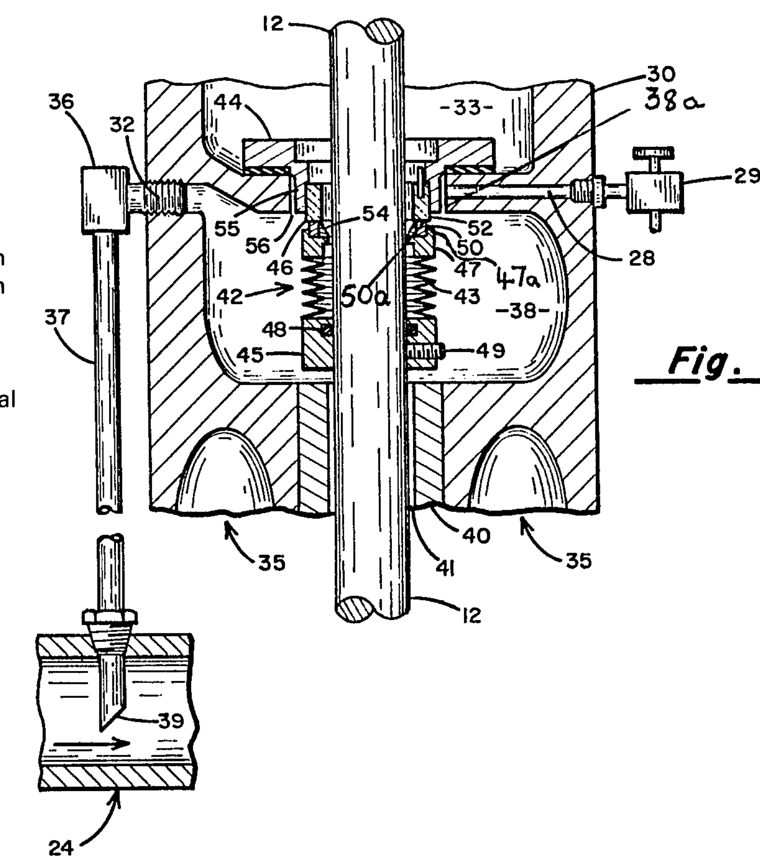

Fig. 4

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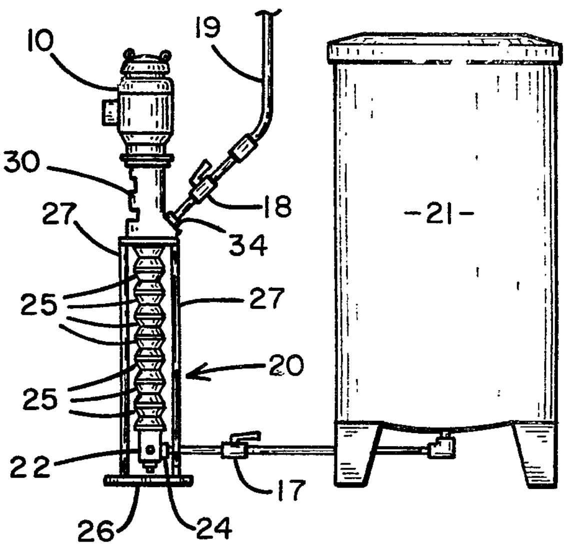

