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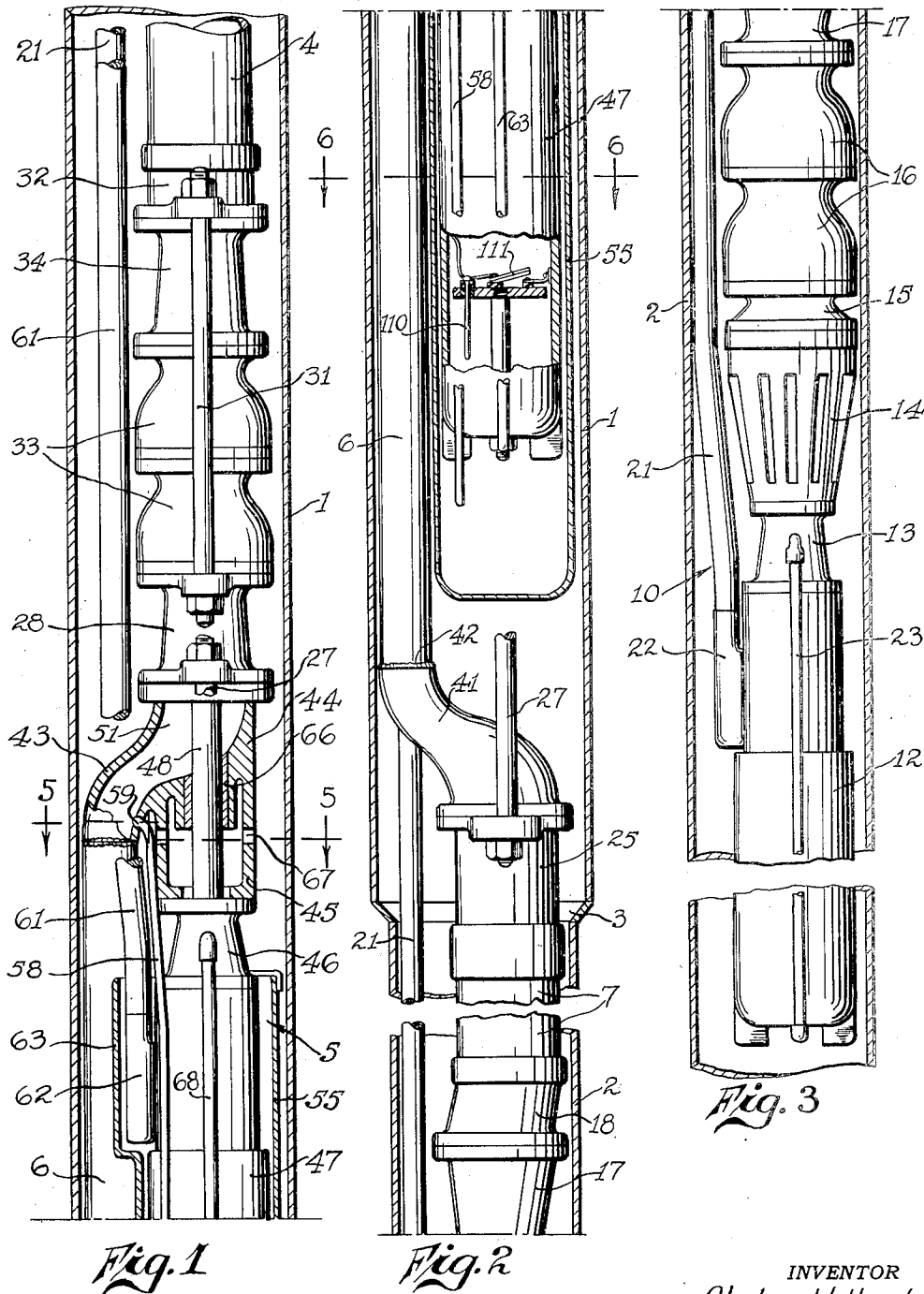
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2,221,798

