

[54] SUBMERSIBLE ELECTRIC PUMP HAVING
FLUID PRESSURE PROTECTIVE MEANS

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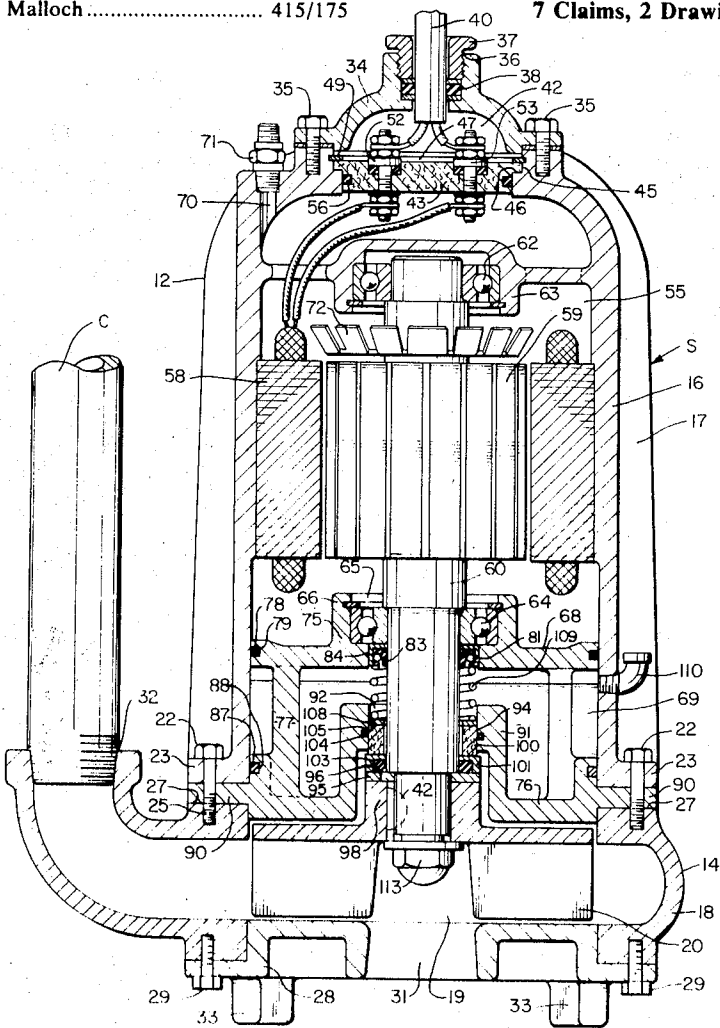
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[57] ABSTRACT

A submersible electric motor driven pump having a motor chamber and a pump chamber separated by a seal chamber. A shaft seal is immersed in oil in the seal chamber and prevents the flow of liquid from the pump chamber into the motor chamber. The motor chamber is filled with gas under pressure which aids in sealing it. The gas is introduced to a pressure operated switch and a pressure gauge, which may be located above the surface of the liquid in which the pump is submerged. The pressure operated switch is connected in circuit with the power controls to the motor and is held closed by a predetermined minimum pressure of gas in the motor chamber. In case of a pressure loss from a shaft seal failure the switch is automatically opened and power to the motor is interrupted thus preventing pumped liquid from entering the motor chamber while the motor is energized.