Fig. 1

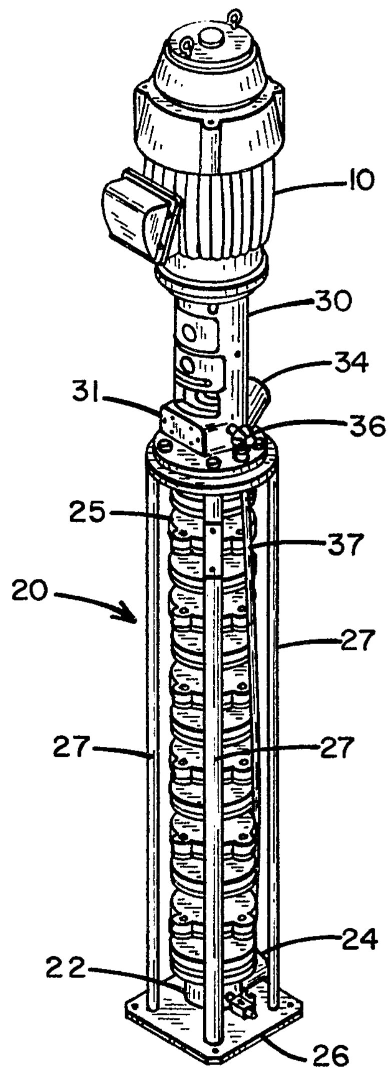

Fig. 2

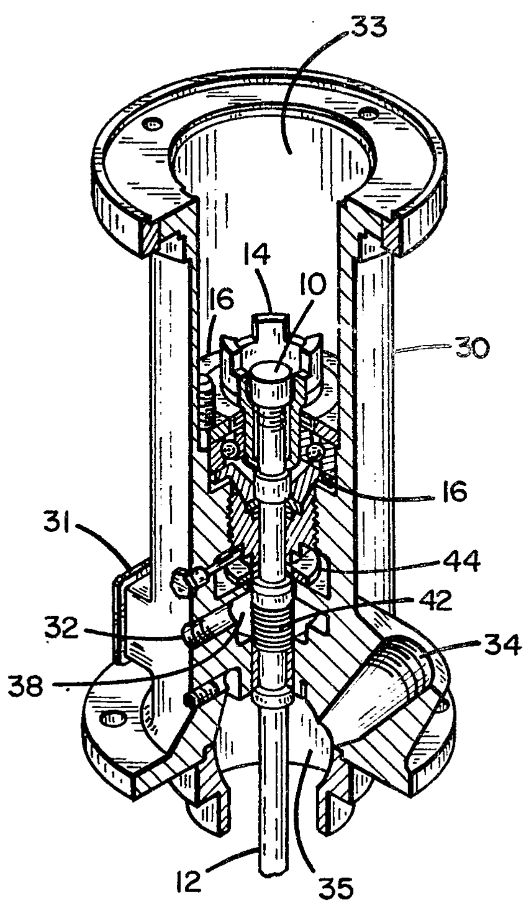

Fig. 3

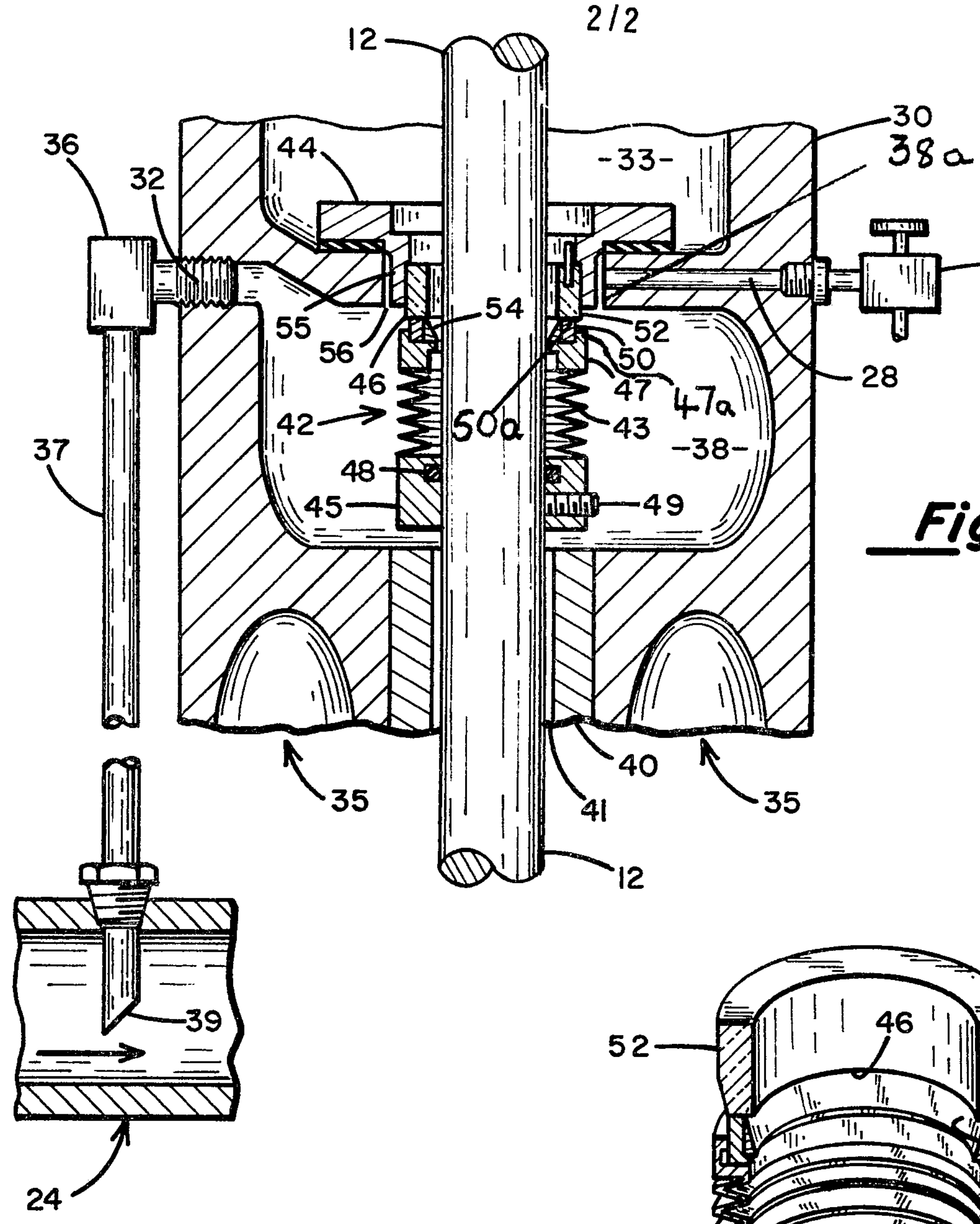
12
30
38a
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Fig. 4

