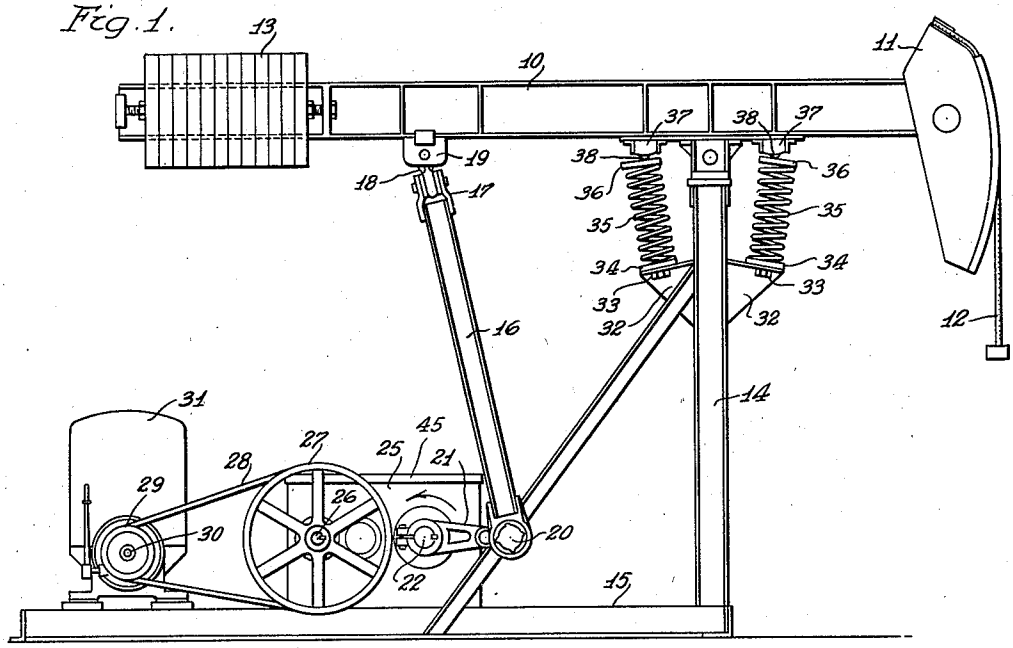
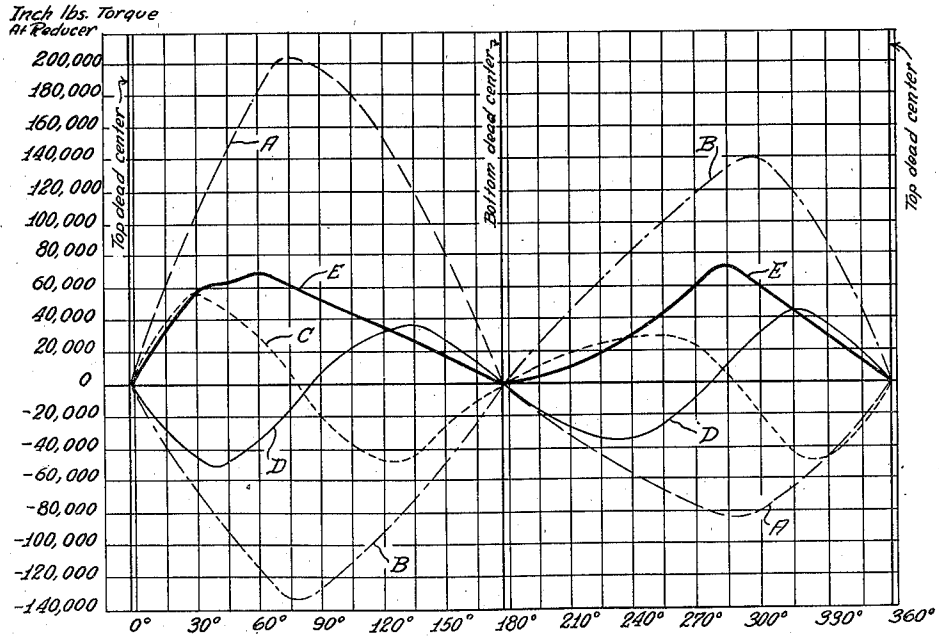
Feb. 24, 1942. J. M. HARTGERING ET AL 2,274,601

OIL WELL PUMPING UNIT

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Fig. 1.





Well load - Static ——— (A)
Counterweight - Static ——— (B)
Total Dynamic - - - - - - - (C)
Springs ——— (D)
Resultant ——— (E)

Fig. 2.

