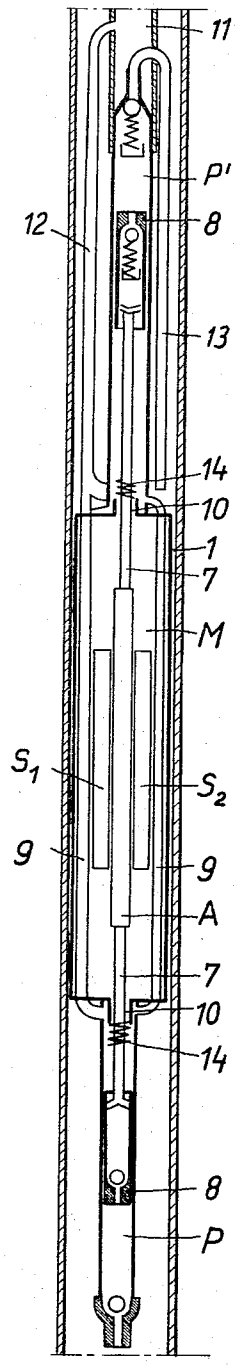
Jan. 23, 1968 P. GHEORGHE 3,364,864

PUMPING DEVICE FOR DEEP OIL WELLS

Filed March 17, 1965 5 Sheets-Sheet 1

Fig. 1



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PUMPING DEVICE FOR DEEP OIL WELLS

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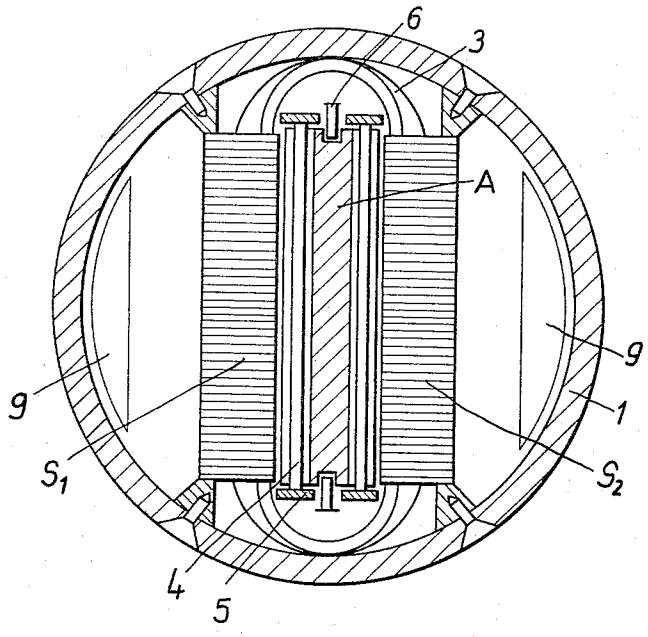
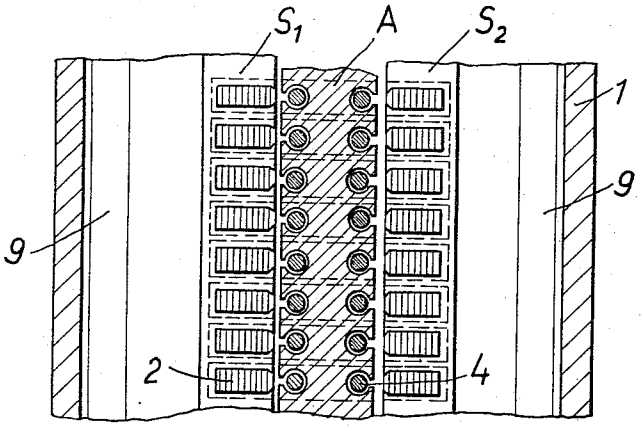


Fig. 2

Fig. 3



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PUMPING DEVICE FOR DEEP OIL WELLS

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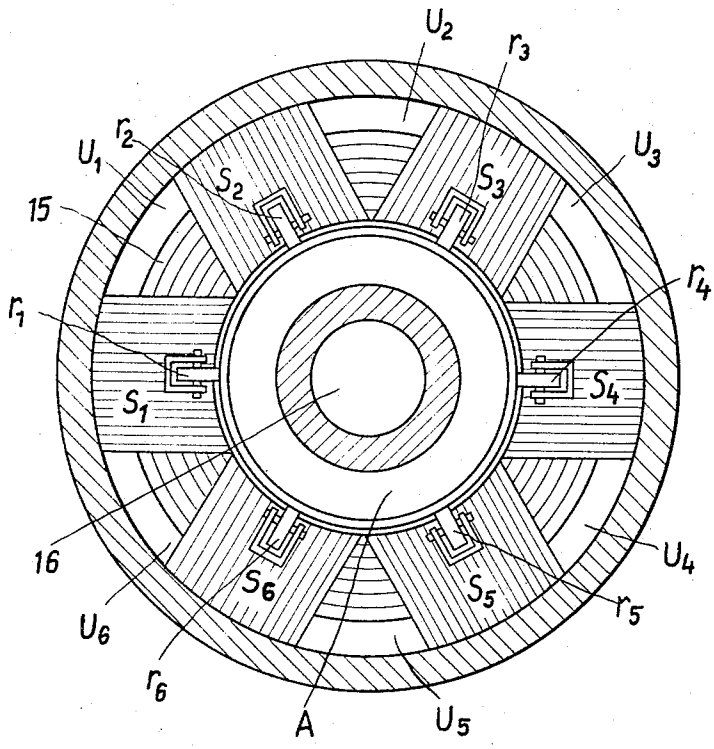


