

June 18, 1940.

W. J. CRITES

2,204,725

MEANS FOR REDUCING STRESSES IN OIL WELL PUMPING EQUIPMENT

Filed Oct. 19, 1937

4 Sheets-Sheet 1

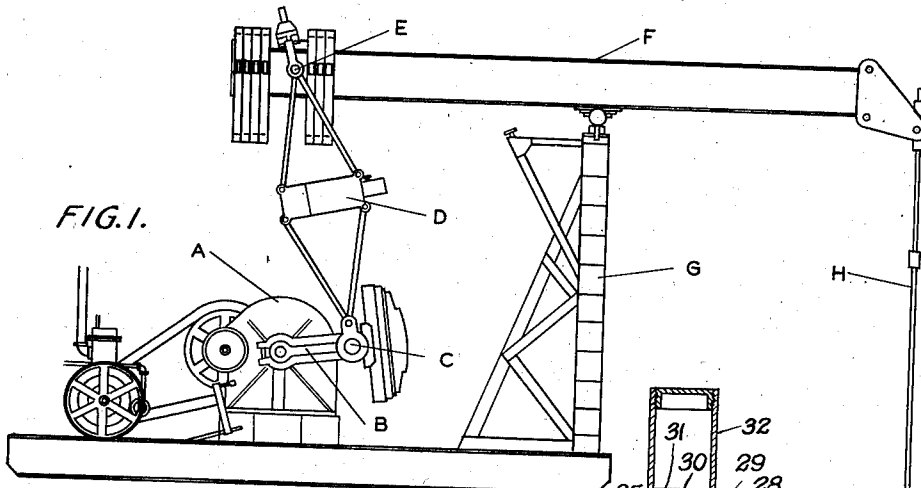


FIG. 3.

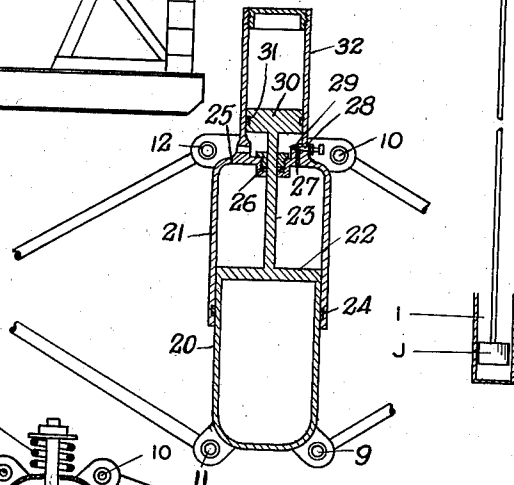
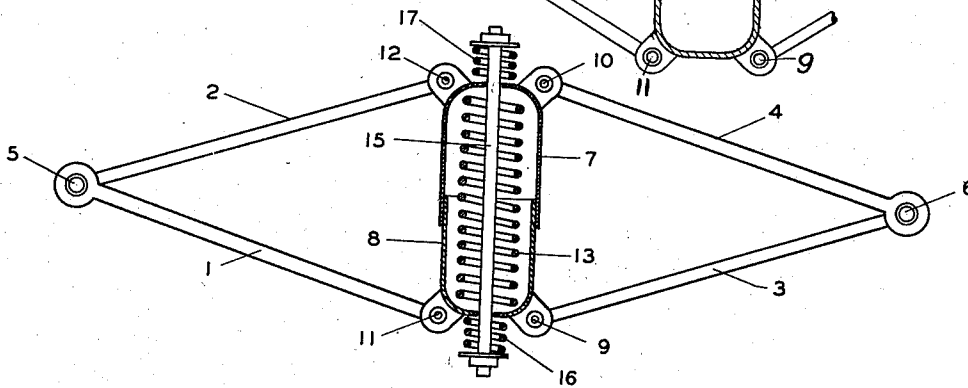


FIG. 2

INVENTOR.
WILBUR J. CRITES.
BY *Hudson, Cowan, Young, & Shaeffer*
ATTORNEYS.

June 18, 1940.