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OIL WELL PUMPING UNIT

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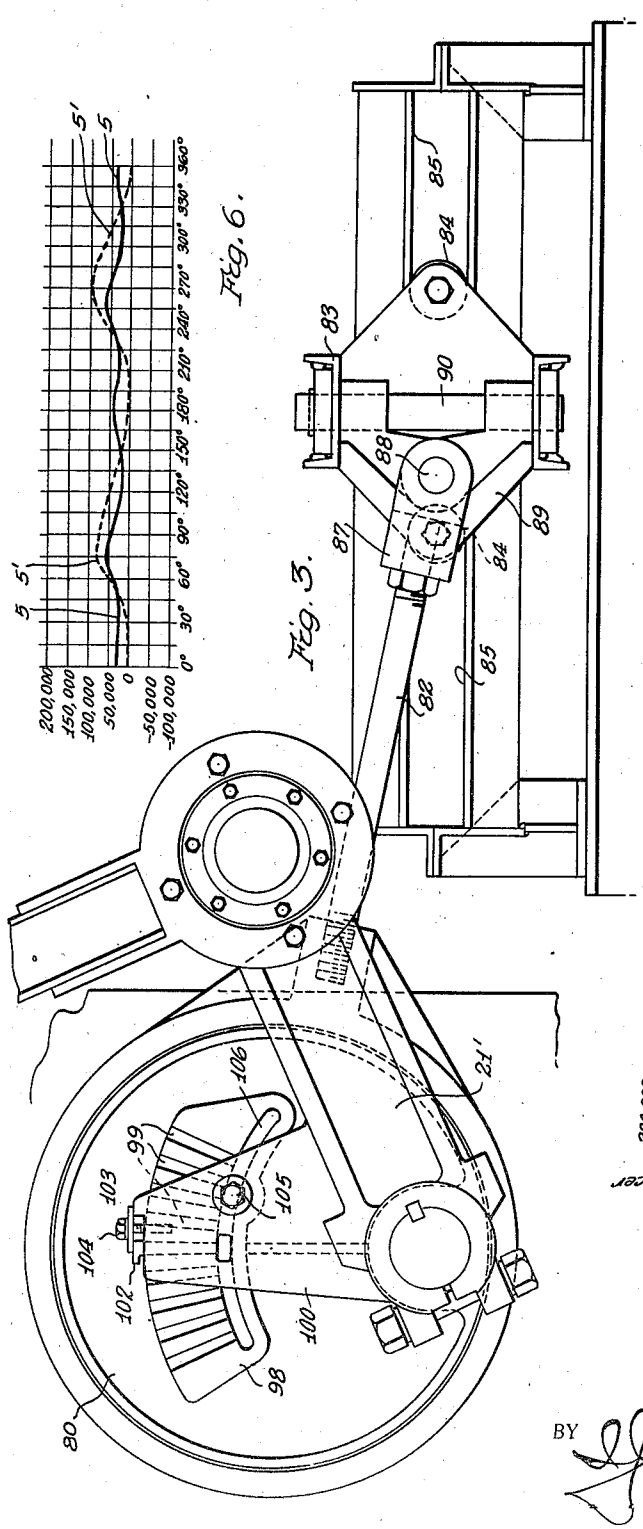


Fig. 3.

Fig. 6.

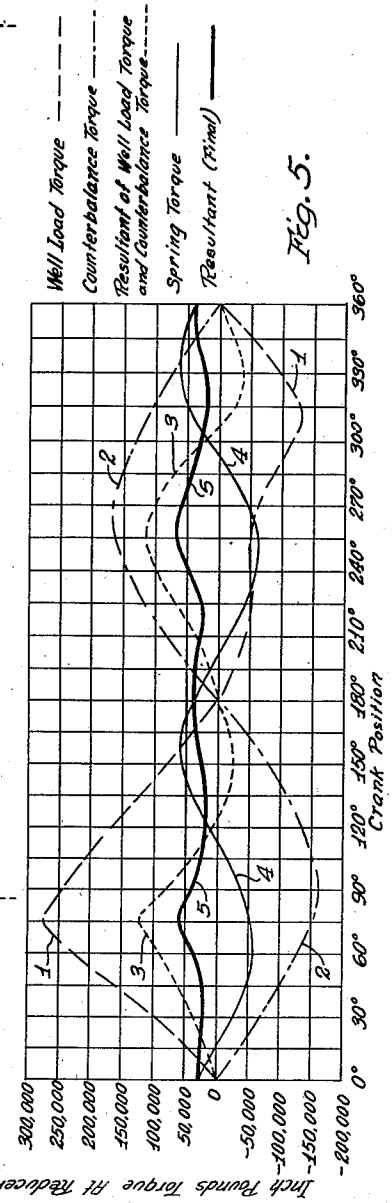


Fig. 5.

