

July 5, 1938.

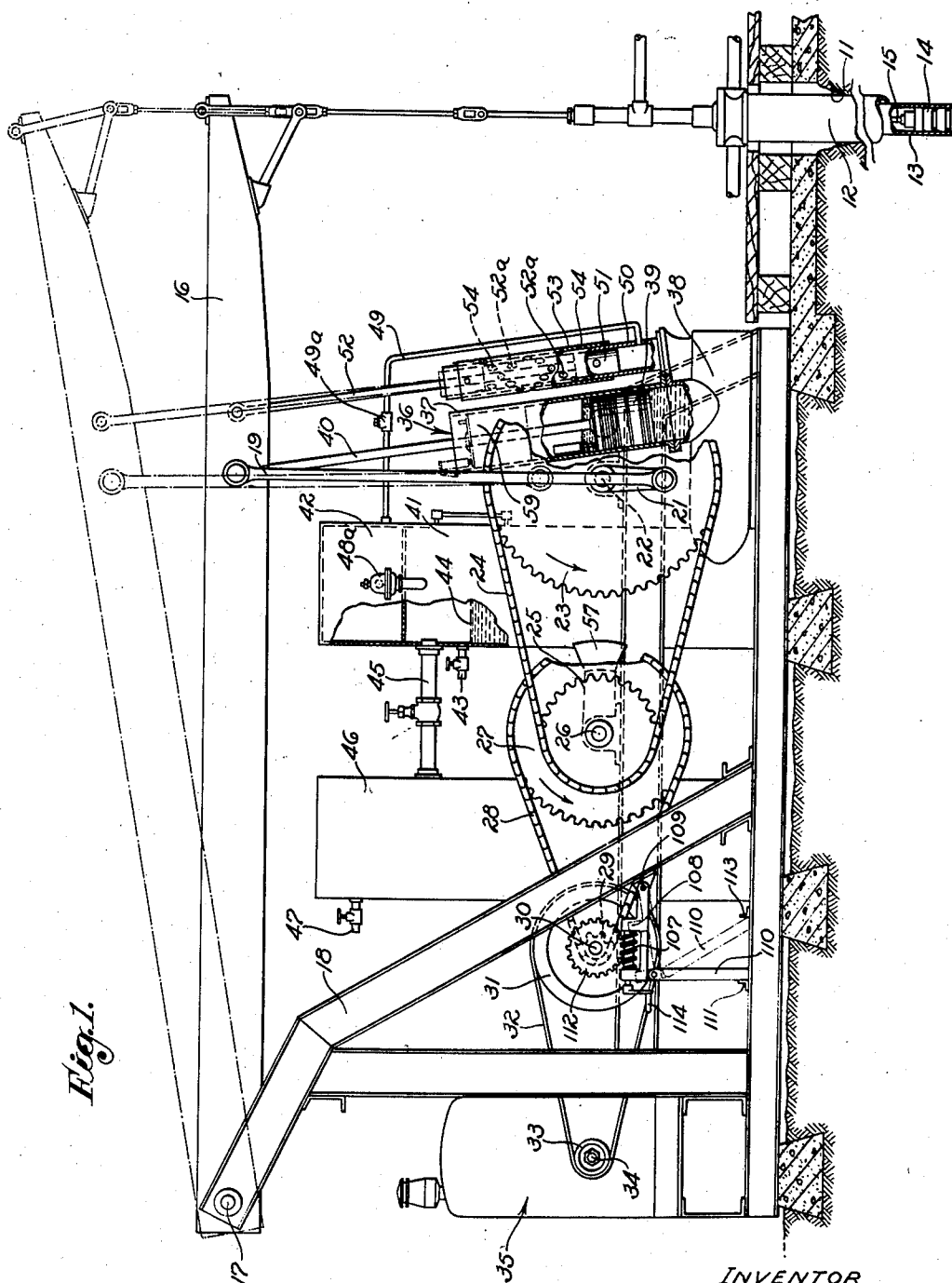
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2,122,871

METHOD AND APPARATUS FOR COUNTERBALANCING OIL WELL PUMPING APPARATUS

Filed Sept. 29, 1936.

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4.

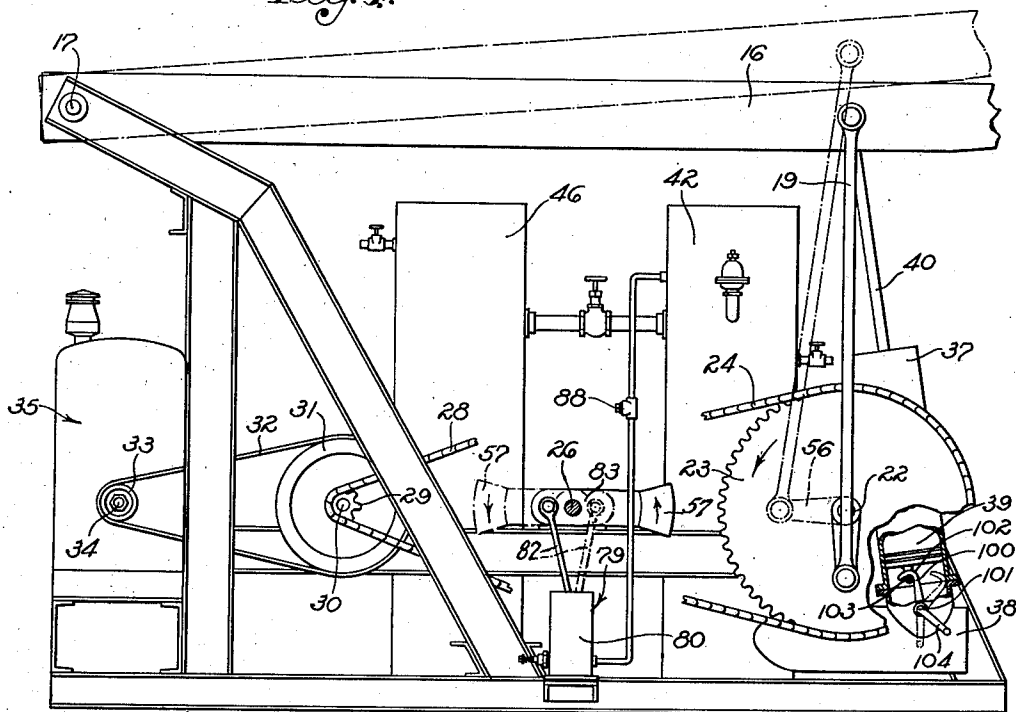


Fig. 2.

