Aug. 17, 1937. J. G. KEEGAN 2,090,127

SOLENOID PUMP

Filed March 3, 1936 2 Sheets-Sheet 1

Fig. 1.

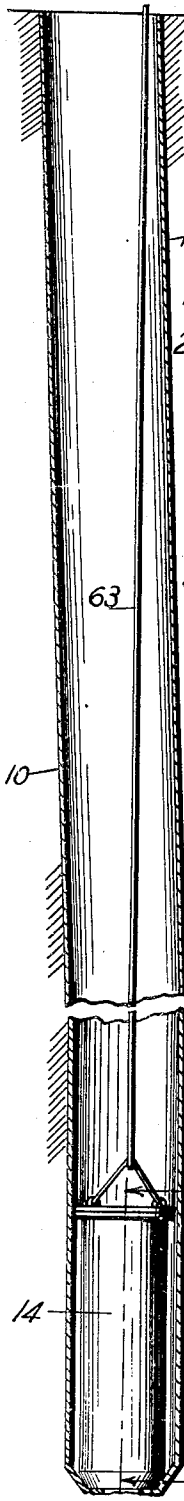


Fig. 2.

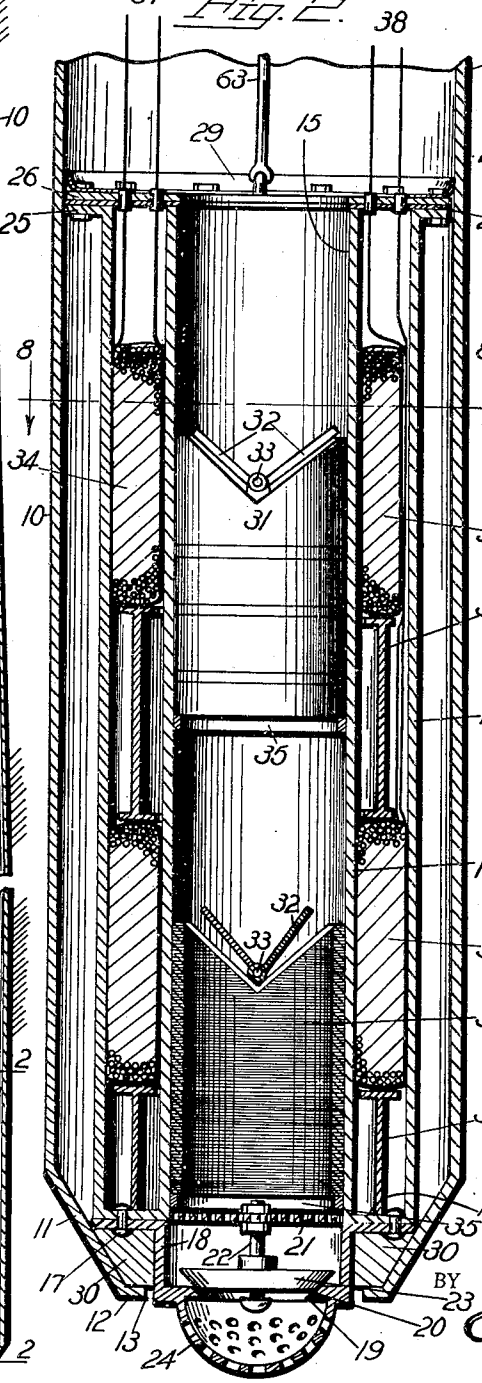


Fig. 3.