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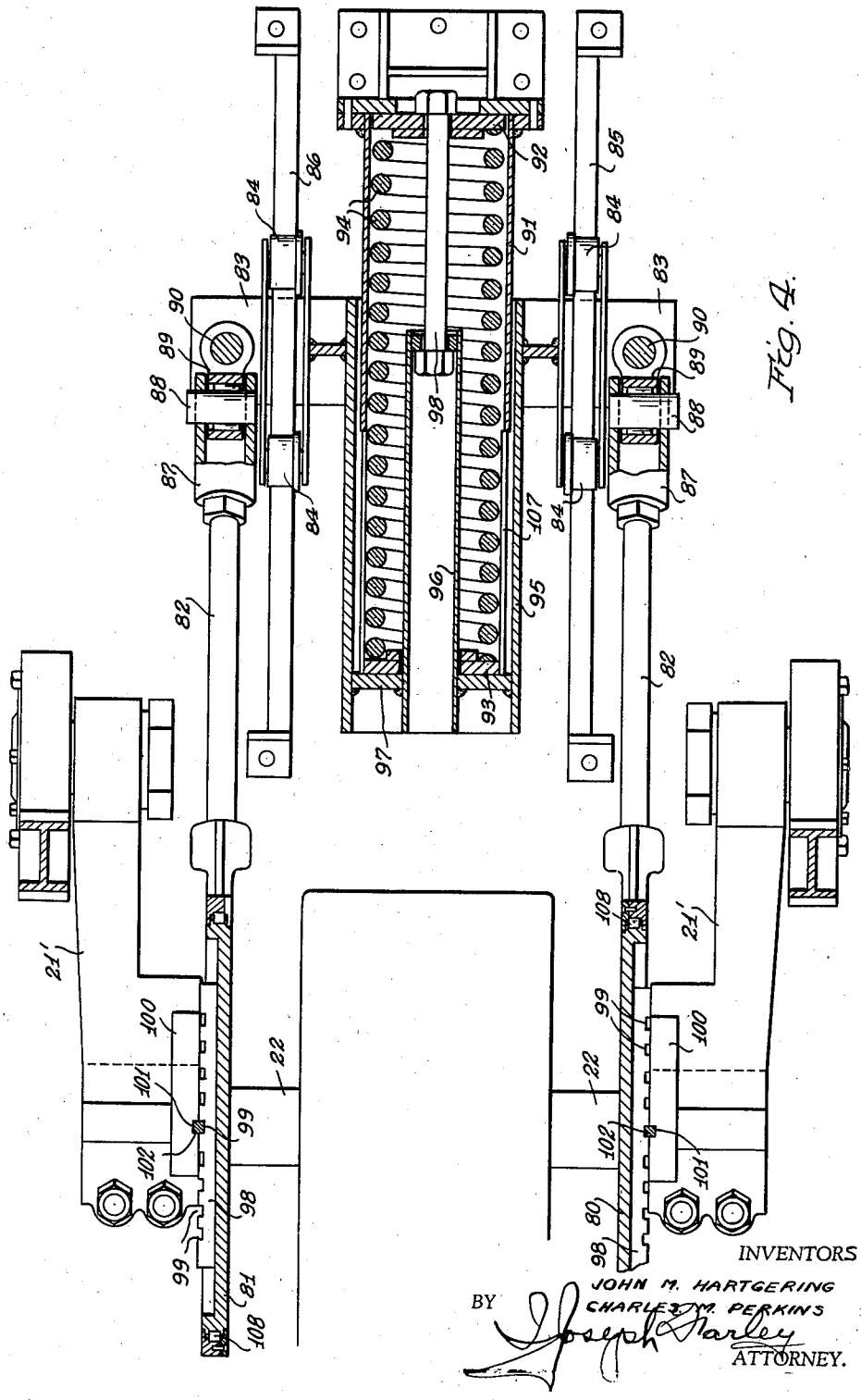


Fig. 4.

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UNITED STATES PATENT OFFICE

2,274,601

OIL WELL PUMPING UNIT

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Application July 1, 1939, Serial No. 282,388

14 Claims. (Cl. 74—41)

This invention relates to pumping units for oil wells.

