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DOUBLE-ACTING SOLENOID PUMP

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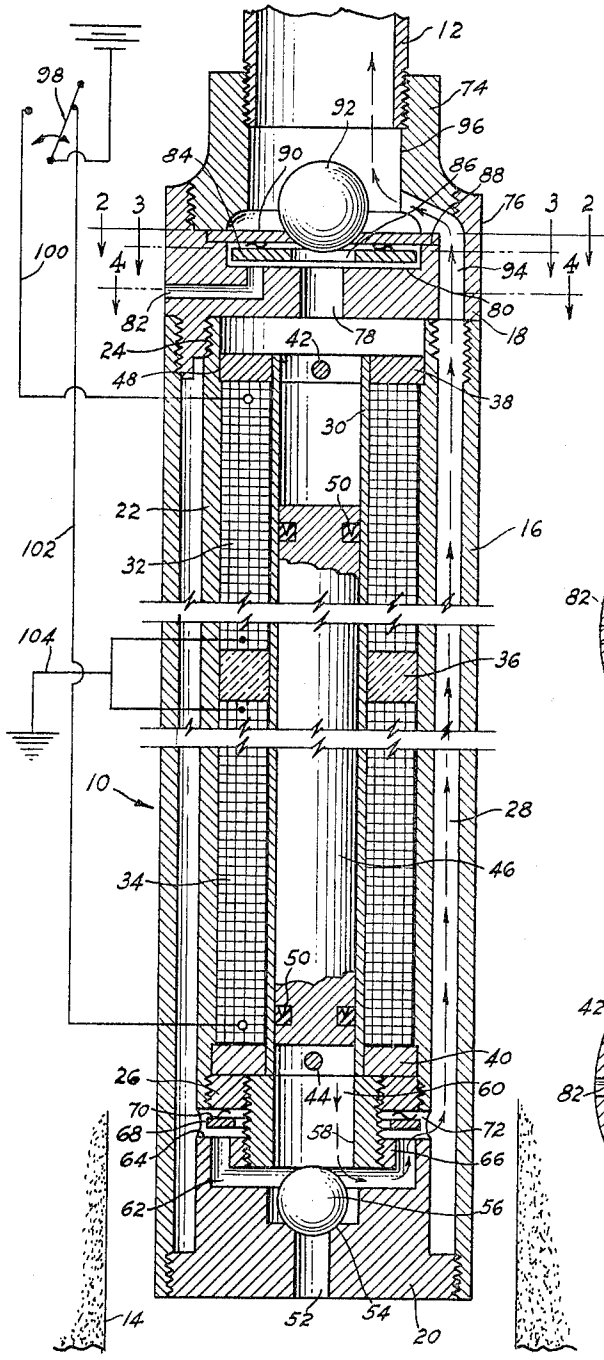


Fig. 1

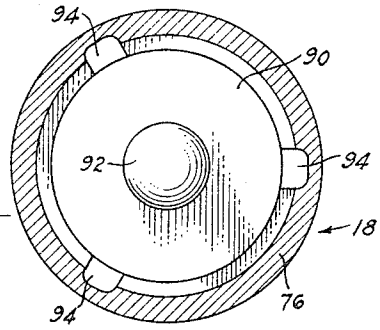


Fig. 2

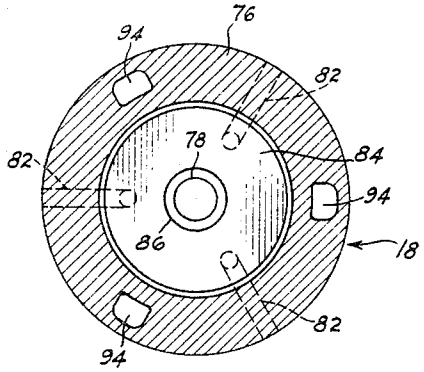


Fig. 3

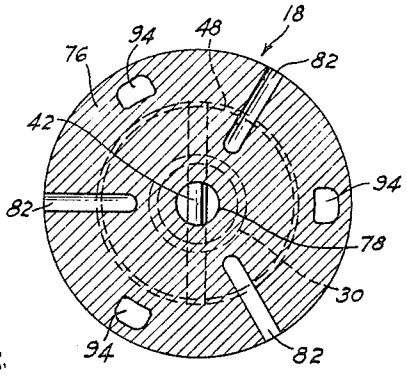


Fig. 4

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DOUBLE-ACTING SOLENOID PUMP

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This invention pertains to a double-acting solenoid pump and, more particularly, to a pump of the type intended to be submerged in a fluid to be pumped thereby into a pipe or similar conduit. A pump of this type is especially adapted for use within a well casing and particularly a casing of substantial depth not very well adapted to the use of well rods to operate bottom valves and the like.

