Jan. 23, 1951 A. ARUTUNOFF 2,539,048

MOTOR-DRIVEN PUMPING APPARATUS FOR WELLS

Filed July 28, 1947

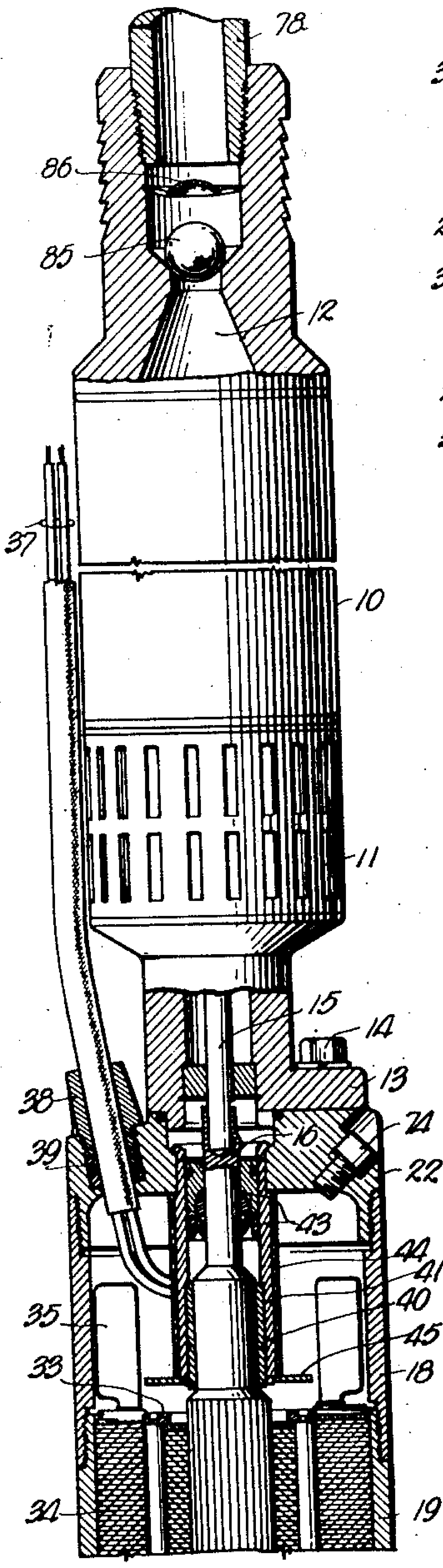

Fig. 2.