Fig. 4

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PUMPING DEVICE FOR DEEP OIL WELLS

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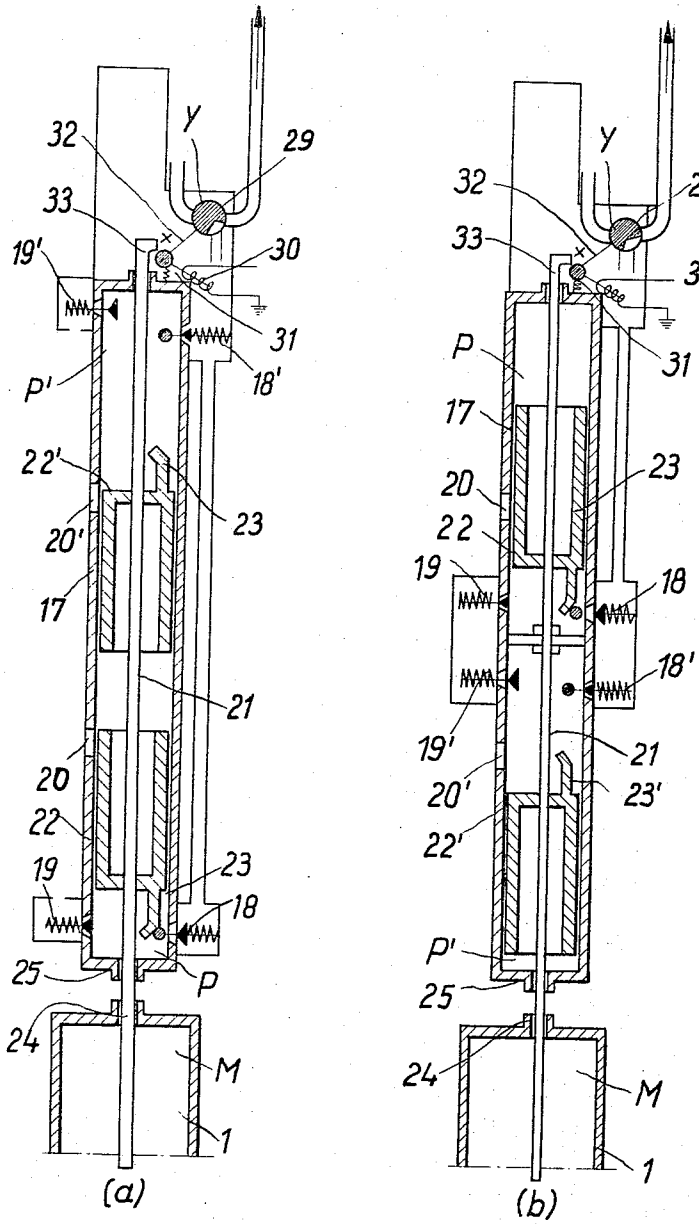


Fig. 5

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Jan. 23, 1968 P. GHEORGHE 3,364,864

PUMPING DEVICE FOR DEEP OIL WELLS

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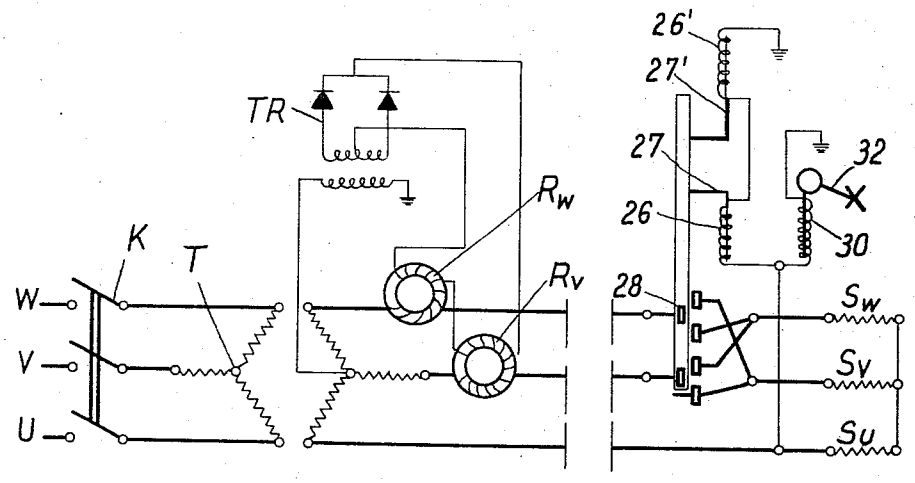


Fig. 6

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United States Patent Office 3,364,864
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3,364,864

PUMPING DEVICE FOR DEEP OIL WELLS

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Filed Mar. 17, 1965, Ser. No. 440,455
Claims priority, application Rumania, Mar. 21, 1964, 47,695
15 Claims. (Cl. 103—46)

This invention relates to an installation for oil pumping, the working conditions of which are not influenced by the pumping depth.