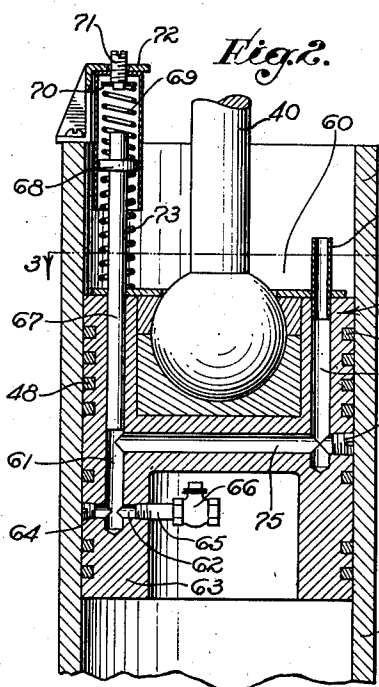


Fig. 6.

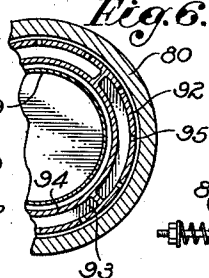


Fig. 3.

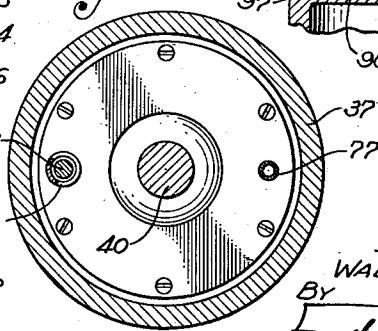
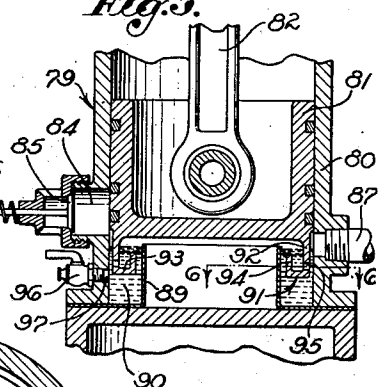


Fig. 5.



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METHOD AND APPARATUS FOR COUNTER-BALANCING OIL WELL PUMPING APPARATUS

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Application September 29, 1936, Serial No. 103,169

18 Claims. (Cl. 74—589)

My invention relates to a method and apparatus for counterbalancing, and particularly to a method and apparatus for counterbalancing a reciprocating member which is driven by a rotating shaft and which if not counterbalanced, subjects the rotating shaft to unequal loads upon its two strokes.

My invention finds particular utility in the counterbalancing of pumping apparatus for oil wells, and an embodiment of the apparatus of my invention and apparatus capable of performing the method of my invention will be described in connection with such use, it being understood that my invention is not limited to such use.

It is a general object of my invention to provide a method of and apparatus for equalizing the load upon a prime mover of an oil well pump so that this load is substantially equal in the two strokes of the pump plunger and substantially equal throughout the various portions of each stroke.

It is a more specific object of my invention to provide a method of and apparatus for equalizing the maximum loads to which a prime mover driving the pump plunger is subjected in the two strokes of the pump plunger.

As a pump plunger nears the end of its downward stroke it is decelerated until it comes to rest at the lower end of its stroke. The pump plunger, string of sucker rods and walking beam, all of which are subjected to this deceleration, have considerable momentum at the midpoint of their downward stroke, and this energy of momentum must be dissipated during the travel of these reciprocating parts in the second half of their downstroke. During the first half of the upstroke of these reciprocating parts they are accelerated; therefore, without counterbalancing, the load upon the prime mover during the latter half of the downstroke of the reciprocating parts is greatly lessened by their deceleration and during the first half of the upstroke of the reciprocating parts the load on the prime mover is greatly increased due to the necessity for this acceleration.

It is an object of my invention to provide a method of and apparatus for absorbing and storing the energy of momentum during the deceleration of the reciprocating parts on their downstroke and to return this energy to the reciprocating parts to accelerate their motion on the first half of the upstroke and thus equalize the load upon the prime mover in such parts of the strokes of the reciprocating parts.

In oil well pumping apparatus it is customary

to employ a prime mover for rotating a shaft and to translate the rotary movement of such shaft to the reciprocating movement of a pump plunger through a crank arm, or eccentric mounted on a wheel equivalent to a crank arm, and a walking beam. During that time in the use of such apparatus at which the crank arm is nearly vertical it has a relatively small component of its angular movement parallel to the direction of travel of the walking beam and the pump plunger and therefore the load upon the prime mover during a given angular movement of the crank arm in such position is relatively small. On the other hand, when the crank arm is near either of its horizontal positions it has a relatively large component of its movement parallel to the direction of travel of the walking beam and the pump plunger and therefore the load upon the prime mover during the same given angular movement, of the crank arm in such position is relatively great.

It is an object of my invention to provide a method and apparatus for making the loads upon the prime mover substantially equal when the crank arm is moving near either of its vertical positions and when the crank pin is moving near either of its horizontal positions.

More specifically, it is an object of my invention to provide a method and apparatus for accomplishing the object last stated which utilizes a counterweight rotated twice for each revolution of the crank arm, storing energy when the crank arm is near its vertical positions, and returning energy to the crank arm when the crank arm is near its horizontal positions.

It is still another object of my invention to equalize the maximum loads upon the prime mover during the two strokes of the pump plunger by compressing a gas during that stroke of the plunger during which the prime mover is normally subjected to the lesser load, and expanding the gas during that stroke of the pump plunger in which the prime mover is normally subjected to its greater load.

It is still another object of my invention to provide a method and apparatus for maintaining this equalization by maintaining substantially constant the quantity of gas subjected to such compression and expansion in spite of leakage. I find it advantageous to compress such gas by pumping a liquid into a closed chamber of gas, and it is a further object of my invention to provide a method of and apparatus for maintaining constant the quantity of liquid so pumped to

maintain constant the counterbalancing effect thus achieved.

It is sometimes necessary to disconnect the string of sucker rods and the pump plunger from the walking beam in order to work upon the well. The pumping apparatus being counterbalanced for the load of the pump plunger and string of sucker rods, the equilibrium of the apparatus is upset by such disconnection. It is a purpose of my invention to provide a method of and apparatus for preventing the movement of the driving apparatus and walking beam when the string of sucker rods and the pump plunger are disconnected from the walking beam.

In accomplishing the foregoing objects I may utilize a piston reciprocable in a cylinder, and it is an object of my invention to provide a method of and apparatus for maintaining a body of lubricating and sealing liquid in contact with the piston and wall of the cylinder when a piston and cylinder apparatus is so used.