7 Claims, 2 Drawing Figures



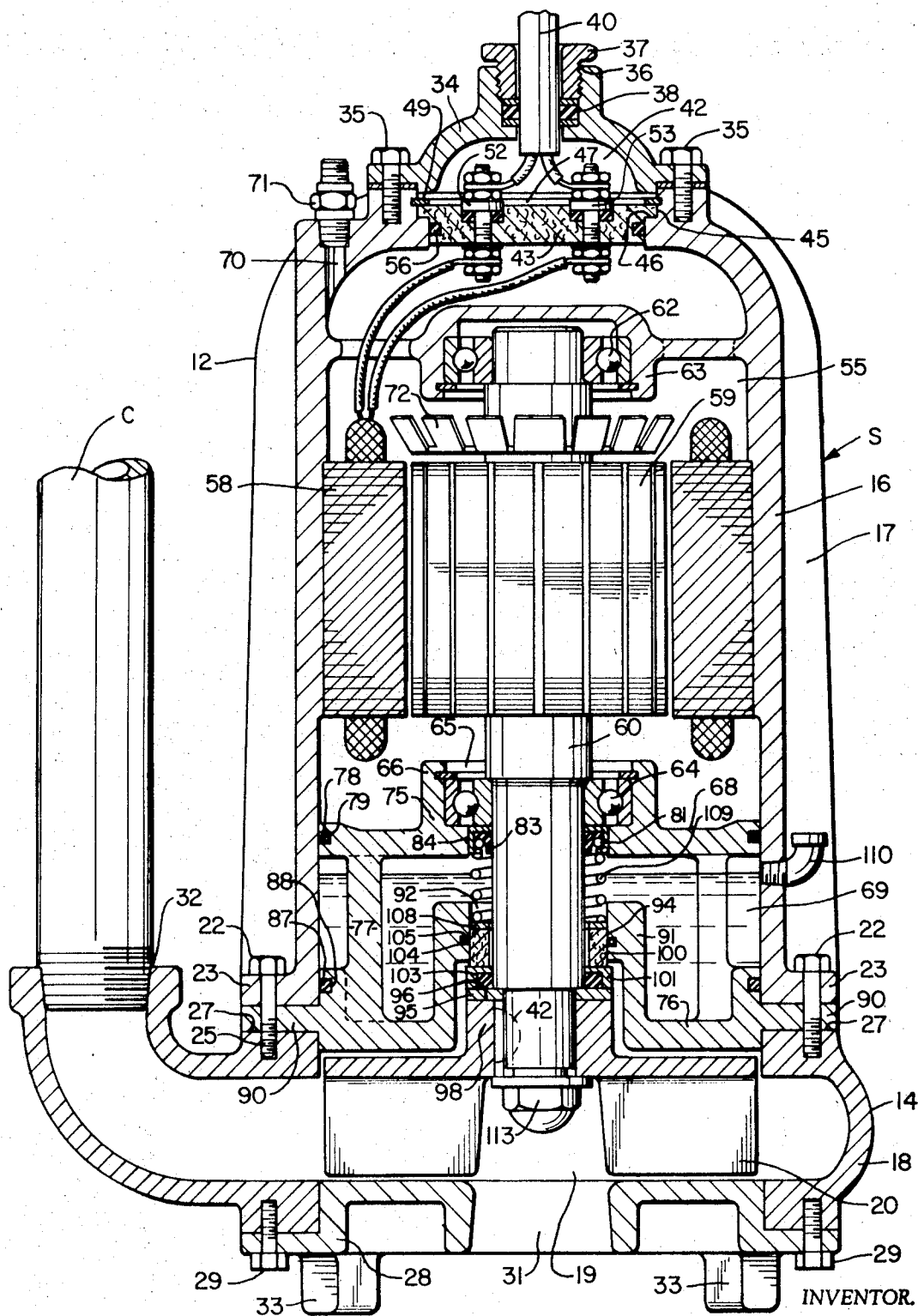


Fig. 1.