The pumping method using piston pumps driven from the surface by sucker-rods-string actuated with a reciprocating motion by a walking beam connected to a pitman and by a speed reducing gear, coupled with an electric motor is known in the art.

This known pumping method, which is today in widespread use, has the disadvantage that the transmission system for the reciprocation motion, and especially the sucker-rods-string with a length of 2000–2500 m., causes considerable friction, reducing the pumping system efficiency to about 0.4 and causing numerous interruptions due to the frequent failures of the sucker-rods-string.

On the other hand, the depths to which this pumping system can be used is limited by the sucker-rods-string ultimate tensile strength, under the strain of the dead weight of the string and the actuating forces of the pump.

It is also known to use a pumping method which employs a centrifugal pump directly couples with a three-phased asynchronous motors. The disadvantage of this known pumping method consists in the fact that, at high pressures of over 200 kg./sq. cm. under which the pump has to work at these depths, the dimensional limitations for the construction of the centrifugal pump within the space restriction of the well casing demands a large number of stages (250–300 stages), a fact which complicates very much the construction, raises the capital investment, increases the danger of the impellers being eroded by the sand contained in the oil, and reduces greatly the operating efficiency.

There are also known in the art pumping devices using electromagnetic drives by using solenoid type coils which, due to a shifting magnetic field produced by the three-phased currents, produce alternating magnetic forces on the magnetic armature solid secured to the piston of the pump.

Also forming part of the prior art is, for example, the device disclosed in U.S. Patent No. 1,740,003 entitled, Electrically Driven Oil Well Pump. This device uses a double piston pump driven by a cylindrically shaped three-phased induction motor, which imparts a rectilinear reciprocal motion to a double piston. This double piston can advantageously be positioned inside well holes, since the double piston is axially mounted inside the mobile armature. The stator of the motor for the device is composed of annular sections between which annular spaces are provided for the coils of the stator, which alternately are connected to one of the three phases of an electric power source. The interrupting of the current and the reversal of the phases at the end of the strokes in order to reverse the direction of motion of the double piston is effectuated by well known switching means. This type of a device has the inherent weakness of requiring the reversing of the direction of motion of the double piston at relatively high frequencies (30 to 60 strokes per minute) which leads to two unfavorable effects:

A rapid wear of the contactors used for reversing the current;

An excessive coil heating, due to the very big starting currents which appear at each direction change.

The pumping device disclosed in U.S. Patent No. 1,740,003 has the further disadvantage that the pump, which is mounted within the mobile armature of the electric motor, requires, of course, an increase in the outside diameter of the motor itself, which reduces the possibilities of using this device for pumping oil in deep wells, where only small diameter casings are used. Since the stator of the motor consists of annular sections, there is furthermore an inherent disadvantage in the construction of the electric motor itself because the magnetic force lines of the magnetic multipolar field act transversely to these annular sections by passing through the spaces between the magnetic sheets, which means an increase of the air gap, which in turn has a negative effect on the maximum power output of the device, the power requirement for the starting forces, etc.

The above mentioned disadvantages of the known oil pumping systems for deep wells are eliminated by the pumping installation according to this invention, due to the fact that it is using two pumps directly actuated by an induction electric motor with rectilineal alternating motion having a construction fitted to the overall dimensions of the well casing and due to the fact that the device of this invention eliminates the unfavorable effects caused by the high frequency reversal of motion present in the prior art devices by the following means taken separately or combined:

In the device of this invention the requirement for producing large forces during each direction reversal of the pump by electrical means has been eliminated. In lieu thereof, there is used a hydraulic device for starting and reaching the normal speed. This hydraulic drive is effectuated by the pressure caused by the pumped liquid, which is applied to one piston of the device, while simultaneously being eliminated at the other, in accordance with the direction of the moving armature of the device. In this manner, in the device of this invention during the starting period one of the pumps is being energized by a hydraulic force, while the other is idling. Consequently, despite the fact that the device has an alternating rectilinear motion, the electric motor is operating, insofar as its power input is concerned, with a practically constant speed and with rigorously maintained constant traction forces.

Furthermore, the mechanical current breaking arrangements of the prior art devices for interrupting the current supply at each direction change of the pump have been eliminated. In lieu thereof, there are used stationary electronic means which are controlled by the motion of the mobile armature.

Several illustrative embodiments of pumping devices in accordance with this invention, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing in which:

FIG. 1 is a cross-sectional elevation illustrating a general set up of the pumping device of this invention;

FIG. 2 is a transverse cross-section through one embodiment of an electric motor of the device of this invention;

FIG. 3 is a longitudinal cross-section through the electric motor illustrated in FIG. 2;

FIG. 4 is a cross-sectional view of another embodiment of an electric motor in accordance with this invention;

FIGS. *5a* and *5b* are cross-sectional elevations illustrating schematically the electric and hydraulic drives of the device of this invention;

FIG. 6 is an electric circuit diagram for the motion direction changing means of the device.

