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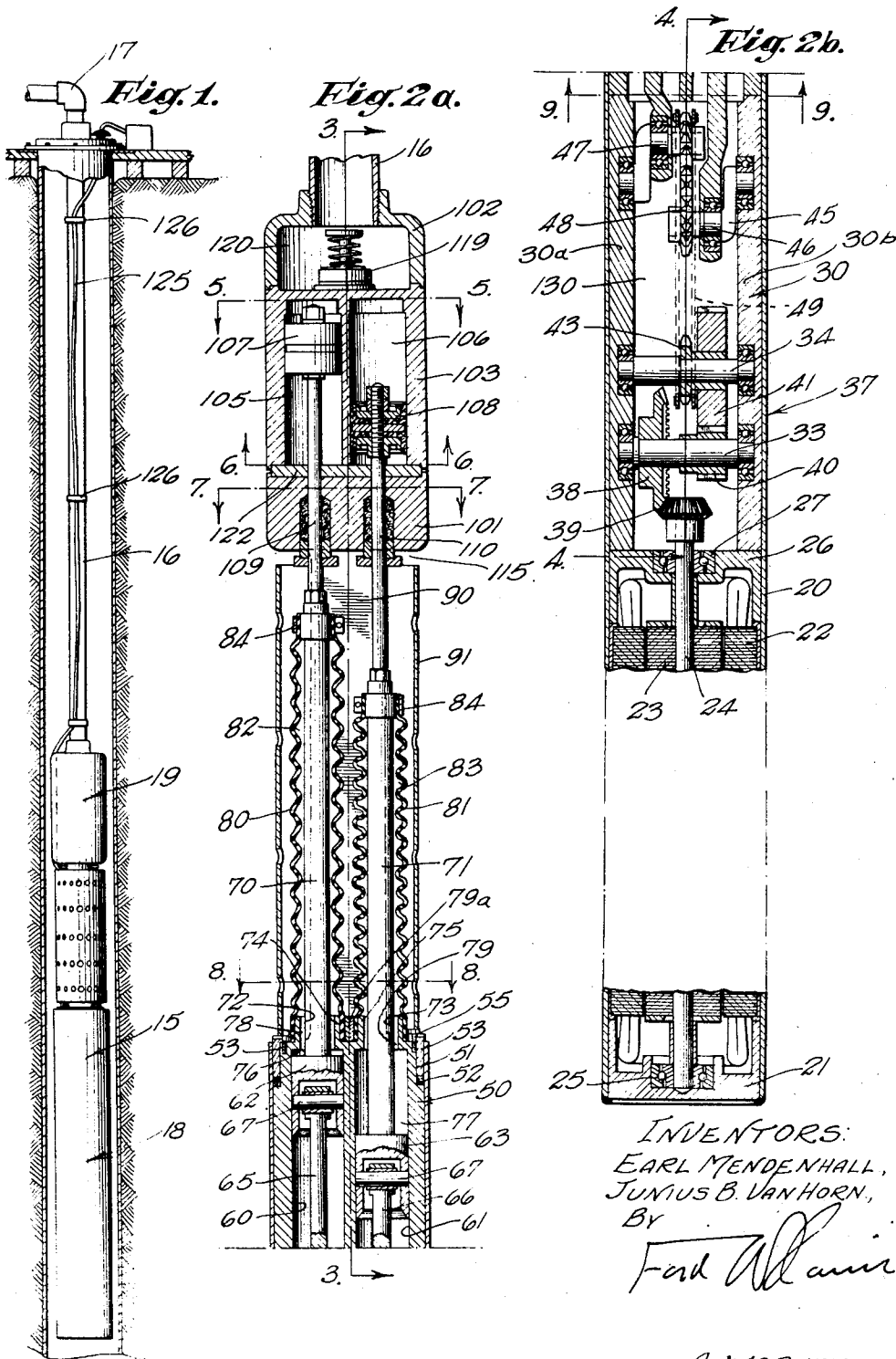
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1,891,771

DOUBLE ACTING RECIPROCATING PUMP

Filed June 16, 1931

4 Sheets-Sheet 1



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Fig. 3.