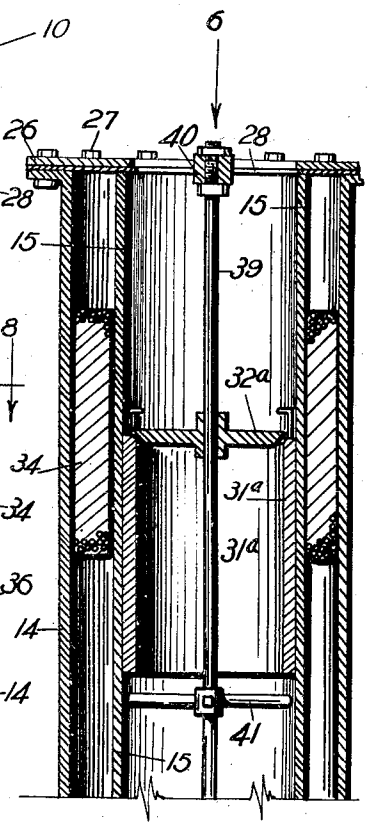
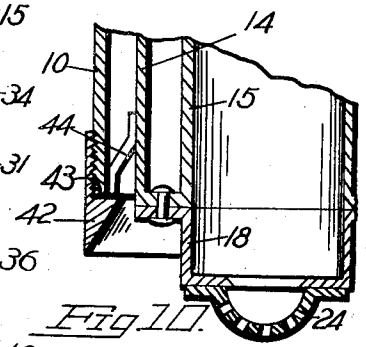


Fig. 10.



INVENTOR.
JOHN G. KEEGAN
BY
ATTORNEY.

Aug. 17, 1937. J. G. KEEGAN 2,090,127

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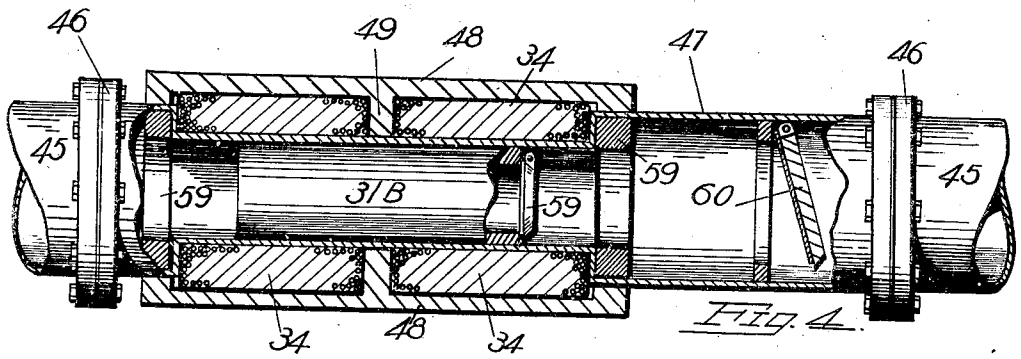


Fig. 4.

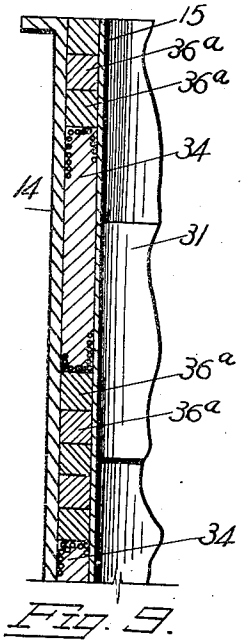


Fig. 9.

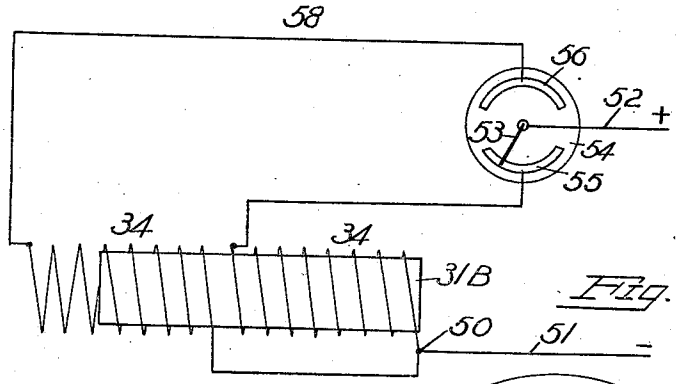


Fig. 7.

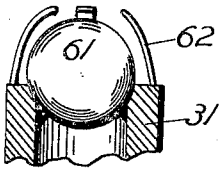


Fig. 5.