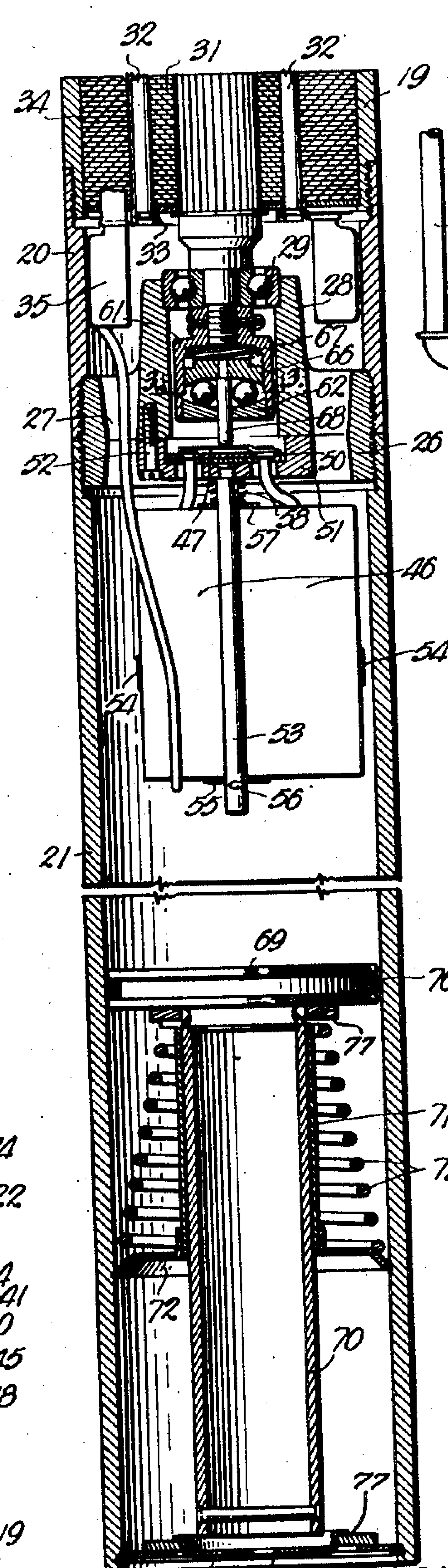

Fig. 2a.

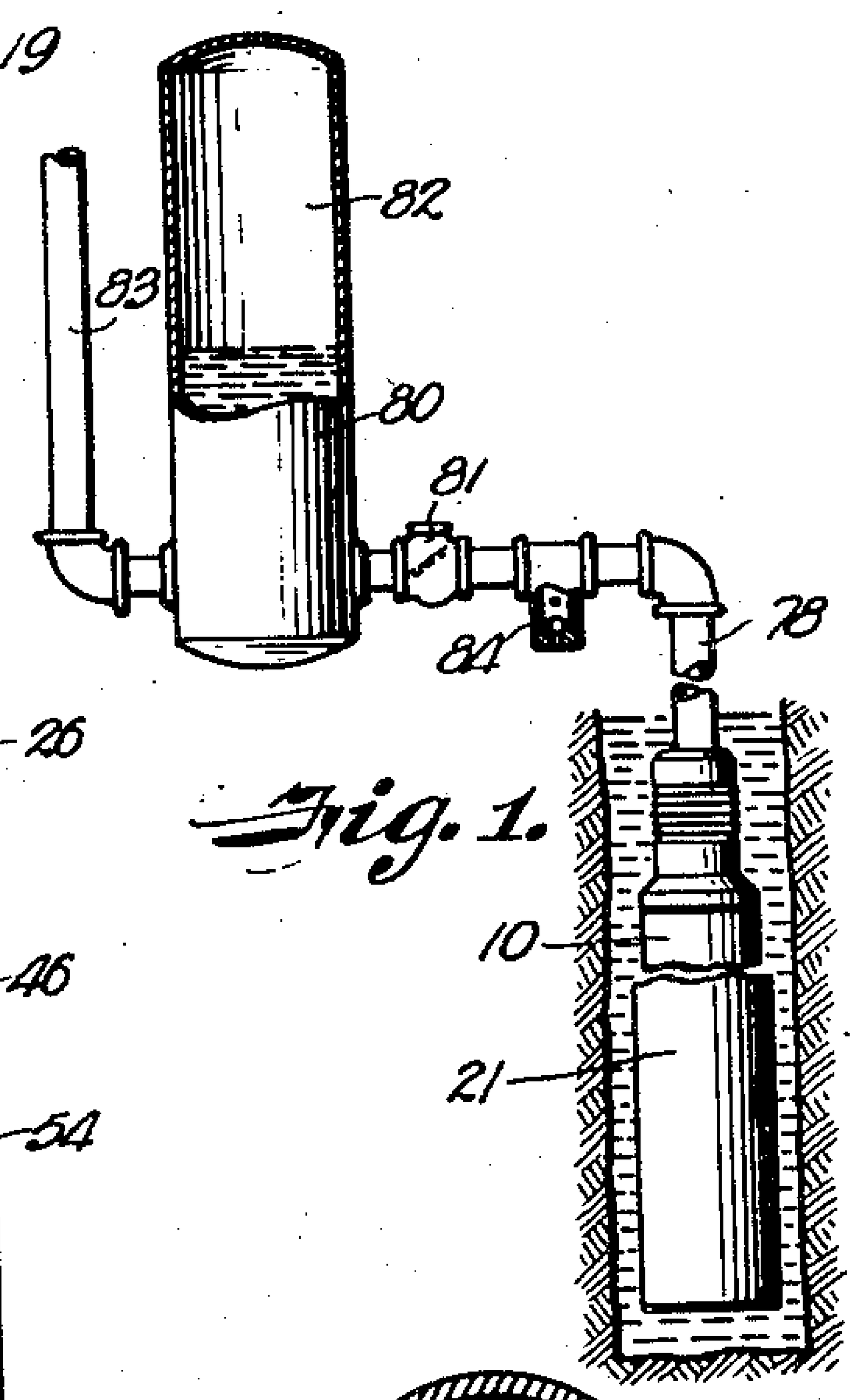

Fig. 1.

