Feb. 15, 1944. L. GRUMBAUGH 2,341,864

PNEUMATIC COUNTERBALANCE FOR WELL PUMPS

Filed Aug. 21, 1942 3 Sheets-Sheet 1

Fig. 1.

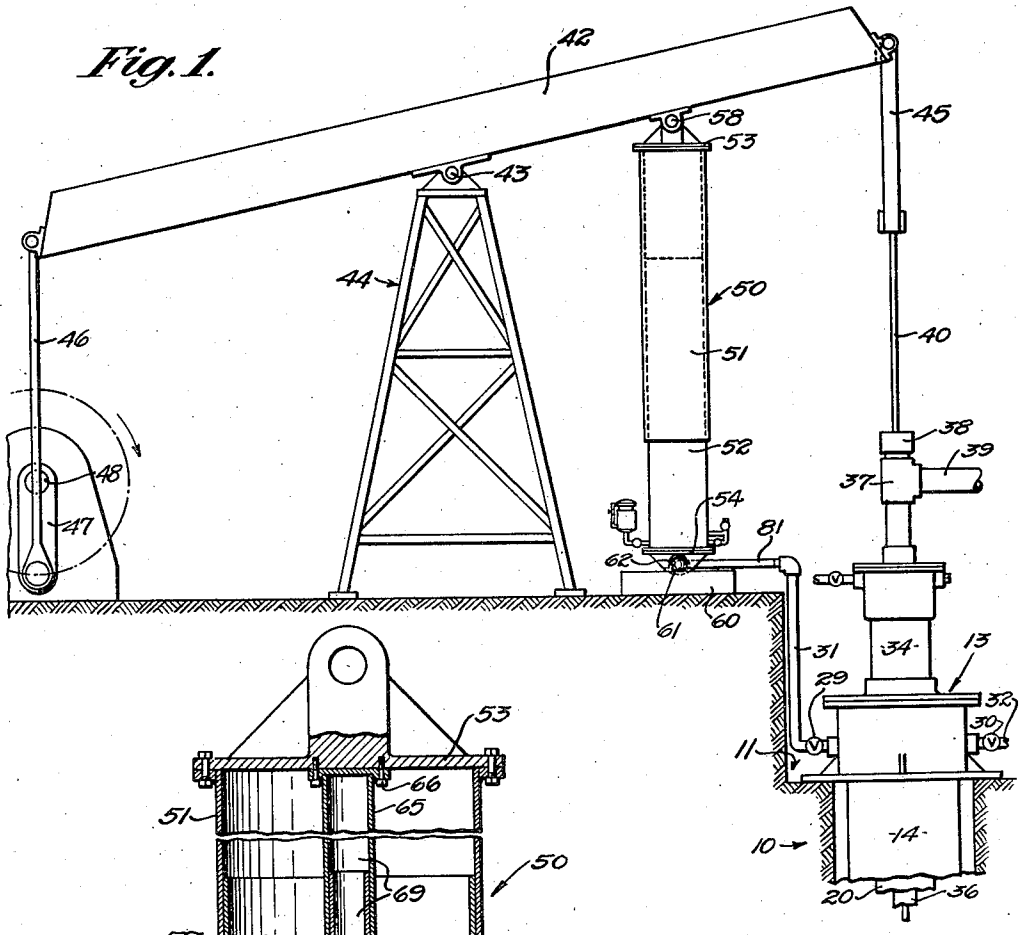
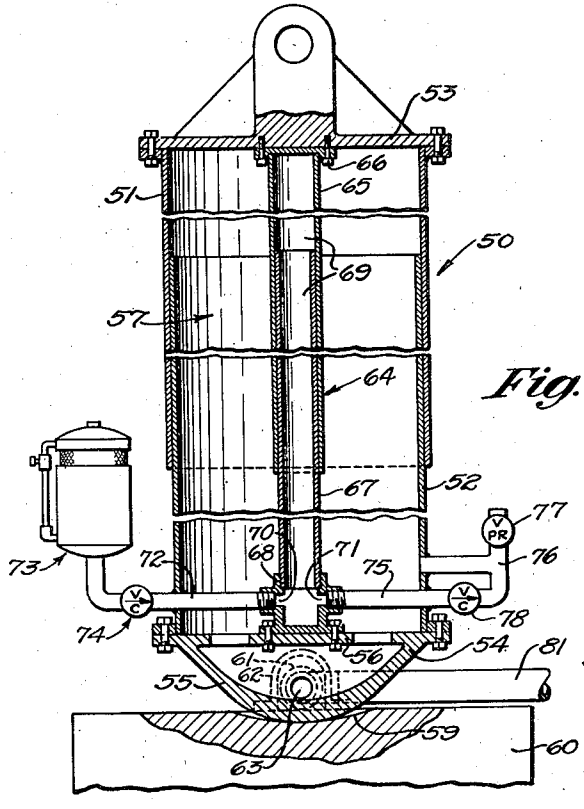


Fig. 3.