Referring specifically to the drawing there is illustrated in FIG. 1, the electric motor M which drives two piston pumps P and P' which have alternating active strokes, one having an ascending stroke while the other has a descending stroke. With this arrangement both of the strokes of the electric motor M are active, which fact reduces to a half the power loses in the motor winding when comparing the device of this invention with these prior art devices employing a single pump which for the same output has one active stroke and one idle stroke.

In order to ensure a good insulation of the coils, taking into consideration the fact that the motor is immersed in oil, the housing shell of the motor M is made fluid-tight and is filled with air or with insulating oil, which is serving as cooling fluid as well.

One constructional arrangement of the electric motor M is illustrated in FIG. 4. The electric motor is of the poly-phase induction type having its secondary mounted in a squirrel cage. A cylindrical housing **1** in which there are mounted several stators S_1–S_6, each of which is composed of a plurality of radially disposed sheets. Each stator S is provided with radially extending teeth and slots. The coils for an armature A are mounted within the slots. The armature A is axially mounted in the motor M and is, due to the action of the shifting magnetic field produced in the air gaps, alternatively moving in the vertical direction.

In order to obtain the stroke lengths and pumping frequencies comparable to those obtained with ordinary oil well pumps (2*o* . . . 3*o* double strokes of 2 . . . 4 m. per minute) while using currents of industrial frequency, the electric motor M is provided with a great number of pole pairs, having a poler pitch as short as possible, and having thus the smallest possible number of slots per pole and phase, preferably only one slot. The oil terminals **3** of the statoric winding are obtained by passing the winding from a stator S_1 slot to a stator S_2 slot, inasmuch to allow the magnetic flux lines of force to pass farther from a stator to another, alternating the direction from a pole to another.

The mobile armature A is provided with two ladder shaped plane cages, constituted each from active bars **4** placed inside the slots and with hte ends welded to two rectilineal strips **5**, which act as the rotor rings for the squirrel cage type motor.

The mobile armature A extends beyond the stator a distance equal to the stroke length, and is alternatively moving on two slide bars **6** secured to the two stators, causing, by means of rods **7**, the movement of the pistons **8**. The motor winding is cooled by displacing in an inverse direction the fluid from inside the housing. The oil pumped by the lower pump is delivered upwardly through the pipe lines **9**.

The motor housing is provided with two stuffing-boxes **10**. For the balancing of the pressure from the housing with the external pressure adequate balancing devices are used.

The connection between the two pumps and the tubing string **11**, is made by means of a pipe line **12** and the suction of the upper pump is effected via the pipe **13**.

The stuffing boxes **10**, are provided in order to absorb shocks when the pump exceeds its normal stroke.

In order to utilize to the fullest extent the small interior diameter of the casing a great number of stators may be used.

In the embodiment illustrated in the transverse cross-sectional view of FIG. 4, six stators S_1–S_6, each having the shape of a circular arc, are mounted directly in the housing. In this arrangement, the coil terminals **15** are almost completely eliminated, the coils passing directly from the slot of one stator to the slot of an adjacent stator, thus passing through all six stators.

The coil of one slot is connnected in series with the coil of the other slots shifted so that a predetermined number of slots correspond to a pair of poles. Consequently, the winding is composed of coils corresponding to the number of phases and to the number of poles, of which half are connected inversely to the other half, in order to obtain alternatively the north and south polarities.

The manufacturing of the winding can be simplified by choosing completely open slots and pressing successively from the exterior, and in a radial direction, the six stators upon the winding previously prepared on a cylindrical mandrel with a corresponding diameter.

The mobile armature A has a length equal to that of the stators plus the length of the stroke. It is displaced alternatively, being guided by the rollers r_1 . . . r_6 secured to both ends of the stators. It effectuates the reciprocal motions of the pistons via the rod **7** and also effectuates the displacement on the inverse sides of the cooling liquid present in the radial spaces U_1 . . . U_6 near the coil terminals **15**.

The mobile armature A for the embodiment of FIG. 4 has a cylindrical shape being made out of sheets or solid steel and is provided with teeth and slots which contain the winding consisting of a single annular conductor for each slot. Thus, the armature A forms a cylindrical cage having annular bars.

In the center of the mobile armature A there is provided a channel **11**, which ensures the cooling of the mobile armature A by means of the circulating liquid.

The housing shell **1** of the motor illustrated in FIG. 4 has a length equal to that of one of the stators S_1–S_6 plus double the length of the stroke so as to be able to accommodate the stroke of the mobile armature A.

The housing shell **1** of the motor is sealed at its top and bottom by the stuffing boxes **10** from the liquid under pressure in the well hole. The housing shell **1** includes means for permitting an expansion of the cooling liquid. In order to absorb shocks that may occur under high frequency operation of the armature A, damping springs **14** are coaxially mounted on the upper and lower rods **7**.

Both pumps P and P' are connected via ducts **9** to the tubing **11**, suction by pumps taking place through the intake ducts.