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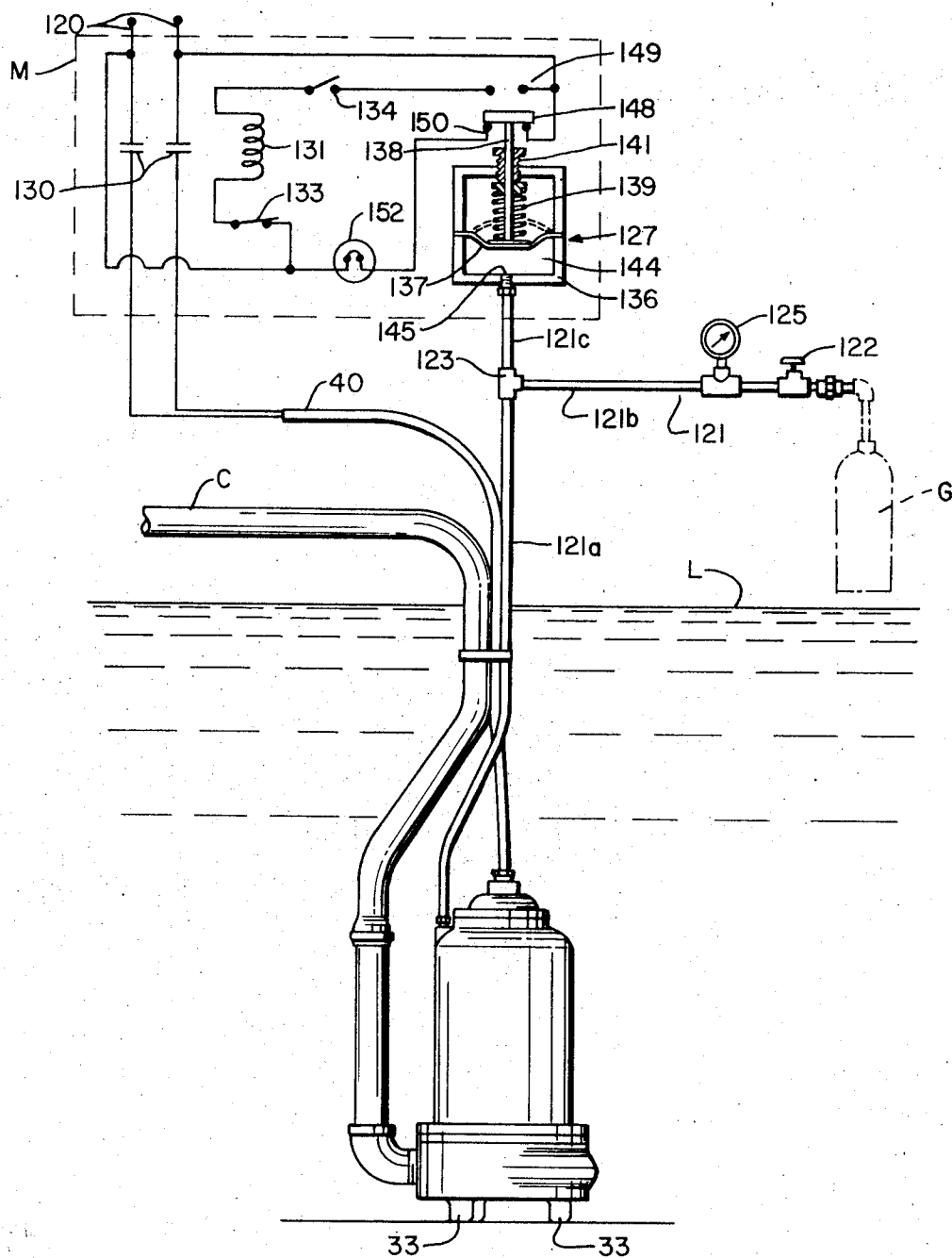


Fig. 2.

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SUBMERSIBLE ELECTRIC PUMP HAVING FLUID PRESSURE PROTECTIVE MEANS

BACKGROUND OF THE INVENTION

This invention relates to submersible motor driven pumps and more particularly to pumps of that type having improved means for sealing the motor against entry of the liquid in which the motor is submerged.

Submersible motor driven pumps have many recognized advantages over pumps previously employed for dewatering excavations and the like and as sewage pumps for applications such as in sewage lift stations. Many of these advantages derive from the fact that the entire assembly, including pump and motor can be submerged in the liquid to be pumped. One such advantage is the elimination of priming problems which are a major concern when pumping liquid having foreign material in suspension as in sewage pumping and in construction projects where waterfilled excavations having particles of stone, sand and dirt in liquid suspension must be dewatered. The motor driven submersible pump, being submerged in the liquid to be pumped, is inherently primed.

A problem with submersible pumps, however, has been ensuring that foreign material, particularly the liquid in which the assembly is submerged, does not enter the motor. An area particularly vulnerable to the entry of liquid is along the shaft that extends from the motor to drive the pump. Adequate sealing means for this area has been difficult to provide for pumps used in dewatering sewage and excavations because the pumps are called upon to handle abrasive materials in suspension such as dirt, sand and inorganic wastes in sewage sludge. Such abrasives considerably shorten the life of even the best seals.