Various types of solenoid-actuated pumps have been devised heretofore but most of these have been of the type effecting the pumping operation when the solenoid is operating only in a single direction. Pumps of this type have been employed for example, as fuel pumps for motor vehicles and the like.

In contrast to such aforementioned solenoid pumps which effect pumping when operating in only one direction, it is the principal object of the present invention to provide a very compact, efficient, and economically operable pump employing a reciprocable armature preferably operated within a pair of longitudinally aligned solenoid coils mounted in fluid-tight manner within a pump housing or casing adapted to be submerged within liquid fluids to be pumped thereby, and particularly fluids in relatively deep wells such as oil wells or the like, the armature within the solenoid serving as a piston within a pump cylinder and pumping being effected by the opposite ends of said piston-armature during both directions of reciprocable movement thereof within the pump cylinder.

Another object of the invention is to provide a relatively simple, preferably cylindrical outer housing having heads in opposite ends thereof, said heads each being provided with both inlet and discharge valves which are cooperable to effect unidirectional flow of fluid from a single discharge port in said pump housing.

A further object of the invention is to provide such pump housing with fluid inlet ports respectively adjacent the opposite ends thereof to implement the intake of fluid by said pump and said aforementioned valve structures are such as to accommodate the inlet of fluid to the pump housing at said opposite ends thereof while providing for only a single discharge port from said pump housing.

Still another object of the invention is to provide relatively simple types of check-type valves in the opposite end portions of the pump housing, said valves preferably being arranged so that the movable members of each may be actuated by gravity to move to the valve seats of each valve and thereby close the same.

A still further object of the invention is to provide, in the preferred construction of the double-acting solenoid pump comprising the same, a design which permits formation of a number of the essential housing members and pump cylinder from standard types of tubing or pipe stock, only simple threading operations being required to permit assembly of said members with housings and the like otherwise included in the pump construction.

Details of the foregoing objects and of the invention, as well as other objects thereof, are set forth in the following specification and illustration in the accompanying drawing comprising a part thereof.

In the drawing:

FIG. 1 is a vertical sectional view of a pump embodying the principles of the present invention and connected to a fragmentarily illustrated lower end portion of a well tube or pipe, the pump being shown as being disposed within a fragmentarily illustrated portion of a well casing or bore hole.

FIG. 2 is a transverse sectional view of the pump taken on the line 2—2 of FIG. 1.

FIG. 3 is a transverse sectional view taken on the line 3—3 of FIG. 1.

FIG. 4 is a transverse sectional view taken on the line 4—4 of FIG. 1.

Referring particularly to FIG. 1, it will be seen that the pump **10**, which embodies the preferred constructions and details of the present invention, is illustrated as being connected to the lower end of a fragmentarily illustrated well tube or pipe **12** so as to depend therefrom and receive fluid discharged from said pump at the upper end thereof into said well tube **12**. FIG. 1 also illustrates the pump **10** being disposed substantially longitudinally within a well casing or bore hole **14** which is only fragmentarily illustrated. It is to be understood however that, although the construction and proportions of the design are well adapted to the pump being accommodated within a well casing or bore hole, the pump may be employed in any other volumes of fluids which are to be pumped such as those contained in tanks, natural formations or the like. Also, while the design of the pump readily lends itself to pumping petroleum and similar products from wells of substantial depth, the structure of the pump is actually such as to adapt it to pump fluids of various other types but preferably those which are liquid.

The pump **10** comprises a preferably cylindrical outer housing **16** which may be formed from conventional pipe or tube stock, the opposite ends of which are preferably internally threaded respectively to receive complementarily threaded portions of upper head **18** and lower head **20** of the pump to connect the same detachably to said outer housing. Extending coaxially within the outer housing **16** is an inner housing **22** which also may be formed from conventional tube or pipe stock and is externally threaded, for example, at the upper end thereof, to be received within and connected to the inner cavity **24** within upper housing **18**, while the lower end of the inner housing **22** preferably is internally threaded to receive an annular locking collar **26** which also is internally threaded for purposes to be described. The inner housing **22**, while concentric with outer housing **16**, is of smaller outer diameter than the inner diameter of outer housing **16**, thereby providing an annular fluid-conducting space **28** between the two housings.

A pump cylinder **30** is concentrically mounted within the inner housing **22** so as preferably to be exactly coaxial therewith and thereby provide a longitudinally extending annular space therebetween to accommodate preferably a pair of solenoid coils **32** and **34** which, if desired, may have an annular insulating member **36** mounted therebetween and also surrounding the pump cylinder **30**. The solenoid coils **32** and **34** preferably closely surround the pump cylinder **30** and otherwise are compactly disposed within inner housing **22** to render the entire construction of the pump as compact as possible.