A large amount of equipment for pumping the oil out of oil wells is used annually. These wells are in many instances of very great depth and although pumping devices for oil wells have been in extensive use for very many years such mechanisms have been rather crude and have not been very efficiently employed throughout their long period of use. The equipment which has been more or less universally employed to bring the subterranean oil to the surface in an oil well consists of a hollow steel tubing which is sunk into the hole as the drilling of the well proceeds and which tubing extends from the surface of the ground down into the oil pool. After the well has been drilled to the required depth a pump plunger is located at the bottom of the tubing to the top of which is usually connected the lower end of a string of sucker-rods, which extend upwardly through the tubing or casing for connection to a pumping mechanism. The pumping mechanism ordinarily employed is in the form of a walking beam pivoted between its ends to an upright post known as a Samson post. The upper ends of the sucker-rods are connected usually by one or more cables to one end of the walking beam while the other end of the walking beam is provided with a series of counterbalancing weights and at a point intermediate the counterbalancing weights and the Samson post connection is made to a suitable driving mechanism for oscillating the walking beam in a vertical plane. The driving mechanism for this type of equipment takes the form usually of an internal combustion engine connected to a gear reduction box having on the output end thereof a suitable crank, the crank being connected by a pitman to the walking beam for oscillating the same. The walking beams used are quite long and the oscillation of such beams is usually of sufficient amplitude to give a pumping stroke that may vary from usually 24 to 72 inches. As such wells may range anywhere from 1,000 to over 4,000 feet in depth it will be apparent that the weight of the sucker-rods is very great and that to such weight is added the weight of the column of fluid in the casing above the pump plunger. Consequently, very heavy loads are placed upon the pumping mechanism. The heavy loads placed upon the pumping mechanism are rendered more severe by the necessity to reverse the walking beam and connected parts at the ends of the oscillations thereof as obviously the walking beam and the parts connected thereto must be brought to a full stop and the direction of movement of the parts reversed at the ends of the strokes. Due to inertia and momentum effects, it has been found to be more or less an inherent characteristic that in pumping mechanism of this character the parts attain an acceleration as the walking beam has traversed from ⅔ to ¾ of its stroke in either direction that it overruns the driving mechanism and places a very heavy negative torque on such mechanism which decreases toward dead center positions and then the load mounts with great rapidity toward the mid-stroke position of the walking beam.

Many attempts have been made to offset these extreme fluctuations in the load conditions, including the use of counterbalancing weights upon the actuating crank of the pitman, fluid pressure pistons and cylinders and other devices but such expedients have been directed mainly toward reducing or cushioning the shocks on the mechanism upon the reversals of the walking beam at the ends of its strokes corresponding to the top and dead center positions of the actuating crank of the driving mechanism rather than towards entirely eliminating negative torque effects.

One of the principal objects of the present invention is to provide a new and improved mechanism whereby negative torque effects upon the driving mechanism are eliminated entirely.

Another object is to provide a mechanism which, in addition to eliminating negative torque effects, serves also to reduce very substantially the amount of torque or load placed upon the driving mechanism at the peak points.

A further object is to provide spring loading means in addition to the usual counterbalancing weights to oppose the action of the walking beam at the points of its travel wherein the overrunning or negative torque effects produced by the momentum of the moving parts tend to reach their maximum effects.

Another object is to provide spring loading means for use with the larger sizes of pumping units whereby positive driving torque of substantially constant magnitude will be required to operate the unit.

A further object is to design the spring means and its method of connection to the pumping unit in such a manner that the phase of the spring cycle can be varied in relation to that of the unit.

Another object is to so design the spring means and associate such means with the walking beam that during the movement of the walking beam

such spring means will be actuated by the walking beam to store energy during those portions of travel in which the walking beam and associated parts would, if unaffected by the spring means, normally be producing negative torque and which stored energy of the springs is returned to the walking beam during those periods in which maximum torque is required to produce its movement.

A further object is to provide spring loading means for a pumping unit of the type described above consisting of a pair of spring devices, the members of which pair are mounted on opposite sides of the Samson post and interposed in the path of travel of the walking beam in such manner that each spring means operates independently of the other and each is brought into action in those portions of the travel of the walking beam only in which were it not for the presence of the spring means negative torque effects would normally be developed.

Another object is to so associate the spring means of the type described with the walking beam and in the path of movement thereof that the members of the pair of spring devices are automatically brought into operation alternately and during those portions of the travel of the walking beam in which one of the spring means is being actuated by the walking beam to store energy therein and to return such energy back to the walking beam, the beam is substantially unaffected by the other member of the pair of spring devices.

The above and other objects will become more readily apparent from the following more detailed description and by reference to the accompanying drawings forming a part hereof wherein we have selected for illustration a form of construction which has proved to be highly satisfactory in actual operation.

In the drawings

Fig. 1 represents a side elevation of an oil well pumping unit constructed in accordance with the present invention;

Fig. 2 is a graphical representation of the static and dynamic loads on the walking beam, also showing graphically the effect of the springs and resultant with the various forces involved.

Fig. 3 is a side elevation of an alternate form of the invention, showing a portion of the pitman rod and the crank.

Fig. 4 is a plan view of the structure of Fig. 3.

Figs. 5 and 6 are graphical representations of the loads encountered in a typical oil well installation showing the results obtained from the invention.