Elaborate shafts seals have been employed for submersible pumps, some including two stages of sealing so that two sets of seals must fail before liquid can enter the motor. Submersible pumps have also been employed in which the motor chamber is filled with oil under pressure sufficient to balance that exerted by the liquid in which the pump is submerged. The oil must have good dielectric properties so that insulation will be provided between the motor windings.

There are, however, disadvantages in the use of oil filled submersible motors. Any moisture that may leak past the shaft seal is mixed with the oil and reduces its dielectric properties. Another disadvantage of an oil filled motor chamber is that the oil creates resistance to the rotation of the rotor. The drag due to the oil and the resulting energy loss increase with the diameter of the rotor and can result in a significant decrease in efficiency in a large dewatering or sewage pump.

Also, oil filled submersible motors have generally had inadequate provision for controlling the pressure of the oil relative to that exerted by the liquid in which the assembly is submerged. In such cases the pressure of the oil can vary from being insufficient in some applications to being excessive in others.

There has been proposed a submersible motor driven pump that, in addition to having means for preventing the entry of moisture into the motor chamber, is provided with a pair of electrodes which sense the presence of moisture in the chamber and open a switch through which power is supplied to the motor. This, however, is after the fact since moisture must have en-

tered the motor chamber in sufficient quantity to be detected by the sensing electrodes.

SUMMARY OF THE INVENTION

A general object of this invention is to provide a sealing arrangement for electric motor driven submersible pumps that overcomes the disadvantages noted above in prior sealing arrangements for such pumps.

A particular object is to provide such a sealing arrangement that employs a fluid under positive pressure to assist mechanical shaft sealing means in preventing the entry of liquid into the motor enclosure.

A more particular object is the provision of such a fluid seal arrangement that includes a pressurized gas within the motor enclosure and that includes means for de-energizing the motor in response to a relatively large decrease in gas pressure within the motor enclosure, as from a seal failure.

Another object of this invention is to provide such a sealing arrangement in which the pressure of the gas sealing means can be monitored above the surface of the liquid in which the pump is submerged.

Another object is to provide such a sealing arrangement in which a shaft seal is immersed in oil and the oil is maintained under pressure by gas within the motor enclosure to aid the shaft seal.

Still another object is to provide such a sealing arrangement in which the pressure of gas is maintained high to improve the efficiency of heat transfer from the motor to its housing and the surrounding liquid.

In a preferred embodiment this invention comprises the combination of a submersible motor and pump assembly and controlled gas sealing means therefor. The assembly includes a housing that defines a chamber for the motor and a chamber for the pump. The motor shaft extends into the pump chamber and is connected to the pump. Shaft sealing means prevents the passage of fluid between the chambers. The controlled sealing means includes a gas within the motor chamber exerting a pressure greater than the pressure exterior to the motor chamber, the pressure of the gas aiding the shaft sealing means. Control means responsive to the pressure of fluid within the motor chamber enables the assembly to operate when the pressure of gas within the motor chamber exceeds a predetermined pressure and prevents operation when the pressure is less than the predetermined pressure.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a vertical sectional view of the submersible pump and motor of this invention showing the chambers containing oil and pressurized gas.

FIG. 2 is a diagram showing the submersible motor and pump submerged and connected to a gas seal control arrangement located above the surface of the liquid.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, FIG. 1 shows a motor and pump assembly S employing the controlled fluid sealing arrangement of this invention. The assembly includes a motor section 12 at its upper (as viewed) end and a pump section 14 at its lower end. The motor section 12 includes a motor housing 16 provided with longitudinally extending fins 17 on its outer periphery which assist in dissipating heat from the motor.

The pump section 14 includes a pump housing 18 that defines an impeller chamber 19 for the impeller 20. The pump housing 18 is attached to the motor housing 16 by bolts 22 which extend through holes in flanges 23 in the motor housing and into tapped holes 25 in the annular upper flat face 27 of the pump housing. A base plate 28 is attached by means of bolts 29 to the bottom of the pump housing 18 and has an opening 31 for liquid to enter the impeller chamber 19 from which it is discharged through a discharge conduit C which is connected to a discharge opening 32 in the pump housing. A number of feet 33 are provided on the base plate to raise the assembly off the bottom of the liquid-containing area in which it will rest.

