

July 21, 1970

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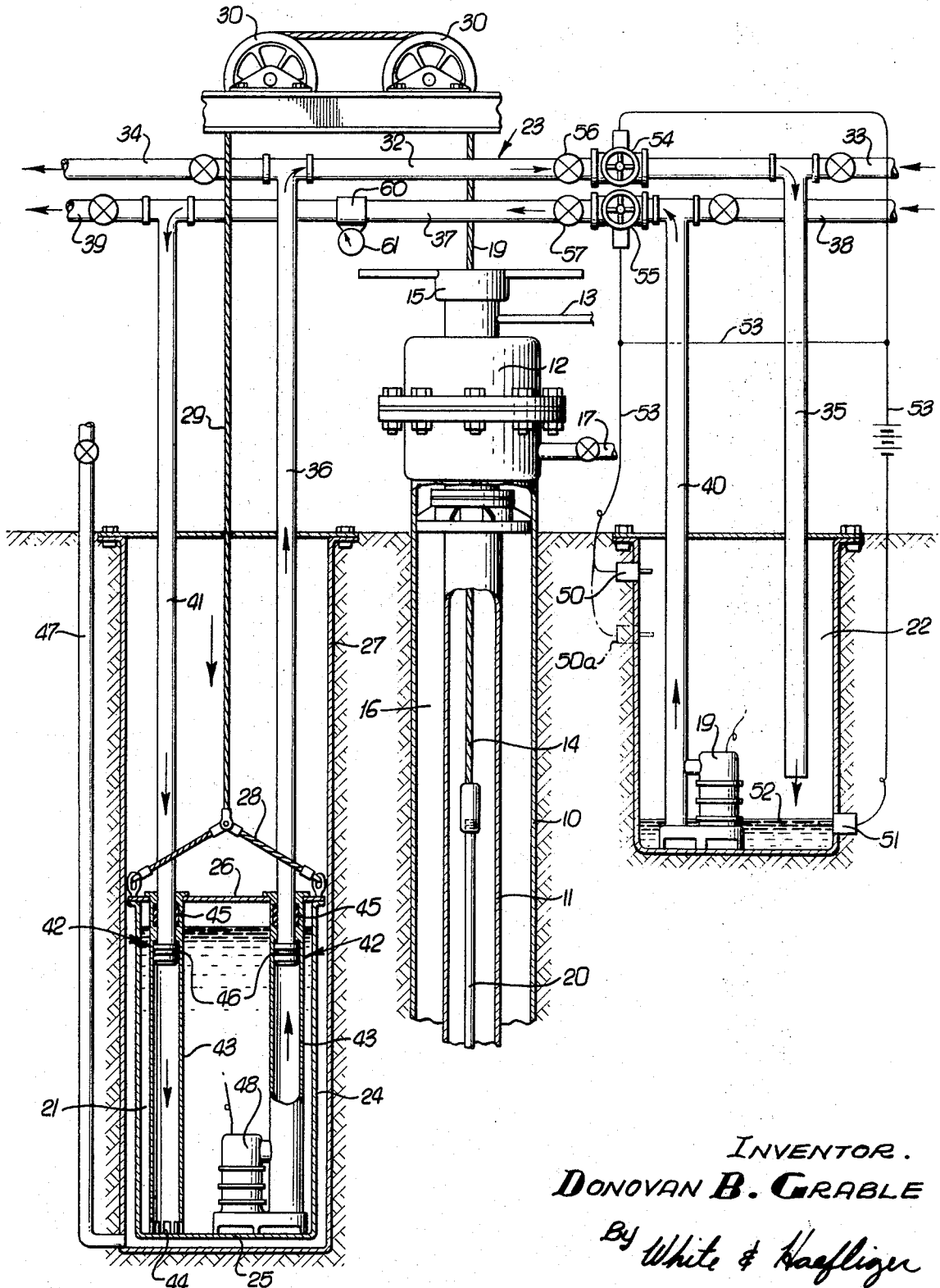
3,521,445

WELL PUMPING SYSTEM

Filed Aug. 15, 1968

2 Sheets-Sheet 1

FIG. 1.