So as to contain the solenoid coils **32** and **34** in fluid-tight condition within the interior of the pump **10**, annular sealing members **38** and **40**, which preferably are formed from insulating material, are mounted in tight engagement respectively with the inner housing **22** adja-

cent opposite ends thereof, and the opposite ends of the pump cylinder **30**. Any desired type of connection between the sealing members and such pump cylinder and inner housing may be used which will be disposed adjacent the opposite ends of the assembled pair of solenoid coils **32** and **34** and maintain the same in fluid-tight condition. Expansible-type packing material is suitable for this purpose and may be maintained against movement with respect to pump cylinder **30** by means of diametrically extending cross-pins **42** and **44** which also are projected across the interior of pump cylinder **30** for the additional purposes of serving as upper and lower stops to limit the reciprocable movement of the combination armature and pump piston **46** within the pump cylinder **30**. The outer perimeter of the sealing members **38** and **40** preferably are tightly disposed within seats **48** and **50** extending inward from opposite ends of the inner housing **22**.

The combination armature and pump piston **46** preferably freely reciprocates within the pump cylinder **30**, in opposite axial directions, when the solenoid coils **32** and **34** are energized successively by means to be described. The opposite ends of the armature-piston **46** preferably are imperforate and, in the most desired design of the pump, the armature-piston is of a solid, ferrous construction. However, annular packing ends **50** of suitable, conventional type are provided around the same adjacent opposite ends thereof for slidable engagement with the inner walls of the pump cylinder **30** and thereby provide efficient pumping of fluids in opposite ends of the pump cylinder **30** without undue leakage past the ends of the armature-piston **46**.

The lower head **20** has a preferably central inlet opening **52** therein which is concentric with a valve seat **54** which accommodates a movable valve ball **56** to comprise a check valve. A short, externally threaded sleeve **58** is threaded into locking collar **26** for support thereby and the interior of said sleeve comprises a passageway **60** between the interior of pump cylinder **30** and inlet opening **52**, all of the same being coaxial. The sleeve **58** also provides a space compactly accommodating valve ball **56** when the lower central valve comprising said ball and valve seat **54** is open for the inlet of fluid to the lower end of the pump **10**. However, upward movement of the valve ball **56** is limited by cross-pin **44** and, due to the size and weight of valve ball **56**, it will quickly move, by gravity, as well as fluid pressure, against valve seat **54** when closing of the valve is to occur.

The lower head **20** also is provided with discharge valve means comprising an inner circular cavity **62** which is directly above and communicates with the valve seat **54** and extends upward to an upper valve seat **64**. A seat ring **66** also may be threaded upon the lower end of the short sleeve **58** and thereby comprise a composite upper valve seat **64** against which a movable discharge valve member **68**, comprising a flat, annular ring of suitable material, may abut when the valve is to be closed. To facilitate such closing, light spring means **70** may be employed between the valve member **68** and the lower surface of locking collar **26**, for example, to insure that valve member **68** will be at least lightly biased toward closing position under operating conditions to be described. Discharge passage means **72** communicate with the valve seat **64** to permit the flow of fluid from inlet opening **52**, past the valve seats **54** and **64**, and into the annular longitudinally extending space **28** within the outer housing **16**.

The upper head **18**, for convenience of construction and assembly, actually comprises an upper collar **74** which is threadably connected into the upper end of a head body **76**. The upper end of the collar **74** is internally threaded to be connected detachably to the threaded lower end of well tube **12**. The head body **76** has a preferably central opening **78** which is coaxial with the pump cylinder **30** and armature-piston **46** so as to communicate directly therewith. The opening **78** extends into a shallow circular seat **80** comprising part of inlet valve means which also include a plurality of valve inlet passages **82** which extend radially inward from the exterior of the pump and terminate in upwardly extending discharge ends which intersect the valve seat **80** against which the annular, flat movable valve member **84** abuts when the valve is in closed condition. The central opening **86** of said inlet valve member preferably is coaxial with opening **78**.

The head body **76** also is provided with another circular, shallow seat **88** which receives a flat, circular valve seat member **90** comprising part of the discharge valve of upper head **18**, the movable valve member of which comprises a ball **92** which coacts with the valve seat **90** to comprise a check valve.

The fluid discharge passages **94** are formed within the upper head **18** at circumferentally spaced locations. As best shown in FIG. 1 and especially in FIG. 2, these passages extend in an axial direction upwardly from the lower ends of the head **20** and then extend inwardly toward the central discharge opening **96** of the upper head **18**.