The motor housing 16 is provided with a cup-shaped closure 34 at its upper end secured thereto by bolt 35. Closure 34 has a central opening 36 which receives a packing gland 37 having a resilient packing ring 38 at its lower end. An electrical cable 40 passes through the packing gland 37 into a wiring chamber 42 defined at one end by the closure 34 and at the other end by an electrically insulated board 43. The board 43 is secured to the interior of the motor housing by a flange 45 that rests upon an inwardly extending annular shoulder 46 within the housing and is maintained in engagement therewith by a snap ring 47 received within an annular recess 49 in the inner wall of the motor housing. The wires from the electrical cable 40 are connected to binding posts 52 and 53 that are mounted on the insulated board 43 and extend through the board into a motor chamber 55. An O-ring 56 seals the wiring chamber 42 from the motor chamber 55.

The motor chamber 55 houses the electric motor which includes a stator 58 and rotor 59 mounted on the shaft 60. Shaft 60 is rotatably supported at its upper end in bearing 62 which is suitably mounted in a frame member 63 and at the lower end of motor chamber 55 in bearing 64 which is housed in a central opening 65 in a hublike part 66 of a mechanical seal supporting frame 68 that is described below. Shaft 60 extends through a seal chamber 69 defined by the frame 68 and into the impeller chamber 19 where it supports the impeller 20.

At the upper end of the motor chamber 55 is a port 70 extending through the wall of the motor housing 16 and threaded at its upper end to receive the coupling 71 through which gas is supplied to the motor chamber 55. Sufficient nitrogen gas is supplied through port 70 into the motor chamber 55 before the pump is submerged to maintain the motor chamber at a pressure above that in the impeller chamber 19. The coupling 71 may be connected to a conduit by which gas pressure is transmitted to a pressure actuated switch when such is located above the surface of the liquid in which the pump is submerged.

A fan 72 is mounted within the motor chamber on shaft 60 to circulate the nitrogen gas to assist it in transferring heat from the motor to the walls of the motor housing. Maintaining the gas in motor chamber 55 at a relatively high pressure improves its ability to transfer heat from the motor. The motor chamber 55 is hermetically sealed from the impeller chamber 19 by a sealing arrangement described below.

The seal supporting frame 68 includes an inner annular frame member 75 and an outer annular frame member 76 which are longitudinally spaced apart and integrally joined by webs 77. The seal chamber 69 is be-

tween the inner member 75 and the outer member 76. The inner frame member 75 has its radially outer periphery in sealing engagement with the inner wall of motor housing 16. An O-ring 78 is received in a recess 79 in the outer periphery of inner member 75 to prevent the passage of fluid between seal chamber 69 to motor chamber 55. The hub-like part 66 extends longitudinally inwardly from the central portion of inner member 75 and as noted above, houses the bearing in which the shaft 60 is journaled. Below the hub-like part 66 is an opening 81 which receives a lip-type oil seal 83 having its lip facing downwardly for reasons discussed below. The lip-type seal 83 is held in sealing engagement with the shaft 60 by a garter spring 84.

The outer seal supporting frame member 76 is generally similar in shape to the inner seal supporting frame member and has its radially outer periphery in sealing contact with the radially inner wall of motor housing 16. An O-ring seal 87 is provided within a recess 88 in the outer peripheral face of outer frame member 76. The seal supporting frame 68 is secured in position by means of an annular flange 90 which extends outwardly from the outer peripheral face of frame member 76 and is clamped between the flange 23 of the motor housing and the upper flat face 27 of the pump housing.

The central portion of outer frame member 76 is an inwardly extending hub-like part 91 having a central opening 92 adapted to receive mechanical sealing means for the motor shaft 60.

