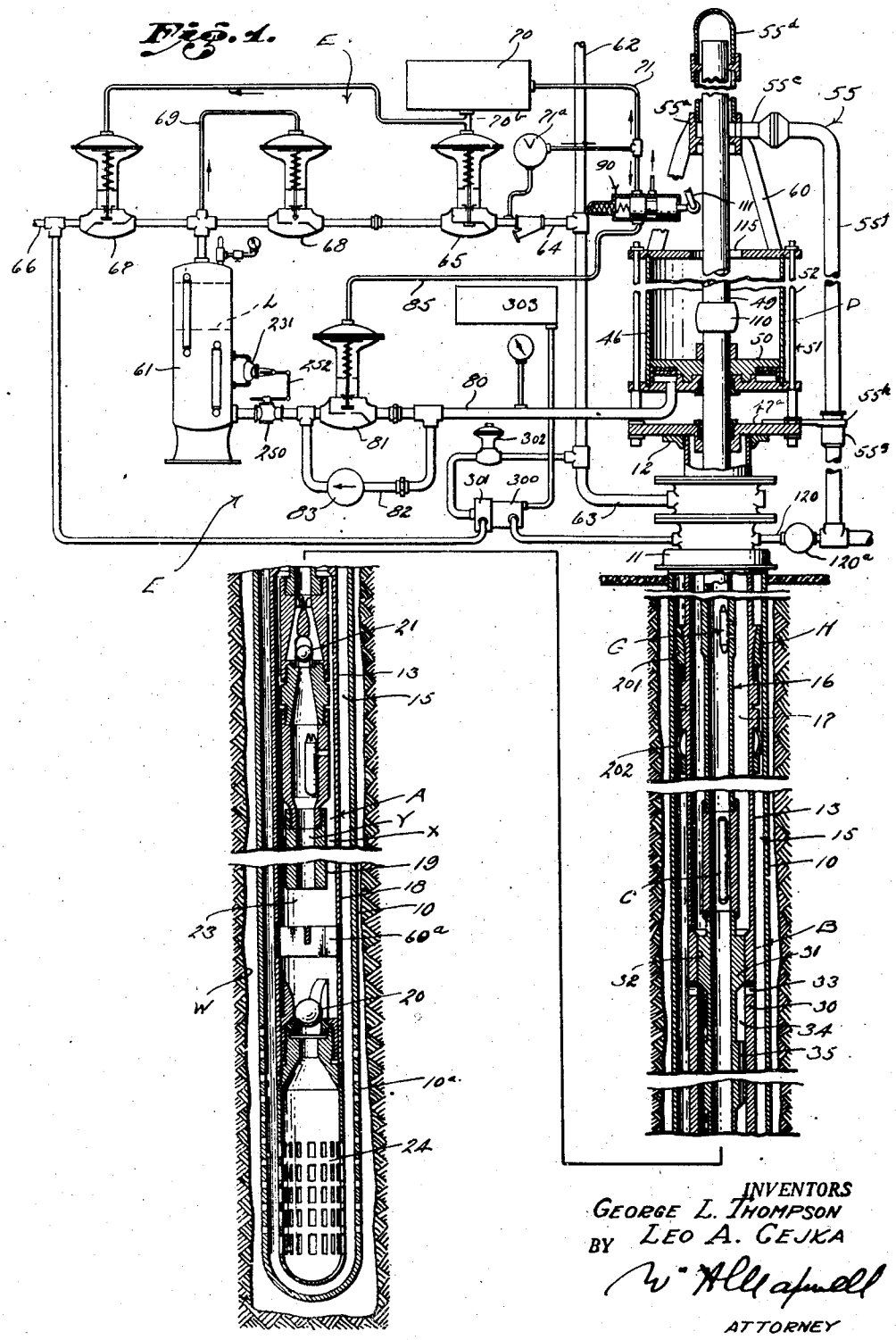
Feb. 25, 1947. G. L. THOMPSON ET AL 2,416,359

APPARATUS FOR LIFTING FLUID

Filed Jan. 17, 1945 6 Sheets-Sheet 1

Fig. 1.



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Fig. 2.

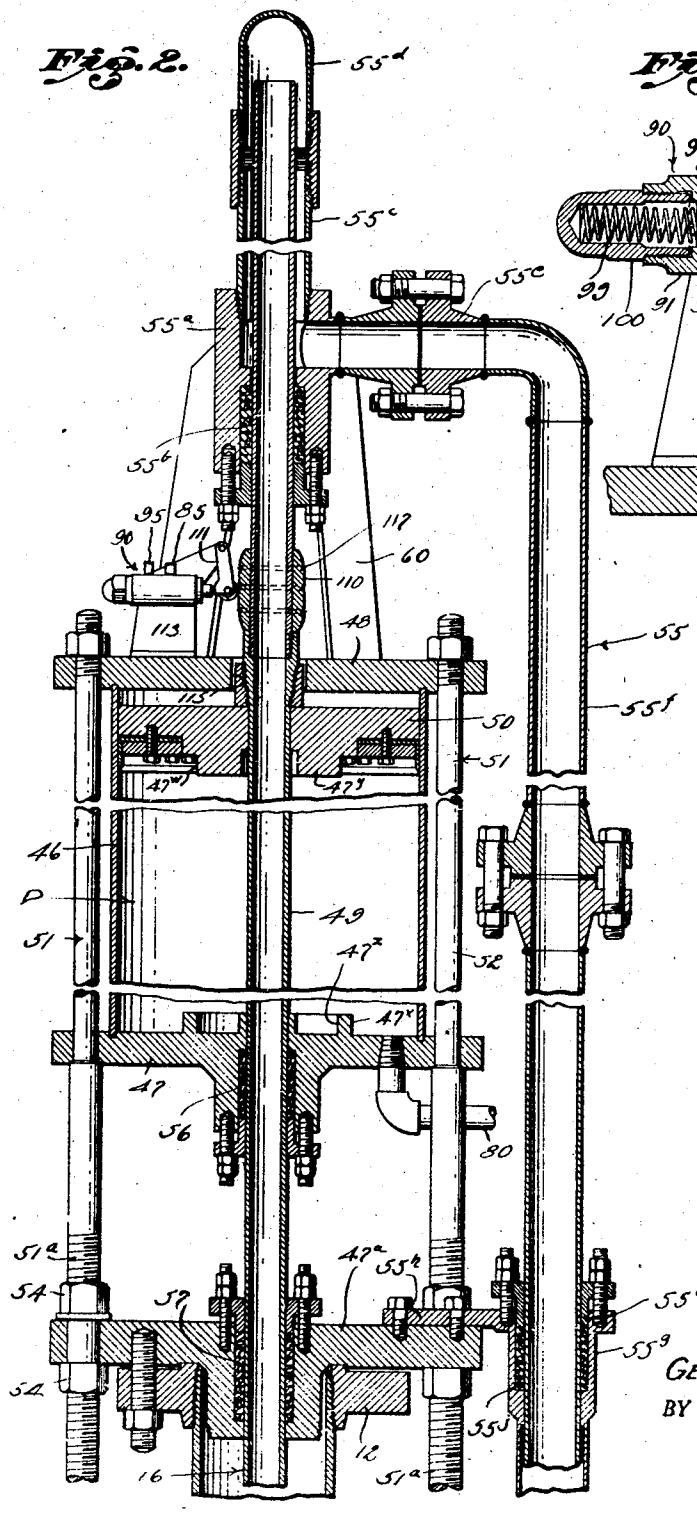
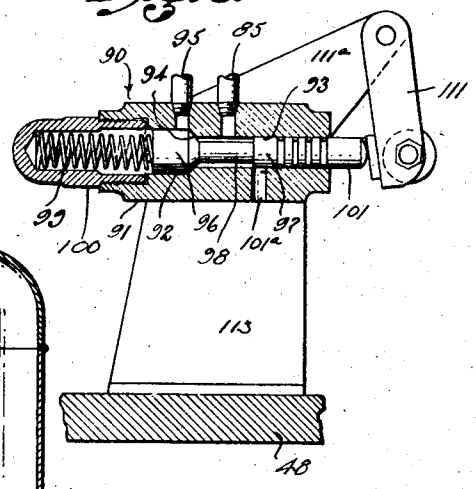


Fig. 3.



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Fig. 5.

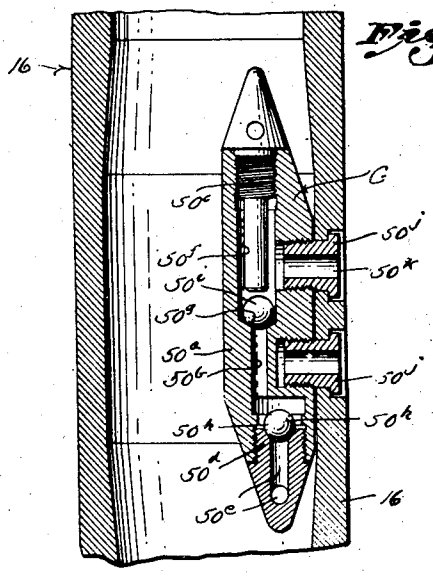


Fig. 9.

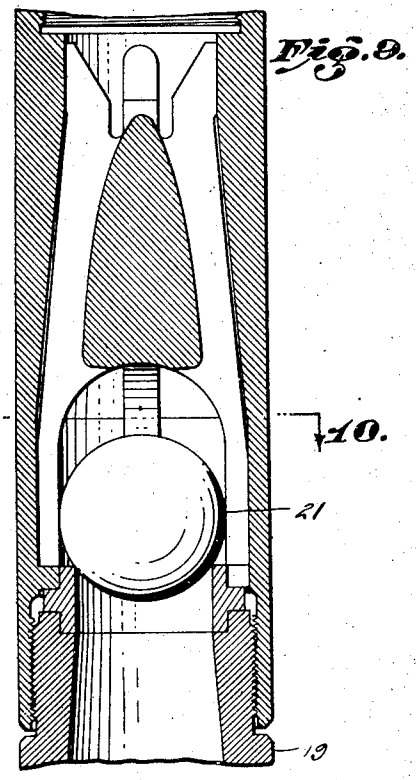


Fig. 4.

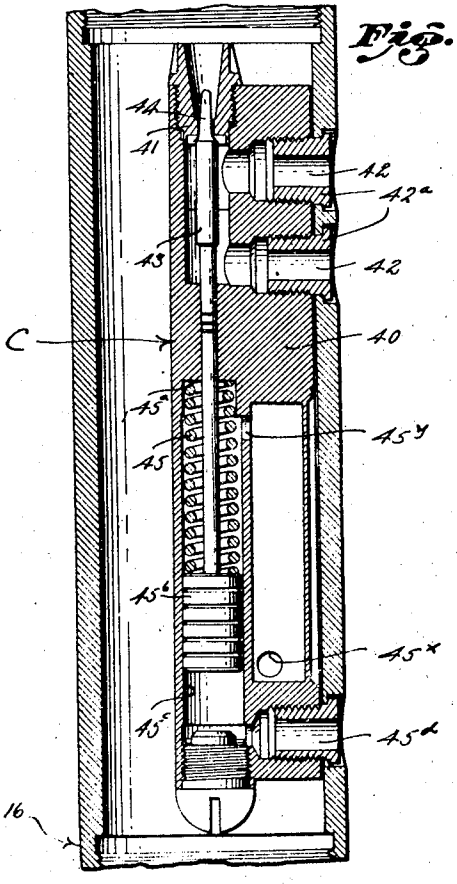
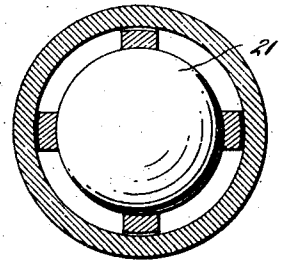


Fig. 10.



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Fig. 6.

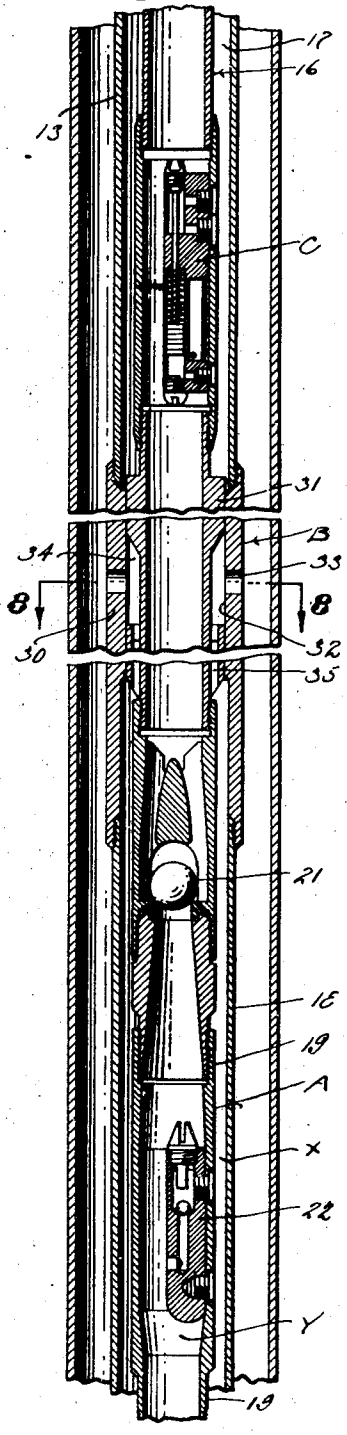


Fig. 7.