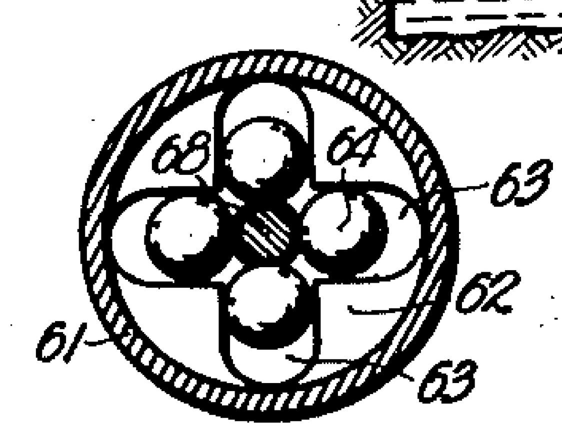

Fig. 3.

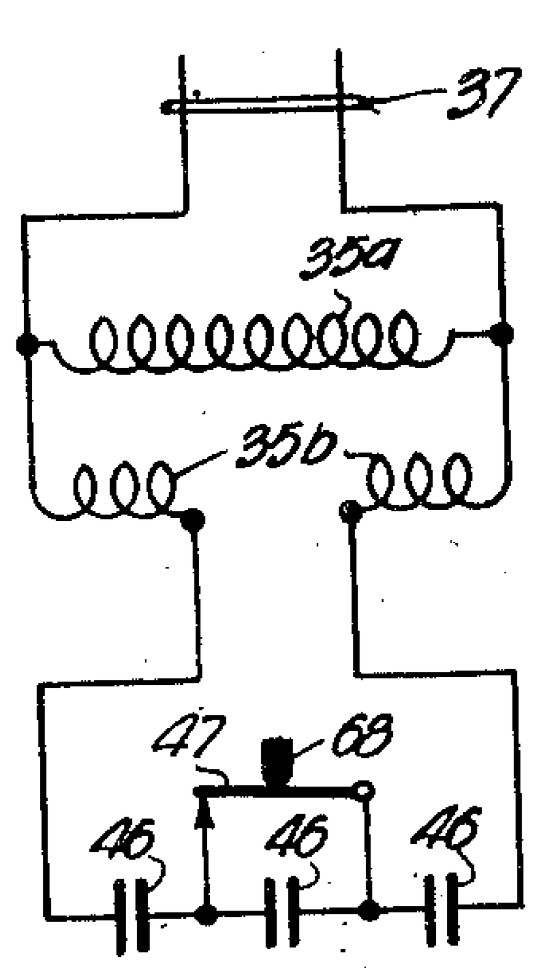

Fig. 4.

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2,539,048

MOTOR-DRIVEN PUMPING APPARATUS FOR WELLS

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Application July 28, 1947, Serial No. 764,104

9 Claims. (Cl. 318—221)

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The present invention relates in general to liquid pumping systems and apparatus, and it deals more particularly with submergible electric motor-driven pumping units.

A broad object of the invention is to provide an efficient and powerful electrically-driven unit fully protected against intrusion of the fluid in which the unit is submerged, the component parts of which are organized and assembled in an improved way to simplify construction and thus minimize expense without sacrificing anything in the way of effective operation.

A subsidiary object is to provide an enclosed single-phase induction motor having two windings, one of which has connected thereto phase-shifting capacitances disposed in the enclosure at one end of the motor shaft while the alternating current supply leads for the windings enter the enclosure at a point adjacent the opposite end of the shaft. Toward the achievement of the latter objective, an important feature resides in the use of a sectionalized winding in an induction motor with phase-shifting capacitances connected serially between the sections thereof.