The pumping unit as shown in Fig. 1 comprises the usual walking beam 10 carrying at one end thereof a member 11 which is usually termed a horse head and which serves for attachment to the walking beam of one or more cables 12, which in turn are connected through the sucker rods, not shown, to the pumping piston located in the usual oil well tubing or casing. At its other end the walking beam is provided with a plurality of counterbalancing weights 13. The walking beam 10 is pivotally mounted at a suitable point between its ends to the upper end of a rigid support or Samson post 14 rigidly supported upon, and braced to, a supporting frame work 15.

Means for imparting oscillating motion to the walking beam 10 consists of a pitman rod 16 to the upper end of which is secured a clevis 17 connected by a swivel connection 18 to a pitman saddle 19 suitably secured to the under side of the walking beam. At its lower end the pitman rod is connected to a crank pin 20 carried by a crank 21 suitably secured to the output shaft 22 of a gear reduction mounted in a gear box 25, the input shaft of which, 26, has secured thereto a suitable driving pulley 27 connected by a belt 28 and second driving pulley 29 to the power shaft 30 of a suitable power source such as an internal combustion engine or electric motor 31.

In the simplest form of the invention the Samson post 14 is provided with a pair of angular spring supporting brackets 32 to the upper faces of which is secured, preferably by bolts 33, spring retaining plates 34. Welded, or otherwise suitably secured to the spring retaining plates 33, are the lower ends of a pair of compression springs 35, such springs being mounted as clearly shown, one upon each side of the Samson post. Each of the springs 35 has secured to it, as by welding or in any other suitable way, a reaction plate 36 which lies in the path of movement of the walking beam 10. Secured to the walking beam upon each side of the Samson post 14 immediately above the reaction plate 36 is a roller retaining member 37 having mounted therein a hardened steel roller 38, suitable roller bearings or the like being mounted between the roller 38 and the housing member.

The operation of the unit as shown in Fig. 1 is as follows: Assuming the shaft 22 is rotated in a counter-clockwise direction, and with the walking beam in the horizontal position as shown, rotation of the crank 21 will cause the lefthand end of the beam 10 to be moved upwardly and the right hand end downwardly in the performance of a pumping stroke. When the beam is in the horizontal position shown, both of the springs 35 are under a slight compression or loading, but as the left hand end of the beam moves upwardly, the roller 38 moves out of contact with the reaction plate 36, thus unloading the left hand spring 35 and leaving the left hand end of the walking beam 10 as it performs the balance of its upward motion, uninfluenced by the action of the left hand spring 35. At the same time the right hand end of the beam, moving downwardly, impresses an increasingly greater load upon the right hand spring 35, which loading reaches its maximum when the crank 21, and its crank pin 20, has reached its uppermost limit, or top dead center position. As the crank pin 20 passes the top dead center and reverses the direction of movement of the walking beam, the energy stored in the right hand spring 35 will be restored, as it were, to the walking beam and will exert an appreciable upward thrust thereon, the spring serving, during its compression, to absorb the violent shock, or cushion the action of the walking beam when reversal of its motion takes place, and in addition, preventing negative torque or overrunning effects that otherwise would be present in the driving mechanism were it not for the presence of the springs 35. When the crank 21 moves the walking beam 10 back to the horizontal position in the reversed direction of movement, the roller 38 on the right hand side of the Samson post will move out of contact with the reaction plate of the right hand spring 35 while the roller 38 on the left hand side will simultaneously engage with the reaction plate of the left hand spring 35 during the time the pumping unit is performing its suction stroke.

The functioning of the springs 35 can best be understood by reference to the graph of Fig. 2 in which dotted line AA represents the values of

the load in inch-pound torque at the gear reducer for corresponding position of the crank 21 and crank pin 20. The dot and dash line BB represents torque load due to the static load of the counterweight 13 of the walking beam and the dotted line CC represents torque load due to total dynamic effects. The light full line DD represents the torque load due to the springs 35 while the heavy full line EE represents the total, or resultant torque load of all of the static and dynamic forces with the counteracting forces due to the action of the spring 35.

As will be seen by referring to Fig. 2 the peak static well load in the example selected for illustration has a value of slightly over 200,000 inch pounds of torque which is reduced as shown by the resultant curve EE to an amount of but approximately 70,000 pounds. As will be seen by the curves CC and DD the springs 35 are so proportioned that the effect thereof is approximately equal and opposite to the dynamic effects for the moving parts, so that when the springs 35 are employed as clearly depicted by the graph EE, no negative torque effects are present when the springs are properly designed and proportioned for the loads encountered. It will be noted by comparing the graph BB with the graph AA that the peak point of the counterweight effect is opposite to the peak of the static well load and that if the resultant curve of the static well load, counterweight load and total dynamic load were drawn, the torque effects would fluctuate from positive to negative during each 180 degrees of crank rotation, this being the condition that would prevail in this particular installation were the springs not used.