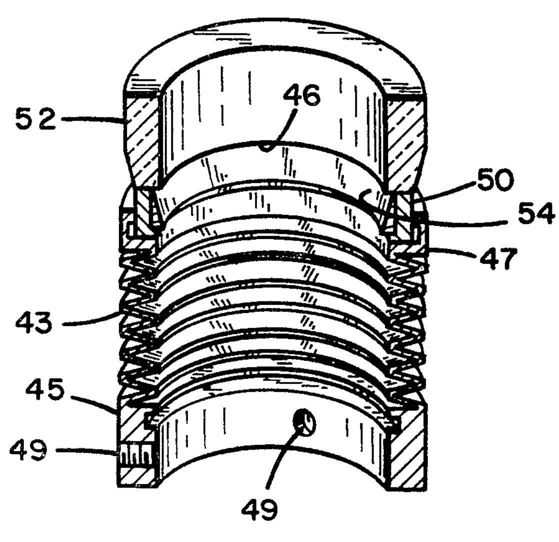
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Fig. 5

SPECIFICATION

Apparatus for Liquid Sealing a Pump Shaft

The present invention relates to pump shaft sealing apparatus. Although not so restricted, it more particularly relates to a novel seal for providing liquid flow isolation between the interior of a centrifugal pump and the exterior through a pump shaft opening. The invention is preferably adaptable for use in connection with centrifugal pumps having a vertical drive shaft orientation, including one or more series-connected stages of pumping elements for developing elevated pressure and flow conditions.

The use of series-connected impeller pumps for developing increasing pressure levels is well-known in the art, including the use of such pumps in connection with a common drive shaft. One such pump is manufactured by the present applicants under the model name "Imperial" centrifugal pump, which utilizes from four to twelve impeller pumps ganged together on a single drive shaft and connected to an electrical drive motor. Each of the impeller stages are series-connected to provide successively increasing pressures and relatively high flow rates of viscous liquids. The impeller stages are assembled in stacked relationship on a pump stand, with a vertical drive shaft extending from the bottom stage through the topmost stage and terminating in a housing mounted on the pump stand above all of the stages. An electric drive motor is mounted on top the housing, and a mechanical coupling link is provided between the drive motor and the drive shaft. An inlet connection is provided into the bottom pumping stage, and internal passages couple successive stages together in series flow fashion. The topmost stage is fluid coupled into an outlet housing, and pumped liquid is delivered from this housing to various conduits.

In an industrial plant setting, a pump of the type described herein is typically placed near a large volume container which may hold paint, oils, or other liquid materials, and the pump outlet is connected to a conduit delivery system which may be piped over fairly long distances within the industrial plant. These pumping systems are typically operated over long periods of time, and may in certain instances be operated twenty-four hours per day indefinitely until a maintenance problem develops within the pump. The most typical maintenance problem is a leakage problem caused when the various shaft seals began to wear away, which initially results in a fairly small amount of leakage which builds up over time until the leaking pump liquid accumulates over the area around the pump. When this occurs the pump delivery system must be shut down for maintenance and repair.