Another object of the invention is to provide a centrifugal switch of improved construction and novel relationship to the other elements of my motor unit.

A further object is to provide a buffered pumping system having an air dome connected thereto to absorb sudden changes in pressure, together with apparatus for automatically replenishing the air in the dome in order to maintain the head of air despite losses such as may occur, for example, due to the air gradually dissolving in the liquid to which it is exposed.

Other objects and features will appear in the course of the following description of the invention.

In the accompanying drawings which form a part of the specification and are to be read in conjunction therewith and in which like reference numerals are employed to indicate like parts of the various views,

Fig. 1 shows my pump in elevation, together with the equipment at the surface of the well connected thereto,

Fig. 2 is an enlarged axial cross section of the upper portion of the pump,

Fig. 2*a* is an enlarged axial cross section of the lower portion of the pump,

Fig. 3 is a transverse cross section taken along the line 3—3 of Fig. 2*a* in the direction of the arrows, and

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Fig. 4 is a schematic diagram of the motor circuit.

Referring more particularly to Fig. 2, the numeral 10 identifies a multistage centrifugal pumping unit having intake ports 11 and an upwardly tapered discharge port 12. Its flanged base 13 is secured by bolts 14 to the upper end of the motor unit about to be described, and a noncylindrical tip on its impeller shaft 15 fits into a correspondingly shaped socket on the upper end of the motor shaft 16 whereby motor torque is transmitted to the pump shaft in order to drive liquid upwardly through the pump when the motor is running.

The motor housing or stator casing is made up of cylindrical sections 18, 19, 20 and 21 threaded so that they may be screwed end-to-end as shown, a cap 22 being screwed onto the uppermost section and an apertured bottom plate 23 being fastened to the lowermost section by a retaining ring 24. Sections 20 and 21 are joined together by a threaded ring 26 having inwardly extending radial arms 27 connecting with and supporting the collar 28. Collar 28 in turn carries the lower bearing 29 of the rotor of the motor.

The motor is of the single phase induction type having a squirrel-cage rotor made up of laminations 31 slotted to receive longitudinal inductor rods 32, the rods being electrically connected at their upper and lower ends by short circuiting rings 33. Stator laminations 34 are rigidly supported in section 19 of the motor housing and have vertically aligned slots for receiving field windings 35. The electrical conductors 37 via which the windings receive their energy enter the motor housing through cap 22, the entrance being sealed by a packing nut 38 and gland 39.

It will be noted that for the sake of compactness the upper end of collar 28 extends into the space encircled by the lower end of the windings, and there supports the lower bearing of the rotor; similarly, the bushing 40 at the upper end of the rotor is supported by a rigid guide tube 41 which extends downwardly from cap 22 into the space encircled by the upper ends of the windings. Above the bushing in the tube there is a fluid seal 43 which may be of any suitable form. An insulating sleeve 44 encircles the tube 41 and at the bottom of the tube there is a radially extending annular lead guard 45.

The motor windings 45 comprise two separate field windings 35*a* and 35*b* arranged in the slots of the stator, one of the windings being connected directly across the power line as shown schematically in Fig. 4 while the other is divided and has condensers 46 connected in series with the two sections thereof. This results in phase displacement of the current in the two windings for starting purposes, the phase relationship being altered when the motor reaches a predetermined speed by the opening of contact 47 thereby to improve operating torque; as indicated in Fig. 4 contact 47 normally short circuits part of the series connected capacitance in series with winding 35b.

Contact 47 is mounted on insulating disks 50 below the end of the motor shaft, the disks in turn being retained in a cup 51 which is secured to the bottom of the bearing support collar 28 by screws 52. Depending from the cup is a rigid post 53 around which condensers 46 are clustered, a tape 54 serving to tie them together. The condensers are supported by a washer 55 encircling the lower end of the post and held thereon by a cotter pin 56; another washer 57 urged downwardly by a coiled compression spring 58 bears against the upper ends of the condensers to prevent vertical movement thereof relative to the post.