These and other objects and advantages of my invention will be made evident in the following description which may be better understood by a reference to the accompanying drawings in which,

Fig. 1 is an elevational view partially sectioned of the counterbalancing apparatus of my invention;

Fig. 2 is a sectional view of a part of the load counterbalancing apparatus illustrated in Fig. 1;

Fig. 3 is a sectional view taken as indicated by the line 3—3 of Fig. 2;

Fig. 4 is an elevational view, partially sectioned, of a locking mechanism of my invention;

Fig. 5 is a sectional view of a pump employed in my counterbalancing apparatus; and

Fig. 6 is a sectional view taken as indicated by the lines 6—6 of Fig. 5.

Referring to the drawings, which are for illustrative purposes only, the numeral 11 indicates an oil well having therein a casing 12 and a pump tubing 13 in the lower end of which a pump plunger 14 is reciprocated by a string of sucker rods 15. The sucker rods 15 extend upwardly through the pump tubing to above the surface of the ground and are attached to the working end of a walking beam 16, the other end of the walking beam in the form illustrated in the drawings being mounted upon a pivot 17 carried by a Samson post 18. Secured to the walking beam 16 intermediate its ends is a pitman 19 which is connected to an eccentric or a crank 21. The crank 21 is mounted upon a crank shaft 22 to which a crank shaft gear 23 is non-rotatably secured. A chain 24 meshes with the crank shaft gear 23 and a smaller gear 25 carried by a second countershaft 26. The second countershaft 26 has mounted thereon a driven gear 27 with a chain 28 meshing therewith and with a driving gear 29 carried by a first countershaft 30. There is mounted upon the first countershaft 30 a driven pulley 31 with a belt 32 in driving engagement therewith and driven by a pulley 33 on a drive shaft 34 of a prime mover 35 which may be a steam engine, a gas engine, or the like. When the prime mover is energized the drive shaft 34 drives the first countershaft 30 and the second countershaft 26 and thus the crank shaft 22 and the crank 21, thus rocking the walking beam 16 about the pivot 17 and reciprocating the sucker rods 15 and plunger 14 in the well. The reciprocation of the plunger 14 elevates liquid in the well so that it may be discharged at the surface in the manner well known in the art.

If no counterbalance is employed, it is apparent that on the upstroke of the string of sucker rods 15 the prime mover is subjected to the load of the walking beam 16, the string of sucker rods 15, and all of the liquid being elevated in the tubing 13, and on the downstroke of the plunger 14 the walking beam 16 and string of sucker rods 15 fall by gravity, subjecting the prime mover to little or no load. For the purpose of making the maximum load upon the drive shaft 34 on the downstroke of the plunger 14 equal to the maximum load on the drive shaft on the upstroke of the plunger 14, I have provided a load counterbalance indicated generally by the numeral 36 of Fig. 1. The load counterbalance includes a cylinder 37 open at its upper end to the atmosphere and secured at its lower end in any suitable manner to a housing 38 with which it freely communicates. Reciprocable within the cylinder 37 is a piston 39 having a connecting rod 40 pivotally connected in its upper face. The connecting rod 40 is pivoted at its upper end to the walking beam 16, the connections of the connecting rod 40 and the pitman 19 to the walking beam 16 being at substantially the same distance from the pivot 17.

The housing 38 communicates with an expansion chamber 41 which has positioned thereabove a supply tank 42. The expansion chamber 41 is provided with a valved supply pipe 43 for the introduction of liquid to the expansion chamber 41, housing 38 and cylinder 37. Liquid may thus be added to the expansion chamber 41 until it reaches the approximate level indicated by the numeral 44. A valved connecting pipe 45 connects the expansion chamber 41 above the level 44 with a second expansion tank 46 having a valved liquid supply pipe 47. The second expansion chamber may be shut off from the expansion chamber 41 or connected thereto and filled with gas or liquid and gas, dependent upon the degree of compression of the gas that is desired. The piston 39 is provided with piston rings 48 of conventional construction to restrain the passage of liquid outwardly of the cylinder 37 between the piston 39 and the cylinder wall.

By varying the space in the expansion chamber 41 above the liquid level 44 and the volume of the second expansion chamber 46 filled with gas if the second expansion chamber is connected to the expansion chamber 41 and thus varying the gas volume relative to the displacement of the piston 39 the degree to which the gas is compressed in the expansion chamber or chambers and the resulting upward pressure upon the bottom of the piston 39 may be varied. Thus it is possible for the gas compressed in the expansion chamber 41 or chambers 41 and 46 to exert an upward force on the bottom of the piston 39 when the piston is at the lower end of its stroke equal to that weight of the walking beam 16 and string of sucker rods 15 and one-half that weight of the liquid being elevated in the tube 13 which is effective at the point at which the connecting rod 40 is pivoted to the walking beam 16. For example, if the connecting rod 40 is pivoted to the walking beam 16 at a distance of twelve feet from the pivot 17 and the string of sucker rods 15 is attached to the walking beam 16 eighteen feet from the pivot 17, and the walking beam has a weight of 2000 pounds effective at the point at which the string of sucker rods is attached to the beam, and the sucker rods have a weight of 3000 pounds, and the fluid has a weight of 6000 pounds, the gas can be compressed in the expansion chamber 41 or cham-

bers 41 and 46 when the piston 39 is at the lower end of its travel so that there is exerted upon the piston 39 and the walking beam 16 an upward force equal to 2000 pounds plus 3000 pounds plus one-half of 6000 pounds, or a total of 8000 pounds times a lever arm of three halves, or 12,000 pounds. With the load so counterbalanced the prime mover 35 is compelled on the upstroke to lift only one-half of the liquid load, or 3000 pounds effective at the point of connection of the string of sucker rods to the beam in the example, the walking beam and the string of sucker rods 15 being lifted by the expansion of the gas. Likewise on the downstroke of the pump plunger 14 the prime mover is compelled to exert a force equal to one-half the liquid load, or 3000 pounds effective at the point of connection of the string of sucker rods to the beam in the example, this force together with the effective weight of the walking beam and the sucker rods at the point of connection of the connecting rod 40 to the walking beam 16 being necessary to force the piston 39 to the lower end of its stroke and to compress the gas to its required volume.