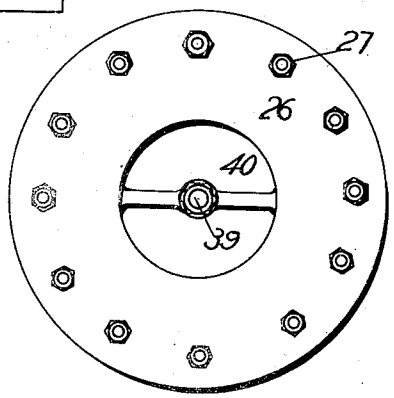


Fig. 6.

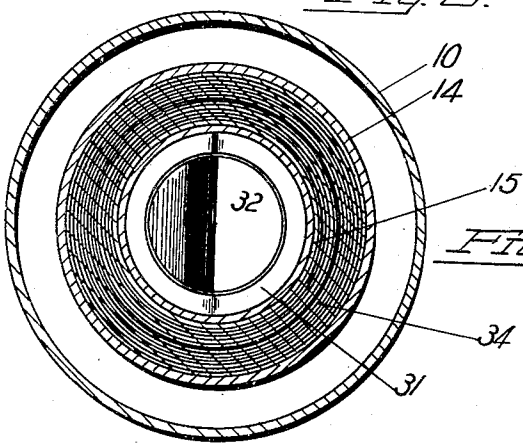


Fig. 8.

INVENTOR.
JOHN G. KEEGAN

BY

G. J. Rallement
ATTORNEY.

Patented Aug. 17, 1937

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UNITED STATES PATENT OFFICE

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SOLENOID PUMP

John G. Keegan, Cheyenne, Wyo., assignor of one-half to Wyoming Southern Oil Company, Cheyenne, Wyo., a Wyoming corporation

Application March 3, 1936, Serial No. 66,842

12 Claims. (Cl. 103—53)

This invention relates to improvements in pumps and has reference more particularly to electro-magnetically operated pumps of the solenoid type.

In many deep wells, either oil or water, it is practically impossible to employ the ordinary type of deep well pump since such pumps comprise a pipe provided at or near its lower end with a cylinder in which the plunger is mounted for reciprocation and require sucker rods for reciprocating the plunger. If the pipe is crooked the rods contact the inner surface of the pipe and produce a binding action which greatly increases the power necessary to operate the pump, the wear and the labor and cost of maintenance.

It is the object of this invention to produce a pump that (*a*) does not require sucker rods for operating the plunger, and (*b*) which does not require an additional pipe, but employs the casing with which the well is provided.

Another object is to produce a pump of such construction that several may be connected in series when the lift is great, so as to use the combined lifting power of the pumps. Where the quantity to be handled is small, a separate pump pipe may be used.

The above and other objects that may become apparent as the description proceeds are attained by means of a construction and an arrangement of parts that will now be described in detail, reference for this purpose being had to the accompanying drawings in which the invention has been illustrated, and in which

Figure 1 is a vertical section through a deep well, having a crooked hole, the pump being shown in operative position at the lower end of the casing;

Figure 2 is a diametrical section, to a somewhat enlarged scale, taken on line 2—2, Figure 1;

Figure 3 is a diametrical section showing a somewhat different pump construction;

Figure 4 is a view, partly in section and partly in elevation, showing a slightly modified pump construction;

Figure 5 is a section through the upper end of a plunger, showing a ball valve;

Figure 6 is a view looking in the direction of arrow 6 in Figure 3;

Figure 7 is a diagram of the wiring employed in connection with the embodiment illustrated in Figure 4;

Figure 8 is a section taken on line 8—8, Figure 2;

Figure 9 is a fragmentary section, similar to that illustrated in Figure 2, but showing a slightly modified construction; and

Figure 10 is a fragmentary diametrical section through the lower end of the casing showing the pump assembly operatively connected with an ordinary well casing.

In Figure 1 reference numeral 10 designates the casing of a deep well and the portion above the break has been shown as having its axis angularly related to the section below the break.

It frequently happens that deep wells are crooked, due to some fault in the rock structure or to other causes that need not be discussed in detail here. The well illustrated in Figure 1 is merely illustrative of a crooked deep well. In oil wells and also in deep water wells, the casing is formed from iron pipes connected by couplings in the usual way, and can therefore be used as a portion of the pump, taking the place of the usual pump pipes.