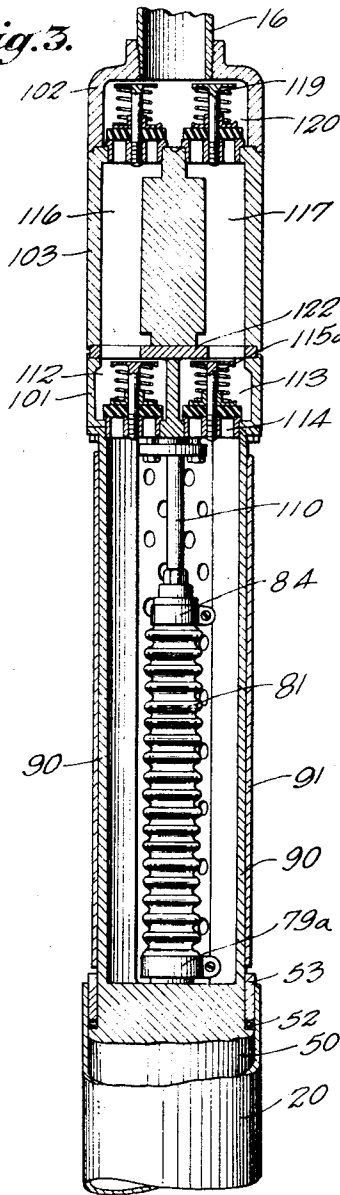
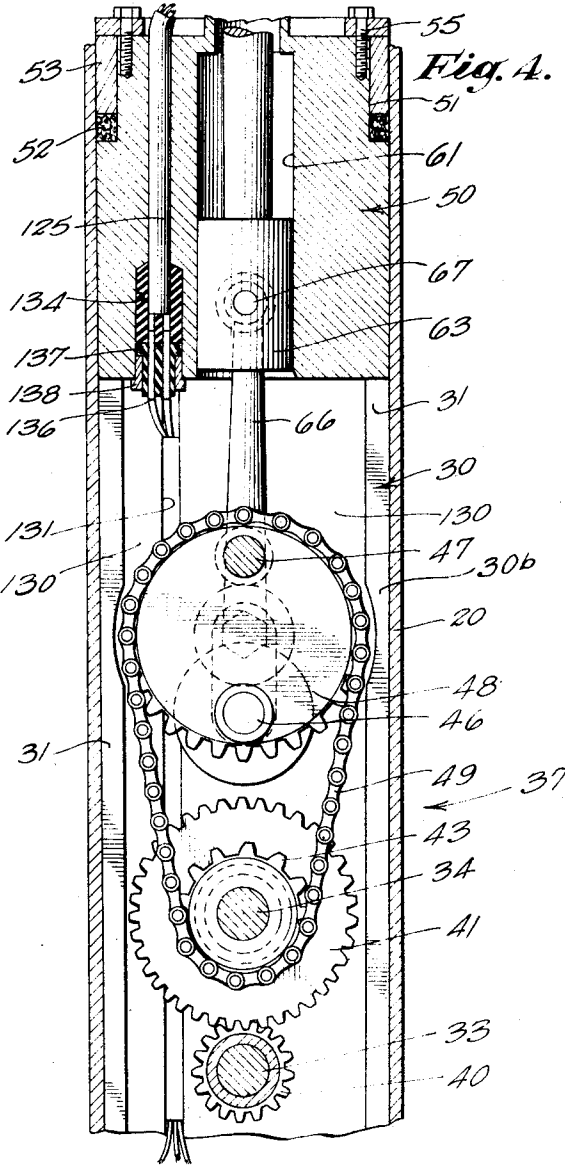


Fig. 4.



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Fig. 5.

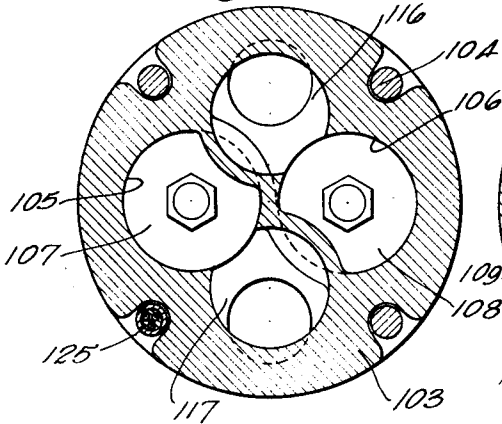


Fig. 7.

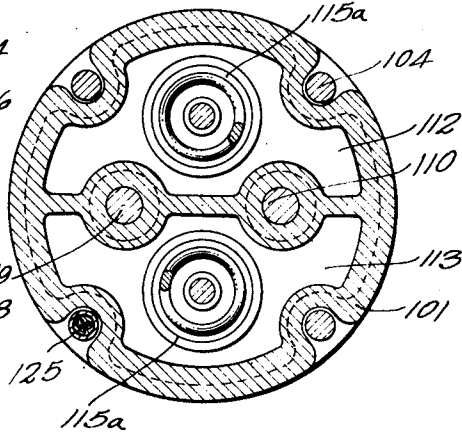


Fig. 8.

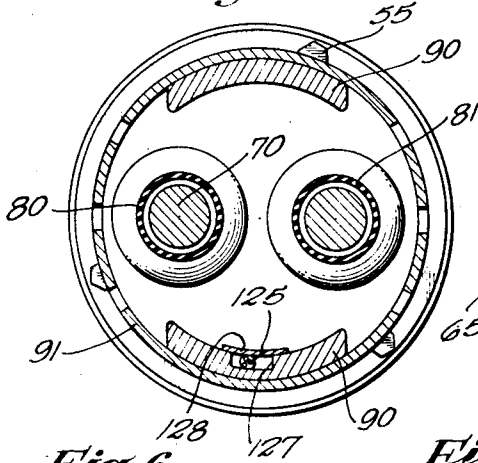


Fig. 9.

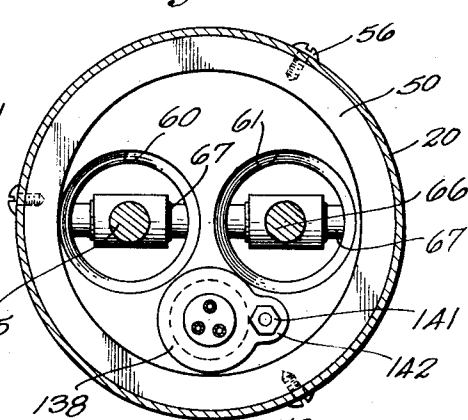


Fig. 6.

