

[54] SUBMERSIBLE PUMPING UNIT  
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[51] Int. Cl.<sup>2</sup> .... F04B 17/00  
[58] Field of Search ..... 417/360, 372, 375, 407,  
417/405

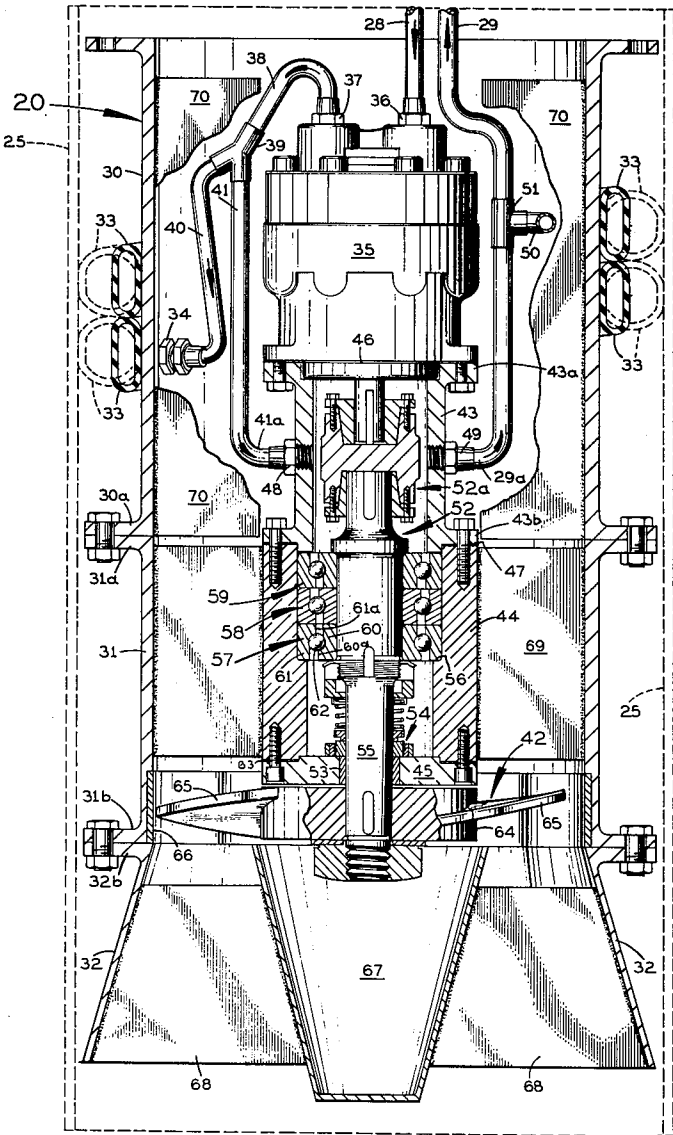
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Attorney, Agent, or Firm—Oltman and Flynn

[57] ABSTRACT  
A submersible pumping unit having a reversible pump driven directly by a rotary hydraulic motor. Bearings for the pump shaft are lubricated by hydraulic liquid from this motor and are capable of taking up end thrusts in either direction. A hose on the outside of the casing for the pump and motor is inflated by hydraulic liquid from the motor to expand radially outward into sealing engagement with a well casing. This pumping unit may be suspended underground to pump water either vertically or horizontally.

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6 Claims, 16 Drawing Figures