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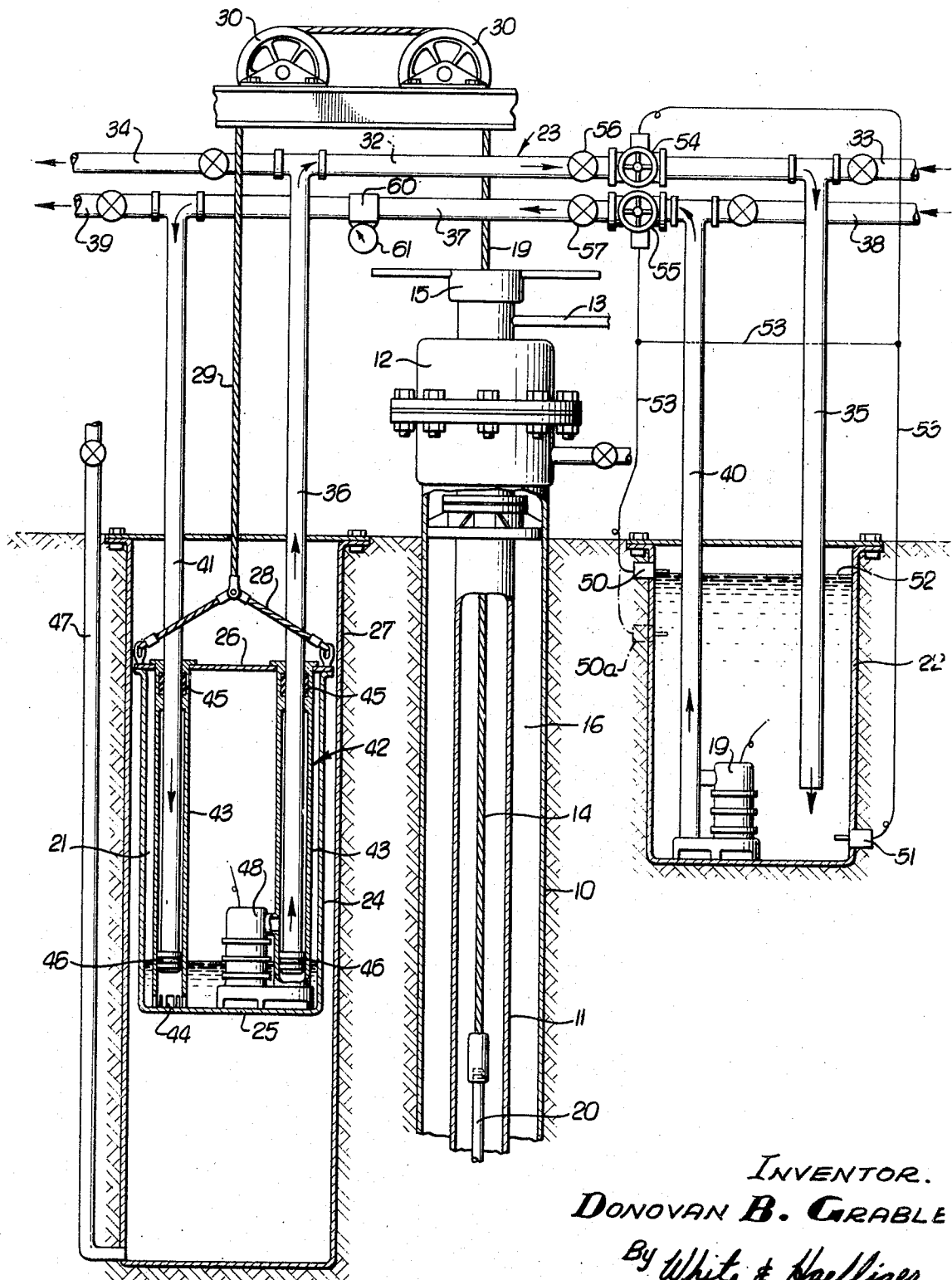
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2 Sheets-Sheet 2

FIG. 2.