In the space encircled by the stationary bearing support collar 28 and secured to the lower extremity of the motor shaft by a cotter pin 60 is an inverted cup 61, the lower end of which is closed by a centrally apertured disk 62. The upper face of the disk contains four upwardly and outwardly inclined grooves 63 adapted to receive balls 64. Above the balls is a concave faced disk 66 urged downwardly by the coiled compression spring 67. The latter disk carries a stem 68 which projects through the central aperture in disk 62 and engages contact 47 thereby normally to maintain same closed.

When the motor is not operating the balls occupy the position illustrated. However, as the motor gathers speed upon the starting thereof the balls move upwardly due to centrifugal force, raising disk 66 and stem 68 against the force of spring 67 until contact 47 finally opens. As previously stated, this removes the short circuit which exists around part of the capacitance in series with winding 35b and thus deduces the overall capacitative reactance of that circuit. Although three condensers have been shown in series with the winding, one of which is short circuited during the starting period, it will be understood that any suitable number of condensers may be employed and contact 47 may be arranged to short circuit any part of the series connected condenser group.

I am well aware that it is not new to use one or more condensers in conjunction with the starting winding of a single phase induction motor to adjust the phase relationship between that winding and the main operating winding. When this has been done in the past, however, it has been customary to connect the condensers to the starting winding at one end thereof, i. e., between one side of the power line and one end of the winding, the opposite side of the power line being connected to the opposite end of the winding.

So far as is known to me no one heretofore has interrupted the winding intermediate its ends to place the capacitance between the two sections thereof as I do. Electrically, the capacitance serves the same purpose when thus connected as it does when connected at one end of the winding; however, it makes possible a structural relationship of parts which is of great importance in my device. Specifically, it makes it possible to connect the power supply line to the motor winding at a point located adjacent one end of the motor shaft while connecting the condensers to the winding at a point located adjacent the opposite end of the shaft.

In most induction motor installations the condensers can be positioned without difficulty adjacent the same end of the motor shaft as where the power supply line connects to the winding. Such is not the case here. Cable 37 cannot advantageously be made to extend downwardly outside the motor housing to a point where it could enter the housing below the motor because to do so, in the light of well bore limitations which must be met, would require reduction of the motor's diameter and a consequent sacrifice of power. On the other hand, to position the condensers above the motor would require undesirable elongation of the motor shaft and housing section 18 to gain space above the motor winding, not only for the condensers themselves but also for a centrifugal switch and associated operating mechanism. The fact that the shaft extends through the space above the motor would immeasurably complicate the design of parts and their arrangement in this space.

By connecting the power supply leads to the top end of the winding and opening the winding at its lower end between two adjacent turns in order to insert the capacitance in series with the two sections thus formed, a simple and completely satisfactory solution to the problem indicated above is reached. The length of the motor shaft is kept to a minimum, maximum motor diameter is retained, and the centrifugal switch and condenser are mounted where (1) space is less at a premium and design hence is not dictated or complicated by excessively cramped quarters, and (2) cooling of the condensers is achieved more satisfactorily.

Below the condensers is a piston 69 having rigidly secured thereto a downwardly extending hollow stem 70 adapted to slide in a stationary guide tube 71 as the piston moves up or down. The guide tube has affixed to its bottom a radial flange 72 which is toed into the inner wall of the casing 21 and which supports a compression spring 73 urging the piston upwardly. Standing on the piston is a column of oil introduced into the motor chamber through the oil fill hole shown closed by screw 74. This oil bath surrounds and encloses all parts of the motor and associated electrical equipment, insulating same and also lubricating the motor bearings.

Well fluid enters the chamber below the piston via aperture 75 and the piston automatically moves up or down as needed to equalize the pressure between this fluid and the oil, as the oil expands and contracts due to heating and cooling. Due to the fact that the upward pressure exerted on the piston by the well fluid is supplemented by the pressure of spring 73, it will be seen that the oil is under slightly greater pressure than the well fluid. Consequently, any leakage which occurs around piston ring 76, around fluid seal 43, or at any other point in the motor chamber will result in gradual extrusion of oil rather than intrusion of well fluid, thus safeguarding the motor. Inhibitor rings 77 are employed in conventional fashion at points subject to erosion due to electrolytic action in the well fluid.