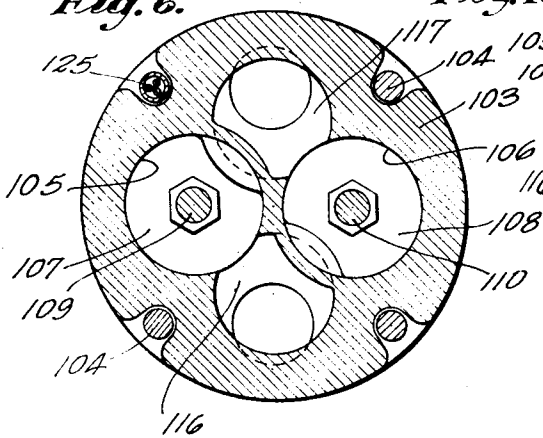
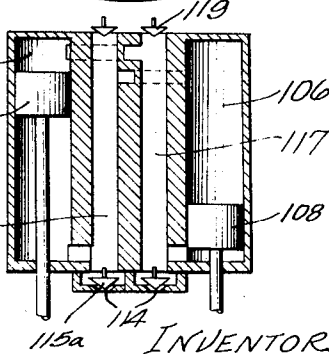


Fig. 10.



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Fig. 11.

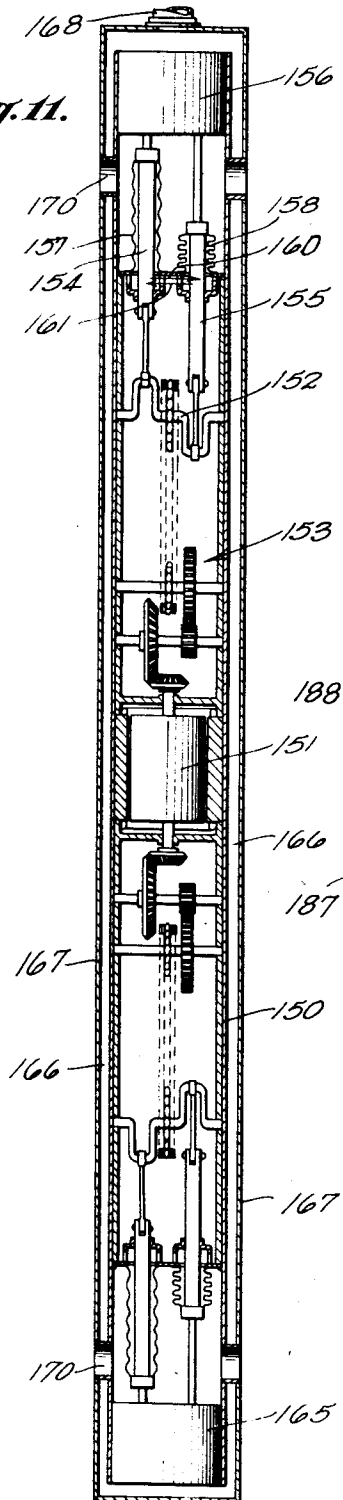


Fig. 12.

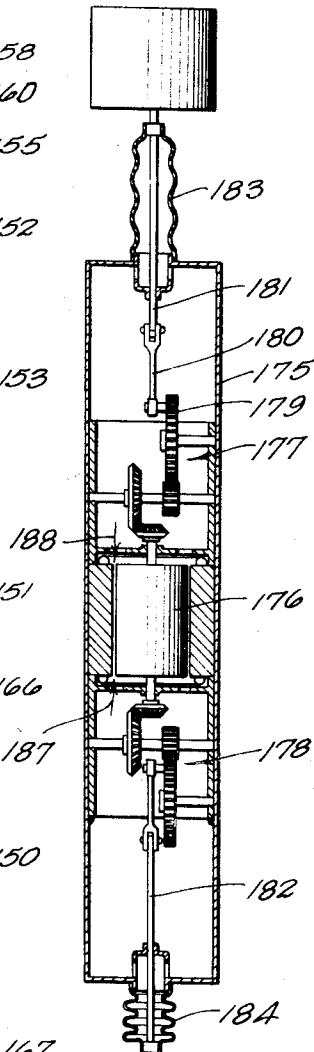
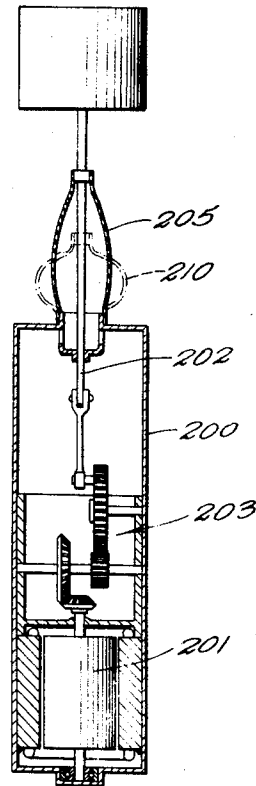


Fig. 13.



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DOUBLE-ACTING RECIPROCATING PUMP

Application filed June 16, 1931. Serial No. 544,793.

The present invention relates to a submersible structure such, for instance, as a submersible motor, and is an improvement on a co-pending application entitled "Submersible motor and reciprocating pump", Serial 239,428, patented January 26, 1932, #1,842,457.

In our co-pending application we have disclosed a submersible motor structure including an electric motor and a mechanism for transforming rotary motion of the motor to a reciprocating motion which is transmitted to the exterior of the motor shell through a plunger, this plunger operating a reciprocating pump. That application also discloses a flexible bellows, one end of which is attached to the shell, the other end being attached to the plunger, and includes a pressure-equalizing bellows which operates to maintain the pressure inside the motor shell substantially equal to the pressure of the liquid in which the structure is submerged. Inasmuch as the motor chamber is usually completely filled with oil, this pressure equalizing means also compensates for changes in volume in the motor chamber due to the reciprocation of the plunger.