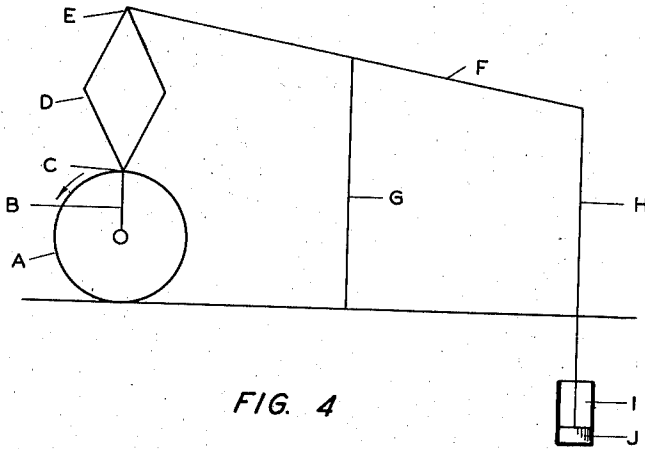
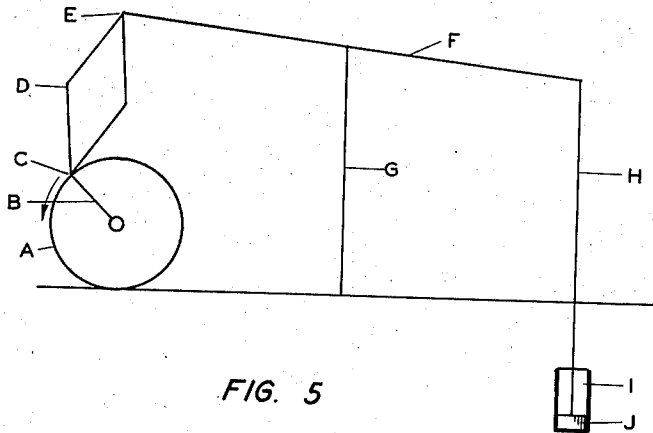
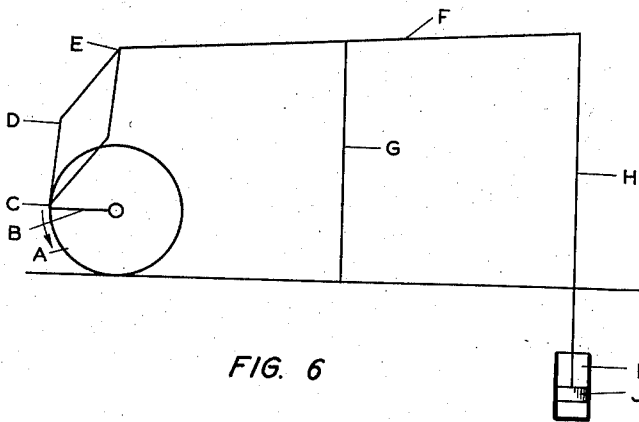
W. J. CRITES

2,204,725

MEANS FOR REDUCING STRESSES IN OIL WELL PUMPING EQUIPMENT

Filed Oct. 19, 1937

4 Sheets-Sheet 2



INVENTOR.
WILBUR J. CRITES

BY *Hudson, Corwin, Young & Hawley*
ATTORNEYS.

June 18, 1940.

W. J. CRITES

2,204,725

MEANS FOR REDUCING STRESSES IN OIL WELL PUMPING EQUIPMENT

Filed Oct. 19, 1937

4 Sheets-Sheet 3

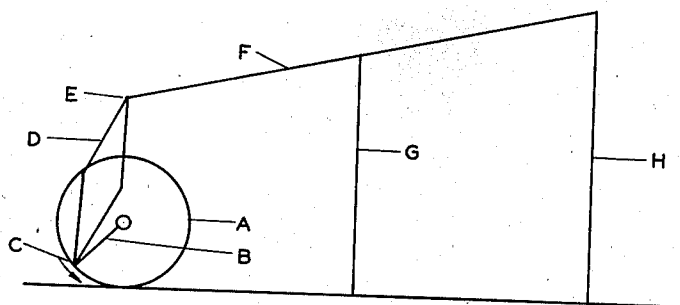


FIG. 7

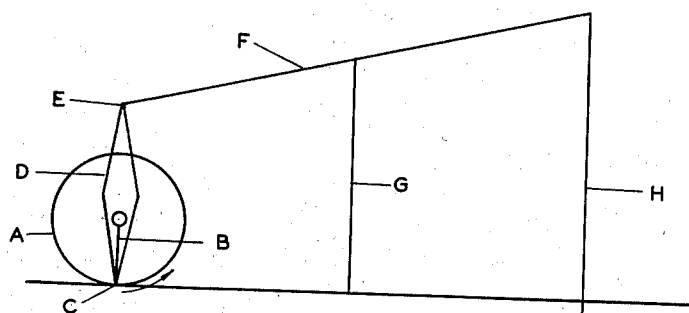


FIG. 8

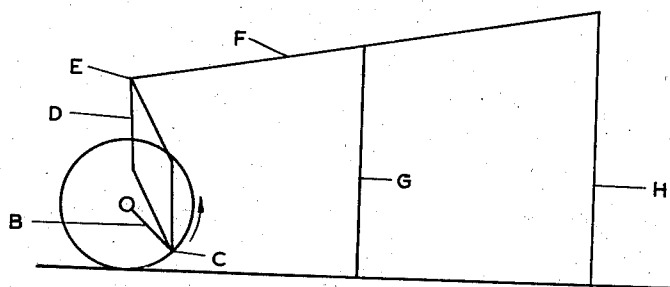


FIG. 9

INVENTOR.
WILBUR J. CRITES

BY *Hudson, Connor, Young & Hanley*
ATTORNEYS.