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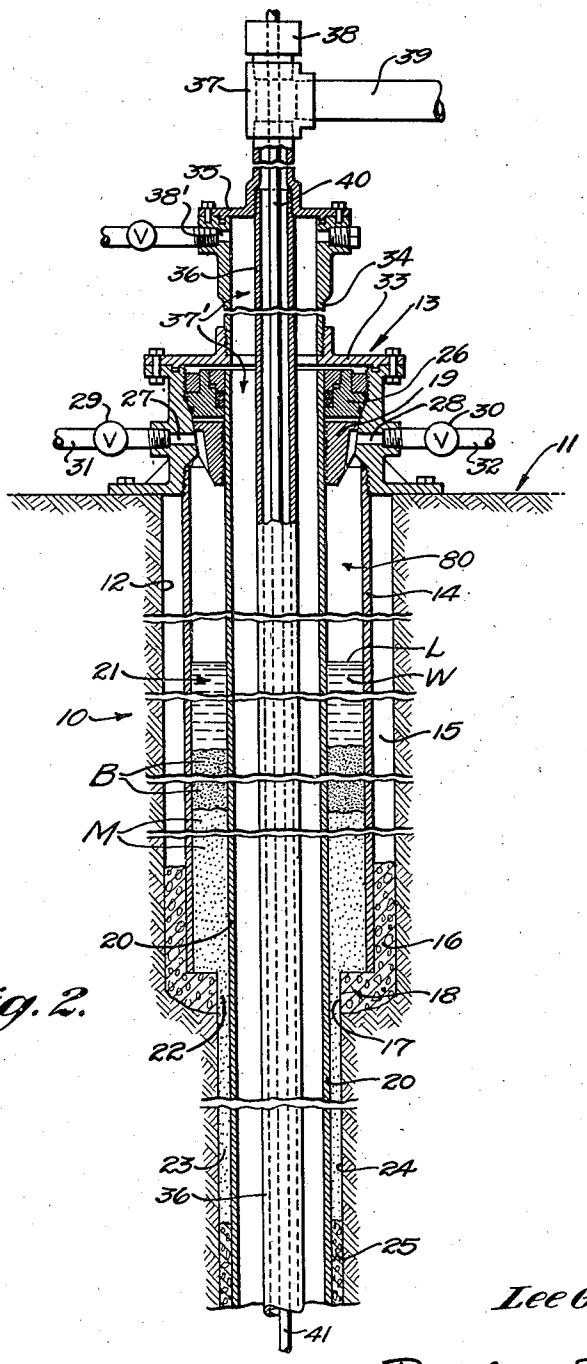


Fig. 2.

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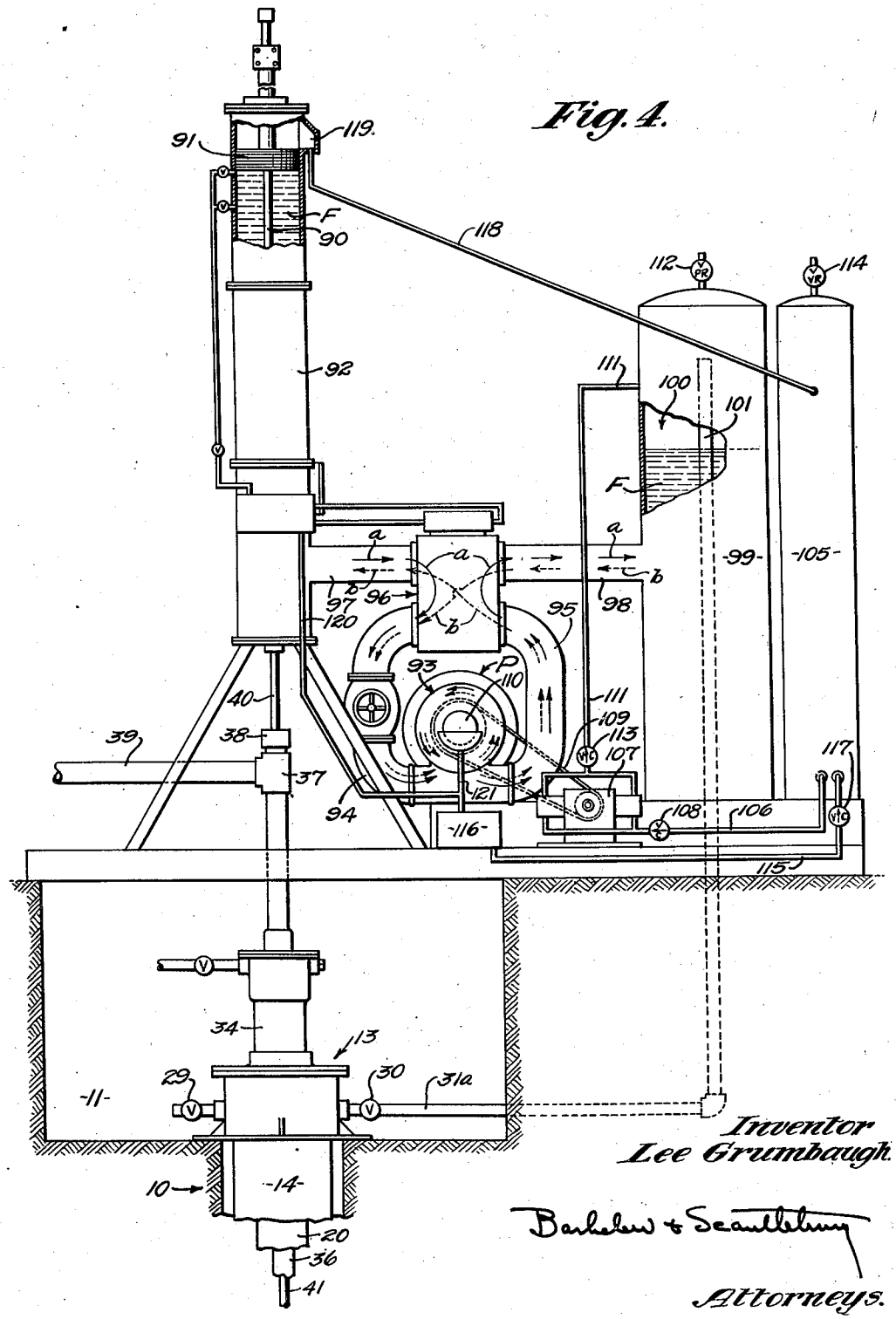
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PNEUMATIC COUNTERBALANCE FOR WELL PUMPS

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Fig. 4.