SERIES SUBMERSIBLE MOTOR PUMP

Filed March 4, 1938

3 Sheets-Sheet 1



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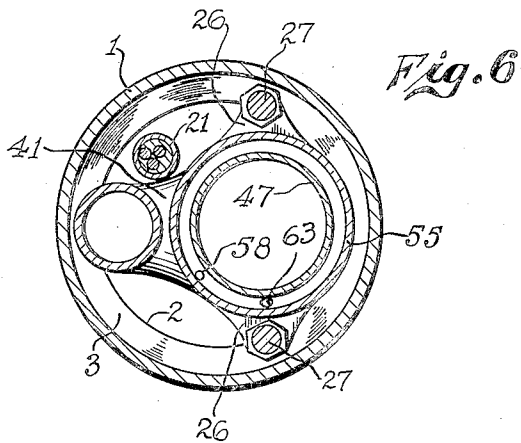
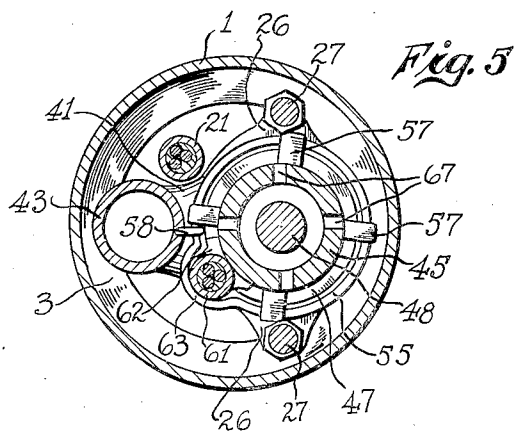
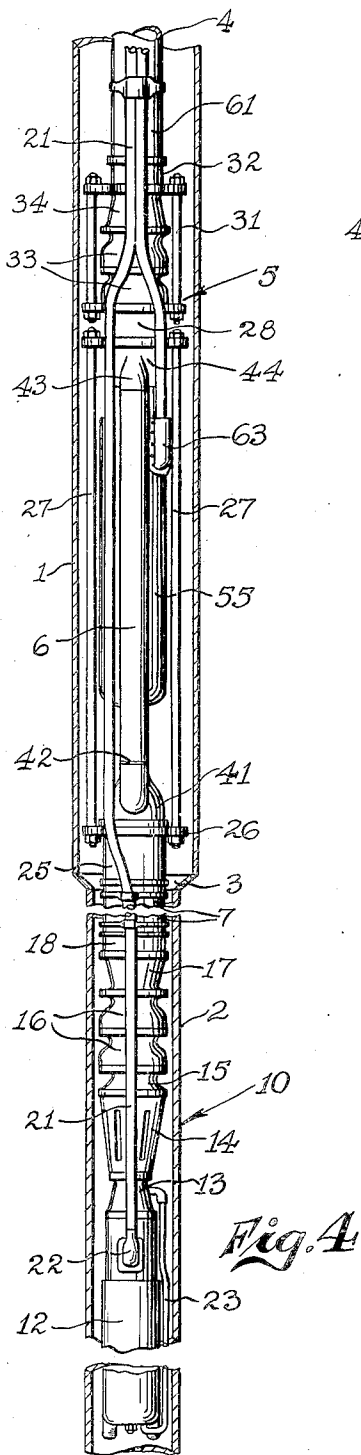
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SERIES SUBMERSIBLE MOTOR PUMP