It is an object of the present invention to provide an improved form of collapsible bellows which can expand in more than one direction.

A further object of the invention is to provide an improved structure in which a pair of plungers is utilized, and wherein the change in volume due to the alternate reciprocation of these plungers is automatically compensated for without the necessity of a separate pressure-equalizing means.

A further object of the invention is to provide a structure including a deformable member secured to a plunger so as to define a chamber therearound, the volume of this chamber changing as the plunger is reciprocated, and to provide an auxiliary volume-changing means driven in step with the plunger for compensating for this change in effective volume of the motor chamber.

Still a further object of the invention is to provide a novel combination of a collapsible member which is reciprocated by a plunger

and which combination includes a cylinder-piston arrangement which compensates for changes in volume inside the deformable member.

Further objects of the invention lie in the provision of a novel pumping structure, and in the details of the pump itself, as well as in the mechanism for transferring rotary motion into reciprocating motion.

Further objects and advantages of the invention will be made evident hereinafter.

Referring to the drawings,—

Fig. 1 is a utility view showing the preferred embodiment of our invention installed in a well.

Figs. 2A and 2B are upper and lower sectional views of the preferred embodiment of the invention.

Fig. 3 is a sectional view taken on the line 3—3 of Fig. 2A.

Fig. 4 is a sectional view taken on the line 4—4 of Fig. 2B.

Figs. 5 to 9 are sectional views taken on corresponding lines of Figs. 2A and 2B.

Fig. 10 is a diagrammatic view illustrating the pumping arrangement.

Figs. 11, 12, and 13 represent alternative forms of the invention.

Referring particularly to Fig. 1, our invention has been illustrated in combination with a pumping structure 15 which is suspended in a well by a discharge pipe 16 provided with an elbow 17 at its upper end. In the preferred embodiment our invention comprises a driving unit 18 positioned below and operatively connected to a pump of the reciprocating type indicated generally by the numeral 19.

Referring particularly to Fig. 2B, the driving unit 18 includes a shell 20, the lower end of which is closed by a plug 21 which is welded or otherwise secured thereto. An electric motor is positioned in the lower end of the shell and is shown as comprising a stator 22 and a rotor 23 which is secured to a shaft 24. The lower end of the shaft is journaled in a bearing 25, while the upper end is journaled in a wall 26 by means of a bearing 27.

Snugly retained in the shell above the wall

26 is an inner structure 30 which is in the form of a longitudinally split sleeve, the halves 30a and 30b of which can be readily separated when the structure 30 is withdrawn from the shell 20. These halves 30a and 30b provide engaging faces 31, best shown in Fig. 4, which are held in abutting relationship with each other by the shell 20. This split construction is utilized so as to permit easy installation of countershafts 33 and 34 which are journaled in bearings retained in the structure 30, as best shown in Fig. 2B. These shafts are inserted in place prior to the time that the inner structure is lowered into the shell, and the shafts are thus held in correct position.

The shafts 33 and 34 form a part of the transmission unit 37 of our invention, the shaft 33 mounting a bevel gear 38 which meshes with a pinion 39 secured to the upper end of the shaft 24. The shaft 33 also mounts a pinion 40 which meshes with a gear 41 which is secured to the countershaft 34 adjacent a sprocket 43, this sprocket being centrally disposed with regard to the shell.

The transmission unit 37 also includes a crank shaft 45 journaled in bearings mounted in the inner structure 30, as previously described, this crank shaft providing two cranks 46 and 47 disposed 180° from each other. Between these cranks is positioned a sprocket 48 which is connected to the sprocket 43 by a chain 49 shown in Fig. 4.

Positioned above the inner structure 30 and in abutting relationship therewith is a body structure 50 which also snugly fits in the shell 20, the upper end of this body structure providing a depression 51 which cooperates with the upper end of the shell 20 in defining a packing chamber in which a packing ring 52 is positioned. This packing ring is compressed by an annular gland 53 through the action of cap screws 55 in a manner to tightly seal the body structure relative to the shell. Screws 56, best shown in Fig. 9, may be used for preventing any axial movement between the body structure 50 and the shell 20, this body structure thus maintaining the stator 22 and inner structure 30 in correct relationship in the shell 20.

The body structure 50 provides a pair of cylinders indicated respectively by numerals 60 and 61 which act as cross-head guides for pistons 62 and 63 which preferably slide smoothly therein and maintain a relatively tight sliding fit therewith. The pistons 62 and 63 are respectively connected to the cranks 47 and 46 by connecting rods 65 and 66, these rods being pivoted to the pistons on piston pins 67 in the usual manner. The upper ends of the pistons are provided with plungers 70 and 71 journaled in openings 72 and 73 formed through projections 74 and 75 on the walls defining the upper ends of the cylinders. The pistons 62 and 63 cooperate

with these walls and with the cylinder walls in defining variable-volume spaces 76 and 77 which are in open communication with passages 78 and 79 formed by slots cut in the openings 72 and 73.