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UNITED STATES PATENT OFFICE

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PNEUMATIC COUNTERBALANCE FOR WELL PUMPS

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Application August 21, 1942, Serial No. 455,662

15 Claims. (Cl. 103—206)

This invention relates generally to pneumatic counterbalances for well pumps and is more particularly concerned with such counterbalances wherein there is incorporated the use of an accumulator or air reservoir in communication with the equalizing or compression chamber.

The invention is applicable to both mechanical and hydraulic types of pumping engines.

It is the principal object of the invention to provide a counterbalance whereby the general efficiency of pumping mechanisms is materially improved, particularly in the senses that pump rod reciprocation is smoothed out and that the load requirements on the prime mover are substantially evenly distributed, thus avoiding wide variations in the power input to the prime mover; and it is a further object to accomplish this by means which, in normal times, would be of significance enough, but, in these abnormal times of material and workman scarcity, is of the utmost significance.

As to this last point, advantage is taken of materials already at hand in every pumping installation, to supplant and improve upon elements which formerly had to be specially provided.

The general advantages of the pneumatic over the mechanical type of counterbalance, are well known. It has likewise been recognized that in the pneumatic type of counterbalance there is inherently present one troublesome factor. That factor is the tendency to build up increased air pressure during the down stroke of the pump rods, which increased pressure imposes additional load on and additional power consumption by the prime mover, and, during the upstroke of the pump rods, the decreased pressure results in relatively underloading the prime mover. These load variations on the prime mover naturally decrease the operating efficiency of the mechanism.

It has been recognized that this disadvantageous factor may be considerably reduced by the use of an accumulator or pressure reservoir chamber in connection with the displacement or compression chamber. That is, by the use of an accumulator having large volumetric capacity, or, at least, large capacity with respect to the displacement or compression chamber, excessive pressures will not be built up during the down stroke of the pump rods, and therefore excessive power will not be required from the prime mover during this half of the cycle, while the compressed air, though aiding in the upward movement of the pump rods, will not take the entire burden of this upward movement and will therefore not excessively underload the prime mover.

In designing a counterbalance for any given installation, various factors are taken into account as follows, though we will, for the present, disregard the factors of inertia and, in the case of the walking beam type of pumping mechanism, the acceleration and deceleration factors. The total load during the up stroke of the rods is the sum of the rod weight and the weight of the plunger-carried oil column. During the down stroke of the rods, the fluid load is assumed by the standing valve of the pump barrel, and the total load on the pumping mechanism is the weight of the pump rods. Thus the difference in load between the up and down stroke of the pump is the weight of the fluid column supported by the pump plunger.

With those values known, the pressural effects of a counterbalance are caluculated so that the counterbalance will support the weight of the pump rods plus one-half the weight of the fluid column above the plunger. With a given piston area presented to the air under pressure, that pressure is selected which will have an effective lifting force equal to the weight of the rods plus one-half the weight of the fluid to be lifted. Then, during the upstroke of the rods, the unequalized load to be lifted by the input power from the prime mover will be equal to the sum of the weight of the rods and supported fluid minus the effective lifting force of the air under pressure. During the down stroke of the rods, the power requirement will be that necessary to move them down against the lifting power of the air under pressure, which will be equal to the unequalized load lifted by the prime mover during the upstroke. Thus, the power factors for both the up and down strokes would be equalized and full efficiency would be had, were it not for the following consideration.

Assume the lifting force of the air to be of X value in order to answer the above desideratum of equalizing the weight of the rods and one-half the weight of the supported fluid column. Then, as the rods descend, the pressure within the compression chamber is increased to X+ value, and the prime mover is relatively over-loaded to the extent of the plus value. Then, at the beginning of the up stroke of the pump rods there is X+ lifting force applied by the air under pressure, and the plus value is a measure of the subsequent relative "underloading" of the prime mover. Such variations in load effects, if of appreciable value, obviously materially reduce the efficiency

of the entire installation. From a practical standpoint, these variations cannot be entirely eliminated in a system of this type, but they may be reduced so as to be not prohibitive, by increasing the volume of the accumulator with relation to the displacement volume (the volume displaced by the counterbalance piston between the limits of its stroke).

The larger the volume of the accumulator with relation to the displacement volume, the less will be the differential between the pressure at the top and the bottom of the pump rod strokes, and the less the differential, the more nearly will be approached the ideal counterbalancing situation—that is, the more constant will be the lifting effect of the counterbalancing air, the more nearly constant will be the load on the prime mover, and the smoother will be the pump rod reciprocation.

Accordingly, accumulators of relatively large size have been manufactured and put into use, but practical considerations of cost, material, and space economy have heretofore prevented the use of accumulators or reservoirs of a volumetric capacity that would closely approach the ideal condition.

On the other hand, I have devised an arrangement whereby the volumetric capacity of the accumulator may approach much more nearly that which will give ideal results, and I have accomplished this end in a manner which dispenses with the pre-fabrication of a separate accumulator and utilizes in its stead structures which are already present in any producing well—namely, the annularly spaced pipes which surround the pump tubing and which have been set in place during the well drilling operations.

How this is accomplished, as well as other objects and features of the invention will be made apparent from the following detailed description, reference being had to the accompanying drawings, wherein:

Fig. 1 is a side elevation showing an embodiment of my invention in connection with a pumping unit of the walking beam type, but showing only the upper part of my improved accumulator;

Fig. 2 is an enlarged section through the upper part of the accumulator shown in Fig. 1 and showing, in addition, the lower part of the accumulator;

Fig. 3 is an enlarged, longitudinal contracted section through the compression assembly or displacement cylinder of the mechanism; and

Fig. 4 shows an embodiment of my invention as applied to an hydraulic type of pumping mechanism.