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3 Sheets-Sheet 3

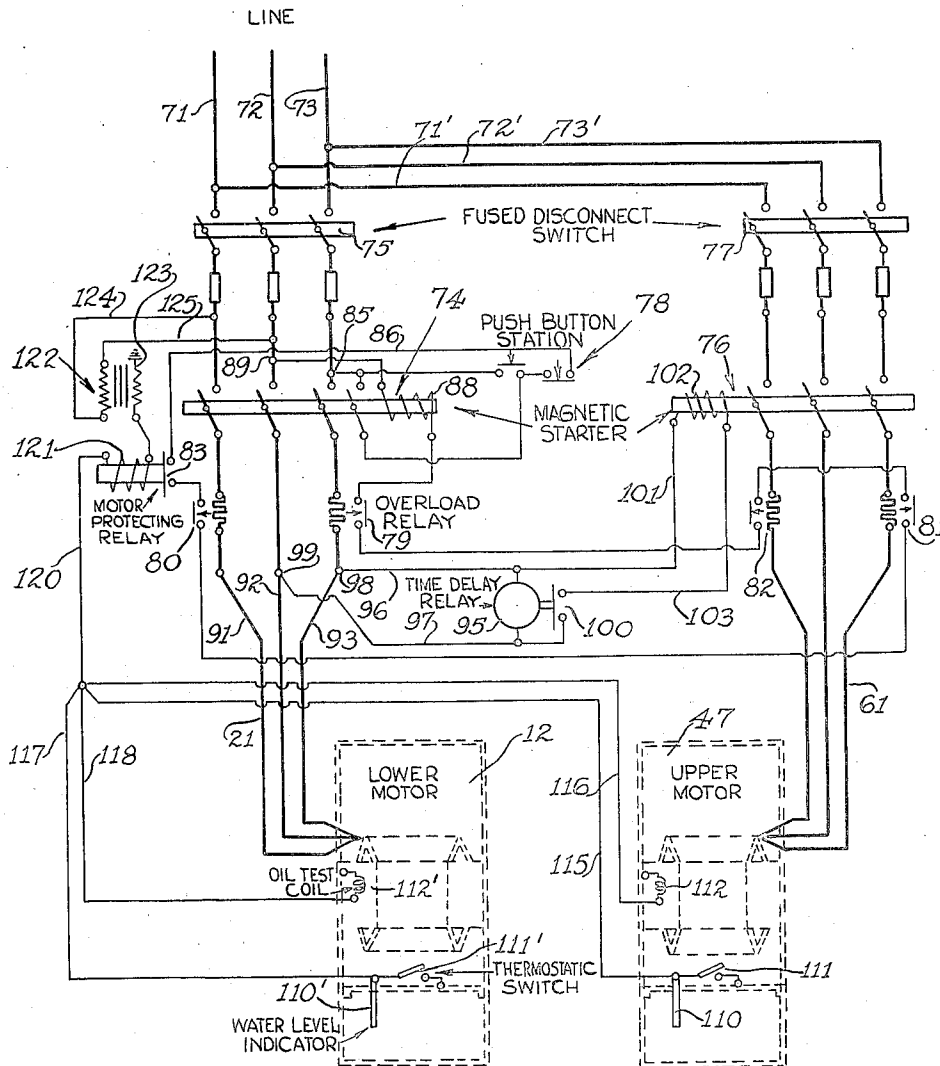


Fig. 7

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UNITED STATES PATENT OFFICE

2,221,798

SERIES SUBMERSIBLE MOTOR PUMP

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Application March 4, 1938, Serial No. 193,968

3 Claims. (Cl. 103—87)

This invention relates generally to submersible motor pumps, and is directed particularly to the provision of a plurality of submersible motor-pump units in series.

5 The development of submersible motor-pump units for pumping deep water wells has in recent years been confined mainly to the perfection of a submersible electric motor for direct connection to a multi-stage centrifugal pump, to re-
10 place the standard "deepwell turbine," or multi-stage centrifugal pump driven by a motor at the surface through a long drive shaft. When pumping from depths exceeding 300 feet the power losses in rotating the shaft, and other difficulties arising from the use of such a long shaft, are
15 such as to make the submersible motor pump superior thereto in many respects.

For various reasons, many water wells are drilled to two diameters, with an upper, relatively
20 short section of large diameter and a lower section of decreased diameter. The water-bearing formation may be at considerable depth, but of sufficient pressure to provide an original pumping level at only a relatively shallow depth. In the
25 course of time, however, the pumping level may be gradually lowered until it stands a considerable distance below the large diameter portion of the well.

30 The final depth of the pumping level and the small diameter of the lower portion of the well may be such as to make it impracticable to install a single submersible motor-pump unit of sufficient head and volume capacity.

Under these circumstances, I propose to utilize
35 two or more submersible motor-pump units, one within the lower, small diameter portion and at least one booster unit in the upper, enlarged portion of the well. A small unit, of sufficient head capacity to lift the water to the booster
40 unit, may be installed in the lower, reduced portion of the well. If the water level conditions are known before the well is drilled, the depth of the large diameter section may be predetermined so that a booster unit installed near the lower
45 end thereof will be substantially midway between the surface and the lower unit, thus dividing the total lift into two substantially equal stages and enabling the use of identical motor-pump units. A single unit may be installed initially, until the
50 pumping level has been lowered beyond the head capacity of one unit, and a second unit may then be added.