In the embodiments of FIGS. 5*a* and 5*b* there are illustrated the electrohydraulic driving systems which allow starting at the end of the strokes when the motion direction is reversed, by using the hydraulic pressure exerted by the pumped oil column and acting upon the pump pistons.

In FIG. 5*a* there is illustrated an embodiment in which both the pumps P and P' are assembled in a single cylinder **17**, mounted above the electric motor M and being provided at their respective stroke ends with two discharge valves **18** and **18'** and two suction valves **19** and **19'**, and toward the middle of the common piston housing, with two valveless windows **20** and **20'**, which are shut and opened directly by the motion of the respective pistons.

Inside the cylinder **17** and on the common rod **21** driven by the electric motor are mounted two pistons **22** and **22'** provided each with a slide plate **23** and **23'** which serves to keep open the respective discharge valves **18**, during the starting period by hydraulic action, thus functioning like a car with rectilineal motion.

The electric pump acted on by the hydraulic drive operates as follows:

During the down stroke, due to the action of the electric motor M, the piston **22**, pressing the oil in the cylinder, keeps the suction valve **19** shut (which during suction is opened toward the interior pressing upon its spring) and causes the discharge valve **18** to open (which opens toward the outside, and which during the suction is kept closed by its spring), discharging through it the oil from cylinder.

When approaching the end of the stroke, the electric current is cut-off by the switching-reversing device illustrated in FIG. 6 and the piston motion is checked by the pressure exerted by the discharged oil column.

At the end of the down stroke the oil discharge action ceases and the valve **18** closes under the pressure of its spring and due to pressure of the delivered oil column, but is kept open by the slide-bar **23**, so that the oil column can further exert its pressure upon the piston.

During its down stroke (which is really an up stroke), the other piston **22'** is working under suction, with the suction valve **19'** open under the pressure of the oil from the oil well, which enters into the free space left in the cylinder caused by the piston displacement, during which the corresponding discharge valve **18** is closed.

When the piston **22'** approaches the lower end of the stroke, it passes slightly beyond the window **20'**, thereby establishing communication with the outside, so that only the pressure, of the liquid in the oil well is exerted upon this piston, while upon the piston **22** there is exerted the larger pressure of the discharged oil column, causing the entire mobile string to start an inverse motion, by hydraulic action. At the point where the mobile string has reached its normal speed, the slide-bar **23** (correspondingly adjusted) ceases to maintain open the lower discharge valve **18**, the piston **22'** during its upstroke closes the window **20'**, and the device for switching and reversing reestabilshes the electric current in the circuit, in the corresponding direction, so that the electric pump passes from an hydraulic drive to an electric drive.

The upstroke being continued due to the action of the electric motor M, the piston **22'** discharges the oil from the cylinder through the valve **18'** and the piston **22** is practicing suction witht he discharge valve **18** closed and the suction valve **19** opened by the pressure of the oil from the oil well, which enters in the void left behind the piston.

At the end of the upstroke, the braking of the mobile string and its start in a reverse direction is effectuated in conditions similar to the down-stroke, due to the action of the discarge valve **18'** controlled by the slide-bar **23'**, and due to the opening of window **20** by the piston **22**.

In this manner, by combining the hydraulic drive at the beginning of the stroke, with the electric drive during the rest of the stroke, a constant speed and a constant driving force by the electric motor is obtained, and thereby the unfavorable effects of direction reversals of the structure that appear during the running of asynchronous electric motors with alternative rectilineal motion are completely eliminated, the hydraulic action can be complemented advantageously by having compression springs act during the braking period, which by their subsequent expansion which takes place in the period of starting the vertically moving parts in a reverse direction, aid in the direction reversals. These springs may be advantageously mounted at the stroke ends.

In the constructional arrangements illustrated in FIG. *5b*, the cylinders of the pump are separated from the electric motor housing by using two separate stuffing boxes, one (**24**) adjacent to the electric motor and the other (**25**) adjacent to the pump. The two pumping compartments and the appurtenant valves are arranged adjacent to each other at the middle of the cylinder of the pumps, being separated by a common wall, through which the actuating rod of the upper piston is passing and which needs only a single stuffing box, the sealing means of which are under pressure, and the direction of which continuously alternates which reduces the possibility of leakage of liquid under pressure therethrough.

In the embodiment of the pump illustrated in FIG. *5a*, where the two pumps P and P' are mounted above the electric motor M, the pumping compartments with their valves are placed at opposite ends of the pump cylinders, and require two boxes which are under the high oil column pressure. In the construction illustrated in FIG. *5b* the two pumping compartments with their valves are placed between the two cylinders of the pump, being separated by a common wall through which passes the driving rod for both pistons and which needs only one stuffing-box working under high pressure.

As control means for interrupting and reestablishing the current in the electric motor winding, when the running direction thereof is changed, a static switching device is used, which in case of the construction illustrated in the electric circuit diagram of FIG. 6 uses saturant reactors.

In this diagram K represents the automatic switch of the device; *u*, *v* and *w* represent the three phases of the secondary winding of the transformer T feeding the electric pump from ground level the primary winding of which is connected by a three conductor cable, the windings S*u*, S*v* and S*w* of the electric motor stator. The saturant reactors R*v* and R*w* are mounted in the phases *v* and *w*.

