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DIAPHRAGM PISTON PUMP

Filed March 29, 1955

2 Sheets-Sheet 1

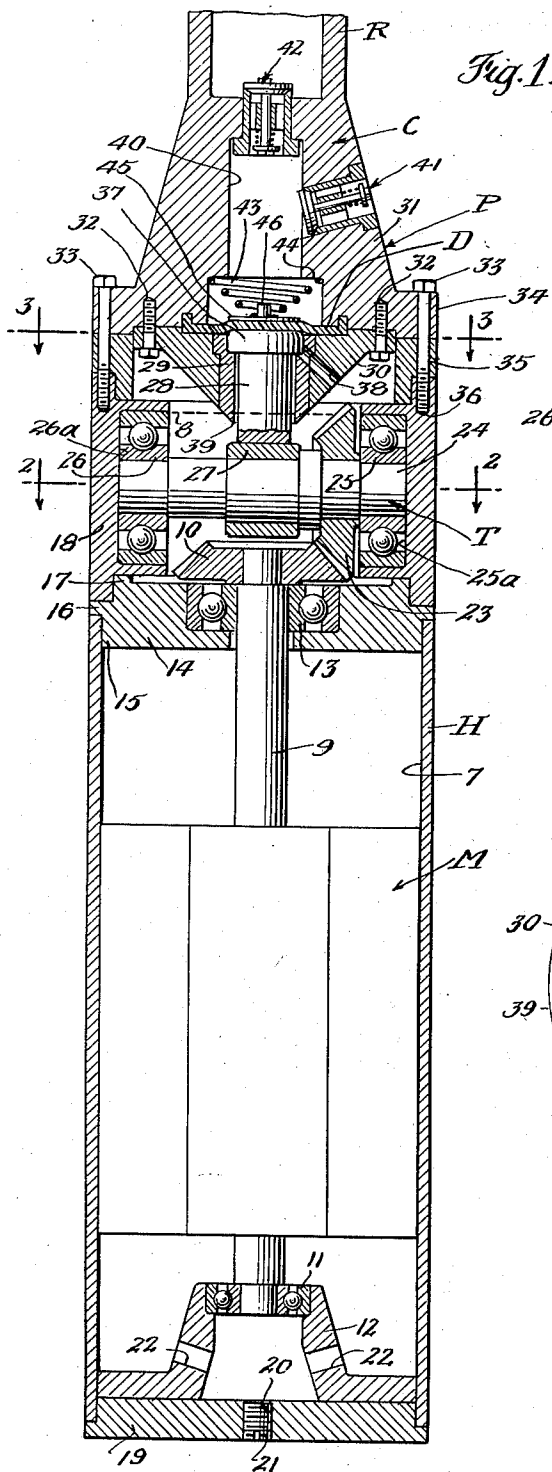


Fig. 1.

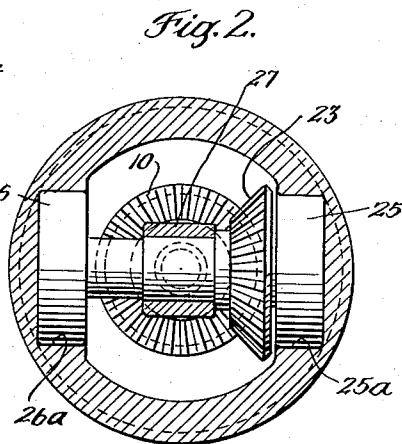


Fig. 2.

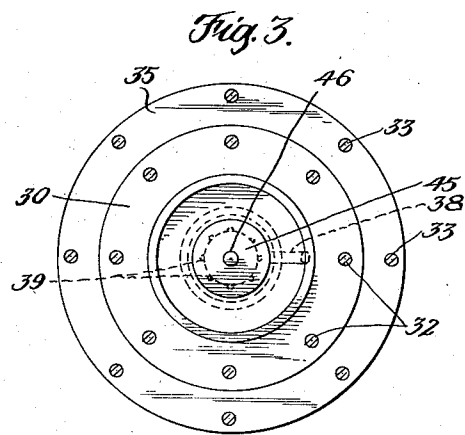


Fig. 3.