Since these pumps typically operate over long periods of time and are unattended, it is extremely important that a high degree of reliability be built into the pump. Since the most frequent maintenance problem arises out of leakage through shaft seals, great care is usually taken to design effective seals which will operate over extended time periods. The most frequent cause of shaft seal leakage results from over heating caused by friction, and it is therefore extremely important to design such seals to operate with as little frictional heat build-up as possible.

The object of the present invention is an improvement in pump design to minimize frictional heat build-up in the vicinity of a pump shaft seal, and further to provide a shaft seal design which is not adversely affected by small accumulations of material resulting from a leakage and other factors, which would otherwise adversely accumulate to hinder the efficient operation of the seal.

According to the present invention, there is provided an apparatus for liquid sealing a pump shaft projecting externally of a housing which houses a pump chamber, said housing being provided with

a) a seal chamber formed adjacent said pump chamber, said seal chamber having an external opening through which said shaft projects and having a liquid flow outlet,

b) a first seal member mounted about said shaft, said first seal member being sealably affixed to the housing around said external opening and having a neck projecting into said external opening;

c) a second seal member sealably affixed to said shaft in said seal chamber and which has a shoulder in said seal chamber;

d) a first sealing ring affixed to the said first seal member, and having a first smooth seal face in said seal chamber; and

e) a second sealing ring seated in said shoulder, and having a second smooth seal face in said seal chamber and mated to said first smooth seal face; whereby liquid in said seal chamber is in flow contact with said first and second seal members and said first and second sealing rings.

Preferably the first and second seal members are parts of a bellows seal.

The invention enables a portion of the pumped liquid to be used as a cooling agent to carry away heat developed through the frictional contact necessarily present in a bellows seal. The bearing elements which comprise the said bellows seal are thus housed within the said seal chamber, and a maximum surface area of these bearing elements may be exposed to the cooling effects of such liquid flow in the seal chamber. Further, the said smooth seal faces avoid accumulations of sediment build-up which would otherwise impair the sealing relationship.

Preferably, the apparatus comprises a conduit connected to said liquid flow outlet.

A flange ring may be seated in said shoulder adjacent the inner circumference of said second sealing ring.

Preferably, one end of said flange ring has an inner diameter approximately equal to the inside diameter of said first sealing ring, the other end of the flange ring having an inner diameter approximately equal to the inside diameter of said shoulder.

Preferably the neck is smaller than said external opening of said seal chamber.

Preferably said liquid flow outlet and said neck are substantially disposed in a common place.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:—

Figure 1 shows a multistage centrifugal pump in typical operating use;

Figure 2 shows an isometric view of the pump of Figure 1;

Figure 3 shows an isometric view and partial cross section of the outlet housing of the pump of Figure 1;

Figure 4 shows an expanded elevational view and cross section of a portion of the housing of Figure 3; and

Figure 5 shows a cross sectional isometric view of a shaft seal.

Referring first to Figure 1, there is shown a multistage centrifugal pump 20 connected in a typical operating environment. Pump 20 has a plurality of impeller pump stages 25 which are stacked one on top of another on a mounting stand 26. Support rods 27 are attached to the mounting stand 26, and an outlet housing 30, which houses an upper or pump chamber 33, is support by the support rods 27. An electric drive motor 10 is mounted on the outlet housing 30 and is connected in driving relationship through a common drive shaft to all of the impeller pump stages 25. An intake bowl assembly 22 is mounted beneath the bottom most impeller pump stage 25, and is connected via a liquid inlet 24 to an inlet valve 17. Inlet valve 17 is connected through suitable conduits to a liquid reservoir 21 which typically contains a large volume of liquid for pumping.

A liquid outlet 34 is provided in the outlet housing 30, for connection to an outlet valve 18. Outlet valve 18 is connected to a conduit 19 for delivery of the pumped liquid.

Figure 2 shows an isometric view of the pump 20, illustrating that the impeller pump stages 25 are bolted together in series connection relationship, to form a series flow path from the liquid inlet 24 to the liquid outlet 34. A 90° elbow 36 and a drain tube 37 are connected to the outlet housing 30 and to the liquid inlet 24 for purposes to be hereinafter described. The outlet housing 30 has a sealable service door 31 which provides access to the interior of the outlet housing 30 for maintenance and service.