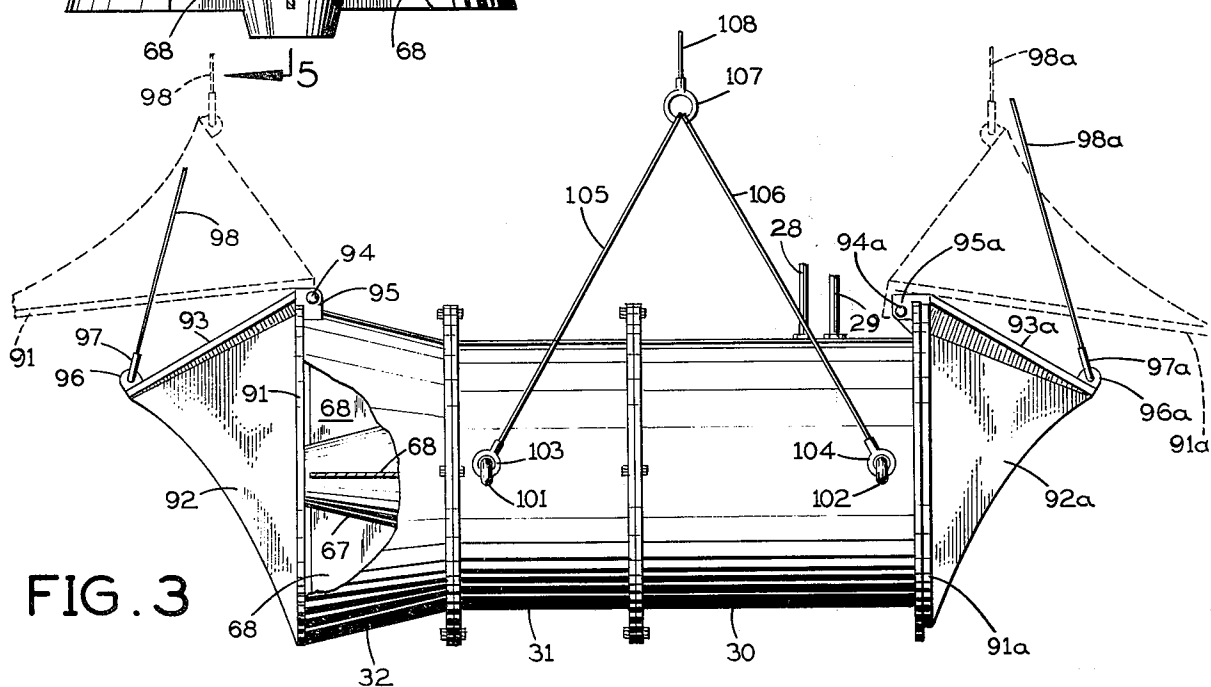
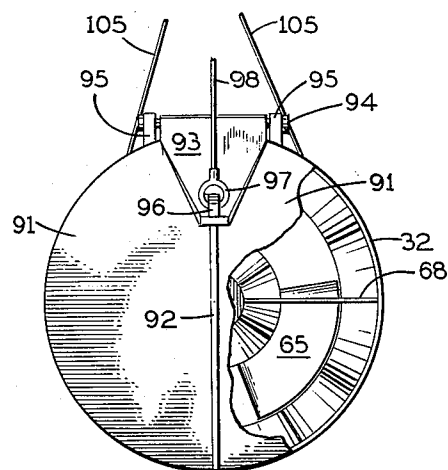
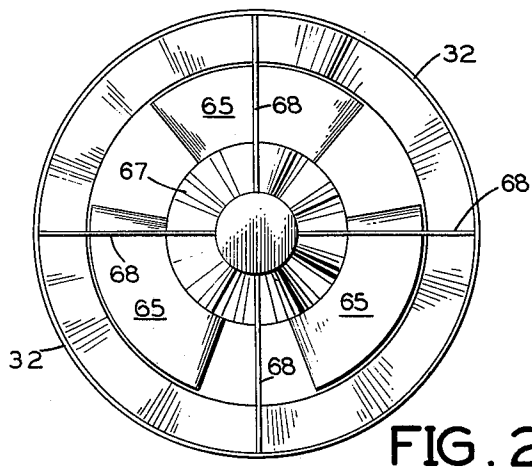
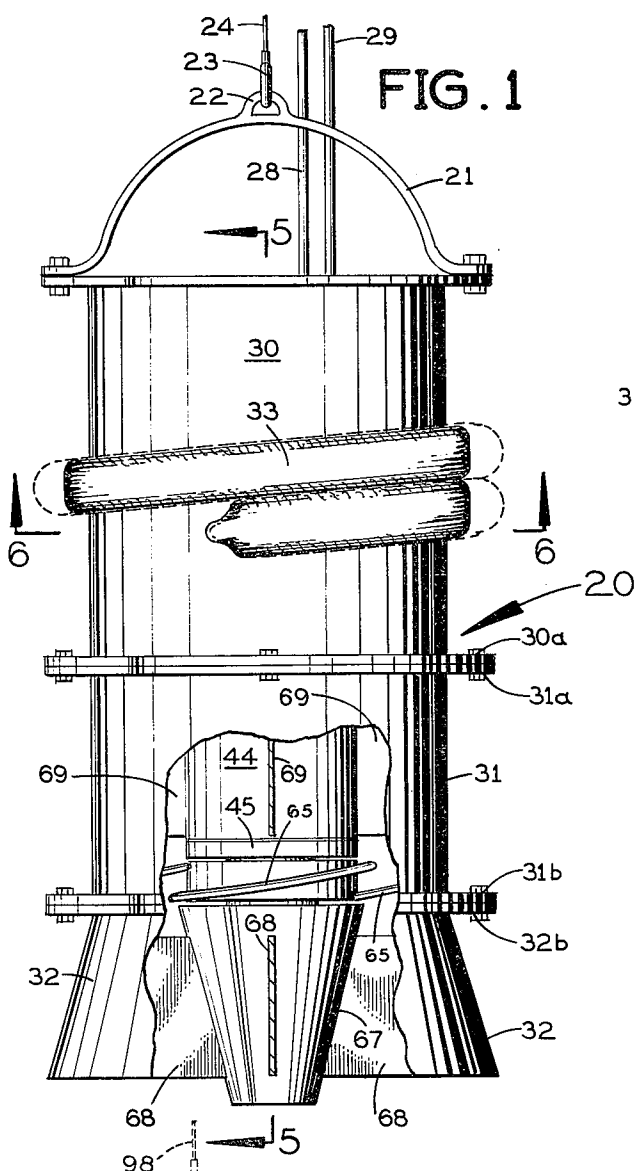