A principal object of this invention is to provide a series submersible motor-pump installation for wells having an upper portion of rela-

tively large diameter and a lower portion of reduced diameter, wherein a submersible motor-pump unit is installed in the lower, reduced portion and a second unit is installed in the upper, enlarged portion and connected in series with
5 the lower unit to serve as a booster therefor.

An arrangement permitting the use of a plurality of units is particularly advantageous in cases where the initial and final pumping levels are not known. In such cases a single submersible motor-pump unit may be installed and periodically lowered as the pumping level lowers, and when the depth exceeds the head capacity of the unit a second unit may be added instead of substituting a larger unit for the original one.
15

Various schemes have been proposed heretofore for connecting submersible motor-pump units in series, but such schemes are all defective in one respect or another, because of practical operating difficulties which have been overlooked
20 or under-estimated. A further object of this invention is to provide a series submersible motor-pump arrangement which will give trouble-free operation over a long period of time, and which permits utilization of identical motor-pump units
25 which have been proven successful.

The motor-pump unit under consideration consists generally of a submersible electric motor having its rotor shaft direct-connected to the pump shaft. The motor is encased in a fluid-tight housing which is filled with a dielectric liquid, pressure equalizing means being provided whereby the pressure within the housing is equal to that of the liquid in which the housing is immersed. When the unit is immersed in the well
35 liquid, the flow of the latter past the motor housing serves to cool the motor. A liquid seal is provided where the rotor shaft extends through the housing, the seal being exposed on opposite sides to the well liquid and the dielectric liquid
40 within the housing. Electric current is conducted to the motor from the surface through an insulated and fluid-tight cable having fluid-tight connection to the motor housing. The interior of the cable is in communication with the interior of the motor housing, whereby the dielectric liquid filling the housing may rise in the cable, the hydrostatic head of the well liquid being thus balanced internally of the cable as well as within the motor housing.
50

In order to insure trouble-free operation of the upper motor-pump unit when it is located a sufficient distance above the lower unit so as not to be immersed in the well liquid, it is necessary to simulate as nearly as possible the conditions
55

of operation when submerged. In other words, the motor housing should be water-cooled, the internal and external pressures should be balanced, the pressure should be relatively low so as to avoid forcing the dielectric liquid upwardly within the cable at a pressure greatly in excess of the external pressure, and the liquid seal should be exposed to well liquid at substantially the pressure exerted on the housing.

A further object of the invention is to provide a plurality of submersible motor-pump units in series, wherein all of the units operate under substantially the same conditions.

A still further object is the provision of water-cooling for a submersible motor when operating above the level of the well liquid.

A still further object is to provide a series submersible motor-pump assembly wherein the upper unit may be located above the well liquid level and be cooled by circulation of well liquid thereover, the cooling liquid being supplied by the discharge from the lower unit and being at a relatively low pressure irrespective of the discharge pressure.

Standard submersible motors and pumps are not intended to support any great weight, and hence if a motor-pump unit is to be interposed in the discharge column above the lower unit and separated therefrom by a lower section of discharge column, it is necessary to provide for supporting the lower section of column and the lower motor-pump unit from the upper section of column independently of the upper motor-pump unit. A still further object of this invention is to provide, in an assembly as referred to herein, a supporting connection between the upper and lower sections of the discharge column and bridging the upper motor-pump unit, thereby relieving the latter of the weight of the sub-jacent parts.

In a series motor-pump installation wherein the upper unit serves as a booster and the lower unit is incapable alone of pumping to the surface, it is useless to operate either unit unless the other one is operating. It is also dangerous to operate the upper unit unless it is receiving liquid from the lower one, especially if the pump bearings are lubricated by the liquid being pumped. If run dry for any length of time the bearings will overheat and seize, overloading the motor.

For the latter reason, the upper unit should not be started until the discharge from the lower unit reaches it, thus requiring a time interval between the starting of the lower and upper units.

A still further object of this invention is to provide a series motor-pump installation wherein suitable controls are provided for stopping both motors if a condition adverse to proper operation arises within either motor.

A still further object is to provide a series motor-pump installation in which provision is made for delaying the starting of the upper unit until sufficient time has elapsed for the discharge of the lower unit to reach the upper unit.