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Fig. 4.

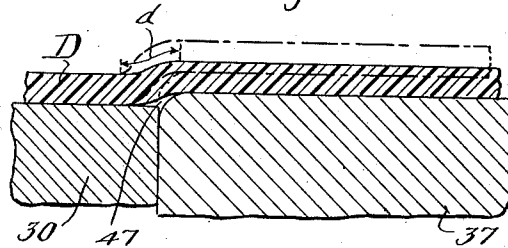


Fig. 5.

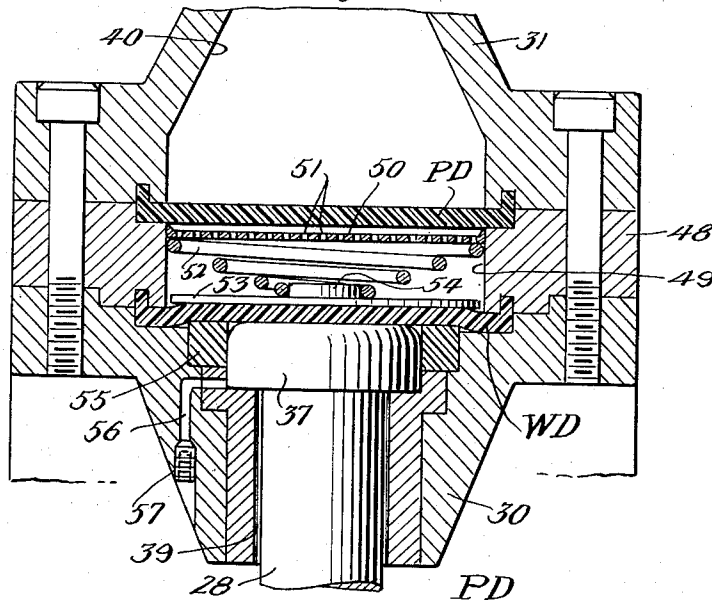
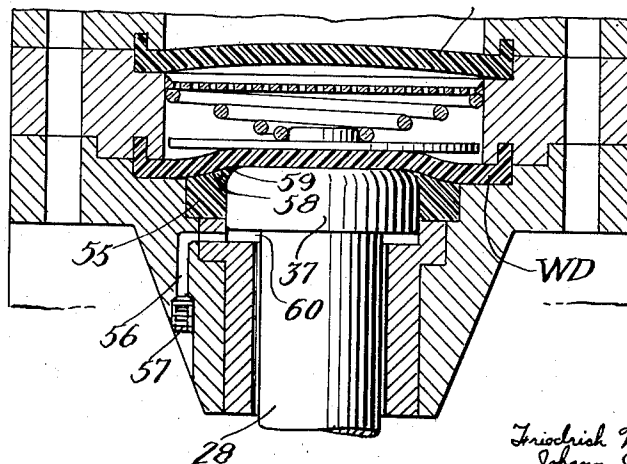


Fig. 6.

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DIAPHRAGM PISTON PUMP

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Claims priority, application Germany July 24, 1954

11 Claims. (Cl. 103—152)

This invention relates to submersible equipment for pumping sillage from deep wells and, more particularly, relates to a diaphragm piston pump for submersion down an oil well to pump petroleum from great depths.

Problems are encountered when it is attempted to submerge a pump to the bottom of an oil well, rather than maintaining the pump above the surface and effecting pumping action by a piston driven through a long series of tie rods.

The primary object of the invention is the provision of a diaphragm piston pump capable of submersion in a deep well and capable of sustained pumping operation over a relatively extended period of time without breakdown necessitating surfacing of the pump.