FIG. 6

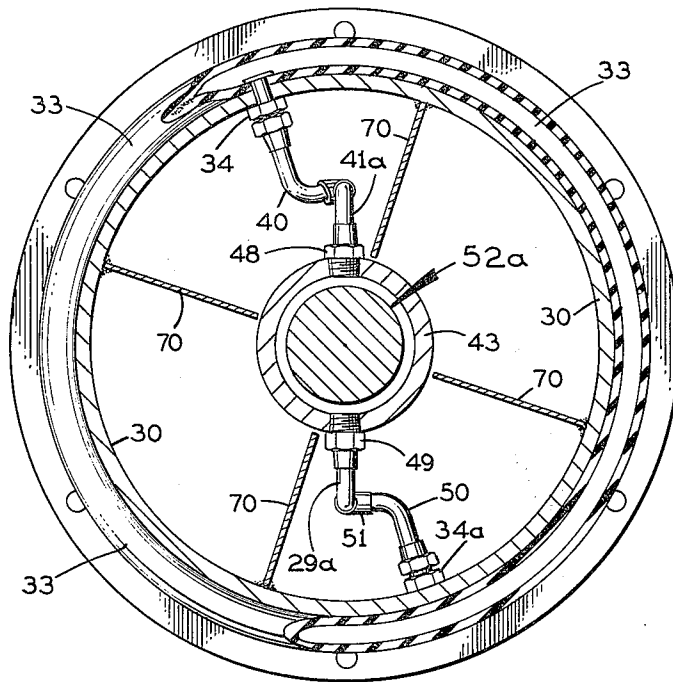


FIG. 7

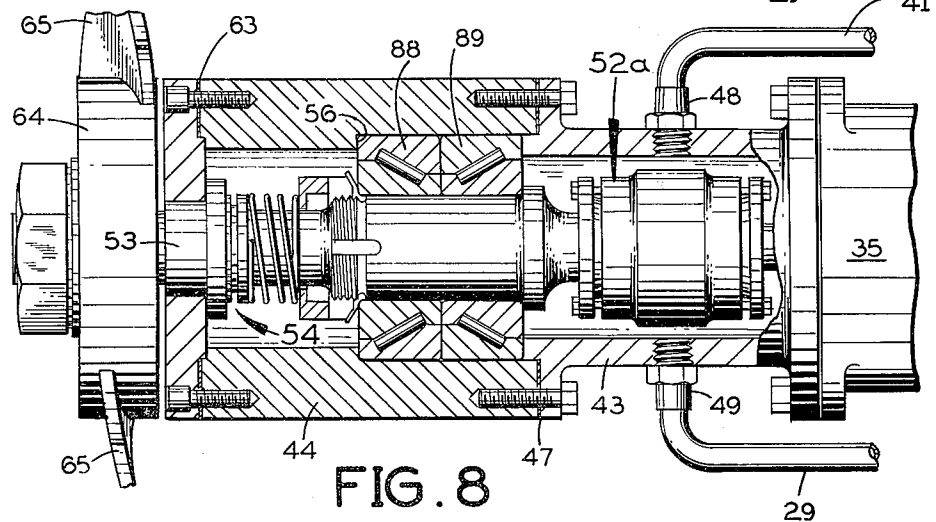
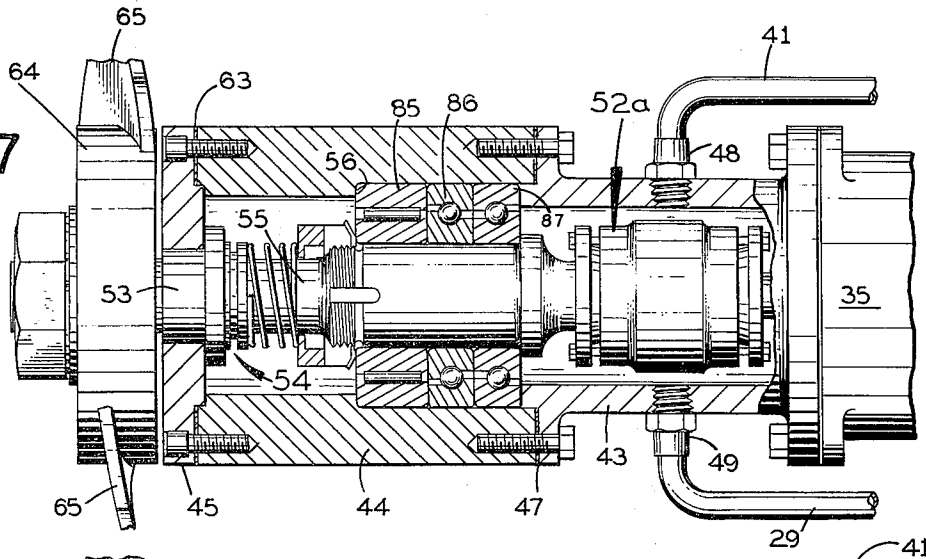