Installation of my pump is quick and easy. A discharge pipe 78 simply is screwed into the pump and the whole unit lowered below the water level in the well. The pump performs perfectly in a well of any depth and at any submergence below water level. Water tables which become lower year by year impose no hardship since the pump can be lowered as necessary simply by adding more discharge pipe and extending the electrical cable.

The surface equipment (in addition to the switch which starts and stops the pump motor) preferably is as shown in Fig. 1. It comprises a buffer tank **80** to which the supply pipe **78** is connected through a light-weight, fast-acting check valve **81**, the valve opening to admit fluid to the tank but closing quickly to prevent a reverse flow when the pump ceases to operate. The tank contains a head of air **82** serving to absorb pressure changes in the system and thus smooth the flow of liquid discharged through pipe **83**.

Over a period of time the air trapped in tank **80** slowly dissolves in the liquid passing through the bottom thereof and accordingly the following arrangement for automatically replenishing the air in the tank is provided. In the supply line **78** just ahead of check valve **81** is a small air intake aperture normally maintained closed by a ball valve **84**; at the bottom of pipe **78** in the discharge port of the pump is a check valve comprising a light ball **85**, shown seated in Fig. 2 but normally carried upwardly by the flow of fluid so it is held against stop **86**.

Whenever the pump ceases to operate the column of liquid in pipe **78** tends to settle downwardly under the influence of gravity, causing check valve **81** quickly to close as already explained. Ball **85** also returns to its seat but does this less rapidly whereby there is a slight downward movement of fluid in the pipe after check valve **81** has closed. This creates a partial vacuum in the upper end of pipe **78** and accordingly atmospheric pressure outside of the pipe causes ball valve **84** to open momentarily and admit air to the pipe. When next the pump is started this air is driven into tank **80** insuring that the head of air **82** is maintained.

The amount of air thus added to the tank each time the pump stops and starts naturally will depend upon the extent of the lag between the closing of check valve **81** and the closing of the ball valve **85** in the discharge port of the pump; the speed of the latter valve can be adjusted by varying the weight of the ball **85**, the warding action of the cup-shaped stop **86** sheltering the ball, and the distance above the valve seat that stop **86** is located.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinbefore set forth together with other advantages which are obvious and which are inherent to the apparatus.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

Inasmuch as many possible embodiments of the invention may be made without departing from the scope thereof it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. A submergible single phase induction motor, comprising a tubular housing having the motor shaft extending through one end wall thereof, a fluid seal between the housing and said shaft, a piston slidably closing the other end of the housing, yieldable resilient means urging the piston toward said one end of the housing, a sealing and lubricating fluid under pressure in the housing between said piston and said one end wall, a stator and field winding in the fluid, a power supply line connected to said winding at the end of the stator nearest said one end wall of the housing, a phase shifting reactance device in the fluid between the piston and stator and connected to the winding at the end of the stator nearest said piston, whereby said device is connected to said power supply line solely through said winding and independently of any other electrical conductor extending past said stator.

2. A submergible motor as in claim 1 wherein said piston is spaced axially of the housing from the nearest end of said motor shaft, and said reactance device is disposed in the housing in the space between the end of the shaft and the piston.

3. A submergible motor as in claim 2 having a switch connected to said reactance device and mounted between said reactance device and the end of the shaft in alignment with the shaft, and centrifugal mechanism on the shaft for operating said switch responsive to changes in the speed of rotation of the shaft.

4. A submersible single phase alternating current motor comprising a housing having the motor shaft extending vertically upward therethrough for driving a load located above the motor, a fluid seal between the housing and said shaft, a piston slidably closing the lower end of the housing, yieldable resilient means urging the piston upwardly, a sealing and lubricating fluid filling the housing above the piston, a perforate frame in the housing spaced above said piston, a bearing for the lower end of the motor shaft carried by said frame, a phase shifting reactance device mounted on the under side of said frame, a power supply line entering the upper end of the housing, a field structure in the housing above said frame, a pair of field windings on said field structure, one end of each winding terminating at the upper end of the field structure and connecting directly to said line, the other end of each winding terminating at the lower end of said field structure and connecting directly to said reactance device, said reactance device being connected to said line solely through said windings and independently of any other electrical conductor passing between the upper and lower ends of said field structure.

