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PUMPING EQUIPMENT FOR VISCOUS LIQUIDS

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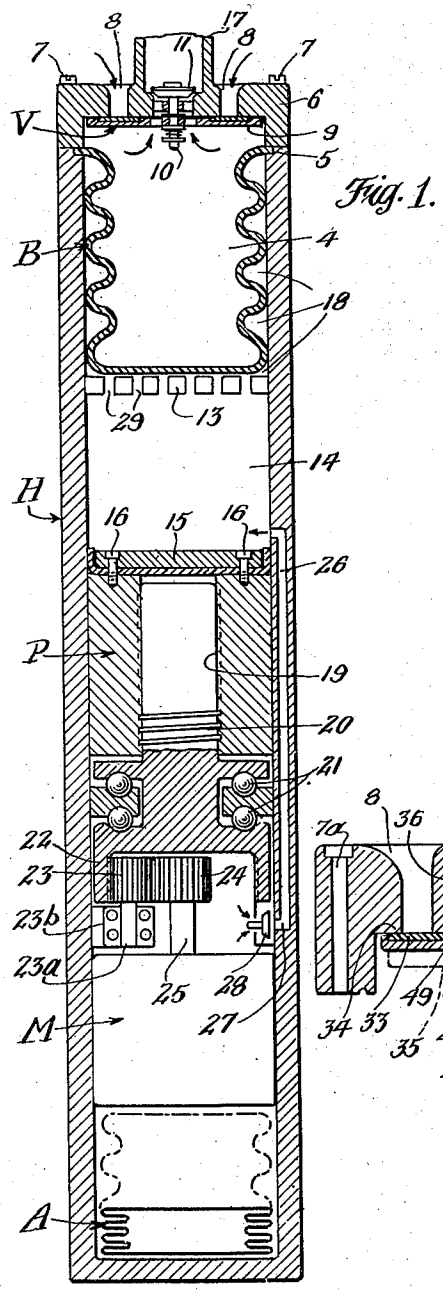


Fig. 1.

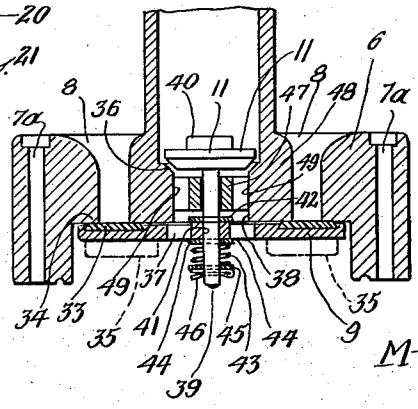


Fig. 3.

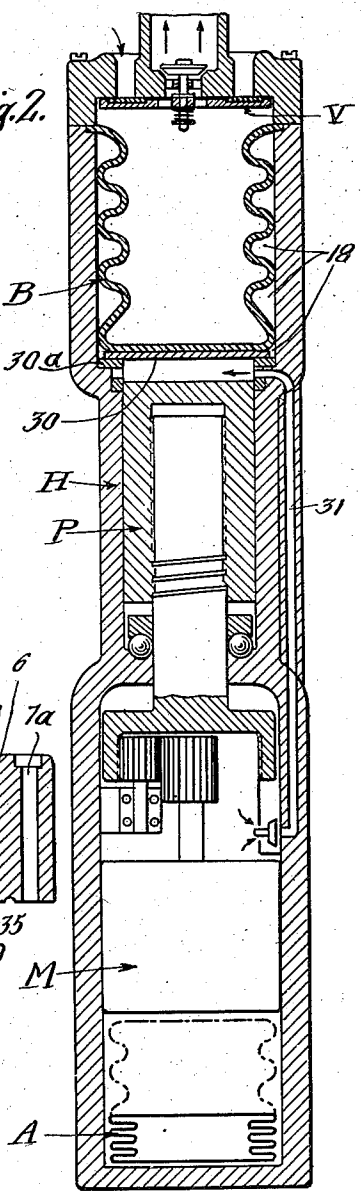


Fig. 2.

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PUMPING EQUIPMENT FOR VISCOUS LIQUIDS

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7 Claims. (Cl. 103—44)

This invention relates in general to apparatus for deep well pumping, and more particularly relates to a piston actuated bellows pump having a specially constructed inlet-outlet valve mechanism facilitating the pumping of exceptionally viscous liquids, specifically, heavy types of petroleum.