Inside the housing of the electric pump there are mounted two coils **26** and **26'** provided with the magnetic cores **27** and **27'** fed in series through a singlephase circuit connected in parallel on the voltage of the phase *u*, and closing through the mass of the discharge duct and the primary winding of a transformer-rectifier group TR the secondary circuit of which is feeding the existing coils of the saturant reactors R*v* and R*w* with rectified current.

When the pump is working by electric drive the magnetic cores **27** and **27'** are being taken out of the coils **26** and **26'**, their reactance is negligible and the group transformer rectifier TR is feeding the excited coils of the reactors R*v* and R*w* saturating them, so that their reactance is negligible and the electric motor is fed from the network.

The magnetic cores **27** and **27'** shift with the movement of the mobile armature A of the electric motor, so that when the armature arrives at a certain established distance from the up-stroke, respectively the down-stroke end, the corresponding magnetic core is introduced into the coil **26** (respectively **26'**), producing an increase in the reactance of the coil, which reduces to about zero the current in the feeding circuit of the group transformer-rectifier TR, causing the suppression of the exciting of the saturant reactors R*v* and R*w* and thereby introducing in the circuit of these two phases reactances which practically cancel the three-phase feeding current of the electric motor.

After reversing the moving direction of the mobile armature when it arrives at the predetermined distance from the stroke end, the magnet core is pushed out of the respective coil **26**, **26'** and the current is reestablished in the exciting circuit of the saturant reactors R*v* and R*w*, as well as in the three-phase electric motor feeding circuit.

The reversal of the electric motor magnetic field shifting direction at stroke ends is realized by reversing the phases *v* and *w* by means of a switch **28**, actuated by the movement of the mobile armature A shifting in the interval in which the current is interrupted in the circuit, the switching of the phases being realized without any current. In order to avoid working with a single phase resulting in an overload, in which case the voltage would be interrupted in one of the phases *v* or *w*, the automatic break switch K is provided with zero voltage relays in each one of its three phases.

The same control means can also be used when instead of using the saturant reactors R*v* and R*w*, electronic devices (i.e. transistors) are used which would be placed either at the surface or inside the electric motor housing.

In the case of a voltage breakdown (deliberate or accidental) in order to avoid, when the power is restored, the danger of a starting under full load by electric drive from any position, which would require the use of an oversized electric motor, the discharge line of the electric pump is provided with a three-way valve **29** FIGS. *5a* and *5b*, controlled by an electromagnetic relay **30** having zero voltage, mounted on the phase *u*.

When the voltage of phase *u* is cut off, the relay **30** releases the spring **31** which causes the lever **32** to rotate out of the normal working position *x* of the valve which establishes the connection between the electric pump and the oil discharge duct, and into the turned off position *y* of the device, which establishes the connection between the electric pump and the outside.

In this state, as the pump discharges without any pressure acting from outside, the weight of the mobile armature in any position, would determine its downward displacement to the down-stroke end, where a cam with rectilinear motion **33**, mounted on the piston rod **22'**, is causing the lever **32** to come back to the working position *x*, further causes the relay **30** to reset itself and the cam **33** to lock in position thereby bringing the pumps P and P' to the end of their down stroke.

When the voltage is reestablished, the relay **30** unlocks the cam **33** and the electric pump is placed again in starting position by the hydraulic drive, as it is at each motion direction reversal.

Instead of the above described three-way valve **29**, two oppositely working valves (push-pull) can be used, one of these valves would be built in the discharge pipe in the tubing and the other in the outside discharge duct, the valves being controlled by a common voltage relay or by two different relays, so that when the voltage fails, the discharge valve toward the tubing will be closed and the discharge valve toward the outside will be open, and when the voltage is reestablished the discharge valve toward the outside is closed and the discharge valve toward the tubing is opened.

The pumping device of this invention can be constructed with only one pump. In this case, at the up-stroke, the motor is used for lifting the mobile armature and at the down-stroke the pump is driven as well by the force produced by the motor and also by the weight of the mobile armature.

When the hydraulic drive is used for starting, at the changing of direction, the movement of the mobile armature, while the electric drive is being used only in the device in a constant speed operation, the electric motor can be built as a synchronous motor, replacing thereby the mobile armature with a cage with a mobile armature of similar construction, but provided with excitation coils mounted in slots and fed with direct current, obtained from a transformer-rectifier group connected in parallel with the electric motor feeding circuit, or from a generator, driven by the mobile armature motion.

The utilization of the synchronous motor for driving the pump has the following advantages when compared with the asynchronous motor:

The power factor can have a value close to one, the losses in stator windings for the same useful power are reduced to less than a half, because due to the great number of pole pairs, the value of the power factor in such an embodiment is under 0.7.

For the same losses and respectively of the current in the stator, the electric motor power is increased with 40–50% by comparison to an embodiment using an asynchronous motor.

For the same electric motor dimensions, the air gap of the synchronous motor can be considerably increased, a fact which facilitates the manufacture of stators of great length and respectively of more powerful motors.