A still further object is to provide a series motor-pump installation in which the motor of the lower unit is started manually, and in which the motor of the upper unit is started automatically at the end of a predetermined time interval following the starting of the lower motor.

A still further object is to provide a series submersible motor-pump installation wherein the motor of the upper unit is cooled by circulation of discharge fluid from the lower unit, and where-

in means are provided for stopping both units in the event the cooling means fails to function properly.

Other objects and advantages will be apparent from the following description, taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is an elevation of the upper portion of the upper motor-pump unit, with parts broken away;

Fig. 2 is an elevation of the lower portion of the upper unit and the lower discharge column;

Fig. 3 is an elevation of the lower motor-pump unit;

Fig. 4 is an elevational view of the two units combined, as they appear when viewed from the left of Figs. 1 to 3;

Fig. 5 is a horizontal section taken substantially on line 5—5 of Fig. 1;

Fig. 6 is a horizontal section taken substantially on line 6—6 of Fig. 2; and

Fig. 7 is a wiring diagram of interconnected starting and motor protection circuits for the motors.

Referring to the drawings and particularly to Fig. 4, the assembly is shown installed in a well equipped with an upper casing 1 of relatively large diameter, and a lower casing 2 of reduced diameter, the two casings being joined by a conical reducer 3. An upper discharge column 4 extends to the surface where it is suitably anchored to support the weight of the entire assembly. The upper motor-pump unit, generally designated 5, is connected to the lower end of the column 4, and is shown as disposed within the upper casing 1 adjacent the lower end thereof. A laterally offset connector pipe 6 is connected to the suction inlet of the pump of the upper unit, and extends downwardly to a point below the motor of the upper unit, where it merges with a lower discharge column 7 extending downwardly within the lower reduced casing 2 to the point at which it is desired to locate the lower motor-pump unit. The latter, generally designated 10, is secured to and suspended from the lower end of the column 7.

The lower motor-pump unit 10 is preferably, although not necessarily, similar to that shown and described in the application of Aladar Hollander and Vaino A. Hoover, Serial No. 178,741, filed December 8, 1937, for Submersible motor assembly, now matured into U. S. Letters Patent No. 2,171,749, dated September 5, 1939. It comprises generally an electric motor encased within a fluid-tight housing 12 connected to the lower end of an adapter 13. The latter is bolted to the lower end of a strainer 14 through which well fluid is drawn to the pump. A suction piece 15 is interposed between the strainer and the lowermost of a plurality of pump bowls 16, herein shown as two in number in order to conserve space. It will be appreciated, however, that any desired number of stages may be provided, up to the limitations imposed by the motor capacity as determined by the casing diameter. The rotor shaft of the motor extends through the upper end of the housing 12 and is coupled to the pump shaft, a suitable seal (not shown) being provided where the shaft projects through the housing. The uppermost bowl 16 is secured to a discharge piece 17 which in turn is connected to an offset flange 18 secured to the lower end of the discharge column 7. The offset flange displaces the discharge column eccentrically of the axis of the motor and pump to provide adequate

space for the motor cable while permitting the use of a discharge column of sufficient capacity. A motor cable 21 extends from the surface to the motor, the cable being fluid-tight and being connected in fluid-tight relation to the motor housing by a terminal box 22. A balance tube 23 extends from the lower end of the motor housing to the adapter 13, and establishes communication between the interior of the housing and the well liquid whereby the pressure within the housing equals the hydrostatic pressure of the well liquid at the point in the well where the motor is located.

In the type of motor-pump unit referred to herein, the motor housing is filled with a dielectric liquid. The interior of the cable 21 is in communication with the interior of the motor housing through the terminal box, as shown in Fig. 2 of the aforementioned application of Aladar Hollander and Vaino A. Hoover. The dielectric liquid will be forced upwardly within the cable by the pressure of the well liquid and the pressures will thus be balanced internally and externally of the cable.

It is highly desirable, although not absolutely necessary, that the motor of the upper unit be identical with that of the lower unit, and that it be operated under conditions simulating as closely as possible the conditions under which the lower motor operates. The construction whereby this is accomplished will now be described.