FIG. 8

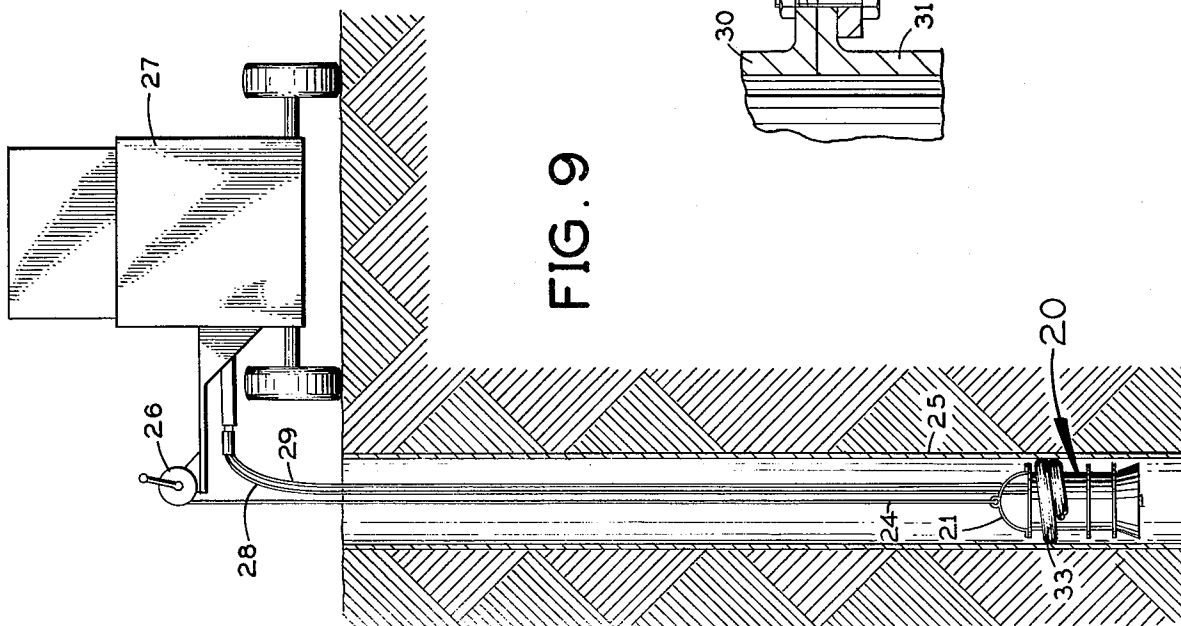


FIG. 9

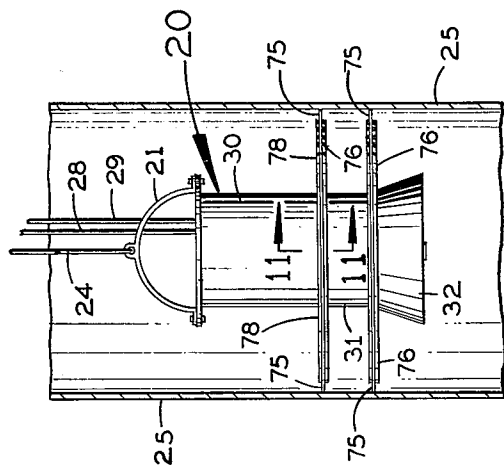


FIG. 10

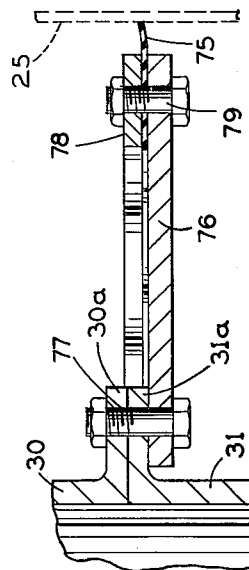


FIG. 11

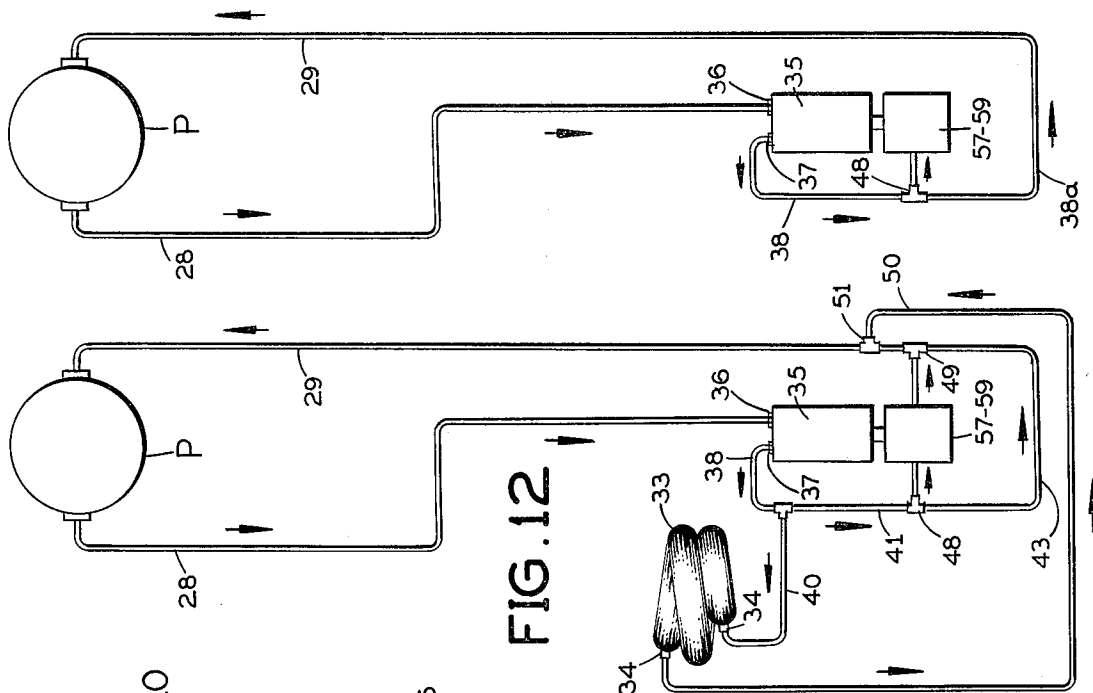


FIG. 12

FIG. 13

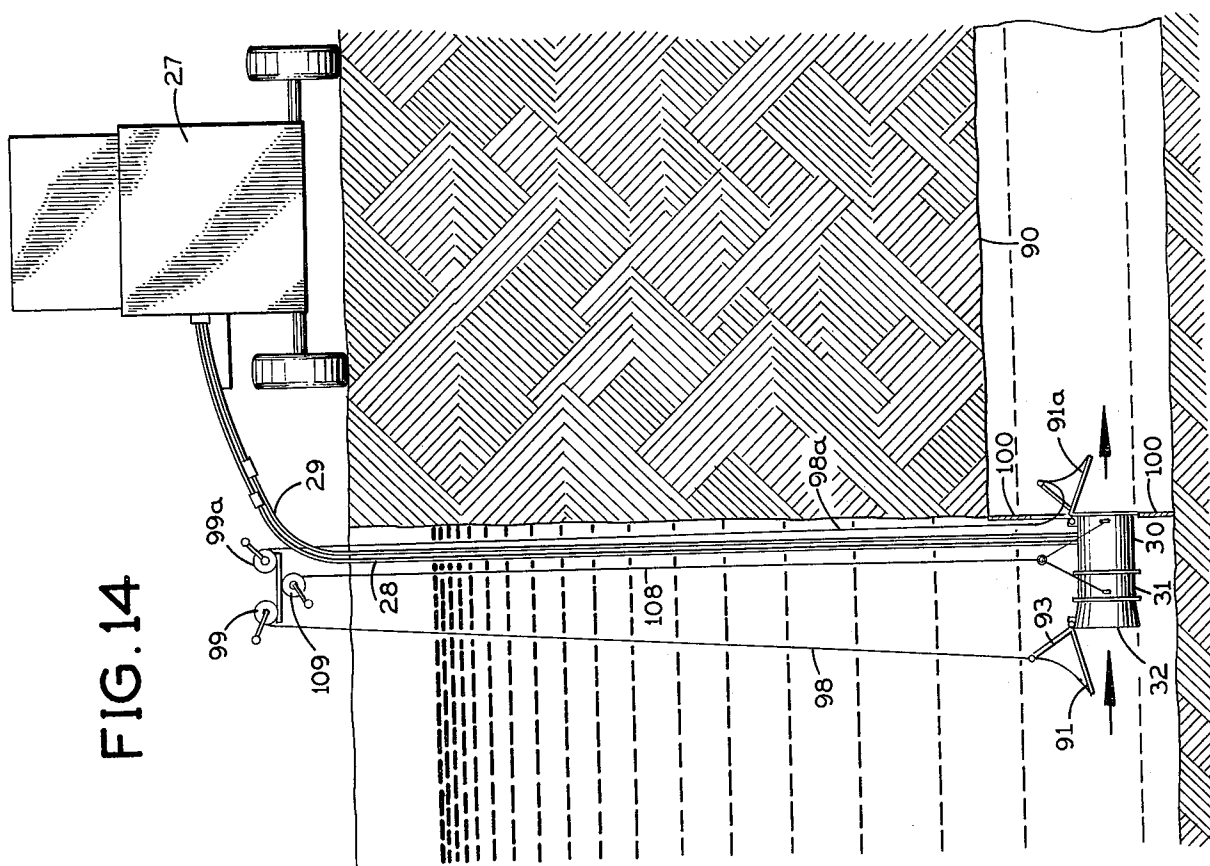


FIG. 14

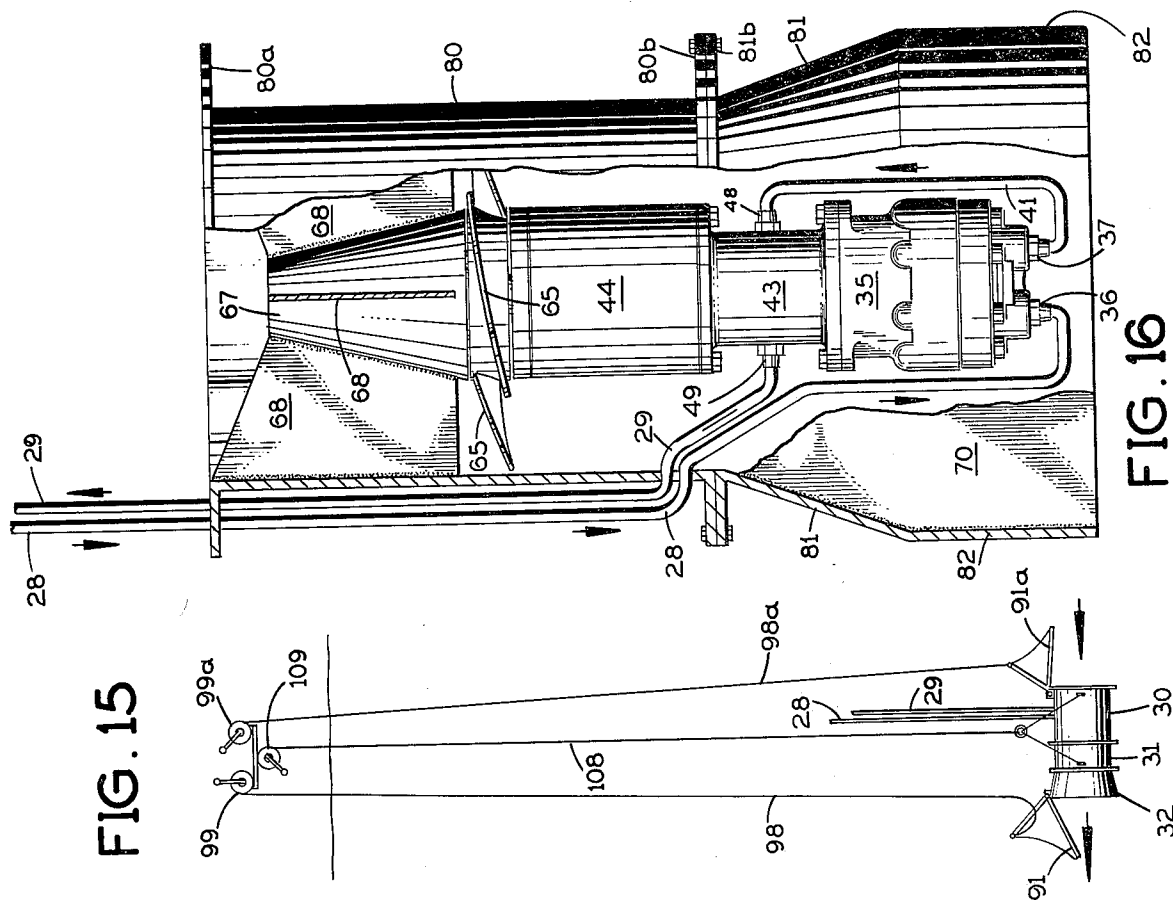


FIG. 15

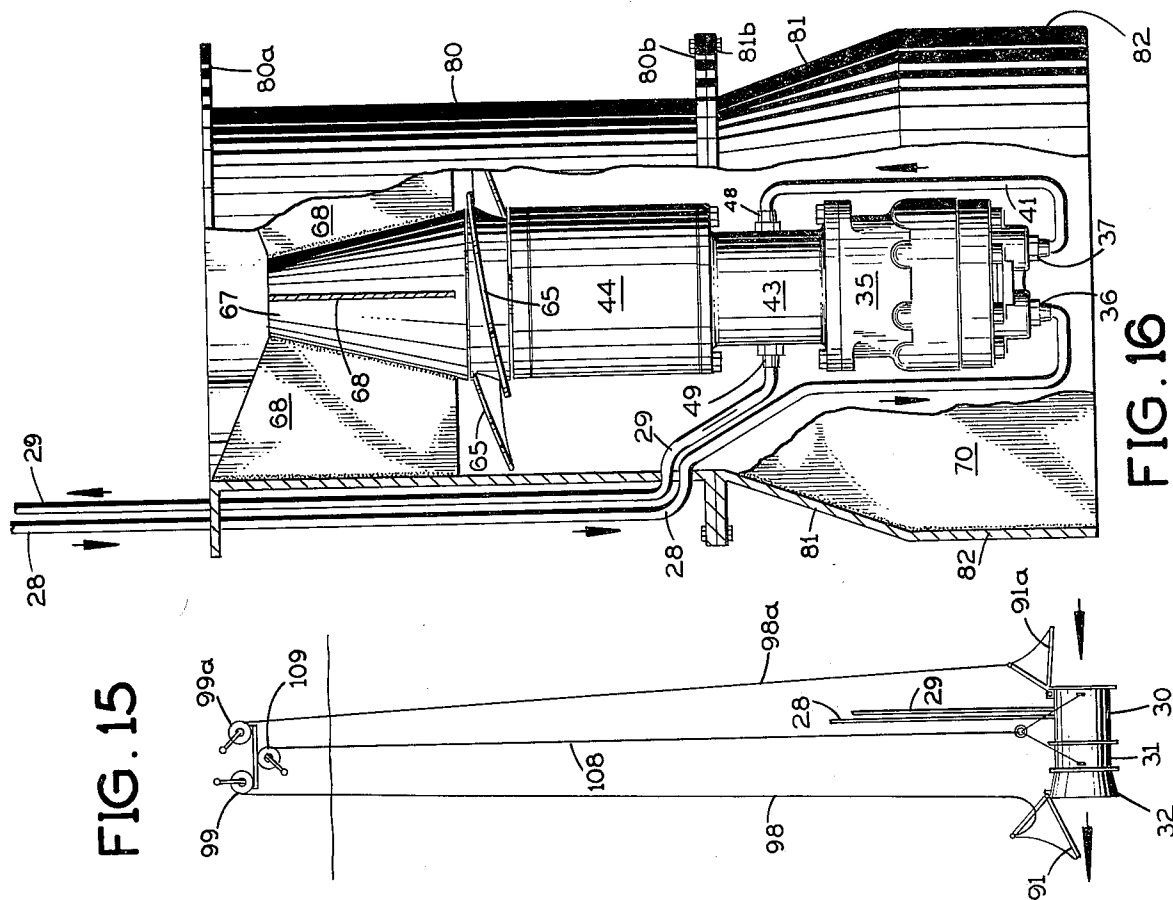


FIG. 16

## SUBMERSIBLE PUMPING UNIT

## BACKGROUND OF THE INVENTION

Conventional submersible pumps, such as for water wells, usually are driven by an electric motor which, of course, must be sealed against the intrusion of water or other foreign matter. This has led to rather elaborate and costly precautions since the pump normally cannot function long after the motor seal has failed.

In order to overcome the difficulties and disadvantages associated with electric motor-driven, submersible pumps, it has been proposed heretofore to drive the pump from a hydraulic motor which in turn, is driven by hydraulic liquid pumped down to it from a ground-level pump.

## SUMMARY OF THE INVENTION

This invention is directed to improvements in a submersible pumping unit in which a hydraulic motor drives the pump.

One important object of this invention is to provide such a pumping unit having a novel and improved arrangement for lubricating the shaft bearings for the pump.

Another object of this invention is to provide a novel submersible pumping unit with an improved lubricated bearing arrangement that enables the pump to be driven in either direction, as desired, since the bearing arrangement is capable of withstanding axial thrusts on the pump shaft in each direction.

Another object of this invention is to provide a novel submersible pumping unit having a novel and improved, hydraulically inflatable arrangement for sealing it against a well casing.

Another object of this invention is to provide a novel submersible pumping unit that may be positioned either vertically or horizontally underground to pump water in either direction.