The driving of the pumping device of this invention can also be performed with a single-phase motor which has the following advantages:

It allows the use of a single conductor cable, the current return being achieved through the discharge duct.

It is possible to eliminate the switch used for reversal of the phases.

On the other hand, the use of a single-phase motor presents in turn the disadvantage of a slight increase in losses.

For feeding the electric pump with electric power, especially when it is working at a great depth, and in order to realize the most favorable conditions from the windings insulation point of view, there can be used two single-phase transformers which are mounted in stages over the electric pump to reduce the supply voltage.

Based on a dimensioning calculation, in case an induction three-phase motor is used, it has been noted that an electric motor having a pumping frequency of 30 double strokes per minute (the length of stroke 3.50 m.), which can pump 80 tons of oil in 24 hours from a depth of 1500 m. and which can be introduced in a casing having an interior diameter of 120 mm., will have an efficiency of 0.7 and a stator height of about 2.60 m.

Taking into account also the two extensions (of smaller diameter) of the housing for the stroke of the mobile armature, the total electric motor length is not greater than 10 m.

The advantages of the electric motor according to this invention, are becoming more evident as the pumping depth increases, because the pump construction and the operation are not at all influenced by the increasing depth, if the driving force and respectively the power are maintained constant; consequently, the same electric motor used for a certain depth can be also used at a much greater depth if a pump is used which has an output inversely proportional to the depth.

What is claimed is:

1. A pumping system adapted to be mounted in the casing of wells, comprising in combination, an electric induction motor, having an axially reciprocally moving armature operatively mounted in said motor; a double-pumping means reciprocally mounted in said casing, and coaxially connected to said armature of said electric motor; said double-pumping means include means for discharging liquid via said casing and also include means for exerting on said armature pressure produced by the column of discharging liquid immediately after reversal of motion of said armature, in the direction of movement thereof; and an electric power source operatively connected to said electric motor.

2. The pumping system as set forth in claim **1**, wherein said double-pumping means comprise a pump housing and two pistons coaxially reciprocally mounted therein, said two pistons being respectively connected to each other and to said armature of said electric motor by means of an axially extending piston rod, whereby immediately after reversal of motion, one of said two pistons is idling whereas the other one is under pressure by said column of discharging liquid.

3. The pumping system as set forth in claim **1**, including electric switching means operatively connecting said electric motor to said electric power source, for electrically energizing alternately in opposite polarities the stator of said electric motor, said electric switching means including saturant reactor means, an actuating member operatively connected to said saturant reactor means and mechanically linked to said armature, thereby disconnecting said electric power source from said armature at a preselected point near the end of its stroke and reconnecting said electric power source at said preselected point near the beginning of the next opposite stroke, said armature being actuated hydraulically by said double-pump means in the intervening period.

4. A pumping system as set forth in claim **2**, wherein said pump housing (**1**) of said electric motor is cylindrical, said motor includes a plurality of stators (e.g. six stators S_1–S_6) which are made out of sheet packs and which are disposed on a circle in said housing (**1**) and have slots (**3**) in which a plurality of annular coils (**4**) are mounted, each coil passing from the slot of one stator directly into the slot of the adjacent stator, said plurality

of coils being connected in series so that each coil is mounted in a pair of oppositely positioned stators of said plurality of stators, so that when said plurality of coils are connected to said electric power source so as to form windings which are fed with three-phase currents a magnetic field will be produced in said plurality of stators with an alternating rectilineal motion which will actuate upon said armature A, the latter being provided with a cage constituted out of annular conductors which are mounted in slots of said armature A.

5. A pumping system as set forth in claim 4, wherein in said housing of said motor there is provided a cooling fluid (insulating oil or air) which, due to the displacement of said armature, circulates through free spaces (u_1–u_6) between said housing and terminals of said plurality of coils which exit from one stator and extend into the adjacent stator of said plurality of stators; a plurality of small baffle plates extending radially inwardly from the interior wall surfaces of said housing, said plurality of small baffle plates serving to conduct the cooling liquid in such a manner as to wash all the better the surfaces of said stator windings.

6. A pumping system as set forth in claim 5, wherein said electric motor (M) is connected to said two pistons (22, 22', 22*a*, 22'*a*) by means of said piston rod (7, 21), a pair of valves (18, 18') operatively mounted in the walls of said pump housing, a pair of cams (23, 23') respectively projecting from said two pistons (22, 22', 22*a*, 22'*a*) and being given a reciprocal rectilinear motion by said armature (A), said pair of cams (23, 23') being adapted to cooperate with said pair of valves (18, 18'), said pump housing including a pair of openings (20, 20') in the walls thereof which are positioned so as to cooperate with said two pistons (22, 22', 22*a*, 22'*a*); whereby said pair of cams (23, 23') are adapted to maintain open the corresponding valve of said pair of valves (18, 18') at the end of the discharge stroke of a corresponding piston of said pair of pistons until said piston has started its motion in the reverse direction and has accelerated to normal speed at which time the action of said armature via said piston rod (7, 21) takes over; while said valve remains open as set forth above, a hydraulic pressure is exerted on said piston by a column of liquid being discharged which is in communication with said piston via said valve while the other piston of said two pistons (22, 22', 22*a*, 22'*a*) is in communication with the interior of the well casing via an associated opening of said pair of openings (20, 20').