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WELL PUMPING SYSTEM

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Filed Aug. 15, 1968, Ser. No. 752,886

Int. Cl. F04b 17/00, 47/00

U.S. Cl. 60—22.1

15 Claims

ABSTRACT OF THE DISCLOSURE

The invention achieves long stroke pumping of wells by powering the operating string of a well pump by a traveling tube forming a chamber vertically reciprocable within an earth bore at one side of the well, the tube chamber being connected by conduit means with a reservoir chamber, and pumps being provided within the chambers to alternately displace water through the conduit means to water-load the traveling tube chamber for elevation of the well pump and to release water therefrom to lower the well pump.

BACKGROUND OF THE INVENTION

Oil wells are conventionally pumped by vertically reciprocated plunger-type pumps stroked by rod connections with various types of mechanisms operating at the ground surface usually to stroke the pump in relatively shorter travel ranges and at correspondingly higher frequencies.

Under many pumping conditions, as in low production wells, its found desirable for various reasons including increased operating efficiencies and economies, to be able to greatly increase the well pump stroke at reduced stroking frequencies beyond the capabilities of conventional power mechanisms, or the practicabilities of their accommodation at the ground surface.

Benefits of extended stroking of the well pump may result, for example, from more efficient utilization of the range and rate of the pump displacement in relation to the rate of well liquid availability to the pump, power savings in minimizing non-production in relation to pumping energy expenditures, as well as equipment wear and maintenance costs attributable to less efficient stroking of the pump.

Of increasing concern in the industry are possibilities for greater safeties in the operation of ground surface pumping equipment which has continued to present hazards and at times serious injury to personnel by reason of both the nature and exposure of the equipment. Related have been continuing problems resulting from equipment wear, particularly of pump rods subject to failure through abrasions in reciprocating engagements with the well casing, as well as accompanying excessive wear of conventional rod actuating cable.

Involved also in conventional well pumping operations has been the necessity for periodic determinations of well liquid levels by special service facilities and at considerable and desirably avoidable expense.

GENERALITIES AND OBJECTS OF THE INVENTION

The present invention has for one of its general objects to improve well pump operation with respect to pumping efficiencies and greater economics in equipment and operating costs, as well as to assure heretofore unattainable safeties, by underground accommodation of pumping power equipment.

In realization of this object the invention employs the concept of a pair of chambers, one at least of which is contained in an earth bore at one side of the well and

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is formed by a water (or other liquid) loadable tube connected to the well pump and having in the earth bore a range of vertical travel sufficient to stroke the pump within ranges that may be greatly in excess of those conventionally attainable. Used in conjunction with the traveling tube chamber and in conduit communication therewith is a reservoir chamber, which may also be underground, and means for alternately pumping water to and from the chambers. By predetermination, the effective weight of the water-loaded traveling tube and any associated traveling parts is made to exceed the well pump load, including that of the pump operating string and pumped fluid column, so that the pump is operated throughout its production stroke by gravity fall of the traveling tube.

Provision is made for automatic control of the traveling tube to stroke the well pump, by displacing water from the traveling tube chamber to the reservoir chamber at the end of the pump production stroke, and continuing such displacement so that the pump load exceeds that of the water-depleted traveling tube and the pump is thus caused to travel its down stroke.

An important and distinctive accomplishment of the invention is its inherent capacity, as later explained, to indicate and in effect measure the well liquid level however it may vary, by correlation with water displacement from one to the other of the traveling tube and reservoir chambers, all in a manner obviating the necessity for interruption of the pumping operation or for the employment of special level determination services.