Fitting over these projections 74 and 75, and clamped therearound by any suitable means, such as the clamps 79a of Figs. 2A and 3, are deformable members 80 and 81 which surround their respective plungers 70 and 71, but which are spaced therefrom to respectively provide chambers 82 and 83, these chambers being in open communication with the spaces 76 and 77 through the passages 78 and 79. The chambers 82 and 83 and the spaces 76 and 77 are substantially completely filled with oil or other internal liquid, as are also the passages 78 and 79 which serve as an intercommunicating means through which the liquid may surge from the chambers to their respective spaces when the plungers are reciprocated. The upper end of each deformable member surrounds an enlarged portion of its respective plunger and is tightly clamped therearound or otherwise secured thereto by any suitable means such as by clamps 84. Each deformable member is preferably formed of flexible material so as to be deformable both longitudinally and transversely, though other material may be used, as hereinafter mentioned. In this manner the pressure in the chamber 82 will be maintained equal to the pressure of the external liquid when the structure is submerged, this external liquid being in contact with the deformable members. We have found it very satisfactory to make these deformable members from a rubber compound, and in most instances it is preferable to form the members with a corrugated surface as shown in Fig. 2A, though this is not in all cases necessary.

Extending upward in the body structure 50, and suitably secured thereto, is a pair of supporting arms, indicated by the numeral 90 of Figs. 2A and 8. These arms serve the dual purpose of retaining a perforated protecting member 91 in place around the deformable members in protecting relationship therewith, as best shown in Fig. 2A, and of securing the driving unit 18 to the pump 19.

This pump may be of the conventional dual-cylinder type, and may or may not be double-acting. It is also possible to use a pump of the well-known two-stage type wherein the liquid is pumped successively through the cylinders before being discharged. In the preferred embodiment, however, we prefer to use a dual-cylinder double-acting pump, and the pump shown in Figs. 2A, 5, 6, and 7 is of novel construction and finds particular utility in combination with the driving unit 18 to form a pumping structure suited for use in a well.

Referring particularly to these figures, the pump body is formed of three parts which include a lower head 101, an upper head 102, and an intermediate head 103, which are clamped together by studs 104 (see Figs. 5, 6, and 7), to the ends of which nuts are secured in the usual manner. The intermediate head 103 provides cylinders 105 and 106 in which pistons 107 and 108 respectively reciprocate, these pistons being secured respectively to rods 109 and 110 which respectively extend through suitable stuffing boxes and are connected to the upper ends of the plungers 70 and 71 in any suitable manner. As best shown in Fig. 7, the lower head 101 provides intake chambers 112 and 113 which communicate with the external liquid through openings 114, this liquid reaching these openings either through the perforations of the protecting member 91 or being withdrawn through a space 115 between the upper end of this protecting member 91 and the lower end of the lower head 101. These openings 114 are equipped with pressure-operated valves 115a which allow water to enter the chambers 112 and 113, but prevent any escape therefrom. The upper ends of the chambers 112 and 113 are respectively connected to passages 116 and 117 formed through the intermediate head 103, the upper ends of these passages being closed by a pair of valves 119, one of which is shown in Fig. 2A, both valves being diagrammatically shown in Fig. 10. These valves are also pressure-operated and allow fluid to move from these passages into a discharge chamber 120 of the upper head 102 which is in turn connected to the discharge pipe 16, but prevent any downward flow of liquid. As diagrammatically shown in Fig. 10, the lower end of the cylinder 105 is connected to the passage 116, while the upper end is connected to the passage 117. Similarly, the lower end of the cylinder 106 is connected to the passage 117, while the upper end thereof is connected to the passage 116. This communication at the upper ends of the cylinders 105 and 106 is effected by suitably casting the intermediate head 103, and at the lower end of these cylinders it is effected by means of a plate 122 which is clamped between the intermediate head 103 and the lower head 101. This plate provides a pair of openings which respectively connect the chambers 112 and 113 to the passages 116 and 117. Details of this pump construction are clearly shown in Figs. 5, 6, and 7. It will thus be apparent that as the pistons are reciprocated liquid will be forced alternately from opposite ends of each cylinder and that liquid will alternately be discharged from the upper ends of the passages 116 and 117 through the valves 119. The arrangement of parts in this pumping structure is novel, but

it is not per se a part of the present invention.

Current is supplied to the structure through a cable 125 which extends downward along the discharge pipe 16 and is secured thereto at intervals by clips 126. One or more of the studs 104 are hollowed out to permit this cable, or its individual conductors, to extend therethrough, as best shown in Fig. 5. Below the pump the cable extends through a channel 127 formed in one of the arms 90, as best shown in Fig. 8, being retained therein by a suitable cover 128. The cable extends through the body structure 50 and into a transmission chamber 130 and thence downward through a channel 131 formed in the inner structure 30, as best shown in Fig. 4, the cable then extending through the wall 26 and being connected to the motor.

A novel packing means is provided for the cable at the point where it leaves the body structure and enters the transmission chamber 130, the details thereof being best shown in Fig. 4. As shown therein, the lower end of the cable 125 enters an enlarged chamber 134, the insulation being stripped from the individual conductors so that these conductors may extend into three or more junction tubes 136 in which they are suitably soldered. These tubes are permanently retained in a plug 137 formed of insulating material, and the space inside the enlarged chamber 134 is filled with a suitable insulating compound which may be forced into place in a fluid state and which subsequently hardens into a semi-solid mass. A gland 138 slides into the lower end of the enlarged chamber 134 to move the plug 137 upward into compressing relationship with the insulating compound, thereby compressing this insulating compound tightly around the cable 125 and the individual conductors and preventing any of the external liquid from entering the transmission. Movement of the gland 138 is preferably effected through a bolt 141 which passes through a tab 142 on this gland, as best shown in Fig. 9, this bolt being threaded into the body structure 50. A new section of the cable 125 is utilized below this packing means, the conductors thereof being suitably connected to the lower ends of the junction tubes 136.