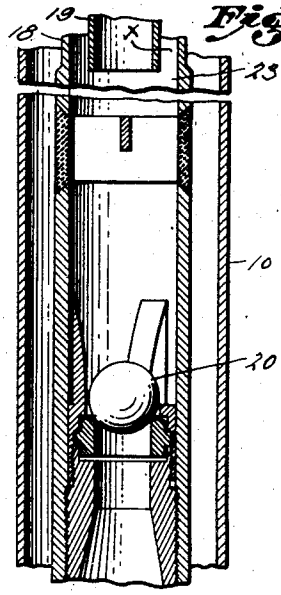


Fig. 8.

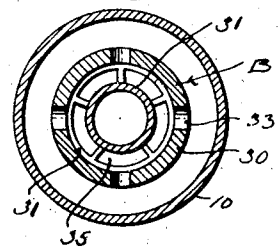
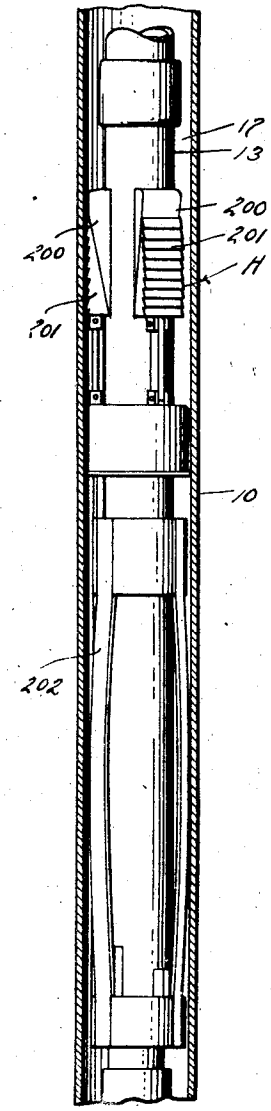


Fig. 14.



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Fig. 11.

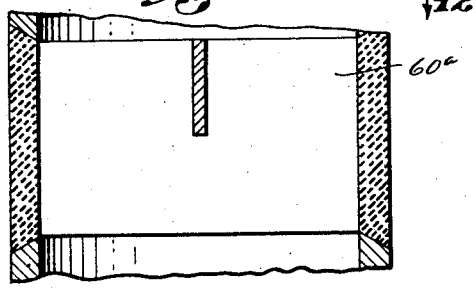
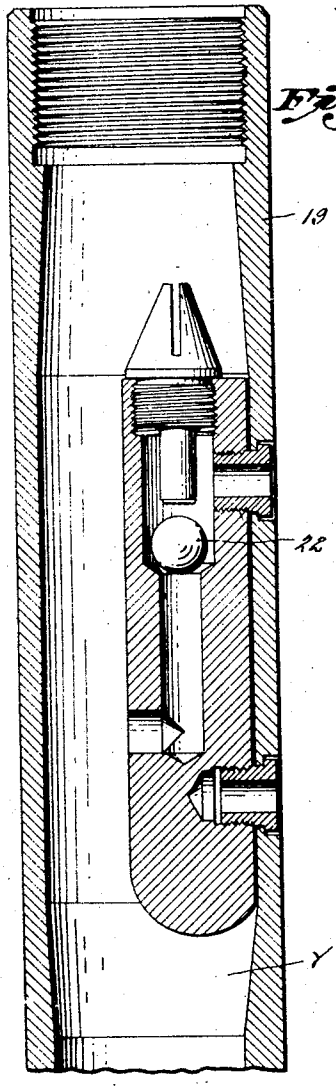
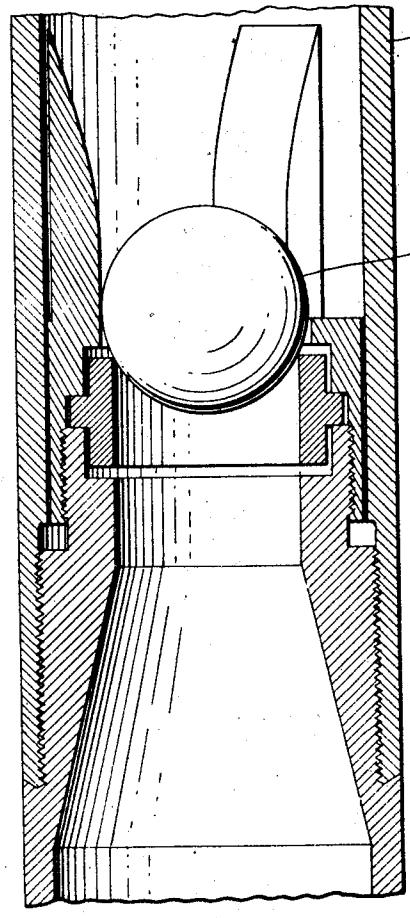


Fig. 13.





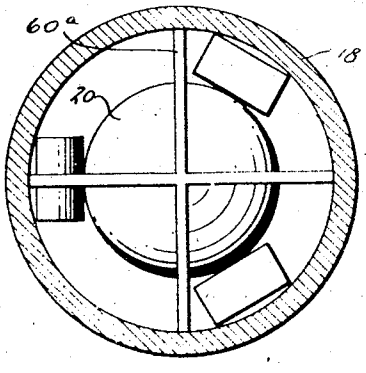


Fig. 12.

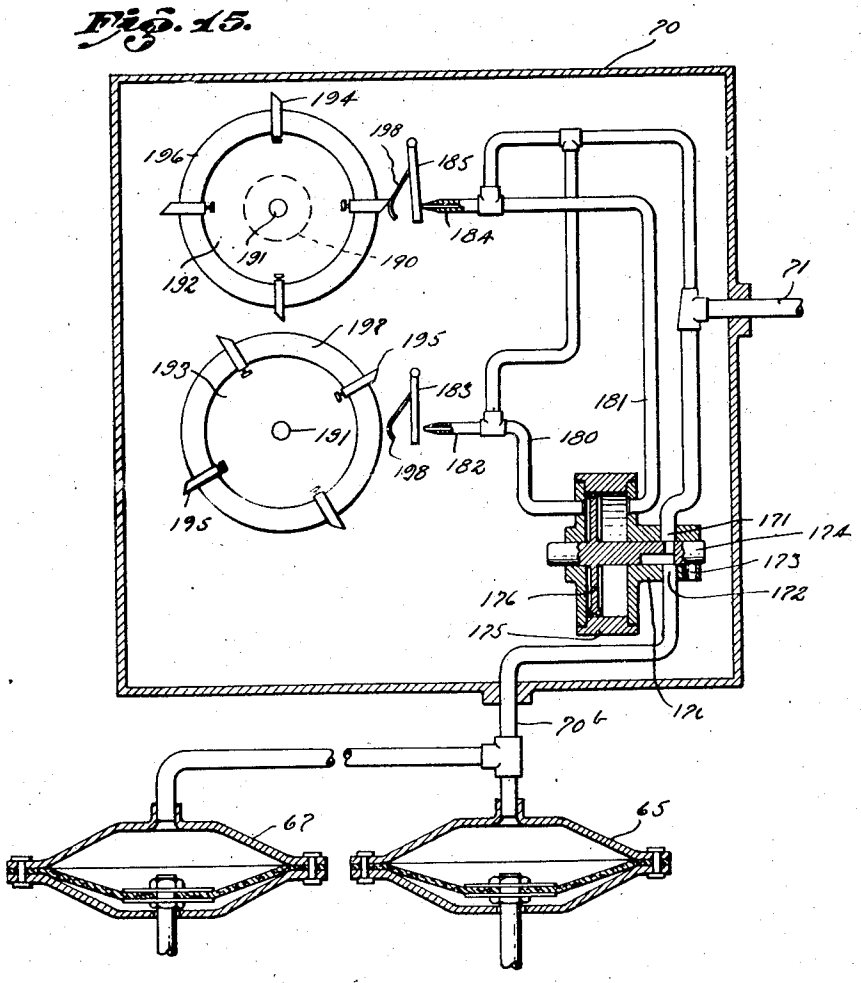
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Fig. 15.



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UNITED STATES PATENT OFFICE

2,416,359

APPARATUS FOR LIFTING FLUID

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Application January 17, 1945, Serial No. 573,236

51 Claims. (Cl. 103—231)

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This invention relates, generally, to apparatus for handling or lifting fluid and which can be used to advantage in lifting fluid from wells, and particularly from deep wells. It is a general object of our invention to provide an improved, simplified, and highly efficient mechanism or apparatus of the character referred to.

In removing fluids from wells, or the like, it has been common practice to employ pumps located in the wells to be submerged in the fluids therein, which pumps have been operated through strings of sucker rods by means of pump jacks, or like mechanisms, located at the heads of the wells. In such cases the pumps and pump jacks have had no particular cooperative relationship except that the pump jacks serve to reciprocate the rods which, in turn, in a general way, operate the plungers of the pumps, which plungers handle fluid so long as they are reciprocated. Usually such aggregations of equipment work satisfactorily in shallow wells, but their usefulness decreases rapidly as well depths increase, and they are practically useless in deep wells. So-called gas lifts have been used to remove fluids from deep wells. However, it has been customary, in employing gas lifts, to treat the equipment employed as an aggregation of well parts and surface operating mechanisms and, as a result, such equipment has not been generally satisfactory, but rather has been wasteful of gas and undependable in action.

It is a general object of our present invention to provide a unitary or composite apparatus for lifting fluids from great depths, for instance from deep wells, by means of pressure fluid or high pressure gas, and which involves a definite cooperative relationship between the parts located in the well and those operating at the head of the well, to the end that we obtain high operative efficiency, or effective conservation of the power medium, and also improved well production.

The mechanism or apparatus that we have provided by our present invention involves a pressure fluid displacement type working unit to be located in a well, or the like, to be immersed in the fluid therein, a gas control at or in the said unit for controlling the pressure fluid or actuating gas, inner and outer strings of tubing extending into the well to handle the well liquids and to operate the said unit and gas control, a fluid pressure operated actuating means at the top of the well for operating the flow string or tubing conducting fluids from the well, and a control for the actuating means connected with the

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gas control through the flow string so that the action of the equipment in the well is directly coordinated with that of the surface equipment so the entire pumping operation is carried out smoothly, without shock, and in a highly efficient manner. With the apparatus that we have provided the fluid issues from the well in a substantially steady stream and not intermittently or in slugs, as is the case when using most "gas lifts" or methods employing pressure fluid as an actuating medium. In carrying out the broader principles of our invention we may employ various mediums or fluids under pressure, which we will term "pressure fluid" as the working medium; however, in practice and particularly when lifting fluids from deep wells, we employ gas at high pressures as the working medium and, therefore, it may be said that the invention relates to that general class commonly referred to as gas lifts.

So-called gas lifts that have been proposed for handling well fluids have been used with limited success in a few limited situations. Gas lifts generally involve complicated or delicate valves, or intricate controls which give considerable difficulty under actual working conditions, and, in most cases where they work at all, they are very inefficient or wasteful of gas. We recognize that various pump actuating mechanisms also have been provided and used for working or handling pumps of various kinds, such mechanisms being known, generally, as pump jacks. Such mechanisms are merely reciprocators designed to stroke or reciprocate a string of sucker rods or tubing to work a pump plunger, and as a general rule any pump jack will operate any well pump within its limited range of use.

We have found that a working mechanism in a well handling pressure fluid has certain highly advantageous features. For instance, it may have very few simple, dependable parts, and it is practical to manufacture. However, such structures have certain peculiarities which make them more or less inefficient when operated by the conventional type of pump jack. With the simple gas displacement type device when the gas is introduced into the displacement unit in the well to displace well fluid therefrom there is a very marked and sudden release of pressure from the operating string of tubing through which the flow is handled and the pump is operated. The sudden change of pressure occurring when the gas is introduced into the displacement unit results in a shock upon the operating string and this shock is communicated to the operating mecha-

nism. Further, sudden stopping of the actuating mechanism at the top of the well at the ends of its stroke also causes shocks that are communicated to the operating string in the well.

The shocks imparted to the operating string present very serious operating problems that are not satisfactorily met by the ordinary operating mechanisms or pump jacks because they are not related to the well parts to be under immediate control thereof. Excessive strains or shocks on operating strings, even in shallow wells, are undesirable, but when they occur in very long strings they are very dangerous. Failure of a long string of tubing may be very costly, in fact, it may permanently injure the well.

We have found that for practical and highly efficient operation of a pressure fluid apparatus it is not merely a matter of having an operating mechanism or pump jack that will reciprocate the flow handling string without shock, but that when the pump is working at substantial depths it is necessary to employ a density control regulator at the unit in the well, and further, that for high efficiency the actuating mechanism must be directly coordinated with the gas control and the displacement units located in the well.