Petroleum is a complex mixture of saturated and non-saturated aliphatic and also aromatic hydrocarbons and compounds thereof, in addition to other components of inorganic substances and dissolved gases, whose boiling points, viscosities, and chemical reactivities differ greatly one from another. Such mixtures, found in underground deposits, lead to a number of problems when it is attempted to pump the mixtures to the surface by means of ordinary diaphragm pumps. These problems are of three general types, namely, physical, chemical and geological.

Attention is first directed to various of the physical problems encountered when it is desired to pump liquids of exceptionally high viscosity. In ordinary pumping equipment the piston on the suction stroke tends to create a vacuum in the pumping chamber and thereby effects displacement of the intake valve off of its seat to permit petroleum to flow into the pumping chamber from the surrounding strata. No problems are thus created when the liquid being pumped is of relatively low viscosity (whether it be petroleum or some other liquid) since it will readily flow into the pumping chamber. However, when pumping liquids of exceptionally high viscosity, problems are encountered since the mass behaves somewhat like a solid. The mass will begin to flow through the suction valve into the pumping chamber only after the piston has traveled on the suction stroke a considerable distance. As a result the volumetric efficiency and delivery performance are seriously impaired.

In addition, when the high viscosity liquid being pumped is crude petroleum or some other liquid including relatively volatile fractions, further difficulties are encountered since these fractions tend to volatilize when the pressure on the liquid decreases. In effect the pump "pulls" the volatile substances out of the liquid mass on the suction stroke.

As the foregoing paragraphs indicate, the higher the viscosity of the liquid to be pumped, the less effective will be the intake valve which will lower the volumetric efficiency and delivery of the pump.

The various chemical difficulties encountered will be considered next. Certain rubber-like materials (either natural or synthetic) are structurally satisfactory for use as diaphragms because of their ability to be flexed a large number of times without rupture. Unfortunately, practical experience has shown that such materials cannot be subjected to the chemical action of petroleum without destroying the strength of the material after a fairly short pumping life, perhaps no more than two to three weeks. The primary constituents of the petroleum liquids

which tend to attack such rubber materials are the cyclic hydrocarbons and their compounds.

On the other hand, materials, such as plastics, which are more resistant to chemical attack sometimes do not have the structural strength necessary to withstand the severe and repeated flexure to which the diaphragm in an ordinary pump is subjected.

In addition to the above, the relatively high temperatures in the probe accentuate the above difficulties. Certain material having sufficient mechanical strength and elasticity to act as diaphragms cannot withstand the high temperatures encountered in deep wells, whereas some material able to withstand the high temperatures are somewhat limited in their structural strength.

Attention is now turned to the third type—geological problems. Care must be taken in the probing of oil deposits to utilize techniques which will not damage the possibilities for future extraction from the well and which will avoid pumping excessive quantities of foreign matter, particularly solid particles tending to erode the riser and other equipment.

It is well known in the art of petroleum extraction that the ordinary deposit involves a central pool and innumerable small passages leading therefrom into the oil bearing strata. These small passages act as capillary tubes feeding the central pool as the pump removes oil. Extraction of the oil too rapidly from the central pool results in a breakdown of the feed through the capillary tubes which may do serious permanent damage to the oil deposit by making it virtually impossible to extract further oil therefrom. Such interruption of the capillary feed may be caused by strong jolting suction. In addition, such harsh suction causes eddies in the oil which tend to pull solid particles off of the surrounding strata and entrain them in the liquid being pumped. Also it is noted that when the sucking is done in quick jerks many impurities, such as water, salt, etc., are dragged along with the oil instead of settling in the oil pool surrounding the pump.

One of the principal objects of the invention is the provision of a bellows type pump capable of drawing oil into the pumping chamber at a relatively low and uniform rate, and, more specifically, the invention has an object the provision of inlet passage means for the pump having a cross sectional area substantially larger than that of the outlet passage means.

Further the invention has as an object the provision of means to positively open the intake valve during motion of the discharge valve toward flow occluding position, and thereby to lower the resistance to flow of liquid into the pumping chamber.

Another object of the invention is the provision of a casing or housing enclosing the motor and pump and capable of submersion as a sealed unit to the bottom of an oil well.

Yet another object of the invention is the utilization of a pump driving mechanism capable of operation under the surface of an oil reservoir and the provision therewith of an auxiliary, gas-filled bellows within the housing and exposed to the pressure of the oil in the reservoir whereby the pump may be operated without volatilization of the oil in the reservoir.