Further objects and advantages of this invention will be apparent from the following detailed description of a presently-preferred embodiment thereof, which is shown in the accompanying drawings, in which:

FIG. 1 is an elevational view of a vertically suspended underground pumping unit in accordance with a first embodiment of this invention;

FIG. 2 is a bottom plan view of the FIG. 1 pumping unit;

FIG. 3 is an elevational view of a horizontally suspended underground pumping unit in accordance with a second embodiment of this invention;

FIG. 4 is a left end view of the FIG. 3 pumping unit;

FIG. 5 is a longitudinal vertical section taken centrally through the FIG. 1 pumping unit along the line 5 — 5 in FIG. 1;

FIG. 6 is a cross-section taken along the line 6 — 6 in FIG. 1;

FIG. 7 is a fragmentary longitudinal section showing an alternative bearing arrangement in the FIG. 1 pumping unit;

FIG. 8 is a fragmentary longitudinal section showing another alternative bearing arrangement in the FIG. 1 pumping unit;

FIG. 9 shows schematically the FIG. 1 pumping unit suspended from ground level inside a vertical well casing and sealed to the well casing;

FIG. 10 shows the FIG. 1 pumping unit in a substantially wider vertical well casing and provided with an

alternative arrangement for sealing engagement with the well casing;

FIG. 11 is an enlarged fragmentary vertical section, taken along the line 11 — 11 in FIG. 10 and showing the structural details of this alternative sealing arrangement;

FIG. 12 is a schematic diagram showing the circulation of hydraulic liquid from ground level to and from the hydraulic motor and the inflatable well casing sealing arrangement in the FIG. 9 assembly;

FIG. 13 is a schematic diagram showing the circulation of hydraulic liquid from ground level to and from the hydraulic motor in the FIG. 10 assembly;

FIG. 14 shows schematically the FIG. 3 pumping unit suspended horizontally from ground level at a horizontal underground irrigation conduit;

FIG. 15 is a similar view with the water flow through the pumping unit reversed from the direction shown in FIG. 14; and

FIG. 16 is an elevational view, broken away for clarity, showing a vertically suspended pumping unit with the hydraulic motor and the pump reversed, end-to-end, from their positions in FIGS. 1 and 5.

Before explaining the disclosed embodiment of the present invention in detail, it is to be understood that the invention is not limited in its application to the details of the particular arrangement shown, since the invention is capable of other embodiments. Also, the terminology used herein is for the purpose of description and not of limitation.

Referring first to the embodiment of this invention shown in FIGS. 1, 2, 5, 6, 9 and 12, this particular pumping unit has an annular casing 20 (FIGS. 1 and 9) with a semi-circular piece 21 bolted to its upper end and formed with an eye 22 at the top for receiving a ring 23 on the lower end of a suspension cable 24. This ring and eye preferably are aligned vertically with the longitudinal axis of the pumping unit.

In use, as shown in FIG. 9, the pumping unit is suspended by the cable 24 to extend vertically down inside a well casing 25 of circular cross-section. The upper end of the suspension cable 24 extends around a reel 26 mounted on a ground-level mobile unit 27 that contains an electric motor-driven pump, not shown. This pump discharges suitable hydraulic liquid, such as oil, down through a first hose 28 extending down to the cable-suspended pumping unit inside the casing 20. A return hose 29 extends from the cable-suspended pumping unit back up to a sump in the mobile unit 27.

As best seen in FIG. 5, the casing 20 of the suspended pumping unit has three sections 30, 31 and 32, which are welded or otherwise secured end-to-end at respective abutting annular flanges 30a and 31a, and 31b and 32b. Sections 30 and 31 are cylindrical, while section 32 is frusto-conical, being flared outwardly toward its lower end in FIG. 1.

An inflatable, radially expandable diaphragm in the form of a hose 33 of fabric-reinforced rubber-like material or the like is secured to the outside of the upper end section 30 of the casing. In one practical embodiment, this hose extends circumferentially around the outside of the casing section 30 for about 1½ turns or so, and has its opposite ends attached to respective metal fittings 34 and 34a (FIG. 6), which extend radially through the wall of this casing section. The hose 33, when inflated hydraulically, expands radially outward from the normal, full-line position in FIGS. 1 and

5 to the dashed-line position for sealing engagement with the inside of the well casing 25, as shown in FIG. 9. In one practical embodiment, the hose 33 is a section of fire hose of proven durability.

This inflated diaphragm sealing arrangement is preferred where the inside diameter of the well casing 25 is not much larger than the outside diameter of the casing 20 of the pumping unit.

As best seen in FIG. 5, a rotary hydraulic motor 35 of known design is supported rigidly centrally inside the casing section 30. This motor has a hydraulic inlet 36, connected to the lower end of hose 28, and a hydraulic outlet 37, connected through a reversely-bent, rigid pipe 38 to the middle leg of a Y-fitting 39. One branch of this Y-fitting is connected through a rigid pipe 40 to the fitting 34 for one end of the hose 33. The other branch of the Y-fitting 39 is connected to a rigid pipe 41 that extends down outside the hydraulic motor parallel to the axis of the pumping unit and has its lower end bent radially inward at 41a.

A three-piece annular housing is sealingly engaged axially between the hydraulic motor 35 and the pump 42 in this underground pumping unit. This housing comprises an upper cylindrical section 43, a middle cylindrical section 44, and a bottom end plate 45. The upper cylindrical section 43 of this housing is bolted at an annular, radial flange 43a on its upper end to the casing of the hydraulic motor 35, and it is bolted to the middle housing section 44 at a similar flange 43b on its lower end. Suitable liquid-tight sealing gaskets 46 and 47 are engaged respectively between the upper end flange 43a and the motor casing and between the lower end flange 43b and the top of the middle housing section 44 to prevent leakage.

The inturned lower end 41a of pipe 41 is rigidly connected through a metal fitting 48 to the upper housing section 43, and it communicates with the interior of this housing through this fitting.

At the opposite side of the upper housing section 43, the lower end of the return hose 29 (which extends back up to the sump in the mobile unit 27 at ground level) is turned in radially at 29a (FIG. 5) and is connected here through a similar metal fitting 49 to the housing section 43, so as to pass hydraulic liquid from the interior of this housing to the return hose 29.

The fitting 34a (FIG. 6) at the opposite end of the inflatable, radially expandable hose 33 is connected through a rigid pipe 50 to a T-fitting 51 (FIG. 5) on the return hose 29 for passing hydraulic fluid from inside this hose 33 back to the sump in the ground-level mobile unit 27.