In order to compensate for the leakage of gas the supply tank 42 is maintained filled with gas at a higher pressure than the maximum pressure upon the gas in the expansion chamber 41. A valve 48a is interposed between the supply tank 42 and the expansion chamber 41, this valve being of a construction well known in the art, to permit the passage of gas from the supply tank 42 to the expansion chamber 41 to maintain the pressure in the chamber 41 above a predetermined value. Gas is supplied to the supply tank 42 through a conductor pipe 49 from an auxiliary cylinder 50, the conductor pipe 49 containing a valve 49a for passing gas to the chamber 42 when the pressure therein falls below a predetermined value. The auxiliary cylinder 50 is mounted upon the housing 38 and has reciprocable therein a piston 51 connected through a connecting rod 52 with the walking beam 16. The volume of displacement of the auxiliary piston 51 and the volume of the conducting pipe 49 is made less than the volume of the gas space in the expansion chamber 41 so that although the auxiliary piston 51 has a stroke substantially equal to the stroke of the piston 39 the gas is compressed in the auxiliary cylinder 50 to the desired extent above the maximum pressure on the gas in the expansion chamber 41.

As the pump plunger 14 nears the lower end of its stroke the walking beam 16 and string of sucker rods 15 have momentum of considerable value that must be dissipated. I absorb the energy of this momentum and store it for imparting momentum during the first part of the upstroke of the plunger 14 by means of the auxiliary cylinder 50 and piston 51. As illustrated in Fig. 1 the cylinder 50 is provided with a series of ports 52a intermediate the ends of the stroke of the auxiliary piston 51. A sleeve 53 is rotatably mounted upon the auxiliary cylinder 50 in air tight relationship therewith and has openings 54 therein. The openings 52 and 54 are spaced both circumferentially and longitudinally in the auxiliary cylinder 50 and sleeve 53, respectively, the openings in the cylinder 50 being offset circumferentially in a direction opposite to that in which the openings in the sleeve 53 are offset. Thus by rotating the sleeve 53 upon the cylinder 50 the openings 52a and 54

at different elevations are brought into coincidence. As the pump plunger 14 moves downwardly the auxiliary piston 51 moves downwardly in the cylinder 50. No compression of gas occurs in the auxiliary cylinder 50 until the piston 51 has covered that one of the openings 52 registering with one of the openings 54. Thus resistance to the downward movement of the walking beam 16 and string of sucker rods 15 is offered only during the latter part of the downstroke of the plunger 14. The momentum of the walking beam 16 and string of sucker rods 15 is thus absorbed and their downward movement is decelerated until the reversal of movement occurs and the pump plunger 14 begins its upward stroke. As soon as the plunger 14 begins its upward stroke the gas compressed in the auxiliary cylinder 50 exerts its compressive force urging the walking beam 16 and string of sucker rods 15 upwardly, and this accelerating force is applied until the auxiliary piston 51 uncovers that one of the openings 52 registering with one of the openings 54. While it is possible by adjusting the sleeve 53 upon the auxiliary cylinder 50 to compress gas in the auxiliary cylinder 50 during any desired part of the stroke of the auxiliary piston 51, I have found that good results are secured if the sleeve 53 is so adjusted that the auxiliary piston 51 covers the registering openings when about one-half of the downstroke of the walking beam 16 has occurred. I have found that it is not necessary to provide an auxiliary cylinder such as the auxiliary cylinder 50 to decelerate the walking beam 16 and string of sucker rods 15 as they approach the upper end of their stroke since their weight is sufficient to accomplish this deceleration.

It is possible to employ in the expansion chamber 41 a pressure somewhat higher than that required to counterbalance the effective weight of the walking beam 16, string of sucker rods 15 and one-half the liquid load, this excess in pressure being utilized to decelerate the walking beam 16 and string of sucker rods 15 as they near the lower end of their travel and to accelerate them as they begin their upstroke. However, this excess of pressure is exerted also in the upper part of the upstroke and tends to cause racing as the walking beam and sucker rods reach the end of their upstroke and begin their downstroke. A 5% increase in pressure in the gas in the expansion chamber 41 over that necessary to counterbalance the effective weight of the walking beam 16, string of sucker rods 15 and one-half the liquid load I have found can be utilized.

When the crank is in the position indicated by dotted lines 56 of Fig. 4 the prime mover is subjected to greater load than when the crank is in the positions indicated by the full and dotted lines in Fig. 1 since when the crank is in its horizontal position the ratio of the vertical component of the velocity of the free end of the crank to the angular velocity of the crank shaft 22 is greatest. To make the load upon the drive shaft 34 more nearly equal throughout each stroke of the walking beam 16 I apply a counterweight 57 to the apparatus. This counterweight is applied to the apparatus so that it revolves twice for each revolution of the crank shaft 22. If the driving gear 25 is made of half the circumference of the driven gear 23 on the crank shaft 22, the counterweight 57 may be applied directly to the second countershaft 26, and I have illustrated it in this position in the drawings. The counterweight 57 is non-rotatably se-

cured in any suitable manner to the second countershaft 26 so that it is horizontal when the walking beam is at each end of its stroke. Thus when the crank is in the position indicated by the dotted lines of Fig. 4 the counterweight 57 is in its horizontal position and descending so that it is imparting its maximum energy to the second countershaft 26 and to the crank shaft 22, thus diminishing the load upon the drive shaft 34. When the crank shaft is in its vertical position illustrated in the full lines of Fig. 4 the counterweight 57 has rotated 180° and is in its horizontal position and ascending so that it is absorbing its maximum energy from the drive shaft 34. If the maximum pull on the chain 28 when the crank 21 is horizontal is 1500 pounds, for example, and the maximum pull upon the chain when the crank is in either of its vertical positions is zero or nearly zero, I install a counterweight 57 of an effective value of 750 pounds so that the pull upon the chain 28 when the crank is in a horizontal or vertical position is approximately 750 pounds.

While any suitable liquid may be employed in the cylinder 37 I prefer to employ an oil. Although the piston 39 is provided with rings 48 some of this liquid leaks from the cylinder 37 around the piston 39. I provide the cylinder 37 with an extending portion 59 projecting above the upper end of the piston 39 when the piston is at the upper end of its stroke to provide a liquid reservoir 60. The liquid leaking from the cylinder 37 around the piston 39 is thus collected in the reservoir 60 where it exerts a sealing and lubricating function between the piston 39 and the wall of the cylinder 37. In order that the counterbalancing effect of the expansion and contraction of the gas in the expansion chamber 41 shall be maintained constant, it is necessary to maintain substantially constant the volume of liquid within the cylinder 37, housing 38 and expansion chamber 41. For the purpose of returning to the system the oil which has leaked therefrom, I provide in the piston 39 a vertical cylindrical opening 61 communicating with the top of the piston 39 at its upper end and communicating with a transverse bore 62 at its lower end. The transverse bore 62 extends through an annular skirt 63 of the piston 39 and has its outer end closed by a screw 64. Secured in the inner end of the transverse bore 62 is a discharge pipe 65 to which a valve 66 is connected. The valve 66 may be of any conventional construction for discharging fluid from the pipe 65 to the interior of the cylinder 37 when the pressure in the cylinder 37 falls below a predetermined minimum value and the pressure in the discharge pipe 65 is above this value. Reciprocable within the cylindrical opening 61 is a plunger 67 which projects above the upper end of the piston 39 and is provided near its upper end with a collar 68. A compression spring 69 has its lower end bearing against the collar 68 and its upper end engaging a disc 70 carried by a bolt 71 threaded into a horizontal flange 72 which is mounted on the projecting portion 59 of the cylinder 37. A second compression spring 73 surrounds the plunger 67 with its upper end bearing against the lower surface of the collar 68 and its lower end bearing against the upper end of the piston 39.