Among more particular features and objects of the invention is the provision for automatic valvular control in the chamber intercommunication for automatically reversing the water displacements between the chamber at the ends of the well pump strokes, all in a manner consistent with most efficient control of the stroke frequencies and rate of travel.

The invention further contemplates inter-chamber water displacements by self-priming pumps contained in the chambers and of types capable of constant running in a manner to be responsive for both pumping out of the chambers and permitting pumped inflows thereto.

The invention has various additional features and objects, all of which together with those outlined in the foregoing will be understood from the following detailed description of illustrative embodiments of the invention shown by the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the pumping system as it appears at the end of the well pump up-stroke and down-travel of the water-loaded chamber; and

FIG. 2 is a similar illustration of the system at the end of the well pump down-stroke and up-stroke of the traveling chamber.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The drawings illustrate diagrammatically a typical pumping oil well having the usual casing 10 and production tubing 11 extending up through the casing head 12, the bottom of the tubing (not shown) carrying or being connected to a pump of the reciprocating type and having a plunger, piston or swab operating to pump the well liquid to the tubing production outlet 13 at the ground surface. The pump is stroked by what may be termed the operating string 14 connected to the pump plunger, piston or swab and extending up through a conventional stuffing box 15 to the later described power source.

Related to the operation of the invention are certain known conditions in the well. The pump takes fluid

from what is termed the well fluid column occupying the annular space 16 about the tubing and variable in height, depending upon the productive capacity of the well, from the pump location to the height of the conventional casing outlet 17. By conventional calculations and determinations, the height, volume and weight of the well fluid column are measurable and in practice periodic well liquid level measurements are made because of their relation to such factors as rates of production flow into the well and hydrostatic column pressures, all of which relate to the pumping operation as is understood by those familiar with the art.

The production column in tubing 11 to the outlet 13 also is measurable in terms of volume and weight, as is also what may be termed the pumping load which is the combined weights of the pumping column and the pump operating string 14 below its location of support or suspension at the ground surface. In reference to the pumping string, the latter may consist of a cable or wire rope 19 extending through the stuffing box 15 and connected to a usual sucker rod string 20, or in the environment of the present invention and because of operating characteristics later described, the entire operating string may consist of cable or wire rope connected to either a pump plunger or a swab operating within the tubing.

From the foregoing it will be understood that operation of the well pump requires for its production or up-stroke, application of power sufficient to elevate the production column throughout the range of the pump stroke and in so doing to overcome the pump load, i.e. the combined weights of the production column and pump string, and that by lifting power reduction or release the pump is permitted gravity return on its down stroke. The pumping in effect being assisted and influenced in its power requirements by the weight of the well fluid column, it is desirable that facilities be available for consistent determination of the column weight.

Continuing now with reference to features more directly concerning the invention, the pumping system employs a pair of chambers 21 and 22 from one to the other of which water is alternately pumped through intercommunicating conduit means generally indicated at 23. Chamber 21 may be formed practicably by a section of well casing which forms what may be termed a traveling tube 24 having a bottom closure 25 and removable top closure 26. This traveling tube is accommodated for vertical movement within the casing 27 of a bore drilled in the earth at one side of the pumping well bore and to a depth sufficient to permit maximum chamber travel corresponding to selected ranges for stroking of the well pump. As previously indicated, the invention has been conceived primarily, though not necessarily, for the pumping of low production wells at abnormally long range, relatively low frequency pumping strokes. As illustrative, the depth of the casing 27 may be sufficient to accommodate travel of chamber 24 within a range up to around 60 feet, and in a specific instance the chamber travel may be about 40 feet with the pump cycled at a frequency of about one minute or less.

Chamber 24 is suitably connected as by wire rope 28 with the pumping string cable 29 which passes over sheaves 30 and downwardly within the tubing 11 so that except for elongations and contractions of the pumping string due to variations in the pumping load, the traveling chamber and pump plunger or swab have corresponding travel.