5. A submersible single phase alternating current motor comprising a housing having a motor shaft extending vertically upward therethrough for driving a load located above the motor, a fluid seal between the housing and said shaft, a piston slidably closing the lower end of the housing, yieldable resilient means urging the piston upwardly, a sealing and lubricating fluid filling the housing above the piston, a perforate frame in the housing spaced above said piston, a bearing for the lower end of the motor shaft carried by said frame, a phase shifting reactance device mounted on the under side of said frame, a switch fixedly mounted on the frame and connected to said reactance device, a centrifugal mechanism on the lower end of the shaft for operating the switch responsive to changes in the speed of the shaft, a power supply line entering the upper end of the housing, a field structure in the housing above said frame, a pair of field windings on said field structure, one end of each winding terminating at the upper end of the field structure and connected directly to said line, the other end of each winding terminating at the lower end of the field

structure and connected directly to said reactance device, said device being connected to said lines solely through said winding and independently of any other electrical conductor passing between the upper and lower ends of said field structure.

6. A submersible single phase alternating current motor comprising a tubular housing having the motor shaft extending through one end wall thereof, a fluid seal between the housing and said shaft, a piston slidably closing the other end of the housing, said piston spaced axially of the housing from the nearest end of the motor shaft, a phase shifting reactance device in the housing in the space between the piston and end of the shaft, yieldable resilient means urging the piston toward said one end of the shaft, a sealing and lubricating fluid under pressure in the housing between said piston and said one end of the housing, a field structure in the fluid having a main winding and a plurality of auxiliary windings, said one end of the wall of the housing having an aperture through which a power supply line enters said housing and connects to said main winding, one end of each auxiliary winding terminating at the end of the field structure nearest said aperture and being connected directly to said power line, the other end of each auxiliary winding terminating at the end of the field structure nearest said piston and being connected directly to said device.

7. A motor as in claim 6 having a switch connected to said reactance device and mounted between said reactance device and the end of the shaft, and a centrifugal mechanism on the shaft for operating the switch responsive to changes in the speed of the shaft.

8. A vertically-axised, submersible, single-phase, alternating current motor, comprising a stator casing, a motor shaft extending vertically upward through the casing for driving a load located above the motor, a bearing mounted in the casing and journalling the lower end of the motor shaft, a phase-shifting reactance device within the casing and positioned below said bearing, power leads entering the upper end of the casing from above, a stator field structure in the casing between said bearing and the upper end of the casing, field windings on said stator field structure, one of said field windings being split and provided with two pairs of terminals, one pair of terminals being disposed at the upper end of the stator field structure and being connected directly to said power leads, the other pair of said field terminals being disposed at the lower end of said stator field structure and connected directly to said reactance device, said reactance device being connected to the power leads solely by said split winding independently of any other electrical conductor passing from the upper to the lower end of said stator field structure.

9. A vertically-axised, submersible, single-phase alternating current motor, comprising a stator casing dimensioned externally for operation within a well-casing, a motor shaft extending vertically upward through the stator casing for driving a load located in the well-casing above the motor, a bearing mounted in the stator casing and journalling the lower end of the motor shaft, a phase-shifting reactance device within the stator casing and positioned below said bearing, power leads entering the upper end of the stator casing from above, a stator field structure in the stator casing between said bearing and the upper end of the stator casing, field windings on said stator field structure, one of said field windings being split and provided with two pairs of terminals, one pair of terminals being disposed at the upper end of the stator field structure and being connected directly to said power leads, the other pair of said field terminals being disposed at the lower end of said stator field structure and connected directly to said reactance device, said reactance device being connected to the power leads solely by said split winding independently of any other electrical conductor passing from the upper to the lower end of said stator field structure, a centrifugal switch operatively connected to said reactance device and mounted within the stator casing below said bearing, and means for driving said centrifugal switch from said shaft, said centrifugal switch when closed being effective to short circuit at least a part of the reactance of said reactance device.

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