The lower discharge column 7 extends upwardly whatever distance it is desired to separate the two units, and is connected at its upper end to a special flange member 25. The latter has formed integral therewith a flange provided with laterally projecting bolting ears 26, 26 (Figs. 4, 5 and 6) apertured for the reception of a pair of elongated suspension rods 27, 27 extending upwardly on either side of the motor of the upper unit. The upper ends of the rods extend through apertures in ears formed on the lower flange of a special connector 28 of extra strength. The weight of the lower discharge column, lower motor-pump unit 10, and the column of water in the discharge column when pumping is thus transmitted from the flange member 25 through the suspension rods 27, 27 to the connector 28 independently of any structure which may be interposed between member 25 and connector 28.

The upper flange of connector 28 is similarly provided with ears through which project a second pair of suspension rods 31, 31 extending upwardly to a flange piece 32 secured to the lower end of the upper discharge column 4. Interposed between the connector 28 and the flange piece 32 are the pump bowls 33 and discharge piece 34 of the upper motor-pump unit. It will be apparent that the weight of the subjacent parts is thus transferred from the connector 28 to the upper discharge column 4 independently of the pump bowls enabling the use of standard bowls, the bolting flanges of which are of insufficient strength to withstand such stresses.

In order to connect the upper end of the lower discharge column 7 with the suction inlet of the upper pump, while at the same time disposing the upper motor in axial alignment with the pump, the offset connector pipe 6 is provided. An eccentric reducer 41 is mounted on the upper flange of the flange member 25 with its lower enlarged end in communication with the discharge column 7. The upper offset reduced end is welded at 42 to the connector pipe 6 which ex-

tends upwardly and is welded at its upper end to a similar offset reduced end 43 formed on a special casting 44 bolted to the under side of the connector 28. It will be observed that the suspension rods relieve the connector pipe of all tensile stresses imposed by the weight of the parts therebelow.

The casting 44 has formed thereon a downwardly projecting cylindrical portion 45 (Figs. 1 and 5) concentric with the upper end thereof. A motor adapter 46, similar to that shown at 13 in connection with the lower motor 12, is secured to the lower end of the portion 45, and a motor housing 47 similar to housing 12 is bolted to the lower flange of the adapter 46. The shaft of the motor extends through the housing into the adapter 46, and is there coupled to the pump shaft 48.

A suction passage 51 extends downwardly and outwardly through the casting 44 from its upper end to the offset reduced end 43, to connect the connector pipe 6 to the inlet of the upper pump. The two pump units are thereby connected in series.

It is desirable to cool the upper motor by circulation of water over the housing. This could be accomplished by providing an enlarged discharge pipe surrounding the motor housing, instead of by-passing the discharge around the motor. However, as pointed out in the introductory remarks, this would give rise to troublesome complications because of the discharge pressure. A pressure balance is preferred within and without the motor housing, and for various reasons it would be undesirable to subject the interior of the housing to the discharge pressure. Furthermore, wide fluctuations of pressure occur in the discharge pipe at the location of the upper motor, varying from zero when the pumps are idle, to the total head up to the surface when the pumps are stopped and the discharge column is full of well liquid.

In order to avoid the difficulties attendant upon such an arrangement, I prefer to dispose the upper motor outside the discharge column and within a cooling chamber through which well liquid is circulated at constant head. Referring to Figs. 1 and 2, a cooling chamber 55 is disposed about the motor housing 47, and comprises an elongated cylindrical can of slightly greater internal diameter than the outer diameter of the motor housing, the can being open at its upper end and closed at its lower end. The can is suspended at its upper end from the upper flange of the motor housing, by a plurality of L-shaped clips or brackets 57 (Fig. 5) welded to the upper edge of the can and extending radially inwardly over the lower flange of the adapter 46. The brackets are suitably spaced so as to be engaged by certain of the bolts securing the adapter and motor housing in assembled relation. A bleeder pipe 58 is connected to the offset portion 43 of the casting 44 at 59, and extends downwardly into the cooling can to a point below the motor housing 47, whereby a small portion of the well liquid will be bled from the discharge pipe into the cooling can where it will circulate upwardly around the motor housing and overflow at the top of the can. The amount of cooling water required would be negligible, in the neighborhood of one or two gallons per minute for a 12-inch 100 H. P. motor.