The shaft sealing means includes a face-type seal generally indicated at 94 which seals the shaft as it passes from the seal chamber 69 to the impeller chamber 19. A washer 95 is seated on the upper annular face 96 of the impeller hub 98 within the impeller chamber 19 and provides a seat for the face-type seal 94. The face-type seal 94 includes a stationary seal member 100 which is preferably made of carbon or of bearing bronze such as SAE 660 and a rotating seal member 101 preferably made of tungsten carbide or of alumina ceramic such as Coors AD 999. The rotating seal member 101 is connected to the motor shaft 60 for rotation therewith with respect to the stationary seal member 100. The rotating seal member is backed by an inner resilient ring 103 of rubber or similar material and both the rotating seal member 101 and the inner resilient ring 103 are supported by the washer 95. An O-ring 104 is provided in a recess 105 in the radially inner cylindrical face of the outer seal supporting frame member 76 and bears against the radially outer face of stationary seal member 100 to prevent the passage of liquid.

A coil spring 109 acts between the retaining member for the lip-type oil seal 83 and a washer 108 which is seated upon the stationary seal member 100. The coil spring 109 compresses the various parts of the mechanical shaft seal.

The seal chamber 69 is filled with oil which contacts the parts of the face-type shaft seal 94 down to the interface between the stationary and rotating seal members and provides lubrication and a clean environment for the face-type seal. Oil is introduced into the seal chamber 69 by means of an inlet 110 which extends through the wall of the motor housing. The inlet 110 is provided with a cap or other suitable closure means to seal the inlet against the entry of liquid when the motor and pump assembly is submerged.

Motor shaft 60 extends through seal chamber 69 and beyond outer seal supporting frame member 76 into impeller chamber 19. The pump impeller 20 is mounted on the portion of shaft 60 that is within the impeller chamber 19 and is keyed to the shaft for rotation therewith as shown at 112. An acorn nut 113 is threaded onto the lowermost portion of shaft 60 and retains the impeller 20 on the motor shaft.

During operation of the motor and pump assembly S the motor chamber 55 is, as noted above, filled with gas under pressure, preferably dry nitrogen gas at a pressure of about 50 psi. The gas is circulated in the motor chamber 55 by the fan 72 to aid in transferring heat from the motor parts to the walls of the motor housing from where it is transferred to the liquid in which the motor and pump assembly is submerged.

The pressure of the nitrogen gas also overbalances the pressure exerted by the external liquid so that any leakage will be of gas out of the motor chamber 55 and not of liquid into the chamber.

The pressurized gas also aids the face-type seal 94 in its shaft sealing function. As noted above the lip-type oil seal 83 is oriented so that the lip faces toward the seal chamber. This prevents the passage of oil from the seal chamber 69 into the motor chamber 55 should the motor and pump assembly be upset in use or be turned over in handling. This orientation also allows pressurized nitrogen gas to flow past the lip-type oil seal into seal chamber 69 and transmit pressure to the oil therein. The pressure of the gas aids the coil spring 109 in urging the stationary seal member 100 of the face-type seal down against the rotating seal member 101.

Also, since the pressure in seal chamber 69 is higher than that in impeller chamber 19, the oil attempts to flow past the stationary sealing member 100 into the impeller chamber 19 which bathes and lubricates the seal members. It should be noted that the impeller chamber 19 extends up to the radially outer portion of the rotating seal member 101 where liquid containing suspended solids may be present. The rotating seal member 101 tends, by centrifugal force, to throw solids, which may include abrasive material, away from the seal and provides a cleaner area in which the seal members can work.

In the event of a failure of the shaft seal, oil will flow into the impeller chamber 19 rather than liquid flowing into the seal chamber 69. When a seal failure is such that the loss of oil results, then a rapid decrease in pressure of nitrogen gas will occur which can be detected in the manner described below and used to de-energize the motor before the motor chamber 55 becomes contaminated with liquid being pumped and damage to the motor results. Further, if the shaft seal should fail and the motor be automatically shut off, liquid could enter the seal chamber 69. Lip-type seal 83 would, however, prevent the liquid from entering the motor chamber.