Formed in the piston 39 is a vertical supply pipe 74 communicating at its upper end with the top of the piston 39 and at its lower end with a horizontal supply pipe 75. The horizontal supply pipe 75 extends from the cylindrical bore 61

to the periphery of the piston 39, being closed at the periphery of the piston 39 by a screw plug 76 threaded into the piston 39. A vertical control pipe 77 may be threaded into the upper end of the vertical supply pipe 74 so that its upper end projects above the upper end of the piston 39 a variable distance for a purpose which will now be described.

As the liquid in the cylinder 37 leaks therefrom around the piston 39 it collects in the liquid reservoir 60. This body of liquid travels with the piston 39 in contact with its upper surface. As the piston 39 moves upwardly the compression spring 69 resiliently urges the plunger 67 downwardly in the cylindrical bore 61. The length of stroke of the plunger 67 may be varied by adjusting the bolt 71, moving it upwardly or downwardly. The stroke of the piston 67 is adjusted so that if any gas is supplied through the supply passages 74 and 75 the gas is compressed to a pressure less than the minimum pressure at which the valve 66 will discharge fluid from the cylindrical bore 61 into the cylinder 37. However, the stroke of the plunger 67 is maintained great enough to exert a pressure on the liquid contained in the cylindrical bore 61, if this bore is filled with liquid, to a pressure greater than the minimum pressure at which the valve 66 will discharge fluid from the cylindrical bore 61 into the cylinder 37. Thus as long as the cylindrical bore 61 below the plunger 67 is filled with liquid the liquid will be compressed to such an extent that the valve 66 will discharge this liquid into the cylinder 37 to maintain substantially constant the minimum pressure in the cylinder 37, while if there is insufficient liquid to fill the cylindrical bore 61 below the plunger 67, the plunger 67 will not force gas into the cylinder 37.

The vertical control pipe 77 is provided to maintain a body of liquid above the piston 39 of a depth equal to the length of the control pipe 77 projecting above the piston 39 so that some liquid is maintained at all times in lubricating relationship with the piston 39 and the wall of the cylinder 37 and in lubricating relationship with the plunger 67 and the wall of the cylindrical bore 61. The depth of this body of liquid may be readily varied by threading the control pipe 77 into or out of the vertical supply passage 74.

If it is desired to vary the quantity of liquid in the cylinder 37, housing 38 and expansion chamber 41 to vary the counterbalancing effect of the expansion and contraction of the gas in the expansion chamber 41, this may be accomplished by threading the control pipe 77 into or out of the vertical supply passage 74 and if desired, by adding liquid to the reservoir 60. The quantity of gas within the expansion chamber 41 is maintained substantially constant by the discharge through the valve 49a of gas compressed by the auxiliary piston 51 when the pressure within the expansion chamber 41 falls below a predetermined value.

If desired a gas compressing pump, indicated generally by the numeral 79 of Fig. 4, may be employed instead of the auxiliary cylinder 50 for maintaining substantially constant the quantity of gas in the expansion chamber 41. This gas compressing pump 79 includes a cylinder 80 having a piston 81 reciprocable therein, this piston being connected as illustrated in Fig. 5 by a connecting rod 82 to a crank 83 on the second countershaft 26. An intake port 84 is provided at the lower end of the cylinder 80 and is closed during the compression stroke of the piston 81

by a valve member 85. The valve member 85 is resiliently urged to position closing the intake port 84 by a compression spring 86. When the piston 81 moves upwardly the decrease in pressure in the cylinder 80 causes the valve member 85 to move inwardly against the resistance of the spring 86 opening the intake port 84 and permitting air to enter the cylinder 80. When the piston 81 moves downwardly the spring 86 urges the valve member 85 into position closing the intake port 84 which position it maintains during the compression stroke of the piston 81. Air compressed in the cylinder 80 is discharged therefrom through a discharge pipe 87 communicating with the gas supply chamber 42. The discharge pipe 87 has a valve 88 therein permitting the passage of gas through the discharge pipe 87 only in one direction, i. e., from the cylinder 80 to the high pressure chamber 42.

While I have illustrated the connecting rod 82 as driven by the second countershaft 26, it will be obvious that the connecting rod may be driven by any other driving or driven part of the apparatus.

For the purpose of lubricating the piston 81 I provide in the lower end of the auxiliary cylinder 80 an upwardly extending annular flange 89, illustrated in Fig. 5, which cooperates with the wall of the auxiliary cylinder 80 in defining an annular lubricant chamber 90. Formed on the lower end of the piston 81 is a carrying member 91 which includes a vertical wall 92 adjacent the wall of the cylinder 80, a horizontal wall 93 and an inner vertical wall 94 of lesser length than the outer vertical wall 92. Openings 95 are provided in the outer vertical wall 92 for the escape of lubricant from the carrying member 91. In Fig. 5 the auxiliary piston 81 is illustrated in the lower end of its stroke with the carrying member 91 submerged in the lubricant contained in the annular chamber 90. As the piston 81 moves upwardly in the cylinder 80 the lubricant contained in the carrying member 91 is discharged therefrom through the openings 95 to the space between the outer vertical member 92 and the wall of the auxiliary cylinder 80. This space is made of small radial thickness so that a film of oil is maintained therein from the discharge of the carrying member 91 throughout the upward and downward strokes of the auxiliary piston 81. A valve member 96 communicates through a passage 97 with the annular lubricant chamber 90 to enable the operator to determine whether the chamber is filled with lubricant and to add to the body of lubricant in the annular chamber when necessary.

When it is desired to disconnect the string of sucker rods 15 from the beam 16 to work upon the well, it is desirable to maintain the gas under pressure in the expansion chamber 41 so that the energy expended in accomplishing this compression will not be wasted. I therefore provide a latch member 100 which is swingably mounted upon a pin 101 mounted in the housing 38. The latch member 100 is swingable from the position illustrated in the full lines of Fig. 4 in which position a hook 102 on its inner end engages a horizontal pin 103 secured to the lower end of the piston 39 to the position illustrated in the dotted lines of Fig. 4 in which position the pin 103 and the piston 39 are released so that the piston may freely reciprocate. An arm 104 is mounted upon the pin 101 exterior of the housing 38 for moving the latch member 100 between its two positions. Thus when it is desired to disconnect

the string of sucker rods 15 from the beam 16 the piston 39 is moved to its lowest position by the prime mover 35 and the arm 104 is swung to accomplish the engagement of the pin 103 by the latch member 100. The sucker rods may then be disconnected from the beam and the pistons 51 and 39 will be maintained stationary.