In the embodiment illustrated in Figures 1 and 2, the casing has been shown as provided at its lower end with a frusto-conical section 11 which terminates in a bottom 12 having an opening 13. Such casings cannot, of course, be in place during the drilling operation, but are inserted afterwards. In Figure 10, a modification has been shown in which the regular well casing is employed.

Positioned within the casing 10 is the pump unit which consists of an iron pipe 14 that is connected at its lower end with a similar pipe 15, of smaller diameter and of non-magnetic material, such as brass. The connection at the bottom may be made in any suitable way, but has been shown as effected by a ring 16 whose edges are electrowelded to the ends of the two pipes and holds them in concentric spaced relation.

Attached to the ring 16, as by bolts or rivets 17, is a valve housing 18 having a bottom 19 provided with a central opening 20 whose edge is beveled to form a valve seat. The lower end of pipe 15 is provided with a foraminated bottom 21 from the center of which a bolt 22 projects downwardly. A valve 23 is loosely mounted on the bolt and cooperates with the valve seat in bottom 19 to form a foot valve. A semi-spherical, or otherwise shaped screen 24 surrounds opening 20. The outer pipe 14 is provided at its top with an outwardly projecting flange 25 to which the cover plate 26 is connected by means of bolts 27. A gasket 28 separates the lower surface of plate 26 from the upper surface of flange 25, and the upper end of pipe 15. A sealing cup 29, of any suitable material and construction,

is secured to the upper end of the pump by means of the bolts **27**. When the pump is in operative position the valve housing **18** extends through the opening **13** and the weight of the pump is supported on a gasket **30**, which may be made of rubber, or other suitable material.

Within the pipe **15**, which forms the cylinder, are two plungers or pistons **31**, which may be identical. In the drawings the lower piston has been shown as built up of soft iron rings to reduce hysteresis losses, but it may be made from a single piece of soft cast iron or wrought iron, and this form has been illustrated in connection with the upper piston.

The pistons are tubular and are provided with any suitable form of valve which will permit liquid to move upwardly and prevent it from moving downwardly. In the drawings a double flap valve has been illustrated. The valve members have been designated by numeral **32** and have been shown as movable about a hinge pin **33**. Any other suitable valves may be substituted for the one shown.

The annular space between pipes **14** and **15** serves as a compartment for the magnet coils **34** of which there is one for each piston. Before proceeding to the description of the magnet, attention will be called to the rings **35** which limit the downward movement of the pistons. The coils **34** are preferably so located that when the pistons rest on rings **35**, their upper ends will be on the level of the center points of the solenoid coils although a slight variation from this is not material.

In order to secure the proper position and spacing of the magnet coils, cast iron rings **36** are used and positioned as shown. The pipe **14** and the rings **36** form a portion of the magnetic circuit. The pistons **31** serve as core armatures and will move upwardly and close the magnetic circuit whenever the coils are energized. In the form illustrated in Figure 2, the pistons move downwardly in response to the action of gravity whenever the coils **34** are de-energized.

It is evident that when the coils **34** are successively energized and de-energized, at a rate which permits the pistons to respond, the assembly will work as a pump and move liquid upwardly.

If the lift is high the two pistons can be simultaneously moved in the same direction so as to utilize their combined lifting force, but if the head is low, they can be moved simultaneously in opposite directions, so as to get the combined capacity. The operation will not be described in detail as it is presumed that the operation of an ordinary piston pump is understood by all.

The upper coil **34** is supplied with current through wires **37** and the lower coil through wires **38** and a suitable rotating switch, similar to that illustrated diagrammatically in Figure 7 alternately opens and closes the circuit at the desired speed.

In Figure 3, a slightly modified form of construction has been shown. The difference between the construction shown in Figure 2 and that illustrated in Figure 3 consists primarily in the valve and in the form of stops employed for limiting the downward movement of the pistons. Instead of the double flap valves illustrated in Figure 2, a single plate valve **32***a* is employed. Instead of the rings **35**, shown in Figure 2, a rod **39** is employed, which extends axially through the cylinder **15**, coaxially therewith, and has its upper end supported by a cross bar **40**, a similar cross bar can be employed for the lower end or else the lower end may replace the bolt **22**.