Figure 2 shows twelve series-connected impeller pump stages 25 for purposes of illustration. In practical applications the number of impeller pump stages may vary over a considerable range, it being typical to connect from four to fourteen impeller pump stages together in particular pumping applications. The lengths of the respective support rods 27 may be varied to accommodate the number of impeller pumping stages which are connected together in this fashion, and the overall height of the pumping assembly and electric drive motor is a function of the number of series-connected stages.

Figure 3 shows the outlet housing 30 is isometric and partial cross section view. The outlet housing 30 is formed into the upper or pump chamber 33 wherein the mechanical linkage between the shaft of the motor 10 and a vertically aligned pump or impeller shaft 12 are coupled, a seal chamber 38 which is adjacent to the chamber 33 and wherein the shaft liquid seal is housed, and a lower outlet chamber 35 through which the pumped liquid passes to the liquid outlet 34. The seal chamber 38 has an external opening 38*a* through which the impeller shaft 12 projects. The impeller shaft 12 passes through a pressure throttle bushing 40 (Figure 4) which is pressed into the outlet housing 30. The impeller shaft 12, which projects externally of the outlet housing 30, is further supported by a thrust bearing 16 which is adjacent a motor shaft coupler 14 in the upper chamber 33.

A seal housing 44 is fixedly attached to the outlet housing 30, and forms the upper wall of the seal chamber 38. A bellows seal 42 is associated with the seal housing 44 and is hereinafter described. A drain or liquid flow outlet 32 is threaded to accommodate a 90° elbow 36, and to provide a flow drain from the seal chamber 38. The drain outlet 32 is provided proximate the elevation of the external opening 38*a* of the seal chamber 38.

Figure 4 shows an expanded cross sectional view of the outlet housing 30, and particularly illustrates the components associated with the seal chamber 38. The impeller shaft 12 passes entirely through the seal chamber 38, and at the lower side of seal chamber 38 the impeller shaft 12 passes through the pressure reducing throttle bushing 40. An annular path 41, shown in Figure 4 in exaggerated fashion for purposes of illustration, provides a liquid flow path about the impeller shaft 12 from the outlet chamber 35 to the seal chamber 38. The outlet chamber 35 is typically relatively highly pressurized, and therefore liquid may flow through annular path 41 at a reduced pressure upwardly into the seal chamber 38. As the seal chamber 38 fills with such liquid, there is provided a drain or liquid flow outlet 32 proximiate the top of the seal chamber 38. The drain outlet 32 is connected to the elbow 36, which in turn is coupled via a drain tube or conduit 37 downwardly into the liquid inlet 24. An overflow adapter 39 projects into the liquid inlet 24, the adapter 39 having a tapered opening facing downstream of the liquid flow through the liquid inlet 24, creating a negative pressure to assume drainage flow for cooling the components in the seal chamber 38, which flow is illustrated by the arrow in Figure 4. An air bleed opening 28 is provided near the top of the seal chamber 38, and is connected externally to an air bleed valve 29. The bleed valve 29 may be selectively opened to bleed entrapped air from the seal chamber 38, and thereby ensure that liquid entirely fills the seal chamber 38.

A seal member or housing 44 is mounted about the impeller shaft 12 and is sealably affixed to the outlet housing 30 around the external opening 38*a* and has a downwardly projecting neck 55 facing towards the seal chamber 38. The neck 55 projects into the external opening 38*a* and may project into the seal chamber 38. The neck 55 has a reduced diameter lower portion so as to provide an annular gap 56 into the seal chamber 38. That is to say, the neck 55 is sized smaller than the external opening 38*a* of the seal chamber 38. A recessed shoulder is provided at the bottom of the neck 55 for receiving a seal ring 52, which is fixed to the latter. The seal ring 52 is fixedly attached to the seal housing 44 by means of a slot or key way which prevents relative rotation of seal ring 52 when it is seated into the receiving shoulder of the neck 55. The seal ring 52 is also fixed to the neck 55. The seal ring 52 is preferably constructed of a carbon material, or of a tungsten carbide material, and has a polished lower, downwardly facing seal face 46 which forms a liquid sealing surface, and which is disposed in the seal chamber 38. The liquid flow outlet 32 is at approximately the same elevation as the neck 55. That is to say, the liquid flow outlet 32 and the neck 55 are substantially disposed in a common plane.