Another object of the invention is the provision of a submersible pump having the motor and associated mechanism protected from contact with sillage from the surrounding strata.

Further the invention has an object the provision of a continuous and unbroken diaphragm sealing the pumping chamber off from the mechanism of the pump, said diaphragm being supported over substantially its entire area on the face opposite the pumping chamber, such support being effective during all phases of the pumping cycle.

Yet another object of the invention is the provision of resilient supporting means closely surrounding the piston beneath the diaphragm in order to ensure support of the diaphragm across its entire face even during the portion of the cycle when the diaphragm is displaced toward the pumping chamber.

Still further the invention has an object the provision of a double diaphragm construction including one diaphragm made of a material selected for its ability to withstand repeated flexure and another diaphragm made of a material selected for its resistance to chemical attack by the sillage being pumped.

Additionally the invention has as an object the provision of a hydraulic chamber separating the diaphragms of a double diaphragm construction and adapted to transmit force from one to the other.

How the foregoing and other objects and advantages of the invention are attained will appear more clearly from the following description, taken together with the accompanying drawings in which:

Fig. 1 is a diagrammatic sectional elevation of pumping equipment according to the invention;

Fig. 2 is a cross section taken on the line 2—2 of Fig. 1;

Fig. 3 is a cross section taken on the line 3—3 of Fig. 1;

Fig. 4 is a fragmentary sectional view, on an enlarged scale as compared with Fig. 1, showing a portion of the diaphragm, the piston and the surrounding support for the purpose of illustrating diagrammatically the nature of the diaphragm distortion which occurs during operation of the pump;

Fig. 5 is a fragmentary sectional elevation on an en-

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larged scale as compared with Fig. 1 showing another embodiment of the invention utilizing a pair of diaphragms and further showing a resilient supporting ring surrounding the piston, this view showing the piston in retracted position; and

Fig. 6 is a view similar to Fig. 5 but showing the piston in extended position deflecting the working diaphragm toward the pumping chamber.

Preliminarily it is pointed out that various equipment useful with features of the invention is fully illustrated and described in copending applications Serial No. 497,629, filed March 29, 1955, issued January 7, 1958 as Patent No. 2,818,818, and Serial No. 497,630, filed March 29, 1955, issued November 26, 1957 as Patent No. 2,814,253, entitled Pumping Equipment and Pumping Equipment for Viscous Liquids respectively, assigned to the assignee of the present application.

Considering Fig. 1 first, it is pointed out that a multi-part housing H is associated with the bottom end of riser R and may be positioned beneath the surface of the earth a distance of 2,000 m. or more. Within the housing H are the motor M, transmission T, pumping means P and, separating and sealing the pumping means from the motor and transmission, a continuous, unbroken flexible diaphragm D.

In more detail, the motor M, operating in motor chamber or reservoir 7 filled with oil up to oil level 8, has a shaft 9 carrying bevel gear 10 and journaled in ball bearings 11 (mounted in supporting structure 12) and 13 (mounted in motor cover plate 14). Plate 14 is shouldered to provide a portion 15 fitting into the housing H, a portion 16 of diameter equal to that of housing H, and a portion 17 fitting inside of transmission housing 18.

Closure plate 19 (having oil supply passage 20 fitted with screw plug 21) seals off the bottom of housing H. Passages 22—22 through support member 12 permit oil supplied through aperture 20 to flow into the reservoir up to the oil level 8.

Bevel gear 10 meshes with bevel gear 23 fixed to shaft 24 disposed at right angles to shaft 9 and journaled in ball bearings 25 and 26 mounted in recesses 25a and 26a in the walls of transmission housing 18.

An eccentric or cam 27 is fixed to shaft 24 intermediate the bearings 25 and 26. Piston 28 reciprocates in the bore of bushing 29 with its lower end in contact with the cam 27. Bushing 29 is mounted within support member 30 which may be bolted to pump cap 31 as by bolts 32—32. The pump cap 31 is secured to transmission housing 18 by bolts 33—33 passing through apertures in the shoulder 34, through spacer ring 35, and into threaded apertures 36.