Arms **41** extend radially from bar **39** and serve as limit stops for the upper piston. In the modification illustrated in Figure 3, the rings **36** have not been shown but the coils **34** are spaced and held in the same way as explained in connection with Figures 2 and 9.

In very deep wells, a plurality of pumps can be used, and spaced vertically so that the lift for each will be the most suitable. Where a plurality of vertically spaced units are employed, they must be so synchronized that the pistons move in opposite directions at the same time, in order to obtain maximum capacity, as this gives uniform upward flow, a more uniform load, and smoother operation than simultaneous movement in the same direction. The necessary synchronization is effected by the simple expedient of connecting corresponding magnet coils in parallel.

When the pump is to be employed in connection with deep oil wells, the casing **10**, instead of terminating in a frusto-conical, tapered surface **11** and a flange **12** as shown in Figure 2, is provided with the usual shoe **42**, in the manner shown in Figure 10. The shoe has a sharp cutting edge and an inwardly projecting shoulder **43** which serves as a stop for the lower end of the casing **10**. The shoulder is wider than the thickness of the casing and the lower end of pipe **14** may be provided with radial lugs **44** that engage the shoulder and limit the downward movement of the pump. The seal **29** is sufficient to produce an operative connection between the pump and the casing. Any other suitable way of supporting the pump can be substituted for that shown and described.

Where several pump units are to be operated in series, as in a long pipe line or in a very deep well, the pumps can be made in units of such construction that they may be connected between adjacent sections of pipe in the manner shown in Figure 4.

In the example illustrated, reference numbers **45** designate sections of pipe having flanges **46**. The pump consists of a section **47**, which in the embodiment illustrated, is made from non-magnetic material, such as brass. In Figure 4, pipe **47** has been formed with an annular recess in its outer surface in which the coils **34** have been wound as on a spool.

A tubular sheath **48** formed of two semi-cylindrical sections, covers the coils **34** and forms a portion of the magnetic circuit. The flange **49** separates adjacent ends of the coils and forms a common pole for the two coils.

In Figure 7, a diagram has been shown of the electrical connections to the coils **34**. The two coils have been shown as connected in series so as to form a single coil. The center point **50** is connected with one pole of a direct current supply, by means of a conductor **51**. The other pole is connected by means of a wire **52** with the center of a rotary switch arm **53** that is mounted on a base **54**. The base carries two arcuate contacts **55** and **56**, the former of which is connected to one end of a coil **34** by conductor **57** and the latter to one end of the other coil by means of conductor **58**. The arm **53** is rotated by suitable means and alternately energizes the coils **34**.

In the drawings, the piston or plunger **31B** is shown as overlapping the two coils **34** to the same extent and if the right hand coil is ener-

gized, the piston will move toward the right, in response to the magnetic flux, until it bridges the gap between the iron rings **49** and **59**, which form the two magnetic poles.

When the rotating switch arm **53** engages the contact **56** the left hand coil will be energized and the piston will be moved toward the left until it bridges the gap between the center pole **49** and the ring **59**, at the left end of the coil assembly.

As long as the switch arm **53** rotates to energize the coils **34**, alternately, the plunger will reciprocate. The piston has a valve **69** and a foot valve **60** is provided at the delivery side of the pump. When several pumps are connected in series there is preferably a foot valve between each unit. Since the coil at the left merely returns the piston, it does not have to be as powerful as the other which also serves to advance the liquid, but in the drawings they have been shown as being of the same size. Where several pumps are connected in series, they must be synchronized which is effected by connecting corresponding coils **34** of the several pumps in parallel.

It is evident that the exact construction shown in Figure 4 can be departed from without effecting the mode of operation.

In Figure 5 a section through one end of a plunger has been illustrated and a ball **61** has been shown as replacing the other types of valves that have been illustrated. Fingers **62** serve as a cage to hold the ball in place.

In Figure 9 a fragmentary section has been shown which shows how the rings **36** of I-shaped cross section, that serve as spacers for the coils **34** can be replaced by cast iron rings **36***a*.

By using a number of smaller rings, the coils can be positioned and spaced as desired by adding or subtracting rings to any of the spaces. The solid rings **36***a* also form magnetic paths of less reluctance than the corresponding spacers **26** shown in Figure 2.