Figs. 3 and 4 show another type of spring mechanism which operates at the output shaft of the reducer rather than directly upon the walking beam as does the form just described. Essentially it consists of a pair of eccentrics 80 and 81, mounted at either end of the reducer output shaft 22 inside the cranks 21', and connected by rods 82 to the cross head 83 which is carried by four roller bearing trolley wheels 84 running in the guides 85 and 86. The connection between the rods 82 and the cross head 83 is made using a universal type joint composed of the clevis 87, mounted on the horizontal shaft 88, carried by the yoke shaped member 89 which in turn is mounted upon the vertical shaft 90. This construction insures the spring load being evenly divided between the two eccentrics.

One spring only is used in this embodiment of the invention. It is confined within a length of pipe 91 by right and left hand back-up plates 92 and 93 respectively at each end thereof which are free to move towards each other. Movement of the cross head is transmitted to the spring 94 by means of an outer sleeve 95 welded to the cross head at one end. A smaller sleeve 96 is secured at its other end by means of the ring 97 which has its outer periphery recessed at intervals to slide in slots 107 provided in the pipe 91. The smaller sleeve 96 is then connected by the bolt 98 to the right hand back-up plate 92, and by means of this bolt the spring 94 can be placed in precompression if desired.

To illustrate the action of this mechanism, as the cross head is moved to the right of its position shown in Fig. 4, the ring 97 will move correspondingly, acting upon the left hand back-up plate 93 and compressing the spring against the right hand back-up plate 92. When the motion of the cross head is reversed the energy stored in the spring will be returned to the reducer shaft, less, of course, the inevitable losses. At the mid-position of the cross head, the spring will be at its full length, and upon further travel of the cross head towards the left, it will be compressed against the left hand back-up plate. In other words, the spring 94 is double acting and is, therefore, the equivalent of the two springs used in the construction shown in Fig. 1.

Another feature of this construction, even more important, is the way in which the eccentric is connected to the moving parts. Instead of being keyed directly to the reducer shaft 22, its outer surface is formed with a boss 98 in which a series of keyways 99 are located in angular relationship to the center of the shaft 22. The crank 21' used in this case is of different design than the crank 21 of Fig. 1, having an integrally cast flange 100 in which is located a single keyway 101 similar in all respects to those of the eccentric, so that the angular relationship of the crank and eccentric can be varied by keying ony one of the numerous keyways of the latter to the single keyway of the former. Taper keys are preferably used because of their ease of insertion and because they will act to bring the keyways of the crank and eccentric into final alignment more readily than would straight keys. Once a key 102 has been driven home between the crank and the eccentric, it is locked in place by the small plate 103 clamped in position by the bolt 104, and the crank flange is attached to the eccentric by the bolt 105 which passes through the arcuate slot 106 in the boss of the eccentric.

The whole spring unit is designed to operate with the least possible amount of friction, first because of the inclusion of the cross head rollers 84, and also because of the provision of a plurality of small rollers 108 between the adjacent peripheries of the eccentric and strap.

The results obtained by the use of this second form of the invention are graphically illustrated in Fig. 5 by a set of curves similar in some respects to those of Fig. 2, but representing the conditions encountered in the operation of a deep well where the forces present are complicated by the great amount of stretching which occurs in the sucker rods on each pumping stroke. This explains the break which occurs in the negative or down stroke portion of the well load torque curve 1—1 which was taken from an actual dynamometer card and hence includes both the static and dynamic loads. Therefore, a curve similar to C—C of Fig. 2 is not needed in this case. Counter-balance torque is shown by the curve 2—2 opposing the well load torque and the resultant of the well load and counterbalance torques is shown by the curve 3—3 which is the sum of curves 1 and 2. For this particular installation, as can be seen from the curve 3—3, the resultant torque is in the nature of a second harmonic to the well load torque of curve 1—1 and lies between a positive peak value of about 120,000 inch pounds and a negative peak value of about 35,000 inch pounds with a total variation of about 155,000 inch pounds. To counteract these torque variations, the spring torque is added as shown in curve 4—4 by means of the mechanism previously described and shown in Figs. 3 and 4. Instead of being ninety degrees out of phase with the resultant torque of curve 3—3 as would necessarily be the case were the installation of Fig. 1 used, it was determined that for the particular set of conditions existing in Fig. 5 better results could be obtained if the phase of

the spring torque were displaced somewhat from its ordinary position. Consequently the eccentric was rotated upon the output shaft and keyed to the crank to advance the spring torque approximately 22.5 degrees in relation to the resultant torque of curve 3—3 with the result that the final resultant torque of curve 5—5 is subject to less variation and more closely approximates the ideal condition of a straight line or constant torque.