The piston 28 is shouldered at the upper end to form a portion 37 of larger diameter which operates within a bore portion of correspondingly larger diameter, said portion contacting the lower face of the diaphragm D. A passage 38 leads from the reservoir to the larger diameter bore portion. Oil picked up by the bevel gear 23 during rotation is splashed into the passage 38 and serves as a means for lubricating the contacting surfaces between the piston and the diaphragm. Oil return grooves 39 are provided so that excess oil delivered up the passage 38 can flow down between the piston and bushing into the reservoir. Thus, by means of the oil delivery passage 38 and the oil return grooves 39, a continuous circulation of oil from the reservoir to the region of the piston face and back to the reservoir takes place.

Within the pump cap 31 is the pumping chamber 40 having an inlet check valve generally indicated at 41 and an outlet check valve generally indicated at 42, which valves are adapted to permit flow of oil into the pumping chamber and into the riser respectively.

A spring 43 abuts the bottom of a counterbore 44 in

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the pump cap 31 and also abuts a disc 45 having a centering post 46, said disc bearing against the upper or pumping chamber face of the diaphragm D. This arrangement of the spring causes a force tending to urge the diaphragm toward the piston 28, which force aids in returning the diaphragm to its lowermost position after the piston 28 has displaced it upwardly on the pressure stroke and commenced its downward motion on the suction stroke.

The operation of the equipment proceeds as follows. As the motor rotates, the bevel gears 10 and 23 effect corresponding rotation of the shaft 24 and the cam 27. The cam 27 displaces the piston upward and the piston in turn, by direct contact with the underface of the diaphragm D, deflects or distorts the diaphragm upward toward the pumping chamber, in a manner more clearly seen in Fig. 4 in the dot-and-dash line position.

Motion of the diaphragm toward the pumping chamber tends to build up pressure in the oil within the chamber and effects closing of the intake valve 41 and displacement of the outlet valve 42. For the remainder of the pressure stroke of the piston, the sillage will be discharged from the pumping chamber into the rising main R. When the cam passes the position in which the piston is displaced upward the greatest distance, the spring, together with the head of liquid above the pump in the riser, urges the diaphragm to follow the piston on the suction stroke. During this stroke, the discharge valve 42 closes, the intake valve 41 opens, and sillage flows into the pumping chamber from the surrounding strata. At this point the cycle is ready to repeat.

During operation oil is continuously splashed by the bevel gear 23 up the passage 38 and such oil surrounds the piston enlargement 37 and fills the relatively small pocket 47 (see Fig. 4) between the support 30, the piston 37 and the diaphragm D.

Fig. 4 illustrates in solid lines the position of the diaphragm when the piston is fully retracted and in dot-and-dash lines the position of the diaphragm when the piston is fully extended. The annular portion of the diaphragm indicated by the double-headed arrow *d* is the portion which bears most of the flexure stress during distortion and return of the diaphragm. If the piston stroke is increased, this portion *d* will undergo an increased stretching, thereby increasing the stress and the danger of rupture.

On the other hand, increasing the diameter of the piston merely results in locating the stressed portion *d* somewhat further from the center of the piston, without causing any material increase in the stress imposed thereon. By way of specific example, it has been found from practical experience that when using a constant speed motor rotating within the range of approximately 1000/1500 up to 3000 R. P. M. with a diaphragm of synthetic material 1 to 3 mm. thick and a piston whose edge is rounded to a radius of 3 mm., the stroke should not exceed 2 mm., if it is desired to lift oil up the rising main a distance of more than 500 m. From this it can be seen that, if it becomes desirable to attain a certain minimum delivery, it is preferable to increase the piston diameter, rather than to increase the length of stroke.