A connecting shaft arrangement of known design, designated in its entirety by the reference numeral 52 in FIG. 5, extends axially between the hydraulic motor 35 and the pump 42 to impart the rotation of the rotor in the motor directly to the pump rotor. It includes a coupling 52a connecting the output shaft 35a of the motor to the pump shaft 55. This connecting shaft arrangement extends centrally through the three-piece annular housing 43, 44, 45, and it is rotatably supported in the end plate 45 of this housing by a sleeve bearing 53. A liquid-tight seal 54 of known design acts against this sleeve bearing and the inside of the housing end plate 45 to prevent leakage around the pump shaft 55.

An annular sealing gasket 63 is clamped axially between the end plate 45 and the middle housing section 44 to prevent leakage between them.

A bearing assembly is engaged axially between the lower end of the upper housing section 43 and an internal upwardly facing, annular shoulder 56 on the middle housing section 44. In FIG. 5 this bearing assembly comprises three ball bearings 57, 58 and 59 arranged end-to-end and each constituting both a radial bearing and an axial thrust bearing.

The lower-most of these bearings (57) has an annular inner race 60, an annular outer race 61, and balls 62 engaged radially between these races. The inner race 60 presents an upwardly-facing shoulder 60a below the balls 62 and the outer race 61 presents a downwardly-facing shoulder 61a above these balls. With this arrangement, the bearing unit 57 will resist an upward axial thrust on the connecting shaft arrangement 52.

Both the middle bearing 58 and the upper bearing 59 have essentially the reverse configuration of the races, with the inner race having a downwardly-facing shoulder that engages the balls, and the outer race having an upwardly-facing ball-engaging shoulder. Consequently, both of these bearings 58 and 59 oppose a downward axial thrust on the connecting shaft arrangement 52.

It will be evident from FIG. 5 that the upper end of the upper bearing 59 communicates with the interior of the upper housing section 43 around the connecting shaft arrangement 52. Consequently, the hydraulic liquid supplied through pipe 41 to the interior of this housing section 43 lubricates the bearings 59, 58 and 57 which support the connecting shaft arrangement for rotation and withstand axial thrusts in either direction on this connecting shaft arrangement.

The pump 42 has a rotor consisting of a central hub 64, rigidly secured to shaft 55, and outwardly projecting, curved propellor blades 65 whose outer edges have a close running fit inside a cylindrical liner 66, which is secured to the inside of the middle casing section 31 at the latter's lower end. A frusto-conical nose 67 extends down axially from the rotor hub 64. A plurality of radially disposed fins 68 (FIGS. 2 and 5) are welded to the nose 67 and have a close running fit inside the frusto-conical casing section 32.

A plurality of circumferentially spaced, radially disposed spacers 69 (FIG. 5) are welded to the inside of the middle casing segment 31 and have their inner ends welded to the outside of the middle housing section 44 to center the three-piece housing 43-45 inside the three-piece casing 30-32.

At the same circumferential locations, a plurality of radially disposed spacers 70 (FIGS. 5 and 6) are welded to the inside of the upper casing section 30 and extend inward therefrom, terminating at their inner edges just short of the end flanges 43a and 43b on the upper housing section 43.

These aligned radial spacers 69, 70 serve to channel the output flow from the propellor blades 65 into separate, substantially axial streams, which flow up inside the casing sections 31 and 30 and then merge with each other as they flow up into the well casing 25 above this pumping unit.

In the operation of this pumping unit, the pump in the ground-level mobile unit (FIG. 9) pumps hydraulic liquid down through hose 28 to drive the hydraulic motor 35. The rotor in the hydraulic motor drives the pump 42 to draw in water through the wider open end of the

casing section 32 and force it up through the interior of casing sections 31 and 32 (around the outside of the housing 43-45) and up past the hydraulic motor 35 through the well casing. The hydraulic liquid flowing out of the motor 35 also inflates the hose 33 to expand it radially outward so as to seal this pumping unit against the inside of the well casing 25. (This sealing action takes place only as long as the hydraulic motor 35 is operated.) The hydraulic liquid flowing out of the motor 35 also lubricates the bearings 57 - 59 for the pump shaft 55. The return hose 29 provides a return path for hydraulic liquid flowing out of the sealing hose 33 and out of the housing 43 - 45 for the bearings 57 - 59.

FIG. 12 illustrates the hydraulic flow circuit schematically, with the pump in the ground-level mobile unit 27 being designated by the reference character P. In this Figure, for the sake of simplicity, the flow path through the inside of housing section 43 directly from the inlet fitting 48 to the outlet fitting 49 is shown schematically as an unobstructed pipe, while the bypass to the bearings 57, 58 and 59 is designated schematically by a block.

If desired, the inflatable sealing hose 33 may be omitted and the outlet fitting 49 on housing section 43 may be omitted. In that case, the schematic diagram of the hydraulic circuit is as shown in FIG. 13, with a direct bypass pipe 38a being shown between the motor outlet pipe 38 and the return hose 29.

With the inflatable hose 33 omitted, an alternative sealing arrangement may be provided, as shown in FIGS. 10 and 11. This alternative sealing arrangement is preferred for use where the inside diameter of the well casing is substantially larger than the cross-sectional size of the pumping unit. It comprises an annular, flat, flexible and resilient sealing ring 75 of neoprene or other suitable rubber-like material in wiping engagement with the inside of the well casing 25. This sealing ring 75 is secured by an annular clamping plate 78 and bolts 79 to the outside of a rigid annular plate 76, which extends radially out from the casing 20. The inside of this plate 76 is attached to the casing by bolts 77 which extend through openings in the abutting flanges 30a, 31a on the adjoining sections of this casing.

As shown in FIG. 10, two such sealing arrangements 75-79 are provided, one at the abutting flanges 30a, 31a on the upper and middle sections 30, 31 of the casing, and the other at the abutting flanges 31b and 32b on the middle and lower sections 31, 32 of the casing.

As shown in FIG. 16, the present pumping unit may be reversed, end-to-end, inside its casing so that the pump 42 is above the hydraulic motor 35. In that case the direction of rotation of the motor and the pump rotor will be reversed, also, so that the water is still pumped upward in the well casing 25. The principal advantage of reversing the relative positions of the motor and the pump vertically is to position respective sealing gaskets 63, 47 and 46 for the bearing and connecting shaft housing and for the hydraulic motor on the low pressure side of the propeller blades 65, so as to minimize the possibility of leakage at these seals.

In FIG. 16, the casing for the pumping unit is of two-piece construction, and comprises a cylindrical upper section 80 with radial flanges 80a and 80b on its opposite ends, and a lower section with frusto-conical upper half 81 and a cylindrical lower half 82. The lower sec-

tion has a radial flange 81b at the top which is welded or otherwise attached to the bottom flange 80b on the upper section 80.