June 18, 1940.

W. J. CRITES

2,204,725

MEANS FOR REDUCING STRESSES IN OIL WELL PUMPING EQUIPMENT

Filed Oct. 19, 1937

4 Sheets-Sheet 4

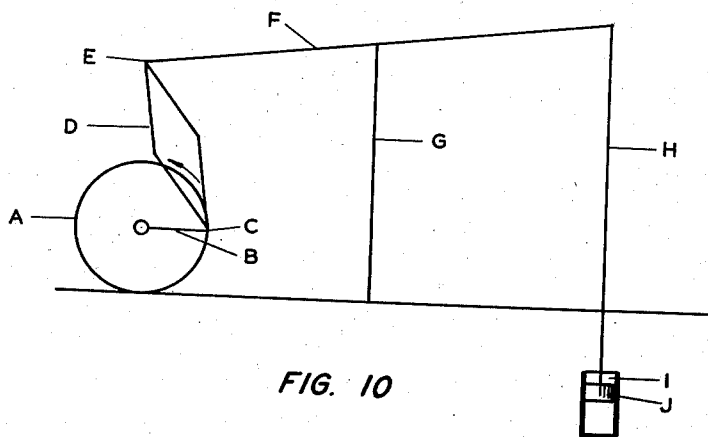


FIG. 10

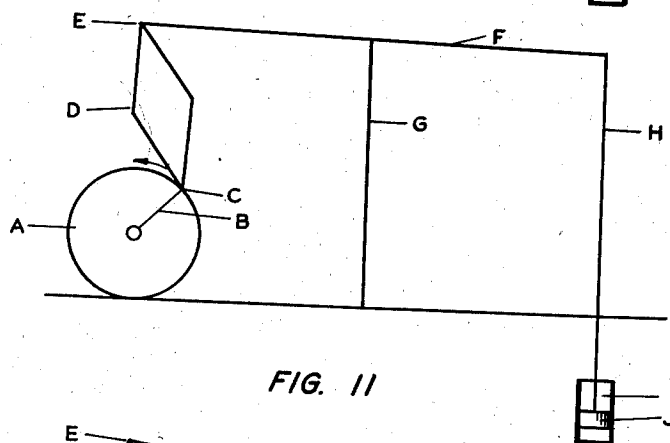


FIG. 11

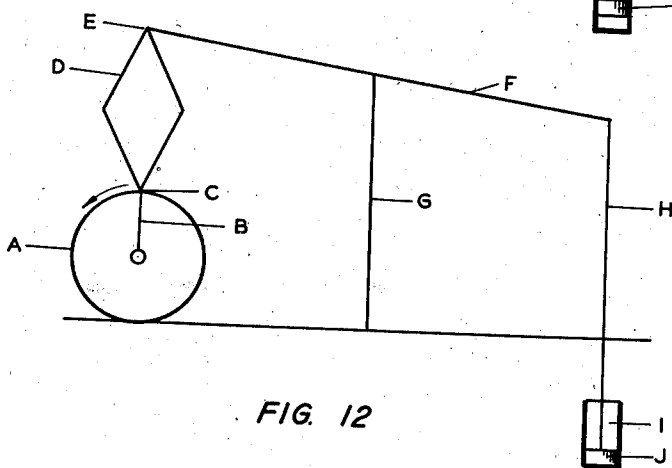


FIG. 12

INVENTOR.
WILBUR J. CRITES

BY *Hudson, Connor, Young & Hanley*
ATTORNEYS.

UNITED STATES PATENT OFFICE

2,204,725

MEANS FOR REDUCING STRESSES IN OIL
WELL PUMPING EQUIPMENTWilbur J. Crites, Bartlesville, Okla., assignor to
Phillips Petroleum Company, a corporation of
Delaware

Application October 19, 1937, Serial No. 169,880

2 Claims. (Cl. 74—581)

This invention relates to improvements in pumping machinery, more particularly to that specific type of pumping machinery which is used in the production of oil from wells.