The operation of a mechanism deep in a well, and particularly the operation of a mechanism involving reciprocating parts and utilizing gas pressure in the course of operation, involves several serious problems, one of which is the maintenance of the proper relationship between the parts under varying conditions. In the case of a mechanism utilizing gas under pressure to displace fluid at the bottom of the well and having a reciprocating valve controlling the gas and operated by a mechanism at the top of the well, there is commonly a working or movement of the pump element intended to be stationary due to stretch, changing pressures or loads, and changes in temperature. Checking of the movement of the element intended to be stationary is beneficial but is not alone a fully practical solution. Gas used for operation in most cases varies widely in temperature, as for instance, between day and night, or under varying field conditions, so if the one element of the well mechanism or unit is fixed at its upper end only then expansion or contraction of the other element, which is free to move, may cause it to move so that the relationship of parts is seriously disturbed.

It is an object of this invention to provide a deep well mechanism or unit utilizing high pressure gas to displace well fluid at the bottom of the well, and in which the so-called fixed or stationary element of the unit is anchored or fixed at a point deep in the well so that it is practically free from movement and thus establishes a position from or with relation to which the other parts, including the actuating unit at the top of the well, can be set and operated. By our present invention we eliminate the disadvantages of having the entire well unit or mechanism subject to working or shifting in the well and we make possible features that will be hereinafter set forth.

Another object of our invention is to provide an assembly including a displacement unit of the general character referred to having an anchored stationary element that cannot move and an actuating unit at the top of the well with a range of action or freedom of movement which compensates for variations which are at a maximum because the stationary element is fixed. By providing for overtravel or over-stroking of the actuating unit we are able to absorb or neutralize

variations that would otherwise complicate and materially detract from the action of the apparatus.

A general object of our present invention is to provide a combined or coordinated assembly of elements including a pressure fluid displacement unit located in the well itself, a liquid operated pump actuator located at the head of the well, and a control system for the actuator directly coordinated with the action of the displacement unit itself. We effect the desired coordination through the operating string which is also employed to conduct fluid from the well.

Another object of our invention is to provide a highly efficient and practical combination of pressure fluid displacement well unit operated by a tubular flow string, a fluid pressure actuated pump operator at the top of the well energized by gas under pressure, and means in the flow string controlling the specific gravity of the fluid being lifted, all in a closed circuit so that there is no waste of gas or back pressure on the well formation.

Another object of our invention is to provide for effective and dependable lubrication from the top of the well of working parts of the mechanism in the well. In practice gas usually available for use in apparatus such as we provide is dry gas, and regardless of the gas being used the valve surfaces in the well are blown or wiped clean and dry at each stroke of the actuating piston. Need of lubrication is particularly important in an arrangement or structure such as we have provided, which is, in effect, a closed circuit. We have overcome the difficulty referred to by providing for thorough and continuous lubrication of the working parts by apparatus at the top of the well where it can be easily and conveniently serviced. In the preferred form of the invention the lubrication is synchronized with the action of the entire apparatus so that continuous and adequate lubrication is assured whenever the apparatus is operating.

Another object of our invention is to provide a safety control in connection with the supply of actuating fluid for the unit at the top of the well, which fluid is held under pressure by gas, so that gas cannot reach the unit to cause operation that might cause injury to the parts or equipment connected thereto. If gas should get into the actuating unit it might cause serious injury to either or both of the tubings employed in carrying the parts that are located in the well. By our invention we provide a control in connection with the accumulator provided as an element of the apparatus so that flow is cut off when the level of liquid in the accumulator drops below a predetermined point.

Another object of our present invention is to provide a cushioning means in the actuating unit at the top of the well to eliminate shock or hammer at the surface parts and, more important, to eliminate shock of the inner tubing that carries the reciprocating parts in the well. By our present invention we provide means in the actuating unit utilizing fluid supplied to operate the unit as a medium for checking the movement of the reciprocating parts at the lower end of the stroke so that hammer or sudden jar is eliminated.

Another object of the invention is to provide a unit at the top of the well combining an actuating mechanism and a flow connection and provision for adjustment of the mechanism bodily to synchronize it to the parts in the well so that the flow connection is not disturbed and needs

no special attention when the unit is adjusted. In accordance with the preferred form of our invention the flow line has a section arranged coaxially with the actuating unit or mechanism and that section has a slip joint which operates when the actuating unit is adjusted.

Another object of the invention is to provide apparatus such as we have referred to in which there is a stop in a fixed position in the stationary element of the displacement unit in the well to be engaged by the movable element. The stop is in a definite known spaced relation to the gas control at the displacement unit, so that an operator can by adjusting or manipulating the actuating unit at the top of the well easily and accurately set the parts so that the working parts of the gas control are in proper working relationship.

It is a general object of our present invention to provide a fluid lifting apparatus of the general character referred to wherein the parts located in the well are characterized by apparatus for effecting displacement of the well fluid by means of high pressure gas under control of a valve and by a density control device in conjunction with the parts just named, which operates to introduce gas into the displaced fluid to lower its specific gravity and to keep its specific gravity down to a point where the operating medium or high pressure gas will effectively operate to displace the well fluid up through the discharge string provided for conducting the well fluid to the surface.

It is another object of our invention to provide apparatus of the general character referred to wherein the parts or equipment located in the well establish what we will term a closed system keeping the high pressure operating gas entirely away from the well or earth formation, so that no back pressure is built up or established in the well, but rather the well is allowed to flow naturally or freely and thus to produce in a most efficient manner.

In well apparatus of the general character that we have referred to, and where there is an inner tubing through which the well fluid is flowed out of the well and an outer tubing through which gas under pressure is introduced into the well to the bottom or lower regions thereof, to effect displacement of the well fluid, initiation of operation may be impossible if there is a substantial level of liquid standing in the inner tubing.

It is a general object of our present invention to provide for the removal of liquid from the inner tubing in order to initiate operation of the apparatus. By our invention we provide one or more devices which we will term unloading valves in the inner tubing. The unloading valve, or valves, as the case may be, operates so that high pressure introduced into the inner tubing or flow string from the top of the well, for instance gas under high pressure, drives fluid from the inner tubing into the outer tubing and thus clears the inner tubing so that the apparatus will function properly when the high pressure is taken off of the inner tubing and high pressure gas is introduced into the outer tubing.

There are numerous other objects and features of our invention that will be apparent and fully understood from the following detailed description of a typical preferred form and application of the invention, throughout which description reference is made to the accompanying drawings, in which:

Fig. 1 is a diagrammatic or schematic illustration of the general apparatus of the present invention showing a form of the invention wherein high pressure gas from a suitable source is utilized as the prime mover for the entire operation, the parts which occur in the well being shown broken and arranged side by side rather than in line, as they actually occur. Fig. 2 is an enlarged vertical detailed sectional view of the actuating unit provided by our invention for operation at the head of the well to reciprocate the flow string which extends into the well to actuate the gas control at the displacement unit. Fig. 3 is an enlarged longitudinal detailed sectional view of the three-way pilot valve employed in the control system, being the element of the control system coupling the reciprocating element operating in the well with the working part of the control system of the actuating unit. Fig. 4 is an enlarged, detailed, sectional view of the density control regulator employed at the mechanism in the well or at the lower end of the operating string which conducts the well fluid from the displacement unit at the bottom of the well to the surface of the well. Fig. 5 is an enlarged, detailed, sectional view of one of the unloader valves that may be used in the operating string for starting the operation. Fig. 6 is an enlarged, longitudinal, detailed, sectional view of parts in the well, showing in particular the general location or application of the density control regulator and also the gas control provided for the displacement unit and showing the upper end portion of the displacement unit itself. Fig. 7 is a view similar to Fig. 6 showing the lower end portion of the displacement unit. Fig. 8 is a detailed transverse sectional view taken as indicated by line 8—8 on Fig. 6. Fig. 9 is a longitudinal, detailed, transverse sectional view of the top valve of the displacement unit. Fig. 10 is a detailed, transverse, sectional view taken as indicated by line 10—10 on Fig. 9. Fig. 11 is a vertical detailed sectional view of the bottom valve employed in the displacement unit showing also the stop provided in the stationary element of the displacement unit. Fig. 12 is a transverse, sectional view taken on line 12—12 of Fig. 11. Fig. 13 is a vertical, detailed, sectional view of the vent valve provided in the displacement unit. Fig. 14 is a view showing the manner in which the stationary tube is anchored in the well. Fig. 15 is a diagrammatic view illustrating the intermitter and its relationship to the inlet and exhaust valves.

The apparatus that we have provided by our present invention is useful, generally, for lifting fluid and it is particularly useful in lifting fluid from deep oil wells. The apparatus can be operated in single units, that is, on a single or individual well, or a number of units can be combined so that they operate in a system or circuit using a single source of pressure fluid, preferably gas. For purpose of example we will describe a single or individual unit, it being understood that we do not thereby wish to limit ourselves to use of the invention in this particular manner. It is also to be understood that the invention can be carried out in connection with wells of various constructions or under varying field conditions, in which case variations will be made to meet the conditions encountered. In the drawings we illustrate a typical or simple well arrangement and we show the apparatus employed by our invention in connection with a simple cased well such as is commonly encountered in practice.

In the drawings, and in particular in Fig. 1 of the drawings, we show a well bore W carry-

ing a common form of well casing 10. The casing extends downwardly into the well W from a suitable casing head 11 provided at the surface or top of the well. The casing is provided, opposite the oil bearing strata, with a perforated section or liner 10a, which admits well fluid into the well or casing so that it is available to be removed by the apparatus that we have provided.

The casing head 11 provided at the upper end of the well is joined to the upper end of the casing 10 and is such as to provide a landing for other elements such as the outer tubing and other parts that will be hereinafter described. In the preferred form of the invention we employ the casing head of the well as a base or mounting for our actuating unit. When thus employing the casing head of the well we employ a form of head that is adaptable to take the nipple of a landing flange 12. The flange 12 carries flange 47a of the cylinder D and supports the adjusting posts and passes the piston rod, all as will appear from the following description.

In carrying out our invention we equip the well, that is, the cased well that we have just described, with a fixed or outer tubing 13. The tubing 13 is landed in the head 11 to depend therefrom downwardly through the casing 10 and it extends down in the casing to the bottom of the well or to the point where the fluid is to be taken from the well, which point will be referred to as the bottom of the well, although in some cases this may not be literally true.

Our present invention provides, in combination with the parts or elements hereinabove described, a working string or tube that we will term the flow string 16, a displacement unit A, a gas control B at the unit A for controlling the actuating fluid, or high pressure gas, a density control regulator C immediately above the displacement unit connecting the space between the flow string 16 and tubing 13 with the interior of the flow string 16, one or more unloading valves G in said flow string, an actuating unit D at the head of the well for working the flow string so it operates the gas control, and a control system E for operating and controlling the actuating unit.

The flow string 16 serves as the conduit or pipe for conducting the fluid from the unit A to the surface or head of the well, and also as the means for actuating the control B. The fluid that is thus handled is a mixture of well fluid and actuating gas. In practice the flow string 16 is a string of tubing, or the like, of the type known in the art as "macaroni."

The flow string 16 is smaller in diameter than the tubing 13 so that there is an annular space or annulus 17 left between these elements, this being the space through which the actuating fluid or high pressure gas flows in passing from the head of the well to the control B.

In accordance with the arrangement that we have provided the flow string extends from or through the actuating unit D down through the head 11 to the gas control B where it carries the inner or working element of the gas control which element is in the nature of a plunger valve. The flow string 16 is in communication with the outlet of the unit A through the tubular inner element or plunger valve of the gas control B, and it serves to conduct the fluid from the well up through the tubular piston rod of the actuating unit D which in turn connects with the delivery line 55 that carries the fluid mixture from the well.

The displacement unit A is carried at the desired location in the well or within the well casing 10 by means of the tubing 13 and the flow string 16, the connection between these elements and the displacement unit being made through the gas control B. In accordance with our invention the displacement unit A utilizes pressure fluid, preferably high pressure gas introduced through the annulus 17 under control of the gas control B, so that it displaces well fluid that has entered the unit. It may be said that the displacement unit operates to move or displace the well fluid by pneumatic action, the word "pneumatic" in such case being used broadly enough to include not only air but also gas. It is to be understood that in carrying out some phases of our invention a medium other than gas may be used; for instance there may be cases where a liquid can be used. Because of this we do not use the terms "gas" or "pneumatic" in a limited sense but broadly, and we mean to include liquids where they are usable within the scope of our invention.

The fixed tubing 13 is an elongate tubular element or string of tubing such as is commonly employed in wells when they are to be pumped. The upper end of the fixed tubing 13 is sealed in the head 11 by a suitable packer, or the like, so that the upper end of the annular space or chamber 15 provided between the casing 10 and the tubing 13 is sealed off or closed. The tubing 13 extends downwardly into the fluid to be pumped from the well and at that point, which is near the bottom of the well, it carries the outer or fixed elements of the gas control and displacement units that we will hereinafter describe.

In the ordinary well installation where well pumps are employed the depths are not so great that shrinkage and expansion or stretch of the principal elements involved cause any serious difficulties, However, in the case of very deep wells, for instance under operating conditions such as we will hereinafter refer to, shrinkage and expansion, stretch and the pressures involved, generally, have a very marked influence upon the equipment or apparatus used. In accordance with our invention to avoid difficulties due to conditions such as we have just referred to, we anchor the parts at the bottom of the well that are required to be stationary or fixed. We may in some instances anchor those parts, for instance, parts of the control B, or of the displacement unit, directly, as by anchoring them in the well casing or liner 10. However, in practice it is advantageous to anchor or fix the parts for practical purposes by anchoring the lower end portion of the outer tubing 13.