As has been said, my invention is applicable to both mechanical and hydraulic types of pumping mechanism and I will therefore first describe the features which are common to both types, namely the well bore installation generally indicated at 10 and more particularly disclosed in Fig. 2. Except for particular adaptations utilized in connection with my improved system, as will be later described, the showing of the structural elements of Fig. 2 may be considered as typical of well-bore installations. The showing is also to be considered as conventional, since the precise type of casing head, and the precise type and number of pipe strings will vary according to the particular characteristics of individual wells and the practices of individual drilling operators.

Placed in pit or cellar 11 over the relatively large surface bore 12, is a casing head 13 which is connected to the upper end of surface casing or conductor pipe 14. Surface casing is usually from 500' to 1000' in length, though these figures are not limitative. Pipe 14 is annularly spaced from the wall of formation bore 12, as at 15, the lower end of space 15 being closed off by a cement "shoe" 16 during the initial cementing operation, shoe 16 being subsequently drilled out at 17 to leave an annular flange 18 projecting partially across the lower end of the bore of the pipe.

Supported by casing head slips 19 is a pipe 20, usually known as a "water string," which is annularly spaced as at 21 from surface pipe 14 and annularly spaced as at 22 from the bore of flange 18. Likewise, string 20 is annularly spaced as at 23 with respect to the formation wall of relatively reduced bore 24. The annular space 23 is normally cemented off as at 25, the space above this cement barrier, as well as spaces 22 and 21, being normally full or partially full of "mud" and water.

Within casing head 13 is an annular packer 26 which seals off the upper end of space 21, and diametrically opposite ports 27 and 28 open through the head to this space. Valve fittings 29 and 30 are provided for ports 27 and 28, respectively, which valves are adapted to take pipes 31 and 32, respectively.

The top plate 33 of head 13 supports tube 34 which is, in effect, an extension of water string 20, its cap 35 supporting the upper end of pump tubing 36 and the pipe fitting 37, which latter carries stuffing box 38 and oil delivery pipe 39. Tubing 36 is annularly spaced at 37' from tube 34 and water string 20, a valved outlet 38' leading from space 37'.

Polish rod 40 extends upwardly into connection with the pump actuating mechanism, and downwardly into connection with pump rods 41. Rods 41 extend into connection with a vertically reciprocatory pump plunger (not shown) in a pump barrel (not shown) at the bottom of tubing 36. The pump barrel, plunger, travelling and standing valves, etc., may be of any suitable type, it being unnecessary to show or describe them here since their structure and operation are well understood and the particularities thereof are not at all controlling on the present invention.

It need merely be stated that on the down stroke of rods 40, 41 and the plunger, the standing valve supports the fluid column thereabove while the fluid between the standing and travelling valves is admitted to the barrel above the plunger, and on the up stroke of the pump rods the fluid column above the plunger is lifted to deliver a commensurate quantity of oil through pipe 39, while a new charge of oil is drawn in between the ascending plunger and the standing valve. It follows that, during the down stroke of the plunger, the total load applied to the load reciprocating mechanism is equal to the weight of the rods (the weight of the oil column being taken by the standing valve) and, during the up stroke of the rods, the total load on the reciprocating mechanism is equal to the sum of the weight of the rods and the weight of the fluid column being lifted by the plunger.

The well bore installation so far described may be considered as conventionally illustrating the conditions typically found in connection with active wells. The pump rods 40, 41 may be reciprocated by any suitable mechanism. For in-

stance, in Figs. 1 and 3, I have shown this mechanism as being of the walking beam type, wherein walking beam 42 is pivoted at 43 on Samson post 44, with the work end of the beam pivotally connected through any suitable fitting 45 with polish rod 40. The power end of the beam is connected by pitman 46 to crank 47 on shaft 48, the latter being rotated by any suitable prime mover (not shown). It is obvious that crank shaft rotation oscillates or rocks beam 42 and thus vertically reciprocates rods 40, 41 and the pump plunger to accomplish the pumping operation.

The pneumatic equalizing or compression piston and cylinder assembly generally indicated at 50 will now be described. While any suitable pneumatic shock absorbing assembly may be utilized in connection with my invention, and the broader aspects of my invention contemplate such utilization, I have devised a particularly efficient arrangement having features of novelty, per se, and will therefore describe the illustration thereof with some particularity.

A pair of sleeves 51 and 52, either of which may be considered the piston and the other the cylinder, are fitted for relative longitudinal telescopic movement. The upper end of sleeve 51 is closed by detachable head 53, and the lower end of sleeve 52 is closed by detachable head 54 which is formed with a rocker base 55 and an apertured false bottom or plate 56. The sleeves and heads thus make up what may be considered a telescopic cylinder, the composite bore 57 forming a compression or displacement chamber.

The upper head 53 is suitably pivoted at 58 to walking beam 42, while rocker base 55 rests in the cradling recess 59 in stationary pillow 60. Integral, external studs 61 on head 55 are loosely embraced by hold-down straps 62 to prevent bodily displacement of the lower end of cylinder 50, and one of the studs is bored out as at 63 to provide a port opening from chamber 57 to the exterior of the cylinder.