5 In the pumping of oil from wells, the method that is almost universally used involves a string of tubing supported at the well head, on the lower end of which is a working barrel with a valve on the bottom of the working barrel. This valve is called a standing valve and will allow fluid to pass upward from the well bore to the working barrel but will not allow fluid to pass from the working barrel to the well bore. In-
10 side of the working barrel is a plunger or piston in which is incorporated a working valve and will allow fluid to pass from the working barrel to the tubing.

On the surface, at the well head is a reciprocating machine to which is attached a string of rods suspended within the tubing on the lower end of which is attached the plunger or piston. The operation of the reciprocating machine causes the plunger or piston to travel back and forth in the working barrel thus lifting fluid from the well bore, through the working barrel and tubing to the surface.

The operation of the pump would be simple and efficient were it not for two factors. First, the travel of the plunger would follow exactly the travel of the reciprocating machine were it not for the elasticity of the rods and tubing and secondly, the upward travel of the fluid would follow exactly the upward travel of the plunger were it not for the compressibility of the fluid where gas is included. Both of these factors working in conjunction produce destructive effects on all of the equipment and more particularly on the rods. These destructive effects are the result of stress.

40 It is an object of this invention to reduce the stresses on the pumping equipment.

It is a further object of this invention to increase the volumetric efficiency of the pump.

45 It is a still further object of this invention to distribute the stresses on the pumping equipment in such a manner that the equipment is never subjected to the ultimate stress load possible.

50 It is a still further object of this invention to have a lag between the power transmission means and the lifting action of the pump so that the impact stresses set up in the pump do not occur when the power transmission means is traveling at its greatest velocity.

55 It is a still further object of this invention to compensate for the stretch in the pump rods

upon the lifting action of the pump, in order that the impact stresses set up in the pump do not occur when the power transmission means is traveling at its greatest velocity.

It is a still further object of this invention to prevent bending of the pump rods which set up shear stresses tending to fatigue the metal of the rods.

It is a still further object of this invention to compensate for the bending of the pump rods upon the downstroke of the pump plunger.

Other objects and advantages of the invention will be apparent during the course of the following description.

In the accompanying drawings, forming a part of this specification, and in which like numerals are employed to designate like parts throughout the same,

Fig. 1 of the drawings is a side elevation showing a pump operating mechanism embodying the invention;

Fig. 2 is a side elevation of the pitman, with parts broken away;

Fig. 3 is a side elevation of a different modification of the pitman, with parts broken away; and

Figs. 4-12 are schematic diagrams showing the operation of the pump structure, pitman and walking beam for one complete revolution of the crank arm of the power mechanism.

Turning to Fig. 1 of the drawings there is represented the entire pumping unit with A representing the power unit, which may be of any conventional type and forms no part of this invention. The power unit A has attached thereto a crank arm B which is rotated by the power mechanism and the end thereof being pivotally connected to the pitman member D. The pitman member D in turn is pivotally connected at E to the walking beam F and transmits a reciprocating motion to the walking beam. The middle of the walking beam is pivoted to the Samson post G and has its opposite end rigidly attached to the polish rods H. In the operation of the mechanism, the power unit A is set in motion which in turn rotates the crank arm B. The pitman structure D being pivotally connected to the crank arm B will not rotate with the crank arm, but will translate the rotary motion of the crank into a reciprocating motion of the pitman which in turn will be transmitted to the walking beam F. The walking beam being pivoted to the Samson post, each end of the beam will have a reciprocating motion. The polish rods H on the one end will then be given a reciprocating motion which in turn will be

transmitted to the plunger of the pump mechanism, in the bottom of the well and operate to raise the oil from the well.

In the pumping of oil from wells, there are two types of stresses, static and dynamic. Static stresses are those which result from suspended weight while dynamic stresses are those which result from motion application. Static stresses are simple and can be computed easily while dynamic stresses are complicated and often defy exact computation. The static stresses are only slightly destructive but the dynamic stresses are highly destructive and lead to severe strains on the pumping rods.

Since the dynamic stresses are those which result from motion, the greater the rate of motion change, the greater these stresses will be and consequently the more highly destructive. The greatest dynamic stress in the pumping of an oil well occurs from the interruption of motion and is normally at that point in the pump stroke cycle that the fluid starts in motion from the action of the pump plunger. Therefore, the higher the rate of motion at this point, the greater the dynamic stress.

One of the most destructive conditions encountered in the pumping of oil is in those wells in which the gas cannot be effectively separated from the oil before the fluid enters the working barrel. Under this condition impacts will be increased on both the upstroke and downstroke because a part of the plunger travel will be used in gas compression. The volume relationship between the gas and oil may be such that a substantial portion of the stroke is used on the upstroke in compressing the gas before the oil is started in motion and, if so, very destructive dynamic stresses may result therefrom.