The advantages attributable to this construction, which makes it possible to vary the disposition of the spring torque, are very important, for a maximum reduction in final net torque can thereby be achieved. This is strikingly illustrated by the graph, Fig. 6, where the final resultant curve 5—5 of Fig. 5 is shown together with the broken line curve 5'—5' which indicates what the final resultant torque would be were not the spring torque displaced from its normal position. It shows a required maximum torque of about 100,000 inch pounds and a variation of minimum to maximum of about the same amount as compared with a resultant maximum of 60,000 inch pounds and a variation of 45,000 inch pounds required from the unit as shown by curve 5—5.

The conditions as shown by the graphs of the operation of both types of construction are quite analogous to well-known harmonic series effects in that although the curves are not true harmonic sine curves, it will be seen that the resultant curve for a pumping unit not provided with the counteracting springs, would be in the nature of a second harmonic to the well load torque. A resultant load variation of this character is almost universally found to be present in these oil well pumping units because the customary counterbalance cannot counteract the dynamic torque effects which vary with double the frequency of the well load and counterbalance torques. This is the reason for the effectiveness of the present invention, since it superimposes a counteracting double harmonic upon the simple counteraction of the counterbalance, thereby eliminating all negative torque effects and reducing the peak values of positive torques.

Practically, this means that the required capacity of the prime mover is correspondingly reduced, that it can be run more efficiently because of the more constant load conditions, and that the reducer unit and driving mechanism can be of a much smaller load capacity than would otherwise be required because of the lower values of torque encountered.

In either form of the invention, namely that shown in Figs. 1 and 2 or in Figs. 3 to 5, if for any reason it becomes necessary or desirable to employ the counteracting force of only one spring, one of the springs 35 shown in Fig. 1 may readily be removed from the Samson post, while the same effect may be secured with the mechanism of Figs. 3 and 4 by simply disconnecting the bolt 98.

As the result of employing the resilient members to counteract the momentum of the very heavy moving loads which the pumping units are called upon to carry, it is possible to employ a lighter construction throughout all of the driving members of the gear reduction as well as the housing in which they are supported. Moreover, by the use of these resilient members or springs, the following advantages are obtained—(*a*) elimination of negative torque on reducer and consequent reduction of shock load on the reducer; (*b*) a large decrease in peak torque; (*c*) a substantial decrease of saddle bearing load; (*d*) a decrease in the pitman and wrist pin bearing loads; (*e*) a decrease of bending moment on the walking beam; (*f*) smaller speed variation in reducer; (*g*) reduction of the amount of counterbalance required on end of walking beam or on reducer slow speed shaft.

While we have shown a satisfactory constructional example, it will be understood that many changes, variations and modifications of the constructional details may be resorted to without departing from the spirit of the invention.

We claim:

1. A pumping device of the type described, consisting of a walking beam pivotally mounted between its ends upon a Samson post having at one end thereof means for connecting thereto a reciprocating pump plunger and at the other end counterbalancing means and driving means to actuate said walking beam, said device characterized by the combination with said walking beam of spring loading means mounted upon opposite sides of said Samson post in the path of travel of said walking beam but unattached thereto, each of said spring devices being alternately and automatically compressed by the action with said beam to counteract negative torque effects in said gear box driving means and to store in such spring means power ordinarily dissipated in the production of such negative torque effects and to automatically restore to the walking beam such stored power during the portion of the travel of such walking beam in which maximum positive torque is required.

2. A pumping device of the type described consisting of a walking beam pivotally mounted between its ends upon a Samson post having at one end thereof means for connecting thereto a reciprocating pump plunger and at the other end counterbalancing means and driving means to actuate said walking beam, said device characterized by the combination with said walking beam of a pair of energy-storing devices located in the path of travel of said walking beam but unattached thereto, each of said devices being actuated independently of the other during the downward travel of the respective portion of the beam with which each device is adapted to engage, to store energy in said device during such downward travel and to return the energy so restored to said walking beam during the upward travel of such beam, the energy stored reaching its maximum at the point of lowest movement of said beam and the device becoming ineffective upon said walking beam after the latter has reached approximately its horizontal central position.

3. A pumping device of the type described, consisting of a walking beam pivotally mounted between its ends upon a Samson post having at one end thereof means for connecting thereto a reciprocating pump plunger and at the other end counterbalancing means and driving means including a crank to actuate said walking beam, said device characterized by the combination with said walking beam of resilient members mounted upon opposite sides of said Samson post in the path of travel of said walking beam but unattached thereto, each of said resilient members being loaded and unloaded by the action of said walking beam during substantially alternate 180° of revolution of said crank such that the maximum loading of said resilient members during said 180° of crank rotation occurs to counter-

act negative torque effects ordinarily present in the operation of said pumping device.

4. In an oil well pumping unit having a counterbalanced walking beam, driving means, and means connecting said driving means to said walking beam to impart a reciprocating motion to the latter, characterized by the combination with said walking beam of resilient members positioned to oppose the motion of said walking beam and counteract negative torque effects in said driving means with a corresponding decrease in the maximum torque present in said driving means.