In the operation of the preferred embodiment of our invention, we prefer to completely fill the space around the motor, transmission chamber 130, the spaces 76 and 77, the passages 78 and 79, and the chambers 82 and 83 with a neutral liquid which is preferably in the form of an oil of high dielectric strength. In doing this, it becomes necessary to maintain constant the volume of the oil-filled spaces in the shell below the pistons, due to the incompressible nature of the liquid. This is accomplished by operating the pistons 62 and 63 directly out of phase

with each other, the lineal velocity of the pistons being equal at any instant. It is true that as the pistons are thus reciprocated a certain amount of the internal liquid must flow from one cylinder to the other, but this surging of the liquid back and forth between the lower ends of the cylinders can freely take place due to the open communication between these cylinders. This flow also tends to wash the bearings of the crank shaft and the chain 49. It is at once apparent that with the system herein shown the chambers can be completely filled with oil and that the pressure therein will be substantially constant due to the fact that the pistons are so moved that the volume remains constant.

Considering, for instance, the action which takes place above the piston 62 when this piston is reciprocated, it has previously been pointed out that the liquid must surge from the chamber 82 into the space 76 through the intercommunicating means 78. It is an important feature of the preferred form of the present invention to so design the piston and deformable member that a given amount of movement of the plunger will increase the volume of the chamber 82 by an amount substantially equal to the decrease in volume of the space 76, or vice versa. Stated in other words, the combined volume of the space 76, the chamber 82, and the inter-communicating means, defined by the passages 78 should be a constant. The size of the deformable member and piston can be calculated or determined empirically, and if properly designed for constant volume, there will be no lateral extension of the deformable member as the pistons are reciprocated, and it is thus not necessary to utilize deformable members capable of lateral expansion, though, as previously pointed out, this is often desirable.

It is, of course, possible to utilize the pistons 62 merely as a cross-head means sliding in a cross-head guide provided by the cylinders. If only used in this capacity, the space 76 could be in open communication with the lower portion of the cylinder either through ports along the side of the piston or through ports through the piston. In some instances such a combination is entirely practical, as will be hereinafter pointed out, but the advantage of preventing communication between the space 76 and the liquid in the lower end of the cylinder is at once apparent when considering that if such open communication took place, the liquid would of necessity surge from one deformable member into the other, and it would be necessary to rely upon the rigidity of the deformable member in overcoming the inertia of the liquid therein and in forcing this liquid into and from this and the other deformable member. Such inertia force can, of course, be decreased by having the deformable members communicate through relatively large

passages so that no throttling of the flow will take place. With such a combination, however, it is inevitable that the deformable member will tend to expand and contract laterally, thus tending to decrease its life and tending to prevent maintaining the pressure in the chamber 82 equal to the pressure of the external liquid, and thus tending to disrupt the flexible member. If, however, a piston-cylinder structure such as shown in Fig. 2A is utilized, it is at once apparent that when the plunger 70 moves downward from its position shown in Fig. 2A, the piston tends to create a partial vacuum in the space 76 which greatly assists in moving the liquid in the chamber 82 downward into the space 76. The cylinder-piston structure thus relieves the internal stresses on the deformable member which would otherwise be set up in forcing the liquid in the chamber 82 downward into the space 76.

It should be noted also that the pressure inside the shell is maintained substantially equal to the pressure of the external liquid in view of the fact that the collapsible members 80 and 81 act as a pressure-equalizing means, being laterally compressible. This is due to the fact that it is impossible to form a joint between a moving piston and the cylinder wall which is completely fluid-tight. If, for instance, the pressure inside the shell should build up slightly due to expansion of the liquid, a small amount of the internal liquid will work past the pistons 62 and 63 and will slightly expand the deformable members until the pressure inside the shell substantially equals the pressure of the external liquid contacting the deformable members, disregarding the very slight additional pressure on the liquid inside the shell due to the lateral deformation of the collapsible members if these members are formed of a flexible material.

It should not be inferred, however, that our invention is limited to the structure shown in the preferred embodiment. Thus, in Fig. 11 we have illustrated a shell 150 enclosing a motor 151 and driving a crank means 152 through a transmission means 153 similar to that shown in the preferred embodiment. Plungers 154 and 155 are reciprocated thereby, and operate a pump 156 in the manner previously described. In this form of the invention, however, deformable members 157 and 158 are in open communication with the interior of the shell 150 and no auxiliary piston-cylinder structures are utilized, the internal liquid which completely fills the interior of the shell 150 surging from the collapsible member 157 and into the collapsible member 158, as indicated by the arrow 160, or flowing in a reverse direction, as indicated by the arrow 161.

So also, in Fig. 11, we have illustrated a pump 165 positioned below the motor and

connected therewith through a mechanism similar to that shown in the upper part of Fig. 11. The pump 165 discharges into an annular passage 166 formed between the shell 150 and an outer shell 167, this liquid discharged from the pump reaching the main discharge pipe 168 above the pump 156. Both the pump 156 and the pump 165 intake through one or more pipes 170 communicating between the external liquid and the space immediately around the collapsible members. This combination of a pump above and below the motor finds particular utility in those installations where a greater volume of flow is required. In other instances, it is possible to connect the pumps 156 and 165 in boosting relationship with each other.