The second chamber 22 serves as a water reservoir, and while it may be located above or below ground level, the latter is preferred in the interests of reducing above-ground equipment. Thus, like the cased hole 27, the reservoir 22 may be formed by a section of closed bottom well casing having dimensions sufficient to accommodate the full volume of water displacement between the chambers. At this point it may be mentioned that the described chamber accommodations within the earth con-

tribute considerably to minimized equipment costs and to desirable isolation of the reservoir portions of the equipment from unnecessary and perhaps troublesome surface exposure.

In broad aspects of the invention the conduit means 23 may permit of different variations capable of water transmission between the reservoirs and of accommodating controls to automatically govern the pumping operation. Merely as illustrative, the conduit means is shown to comprise a pipe 32 equipped with a valved make-up water inlet 33 and valved excess water outlet 34, the pipe having a branch 35 extending into the reservoir chamber 22, and a second branch 36 extending down into the traveling reservoir 24. A second pipe 37 which may also have valved inlet and outlet lines 38 and 39 corresponding to 33 and 34, includes branches 40 and 41 extending respectively into the reservoirs 22 and 24. To accommodate travel of chamber 24, the pipes 36 and 41 are in fluid communication with the chamber through telescopic connections generally indicated at 42 and which may be of a circulation joint type. Each of the connections 42 is shown to comprise a tubular section 43 having bottom porting at 44 and mounted to the chamber head 26 to receive the stationary pipe terminal passing through packing 45 and carrying a suitable arrangement of seal rings 46. By the connections 42 the chamber is permitted its vertical travel while receiving or expelling fluid through the sealed stationary pipe connections.

From time to time it may be necessary to remove dirt and foreign accumulations from the bottom of the casing 27, for which purpose I provide a clean out line 47 through which water may be circulated into or out of the casing.

While the invention is susceptible to different pumping means and arrangements for alternating transference of water from one to the other of the reservoirs, I preferably provide within the chambers self-priming electrically driven pumps 48 and 49, the former taking suction from within the traveling chamber and discharging into pipe 36; pump 49 taking suction from within chamber 22 and discharging into pipe 40. As a further preference, these pumps are of a type, e.g. centrifugal, which permit constant running, with one pump displacing through its pipe connection and the other pump operating in effect with slippage to accommodate water in-flow to the second reservoir. The pumps require comparatively little horsepower for their operation and can beneficially be left consistently running, particularly because of their immediacy of water output.

The pumping system provides also for automatic control of the rate and frequency at which the well pump is to be cycled, and while any of various specific types of operative controls may be employed, I show as illustrative, a control arrangement of upper and lower liquid level sensors 50 and 51 of known types capable of response to arrival of the reservoir liquid level 52 at its upper and lower limits corresponding to the sensor locations, to energize through suitable circuitry 53 a pair of motor driven valves 54 and 55 in lines 32 and 37. In general, pump displacement of water from the reservoir chamber of the water volume between the liquid level extremes, determines the water loading to be added to traveling chamber 24 to up-stroke the well pump. For variation of the pump stroke, and particularly its rate of travel, the position of the sensor 50 may be varied as to a lower level indicated by the broken lines 50a. The return of pump cycling may be further varied by different degrees of throttling of the line 32 and 37 water streams, for which purpose manually operated valves 56 and 57 may be provided.

In considering the operation of the system, it will be recognized that the total traveling chamber load must exceed the total well pumping load, and that the quantity or control of such excess may determine the well pump cycle return and frequency. In reference to FIG. 1, it may

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be assumed that chamber 24 has reached bottom position after receiving the maximum water displacement through pipes 37, 40 and 41 from the reservoir 22, during which time valve 55 has remained open and valve 54 closed. Upon lowering of the liquid level in the reservoir to the FIG. 1 position, the sensor 51 opens valve 55 and closes valve 54 so that the traveling pump 48 commences its displacement of water from chamber 24 through pipes 36, 32 and 35 into the reservoir with progressive reduction of the traveling load so that it becomes less than the well pump load and permits down-stroking of the well pump. Such displacement continues until the reservoir water level rises to the sensor 50, whereupon the open and closed conditions of valves 54 and 55, as well as the inter-chamber water displacement are reversed to progressively fill the traveling chamber until it overcomes the well pumping load to power the well pump throughout its up-stroke.