A still further object of the invention is the provision of a drive for the pump piston adapted to effect uniform and relatively slow motion in both directions.

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

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

Fig. 2 is a diagrammatic sectional elevation of another embodiment; and

Fig. 3 is a diagrammatic sectional elevation on a larger scale than Figs. 1 and 2, and showing the details of the intake and outlet valve means of the invention.

Certain aspects of the invention are useful with different types of pumps than those here considered and, by way of example, reference is made to the equipment shown in copending applications 497,629, filed March 29, 1955 and 497,628, filed March 29, 1955, entitled Pumping Equipment and Diaphragm Piston Pump, respectively, and assigned to the assignee of the present application.

Referring to Fig. 1, the housing H encloses the bellows B having intake and outlet valve means generally indicated at V. Also located within the housing H are the motor M, piston P, and auxiliary bellows A.

In more detail Fig. 1 illustrates, within the generally cylindrical housing H, a flexible bellows B which serves two functions, namely, to form pumping chamber **4** and to act as a seal to prevent the sullage being pumped from coming in contact with the motor and drive mechanism. For the sealing function the open edge of the bellows is secured as at **5** in a recess in the housing wall.

A cover plate **6** connected to the housing as by bolts **7—7** bears against the material of the bellows to ensure a tight seal. While the details of the inlet-outlet valve mechanism will be discussed below in connection with Fig. 3, it is here pointed out that the inlet ports **8** are associated with valve member **9** mounted on the valve stem **10**, which also carries the outlet valve member **11** in the discharge passage or rising main **17**.

A screen or apertured plate **13** is supported against the housing walls in position to prevent over-extension of the bellows.

In the embodiment of the invention shown in Fig. 1 a hydraulic chamber **14** is provided between the screen plate **13** and the cup **15** mounted by screws **16—16** on the end of the piston P. This chamber **14**, together with the space indicated at **18** surrounding the bellows within the housing, is filled with a suitable hydraulic liquid, such as oil.

The piston P includes a threaded bore **19** cooperating with corresponding threads on the shaft **20** journalled in bearings **21** (arranged to take up thrust in both directions). A planetary gear **22** formed on the end of the shaft **20** meshes with a pinion **23** rotating on shaft **23*a*** journalled in support member **23*b*** and in turn meshing with pinion **24** on the shaft **25** of the motor M.

As the motor rotates, the planetary gear will be driven through the gear train and thus the shaft **20** will rotate at a speed considerably slower than the speed of rotation of the motor shaft. As the shaft **20** rotates the threads thereon cooperate with the threads in the bore **19** of the piston and serve to advance the piston (upward when viewed in Fig. 1). After the piston has travelled in one direction a predetermined distance, the direction of travel is reversed by any suitable means. As an example, this may be accomplished by a phase reversal switch unit, not shown in the drawing, that is directly driven by the motor.

Instead of the screw thread shown in Fig. 1 and the motor reversing mechanism mentioned above, a cross thread may be provided on the shaft **20** for cooperation with a follower pin protruding from the bore **19** to effect reversal of the direction of travel of the piston without necessitating a reversal of the direction of rotation of the motor.

The entire motor and transmission chamber may be filled with oil to facilitate smooth running and cooling of the unit. However, as the piston moves up and down the volume of the space inside the housing behind the piston will increase and decrease. In order to provide for such change in volume without volatilizing the oil, an auxiliary bellows A, filled with gas, is located within the housing and exposed to the oil pressure in the reservoir of oil surrounding the motor. When the piston is in its lowermost position, as shown in Fig. 1, the oil in the reservoir will compress the auxiliary bellows A to the solid line position. However, when the piston moves upward, the auxiliary bellows A will expand to take the position indicated by the dash lines.

Notwithstanding the use of oil cup **15** on the piston, some oil will escape from the hydraulic chamber **14** and space **18** backward and downward between the piston and cylinder wall into the reservoir. It is undesirable to permit the volume of oil in the chamber **14** and space **18** to become smaller because, in view of the constant stroke of the piston, the result will be a tendency to create a vacuum toward the end of the suction stroke when the bellows has come against the limiting plate **13**. In order to compensate for any oil which may leak out of the space **18** or chamber **14**, an oil supply conduit **26** is provided (which may advantageously be formed in the wall of the housing) which conduit communicates with the chamber **14** at a position just above the cup **15** in the extreme downward position of the piston. This oil conduit **26** communicates with the oil reservoir as at **27** and includes a check valve **28** adapted to permit flow of oil from the reservoir to the chamber **14** but to prevent flow in the opposite direction.