Reciprocation of beam 52 alternately telescopically extends and collapses the compression cylinder 50 and thus alternately enlarges and reduces the volumetric capacity of chamber 57. As will presently appear, chamber 57 is in communication with an accumulator or pressure reservoir and the air in chamber 57 and the accumulator is to be held substantially at a predetermined pressure value which is well above that of the atmosphere. During operation of the mechanism, a portion of the air within chamber 57 is alternately displaced and returned, the displacement being into the accumulator, and consequently the common pressure within chamber 57 and the accumulator varies, but the variance is held within a predetermined pressure range. In order to hold the pressure up to predetermined value in spite of leakage losses which are bound to occur, it is highly desirable to provide an automatically acting air replenishing device.

While, broadly, any suitable replenishing means, operated in any suitable manner, may be employed, I have devised and have here shown a particularly effective means. It is actuated by walking beam reciprocation and, by reason of its peculiar location and nature, much of the complication and expense of usual replenishing means is avoided. By reason of this replenishing provision, it is possible to reduce, to a marked degree, the cost and complications of compression cylinder 50, for it becomes unnecessary to provide usual close fits or pressure sealing means between sleeves 51 and 52. In other words, the design of the main telescopic cylinder 50 may be such that it is fully to be expected that leakage will occur, but the auxiliary pump or replenishing means constantly compensates for the leakage losses. Thus, instead of using cast cylinders and insuring usual snug piston-and-cylinder fit between sleeves 51 and 52 by providing piston rings or liquid seals (which provisions have been necessary heretofore in order to hold the pressures up to predetermined values) these sleeves may be formed of ordinary pipes which need merely be machined on their opposed peripheral faces to give working fit with relatively large clearance tolerances.

The replenishing pump generally indicated at 64 (Fig. 3) is made up of cylinder 65, attached at 66 to the center of head 53, and hollow piston 67 secured through hollow fitting 68 to the center of base plate 56. The composite bore 69 of members 65 and 67 makes up the compression chamber of the replenishing pump, it being obvious that the volumetric capacity of this chamber is varied by reason of alternate telescopic extension and collapse of members 65 and 67 as accomplished by corresponding telescopic movement of cylinder 50 under the influence of walking beam oscillation.

Pump 64 has inlet and outlet ports 70 and 71, respectively, inlet port 70 being connected by pipe 72, which extends through and to the exterior of sleeve 50, to an air filter and lubricant container 73, there being a check valve 74 in line 72 to prevent the back flow of air during the compression stroke of the replenishing pump. Outlet 71 is connected by pipe 75, which extends through and to the exterior of sleeve 52, to a pipe 76 which returns and opens to chamber 57, there being a pressure release valve 77 and a check valve 78 in line 76, the check valve preventing flow of air from chamber 57 to chamber 69 during the up stroke of the replenishing pump.

During the up stroke of walking beam 42, the volumetric capacity of chamber 69 is increased and air at atmospheric pressure flows into this chamber through member 73, check valve 74, and pipe line 72. On the down stroke of the walking beam, the volumetric capacity of chamber 69 is decreased and a certain amount of the air within that chamber is displaced and is forced under pressure into chamber 57 through pipe 75, check valve 78 and pipe 76. The air thus forced into chamber 57 against the pressure already contained in that chamber and in the accumulator connected thereto, will compensate for leakage losses in all parts of the pneumatic system, that is, in the compression or displacement cylinder 50, the line leading from that chamber through port 63 to the accumulator and in the accumulator itself. With the maximum pressure within chamber 57 and the accumulator having been predetermined for a given installation, pressure release valve 77 is regulated to exhaust to the atmosphere any pressure in excess of that amount, it being realized that since the chamber 57 and the accumulator are in communication, valve 77 serves to predetermine the maximum pressure in both.

Returning now to Fig. 2, it has been said that in usual well bore installations the annular space 21 is normally at least partially filled with mud and water. Upon completion of the well drilling operations, this space serves no useful function except as a container for material which maintains a static head against the wall of formation bore 24 to prevent or control the ingress of

formation gases. It is a purpose of this invention to utilize this normally dead space as an air reservoir or accumulator to be used in connection with chamber 57, and thereby not only dispense with the usual ground surface accumulator but to provide an accumulator which is highly superior in several aspects. I will therefore first describe typical preparatory steps taken to accomplish this end. It will be understood that conditions in different wells vary and therefore the preparatory steps may vary, but the following will give an example from which one may readily understand how other beginning situations may be treated to accomplish the same end.

Fundamentally, the preparatory step consists in creating a closed air chamber within space 21, this space to be defined annularly by pipes 14 and 20, to be defined at its upper end by casing head 13 or its packer 26, and to be defined at its lower end by whatever substance be left in that annular space.

Assuming the space 21 is initially filled with mud and water, the mud is at least partially pumped out, for instance through ports 27 and 28, the remaining mud then being allowed to settle to the bottom, as indicated at M. Then a rubber tube may be introduced through one of the ports 27 or 28 and lowered into the water body above mud M. By then applying air pressure through the opposite port, the water may be jetted out through the hose until the remaining water is at a predetermined level. In a typical situation, this jetting was continued until the level L of water W was lowered to a depth around 200 ft. Water W, backed up by mud M and, finally, by cement 25, forms an end wall for the air space 80 which, in effect, becomes the accumulator or pressure chamber. In certain instances it may be desirable to improve the bottom seal by depositing weighted mud B such as Baroid on top of mud M.

With space 80 thus created, the jetting tube is removed, pipe 31 is connected by flexible hose 81 to port 63 of cylinder head 54 and, with valve 29 open, the pressure of the air within accumulator 80 and chamber 57 is raised to the desired degree by the application of a pump to pipe 32, for instance. When the pressure is built up to the predetermined value, valve 30 is closed and, assuming the pumping mechanism is started immediately in operation, valve 29 is left open. However, if the pumping system is not to be used immediately or if there is occasion to shut it down temporarily for any reason, valve 29 may be closed so the air within chamber 80 will not exhaust to the atmosphere through leakage openings in cylinder 50 or in the connecting line between that cylinder and the accumulator.