The upper motor receives electrical energy from the surface through a cable 61 similar to the cable 21 leading to the lower motor. A ter-

minal box 62 connects the cable 61 in fluid-tight relation to the motor housing 47, and in order to accommodate the terminal box in the cooling can, an outwardly projecting pocket 63 is formed on the can, as shown in Figs. 4 and 5.

The pump shaft 48 extends through a stuffing box 66 between the interior of the cylindrical extension 45 and the inlet passage 51 in the casting 44, the chamber formed within the extension 45 serving as a drain chamber for any leakage past the stuffing box. The chamber communicates at its lower end with the interior of the adapter 46, thus insuring that the liquid seal around the motor shaft operates exposed to water on the outer side, in the same manner as though the motor housing were completely submerged. Overflow outlets 67 are provided in extension 45 to prevent the building up of pressure within the chamber and the adapter. A balance tube 68 similar to the balance tube 23 on the lower motor extends from the lower end of housing 47 to the adapter 46, to provide a balance of pressures internally and externally of the housing.

The conductor cables 21 and 61 extend to the surface, where they are connected to suitable starting and safety cut-out controls. Preferably, the two motors have separate starting switches, with a time-delay relay in the circuit of the upper motor whereby a definite time interval will elapse between the starting of the lower motor and starting the upper motor, the time interval being sufficient to enable the discharge of the lower motor to reach the upper pump before the latter is started.

From the foregoing description, it will be apparent that a simple and practical assembly of submersible motor-pump units has been provided. The units may be identical, and the upper unit operates under conditions closely simulating submerged operation. By the provision of supporting connections between the sections of the discharge column independent of the upper motor-pump unit, standard motor and pump parts may be used.

Standardization of units is made possible by a series connection as described, inasmuch as any number of standard units may be connected together, depending on the pumping depth. A standardized cable may also be used, each unit being provided with a separate cable extending only to the respective unit, whereas if a single large unit were employed, a correspondingly large cable would necessarily extend the full depth.

In Fig. 7 is shown a wiring diagram of interconnected starting and motor protection circuits for the two motors. Conductors 71, 72, 73 supply current for both motors from a three-phase supply line, being connected to a magnetic starting switch 74 for the lower motor 12 through a fused disconnect switch 75, and being connected to a similar starting switch 76 for the upper motor 47 through branch conductors 71', 72', 73' and a similar disconnect switch 77. The starting switch 74 is controlled by a push button station 78, the starting circuit including overload relays 79 and 80 in the power conductors to motor 12, overload relays 81 and 82 in the power conductors to motor 47, and a common motor protecting relay 83. When the push-button switch is closed, current flows from terminal 85 of conductor 73 through the push button switch 78, conductor 86, motor protector relay 83, overload relays 80, 81, 82, and 79 in succession, through the solenoid 88 of the starting switch

74, and back to the line terminal 89, provided all of the relays are closed. Energization of the solenoid 88 closes the starting switch 74 and motor 12 is energized through leads 91, 92, 93.

In order to provide a suitable time interval between the starting of the lower motor 12 and the upper motor 47, a time delay relay 95 is connected by conductors 96 and 97 across the conductors 92 and 93 at terminals 98 and 99 so as to be energized upon starting motor 12. This relay may be of any desired type providing the required time interval before closing its switch 100. Upon closing the latter, current flows from terminal 98 through conductor 96, conductor 101 leading to the solenoid 102 of starting switch 76 of the upper motor 47, through the solenoid 102, conductor 103, switch 100, conductor 97, and terminal 99. Energization of solenoid 102 closes the starting switch 76 to energize the upper motor 47.

Referring now to the motor protecting circuits, Fig. 2 shows a part of the lower portion of motor housing 47 broken away, disclosing a water level indicator 110 and a thermostatic switch 111 mounted therein. It will be understood that well liquid is permitted to enter the lower end of the motor housing to equalize the pressure of the dielectric liquid therein with the pressure externally of the housing. If for any reason the water level should rise above a predetermined point the water level indicator 110 stops the motor by means of the protector relay 83, in a manner to be presently described. The thermostatic switch 111 is arranged to close if for any reason the temperature of the dielectric liquid should reach a predetermined value, such as would occur if the motor were not properly cooled. An oil test coil 112 (Fig. 7) is mounted at any suitable point within the motor housing, and functions to stop the motor if the dielectric strength of the dielectric liquid decreases a predetermined amount as a result of diffusion of water or other conducting liquid through the dielectric liquid. A similar water level indicator 110', thermostatic switch 111', and oil test coil 112' are mounted in the lower motor housing 12.