Illustrated in Fig. 1 is another means of maintaining the piston stationary when the sucker rods are disconnected from the beam. This means includes a worm gear 107 rotatably supported in a journal member 108, one end of which is swingably mounted upon a pivot 109 carried by the Samson post 18. The other end of the journal member 108 is pivotally connected to a supporting member 110. When the supporting member 110 is moved into its vertical position with its lower end abutting a stop 111 secured to the derrick floor, the worm gear 107 is maintained in meshing relationship with a gear 112 non-rotatably secured to the first countershaft 30. When the supporting member 110 is swung relative to the journal member 108 until its lower end abuts against a second stop 113 secured to the derrick floor, the worm gear 107 is swung downwardly about the pivot 109 out of engagement with the gear 112. A handle 114 secured to the worm gear 107 projects beyond the journal member 108 so that the worm gear may be manually rotated.

When it is desired to disconnect the string of sucker rods 15 from the beam 16 using this embodiment of my invention, the prime mover 35 is shut down and the supporting member 110 is moved from the position indicated in the dotted lines of Fig. 1 to the position indicated in the full lines of this figure. The handle 114 is then rotated, moving the pistons 39 and 51 until the walking beam 16 is in its desired position. The sucker rods are then disconnected from the beam 16, the worm gear 107 preventing rotation of the gear 112 and first countershaft 30, and thus preventing movement of the pistons 39 and 51.

While I have illustrated the worm gear 107 as associated with the first countershaft 30, it may be associated with any suitable shaft upon the apparatus. Likewise, while the counterweight 57 is illustrated as applied to one of the shafts in the train of countershafts between the prime mover and the crank 21, this counterweight may be applied to any shaft so related to the crank shaft 22 as to rotate at twice the angular velocity of the crank shaft 22.

While I have described the variations in load as occurring at certain positions of the crank, or other parts of the apparatus, I am aware that due to conditions such as expansion and contraction of the string of sucker rods, deformation of the walking beam and Samson post etc. these variations may actually occur at positions of the crank different from the exact positions I have described, and therefore such positions as I have described for load variations must be understood to be variable in accordance with such conditions.

The foregoing apparatus constitutes one embodiment of apparatus of my invention and one embodiment of apparatus capable of performing the method of my invention. The method of my invention includes the step of making the loads upon the prime mover substantially equal during the two strokes of a reciprocating member such as the walking beam 16, string of sucker rods 15 and/or pump plunger 14. This step, as illustrated in the drawings, may be accomplished

by compressing a gas in the expansion chamber 41 during one stroke of the reciprocating member and thus storing energy, and expanding this gas during the succeeding stroke of the reciprocating member and thus applying energy to the reciprocating member.

The method of my invention also includes the step of storing the energy freed by the loss of momentum during the deceleration of the reciprocating member during one stroke and applying this energy to the reciprocating member during the acceleration period of its succeeding stroke. As illustrated in the drawings this may be accomplished by compressing a gas in the auxiliary cylinder 50 during only the second half of the downstroke of the reciprocating member and expanding this gas during only the first half of the succeeding upstroke of the reciprocating member. By this step my method equalizes the load upon the prime mover during the deceleration of the reciprocating member on one stroke and its acceleration on the succeeding stroke.

My method also includes the step of equalizing the loads upon the prime mover when the crank is near its dead center positions and when the crank is in its positions farthest from dead center. As illustrated in the drawings, this may be accomplished by utilizing a counterweight rotating at twice the angular velocity of the crank, the counterweight, such as the counterweight 57, storing energy while the crank is approaching and passing through and beyond its dead center position, and restoring energy to the system as the crank approaches its next position farthest from dead center.

My method also includes the step of maintaining the load counterbalancing effect substantially constant. As illustrated in the drawings, this may be accomplished by replacing in the expansion chamber 41 gas which escapes therefrom and by returning to the cylinder 37 and expansion chamber 41 liquid which escapes therefrom so that the volumes of liquid and gas in the chamber 41 are maintained substantially constant.

My method also includes the step of utilizing the means for storing energy during the deceleration of the reciprocating member and returning this energy to the system during the succeeding acceleration of the reciprocating member, for maintaining substantially constant the volume of gas in the load counterbalancing means. As pointed out in the foregoing specification, this is accomplished by storing the energy of deceleration by the compression of a gas and conducting the required amount of such compressed gas to the expansion chamber 41 through the storage chamber 42.

My method also contemplates the provision of a body of lubricant in lubricating relationship with the piston and cylinder wall of the load counterbalancing means, the inertia counterbalancing means and the liquid return means. This may include the mechanism by which a body of lubricant is maintained on top of the piston 39 and below the piston 81, as hereinbefore described.

While that embodiment of the apparatus of my invention hereinbefore illustrated and described is fully capable of performing the objects and advantages primarily stated and of performing the method of my invention, the apparatus of my invention may be embodied in other forms and the method of my invention may be performed by other apparatus, and I therefore wish my invention to be understood as not restricted to the spe-

cific embodiment hereinbefore illustrated and described.

I claim as my invention:

1. In an apparatus for reciprocating a member including a drive shaft and a crank arm, the combination of: means counterbalancing the weight of the reciprocating member whereby the maximum loads on the drive shaft are substantially equal on the two strokes of the member; means absorbing energy from and decelerating the member on one stroke and delivering energy to and accelerating the member on its succeeding stroke whereby the loads on the drive shaft near the end of one stroke and the beginning of the succeeding stroke are substantially equalized; and means absorbing energy when the crank arm is near dead center position and delivering energy when the crank arm is farthest from dead center position whereby the load on the drive shaft is substantially uniform throughout the stroke.

2. In an apparatus including a drive shaft for reciprocating a pump plunger, the combination of: means counterbalancing the weight of the reciprocating parts and one-half the weight of the liquid lifted by the plunger; means absorbing the energy of momentum of the reciprocating parts during the latter part of their downstroke and applying energy to accelerate the reciprocating parts during the early part of their upstroke; and means storing energy when the reciprocating members are near the end of their strokes and applying energy thereto when said members are near the middle of their strokes.