In other respects the pumping unit of FIG. 16 is essentially similar to that of FIG. 5, and corresponding elements are given the same reference numerals in FIG. 16 and in FIG. 5.

FIG. 7 illustrates a different bearing arrangement for the pump shaft in the present pumping unit. The other elements of this pumping unit are essentially the same as in FIG. 5 and carry the same reference numerals.

In FIG. 7 the bearing arrangement comprises a roller bearing 85 and a pair of ball bearings 86 and 87, arranged end-to-end. The ball bearing 86 in the middle has an inner race with a ball-engaging shoulder that faces to the right in FIG. 7 and an outer race with a ball-engaging shoulder that faces to the left. The end ball bearing 87 has just the reverse arrangement, its inner race having a ball-engaging shoulder that faces to the left and its outer race having a ball-engaging shoulder that faces to the right. Consequently, the middle ball bearing 86 takes up axial thrusts on the pump shaft 55 to the right in FIG. 7, and the end ball bearing 87 takes up axial thrusts on the pump shaft to the left in this Figure. All three bearings 85, 86 and 87 take up radial thrusts.

FIG. 8 illustrates still another bearing arrangement for the pump shaft in the present pumping unit. The other elements in the pumping unit are essentially the same as in FIG. 5 and are given the same reference numerals.

In FIG. 8 two roller bearings 88 and 89 are provided. Bearing 88 has the raceways for the rollers inclined laterally outward and to the left in FIG. 8, whereas bearing 88 has the raceways for the rollers which are inclined laterally outward and to the right. With this arrangement, both bearings 88 and 89 take radial thrusts, the bearing 88 takes axial thrusts on the pump shaft to the right in FIG. 8, and the bearing 89 takes axial thrusts on the pump shaft to the left.

FIGS. 3, 4, 14 and 15 show another embodiment of the present pumping unit, arranged to pump water through a substantially horizontal underground conduit, such as the irrigation conduit 90 in FIG. 14. This pumping unit is suspended from a ground-level mobile unit 27, which has an electric motor-driven pump for pumping hydraulic liquid down through hose 28 and a sump connected to the return hose 29.

The underground pumping unit has a three-piece casing 30, 31, 32 essentially similar to that in the embodiment of FIGS. 1 and 5, as well as similar hydraulic motor, pump and pump shaft bearing arrangement inside the casing.

As shown in FIG. 3, the tapered nose 67 and the radial blades 68 are foreshortened axially so that they do not extend beyond the open, wider end of the frusto-conical casing segment 32. This end of the casing may be closed by a circular plate 91. A transverse, rigid web 92 extends outward from this closure plate 91 to the left and upward in FIG. 3 and is joined to an upper hinge plate 93. This hinge plate is pivotally supported by a horizontal hinge pin 94 carried by a pair of spaced ears 95 (FIG. 4) that project up from the top of the casing segment 32 at its wider end. Away from this pivot the hinge plate 93 carries an eye 96 that receives a ring 97 on the lower end of a pull cable 98 extending up to a reel 99 at the ground-level mobile unit. By turning

this reel, the cable 98 may pull the closure plate 91 up from the fully-closed position, shown in full lines in FIG. 3, to the fully-open position, shown in phantom in FIG. 3 and in full lines in FIGS. 14 and 15.

The opposite end of the casing for this pumping unit has a similar closure arrangement, corresponding elements of which are given the same reference numerals, with an *a* suffix added, in FIG. 3. The end closure plate 91a may be opened by a pull cable 98a operated by a reel 99a at the ground level mobile unit 27.

As shown in FIG. 14, this pumping unit may be provided with a radially protruding plate assembly 100 for sealing engagement with the opening at one end of the underground conduit 90.

On both sides the casing of this pumping units carries a longitudinally spaced pair of outwardly protruding eyes 101 and 102 (FIG. 3) which receive respective rings 103 and 104 on the lower ends of wires 105 and 106 which are looped through a ring 107 on the lower end of a suspension cable 108. Cable 108 extends up to a reel 109 (FIGS. 14 and 15) at the ground-level mobile unit 27. This reel may be turned to raise or lower the pumping unit to the desired position underground.

In FIG. 14, the water intake is at the pump end of the unit. Therefore, cable 98 is raised to open fully the closure plate 91 for this end of the casing. At the other end, the cable 98a for the end closure plate 91a may remain slack since the water pumped out at this end of the casing will open this plate.

As shown in FIG. 15, this pumping unit may be operated in reverse, so that the water intake is at the motor end of the unit and the water discharge is at the pump end. In that case, the cable 98a will be pulled up to hold the closure plate 91a for the motor end of the unit fully open, while the other cable 98 may remain slack, relying on the force of the water being discharged to open the closure plate 91 at the pump end of the unit.

From the foregoing description and the accompanying drawings, it will be evident that the present pumping unit may have a variety of different constructions and may be used in a variety of different ways for pumping water or other liquid underground, either vertically or horizontally.

We claim:

1. In a submersible pumping unit having a hydraulic motor driving a pump, and an annular casing extending

circumferentially around the motor and pump, the improvement which comprises:

inflatable, radially expandable diaphragm means extending circumferentially around the outside of said casing;

and means for passing hydraulic liquid from the hydraulic output side of said motor into said diaphragm means to inflate the latter so as to expand radially outward for sealing engagement with a well casing which receives said motor, pump and casing.

2. A pumping unit according to claim 1, wherein said diaphragm means is a hose wrapped circumferentially around the outside of said casing.

3. A pumping unit according to claim 1, and further comprising:

a rotary connecting shaft arrangement coupling said motor to said pump;

bearing means supporting said connecting shaft arrangement for rotation;

and means for passing hydraulic liquid from the hydraulic output side of said motor to said bearing means to lubricate the latter.

4. A pumping unit according to claim 3, wherein said bearing means comprises at least two combined radial and axial thrust bearings which withstand opposite axial thrusts, respectively.

5. A pumping unit according to claim 2, and further comprising:

annular housing means disposed inside said casing and sealingly engaged axially between said motor and said pump;

a connecting shaft arrangement extending axially from said motor to said pump and coupling the motor rotationally to the pump;

bearing means inside said housing means supporting said connecting shaft arrangement for rotation;

and conduit means inside said casing means extending outside the motor from the hydraulic output side of the latter to the interior of said housing means to pass hydraulic liquid to said bearing means.

6. A pumping unit according to claim 5, wherein said bearing means comprises at least two combined radial and axial thrust bearings which withstand opposite axial thrusts, respectively.

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