Attention is now turned to the embodiment of the invention shown in Figs. 5 and 6.

Preliminarily it is pointed out that materials, such as rubber, which have excellent flexure properties are unfortunately subject to severe chemical action and damage when brought into contact with crude petroleum. On the other hand, some materials, such as certain of the plastics, which have excellent corrosion and chemical resistance are not sufficiently flexible and resilient to withstand the terrific flexure to which the diaphragms are subjected. As a solution to this problem, the embodiment of Figs. 5 and 6 utilizes a lower working diaphragm WD which may be made of a material having excellent flexure

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properties and an upper protective diaphragm PD which has excellent corrosion and chemical resistance.

The arrangement of the motor, transmission and valve means can be the same for the embodiment of Figs. 5 and 6 as above described in connection with the embodiment of Fig. 1. However, in the embodiment of Figs. 5 and 6 the pump cap 31 and the supporting member 30 are separated by the diaphragm spacer 48 having a bore 49 forming a hydraulic chamber between the two diaphragms.

The upper diaphragm PD seals the hydraulic chamber from the pumping chamber 40 while the lower diaphragm WD seals the hydraulic chamber from the motor and transmission chamber.

A supporting screen 50 having apertures 51 underlies the protecting diaphragm PD. This screen is provided to prevent distortion of the diaphragm PD downward in the event of rupture of the working diaphragm WD. Excessive distortion of the diaphragm PD downward would lead to rupture and permit sillage to flow from the chamber 40 down into the motor and transmission mechanism. It is important to prevent such flow of the sillage since it carries with it considerable quantities of entrained solid substances (such as sand) which might seriously damage the drive mechanism of the pump. A spring 52 is located within the hydraulic chamber and abuts the edges of the screen 50 and a disc 53 provided with a spring centering pin 54. The spring assembly acts to urge the working diaphragm toward the piston to assist in return of the diaphragm to the downward position (illustrated in Fig. 5) when the piston is on the suction stroke.

The support member 30 is recessed adjacent the piston to accommodate a resilient auxiliary supporting ring 55 which closely fits around the piston head and protrudes a short distance toward the diaphragm above the plane of the support member 30. As described in more detail in connection with Fig. 6, the portion of the resilient ring 55 which extends above the surface of the support member 30 will deform under the pressure of the liquid above and transmitted through the diaphragm in a manner to substantially fill the small space which might otherwise exist between the rounded corner of the piston, the diaphragm and the support surrounding the piston.

Instead of the splash lubrication passage 38 shown in Fig. 1, the embodiment of Fig. 5 includes an oil delivery passage 56 provided with a check valve 57 which permits oil to enter into the small spaces around the piston head but prevents flow of such oil back out of the passage 56. By this means more positive lubrication is provided for since the enlargement 37 on the downward stroke will entrap oil and, by pressure feed, force it up around the piston and between the piston face and diaphragm WD. A portion of the oil will also travel out through oil return grooves 39.

Fig. 6 shows the mechanism of Fig. 5 with the piston and diaphragms in the extreme upward position. The working diaphragm WD will distort somewhat in the manner of the diaphragm shown in Fig. 4. However, the resilient supporting ring 55 will distort to provide a portion 58 which tends to extend into the small space between the rounded corner 59 of the piston and the working diaphragm WD. As mentioned above, this extension ensures complete support of the diaphragm across its entire area even when it is distorted upwardly to its greatest extent. This distortion of the supporting ring 55 also prevents pinching of the diaphragm between the piston and cylinder on the downstroke, which pinching might result if a space were left into which the pressure of the fluid above the diaphragm could force a portion of the diaphragm material.

The upper or protective diaphragm PD does not distort as abruptly or markedly as the lower working diaphragm WD. In contrast, the upper diaphragm PD distorts in a gradual arc throughout its entire area. Such flexure is

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not nearly so severe and does not stress the material as vigorously as the distortion given the working diaphragm WD.