The operation of the equipment is as follows. Starting from the position shown in Fig. 1, the piston, driven by the motor through the gear train, will move upward pushing the body of oil in the chamber **14** ahead of it, through the apertures **29** in the screen plate **13** and against the bellows B. Near the beginning of the upward stroke of the piston the valve plate **9** will be forced upward and seated in position to occlude flow through the inlet passages **8**. The discharge valve member **11** will be unseated to permit flow of liquid from the pumping chamber into the rising main. As the bellows are compressed the liquid in the pumping chamber is forced through the discharge valve and into the rising main toward the surface. During the piston advance the auxiliary bellows A expands to compensate for the increase in volume below the piston.

When the piston has reached its extreme upper position, reversal of direction of motion takes place (either by means of the motor reversal switch or the cross thread arrangement described) and the piston starts to move in a downward direction. This results in the closing of the discharge valve **11** and the displacement of the valve member **9** from its seat to permit flow through the intake passages **8**. The incoming oil fills and expands the bellows B until it again rests on the support means **13** and the cycle may then be repeated.

Attention is now directed to the embodiment of the invention shown in Fig. 2. It will be seen that the overall arrangement of the parts of the invention is quite similar. The housing H encloses the bellows B (having intake-outlet valve means V), the piston P, the motor M, and the auxiliary bellows A.

The main difference between the embodiment of Fig. 2 and the embodiment of Fig. 1 is that the hydraulic chamber **14** is eliminated. The screen plate **13** shown in Fig. 1 is replaced by a solid plate **30** secured to the bottom of the bellows. As the piston moves upward it contacts this bottom plate directly, rather than through the hydraulic medium within the interposed chamber shown in Fig. 1. As the piston moves downward the bellows expands until the bottom plate **30** rests on the supporting shoulder **30*a***, which prevents over-extension of the bellows.

The space **18** surrounding the bellows within the housing is filled with oil as is the reservoir surrounding the motor M, the transmission, and the auxiliary bellows A.

As with the embodiment of Fig. 1, an oil conduit **31** is adapted to supply oil from the reservoir to the space surrounding the bellows **18**.

As mentioned above, when pumping highly viscous

liquids, it is particularly important to utilize intake passage means having a cross sectional area substantially greater than that of the discharge passage means. In this connection Fig. 3 shows the details of the intake-outlet valve means of the invention.

As there seen, intake passages 8 are annularly arranged through the cover plate 6 which may be secured to the housing (see Fig. 1) by screws passing through holes 7a. The intake valve member 9, which advantageously is in the form of a disc, may include an annular insert (or a series of annularly arranged individual disc inserts) indicated at 33 which, together with the metal 34 surrounding the discharge passages 8 provides a metal-to-plastic seal. The sealing force on the insert 33 may be supplemented by means of small floats 35 mounted on the underside of the disc 9.

Discharge valve member 11 cooperates with valve seat 36 to occlude flow through the annularly arranged series of discharge outlets 37 and the main discharge channel 38. The discharge valve also preferably provides a metal-to-plastic contact.

The inlet valve means 9 and the outlet valve means 11 are coaxially associated with a common valve stem 39, the outlet valve means being fixed on one end of the stem as by a head 40, while the other end of the stem 39 passes through an aperture 41 in the plate 9. The collar 42 is provided on the stem in position to assure positive displacement of the valve member 9 as the discharge valve member 11 moves in direction to occlude flow but before the discharge member 11 is seated. The positive displacement of the intake valve from its seat is an important aspect of the invention since it results in a reduction of the resistance to inflow of the liquid being pumped.

A spring 43 surrounding the stem and abutting against washers 44 and 45 urges the plate 9 toward the collar or abutment member 42. A cotter pin 46 passing through the stem keeps the washer and spring assembly in place.

The stem is supported in bushing 47 secured to the lower portion 48 of the wall 12 and apertured as at 49—49 to permit flow of liquid from the pumping chamber into the riser.

The operation of the valve V proceeds as follows. As the piston commences the pressure stroke, the valve plate 9 will travel upwardly and the insert 33 will seat tightly against the shoulders 34 surrounding the intake passages 8. The abutment of the center of the plate 9 against the collar 42 fixed on the stem will effect initial displacement of the discharge valve 11 off of its seat 36 and permit the commencement of liquid delivery into the riser. As the piston continues on the pressure stroke, the force of the liquid against the bottom of the valve member 11 displaces it still further upward, compressing the spring 43.