The depth to which the level L is lowered will depend upon the particular situation found in any given well and, in part, upon the calculations which have been made to counterbalance a given pumping unit. Assuming a given volumetric capacity is desired for the accumulator and knowing the effective cross sectional area thereof as determined by the diameters of the defining pipes, the preparatory steps will include the establishment of a water level L which will give the proper effective length to the accumulator or pressure chamber 80. This may involve pumping out mud and water as described above, or, in some instances it may involve the addition of water to raise the level L. Again, during the operation of the device, it may be determined that greater or less capacity should be given to the accumulator, in which case it is either shortened by the addition of water or lengthened by the expulsion of water.

In any event there is available by reason of the annular space between the surface casing and water string, a space of relatively unlimited length which may be put to use as an accumulator, and it only requires comparatively simple operations to vary this size to give any desired volumetric capacity. For instance, it is perfectly feasible to lower the water level L to an extent which will give space 80 a volumetric capacity many times greater than the displacement capacity of cylinder 50. In one installation the ratio was in the order of 50 to 1, but the differential may, in some installations, be much greater.

It will be perfectly obvious that it is utterly unfeasible to provide an accumulator having such relatively great capacity if that accumulator be in the form of a usual ground-surface tank. If this ratio were to be even approached by the provision of a ground surface tank, such a tank would be prohibitively expensive and bulky—and, during current times, would be absolutely unavailable. By virtue of my invention, this exceedingly favorable and hitherto unobtainable ratio has been secured by utilizing materials already at hand and necessary to the drilling of the well, rather than calling for new or enlarged equipment. The saving effected is obvious, and, in this connection, considerable saving can be effected by utilizing space 21 as an accumulator, even though for some reason it be determined that it be only of the volumetric capacity of a usual ground surface accumulator.

With the system connected as has been described and with the loads and volumetric capacities estimated, it can be predetermined as to what air pressure should be maintained beneath cylinder head 53 (of given effective area) in order to counterbalance the load requirements on the prime mover, all as set forth above. The pressure initially introduced to the accumulator chamber 80 and compression chamber 57 will be built up approximately to that value and pressure relief valve 77 will be set to relieve the pressure if, through over-delivery of pump 64, that pressure becomes excessively high. However, replenishment pump 64 may be designed so it will just about compensate for leakage losses and therefore the relief of excess pressure through valve 77 will occur infrequently, if at all.

In any event, with the predetermined pressure existing in chambers 57 and 80 at the top of the walking beam stroke, it will be seen that as the walking beam descends and there is displacement of air from cylinder 50, the pressure within chambers 57 and 80 necessarily will be built up. And on the upstroke of the walking beam, the pressure will diminish as chamber 57 increases in volumetric capacity. However, the volumetric capacity of accumulator chamber 80 is so great with relation to the displacement volume of compression chamber 57 that there will be a relatively little pressure change in the chambers (or, expressed otherwise, the balance pressure range is small) and therefore the alternate overloading and underloading of the prime mover incidental to these changes in pressure will be of a relatively low order, particularly as compared with the overloading or underloading of a prime mover where the accumulator is relatively small. With the potential size of the accumulator practically unlimited, as it is when space 21 is utilized for this

purpose, the differential between the volumetric capacity of the accumulator and of the displacement chamber may be increased to a point where the pressure changes are negligible. As has been said, this reduction in pressure variation is directly and favorably reflected in the smoothness of rod reciprocation and prime mover efficiency.

The system may not only be adjusted by varying the static pressure within chambers 57 and 80 or by changing the water level L, but it may also be regulated to a certain extent by manipulation of valve 29 to create lesser or greater restriction to the flow of air between chambers 57 and 80.

Usually, chamber 80 will be of such volumetric capacity that there will be a measurable, though slight, increase in chamber pressure during the down stroke of the walking beam. Though, with the use of the large accumulator, the differential is reduced to an extent which gives the advantageous results spoken of above, it still may play a part in compensating for other operating conditions such as pump rod inertia and acceleration and deceleration characteristics. For instance, in the walking beam type of pumping mechanism the crank movement drives the walking beam in simple oscillatory harmonic motion and gives to the pump rods simple vertical harmonic motion. During the period of acceleration in the down stroke of the walking beam, a relatively great load is imposed on the prime mover but less resistance is offered by the compression of the air in chambers 57 and 80 than during the immediately following period of deceleration when there is less load on the prime mover. During the period of acceleration in the upstroke of the walking beam, increased load is placed on the prime mover, but the lifting effect of the compressed air is greater than it is during the subsequent period of deceleration where there is less load on the prime mover. Thus the variations in air pressure compensate at least partially for the variation in load requirements on the prime mover as generated by the acceleration and deceleration characteristics of the reciprocating mechanism. Likewise, the effects of rod and fluid inertia are minimized by reason of the fact that the increased air pressure occurs toward the beginning of the up stroke and the end of the down stroke.

In Fig. 4 I have shown my invention as applied to a pumping unit of the hydraulic type. The well bore installation, as shown in Fig. 2, is the same as that used in connection with the walking beam type of mechanism except that the connecting line between the accumulator and compression chamber is taken from valve 30 instead of valve 29. Therefore Fig. 2 may be considered as an enlarged downward extension of Fig. 4 and the description of Fig. 2 may be taken as a description of the well bore installation shown fragmentarily in Fig. 4. All comments as to preparation, nature and functions of the well bore installation previously given, are to be taken as applying likewise to the installation of Fig. 4.