As mentioned above, when the piston is in the upward position, oil may flow past the check valve 57 and through the passage 56 and into the small space 60 surrounding the piston 28 and just below the piston enlargement 37. Some of this small body of oil in the chamber 60 which is forced up and around the piston enlargement during the suction stroke.

The operation of the embodiment of Figs. 5 and 6 is generally similar to that described above in connection with the embodiment of Fig. 1. However, a brief description follows. On the up stroke the piston deflects the working diaphragm toward the pumping chamber. Since the hydraulic chamber 49 is filled with an incompressible liquid, such as oil, the force of the piston and working diaphragm WD is transmitted through the hydraulic chamber to the upper or protective diaphragm PD, causing distortion of this diaphragm into the pumping chamber. On the suction stroke of the piston, the spring and head of oil in the riser combine to urge the protective and the working diaphragms downwardly so that they follow the piston into their lower position ready to repeat the pumping cycle.

From the foregoing description of the various embodiments of the invention illustrated in the drawings it can be seen that the diaphragm which is directly distorted by the piston is substantially completely supported over its entire area in all phases of the operation. In Fig. 1 this support is accomplished by the cooperation of the face of the piston and the support member 30 (together with the bushing 29).

In the embodiments of Fig. 5 this support includes the resilient supporting ring 55 which is formed of a sufficiently elastic material so that it will be deformed by the pressure involved to flow into and fill whatever small space may tend to develop between the piston, the support member 30 and the diaphragm during operation of the pump.

The invention provides for diaphragm distortion in only one direction from rest position. Distortion from rest position in both directions is avoided. The invention thus guards against flexure in both directions which would increase the stress and decrease the diaphragm life.

Both of the embodiments illustrated in the drawings include means for thoroughly lubricating the contact surfaces between the piston and the diaphragm. Such lubrication is an important aspect of the invention since it aids in smooth and cool operation and, more importantly, materially prolongs the pumping life of the diaphragm. In addition, the pocket of lubricant between the rounded corner of the piston, the diaphragm and the support means aids in preventing pinching of the diaphragm when the piston is on the suction stroke.

We claim:

1. Submersible equipment for deep well pumping, comprising a motor, a pump, and a housing enclosing said motor and pump, said pump having a pumping chamber and a continuous flexible diaphragm separating the pumping chamber from the motor, a piston and a cylinder therefor, said piston operating in contact with the diaphragm, said piston being driven by said motor and adapted on the pressure stroke to deflect said diaphragm in the direction of the pumping chamber, and support means closely surrounding said piston adjacent the diaphragm, said support means extending laterally from the piston in position to underlie the diaphragm, said support means and piston being constructed and arranged to cooperate in contacting and supporting said diaphragm over substantially its entire area during pump operation, said support means including a ring of resilient material immediately surrounding said piston and

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extending slightly beyond the rest of the support means toward the diaphragm.

2. Equipment according to claim 1 in which the piston includes an end portion of larger diameter and the cylinder includes a cylinder portion of correspondingly larger diameter, said equipment further including a reservoir of lubricant and passage means connecting said larger diameter cylinder portion with the reservoir.

3. Equipment according to claim 2 in which said passage means includes a check valve adapted to occlude flow when the piston is on the suction stroke.

4. Submersible equipment for pumping sullage from a deep well comprising a motor, a pump, and a housing enclosing said motor and pump, said pump having a pumping chamber, a pair of continuous flexible diaphragms interposed between the pumping chamber and the motor and spaced from each other to form a hydraulic chamber therebetween, one of said diaphragms sealing the pumping chamber from the hydraulic chamber and the other of said diaphragms sealing the hydraulic chamber from the motor, a piston in contact with said other diaphragm, said piston being driven by said motor and adapted on the pressure stroke to deflect said other diaphragm in the direction of the pumping chamber; and support means closely surrounding said piston adjacent the diaphragm, said support means extending laterally from the piston in position to underlie said other diaphragm, said support means and piston being constructed and arranged to cooperate in supporting said other diaphragm over substantially its entire area during pump operation, said support means including a ring of resilient material immediately surrounding said piston and extending slightly beyond the rest of the support means toward said other diaphragm.