As the piston begins motion in the suction direction, the spring 43, together with the head of liquid in the rising main above the valve, propels the valve member 11 downward toward flow occluding position. The abutment 42 contacts the center portion of the plate 9 and effects displacement of the valve member 9 off of the valve seats 34 to facilitate the intake of liquid from the surrounding strata. As the piston continues on the suction stroke the force of the incoming liquid displaces the valve plate 9 further downward and compresses the spring 43. It is noted that the incoming liquid can flow from the passages 8 either around the edges of the valve disc 9 or through the passages 37 annularly arranged around the stem. As the piston reaches the end of the suction stroke and starts on the pressure stroke, the spring, together with the pressure built up in the liquid in the pumping chamber, effects upward motion of the valve plate 9 against its seat and the above cycle can then be repeated.

We claim:

1. Submersible equipment for deep well pumping comprising a motor, a pump, and a housing enclosing said motor and pump with said motor operating in an oil reservoir within the housing, said pump including a bellows forming a pumping chamber and sealing said chamber from the motor, the space surrounding said bellows within the housing being filled with oil, suction and delivery valve means for the pumping chamber, a piston driven by said motor and adapted on the pressure stroke to collapse said bellows, oil supply means adapted on the suction stroke of the piston to supply oil to said space to compensate for leakage and maintain a constant volume of oil therein, said oil supply means including a conduit interconnecting said space and said reservoir, and a gas-filled bellows within the housing and exposed to the oil pressure in said reservoir.

2. Equipment for deep well pumping comprising a motor, a pump, and a housing enclosing said motor and pump to form a submersible pumping unit, a bellows forming a pumping chamber within the housing, a piston driven by the motor and adapted on the pressure stroke to collapse said bellows, inlet passage means and delivery passage means for the pumping chamber, said inlet passage means having a cross sectional area substantially larger than that of said outlet passage means, inlet valve means and outlet valve means alternatively movable toward flow occluding position, and mechanism interconnecting said inlet and outlet valve means and providing positive displacement of said inlet valve means during motion of said outlet valve means toward flow occluding position.

3. A construction according to claim 2 in which the inlet and outlet valve means are coaxially associated with a common valve stem, said outlet valve means being fixed on an end of the stem, the other end of said stem passing through an aperture in said inlet valve means, an abutment on said stem positioned to engage the inlet valve means and displace same during motion of the outlet valve means toward flow occluding position, and spring means urging the inlet valve means toward said abutment.

4. A construction according to claim 2 in which the motor operates in an oil reservoir within the housing, and further including a gas-filled bellows within the housing and exposed to the oil pressure in said reservoir.

5. Submersible equipment for deep well pumping comprising a motor, a pump and a housing enclosing said motor and pump; said pump comprising the following: a bellows forming a pumping chamber and sealing said chamber from the motor, suction and delivery valve means for the pumping chamber, and a piston driven by said motor and adapted on the pressure stroke to collapse said bellows, the space surrounding said bellows within the housing being filled with oil; oil supply means adapted on the suction stroke of the piston to supply oil to said space to compensate for leakage and maintain a constant volume of oil therein; said suction and delivery valve means being alternatively movable toward flow occluding position and mechanism interconnecting said suction and delivery valve means and providing positive displacement of said suction valve means during motion of said delivery valve means toward flow occluding position; and a gas-filled bellows within the housing and exposed to the oil pressure in said reservoir.

6. A deep well pumping unit comprising a generally cylindrical closed ended housing adapted for submersion endwise in a well, a motor mounted within the lower portion of the housing, a bellows forming a pumping chamber within the upper portion of the housing and sealing said chamber from the rest of the interior of the housing, suction and delivery valve means for the pumping chamber, a piston driven by said motor and adapted on the pressure stroke to collapse said bellows, the walls of the housing intermediate the motor and bellows serving as a cylinder for said piston, the space surrounding said bellows above said piston and the space surrounding said motor being sealed within the pumping unit and be-

ing filled with oil, conduit means interconnecting the space surrounding the bellows with the space surrounding the motor, and check valve means in the conduit means adapted to permit flow from the space surrounding the motor into the space surrounding the bellows and to prevent flow in the opposite direction, whereby to compensate for leakage from the space surrounding the bellows and maintain a constant volume of oil therein.

7. A pumping unit according to claim 6 and further including a gas-filled bellows within the housing and exposed to the pressure of the oil in the space surrounding the motor.

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