In an ordinary well installation the liner on the lower end of the well casing may extend several hundred feet up from the bottom of the well. In fact, it is not uncommon that it may be a thousand feet long, or more. We prefer to anchor the tubing 13 at a point in the casing 10 proper rather than in the liner that may extend down from the casing and, therefore, as we have shown in the drawings, we provide an anchor H for the lower end portion of the tubing 13 at a point well above its actual lower end and, preferably, at a point to come within the well casing 10 and not within the liner on the lower end of the well casing.

In practice we may employ any suitable anchoring device so long as it effectively holds the lower end portion of the tubing 13 and does not obstruct the passage of formation gas or exhaust gas through the annulus 17 from the casing 10

to the parts at the bottom of the well. In the drawings in Fig. 14 we show a typical simple anchoring device involving spaced wedge projections 200 on the exterior of the tubing 13 and wedge parts or slips 201 cooperating with the projections. The slips and projections operate so that when the slips are set, as shown in the drawings, downward movement or pressure on the tubing 13 wedges the slips out into gripping engagement with the interior of the casing 10. The slips are suitably connected to a tail piece or control mechanism 202 so that by suitable manipulation they can be released for cooperation with the projections 200. In devices of this kind the control mechanism 202 is usually such that the slips are held down or away from the projections 200 while the mechanism is being run into the casing 10 and when the device has reached the desired point in the casing 10 the control 202 is released by manipulation of the string being anchored to release the slips so that they can be set.

With a securing device such as we have just described the lower end portion of the tubing 13 is suspended from the securing device, there being enough tubing 13 below the securing device to maintain the device properly seated or engaged in the casing 10. The major portion of the tubing 13 or the length of the tubing 13 above the securing device H may be set so that it is held at the head 11 but hangs in the casing 10 rather than being supported from the device H. In a practical installation employing an anchoring or securing device H such as we have described, there may be a substantial length of tubing 13 below the device H, but this will not be so long as to introduce any serious difficulties into the apparatus but rather will, for all intents and purposes, be such as to carry the stationary parts of the control B and displacement unit A so that they are practically rigid or stationary at the desired location in the well.

In practice we prefer to employ a simple, highly efficient form of displacement unit A and have found that a mechanism such as we have shown in our Patent No. 2,318,029, issued May 4, 1943, is highly desirable in carrying out our present invention. This particular type of mechanism, being that illustrated in the drawings, involves, generally, a fixed body or barrel 18, a reciprocating tubular shell forming a flow tube 19 which operates within the barrel 18 and through which the well fluid passes to flow into the flow string 16, a foot or lower valve 20 at the lower end of the barrel 18, a working or upper valve 21 at the upper end of the flow tube 19, a vent valve or valves 22 in the flow tube immediately below the upper valve 21, and various other parts incidental to those referred to.

The fixed barrel 18 is provided primarily to form a displacement chamber 23. In the preferred arrangement the barrel 18 is fixed to the lower end of the outer or fixed element of the gas control B to depend downwardly therefrom.

The lower valve 20 acts like a standing or foot valve and may be of the conventional ball type found in well pumps, and may be applied to the lower end of the barrel 18 by a threaded connection. In the preferred arrangement we provide a suitable strainer 24, or the like, below the lower valve, and in practice we may employ any suitable device or attachment at this point as well conditions may dictate.

The flow tube 19 is a reciprocating element and is operated by means of the reciprocating flow string 16. In the preferred arrangement the tube 19 is attached to the lower end of the plunger or inner element of the gas control B through the upper valve 21, the said element of the control B being secured to the lower end of the flow string 16. The tube 19 extends downwardly from the working valve 21 to divide the chamber 23 formed by the barrel 18 into an outer displacement chamber X and an inner displacement chamber and flow passage Y.

The upper valve 21 acts as a working valve and may be an ordinary ball type valve such as is commonly employed in well pumps. Valve 21 is arranged to pass well fluid upwardly from the tube 19 into or through the inner element of the control B to enter and flow up through the flow string 16. In the particular form of construction illustrated the cage or body of the valve 21 serves as a coupling joining the inner element of the control B with the upper end of the tube 19.

The vent valve or valves 22 which we provide are check valves located at the upper end of the tube 19 and immediately below the upper valve 21. In the drawings we have shown one valve 22 in the upper end portion of the tube 19 (see Figs. 6 and 13). Valve 22 connects the interior of the tube 19, in other words, the inner chamber or flow passage Y, with the displacement chamber X around the tube 19, and acts to allow gas that may be trapped in or which may accumulate in the chamber Y to flow out of the chamber Y into the chamber X and out to the casing through gas control valves and exhaust ports 33, as well fluid flows into the passage Y from its lower end during the filling cycle of the mechanism.

The gas control B, which is essentially a valve mechanism, is located immediately above the displacement unit A and serves as a coupling or means for connecting the displacement unit with the tubing 13 and flow string 16. The gas control is, preferably, a slide valve serving to control the flow of gas from annulus 17 to the chamber X during one cycle and to exhaust spent gas from the chamber X to the well externally of the fixed tubing 13 during the other cycle, when the valve is closed. In its preferred form the gas control involves two simple parts, an outer fixed part in the form of a case or barrel 30, and an inner reciprocating part in the form of a core or plunger 31.

The barrel 30 of the gas control is an elongate cylindrical member or element threaded at its upper end for connection with the lower end of the tubing 13 and threaded at its lower end for connection with the upper end of the pump barrel 18. The barrel 30 has a straight cylindrical central bore 32 and gas exhaust ports 33 are provided laterally through it at a point intermediate its ends.

The core or plunger 31 is an elongate cylindrical member or element designed to be reciprocated in the bore 32 of the barrel 30. The plunger is threaded at its upper end for connection with the lower end of the density control section of the flow string 16 and is threaded at its lower end to receive or make connection with the upper valve 21. The exterior of the plunger 31 is turned and finished to slidably fit the bore 32 of the barrel and, in accordance with the preferred construction, an annular recess 34 is provided around the plunger at a point intermediate its ends, and a plurality of longitudinally disposed ports 35 are provided in the plunger joining the recess 34 with the upper end of the displacement chamber X of the displacement unit. The parts are proportioned and related so that the flow

line 16 can be removed carrying with it the plunger 31 and the tube 19 that normally extends into the displacement chamber X.

When the flow string 16 is at the lower end of its stroke the tube 19 is in its lowermost position and plunger 31 of the control B is located entirely within the barrel 30. When the parts are in this position the recess 34 of the plunger is in communication with the exhaust ports 33 of the barrel so that gas remaining in the chamber X and any gas expelled from the passage Y in the tube 19 through the vent valve or valves 22 is free to escape up through the ports 35 to the recess 34 and out through ports 33 into the well externally of the fixed tubing 13. At the same time fluid begins to flow into the chamber 23 past the lower valve 20. As the flow string 16 is elevated or moved upwardly the upper valve 21 remains closed and well fluids continue to flow into the chamber 23. When the flow string reaches the upper end of its stroke, or when the gas control plunger 31 approaches the upper end of its stroke, the edge or wall defining the upper end of the recess 34 in the plunger 31 passes above or beyond the upper end of the bore 32 so that the recess 34 is in open communication with the annulus 17. By the time the parts reach the position just described the lower end portion of the plunger 31 covers the exhaust ports 33 so that high pressure gas from annulus 17 will not escape through the ports 33.

As soon as the recess 34 opens into communication with annulus 17 there is a sudden change of pressures at or in the chamber 23 with the result that gas from annulus 17 immediately exerts pressure on the fluid in the chamber 23 or, more specifically, on the fluid in the displacement chamber X. The flow of gas or the communication of gas pressure is through the recess 34 and the ports 35. The actuating gas under high pressure is introduced through the head 11 into the tubing 13 so that it acts on the fluid in the displacement chamber to displace fluid up through the tube passage Y past the upper valve 21 so that it flows up through the plunger 31 and into and out through the flow string 16.

In accordance with our invention we provide means whereby the operator can easily establish the proper cooperative relationship between the plunger 31 and the barrel 30. From the foregoing description it will be apparent that the barrel 30 is, for practical purposes, fixed or stationary whereas the plunger which cooperates with the barrel is carried on the lower end of the flow string 16 which reciprocates. It will be apparent that for proper action of the control which involves the barrel and plunger the plunger must be operated or reciprocated in the proper manner relative to the barrel and so that it is maintained in the proper position relative to the barrel.

In practice the flow tube 19 of the displacement unit is of considerable length and the barrel 18 which surrounds the flow tube to form the displacement chamber 23 has to be of greater length so that it supports the lower valve 20 at a point a safe distance below the lowermost point of travel of the flow tube 19 during normal operation of the apparatus. The means which we provide for positioning the plunger 31 in the barrel 30 involves a stop 60^a fixed in the barrel 18 at a point a known distance below the lower end of the flow tube when it is at the lower end of its normal travel. For purpose of example, in practice we may locate the fixed stop 60^a, which is

formed by crossed plates fixed in the barrel 18, a known distance, say for instance, five feet below the lower end of the tube 19 when the tube is at its lowermost point during normal operation of the apparatus.

To set the plunger 31 in the proper position relative to the barrel the operator lowers the entire reciprocating unit, that is, the operating string 16 with its connected parts, until the lower end of the tube 19 strikes the fixed stop 60^a. He then knows that the plunger will be properly positioned at the lower end of its stroke when the operating string is lifted the said known distance, namely five feet.

The density control regulator C is provided immediately above the plunger 31 of control B. Regulator C may be connected between the control plunger 31 and string 16, or it may be inserted in the lower end portion of flow string 16. The regulator C serves to regulate or vary the density or specific gravity of the column flowing out through the flow string 16. The regulator bleeds gas under pressure from annulus 17 into the flow string 16 so that the gas, in effect, aerates the column of well fluid in the flow string and lightens it by displacement. As the high pressure gas enters the tube 16 it foams up and thus assists in including upward flow in the flow string. The regulator is a positively controlled element so that it does not constantly bleed gas into the flow string but only admits gas to the flow string 16 when the pressure differential condition due to increased density of the body in the flow string 16 and annulus 17 is such as to make it desirable that gas be admitted to the flow string.

In the preferred construction the density control regulator is an insert applied to or inserted in a part such as the lower end portion of the string 16. In the form shown the regulator includes a valve body 40 with a vertically arranged opening entering the flow string 16 and having a downwardly facing seat 41. Gas supply ports 42 extend from the exterior of the flow string 16 or from annulus 17 to the interior of the body 40. The ports 42 are shown provided in couplers 42^a which mount the body 40 in the tube 16. A valve proper operates within the body 40 and includes a stem 43 having a head 44 to cooperate with the seat 41. A spring 45 is provided in connection with the stem 43 so that it normally tends to open the valve. The spring 45 acts between a shoulder 45^a in the body 40 and a plunger 45^b on the lower end portion of the stem 43 to normally yieldingly urge the stem down. The plunger 45^b operates in a bore 45^c provided in the body 40 and a port 45^d connects the lower end portion of the bore 45^c with the annulus 17 so that the pressure prevailing in the annulus acts on the lower end of the plunger 45^b and normally tends to move the stem 43 upwardly. Ports 45^x and 45^y admit pressure from the flow string to the upper side of the plunger 45^b. The opening in the body which carries the stem 43 opens up into the tube 16 at the upper end of body 40 and the seat 41 is preferably an insert applied to the upper end of the body opening.

The area of the upper end of the piston 45^b plus the area of the valve head 44 at the seat 41, when the valve is closed, equals the area of the lower end of the piston in the bore 45^c. Pressure from the annulus 17 acts on the lower side of the piston while pressure from the inside of the flow string admitted through ports 45^x and 45^y acts on the top of the piston and, together

with the pressure acting on the valve head 44 and that exerted by the spring 45 normally tends to open the valve against the resistance of the pressure acting on the lower end of the piston.

During operation the pressure in the flow line must be maintained so that it is less than that in the annulus, and the differential necessary depends upon the length of the displacement chamber. We have found that in the case of apparatus having a displacement chamber about 600 feet long it is practical to proportion the parts of the unit just described so that the valve opens at a differential of about 300 pounds pressure per square inch. Assuming operating conditions where the pressure in the flow string is below that in the annulus but the differential is less than 300 pounds, the valve remains open, but when the differential increases until it reaches about 300 pounds then the valve closes. When the valve opens gas from the annulus 17 enters the string 16 to lighten the body of material therein and thus supplement the action tending to flow the fluid up in the string 16.

It will be apparent from the foregoing description that the action of the density control regulator is entirely automatic. When properly designed and proportioned it opens at a predetermined differential between the pressure in the annulus and the load or weight within the string 16 and effectively feeds gas into the string 16 to keep the column of fluid flowing up and to keep the column of fluid mixture light so that, in practice, a substantially uniform flow or discharge of fluid is obtained at the upper end of the flow string 16, even though the column is started up in impulses from the displacement unit.

If an attempt is made to initiate operation of the apparatus when the flow string 16 is full of fluid or has a substantial body of fluid standing in it, the head pressure exerted by such fluid may be sufficient to prevent operation. In accordance with our invention we provide means for unloading the flow string 16 of excessive fluid to bring the level of liquid in the tube 16 down to a point where pressure conditions permit operation. It is to be understood, of course, that when operation has once started and the density control regulator is functioning in conjunction with the displacement unit the operation will continue and this is true even though the flow string 16 is full, as it must be for fluid to reach the top of the well.