A collar 45 is fixedly attached to the impeller shaft 12 by means of one or more set screws 49. An O-ring 48 is contained between the collar 45 and the impeller shaft 12 to provide a liquid seal therebetween. The collar 45 is a part of a bellows seal 42, which is a commercially available component. For example, such bellows seals are manufactured by Sealol, Inc., of Warwick, Rhode Island, in a number of commercially available sizes and constructions. The bellows seal 42 also includes a welded stainles steel bellows 43 and a seal seat or seal member 47 which is sealed to the impeller shaft 12. The bellows 43 is welded to the collar 45 and to the seal seat 47 so as to provide a completely liquid impervious interconnection. The seal seat 47 has a recessed or upwardly projecting shoulder 47*a* in the seal chamber 38 for receiving a seal ring 50, and the seal ring 50 is typically constructed of a carbon or other equivalent material for providing an effective mechanical seal which is reliable under a wide range of operating conditions. The upper surface 50*a* of the seal ring 50 is smooth and highly polished so as to mate against the corresponding lower surface 46 of the fixed seal ring 52, thereby to provide a seal face. An inner flange ring 54, which is seated in the shoulder 47*a* adjcent the inner circumference of the seal ring 50, is pressed fit inside the seal ring 50, so as to provide a tapered contour along the inner surface of the seal ring 50. The flange ring 54 is preferably made from nylon or equivalent material to provide a smooth facing surface toward the interior of the seal. The flange ring 54 has an inner upper diameter approximately equal to the inside diameter of the seal ring 52, and has an inner lower diameter approximately equal to the inside diameter of the upwardly projecting shoulder 47*a* of the seal seat 47.

Figure 5 shows a cross-sectional isometric view of the bellows seal 42. The lower collar 45 has a plurality of threaded holes therethrough for accepting a plurality of set screws 49. The bellows 43 is welded about the periphery of the collar 45 so as to provide a liquid type connection. Similarly, the top of the bellows 43 is welded or otherwise affixed against the seal seat 47 so as to provide a liquid type connection. The seal seat 47 has an inner shoulder for accepting the seal ring 50, and the flange ring 54 is a pressed fit inside of the seal ring 50 so as to provide a smoothly tapered surface along the inner periphery of the seal ring 50. The further fixed seal ring 52 is mated against the upper surface of the seal ring 50, to perform the smooth seal face 46 therebetween. The seal face 46 is preferably lapped and polished so as to provide a tight, liquid sealing contact between the seal ring 50 and the fixed seal ring 52.

In operation, since the collar 45 is fixedly attached to the shaft 12, there is relative rotation of the seal ring 50 in coincidence with the shaft 12. The fixed seal ring 52 is held in a non-moving position by the seal housing 44, and there is therefore relative rotation of the two parts at seal face 46. The seal face 46 is preferably a matched interface of two very highly polished surfaces, and a careful selection of the materials for the seal ring 52 and 50 is made, so as to provide both a liquid seal at face 46 and also to provide a low friction contact between the mating surfaces of seal rings 50 and 52. Since there is inevitably frictional heat build-up at this seal face 46, provision is made for liquid cooling of the components which are closely associated with the seal face 46. For example, the seal chamber 38 and the air bleed valve 29 are constructed so as to permit pumped liquid which is forced upwardly through the annular path 41 to accumulate to a level which completely fills the chamber 38. This pumped liquid then bathes all of the components in the seal chmber 38 with liquid, and the drain outlet 32 provides a circulation outlet for draining the pumped liquid and recirculating it as it collects heat from the frictional losses. The seal housing neck 55 is of reduced diameter to provide an annular gap 56, which provides a cavity for bleeding entrapped air, and liquid within the seal chamber 38 may flow into this gap for further cooling purposes. Further, a portion of the seal rings 50 and 52 is exposed to the pump liquid contained within the seal chamber 38 for transferring frictional heat losses into this liquid.