Here, polish rod 40 extends into connection with piston rod 90 carrying piston 91 which is adapted to reciprocate through vertical power cylinder 92. The showing of the hydraulic pumping engine and accessories, is to be taken as typical of such devices and, since their construction and operation are well known, the showing is conventional and the operation thereof will not be described in detail.

Actuating fluid F, such as water, is alternately admitted to and drawn from the lower end of cylinder 92 by a pump generally indicated at 93 and driven by any suitable prime mover P. Pump 93 has two branch lines 94 and 95 which lead to the reversing valve 96. Pipe 97 leads from one side of valve 96 to the lower end of cylinder 92, while pipe 98 leads from the other side of the reversing valve to receiver or surge tank 99. Actuating fluid stands in tank 99, but its level is always sufficiently low to provide a space 100 which constitutes the counterbalancing or equalizing compression chamber of the system. An open-ended stand pipe 101 extends vertically through receiver 99 to a level above the highest level ever reached by fluid F, the lower end of the line being connected by pipe 31*a* to valve 30, the stand pipe 101 and pipe 31*a* thus putting chambers 80 (Fig. 2) and 100 into communication.

Disregarding for the time being certain of the details of water and air replenishment, it will be seen that the volumetric relation between chamber 100 and chamber 80 is approximately the same as between chamber 57 and chamber 80. It will also be seen that chambers 100 and 80 may be considered together as a single closed air chamber, the volumetric capacity of which may be varied by increasing or decreasing the amount of actuating fluid in receiver 99. It follows that all which has been said of the system of Figure 1 may be said of the system of Fig. 4, except for the remarks regarding acceleration and deceleration of the crank-generated movement.

With the piston 91 and hence pump rods 41 at upper stroke limit (Fig. 4) the reversing valve 96 is automatically put in condition to cause pump 93 to drive the water or actuating fluid in the direction of the full line arrows *a*. Water is thus drawn from beneath piston 91 in cylinder 92 and driven into receiver or surge tank 99. Pump rods 41 descend of their own weight and thus accomplish the down stroke of the pump plunger. This movement of the actuating fluid into receiver 99 reduces the volumetric capacity of chamber 100. The air in this chamber 100 as well as in chamber 57 will preliminarily have been built up to a pressure which is calculated in the same manner as that described in connection with Fig. 1 and therefore the flow of water into receiver 99 is resisted by this built up pressure, which thus acts as a counterbalance for the pump rods; the proportioning of parts and pressures being such that the effective resisting force of the air is approximately equal to the weight of the rods plus one-half the weight of the oil column above the pump plunger.

When piston 91 reaches the bottom of its stroke, valve 96 is automatically shifted so the pump circulates the actuating fluid in the direction of the dotted line arrows *b*, the fluid being drawn from receiver 99 and being forced into cylinder 92 below piston 91, thus driving the piston and rods 41 through their up stroke. The compressed air within chamber 100 acts against the actuating fluid in receiver 99 with an effective force approximately equal to that required to lift the weight of the pump rods plus one-half the weight of the column of oil above the pump plunger, and that force is effective to aid the pump in lifting the load.

If the pressure within chambers 80 and 100 is at the predetermined value when piston 91 is at the top of its stroke, the pressure in those chambers will be slightly increased as the piston 91 descends, but, due to the relatively large volu-

metric capacity of chamber 80 with relation to the displacement volume of chamber 100, the differential in pressure within the chambers throughout the stroke of piston 91 is relatively slight or, expressed otherwise, the balancing pressure range is comparatively small. By increasing the volumetric capacity of chamber 80 through a lowering of level L, this differential may be reduced to a negligible factor, all as has been described in connection with the description of the operation of the pumping mechanism of Fig. 1. Likewise, level L may be raised or lowered to vary the differential, as previously described.

It will be seen that if the system is to be maintained in any predetermined condition, approximately the total amount of actuating fluid F must be maintained in the system and that the pressure in chambers 80 and 100 must be maintained approximately constant, except for variations due to fluctuation of the fluid level in receiver or surge tank 99 as caused by normal pump action. I therefore provide replenishing means to compensate for air losses through leakage and for returning to the surge tank such actuating fluid as may leak from various parts of the flow line. For these purposes, I provide a vacuum tank 105 which is connected at its bottom through pipe 106 with a replenishing pump 107, there being a check valve 108 in pipe 106 to prevent the back flow of fluid from pump 107 to tank 105. Pump 107 is belt-driven at 109 from pump shaft 110 so, in effect, the prime mover for the main pump 93 also drives the auxiliary or replenishing pump 107.

At the discharge side of pump 107 is pipe 111 adapted to deliver fluid into chamber 100, pipe 111 being provided with a check valve 113 which prevents back flow of fluid from chamber 100 to pump 107. A pressure relief valve 112 is provided for chamber 100.

Vacuum tank 105 is provided with a vacuum relief valve 114 which opens into the top of the tank, while from the bottom of the tank a pipe 115 leads to a catch basin 116, there being a check valve 117 in pipe 115 to prevent the back flow of fluid from tank 105 to basin 116. There is also a pipe 118 leading from trap 119 at the upper part of cylinder 92 to the upper part of vacuum tank 105 so that actuating fluid which finds its way above piston 91 may be delivered to the vacuum tank.

Pipes 120 and 121 conventionally represent lines for delivering to catch basin 116 such fluid as may leak from various parts of the pumping engine or from chambers to which the actuating fluid may flow during valve-change periods and thus be temporarily removed from the pump actuating line. Pump 107 draws a depression within tank 105 (to an extent determined by the setting of valve 114) and thus draws into that tank water which has collected in basin 116. This water is then picked up by pump 107 and returned to tank 99 through pipe 111, thus restoring the fluid to the actuating line. Pump 107 will also force such air as it draws from the vacuum tank (the supply of such air being periodically replenished through the opening of valve 114 when the pressure in tank 105 reaches a predetermined negative value) and delivers such air, at times along with actuating fluid, to chamber 100 through pipe 111. Pressure relief valve 112 is set to exhaust this replenishing air to the atmosphere in the event the pressure within chambers 100 and 80 approaches an excessive value. Thus, the amount of actuating fluid and the pressure of the air within the system are kept substantially uniform, to the end that the performance will be substantially uniform.