3. In an apparatus for reciprocating a pump plunger, including a drive shaft and a crank, the combination of: means counterbalancing the reciprocating parts whereby the loads on the drive shaft on the up and down strokes of the plunger are substantially equal, said means including a fluid pump; and means decelerating the reciprocating parts near the end of a stroke and accelerating the reciprocating parts near the beginning of the succeeding stroke, said means replacing in said fluid pump of said first named means fluid escaping therefrom.

4. In an apparatus for reciprocating a pump plunger including a drive shaft and a crank, the combination of: means counterbalancing the reciprocating parts whereby the loads on the drive shaft on the up and down strokes of the plunger are substantially equalized, said means including a piston adapted for pumping liquid in a cylinder to compress a gas in a chamber; return means for returning to the cylinder liquid which has passed between said piston and cylinder whereby the volume of liquid in said cylinder and chamber is maintained substantially constant; pump means, including an auxiliary piston and cylinder, taking energy from the reciprocating parts only during their deceleration by compressing a gas and delivering energy to the reciprocating parts only during their acceleration of the succeeding stroke by expanding the gas, said auxiliary cylinder having a body of lubricant therein; a cup shaped member on the lower end of said auxiliary piston dipping into the body of lubricant at the lower end of each stroke, said member having openings therein for the discharge of a sealing lubricant film between said member and the wall of said auxiliary cylinder during travel of said auxiliary piston; means storing energy when the crank is near dead center position and delivering energy when the crank is farthest from dead center position whereby the load on the

drive shaft is substantially equalized throughout the stroke; and means manually operable for preventing movement of said counterbalancing means, said pump means and said storing means when the pump plunger is disconnected from the crank.

5. In an apparatus for reciprocating a pump plunger including a drive shaft and a crank, the combination of: means counterbalancing the reciprocating parts whereby the loads on the drive shaft on the up and down strokes of the plunger are substantially equalized, said means including a piston adapted for pumping liquid in a cylinder to compress a gas in a chamber; return means for returning to the cylinder, from a body of liquid maintained in sealing relationship between said piston and said cylinder, liquid which has escaped around said piston, whereby the volume of liquid in said cylinder and chamber is maintained substantially constant; pump means, including an auxiliary piston and cylinder, taking energy from the reciprocating parts only during their deceleration by compressing a gas and delivering energy to the reciprocating parts only during their acceleration of the succeeding stroke by expanding the gas, said auxiliary cylinder having a body of lubricant therein; a cup shaped member on the lower end of said auxiliary piston dipping into the body of lubricant at the lower end of each stroke, said member having openings therein for the discharge of a sealing lubricant film between said member and the wall of said auxiliary cylinder during travel of said auxiliary piston; means storing energy when the crank is near dead center position and delivering energy when the crank is farthest from dead center position whereby the load on the drive shaft is substantially equalized throughout the stroke; and means manually operable for preventing movement of said counterbalancing means, said pump means and said storing means when the pump plunger is disconnected from the crank.

6. In an apparatus for reciprocating a pump plunger including a drive shaft and a crank, the combination of: means counterbalancing the reciprocating parts whereby the loads on the drive shaft on the up and down strokes of the plunger are substantially equalized, said means including a piston adapted for pumping liquid in a cylinder to compress a gas in a chamber; return means for returning to the cylinder liquid which has passed between said piston and cylinder whereby the volume of liquid in said cylinder and chamber is maintained substantially constant; pump means, including an auxiliary piston and cylinder, taking energy from the reciprocating parts only during their deceleration by compressing a gas and delivering energy to the reciprocating parts only during their acceleration of the succeeding stroke by expanding the gas, said auxiliary cylinder communicating with said chamber whereby the quantity of gas in said chamber is maintained substantially constant, said auxiliary cylinder having a body of lubricant therein; a cup shaped member on the lower end of said auxiliary piston dipping into the body of lubricant at the lower end of each stroke, said member having openings therein for the discharge of a sealing lubricant film between said member and the wall of said auxiliary cylinder during travel of said auxiliary piston; means storing energy when the crank is near dead center position and delivering energy when the crank is farthest from dead center position whereby the load on the drive shaft is substantially equalized throughout the stroke;

and means manually operable independently of said drive shaft for moving said plunger and preventing movement of all of said means when said plunger is disconnected from said crank.

7. In combination: a walking beam; means for pivotally supporting said walking beam; means for rocking said walking beam; pump means in a well; connecting means extending from said walking beam to said pump means whereby the rocking of said walking beam actuates said pump means; a stationary member; a movable member connected to said walking beam and associated with said stationary member to provide a fluid-tight chamber variable in volume in response to the rocking of said walking beam, said chamber containing fluid at least part of which is gas, whereby the gas will be compressed and energy stored during one stroke of said walking beam and the gas will be expanded and energy delivered during the other stroke of said walking beam; a second stationary member; a second movable member actuated by said walking beam and associated with said stationary member to provide a second chamber variable in volume in response to the rocking of said walking beam, said chamber containing gas; means venting said second chamber whereby gas will be compressed and energy stored in said second chamber during only part of said one stroke of said walking beam and the gas will be expanded in said second chamber and energy delivered during only part of the said other stroke; and means connecting said second chamber to said chamber for supplying compressed gas to said chamber whenever the pressure in said chamber falls below a predetermined value.

8. In combination: a walking beam; means for pivotally supporting said walking beam; means for rocking said walking beam; pump means in a well; connecting means extending from said walking beam to said pump means whereby the rocking of said walking beam actuates said pump means; a stationary member; a movable member connected to said walking beam and associated with said stationary member to close a fluid-tight chamber variable in volume in response to the rocking of said walking beam, said chamber containing a fluid at least part of which is gas, whereby the gas will be compressed and energy stored during one stroke of said walking beam and the gas will be expanded and energy delivered during the other stroke of said walking beam; and means releasably connected to said movable member to prevent movement of said movable member when said connecting means is disconnected from said walking beam.