Over extended periods of operation, it is inevitable that small quantities of liquid will find a leakage path across the seal face 46, and these small quantities of liquid will tend to accumulate inside of the bellows seal 42, particularly in the region between the shaft 12 and above the collar 45. This liquid sediment eventually dries and takes the form of dry sediment deposits. In the past it has been found that such dry sediment deposits can build-up along the shoulder formed in the seal seat 47, and eventually this sediment build-up can expand to the point where it causes a relative separating force between seal rings 50 and 52. Because of this problem, the flange ring 54 is pressed fit into the shoulder space of the seal seat 47, to form a smooth contour which causes accumulated sediments to slide freely downwardly away from the region of the seal face 46. The flange ring 54 is preferably made of nylon or other smooth plastics materials so as to facilitate the removal of sediment away from this critical interface.

The air bleed valve 29 may be adjusted so as to relieve entrapped air from the seal chamber 38, and therefore to ensure that the seal chamber 38 remains completely filled at all times. The liquid which is by-passed through the drain 36 is coupled back to the inlet 24 by means of the drain tube 37. The lower end of the drain tube 37 is formed into an overflow adapter 39, which is diagonally cut so as to provide some venturi suction effect for enhancing the liquid flow through the drain tube 37.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it is therefore desired that the present embodiment be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention.

CLAIMS

1. An apparatus for liquid sealing a pump shaft projecting externally of a housing which houses a pump chamber, said housing being provided with

a) a seal chamber formed adjacent said pump chamber, said seal chamber having an external opening through which said shaft projects and having a liquid flow outlet

b) a first seal member mounted about said shaft, said first seal member being sealably affixed to the housing around said external opening and having a neck projecting into said external opening;

c) a second seal member sealably affixed to said shaft in said seal chamber and which has a shoulder in said seal chamber;

d) a first sealing ring affixed to said first seal member, and having a first smooth seal face in said seal chamber; and

e) a second sealing ring seated in said shoulder, and having a second smooth seal face in said seal chamber and mated to said first smooth seal face; whereby liquid in said seal chamber is in flow contact with said first and second seal members and said first and second sealing rings.

2. An apparatus as claimed in claim 1 in which the first and second seal members are parts of a bellows seal.

3. An apparatus as claimed in claim 1 or 2 further comprising a conduit connected to said liquid flow outlet.

4. An apparatus as claimed in any preceding claim further comprising a flange ring seated in said shoulder adjacent the inner circumference of said second sealing ring.

5. An apparatus as claimed in claim 4, wherein one end of said flange ring has an inner diameter approximately equal to the inside diameter of said first sealing ring, the other end of the flange ring having an inner diameter approximately equal to the inside diameter of said shoulder.

6. An apparatus as claimed in claim 5 wherein said flange ring is constructed of plastics material.

7. An apparatus as claimed in any preceding claim wherein said neck is smaller than said external opening of said seal chamber.

8. An apparatus as claimed in any preceding claim wherein said liquid flow outlet and said neck are substantially disposed in a common plane.

9. An apparatus for liquid sealing a pump shaft substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

10. An apparatus for liquid sealing a vertically aligned pump shaft projecting externally of a pump chamber housing, comprising

a) a seal chamber formed adjacent said pump chamber, said seal chamber having an external opening through which said shaft projects and having a liquid flow outlet proximate the elevation of said external opening;

b) a first bellows seal member about said shaft, said first seal member being sealably affixed around said external opening and having a downwardly projecting neck projecting into said seal chamber through said external opening;

c) a second bellows seal member sealably affixed to said shaft in said seal chamber and having an upwardly projecting shoulder in said seal chamber;

d) a first sealing ring affixed to said downwardly projecting neck, and having a downwardly facing smooth seal face in said said chamber;

e) a second sealing ring seated in said upwardly projecting shoulder, and having an upwardly facing smooth seal face in said seal chamber and mated to said first sealing ring smooth seal face; whereby liquid in said seal chamber is in flow contact with said first and second bellows seal members and said first and second sealing rings.

11. A centrifugal pump seal for providing a liquid seal to a vertically oriented pump drive shaft, including a bellows seal fixedly attached to the drive shaft and having a rotatable sealingh ring as a part thereof, mated to a fixed sealing ring held in a seal housing, and a seal chamber surrounding the bellows seal and shaft, for containing pump liquid, wherein the fixed and rotatable seal rings and a portion of the seal housing are exposed to liquid contact for cooling, including a recirculating bleed line for continuously replenishing the liquid in the seal chamber.

12. Any novel integer or step, or combination of integers or steps, hereinbefore described and/or shown in the accompanying drawings irrespective of whether the present claim is within the scope of, or relates to the same or a different invention from that of, the preceding claims.

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