In Fig. 12 we have shown still another form of our invention inclosed in a shell 175. A motor 176 is positioned in the shell and a pair of transmission units 177 and 178 are operatively connected to opposite ends of the rotor of the motor. In these transmission units a crank pin is provided on a gear 179 so that a connecting rod 180 is driven in a manner to reciprocate a plunger 181 slidably retained relative to the shell. In a similar manner a plunger 182 is reciprocated relative to the lower end of the shell. A deformable member 183 surrounds the upper plunger 181 and a similar deformable member 184 surrounds the lower plunger 182, both members being respectively connected to their plungers and to opposite ends of the shell 175. The interior of each deformable member is in open communication with the liquid inside the shell 175 and the transmission units are so connected to the motor that when the plunger 181 is in its advanced position, the plunger 182 is in its retracted position. By thus operating the pistons out of phase with each other it is possible to maintain constant the volume inside the shell and inside the collapsible members, a small amount of the liquid being surged through the air gap of the motor 176, as indicated by the arrows 187 and 188, the direction of movement being, of course, dependent upon whether both plungers are rising or lowering. So also, in this form the pressure inside the shell 175 is maintained substantially equal to the pressure of the external liquid contacting the deformable members, this action taking place through the deformable members themselves. It is, of course, understood that while we have shown the lower plunger 182 as being merely a follower plunger, this plunger may be connected to a pumping means in a manner similar to that disclosed in Fig. 11 if desired.

Referring particularly to Fig. 13 wherein still another form of the invention is shown, a shell 200 encloses a motor 201, this shell slidably journalling a piston 202 which is reciprocated by the motor through a transmission unit 203 similar to that shown in Fig.

12. A deformable member 205 is utilized, the interior thereof being in open communication with the liquid inside the shell 200. In this case the deformable member is shown as being in the form of a bag formed of rubber or other flexible water-proof material. The walls of this bag are not molded or shaped in the shape of corrugations as are the deformable members previously described. As the plunger 202 is moved into the shell 200 it is, of course, apparent that a portion of the liquid will be forced upward from the interior of the shell into the deformable member due to the fact that an effective volume in the shell is decreased by an amount equal to the volume of the piston drawn thereinto. In addition it should be clear that the liquid previously in this member remains therein, the net result being that the member changes in shape as the piston is moved downward and may assume a shape such as shown by the dotted lines 210 when the plunger is in its lowermost position. In this form of the invention the lateral expansion of the deformable member is particularly illustrated. It will also be noted in this form of the invention that the deformable member tends to maintain the pressure inside the shell equal to the pressure in the external liquid, disregarding any resilient action in the deformable member itself.

It should thus be apparent that our invention is capable of being embodied in various forms, and that the advantages of a deformable member are not limited to use with a cylinder-piston structure such as shown in Fig. 2A. On the other hand, it will be clear that the structure such as shown in Fig. 2A will decrease the stresses set up in the deformable members and will thus be long-lived. It has been found that pumping units utilizing deformable members such as are herein described operate very satisfactorily, even when the deformable members are in contact with oil and are formed of a rubber compound. Ordinarily oil has a detrimental effect on rubber, but prolonged tests have shown that while rubber deformable members may change in shape with prolonged use and may decrease in tensile strength, still if the pressures on opposite sides thereof are maintained substantially equal, there is no danger of leakage or rupture. In some instances, and with certain rubber compounds, it has been found that the oil has an expanding effect on the rubber, but even in these instances failure of the deformable members has not taken place.

It should also be understood that our invention is not limited in utility to a combination with a pump comprehends the provision of a submersible unit which is capable of producing reciprocation of one or more plungers. Nor is the invention limited in all instances to a submersible driving unit, for

in its broadest aspect the invention covers a device for transmitting motion into and from a shell without danger of leakage thereinto or therefrom.

5 We claim as our invention:

1. In a submersible structure, the combination of: an enclosing structure including a cylinder and a transmission chamber communicating therewith; a plunger slidable relative to said enclosing structure and providing walls slidable in said cylinder to define a space, the volume of which changes when said plunger is reciprocated; a deformable member around said plunger and secured at one end in fluid-tight relationship relative to said plunger and at the other end secured in fluid-tight relationship with said enclosing structure; intercommunicating means through which said space communicates with the chamber around said plunger and inside said deformable member; and means in said transmission chamber and operatively connected to said plunger to reciprocate same.

2. In a submersible structure adapted to be submerged in an external liquid, the combination of: a body structure including a cylinder; a piston reciprocable in said cylinder to define a variable volume space; a plunger secured to said piston and extending from said body structure; a deformable member secured at one end to said body structure and at the other end to said plunger, said deformable member surrounding said plunger and being spaced therefrom to define a chamber; and walls forming a passage communicating between said space and said chamber, said space, said chamber, and said passage being filled with an incompressible liquid, said deformable member maintaining the pressure on said liquid substantially equal to the pressure on said external liquid.

3. In combination in a structure adapted to be submerged in an external liquid: a shell providing a chamber substantially filled with an internal liquid; a plunger extending from said chamber and journaled relative to said shell to move into and from said chamber; a deformable member secured at one end to said shell and at the other end to said plunger and deformable in a direction along the length of said plunger and in a direction transverse thereto, said member surrounding said plunger but being spaced therefrom to form an annular chamber filled with said internal liquid whereby the shape of said annular chamber changes when said plunger is reciprocated, said deformable member being subjected to the pressure of said external liquid which contacts said deformable member; and means for reciprocating said plunger.