Reference previously has been had to the desirability for measuring the well fluid column in the annulus 16 by means within the pumping system itself. Recognizing that the height or weight of the well fluid column has an inverse relation to the pumping power requirement, the fluid column assist to the pump has a measurable relation to the quantity of water required to be displaced from the reservoir to the traveling chamber for powering of the well pump throughout its production stroke. Therefore, the determination may be made by correlation between single well pump stroke water displacement from the reservoir to the traveling chamber, and power load variations which reduce or increase according to the well fluid column level which is determinable by calculation, knowing the pump depth, volume of the annulus 16 and the well fluid density. Using this correlation with measurable displacement volume and the known chamber water density, it becomes possible to calibrate a water measurement means such as meter 60 in line 37 and which may operate in conjunction with a chart recorder 61 to show on the latter, by weight, volume or surface level location of the well fluid column.

As will be apparent without necessity for further illustration, it is possible following the structural and operating aspects of the invention as described, to adapt single traveling and reservoir chambers and facilities to the pumping of multiple wells being stroked correspondingly in response to a traveling chamber loading sufficiently to power multiple well pumps.

I claim:

1. A system for pumping a cased well containing a vertically reciprocable pump connected to an operating string extending above the casing, comprising a traveling tube forming a chamber vertically reciprocable within an earth bore at one side of the well and having a cable connection with the pump operating string, a water reservoir chamber, conduit means interconnecting said chambers, and pumping means operable to displace water alternately through said conduit means into and out of said chambers to water-load the traveling tube chamber for elevation of the well pump and to release water therefrom to lower the well pump.

2. A system according to claim 1, in which said earth

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bore has a cased extent in which said traveling tube is reciprocable within a range of about 10 to 60 feet.

3. A system according to claim 1, in which said traveling tube is a vertically extended pipe connected to said conduit means and containing a pump included in said pumping means.

4. A system according to claim 1, in which said reservoir chamber is within a second earth bore.

5. A system according to claim 1, in which said pumping means comprises a continuously operating water pump within one of said chambers.

6. A system according to claim 1, in which said pumping means comprises water pumps within both of said chambers.

7. A system according to claim 1, in which said conduit means comprises a pair of chamber-interconnecting pipes, and valve means for controlling water flow through the conduit means.

8. A system according to claim 1, in which said conduit means comprises a relatively stationary pipe extending into and through the top of said traveling tube.

9. A system according to claim 8, in which the traveling tube contains a tube telescopically receiving the lower extent of said pipe.

10. A system according to claim 1, in which said conduit means includes a pair of relatively stationary pipes extending downwardly into said traveling tubes, a pair of tubes therein telescopically receiving the lower extents of said pipes and having sliding seal engagements therewith, and a flexible cable connecting the traveling tube with said well pump string.

11. A system according to claim 10, including a pump within one of said chambers and operable to pump water through said conduit means.

12. A system according to claim 11, including pumps within said chambers continuously operable to pump water through said conduit means, and valve means for controlling water flow through the conduit means.

13. A system according to claim 1, including liquid level responsive means in one of said chambers operable to alternate the water flow, from one to the other of the chambers through said conduit means.

14. A system according to claim 1, including means for measuring and correlating the well liquid column being pumped with water displaced from one to the other of said chambers.

15. A system according to claim 14, in which said measuring means includes a meter which measures water flow through said conduit means.

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U.S. Cl. X.R.

415—24; 417—329