Referring now to FIG. 2, the submersible motor and pump assembly S is shown submerged in liquid L to be pumped. The liquid L may be, for example, water collected in an excavation pit or may be sewage effluent and in either case is to be pumped through a discharge conduit C out of the hole in which it is contained. Operation of the motor and pump assembly S is controlled by motor controls generally designated M which receive electrical power from a source (not shown) through lines 120 and supply it to the motor and pump assembly by means of electrical wiring 40 below the

surface of the liquid L and into the wiring chamber 42 of the motor.

Nitrogen gas is supplied to the motor chamber 55 from a gas supply G by means of a flexible line 121 when a valve 122 in the gas line is open. Gas line 121 has 3 sections 121a, 121b and 121c. Section 121a is connected at its lower end by means of the coupling 71 to the port leading to the motor chamber 55 and at its upper end is connected to a T-coupling 123. Section 121b is connected to T-coupling 123 and to valve 122 and is provided with a pressure gauge 125 by which the pressure of gas within motor chamber 55 can be monitored. Section 121c is connected to T-coupling 123 and to a pressure operated switch 127 in circuit with the motor controls M. The switch 127 is connected to interrupt the power to motor and pump assembly S in the event of a relatively large decrease in the pressure of liquid within the motor chamber 55 in a manner described below.

In FIG. 2 electrical power is supplied from a supply (not shown) through lines 120 to motor controls M. Lines 120 are connected to contactors 130 which are operated by a coil 131 connected across the lines and in series with an overload switch 133, a control switch 134 and the contacts of the pressure operated switch 127. Control switch 134 may be actuated manually or automatically as by a float which senses the level of liquid to be pumped or by a predetermined pressure of the liquid to be pumped.

The pressure operated switch 127 is connected in series with the power control switch 134 and is normally open but is maintained in the closed position by the pressure of nitrogen gas in line 121. Switch 127 includes a housing 136 which supports a flexible diaphragm 137 to which is connected an actuating rod 138. A coil spring 139 surrounds the lower end of rod 138 and bears against diaphragm 137 and against an adjustable threaded member 141 received within a threaded opening in housing 136 to bias the diaphragm to the full line position in FIG. 2. Adjustable threaded member 141 may be advanced or retracted in housing 136 to select the desired biasing force of spring 139 on diaphragm 137.

The portion of housing 136 below diaphragm 137 defines a pressure chamber 144 which communicates through an opening 145 with section 121c of gas line 121. Rod 138 passes through openings in threaded member 141 and terminates in a contact bar 148 which closes an upper set of contacts 149 or a lower set of contacts 150 in accordance with the pressure in pressure chamber 144 and the biasing force of spring 139. When the pressure in pressure chamber 144 is greater than the biasing force of spring 139 diaphragm 137 is snapped to the dotted line position shown in FIG. 2 and contact bar 148 bridges contacts 149 which enables power to be supplied to coil 131. When the pressure in pressure chamber 144 acting on diaphragm 137 is lower than the biasing force of spring 139 lower contacts 150 are bridged and complete a circuit to an indicator lamp 152. Pressure operated switch 127 may be, for example, a class 9013 type HRG switch manufactured by Square D Company. The switch 127 preferably is set to open its upper contacts 149 when the pressure drops to about 25 psi.

For operation, gas supply G is first connected to line 121b before the motor and pump assembly S is positioned within the pit or tank within which it is to oper-

ate. The valve 122 is opened and pressurized gas, preferably nitrogen gas, is supplied through gas lines 121 to the motor chamber 55 of the assembly S until the desired predetermined pressure therein is reached as determined by reading pressure gauge 125. The pressure is transmitted through section 121c and is sufficient to close normally open pressure operated switch 127 which thereby enables motor controls M to supply power to motor and pump assembly S. Valve 122 is closed when the desired pressure is reached so that thereafter pressure gauge 125 reads the pressure of gas within the motor chamber 55. Gas supply G is then disconnected from line 121 and the motor and pump assembly S is submerged in the liquid to be pumped.