The pump can be lowered into position by means of a steel cable **63** which may also enclose the electrical conductors **37** and **38**.

With the construction illustrated in Figure 10, the well is drilled and cased in the usual manner. The shoe **42** is so designed that it provides a shoulder that extends into the casing. When the well is finished, a pump assembly is lowered into the casing until the lugs **44** rest on the shoulder whereupon the pump can be operated to raise liquid through the casing.

In the above description and in the drawings, a suitable construction has been described and shown. Any minor variations can, of course, be made without departing from the invention. Instead of the specific way of supporting the pump illustrated and described, any other equivalent means can be employed.

It has already been explained that the pumps can be connected for simultaneous movement in the same or in opposite directions, and the latter is contemplated wherever practical, because with such an arrangement the column of liquid is kept in constant motion, which gives greater efficiency than an arrangement where the liquid is stopped and started at each stroke.

When the liquid is prevented from stopping between strokes there results a uniform upward throw, a uniform load on the pumps, a uniform power output, less wear on the equipment, and a uniform power consumption.

It will be understood that the various pumping units illustrated in Figures 2, 3 and 4 are well adapted to be operatively mounted in a casing **14** and suspended in a well, as illustrated in Figure 1.

Where a positive movement in opposite directions is desired, the structure embodying the features illustrated in Figure 4 in which alternate coils will be used to move the pistons in opposite directions, will probably constitute the preferred form of the invention, whereas if the elevated column of liquid provides sufficient pressure to insure a positive down stroke of the piston following the upward power stroke, the embodiment illustrated in Figure 2 would probably constitute the preferred form of the invention.

Changes and modifications may be availed of within the spirit and scope of the invention as defined in the hereunto appended claims.

Having described the invention, what is claimed as new is:—

1. In a deep well having a casing, a pump assembly positioned in the casing near the lower end thereof, means for forming a slidable seal between the pump and the casing, cooperating pump supporting means on the pump and on the casing, the pump comprising a cylinder having a foot valve at its lower end, a hollow piston of magnetic material mounted for reciprocation in the cylinder, a one-way valve in the piston, electromagnetic means for reciprocating the piston, and means comprising a switch located outside of the casing for controlling the electromagnetic means.

2. A submersible pump comprising in combination, a cylinder of non-magnetic material, a foot valve in one end thereof, a cylinder of magnetic material surrounding the non-magnetic cylinder, the inside diameter of the magnetic cylinder being greater than the outside diameter of the non-magnetic cylinder whereby an annular space is formed between the two, means for closing the ends of the annular space, a magnet coil positioned in the annular space, rings of magnetic material at each end of the coil, between the end closures and the coil to hold it in position and to form pole pieces, a tubular piston of magnetic material mounted for reciprocation in the non-magnetic cylinder, the piston having a one-way valve opening in the direction of the liquid flow, means for connecting the ends of the cylinders to seal the annular chamber against the entrance of liquid, and means for intermittently energizing the magnet coil.

3. A submersible pump comprising in combination, a cylinder of non-magnetic material, a foot valve in one end thereof, a cylinder of magnetic material surrounding the non-magnetic cylinder, the inside diameter of the magnetic cylinder being greater than the outside diameter of the non-magnetic cylinder, whereby an annular space is formed between the two, means for closing the ends of the annular space, two magnetic coils surrounding the non-magnetic cylinder and longitudinally spaced thereon, a magnetic spacer between the coils, rings of magnetic material positioned between one end of each coil and the adjacent end closure to hold the coils in position and to form pole pieces, a tubular piston of magnetic material mounted for reciprocation in the non-magnetic cylinder, the piston having a one-way valve, opening in the direction of liquid flow, and means for alternately energizing the magnetic coils whereby the piston will be reciprocated.

4. An electro-magnetic pump for deep wells,

comprising in combination, a casing provided at its lower end with an inwardly projecting shoulder, a cylindrical pump-assembly positioned in the casing, means on the outside of the pump-assembly for engaging the shoulder on the casing for limiting the downward movement thereof, means carried by the upper end of the pump-assembly for effecting a seal between it and the casing, the pump-assembly comprising a cylinder of non-magnetic material provided at its lower end with a foot-valve, a hollow piston of magnetic material mounted for reciprocation in the cylinder, the piston having a one-way valve, and means comprising a magnet coil, encircling the cylinder for effecting an upward movement of the piston therein.