7. A pumping system as set forth in claim 6, including a safety device arrangement which comprises, a third coil (30) electrically connected to said third conductor (U), a second magnetic core reciprocally movably mounted in said third coil, three-way valve means (29) operatively mounted in said pump housing so as to control the outlet thereof, said three-way valve means (29) being operatively connected to said second magnetic core in such a way that when the voltage is cut off in said third conductor (U) said electric motor (M) and said third coil (30) are de-energized, whereby said three-way valve means (29) move from an outlet-open position to an outlet-closed position and place said housing in direct communication with the interior of said casing, said two pistons (22, 22', 22*a*, 22'*a*) sinking to the bottom of said pump housing (17) due to their own gravity, and means (32, 33) operatively connected to said three-way valve means (29) for returning the latter to outlet-open position when said two pistons (22, 22', 22*a*, 22'*a*) have reached their respective bottom positions.

8. A pumping system as set forth in claim 6, including means for interrupting and reversing the current from said source of electric power, the latter being of the three-phase alternating current type and including three conductors (U, V. W) which are operatively connected to said electric motor, two saturant reactors (Rv, Rw) respectively operatively connected to two conductors (V, W) of said three conductors, the third conductor (U) of said three conductors being connected to a control circuit means, the latter being electrically connected to the mass of said pump housing and said third conductor (U) and including two series-connected coils (26, 26'), two magnetic cores (27, 27') reciprocally movably mounted in said two coils (26, 26') respectively and being mechanically connected to said armature (A) and electrically connected to said two saturant reactors (Rv, Rw) respectively, whereby depending on the positions of said two magnetic cores (27, 27') in said two coils (26, 26') respectively said two saturant reactors (Rv, Rw) render said two conductors (V, W) electrically conductive or non-conductive thereby controlling the energizing of said motor by said electric power source.

9. A pumping system as set forth in claim 7, wherein hydraulic driving power is used for starting the stroke of said armature (A) and for electrically driving at constant speed a single-phase asynchronous motor (M) is used.

10. A pumping system as set forth in claim 7, wherein a single pump (P) is used; in the up-stroke the electric motor (M) is used to raise the weight of the mobile armature (A), and in its down-stroke the driving of the pump (P) is effected, partly by the weight of the armature (A) and partly by the drive of the electric motor (M).

11. A pumping system as set forth in claim 7, wherein the interrupting and the reversal of the current for the electric motor having alternating rectilinear motion is obtained by means of electronic devices, controlled by the motion of the mobile armature in similar conditions as the controlling saturant reactors Rv and Rw.

12. A pumping system, as set forth in claim 1, characterized by the fact that, for breaking the current, when the moving direction is reversed, static means for switching are used, e.g. saturant reactors, controlled by the motion of the mobile armature, so that between the moment of the break-off of the current and the moment of its re-establishing in the reversed stroke a displacement must exist during which the deceleration and the acceleration in opposite direction of the mobile garniture is achieved by hydraulic drive, so that the current will be re-established only after the normal speed has been reached.

13. A pumping system as set forth in claim 12, using an electric motor (M), which drives directly with rod 7 the pistons of two pumps (P and P'), characterized by the fact, that the pumps have discharge valves (18 and 18'), controlled by cams with rectilinear motion (23 and 23') actuated by the motion of the mobile armature, so that these valves remain open after the discharge stroke is finished, when the electric current is interrupted at the end of the stroke, making it possible that the starting in opposite direction and the acceleration up to normal speed, when electric drive begins, will be realized by the hydraulic drive, due to the pressure exerted by the column of discharged oil on the respective piston (P and P') and by establishing a direct communication for the pressure between the bore hole and the other piston (P' and P) through the windows (20' and 20).

14. A pumping system as set forth in claim 13, characterized by the fact that the interruption and the reversal of the current in the driving electric motor with alternating rectilinear motion are realized with the help of saturant reactors (Rv and Rw) placed on the feeding conductors (v and w) excepting conductor (U), which feeds the control circuit, a circuit connected between the respective phase and the mass and in which two reactance coils (26 and 26') are intercalated, into which two magnetic cores (27 and 27') are introduced at each stroke end by the motion of the mobile armature, determining the suppression of the control current and thereby the interruption of the feeding current.

15. A pumping system as set forth in claim 14, characterized by the fact, that to the using of the hydraulic drive for starting, the working by electric drive is performed with constant speed, using a synchronous motor with alternating rectilinear motion the exciting winding of which is fed with a rectified current from a transformer-rectifier unit, connected to the main feeding circuit, or from a generator, actuated by the motion of the mobile armature.

References Cited

UNITED STATES PATENTS

1,287,078	12/1918	Newcomb	103—46
1,655,825	1/1928	Schmidt	103—53
1,740,003	12/1929	Coberly	103—46 X
1,840,994	1/1932	Winsor	103—46 X
3,031,970	5/1962	Hobitzelle	103—46

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