5. An oil well pumping unit having a pivoted vertically oscillating walking beam characterized by a pair of resilient members located in the path of movement of said beam, one on each side of the pivotal mounting thereof, said resilient members being unconnected to said beam and each of said members being directly engaged by, and effective upon said beam only when that portion of the beam located upon the same side of its pivotal mounting as the respective resilient member, has reached substantially the horizontal position of its oscillation and during the continued oscillation thereof below said horizontal position whereby said resilient members are effective to substantially neutralize dynamic effects of the moving parts of said unit and prevent negative torque effects.

6. In a driving mechanism operating upon a load which varies from positive to negative alternately, means to counteract the effect of said load variation upon said driving mechanism comprising energy storing devices interposed between said load and driving mechanism, one of said energy storing devices operating at the frequency of said load but in reverse phase thereto, and a second energy storing device operating at a second harmonic of the frequency of said load variation, said second energy storing device comprising a resilient member associated with said driving mechanism.

7. In a driving mechanism operating upon a load which varies from positive to negative alternately, means to counteract the effect of said load variation upon said driving mechanism comprising energy storing devices interposed between said load and driving mechanism, one of said energy storing devices operating at the frequency of said load but in reverse phase thereto, and a second energy storing device operating at a second harmonic of the frequency of said load variation, said second energy storing device comprising a resilient member associated with said driving mechanism, and means whereby the phase of operation of said energy storing device can be advanced or retarded relative to the phase of application of the load upon said driving mechanism.

8. In a pumping unit having a walking beam, driving means, and a gearbox interposed between said driving means and said walking beam, a reciprocating energy storing device connected to the output shaft of said gearbox.

9. In a pumping unit having driving means and a gearbox driven thereby, a reciprocating energy storing device connected to the output shaft of said gearbox, said energy storing device being loaded and unloaded during 180 degrees of rotation of said output shaft.

10. In a pumping unit having driving means, and a gearbox driven thereby, an energy storing device comprising eccentrics mounted upon the output shaft of said gearbox, a crosshead driven by said eccentrics, the reciprocating motion of said crossheads being opposed by a spring associated therewith, said spring being loaded and unloaded during 180 degrees of rotation of said output shaft.

11. In a pumping unit having driving means, a gearbox driven thereby, cranks connected to the output shaft of said gearbox for imparting a reciprocating pumping stroke, an energy storing device comprising eccentrics rotatably mounted upon said output shaft adjacent said cranks, a keyway formed in a flange of said cranks, a plurality of keyways formed on the face of said eccentrics, said eccentrics being keyed to said cranks by a key engaging the keyway of said cranks and one of the plurality of keyways of said eccentrics, a crosshead travelling upon rollers in suitable guideways driven by said eccentrics, the reciprocating motion of said crosshead being opposed by a spring associated therewith, said spring being loaded and unloaded during 180 degrees of rotation of said output shaft, and means whereby the operation of said spring can be made continuous or intermittent.

12. In a pumping unit having driving means, a gearbox driven thereby, cranks connected to the output shaft of said gearbox for imparting a reciprocating pumping stroke, an energy storing device comprising eccentrics rotatably mounted upon said output shaft adjacent said cranks, a keyway formed in a flange of said cranks, a plurality of keyways formed on the face of said eccentrics, said eccentrics being keyed to said cranks by a key engaging the keyway of said cranks and one of the plurality of keyways of said eccentrics, a crosshead travelling upon rollers in suitable guideways driven by said eccentrics, the reciprocating motion of said crosshead being opposed by a spring associated therewith.

13. In a pumping unit having driving means, a gearbox driven thereby, cranks connected to the output shaft of said gearbox for imparting a reciproacting pumping stroke, an energy storing device comprising eccentrics rotatably mounted upon said output shaft adjacent said cranks, a keyway formed in a flange of said cranks, a plurality of keyways formed on the face of said eccentrics, said eccentrics being keyed to said cranks by a key engaging the keyway of said cranks and one of the plurality of keyways of said eccentrics, a crosshead travelling upon rollers in suitable guideways driven by said eccentrics, the reciprocating motion of said crosshead being opposed by a spring associated therewith, said spring being loaded and unloaded during substantially 180 degrees of rotation of said output shaft.

14. In a pumping unit having a driving mechanism, said pumping unit being actuated by suitable means connected to the output shaft of said driving mechanism, whereby said driving mechanism operates upon a load which varies from positive to negative values alternately, means for inducing a counteracting torque upon said driving mechanism comprising a resilient member associated with said pumping unit so as to be loaded and unloaded during substantially 180 degrees rotation of said output shaft of said driving mechanism.

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