In the preferred form of the invention we provide one or more unloading valves G in the string 16. For purpose of example we will refer to a form of the invention where one unloading valve is employed. The unloading valve is located in the string at or somewhat below the point in the string at which liquid may be standing without impairing initiation of operation of the apparatus. In any particular case the exact location of the unloading valve G will be determined by the well conditions and the pressure factors involved.

In the form of construction illustrated the unloading valve G is located at a suitable point in the tubing 16 which may be well above the lower end of the tubing 16 as indicated in the diagrammatic illustration, Fig. 1. In construction the unloading valve may be such as we have shown in Fig. 5. In this illustration we show the unloading valve as including a body 50^a arranged in the tubing 16. The body 50^a has a longitudinal opening 50^b formed in it. The opening

50^b is closed at the upper end of the body by a plug 50^c and has a valve seat 50^d threaded into its lower end, the valve seat having a port 50^e which opens into the interior of the tubing 16. The opening 50^b in the body has an enlarged upper end portion 50^f. A valve seat 50^g is formed where the enlargement of the body opening occurs. Ball valves 50^h and 50^i cooperate with the seats 50^d and 50^g, respectively, and close downwardly. The body 50^a is held in the tubing 16 by couplers 50^j. The uppermost coupler 50^j has a port 50^k through it which communicates with the enlarged opening 50^f in the body.

With the construction above described there is a passage from the interior of the tubing 16 to the exterior thereof through the port 50^e of valve 50^d, body opening 50^b, enlarged body opening 50^f, and the port 50^k in the coupler 50^j. The valves 50^h and 50^i are so located as to be in series in this fluid passage and to normally seat downwardly. Under normal working conditions there is a higher pressure at the exterior of the tubing 16 than there is at the interior thereof, and therefore, the valves 50^h and 50^i are normally closed or held on their seats and since they are in series they supplement each other and positively close the passage against leakage.

When it is desired to unload the tube 16 of fluid down to the point where the unloading valve G is located a high pressure is established in the tubing 16 from its upper end or, in other words, a pressure differential is established between the interior and exterior of the tubing 16 so that the pressure in the tubing 16 is greater than that outside the tubing 16, with the result that fluid in the tubing 16 will be discharged out through the unloading valve past the ball valves of that unit into the annulus 17, or that is, into the space between the inner and outer tubings. When the level of liquid in the tubing 16 has been lowered through this operation to the desired point or to the level of the unloading valve, the apparatus is conditioned to start operation and will start to operate when the pressure differential condition is reversed so that high pressure exists at the exterior of the tubing causing the unloading valve to close.

The actuating mechanism D that we have provided is primarily a cylinder and piston mechanism mounted on the landing flange and nipple above the head 11 of the well. In its preferred form this mechanism includes, generally, a supporting flange 47^a and a cylinder 46 provided with a lower head 47 and an upper head 48. A piston rod 49 extends through the cylinder 46 and both heads of the cylinder and also flange 47^a, and a piston 50 is fixed on the rod 49 to operate in the cylinder 46.

In the preferred arrangement rods 51 are provided for tying the cylinder and heads together and for mounting the cylinder mechanism or unit on the flange 47^a which is supported on the landing flange 12. The rods have threaded lower end portions 51^a which extend through openings in the flange 47^a and they have plain upper end portions 52 which extend between the heads 47 and 48 to tie them together. Nuts 54 are provided on the threaded portions 51^a at opposite sides of the flange 47^a. By adjusting the nuts along the parts 51^a it is possible to bodily adjust the vertical position of the cylinder above the head 11 and landing flange 12 and thus accurately locate the travel of the working or moving part 31 of the gas control.

In the preferred construction the piston rod

49 is an elongate tubular member which projects out through the lower head 47 and flange 47a into the head 11 of the well to connect to the upper end of the flow string 16. The upper end portion of the piston rod 49 extends up or out through the head 48 and into the delivery line 55 which conducts the fluid away from the well.

Suitable packing means 56 is provided at the lower head 47 to pack around the piston rod 49 and suitable packing means 57 is provided at the flange 47a to pack around the rod 49 where it enters the flange 12 and head 11.

The delivery line 55 is provided to receive flow from the upper end of the piston rod 49 which flow is that coming from the flow string 16 to which the piston rod is attached. It is the function of the flow line to receive the flow from the piston rod and conduct it away from the apparaus and, in accordance with our invention, the flow line includes a head 55a above the cylinder and piston unit above described to handle the upper end portion of the piston rod 49, a vertical section 55f offset from and parallel with the cylinder and piston mechanism, and a slip joint in the vertical section 55f whereby the cylinder and piston mechanism can be bodily adjusted vertically, as above described, without disturbing the flow line. The head 55a is mounted a suitable distance above the cylinder head 48 by means of spaced legs 60 which project upwardly from the cylinder head. The head 55a has a packing means 55b which slidably passes the upper end portion of the piston rod 49 and it has an upwardly extending tubular projection 55c which surrounds the piston rod 49 and which is closed at its upper end by a cap 55d. The tubular extension 55c of the head 55a is long enough or of sufficient vertical extent to accommodate the piston rod 49 throughout its entire movement or travel.

The head 55a delivers the flow received from the piston rod 49 to a lateral flow connection 55e which joins to the upper end of the vertical section 55f of the flow line.

The vertical section 55f of the flow line is arranged parallel with the cylinder and piston mechanism adjacent one side thereof. The slip joint provided in the vertical section of the flow line includes a gland body 55g secured to the flange 47a by a suitable mounting bracket 55h and a follower 55i bolted to the body 55g and operable to compress packing 55j. The upper end portion of the vertical section of the flow line slidably enters the slip joint or, in other words, slidably passes through the follower 55i and through the packing 55j and projects below or beyond the body 55g. The lower part of the vertical section of the flow line is fixed or joined permanently to the lower end of the body 55g and continues downward far enough to accommodate the projecting end of the upper part of the said section of the flow line. The parts are arranged and proportioned so that the slip joint has sufficient movement to allow for full operation or adjustment of the cylinder and piston mechanism without disturbing the flow line or, in other words, without requiring manipulation or setting of the flow line other than possibly adjustment of the packing gland of the slip joint.

The control system E for the actuating unit includes, generally, a pressure accumulator 61 and a system of fluid connections and valves whereby the actuating unit is controlled by or from the reciprocating element of the sub-surface equipment or more specifically from the flow string 16 which is directly connected with the plunger or movable element of the control.

In carrying out our invention we can employ different sources of power. In most instances it will be found practical to employ high pressure gas as the prime mover for the entire apparatus or system. We will describe a form of the invention wherein a high pressure gas is employed as the prime mover.

The high pressure gas from any suitable source, for example from one or more wells, or from a compressor plant, is supplied through a high pressure gas line 62. A connection which we will term a well branch 63 extends from the high pressure line 62 to the head 11 to enter the annulus 17. Another connection which we will term the accumulator branch 64 extends from the high pressure line 62 to the upper end of the accumulator 61.

A normally closed inlet valve 65 is provided in the accumulator branch 64. An exhaust line 66 connects with the accumulator branch 64 and is under control of a normally open exhaust valve 67. The exhaust line 66 may finally connect into the delivery line 55. To assure uniformity of operation we prefer to provide a pressure regulating valve 68 in the connection which extends to the accumulator 61, which valve 68 we locate in branch 64 between the inlet valve 65 and the top of the accumulator. In practice we may employ an ordinary diaphragm controlled pressure regulator valve and the desired pressure can be maintained by providing a pressure connecting line 69 between the upper portion of the accumulator and the diaphragm of the valve 68.

In practice the valves 65 and 67 are preferably motor valves of standard design under control of diaphragms and they are alternately opened and closed so that the accumulator is alternately charged and exhausted. A time controlled intermitter of any suitable design is provided to control the pilot gas which operates the valves 65 and 67. In the preferred system pilot gas is supplied from a suitable source through a supply line 71. We have shown the supply of pilot gas taken from branch 64 ahead of valve 65 through a pressure reducing valve 71a. Pilot gas from the intermitter 70 acts on the diaphragms of the valves 65 and 67 through a line 70b with one branch connected to the diaphragm of valve 65 and another branch connected to the diaphragm of valve 67.

The intermitter 70 may be any suitable control device. For instance it may be a clock controlled mechanism which serves to admit pilot gas under pressure to the diaphragms of the valves 65 and 67 at suitable time intervals. With the arrangement illustrated one of the valves is normally open and the other normally closed so that they operate oppositely. When gas is being admitted into the accumulator to force liquid therefrom and into the actuator D the valve 65 is open while the valve 67 is closed, but when it is desired to exhaust gas from the accumulator so that liquid can exhaust from the actuator D, then the valve 65 is closed and the valve 67 is opened. Valves 65 and 67 are disposed and coupled in the system so that when the control or pilot pressure comes on valve 67 closes before valve 65 opens, and when pilot pressure is taken off, then valve 65 closes before valve 67 opens.

In practice we prefer to employ an intermit-

ter 70 adjustable to vary the frequency with which the inlet and exhaust valves are operated and to vary the time between opening and closing of the valves. For instance, we prefer to provide an intermitter adjustable to gain any desired number of operations per hour and one which can be adjusted to gain any desired time interval between the time the inlet valve is operated, say, for instance, to open while the exhaust valve closes, and the time that the inlet valve closes and the exhaust valve opens. In Fig. 15 of the drawings we diagrammatically illustrate one form of intermitter that can be used to advantage.

In the intermitter illustrated a slide valve controls flow from the pilot gas supply line 71 to the line 70b connecting to the diaphragms of valves 65 and 67. The slide valve involves a body 170 with an inlet port 171 at one side to which line 71 is connected, with an outlet port 172 at the opposite side and to which the line 70b is connected, and with an exhaust port 173. The valve element 174 reciprocates in the body 170 between a position where it closes the exhaust port 173 and allows connection between the ports 171 and 172, and a position where it cuts off the port 171 and opens port 172 to port 173. When the valve is in the first mentioned position pilot gas pressure is admitted to the diaphragms of valves 65 and 67, whereas when it is in the second or other position pilot gas is exhausted from the diaphragms of valves 65 and 67.

The intermitter 70 involves means for reciprocating the valve 174 between the two positions above described. Such means may include an operating cylinder and piston mechanism for the valve 174. In the drawings we show a cylinder 175 at one end of the valve body 170 and a piston 176 operating in the cylinder 175 and carried on an extension of the valve 174. With this arrangement when fluid under pressure is admitted to either end of the cylinder while the other end is open, the piston will move toward the said other end of the cylinder.

To alternately admit and exhaust pilot gas to the cylinder 175 to reciprocate the piston 176 therein, we provide a pilot gas line 180 from the pilot gas supply 71 to one end of the cylinder 175 and a pilot gas supply line 181 from the pilot gas supply 71 to the other end of the cylinder 175. An escape nozzle 182 is provided in line 180 adapted to be closed by a pivoted shutter 183, and an escape nozzle 184 is provided in line 181 adapted to be closed by a pivoted shutter 185.

From the foregoing description it will be apparent that when the nozzles 182 and 184 are open pilot gas escapes so that no pressure builds up in the ends of the cylinder 175 but if either one of the nozzles is closed by its shutter, pressure will develop in the line in which the nozzle is connected, and consequently pressure will develop in the corresponding end of the cylinder 175. With this mechanism the desired action or operation of the piston 176 in cylinder 175 can be gained by operating the shutters 183 and 185 at proper intervals and in proper sequence.

Various means may be provided to operate the shutters. For example, as indicated in the drawings, a spring motor, or the like, 190 may be provided to drive a shaft 191 so that it turns constantly. Control discs 192 and 193 may be provided on the shaft 191 to carry stops 194 and 195, respectively, to operate the shutters. In the diagram, Fig. 15, the discs 192 and 193, instead of being one above the other on the common shaft 191, are shown spaced apart and the shutters 193 and 195 are shown in proper relationship to the discs.

In the arrangement illustrated a plurality of stops 194 are adjustable around a rim 196 provided on the disc 192 and they successively engage and operate the shutter as the disc revolves. When a stop 194 engages and operates the shutter 185 the shutter is moved to a position to close the nozzle 184 with the result that pressure develops in the right hand end of cylinder 175, causing movement of the piston 176 to the position shown in the diagrammatic figure, so that pilot pressure enters the diaphragms of valves 65 and 67 causing valve 65 to open and valve 67 to close.

A plurality of stops 195 are provided on a rim 197 on disc 193 and successively engage the shutter 183 to operate it. When shutter 183 is moved by a stop 195 to close the nozzle 182 pressure builds up in the lefthand end of the cylinder 175 causing the piston 176 to move to the righthand end of cylinder 175 and the valve 174 to operate to a position where pilot pressure is cut off from the diaphragms of the valves 65 and 67 and is allowed to exhaust therefrom through the port 173.