Any suitable, relatively simple electric circuit may be employed to operate the solenoids **32** and **34** in sequence or as to energize them and deenergize them in succession at a rate selective in accordance with the power requirements of the pump which, in turn, is designed to effect a unidirectional flow of fluid through the well tube **12** in accordance with the depth of the well, for example, the viscosity of the fluid, the frictional characteristics of the pump elements and various other factors commonly found in pump operations. To accomplish the reciprocation of the combination armature-piston **46** at any such designed and selected cycle or rate of operation, relatively simple control means may be employed such as a preferably quick-acting single-pole, double-throw switch **98**, the poles of which respectively are connected to the upper end, for example, of solenoid coil **32** by means of conduit **100**, while the lower end of solenoid **34**, for example, is connected to the opposite pole of the switch **98** by means of conduit **102**. The lower end of the upper solenoid coil **32** and the upper end of lower solenoid coil **34** may be grounded commonly by conduit **104**. Direct current preferably is employed to energize the solenoid coils **32** and **34**. The preferably quick shifting of the movable member of switch **98** between the poles thereof, at a desired cycling rate, can be performed by any suitable mechanism such as a continuously driven, variable speed electric motor of relatively low power rating, or the like.

Operation of the pump

Following the submersion of the pump **10** into a body of fluid, preferably liquid, such as might be contained in a well casing, bore hole **14** or the like, the cycling operation of the switch **98** is instituted. Upon energizing the upper solenoid coil **32** for example, the armature-piston **46** quickly moves upwardly. The suction created by the lower end of said armature-piston causes inlet valve ball **56** to open relative to inlet opening **52** to permit fluid to be drawn therethrough into the cavity **62** and interior of pump cylinder **30**. Immediately upon the generation of such suction by the armature-piston **46**, discharge valve **68** of the lower head **20** is closed against seat **64**, thereby preventing any fluid within space **28** from escaping from the lower end thereof. Upward movement of the armature-piston **46** is terminated when the upper end of the same engages the stop pin **42**. Such upward movement of the armature-piston moves before it fluid which has been drawn into the upper end of the pump cylinder **30** through the inlet passages **82** of upper head **18** by means to be described. Such upward movement of the fluid in the upper end of pump cylinder **30** immediately forces discharge valve member **92** from the seat **90** and the pres-

sure of such fluid operates against the upper surface of inlet valve member **84** to prevent escape of fluid through the inlet passages **82**.

Immediately upon the armature-piston **46** reaching its upward limit of movement, the switch member **98** again moves quickly in cycling manner to de-energize the upper solenoid coil **32** and quickly energize the lower solenoid coil **34** to effect downward movement of armature-piston **46**. Such downward movement causes suction at the upper end of the armature-piston which immediately causes closing of the discharge valve ball **92** against its seat **90** and said suction also immediately draws in fluid through the inlet passages **82** past the inlet valve **84** which also is opened by such suction, whereby a charge of fluid is drawn immediately into the upper end of pump cylinder.

Such downward movement of the armature-piston **46**, at the lower end thereof, directs fluid pressure immediately against the inlet valve ball **56** which forces it against its seat **54** and the fluid previously drawn into the lower end of the pump cylinder **30** during the upward movement of armature-piston **46** now is forced through the passageway **60** and through the discharge valve **64**, **66** into the annular longitudinally extending space **28** between the inner and outer housings for discharge at the upper end thereof into the circumferentially spaced fluid discharge passages **94** for delivery to the lower end of well tube **12**. Such movement of fluid continues until the lower end of the armature-piston **46** reaches the full extent of its downward movement by engagement with stop pin **44**, whereupon the switch **98** once more quickly shifts in cycling manner to deenergize the lower solenoid coil **34** and energize the upper solenoid coil **32**, whereupon the above-described cycle repeats itself and so on continuously as long as pumping is to be accomplished.

From the foregoing, it will be seen that the pump comprising the present invention constitutes a very compact, efficient, and effective as well as powerful type of double-acting pump, the piston of which is operated by a pair of suitable solenoid coils which are maintained in fluid-tight condition, whereby the pump may be operated by immersion thereof directly in the fluid to be pumped, such as in a well casing. In particular, it will be seen that through the use of fluid-proof type electrical conduits, pumps of the type described above and hereinafter claimed may be employed in wells of substantial depths and operated effectively and efficiently with minimum consumption of power and without requiring foot valves in the well tube or pipe unless desired. Such pump arrangement and operation also eliminates any need for well rods to operate pump pistons and the like and, even more particularly, the employment of the particular type of solenoid-operated pump precludes the need for expensive types of conventional electric motors sometimes employed in submerged pumps but in connection with which unusual and expensive precautions must be taken to maintain said pumps out of contact with any fluid.