The indicator 110 and thermostatic switch 111 are connected to a control wire 115, the other side of the switch 111 being grounded to the motor housing. The test coil 112 is connected at one side to a control wire 116, the other side being grounded to the motor housing. Wires 115 and 116 are housed within the power conductor cable 61 and extend to the surface where they are connected respectively to similar control wires 117 and 118 for the lower motor 12, the latter wires being housed within conductor cable 21. At the surface all four control wires are connected to a common conductor 120 connected to one side of the solenoid 121 of the motor protector relay 83. The other side of the solenoid is connected to the low voltage side of a transformer 122, which is grounded at 123. The transformer is energized through conductors 124, 125 connected respectively to the power conductors 71 and 72.

From the foregoing description, it will be apparent that if the level of the well liquid within either motor housing rises to a point that it contacts the indicator 110 or 110', a circuit will be established from ground 123 through the coil of transformer 122, through solenoid 121, conductor 120, conductor 115 or 117 and indicator 110 or 110' to ground. Energization of solenoid 121 will open the relay 83, breaking the circuit of the

starting switch 74 and stopping motor 12. De-energization of motor 12 immediately stops motor 47, since the starting circuit of the latter is connected to the leads to motor 12. Similarly, if the temperature of the dielectric liquid in either motor housing should rise sufficiently to close either thermostatic switch 111 or 111', the same results will follow. If the dielectric strength of the liquid in either motor should decrease sufficiently to permit sufficient current to flow through the test coil 112 or 112' to energize the solenoid 121, the motors will be stopped in the same manner.

It will be noted that the overload relays 79, 80, 81 and 82 of both motors are all connected in series in the starting circuit of motor 12, so that in the event of excess current flowing to either motor both motors will be stopped.

I claim:

1. Deepwell pumping apparatus comprising, in combination: a sectional discharge column adapted to be suspended in a well; a first pump connected in series between adjacent sections of said column; a second pump connected to the lower end of said column and having its inlet open to the well; a submersible motor operatively connected to each of said pumps; each of said motors comprising a housing exposed externally to the well pressure and containing a dielectric liquid in pressure-balanced relation to the ambient fluid, a rotor and a stator immersed in the dielectric liquid in each of said housings, each rotor having a rotor shaft projecting from the housing into driving relation with the respective pump; a liquid seal sealing the juncture of the shaft and housing and being exposed externally to well pressure and internally to dielectric liquid; and means for cooling the motor associated with said first pump, comprising a casing surrounding the motor housing and open to the well, and a bleeder conduit extending from said discharge column to said casing for by-passing liquid from said discharge column in heat exchange relation to said motor housing and back to the well.

2. A submersible motor-pump unit adapted to be connected between upper and lower sections of a well discharge column, comprising a pump connectible with the lower end of the upper column section, a suction piece for the pump comprising upper and lower coaxial end portions, a suction inlet communicating with the upper end portion, a chamber in the lower end portion having a drain port open to the well, a partition between the suction inlet and the chamber, a submersible motor having a housing secured to the lower end portion of said suction piece and a shaft extending from the motor through the suction piece and operatively connected to the pump, a seal between the shaft and the motor housing and exposed externally to said chamber, a casing surrounding said motor housing and having open communication with the well, a discharge conduit connected to said suction inlet and extending downwardly past said motor and connectible at its lower end with the upper end of said lower column section, and a bleeder passage extending from said conduit to said casing for by-passing liquid from said column in heat exchange relation to said motor housing and back to the well.

3. A submersible motor-pump assembly comprising: a discharge column supported from the surface and extending downwardly into a well, a connector secured to the lower end of said column, a multistage deepwell pump secured to said connector, a second connector secured to the lower end of said pump, tension rods extending between said connectors, a motor supported by said second connector, a laterally offset discharge pipe secured to the inlet of said pump and extending downwardly past said motor, a third connector secured to the lower end of said pipe, tension rods extending between said second and third connectors, a discharge column supported by said third connector, and a submersible motor-pump unit supported by said last-named discharge column.

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