While I have shown and described preferred embodiments of my invention, it will be understood that various changes in design, structure and arrangement may be made without departing from the spirit and scope of the appended claims.

I claim:

1. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, and means for maintaining pressure in said chambers.

2. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a water string annularly spaced from an outer casing, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said casing and water string, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said casing-and-string defined pressure chamber for putting them into communication, and means for maintaining pressure in said chambers.

3. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, means for shifting at least one of the barriers vertically to vary the effective capacity of said pressure chamber, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a

compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, and means for maintaining pressure in said chambers.

4. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a valved connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, and means for maintaining pressure in said chambers.

5. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, the upper barrier comprising a head connecting the two pipes at the ground surface, and the lower barrier comprising a filler between the two pipes, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, and means for maintaining pressure in said chambers.

6. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, the upper barrier comprising a head connecting the two pipes at the ground surface, and the lower barrier comprising a stationary filler between the two pipes and a body of liquid on top the filler, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, and means for maintaining pressure in said chambers.

7. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, and means for introducing fluid under pressure from an external source to one of the chambers.

8. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, and auxiliary pump means for holding the pressure within the chambers up to a given value at any given stage of the pumping cycle.

9. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure

means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, auxiliary pump means for holding the pressure within the chambers up to a given value at any given stage of the pumping cycle, and pressure release means for exhausting fluid from the chambers when the pressure within the chambers exceeds said given value.

10. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a reciprocating member at the ground surface, means for reciprocating the member, pump rods extending from said member to said plunger, fluid pressure means for counterbalancing said rods and comprising a compression chamber, a compressible fluid in the compression chamber, a fluid-compressing medium adapted to act on the compressible fluid, a force transmitting medium between the member and the compressing medium, all in a manner whereby descension of the member and rods is against the pressure within the compression chamber, a connection between said compression chamber and said pipe defined pressure chamber for putting them into communication, and auxiliary pump means operated by reciprocation of said member for holding the pressure within the chambers up to a given value at any given stage of the pumping cycle.

11. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a walking beam, pump rods applied to the work end of the beam and extending into connection with said plunger, means for reciprocating the beam; fluid pressure means for counterbalancing said rods and comprising a substantially vertically arranged cylinder and piston assembly secured against substantial vertical movement at its lower end and applied at its upper end to the beam at a point between its fulcrum and the point of rod application, a connection between said chamber and the cylinder of the assembly for putting them into communication, and means for maintaining pressure in said chamber and cylinder.

12. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a walking beam, pump rods applied to the work end of the beam and extending into connection with said plunger, means for reciprocating the beam; fluid pressure means for counterbalancing said rods and comprising a substantially vertically arranged cylinder and piston assembly secured against substantial vertical movement at its lower end and applied at its upper end to the beam at a point between its fulcrum and the point of rod application, a connection between said chamber and the cylinder of the assembly for putting them into communication, and means operated by walking beam reciprocation for supplying fluid under pressure to said chamber and cylinder.

13. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a walking beam, pump rods applied to the work end of the beam and extending into connection with said plunger, means for reciprocating the beam; fluid pressure means for counterbalancing said rods and comprising a substantially vertically arranged, closed-ended telescopic cylinder secured against substantial vertical movement at its lower end and applied at its upper end to the beam at a point between its fulcrum and the point of rod application, a connection between the cylinder and said chamber for putting them into communication, and a pump within said cylinder and operated by walking beam reciprocation, an inlet duct for said pump and adapted to admit air from a point external of the cylinder, and a discharge duct from the pump to the interior of the cylinder, and a check valve in the discharge duct to prevent return flow from the interior of the cylinder to the pump.

14. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a piston adapted to be reciprocated through a cylinder, pump rods operatively connecting the piston and plunger whereby the plunger is moved upwardly by virtue of piston movement in one direction and whereby downward movement of the plunger and rods move the piston in the opposite direction, a closed container for actuating fluid and connected to the cylinder at one side of the piston, there being an air chamber within the container above the actuating fluid, means for alternately applying the actuating fluid under pressure and for relieving the pressure of said fluid to and from, respectively, one side of the piston to alternately move the rods and plunger upwardly and to allow them to move downwardly, a connection between said chambers for putting them into communication, and means for maintaining pressure in said chambers.

15. A pumping system for oil wells wherein a vertically reciprocating pump plunger is disposed within tubing which extends downwardly through a piping system which includes a pair of annularly spaced pipes, vertically spaced barriers defining the ends of a pressure chamber which is annularly defined by said pipes, pump reciprocating mechanism including a piston adapted to be reciprocated through a cylinder, pump rods operatively connecting the piston and plunger whereby the plunger is moved upwardly

by virtue of piston movement in one direction and whereby downward movement of the plunger and rods move the piston in the opposite direction, a closed container for actuating fluid and connected to the cylinder at one side of the piston, there being an air chamber within the container above the actuating fluid, means for alternately applying the actuating fluid under pressure and for relieving the pressure of said fluid to and from, respectively, one side of the piston to alternately move the rods and plunger upwardly and to allow them to move downwardly, a connection between said chambers for putting them into communication, a flow control valve in said connection, and means for maintaining pressure in said chambers.

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