It is to be understood, of course, that when pressure is developed in either end of the cylinder 175 there must be no pressure developed in the other end of the cylinder, otherwise the piston 176 would not move. In practice the two discs 192 and 193 are, as we have said, on the common shaft 191, and there is an equal number of stops on each disc. The discs are individually adjustable around the shaft 191 and they are set in relative rotative positions so that the stops 94 and 95 operate the shutters successively. For example, if it is desired that there be four complete cycles of operation for each revolution of the shaft 191, then we provide four stops 194 on the disc 192, and we provide four stops 195 on the disc 193, and we arrange the two discs in different rotative positions so that as the shaft 191 turns the shutter 85 will be operated and then, at a predetermined interval thereafter the shutter 183 will be operated. Following this cycle of operation the next succeeding stop 194 will come into position and the shutter 195 will be operated for the second time, and following this, at the desired interval, the shutter 183 will be operated for the second time, and this sequence continuously repeats itself so long as the shaft 191 rotates.

In the particular mechanism illustrated the stops 194 and 195 operate the shutters through spring arms 198 on the shutters, which arms make it unnecessary to provide a very fine adjustment of the parts. The various parts are related and proportioned so that the shutters are only momentarily operated, that is, they are not held closed, with the result that when the piston 176 has been moved to either end of its stroke the pressure that operated it is released and the mechanism is ready for the next operation as soon as a shutter is operated by one of the stops. In other words the system is such that the pilot pressure is normally exhausted from the two ends of the cylinder 175 and positive pressure is developed in the cylinder only long enough to move the piston 76 from one end to the other, depending upon which shutter is operated.

From the foregoing description it will be apparent that the intermitter 70 is in reality the timer for the parts operating in the well, that is, it is the timing device that determines when

the gas control valve located down in the well is operated. The intermitter accomplishes this control through the valves 65 and 67 which, in turn, control the movement of the cylinder and piston mechanism that lifts the flow string, which in reality is a valve stem for the movable valve element of the gas control valve in the well. By providing for simple accurate adjustment of the intermitter, as above described, we are able to conveniently and accurately adjust the action of the well parts.

The period of rest gained at the upper end or top of the stroke through proper setting of the intermitter may be, and preferably is, such as to allow sufficient time for full emptying of the displacement chamber, and likewise, the period of rest gained at the lower end or bottom of the stroke by proper setting of the intermitter may be, and preferably is such as to allow complete filling of the displacement chamber from the well. By setting the intermitter so that the periods of rest allow complete emptying and complete filling of the displacement chamber without excess time delay we gain maximum operating efficiency. It is to be noted that the intermitter is located at the surface of the well and it is through this unit of surface equipment that we are able to vary the periods of rest at the top and bottom of the stroke to initially gain proper setting, and to vary the setting from time to time as well conditions may change. It should be further noted that we can vary either time period, that is, either the period of rest at the top of the stroke, or the period of rest at the bottom of the stroke, or both, and can do this without in any way alterating or manipulating the equipment in the well.

In accordance with our invention we provide a body of liquid L to be handled by the accumulator and to be conducted to the means D to operate it. A suitable conduit 80 is provided connecting the lower end of the accumulator with the lower end of the cylinder of the means D. We provide a control valve 81 in the connection 80 and a by-pass 82 around the valve 81. The by-pass is provided with a check valve 83 arranged to allow free flow only from the means D to the accumulator past the valve 81.

The valve 81 is a normally open motor valve preferably designed to be operated by pilot gas supplied through a gas connection 85 which is joined to the diaphragm or power element of the valve 81. In accordance with our invention a three-way pilot valve 90 controls the supply and exhaust of pilot gas to and from the gas connection 85 so that it controls the action of the valve 81.

The pilot valve 90 shown in Fig. 3 is preferably a simple slide valve including a cylindrical body 91 having a large bore 92 at one end and a small bore 93 at the other end which bores join to form a seat 94. A pilot gas supply connection 95 is connected into the large bore 92 and the pilot gas line 85 connects into the inner end portion of the small bore 93. An exhaust port 101a connects into the outer end portion of the small bore.

A valve element operates in the body 91 and has a large head 96 operating in the large bore 92 and a small head 97 operating in the small bore 93. A stem 98 connects the heads 96 and 97. A spring 99 carried in a suitable cage 100 normally urges the valve to a position where the large head 92 engages the seat 94 thus closing off communication between the supply connection 95 and the pilot pipe 85.

An extension 101 of the valve member proper projects from one end of the body 91 so that it can be operated to move the valve against the spring 99 to a position where the large head 96 is away from the seat 94 establishing connection between the supply connection 95 and the pipe 85, before which time the small head has moved to a position where it covers an exhaust port 101a which is normally open.

The general relationship of the parts thus far described is such that when the valve of the pilot valve 90 is operated against the action of the spring 99 the valve 81 is closed so that fluid under pressure from the accumulator is cut off from entering the cylinder of the means D.

To effect operation of the pilot valve 90 at the desired point during operation of the displacement unit and control in the well we provide an operating connection between the reciprocating element of the control B and the pilot valve 90. Since the working elements of the displacement unit A and of the gas control B are directly linked to the flow string 16 and the flow string is coupled to the piston 49 of the means D we take the operating movement from the piston rod 49.

In the preferred arrangement we provide an adjustable collar 110 on the piston rod 49, and we provide a hinged lever or trigger 111 to actuate the extension 101 of the valve 90. The valve 90 is supported by mounting bracket 113 so that it is at the upper side of the upper head 48 and the trigger 111 which engages the valve extension 101 is pivotally mounted on a bracket arm 111a located adjacent to or in the vicinity of the piston rod 49 as it passes in the zone between the head 48 and the delivery pipe 55. The collar 110 is fixed on the piston rod 49 to pass freely through an enlarged opening 115 in the head 48 and is proportioned so that it will engage and operate the trigger 111. In practice it is desirable to adjust or regulate the position of the actuating collar 110 along the piston rod 49 and, therefore, we split the collar so it is in two sections which assemble around the piston rod. The two sections of the collar are held in tight gripping engagement with the rod by means of annular coiled springs 117.

In operating or during operation of the mechanism that we have thus far described, assuming that the flow tube of the displacement unit is at the lower end of its stroke, or that the flow string 16 is down, the intermitter 70 (Fig. 1) operates to close valve 67 and open valve 65 with the result that high pressure gas from the line 62 enters the top or upper end of the accumulator 61 exerting high pressure on the liquid L in the accumulator. The normally open valve 81 allows the fluid under pressure to pass from the lower end of the accumulator through the connection 80 to the bottom end of the cylinder of the means D. The liquid thus introduced into the cylinder of means D forces the piston 50 up through the cylinder 46 thus causing the flow string which is connected to the piston rod 49 to move up.

The upward movement of the flow string will continue until the movable element or plunger of the gas control B admits gas under pressure to the chamber X of the displacement unit A, whereupon there will be a tendency for the upward movement of the flow string to accelerate due to the pressure acting under plunger 31 instead of only above it. Rather than attempt to mechanically stop this acceleration of the flow

string we use this movement or this portion of the movement of the flow string to bring the collar 110 into cooperative engagement with the trigger 111 so that the three-way pilot valve 90 is then operated. It should be noted that the construction of the control B in the well is such as to allow for considerable overtravel after the control has opened to allow high pressure gas to enter the displacement unit A. It is during this overtravel that the pilot valve is operated to cause gradual termination of the upward movement of flow string 16.

As soon as the three-way pilot valve 90 is operated by the collar 110 the valve 81 starts to close so that flow of operating fluid to the cylinder of the means D is cut down and finally cut off completely. The pressure used in the pilot system and the size and length of the pipes handling pilot gas are related to the diaphragm control of the valve 81 so that it takes some little time, say a fraction of a second, after valve 90 is operated before the valve 81 is actually closed and, therefore, the tubing comes to rest gradually or slowly, and thus prevents jarring of the parts. The intermitter 70 is set so that following closing of valve 81 there is a time interval when piston 50 remains in its up position to allow the displacement chamber in the well to empty after which valve 65 closes and valve 67 opens, so gas exhausts from the accumulator through the connection 66 to the flow line 55. When this occurs the fluid under the piston 50 in the means D is free to escape through the connection 80 and the by-pass 82 and check valve 83 so that it returns into the accumulator. It is to be noted that the weight of the flow string will put pressure on the liquid under the piston 50 to exhaust it from the cylinder of means D back into the accumulator 61.

Through the interconnection of the gas control B at the displacement unit A and the control means E through the pilot valve 90 of the control means we effect a highly efficient and satisfactory operation. There is no damage or difficulty resulting from the surge or acceleration which occurs when the high pressure gas is suddenly admitted to the pump, and the entire system operates smoothly and automatically without the excessive use of gas and without requiring constant or careful supervision.

From the foregoing description it will be apparent that the accumulator 61 handles a body of operating fluid, as for instance, oil or the like, which body of liquid is held in the bottom of the accumulator while high pressure gas is introduced into the top of the accumulator to exert pressure on the liquid. It will be understood that should leakage occur in the system so that the liquid normally handled by the accumulator is dissipated or lost, the high pressure gas might find its way from the accumulator to the means D and cause erratic or unsuitable operation of the means D. To eliminate the possibility of gas ever reaching the means D we provide a liquid level control means in connection with the accumulator. We may provide a stop valve 250 in the line 80 at the accumulator under control of a float control means 231. In the drawings we have shown a stop valve 250 which is normally open and we show a typical float control device 231 connected into the lower portion of the accumulator and joined to the valve 250 by suitable linkage 252. These parts normally have no influence on the operation of the apparatus but rather they remain inactive. However, should the level of liquid in the accumulator fall below a predetermined point the float control 231 will operate and through the linkage 252 will operate the stop valve 250 so that the line 80 is cut off, separating the accumulator from the means D.

In accordance with our invention we provide means to check downward movement of the piston 50 in cylinder 51 as it reaches the lower end of its stroke, in order to prevent a hammer or jar such as would otherwise occur if the piston were allowed to be stopped solely by the cylinder head 47. In the preferred arrangement we provide an annular cup 47^x on the inner side of the lower cylinder head 47 concentric with the piston rod 49 and we provide the cup with a finished bore 47^z. A downwardly extending projection 47^y is provided on the lower side of piston 50 and this projection has its exterior 47^w turned to slidably fit into the bore 47^z. As the piston 50 approaches the lower end of its stroke the projection 47^y enters the cup 47^x and the fit between the projection and cup is such as to allow the actuating fluid trapped in the cup to gradually escape. The mechanism acts as a hydraulic check or stop that effectively prevents hammering or sudden shock when the piston reaches the lower end of its stroke.

From the foregoing description it will be apparent that we have provided apparatus for lifting fluid from a well through the use of a system or arrangement that is closed from the well, that is, the only opening or connection provided between the well, or interior of the well casing 10, and the apparatus that we have provided is through the bottom end of barrel 18 past the bottom valve 20 and since the bottom valve 20 is, in effect, a check valve positively preventing flow out through the bottom of the barrel 18, the apparatus that we have provided is closed so that we never create appreciable pressure on the well or the well formation. The amount of gas exhausted into the well through the control B is, in practice, negligible. The absence of back pressure is a highly important factor in that for effective handling of well fluids with apparatus such as we have provided the actuating medium, for instance, the gas employed in the annulus 17, is necessarily under high pressure and if such pressure is allowed to come upon the well or the well formation it may, and in fact in practically all cases it would materially retard, if not kill, the well. By providing a closed system and by thus keeping pressure off the well we remove the well fluid and at the same time create a condition in the well which actually induces higher production from the well.

By having provided apparatus which forms a closed system and through the particular arrangement which characterizes our invention, the high pressure actuating gas in the annulus 17 flows down through the control B and in thus flowing, and if there is any leakage through the control, that is between the plunger and its barrel, these parts are swept clean so that they may actually operate dry. It is apparent that these parts must handle or control high pressures and consequently will operate more efficiently and without danger of fouling or becoming injured if they are not dry but, rather, are lubricated.

In accordance with our present invention we provide lubrication for the working parts of the control B. We do this by introducing a suitable lubricant into the annulus 17 through the head 11. In accordance with the preferred form of the invention a suitable amount of lubricant is

fed to the annulus 17 as the apparatus operates and to assure the proper feed of lubricant, that is, to assure the feed of lubricant when the apparatus operates, and a quantity of lubricant proportionate to the operation of the apparatus, we coordinate the lubrication with the action of the apparatus.

In the form of the invention illustrated we provide a lubricant pump 300 driven by a gas motor 301 supplied from line 63 through a pressure regulator 302. The pump draws lubricant from a suitable supply reservoir 303 and delivers it to the head 11 to enter the annulus 17. The lubricant pump can be operated by the gas pressure or from the reciprocating element of the apparatus, for instance, it may be connected to the piston rod 19 so that it is operated each time the piston rod acts through its cycle of operation.

The lubricant delivered in suitable quantity and at suitable intervals to the annulus 17 falls by gravity down through the annulus and is finally deposited at the upper end of the control B, that is, at the point where the high pressure gas enters the control for admittance to the displacement unit. The lubricant thus deposited finds its way or is forced between the relatively working parts of the control B and in practice practically all of it finds its way through the control B either between the working parts or with the operating gas, so that it is deposited with the well fluid in the chamber 23 and is carried out of the well through the action hereinabove described.

In order that it may be fully appreciated that we have by our invention provided a combination of elements that will accomplish results not obtainable with ordinary so-called gas lifts, we would explain that our mechanism will work efficiently when taking well fluid from a well at a depth of approximately eight thousand feet, or more. In such application of the invention the initial actuating pressure, that is, the pressure at which the actuating gas is introduced into the head 11 to enter the annulus 17 may be approximately 1200 pounds per square inch. There may be a pressure drop of about 150 pounds per square inch in the annulus from the top of the well to the point where the control B admits the gas to the displacement unit so that there is a displacing pressure of about 1050 pounds per square inch applied to the fluid in the displacement unit.