5. An electro-magnetic pump for deep wells, comprising in combination, a casing provided at its lower end with an inwardly projecting shoulder, a cylindrical pump-assembly positioned in the casing, means on the outside of the pump-assembly for engaging the shoulder on the casing for limiting the downward movement thereof, means carried by the pump-assembly and located above the shoulder for effecting a seal between it and the casing, the pump-assembly comprising a cylinder of non-magnetic material provided at its lower end with a foot-valve, a hollow piston of magnetic material mounted for reciprocation in the cylinder, the piston having a one-way valve, means comprising two magnetic coils surrounding the cylinder and longitudinally spaced thereon, for effecting a reciprocation of the piston.

6. A pump of the character described, comprising a cylinder, two hollow pistons of magnetic material mounted for reciprocation in the cylinder, a valve in each piston for controlling the passage of fluids therethrough, magnet coils embracing the cylinder adjacent the pistons, means for periodically energizing the coils for imparting a power stroke and a return stroke to the pistons, the valves being automatically closed during the said power stroke and being automatically opened during the return stroke, and means positioned between the pistons, and anchored to the cylinder, forming a stop for the pistons.

7. A pump for crooked wells having a casing, comprising a pump assembly in the casing near the lower end thereof, and provided with means adapted to form a sliding seal with the casing, the pump comprising a cylinder, a hollow piston of magnetic material mounted for reciprocation in the cylinder, a valve in the piston for controlling the passage of fluids therethrough, a magnet coil embracing the cylinder, means for periodically energizing the coil for imparting a power stroke to the piston, the valve being closed by the pressure of liquid during said power stroke, and a flexible element anchored at the surface for suspending the assembly at selective elevations in the casing.

8. A pump for crooked wells having a casing, comprising a pump assembly in the casing near the lower end thereof, and provided with means adapted to form a sliding seal with the casing, the pump comprising a cylinder, a hollow piston of magnetic material mounted for reciprocation in the cylinder, a valve in the piston for controlling the passage of fluids therethrough, a magnet coil embracing the cylinder, means for periodically energizing the coil for imparting a power stroke to the piston, the valve being closed by the pressure of liquid during said power stroke, a flexible element anchored at the surface for suspending the assembly at selective elevations in the casing, and means in the flexible element for establishing an electrical connection between the coil and the energizing means.

9. In a solenoid pump of the character described, a piston adapted for reciprocation as the core of a solenoid and comprising a laminated body formed of soft iron rings terminating at its work-engaging end in an angular recess providing a valve seat, and a butterfly valve cooperating with the seat to control the passage of material through the piston.

10. In a solenoid pump of the character described, a piston adapted for reciprocation as the core of a solenoid and comprising a tubular body of magnetic material terminating at its work-engaging end in an angular recess providing a valve seat, and a butterfly valve cooperating with the seat to control the passage of material through the piston.

11. A pump of the character described, comprising a cylinder, two hollow pistons of magnetic material disposed in separated relation in the cylinder for reciprocation therein, means secured to the cylinder wall and positioned between the pistons, for maintaining the pistons out of contact during reciprocation, a valve in each piston for controlling the passage of fluids therethrough, magnet coils surrounding the cylinder adjacent each piston, and means for periodically energizing the coils for alternately imparting a power stroke to each, the valves being automatically closed during the said power strokes.

12. A pump of the character described, comprising a cylinder, two hollow pistons of magnetic material disposed in separated relation in the cylinder for reciprocation therein, means positioned between the pistons and stationary relative to the cylinder, for maintaining the pistons out of contact during reciprocation, a valve in each piston for controlling the passage of fluids therethrough, magnet coils surrounding the cylinder adjacent each piston, and means for periodically energizing the coils for imparting alternate power strokes to the pistons, the valves of each piston being automatically closed during the power stroke and being automatically opened at the termination of the power stroke.

JOHN G. KEEGAN.