9. In an apparatus for reciprocating a pump plunger including a drive shaft and a crank, the combination of: means counterbalancing the reciprocating parts whereby the loads on the drive shaft on the up and down strokes of the plunger are substantially equalized, said means including a piston adapted for pumping liquid in a cylinder to compress a gas in a chamber; a second piston reciprocable in a second cylinder formed in said first cylinder and communicating with both sides of said piston; means associated with said cylinder and operating said second piston during reciprocation of said piston whereby liquid is forced from said second cylinder into said cylinder to maintain substantially constant the volume of liquid in said cylinder and chamber; pump means, including an auxiliary piston and cylinder, taking energy from the reciprocating parts only during their deceleration by compressing a gas and de-

- livering energy to the reciprocating parts only during their acceleration of the succeeding stroke by expanding the gas, said auxiliary cylinder having a body of lubricant therein; a cup shaped member on the lower end of said auxiliary piston dipping into the body of lubricant at the lower end of each stroke, said member having openings therein for the discharge of a sealing lubricant film between said member and the wall of said auxiliary cylinder during travel of said auxiliary piston; means storing energy when the crank is near dead center position and delivering energy when the crank is farthest from dead center position whereby the load on the drive shaft is substantially equalized throughout the stroke; and means manually operable for preventing movement of said counterbalancing means, said pump means and said storing means when the pump plunger is disconnected from the crank.
10. In a well pumping apparatus including a reciprocating member, the combination of: means substantially counterbalancing the weight of the reciprocating member, said means including a primary member and a secondary member reciprocating with the reciprocating member and associated with said primary member to close a chamber variable in volume in response to the reciprocation of the reciprocating member, said chamber containing liquid and gas, whereby the gas will be compressed and energy stored during one stroke of the reciprocating member and the gas will be expanded and energy delivered during the other stroke of the reciprocating member; means for supplying gas to said chamber to maintain the amount of gas therein substantially constant; and means for supplying liquid to said chamber to maintain the amount of liquid therein substantially constant.
11. In a well pumping apparatus including a reciprocating member, the combination of: means substantially counterbalancing the weight of the reciprocating member, said means including a primary member and a secondary member reciprocating with the reciprocating member and associated with said primary member to close a chamber variable in volume in response to the reciprocation of the reciprocating member, said chamber containing liquid and gas, whereby the gas will be compressed and energy stored during one stroke of the reciprocating member and the gas will be expanded and energy delivered during the other stroke of the reciprocating member; means absorbing energy from the reciprocating member by compressing a gas near the end of the stroke of the reciprocating member and applying energy thereto by the expansion of the gas during the early part of the succeeding stroke of the reciprocating member, said means supplying gas to said chamber to maintain the amount of gas therein substantially constant; and means supplying liquid to said chamber to maintain the amount of liquid therein substantially constant.
12. In a well pumping apparatus including a reciprocating pump plunger, the combination of: means counterbalancing the reciprocating parts whereby the loads on the prime mover on the two strokes of the plunger are substantially equalized, said means including a piston adapted for pumping a fluid in a chamber; a second piston reciprocable in a cylinder formed in said piston and communicating with both sides of said piston; and means reciprocating said second piston relative to said cylinder during reciprocation of said piston whereby fluid is forced from said cylinder into said chamber to maintain sub-

stantially constant the amount of fluid in said chamber.

13. In a well pumping apparatus for reciprocating a pump plunger and its connections, the combination of: means counterbalancing the reciprocating parts including the pump plunger and its connections whereby the loads on the prime mover on the two strokes of the plunger are substantially equalized, said means including a piston adapted for reciprocation to compress a fluid in a cylinder; and means for locking said piston against movement relative to said cylinder whereby the plunger and its connections may be disconnected from the apparatus without loss of pressure on the fluid, said means being manually operable to move said piston during the connection of the plunger and its connections to the apparatus.

14. In a well pumping apparatus, the combination of: a prime mover; a member driven by said prime mover; a pump plunger in a well connected to and reciprocated by said member; means counterbalancing said pump plunger and reciprocating parts whereby the loads on the prime mover on the up and down strokes of said pump plunger are substantially equalized; means absorbing energy from said pump plunger and reciprocating parts during the later part of one stroke and applying energy to said pump plunger and the reciprocating parts during the early part of their succeeding stroke; means storing energy when said member is near the end of its travel in one direction and applying energy thereto when said member is near the middle of its travel in the opposite direction; and means for securing said first mentioned means against movement.

15. In a well pumping apparatus including a reciprocating member, the combination of: means storing energy from the reciprocating member during its deceleration and applying energy to the member during its subsequent acceleration; and means for securing said first mentioned means against waste of energy by movement during disconnection of the reciprocating member from the apparatus, said means being manually operable during such disconnection for movement to facilitate connection of the reciprocating member to the apparatus.

16. In an oil well pumping apparatus, the combination of: a prime mover; a drive shaft driven by said prime mover; a crank driven by said drive shaft; a walking beam; means connecting said crank and said walking beam whereby said walking beam is oscillated by the rotation of said crank; a pump including a plunger; means connecting said plunger and said walking beam whereby said plunger is reciprocated by the oscillation of said walking beam; means counterbalancing the reciprocating parts whereby the loads on the drive shaft on the up and down strokes of the plunger are substantially equalized, said means including a piston adapted for pumping fluid in a chamber; return means for returning to the chamber fluid which has leaked therefrom whereby the amount of fluid in said chamber is maintained substantially constant; pump means including an auxiliary piston and cylinder taking energy from the reciprocating parts during their deceleration by compressing a fluid and delivering energy to the reciprocating parts during their acceleration, said auxiliary cylinder having a body of lubricant therein; a cup-shaped member on the lower end of said auxiliary piston dipping into the

body of lubricant at the lower end of its stroke, said member having openings therein for the discharge of lubricant between said member and the wall of said auxiliary cylinder during travel of said auxiliary piston; means storing energy when the crank is near dead center position and delivering energy when the crank is farthest from dead center position, whereby the load on the drive shaft is substantially equalized throughout the stroke; and means for locking the apparatus in stationary position during the removal of said pump and connecting means from said walking beam.

17. The method of counterbalancing a vertically reciprocating pump plunger in a well, which includes the steps of: applying force to the plunger throughout its downstroke resisting movement of the plunger, said force increasing with the travel of the plunger; applying force to the plunger throughout its upstroke assisting its movement, said force being substantially equal to the force resisting the plunger's downward movement and decreasing with the travel of the plunger; applying an auxiliary force to the plunger during only the later part of its downward stroke resisting its movement, said force increasing with the travel of the plunger in that

portion of its stroke in which such force is effective; and applying a force to the plunger substantially equal to the auxiliary force during only the early part of its upstroke, said force decreasing with the travel of the plunger in that portion of its stroke in which such force is effective.

18. The method of counterbalancing a pump plunger vertically reciprocated in a well by the rotation of a crank, which includes the steps of: applying force to the plunger throughout its downstroke resisting movement of the plunger, said force increasing with the travel of the plunger; applying force to the plunger throughout its upstroke assisting its movement, said force being substantially equal to the force resisting the plunger's downward movement and decreasing with the travel of the plunger; applying force to the crank resisting its movement during its travel near dead center position, said force diminishing with the distance of the crank from such position; and applying a force to the crank substantially equal to the last named force assisting its travel in position farthest from dead center position, said force diminishing with the distance of the crank from such position.

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