From the foregoing description it will be apparent that we have provided a fluid lifting apparatus which is subject to considerable variation making it practical for use under a wide range of well conditions. In practice the apparatus that we have provided is so flexible that it can be used from the time that a well requires an artificial lift until it is ready for abandonment.

It should be noted that the gas employed exhausts through the ports 33 into the space between the tubing 13 and the well casing 10 so that it can be bled or taken from the head 11 through a suitable bleeder connection 120 which, in turn, connects into the delivery pipe 55 through a pressure regulating valve 120a so that there is no waste whatever of gas. When the various parts are thus connected the gas used in displacing fluid at the displacement unit A is led to the delivery line, the gas passed into the flow string by the density control regulator C and the gas used in the accumulator all flows to the delivery line 55 so that it is not wasted and so that the system is entirely enclosed. As a result of the hook-up that we have provided the high pressure gas entering the apparatus through the connection 62 performs the various functions we have described and then finally discharges from the apparatus with the pumped fluid through the delivery pipe 55.

Having described only a typical preferred form and application of our invention, we do not wish to be limited or restricted to the specific details herein set forth, but wish to reserve to ourselves any variations or modifications that may appear to those skilled in the art and fall within the scope of the following claims:

Having described our invention, we claim:

1. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line.

2. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line and including a stationary barrel forming a displacement chamber, a flow tube to be reciprocated in the barrel, and valves controlling flow of well fluid through the chamber, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom including a tubular valve barrel forming a connection between the tubing and the first mentioned barrel and a valve plunger forming a coupler and fluid connection between the flow line and flow tube and slidably operating in the said valve barrel, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line.

3. Apparatus for pumping a well by gas under pressure including, a fixed tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a pump carried in the well from said tubing and line, a gas control at the pump operable by reciprocation of the flow line to admit

gas from the tubing to the pump to displace well fluid from the pump into the flow line and to exhaust gas from the pump following displacement of well fluid therefrom, one or more adjustable density control regulators spaced along the flow line to admit gas from the annulus into the flow line to facilitate flow of well fluids upward through the flow line, a cylinder and piston actuator at the top of the well for reciprocating the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line.

4. Apparatus for lifting fluid from a well by pressure fluid including, a stationary tubing extending into the well and receiving fluid under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a fluid control at the unit operable by reciprocation of the flow line to admit fluid from the tubing to the unit to displace well fluid from the unit into the flow line and to exhaust fluid from the pump into the well around the tubing following displacement of well fluid therefrom, a delivery line receiving well fluid from the flow line at the top of the well, a connection between the well around the tubing and the delivery line so that fluid from the well enters the delivery line, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line for stopping flow of said fluid to the cylinder to stop upward movement of the line.

5. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit into the well around the tubing following displacement of well fluid therefrom, a delivery line receiving well fluid from the flow line at the top of the well, a connection between the well around the tubing and the delivery line so gas from the well enters the delivery line, a density control regulator in the flow line adjacent the unit to admit gas from the tubing into the flow line when a predetermined pressure differential exists between the flow line and tubing to facilitate flow of well fluids upward through the flow line, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line.

6. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and holding gas to exert pressure on the liquid, an inlet valve controlling gas flow to the accumulator, an exhaust valve controlling exhaust of gas from the accumulator, an intermitter controlling the inlet and exhaust valves to alternately open and close them, a liquid handling connection between the accumulator and cylinder, a control valve in said connection, and means controlling the control valve from the flow line so the control valve closes following operation of the gas control to admit gas to the pump.

7. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and holding gas to exert pressure on the liquid, an inlet valve controlling flow of gas to the accumulator, an exhaust valve controlling exhaust of gas from the accumulator, an intermitter controlling the inlet and exhaust valves to alternately open and close them, a liquid handling connection between the accumulator and cylinder, a control valve in said connection, a bypass in the connection around the control valve allowing flow only from the cylinder, and means controlling the control valve from the flow line so the control valve closes the following operation of the gas control to admit gas to the unit.

8. Apparatus for handling well fluid by gas under pressure including, a fixed tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the pump to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved

upwardly and including means controlled by the said line stopping flow of said liquid to the cylinder to stop upward movement of the line, the said means including a valve with a control part and a member moved with the flow line to engage and operate the control part.

9. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

10. Apparatus for handling a well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for limiting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve at the actuator controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

11. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line and including a stationary barrel forming a displacement chamber, a flow tube to be reciprocated in the barrel and valves controlling flow of well fluid through the chamber, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the pump to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom including a tubular valve barrel forming a connection between the tubing and barrel of the unit and a valve plunger forming a coupler and fluid connection between the flow line and flow tube and slidably operating in the valve barrel, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

12. Apparatus for handling well fluid by gas under pressure including, a fixed tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and adapted to receive high pressure gas from a supply line, an inlet valve controlling the admission of high pressure gas to the accumulator, an exhaust valve controlling the exhaust of gas from the accumulator, a liquid connection between the cylinder and accumulator, a control valve in said connection, and a pilot valve operated by the flow line controlling operation of the control valve.

13. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and adapted to receive high pressure gas from a supply line, an inlet valve controlling the admission of high pressure gas to the accumulator, an exhaust valve controlling the exhaust of gas from the accumulator, a liquid connection between the cylinder and accumulator, a control valve in such connection, a bypass around the control valve so the weight of the flow line displaces liquid from the cylinder to the accumulator when the control valve is closed and the exhaust valve is open, and a pilot valve operated by the flow line controlling operation of the control valve.

14. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to

the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit into the well around the tubing following displacement of well fluid therefrom, a delivery line receiving well fluid from the flow line at the top of the well, a connection between the well around the tubing and the delivery line so that gas from the well enters the delivery line, a cylinder and piston actuator at the top of the well for lifting the flow line, a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and adapted to receive high pressure gas from a supply line, an inlet valve controlling the admission of high pressure gas to the accumulator, an exhaust valve controlling the exhaust of gas from the accumulator, a liquid connection between the cylinder and accumulator, a control valve in said connection, a bypass around the control valve so the weight of the flow line displaces liquid from the cylinder to the accumulator when the control valve is closed and the exhaust valve is open, and a pilot valve operated by the flow line controlling operation of the control valve, and a connection from the exhaust valve to the delivery line.

15. Apparatus for handling well fluid by gas under pressure including a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit into the well around the tubing following displacement of well fluid therefrom, a delivery line receiving well fluid from the flow line at the top of the well, a connection between the well around the tubing and the delivery line so gas from the well enters the delivery line, a density control regulator in the lower end of the flow line to admit gas from the tubing into the flow line to facilitate flow of well fluids upward through the flow line, a cylinder and piston actuator at the top of the well for lifting the flow line, a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and adapted to receive high pressure gas from a supply line, an inlet valve controlling the admission of high pressure gas to the accumulator, an exhaust valve controlling the exhaust of gas from the accumulator, a liquid connection between the cylinder and accumulator, a control valve in said connection, a bypass around the control valve so the weight of the flow line displaces liquid from the cylinder to the accumulator when the control valve is closed and the exhaust valve is open, and a pilot valve operated by the flow line controlling operation of the control valve, and a connection from the exhaust valve to the delivery line.

16. Apparatus for handling well fluid by gas under pressure including a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the pump following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and adapted to receive high pressure gas from a supply line, an inlet valve controlling the admission of high pressure gas to the accumulator, a pressure regulating valve between the inlet valve and accumulator, an exhaust valve controlling the exhaust of gas from the accumulator, a liquid connection between the cylinder and accumulator, a control valve in said connection, and a pilot valve operated by the flow line controlling operation of the control valve.

17. In apparatus for elevating liquid from a deep well, a tubing extending downwardly in the well and into the fluid therein, an anchor holding the lower end portion of the tubing against movement in the well, a flow line extending downwardly through the tubing with clearance, a gas control valve including a valve barrel held stationary by the lower end of the tubing, and a valve plunger operable by the flow line and sliding in said barrel, a displacement barrel depending from the valve barrel, an inlet valve at the lower end of the displacement barrel, a flow tube depending from the valve plunger into the displacement barrel, an outlet valve at the upper end of the flow tube, a vent valve in the flow tube below the outlet valve for venting gas from the flow tube to the displacement barrel when the outlet valve is closed, means supplying high pressure gas into the upper end of the tubing, means supplying lubricant to the upper end of the tubing to flow downwardly therethrough to the said valve barrel and valve plunger, a density control regulator in the lower end portion of the flow line operable to admit gas from the tubing to the flow line when a predetermined pressure differential exists between the tubing and flow line, the said valve plunger having a part normally fitting the valve barrel to close it and being movable upward to a point out of the valve barrel to allow gas from the tubing to pass through the valve barrel to the displacement barrel, an actuator for moving the flow line to reciprocate the valve plunger including, a cylinder and piston mechanism at the head of the well, a piston rod operated by said mechanism and connected to the flow line, and means for supplying liquid under pressure to the cylinder to operate the piston, including valve means for alternately admitting high pressure liquid under the piston and allowing it to escape from under the piston and a pilot valve control for the valve means operated by the said rod whereby the valve means acts so flow of fluid to the cylinder is slowly checked upon the rod reaching a predetermined point in the course of its upward movement.

18. In apparatus for elevating liquid from a deep well having a casing therein and a liner at the lower end of the casing, a tubing extending downwardly in the well and into the fluid therein, an anchor between the lower end portion of the tubing and the lower end portion of the casing in the well holding the lower end portion of the tubing against movement, a flow line extending

downwardly through the tubing with clearance, a gas control valve including a valve barrel depending from the lower end of the tubing and a tubular valve plunger depending from the lower end of the flow line and sliding in the barrel, a displacement barrel depending from the lower end of the valve barrel, an inlet valve at the lower end of the displacement barrel, a flow tube depending from the valve plunger into the displacement barrel to reach the lower portion thereof, an outlet valve at the upper end of the flow tube, a vent valve in the flow tube below the outlet valve, a fixed stop in the lower end portion of the displacement barrel located at a predetermined distance below the lower end of the flow tube when the valve plunger is at the lower end of its stroke in the valve barrel, means supplying high pressure gas into the upper end of the tubing, means supplying lubricant to the upper end of the tubing to flow downwardly therethrough to said valve barrel and valve plunger to lubricate them, a density control regulator in the lower end portion of the flow line operable to admit gas from the tubing to the flow line when a predetermined pressure differential exists between the tubing and the flow line, the said valve plunger having a part normally fitting the valve barrel to close it and being movable upward to a point where it is out of the valve barrel to allow gas from the tubing to pass through the valve barrel to the displacement barrel, the valve plunger and valve barrel having cooperating parts allowing gas from the displacement barrel to escape into the well casing when the said part of the valve plunger is located in the valve barrel to close it, an actuator for moving the flow line to reciprocate the valve plunger including, a cylinder and piston mechanism at the head of the well including means for cushioning the piston at the lower end of the stroke in the cylinder, means for bodily adjusting the cylinder and piston mechanism vertically, a tubular piston rod joined to the upper end of the flow line and projecting upwardly through the said mechanism and carrying the piston, a fluid delivery line having a vertical section with an upper part connected to the cylinder and piston mechanism to move therewith and connected with the upper end of the rod to receive fluid therefrom, a lower part in line with the upper part and mounted so it is stationary, and a slip joint between said parts of the delivery line, and means for supplying liquid under pressure to the cylinder under the piston and for exhausting such liquid from under the piston including, an accumulator carrying a body of liquid, valve means under control of an intermitter for alternately admitting gas under high pressure to the accumulator above the liquid therein, a liquid connection between the accumulator and cylinder including, an inlet valve and an outlet bypass connection around the inlet valve and a pilot valve controlling the said inlet valve and operated from the piston rod when said rod reaches a predetermined point in its upward travel to cause gradual closing of the said inlet valve.

19. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, the gas control including a stationary part carried by the tubing and a reciprocating part carried by the flow line, anchor means located in the well to check movement of the said stationary part, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line.

20. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, the gas control including a stationary part carried by the tubing and a reciprocating part carried by the flow line, anchor means on the lower end portion of the stationary tubing to hold that portion of the tubing so the said stationary part does not move, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line.

21. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, the gas control including a stationary part carried by the tubing and a reciprocating part carried by the flow line, anchor means located in the well to check movement of the said stationary part, and an actuator at the top of the well for lifting the flow line.

22. Apparatus for lifting fluid from a well by gas under pressure, which well has a casing and a liner at the lower end of the casing, including, a stationary tubing extending into the well through the casing and into the liner and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adopted to be reciprocated, a displacement unit carried in the well from the lower ends of the tubing and liner, a gas control at the unit operable by reciprocation of the line to admit gas from the tubing to the unit so well fluid is displaced therefrom by the gas into the flow line and to exhaust gas from the unit to the well, the gas control including a stationary part carried by the tubing and a reciprocating

part carried by the flow line, anchor means located in the well to check movement of the said stationary part, including an anchor between the tubing and the lower end portion of the casing, and an actuator at the top of the well for lifting the flow line.

23. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and holding gas to exert pressure on the liquid, an inlet valve controlling gas flow to the accumulator, an exhaust valve controlling exhaust of gas from the accumulator, an intermitter controlling the inlet and exhaust valves to alternately open and close them, a liquid handling connection between the accumulator and cylinder, a control valve in said connection, and means controlling the control valve from the flow line so the control valve closes slowly following operation of the gas control to admit gas to the pump.

24. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and holding gas to exert pressure on the liquid, a liquid level control in connection with the accumulator to stop flow therefrom when the liquid level in the accumulator drops below a predetermined point, an inlet valve controlling gas flow to the accumulator, an exhaust valve controlling exhaust of gas from the accumulator, an intermitter controlling the inlet and exhaust valves to alternately open and close them, a liquid handling connection between the accumulator and cylinder, a control valve in said connection, and means controlling the control valve from the flow line so the control valve closes following operation of the gas control to admit gas to the pump.

25. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including an accumulator handling said liquid and holding gas to exert pressure on the liquid, and a liquid level control in connection with the accumulator to stop flow therefrom when the liquid level in the accumulator drops below a predetermined point.

26. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, means for gradually stopping the piston at the lower end of its stroke in the cylinder, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including means acting to gradually stop flow of liquid to the cylinder.

27. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the unit to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, means for gradually stopping the piston at the lower end of its stroke in the cylinder including cooperating parts in connection with the cylinder and piston trapping a body of fluid for gradual escape, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including means acting to gradually stop flow of liquid to the cylinder.

28. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line and including a stationary barrel forming a displacement chamber, a flow tube to be recipro-

cated in the barrel and valves controlling flow of well fluid through the chamber, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the pump to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom including a tubular valve barrel forming a connection between the tubing and barrel of the unit and a valve plunger forming a coupler and fluid connection between the flow line and flow tube and slidably operating in the valve barrel, a density control regulator in the flow line adjacent the gas control to admit gas from the tubing to the flow line when a predetermined pressure differential exists between the tubing and flow line, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

29. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, an anchor holding the lower end portion of the tubing against movement in the well, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line and including a stationary barrel forming a displacement chamber, a flow tube to be reciprocated in the barrel and valves controlling flow of well fluid through the chamber, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the pump to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom including a tubular valve barrel forming a connection between the tubing and barrel of the unit and a valve plunger forming a coupler and fluid connection between the flow line and flow tube and slidably operating in the valve barrel, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

30. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line and including a stationary barrel forming a displacement chamber, a flow tube to be reciprocated in the barrel and valves controlling flow of well fluid through the chamber, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the pump to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom including a tubular valve barrel forming a connection between the tubing and barrel of the unit and a valve plunger forming a coupler and fluid connection between the flow line and flow tube and slidably operating in the valve barrel, a density control regulator in the flow line adjacent the gas control to admit gas from the tubing to the flow line when a predetermined pressure differential exists between the tubing and flow line, an unloading valve in the flow line operable to open when pressure in the flow line exceeds that in the tubing so fluid in the flow line passes into the tubing, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

31. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line and including a stationary barrel forming a displacement chamber, a flow tube to be reciprocated in the barrel and valves controlling flow of well fluid through the chamber, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the pump to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom including a tubular valve barrel forming a connection between the tubing and barrel of the unit and a valve plunger forming a coupler and fluid connection between the flow line and flow tube and slidably operating in the valve barrel, means supplying lubricant to the tubing for lubricating the gas control, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

32. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, an anchor holding the lower end portion of the tubing against movement in the well, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line and including a stationary barrel forming a displacement chamber, a flow tube to be reciprocated in the barrel and valves controlling flow of well fluid through the chamber, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the pump to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom including a tubular valve barrel forming a connection between the tubing and barrel of the unit and a valve plunger

forming a coupler and fluid connection between the flow line and flow tube and slidably operating in the valve barrel, a density control regulator in the flow line adjacent the gas control to admit gas from the tubing to the flow line when a predetermined pressure differential exists between the tubing and flow line, an unloading valve in the flow line operable to open when pressure in the flow line exceeds that in the tubing so fluid in the flow line passes into the tubing, means supplying lubricant to the tubing for lubricating the gas control, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

33. Apparatus for handling well fluid by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line and including a stationary barrel forming a displacement chamber, a flow tube to be reciprocated in the barrel and valves controlling flow of well fluid through the chamber, there being a valve controlling flow from the upper end of the flow tube into the flow line, a vent valve in the upper end portion of the flow tube below the last mentioned valve operable to vent gas from the flow tube when the said last mentioned valve is closed, a gas control at the unit operable by reciprocation of the flow line to admit gas from the tubing to the pump to displace well fluid from the unit into the flow line when the said line approaches the upper end of its stroke and to exhaust gas from the unit following displacement of well fluid therefrom including a tubular valve barrel forming a connection between the tubing and barrel of the unit and a valve plunger forming a coupler and fluid connection between the flow line and flow tube and slidably operating in the valve barrel, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating liquid under pressure to the cylinder to move the piston so the line is moved upwardly including a control valve controlling flow of liquid to the cylinder, a pilot valve controlling the control valve, and an operating element on the flow line cooperating with the pilot valve.

34. In combination, a tubular member extending into a well, means in the well controlled by movement of said member acting to circulate fluid up through said member, and an actuator for said member located at the top of the well and including, a cylinder and piston mechanism, a tubular rod connected with the upper end of the said tubular member and extending vertically through the mechanism and carrying the piston and passing fluid received from said member, means for adjusting the cylinder and piston mechanism vertically, and a delivery conduit to receive fluid from the upper end of the rod including a vertically disposed section with an upper part receiving fluid from the rod, a lower part in line with the upper part, and a slip joint connecting the parts so they remain connected as the mechanism is adjusted.

35. In combination, a tubular member extending into a well, means in the well controlled by movement of said member acting to circulate fluid up through said member, and an actuator for said member located at the top of the well and including, a cylinder and piston mechanism, a tubular rod extending vertically through the mechanism and carrying the piston and connected to said member to conduct fluid from said member up through the cylinder and piston mechanism, means for adjusting the cylinder and piston mechanism vertically including a stationary flange and means adjustably connecting the flange and cylinder, and a delivery conduit to receive fluid from the upper end of the rod including a vertically disposed section with an upper part connected with the cylinder to move therewith and receiving fluid from the rod, a lower part connected with the flange to move therewith, and a slip joint between the parts.

36. In combination, a tubular member extending into a well, means in the well controlled by movement of said member acting to circulate fluid up through said member, and an actuator for said member located at the top of the well and including, a cylinder and piston mechanism, a tubular rod extending vertically through the mechanism and carrying the piston and connected to said member forming a flow conducting continuation thereof, means for adjusting the cylinder and piston mechanism vertically, and a delivery conduit to receive fluid from the upper end of the rod including a vertically disposed section with an upper part, a head receiving fluid from the rod and delivering it to the said upper part, a lower part in line with the upper part, and a slip joint connecting the parts so they remain connected as the mechanism is adjusted.

37. Apparatus for lifting fluid from a well by gas under pressure including an anchored tubing in the well and receiving gas under pressure at the upper end of the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, means supplying lubricant to the tubing to lubricate the gas control valve, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said flow line, and means for moving the flow line to operate the gas control valve.

38. Apparatus for lifting fluid from a well by gas under pressure including an anchored tubing in the well and receiving gas under pressure at the upper end of the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to

the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, means supplying lubricant to the tubing at the top of the well so it flows down therethrough to the gas control valve to lubricate the gas control valve, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said flow line, and means for moving the flow line to operate the gas control valve.

39. Apparatus for lifting fluid from a well by gas under pressure including an anchored tubing in the well and receiving gas under pressure at the upper end of the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said flow line, an unloading valve in the flow line above the regulator to allow flow from the flow line to the tubing when pressure in the flow line exceeds that in the tubing, and means for moving the flow line to operate the gas control valve.

40. Apparatus for lifting fluid from a well by gas under pressure including an anchored tubing in the well and receiving gas under pressure at the upper end of the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, means supplying lubricant to the tubing to lubricate the gas control valve, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said flow line, an unloading valve in the flow line above the regulator to allow flow from the flow line to the tubing when pressure in the flow line exceeds that in the tubing, and means for moving the flow line to operate the gas control valve.

41. Apparatus for lifting fluid from a well by gas under pressure including tubing in the well and receiving gas under pressure at the upper end of the well, means anchoring the lower end portion of the tubing in the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said flow line, and means for moving the flow line to operate the gas control valve.

42. Apparatus for lifting fluid from a well by gas under pressure including a tubing in the well and receiving gas under pressure at the upper end of the well, means anchoring the lower end portion of the tubing in the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, means supplying lubricant to the tubing to lubricate the gas control valve, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said flow line, an unloading valve in the flow line above the regulator to allow flow from the flow line to the tubing when pressure in the flow line exceeds that in the tubing, and means for moving the flow line to operate the gas control valve.

43. Apparatus for lifting fluid from a well by gas under pressure including an anchored tubing in the well and receiving gas under pressure at the upper end of the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber to reciprocate therein, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, the control valve having a part reciprocating with the flow tube and a part held stationary by the tubing, a fixed stop in the lower end portion of the chamber located a predetermined distance below the gas control valve to be engaged by the flow tube when it is a predetermined distance below the lower end of its normal travel, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said

flow line, and means for moving the flow line to operate the gas control valve.

44. Apparatus for lifting fluid from a well by gas under pressure including an anchored tubing in the well and receiving gas under pressure at the upper end of the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber to reciprocate therein, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, the control valve having a part reciprocating with the flow tube and a part held stationary by the tubing, a fixed stop in the lower end portion of the chamber located a predetermined distance below the gas control valve to be engaged by the flow tube when it is a predetermined distance below the lower end of its normal travel, means supplying lubricant to the tubing to lubricate the gas control valve, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said flow line, an unloading valve in the flow line above the regulator to allow flow from the flow line to the tubing when pressure in the flow line exceeds that in the tubing, and means for moving the flow line to operate the gas control valve.

45. Apparatus for lifting fluid from a well by gas under pressure including an anchored tubing in the well and receiving gas under pressure at the upper end of the well, a tubular flow line in the well spaced within the anchored tubing and adapted to be moved, a displacement chamber and valve mechanism suspended in the well from said tubing and flow line, a flow tube on the lower end of the flow line extending into the chamber, a gas control valve at the upper end of the chamber operable by movement of the flow line to admit gas from the anchored tubing to the chamber to displace well fluid therefrom into the flow line and to exhaust gas from the chamber into the well externally of the anchored tubing following the displacement of well fluid from the chamber, a vent valve to exhaust gas from the flow tube to the chamber, a density control regulator to admit gas from the anchored tubing to the flow line at its lower end portion to control the density of the material in said flow line, and means for moving the flow line to operate the gas control valve.

46. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line, and a time control governing the escape of fluid from the cylinder following stopping of flow by said means.

47. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line, and a time control governing the escape of fluid from the cylinder following stopping of flow by said means and governing admission of fluid to the cylinder following escape of fluid therefrom.

48. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line, and a time control governing the escape of fluid from the cylinder following stopping of flow by said means and governing admission of fluid to the cylinder following escape of fluid therefrom, the time control including means for adjusting the time interval between the escape of fluid from the cylinder and the admission of fluid thereto.

49. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cyl-

inder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line, and a time control governing the escape of fluid from the cylinder following stopping of flow by said means and governing admission of fluid to the cylinder following escape of fluid therefrom, the time control including means for adjusting the time interval between successive admissions of fluid to the cylinder.

50. Apparatus for lifting fluid from a well by gas under pressure including, a stationary tubing extending into the well and receiving gas under pressure at its upper end, a tubular flow line extending into the well through the tubing and adapted to be reciprocated, a displacement unit carried in the well from said tubing and line, a gas control at the said unit operable by reciprocation of the flow line to admit gas from the tubing to the unit so well fluid is displaced by the gas from the unit into the flow line and to exhaust gas from the unit following displacement of well fluid therefrom, a cylinder and piston actuator at the top of the well for lifting the flow line, and a control for said actuator operable to admit operating fluid under pressure to the cylinder to move the piston so that the line is moved upwardly and including means controlled by the said line stopping flow of said fluid to the cylinder to stop upward movement of the line, and a time control governing the escape of fluid from the cylinder following stopping of flow by said means and governing admission of fluid to the cylinder following escape of fluid therefrom, the time

control including means for adjusting the time interval between successive admissions of fluid to the cylinder and means for adjusting the time interval between the escape of fluid from the cylinder and the admission of fluid thereto.

51. Apparatus for lifting fluid from a well by gas under pressure including, displacement means for location in the well, a valve in the well controlling admission of operating gas to the said means, the valve being a slide valve with a stationary body and reciprocating core, means holding the valve body stationary in the well, and an operating string for the core of the valve extending from the valve to the top of the well, and means at the top of the well reciprocating the said string from its upper end, the valve having provision for overtravel at the ends of its stroke to allow for stretch of the said string under varying operating conditions.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,777,536	Taylor	Oct. 7, 1930
2,157,219	Salentine	May 9, 1939
2,302,391	Nixon	Nov. 17, 1942
2,318,029	Thompson	May 4, 1943
2,336,808	Simon	Dec. 14, 1943
2,347,301	Twymen et al.	Apr. 25, 1944