Operation of motor and pump assembly S may be initiated by closing control switch 134 in motor controls M to cause electrical power to be transmitted to the assembly. Actuation of control switch 134 initiates operation of the assembly and causes liquid L to be discharged through the discharge conduit C. The pressure of the nitrogen gas within the enclosure is monitored on pressure gauge 125 and so long as it is above the set minimum maintains upper contacts 149 of pressure operated switch 127 in the closed condition. A serious leak will result in a loss of pressure and will cause pressure operated switch 127 to open its upper contacts 149 and interrupt power to motor and pump assembly S. At the same time, the lower contacts 150 of pressure operated switch 127 will close and cause indicating lamp 152 to be energized and indicate that power to the motor and pump assembly has been interrupted because of a pressure decrease indicating a leak in the motor assembly. The operation of the motor and pump assembly S is thereby terminated before moisture is allowed to enter the motor chamber and cause damage to the motor.

While a preferred form and an alternate form of this invention have been described herein, changes and improvements will occur to those skilled in the art who come to understand its essential principles and accomplishments. This invention, therefore, is not to be confined to the specific forms herein specifically disclosed nor in any other way inconsistent with the progress by which the invention has promoted the art.

What is claimed is:

1. In combination, a submersible motor and pump assembly and controlled gas sealing means therefor, said assembly comprising housing means defining a chamber for said motor and a chamber for said pump, a shaft for said motor extending into said pump chamber and being drivingly connected to said pump, and shaft sealing means between said chambers for preventing passage of liquid into said motor chamber, said controlled sealing means comprising a gas within said motor chamber exerting a pressure greater than the pressure exterior to said motor chamber, the pressure of said gas acting upon said shaft sealing means to aid in preventing entry of liquid into said motor chamber, and control means responsive to the pressure of gas within said motor chamber for enabling said assembly to operate when said pressure exceeds a predetermined pressure and for preventing operation of said assembly when said pressure is less than said predetermined pressure.

2. The combination as claimed in claim 1 further comprising an oil filled seal chamber between said motor chamber and said pump chamber and containing said shaft sealing means, and wherein said shaft sealing means includes a lip-type oil seal arranged to prevent passage of oil from said seal chamber to said motor chamber and to permit passage of gas from said motor chamber to said seal chamber whereby gas pressure is exerted on said oil.

3. The combination as claimed in claim 2 wherein said shaft sealing means includes a face-type shaft seal immersed in said oil and preventing leakage thereof into said pump chamber, the pressure of said gas acting upon said oil and aiding said face-type seal, said face-type seal including a stationary seal member and a rotating seal member having a face in said seal chamber and a radially outer face in said pump chamber, said rotating seal member transmitting centrifugal force into said pump chamber during rotation to maintain the area of said seal free from particles entrained in the liquid in said pump chamber.

4. The combination as claimed in claim 1 wherein said gas is nitrogen gas.

5. The combination as claimed in claim 1 wherein said motor is an electrical motor and said control means includes means for supplying electrical power to said motor and pressure actuated switch means connected in circuit with said power supplying means and responsive to pressure within said motor chamber for enabling power to be supplied to said motor when said pressure exceeds a predetermined pressure and for causing interruption of power to said motor when said pressure is less than said predetermined pressure.

6. The combination as claimed in claim 5 wherein said switch means is located external to said motor and pump assembly and including means for transmitting the pressure of gas thereto and a pressure gauge connected to said pressure transmitting means for monitoring the pressure of gas within said motor chamber.

7. In combination, a submersible electrical motor and pump assembly and controlled gas sealing means therefor, said assembly comprising housing means defining a chamber for said motor, a chamber for said pump and a seal chamber therebetween, a shaft for said motor extending through said seal chamber and into said pump chamber and being drivingly connected to said pump, shaft sealing means immersed in oil in said seal chamber and preventing leakage along said shaft between said pump chamber and said seal chamber, said controlled gas sealing means comprising a gas within said motor chamber exerting a pressure greater than the pressure in said pump chamber, the pressure of said gas acting on said oil in said seal chamber and being transmitted thereby to said shaft sealing means to aid in sealing said shaft, means for supplying electrical power to said motor, and pressure actuated switch means connected in circuit with said power supplying means and responsive to pressure within said motor chamber for enabling power to be supplied to said motor when said pressure exceeds a predetermined pressure and for causing interruption of power to said motor when said pressure is less than said predetermined pressure.

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