5. Equipment according to claim 4 in which the first mentioned diaphragm is made of a material selected for its corrosion and chemical resistance, and in which the said other diaphragm is made of a material selected for its ability to withstand repeated flexure without rupture.

6. Submersible equipment for deep well pumping comprising a motor, a pump and a housing enclosing said motor and pump, a pumping chamber, a motor chamber and a continuous flexible diaphragm therebetween, said diaphragm having a rest position and a deflected position, a piston and a cylinder therefor located in said motor chamber, said piston being in contact with the diaphragm, said piston being driven by the motor and adapted on the pressure stroke to deflect the diaphragm in the direction of the pumping chamber from the rest position to the deflected position, and support means mounted in fixed position closely surrounding the piston adjacent the diaphragm, said support means extending laterally from the piston in position to underlie the diaphragm, said support means and piston being constructed and arranged to cooperate in contacting and supporting the diaphragm throughout substantially the entire area of the motor chamber face of the diaphragm, said support means and piston being constructed and arranged to prevent travel of the diaphragm in the suction direction beyond said rest position, whereby the diaphragm is adapted to be deflected from said rest position in only one direction.

7. Equipment according to claim 6 and further including a reservoir of lubricant and passage means interconnecting the reservoir and the cylinder, whereby to supply lubricant to the contacting surfaces of the piston and diaphragm.

8. In pumping equipment the combination of a pumping chamber having a suction valve and a delivery valve, said chamber having one wall formed as a continuous diaphragm, a piston and a cylinder therefor, said piston being adapted to deflect the diaphragm in the direction of the pumping chamber, and support means closely surrounding the piston adjacent the diaphragm, said support means extending laterally from the piston in position to

underlie the diaphragm, said piston and said support means being constructed and arranged to cooperate in contacting and supporting the diaphragm throughout substantially the entire area which lies in back of the pumping face, the piston including an end portion of larger diameter and the cylinder including a cylinder portion of correspondingly larger diameter, said equipment further including a reservoir of lubricant and passage means connecting the larger diameter cylinder portion with said reservoir.

9. Submersible equipment for deep well pumping, comprising a motor, a pump, and a housing enclosing said motor and pump, said pump having a pumping chamber and a continuous flexible diaphragm separating the pumping chamber from the motor, a cylinder and a piston therein in contact with the diaphragm, said piston being driven by said motor and adapted on the pressure stroke to deflect said diaphragm in the direction of the pumping chamber, said piston including an end portion of larger diameter and said cylinder including a cylinder portion of correspondingly larger diameter, said equipment further including a reservoir of lubricant and passage means connecting the larger diameter cylinder portion with said reservoir.

10. A construction according to claim 9 in which said passage means includes a check valve adapted to occlude flow when the piston is on the suction stroke.

11. Submersible equipment for pumping sillage from a deep well comprising a motor, a pump, and a housing enclosing said motor and pump, said pump having a pumping chamber, a pair of continuous flexible diaphragms

interposed between the pumping chamber and the motor and spaced from each other to form a hydraulic chamber therebetween, one of said diaphragms sealing the pumping chamber from the hydraulic chamber and the other of said diaphragms sealing the hydraulic chamber from the motor, a cylinder and a piston therein in contact with said other diaphragm, said piston being driven by said motor and adapted on the pressure stroke to deflect said other diaphragm in the direction of the pumping chamber; said piston including an end portion of larger diameter and said cylinder including a cylinder portion of correspondingly larger diameter, said equipment further including a reservoir of lubricant and passage means connecting the larger diameter cylinder portion with said reservoir.

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