4. In combination in a structure adapted to be submerged in an external liquid: a shell providing a chamber substantially filled with an internal liquid; a plunger extending from

said chamber and journaled relative to said shell to move into and from said chamber; a rubber sleeve member around said plunger and spaced therefrom to define an annular chamber filled with internal liquid, the exterior of said rubber sleeve member contacting said external liquid and substantially equalizing the pressures on said internal liquid in said annular chamber and on said external liquid which contacts said rubber sleeve member, the internal liquid changing the shape of said sleeve member by expanding and contracting it as said plunger is reciprocated; means for securing one end of said sleeve member in fluid-tight relationship with said shell; means for securing the other end of said sleeve member in fluid-tight relationship with said plunger; and means for reciprocating said plunger.

5. A combination as defined in claim 4 in which said annular chamber formed in said rubber sleeve member is in open communication with said chamber in said shell.

6. In a submersible structure adapted to be submerged in an external fluid, the combination of: a shell; a pair of plungers extending through the walls of said shell; means for moving said plungers through identical reciprocating cycles, but out of phase with each other; a deformable member around but spaced from each plunger to form liquid-filled annular spaces therearound, the inner ends of said annular spaces being in open communication with each other whereby liquid may surge from one annular chamber to the other when said plungers are reciprocated out of phase with each other.

7. In a submersible structure, the combination of: a shell defining a chamber; a body structure secured to said shell and providing a pair of cylinders, the inner ends of which open on said chamber; a piston structure in each of said cylinders; and means for reciprocating said pistons in said cylinders at a constant phase displacement relative to each other, said chamber and the inner ends of said cylinders bounded by said pistons being filled with an internal liquid which surges from one cylinder into the other to maintain the pressure in said chamber substantially constant.

8. In a submersible structure adapted to be submerged in an external liquid, the combination of: a body structure; a deformable member in the form of a bellows secured to said body structure and contacted by said external liquid; a plunger extending inside said deformable member and secured to one end thereof, there being a chamber therebetween, said bellows being collapsible both longitudinally and laterally whereby the pressure in said chamber is maintained substantially equal to the pressure of said external liquid; and variable volume means operatively connected to said plunger and

communicating with said chamber for compensating for the change in volume of said chamber when said plunger is reciprocated.

9. In a submersible structure, the combination of: a body structure including a cylinder; a plunger reciprocable relative to said body structure and providing a piston slidable in said cylinder to form a space the volume of which changes when said plunger is reciprocated; a deformable member around said plunger and secured at one end in fluid-tight relationship relative to said plunger and secured at its other end in fluid-tight relationship with said body structure thereby defining a variable volume chamber around said plunger which changes in volume with a given movement of said plunger by an amount equal to the corresponding change in volume of said space with the same amount of movement of said plunger; intercommunicating means through which said space communicates with said chamber, said intercommunicating means thus cooperating with said chamber and said space to form a constant-volume compartment, there being a body of liquid entrapped in said compartment, the only communication with said body of liquid being between the piston and the walls of said cylinder whereby a constant mass of liquid is retained in said compartment and surged from said space into said chamber and vice versa when said plunger is reciprocated.

10. In a submersible structure adapted to be submerged in an external fluid, the combination of: a shell; drive means in said shell; plunger means reciprocable with respect to said shell to change the effective volume of said shell; a second plunger means reciprocable with respect to said shell and thereby changing the effective volume of said shell; and means operatively connecting said drive means to each plunger means to move both of said plunger means through substantially identical cycles and at a constant phase displacement relative to each other whereby the change in volume effected by one of said plunger means is compensated for by the change in volume effected by the other of said plunger means.

11. In a submersible structure, the combination of: an enclosing structure including a chamber and a pair of cylinders, the inner ends of said cylinders opening on said chamber; a plunger extending into each of said cylinders; a pair of pistons slidable in said cylinders, one piston being secured to each plunger, said pistons cooperating with the outer ends of said cylinders in defining variable volume spaces; means in said chamber for reciprocating said plungers at a constant phase displacement relative to each other; a deformable member around each plunger to define a variable volume chamber therearound, one end of each deformable member

being secured to its associated plunger and the other end thereof being secured to said enclosing structure; intercommunicating means communicating between said variable volume chambers and said spaces.

12. In a submersible structure, the combination of: a shell; a drive means in said shell and including a rotatable shaft; an inner structure slidable in said shell to a position adjacent one end of said drive means; a body structure in said shell adjacent said inner structure; plunger means reciprocable relative to said body structure; a transmission unit removable with said inner structure and operatively connecting said drive means and said plunger means to change the rotation of said rotor into a reciprocating movement of said plunger means.

13. In a submersible structure, the combination of: a shell; a drive means in said shell and including a rotatable shaft; an inner structure slidable axially into said shell and being split to comprise halves which can be separated when said inner structure is removed from said shell; bearing means associated with said halves; transmission means journaled by said bearing means and extending across said inner structure, said transmission means including a crank means driven by said drive means; a plunger means extending from said shell and reciprocable with respect thereto; and means operatively connecting said crank means and said plunger means whereby said plunger means is reciprocated.

14. In a submersible structure, the combination of: an enclosing structure; a drive means in said enclosing structure; a plunger at each end of said drive means and reciprocable relative to opposite ends of said enclosing structure; transmission means connecting said drive means and said plungers to reciprocate said plungers at a constant phase displacement whereby the volume of the interior of said enclosing structure is constant; and a deformable member around and secured to each plunger and to said enclosing structure.

15. A combination as defined in claim 14 in which said transmission means includes two transmission units one on each end of said drive means, and in which said drive means includes a shaft extending therethrough, opposite ends of said shaft being respectively connected to said transmission units.

In testimony whereof, we have hereunto set our hands at Los Angeles, California, this 12th day of June, 1931.

EARL MENDENHALL.
JUNIUS B. VAN HORN.