While the invention has been described and illustrated in its several preferred embodiments, it should be understood that the invention is not to be limited to the precise details herein illustrated and described since the same may be carried out in other ways falling within the scope of the invention as claimed.

We claim:

1. A double-acting solenoid pump for immersion in fluid to be pumped and comprising an imperforate uninterrupted cylinder, a solid cylindrical ferrous double-acting piston having imperforate opposed end faces and reciprocable freely within said cylinder, said piston comprising a solenoid armature, a pair of solenoid coils surrounding the exterior surface of at least the opposite ends of said cylinder for support thereby and separated from each other by insulating means surrounding the intermediate portion of said cylinder, an imperforate inner cylindrical housing extending between and enclosing said coils, said housing being coaxial with said cylinder, and the opposite ends extending beyond the ends of said cylinder a limited distance, an outer cylindrical housing surrounding said inner housing in radially spaced relationship and coaxial therewith, upper and lower heads threadably connected to the respective upper and lower ends of said inner and outer housings to connect the same in assembled operative position, said heads being no greater in diameter than said outer housing, discharge port means in said upper head connectable to a fluid line arranged to receive fluid therefrom for unidirectional flow, inlet ports in both of said heads communicating with the exterior of said pump, valve means and passageways in said heads operable sequentially to control and direct the flow of fluid successively inwardly from the inlet ports in said heads for sequential flow into the opposite ends of said chamber by reciprocation of said piston therein and said check valves functioning at the completion of reciprocation of said piston in one direction to close and discontinue flow sequentially through said inlet ports and permit discharge of fluid from said discharge port in said upper head, an electric circuit connected to said solenoid coils and connectable to a source of current, and switch means in said circuit operable at a predetermined rate sequentially to energize and deenergize said coils to effect free reciprocation of said piston-armature in opposite directions within said cylinder to effect substantially constant delivery of fluid through said discharge means in said upper head.

2. The pump according to claim **1** in which said lower head has outlet means communicating with the lower end of the space between said outer and inner housings and said outlet means are operable upon movement of said piston toward said lower head to pass fluid into said space for transmission to said upper head and through said discharge port therein.

3. The pump according to claim **1** in which said check valves in said upper and lower heads comprise a ball-type and a ring-type in each head and coaxially mounted with respect to eath other, one of said check valves in each head normally closing the inlet means therein while the other valve is open relative to the outlet means and vice versa respectively upon reversal of the movement of the piston in the pump cylinder.

4. The pump according to claim **1** in which both heads have substantially central bores having ball seats and receiving movable balls comprising one of said check valves in each head, and ports radially displaced from the central axis of each head terminating in valve openings and movably engageable by circular valve members freely movable toward and from the same to comprise a second check valve in each head, said check valves being arranged to open and close oppositely to each other in each head.

5. The pump according to claim **1** in which said lower head has an inlet port substantially centrally of the lower end thereof communicating with the exterior of said pump, a ball check valve operable relative to the upper end thereof, radially directed outlet port means in the upper portion of said lower head communicating with said space between said inner and outer housings, a circular check valve operable relative to said outlet port means; and said upper head having an inlet port extending upwardly substantially centrally from the lower end thereof to receive fluid from the upper end of said pump cylinder, radially directed inlet ports extending inwardly from the periphery of said upper head to receive fluid from the exterior of said pump but terminating in spaced relation to said central inlet port, circular check valve means movable relative to the inner ends of said radial inlet ports, a ball seat above said circular check valve and aligned with said central inlet port, and a ball check valve movable relative to said ball seat and arranged to be moved from closed position upon said ball seat when said circular valve is closed to permit the flow of fluid from the upper end of said pump cylinder through the center of said circular valve when the latter is in said closed position.

6. The pump according to claim 5 in which said radially directed outlet ports in said lower head communicate with the lower end of said pump cylinder and said circular check valve is movable to close said ports when said piston is ascending and said ball check valve in said lower head is opened by the suction produced by such movement of said piston.

7. The pump according to claim 5 in which said upper head has passages extending upwardly therethrough in circumferentially spaced locations adjacent the outer surface thereof and communicating at the lower ends thereof with the upper end of said space between said inner and outer housings for transmission of fluid pumped by the lower end of said piston, said passages being spaced between said radially directed inlet ports in said upper head and being open at all times for such transmission of fluid from said space between said housings to said discharge port means in said upper head.

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