Analyzing the motion of the pump plunger, it will be assumed that the rate of motion of the plunger on the downstroke is not of sufficient magnitude that the reversal thereof will appreciably elongate the rods. The plunger reverses its motion at or near the top dead center of the crank as shown diagrammatically in Fig. 4. In this figure B represents the crank arm, the circle, the path of travel of the crank arm, the pitman is represented at D, walking beam at F, Samson post at G and the polish rods at H. The chamber of the pump structure at the bottom of the well is represented at I while the plunger is shown at J. In Fig. 4 the crank arm is at the top dead center of its path of travel and with the crank arm in this position, the plunger J is shown in the bottom of the pump chamber and ready to start upward in the chamber. As the crank moves to the left or to the position shown in Fig. 5, the rods begin to elongate and continue to do so until the stress at the plunger is such that the resultant forces overcome the weight of the fluid on the plunger. As can be seen in Fig. 5, the crank arm has moved an appreciable distance to the left, which motion of the crank arm has not lifted the plunger off the bottom of the chamber but has taken the stretch out of the rods, and continued movement to the left of the crank arm from the position shown in Fig. 5 will now lift the plunger in the chamber.

From the position of the crank arm in Fig. 5 to the position of the crank arm as shown in Fig. 6, the motion of the crank arm will be accelerating until it reaches its maximum speed in the position shown in Fig. 6. While the crank is traveling from the position in Fig. 5 to Fig. 6,

it is at the same time lifting the plunger in the pump chamber. If the liquid in the pump chamber is high in gas content, the upward motion of the plunger during this period will be utilized in compressing the gas in the chamber. The compressing of the gas will not offer any great resistance to the motion of the plunger and hence the plunger during this period will be accelerating in speed just the same as the crank arm which is imparting the motion to the plunger. When all the gas has been compressed and the plunger strikes the liquid, the plunger will start to lift the liquid out of the chamber. But, the liquid not being compressible, the plunger is stopped suddenly with a resultant impact force being imparted to the polish rods and back through the remainder of the equipment. At this point the crank may be at or near the point that it is imparting the maximum rate of travel to the rods and further at this point the total static stress has been transferred from the tubing to the rods and the dynamic stress is now being imparted on the rods under the most severe conditions.

Since the dynamic stress is the most destructive and since the dynamic stress can be reduced by reducing the rate of acceleration, it is the purpose of this invention to start the fluid in motion at this point by reducing the rate of motion of the rods and incidently reducing the rate of motion of the plunger. It is proposed to do this by the application of power through a compressible medium that will cause the rate of acceleration to lag behind the applied rate of acceleration at the time the fluid starts in motion and in that part of the crank cycle that the rate of motion is normally high, thus effecting a material reduction in stress. Further after the fluid starts in motion the stress normally decreases, therefore it is proposed to use the reactive effect of the compressible medium to increase the rate of motion of the fluid without increasing the stress on the rods and other equipment in that part of the crank cycle in which the rate of motion is normally low.

Figs. 2 and 3 show examples of pitman arms in which is located a compressible medium to allow for the above discussed action. Fig. 2 shows arms 1 and 2 pivoted together at their ends by the pivot arrangement 5. Arms 3 and 4 are connected together at the pivot point 6. The other ends of the arms 1 and 2 are connected to the telescoping cylindrical members 7 and 8 by means of the pivot points 11 and 12. The arms 3 and 4 are connected on the opposite side of the telescoping cylindrical members 7 and 8 by means of the pivot points 9 and 10. Within the telescoping cylindrical members 7 and 8 is mounted a coil spring 13 tending to force the two telescoping members apart. A bolt 15 goes through both ends of the telescoping members and has head portions spaced from the ends of the telescoping members so as to limit the amount of expansion of the telescoping members. Mounted between the bolt heads and the ends of the telescoping members are coil springs 16 and 17. As can be readily seen the coil spring 13 tends to keep the four arms separated so as to give the pitman the shape of a diamond. Upon the compression of spring 13, the arms all being pivoted, the pitman tends to lengthen thus giving more or less the action of a lazy tong arrangement. Upon excessive shortening of the pitman, the springs 16 and 17 come into play to relieve the strain on the bolt heads.

Fig. 3 shows a modification of the compressible means for the pitman. The arms are connected to the telescoping members by the pivot structures 9, 10, 11 and 12. The chamber 20 is a closed cylindrical member having a head portion 22 to which is connected the rod 23. The second member 21 into which the member 20 telescopes has a piston ring 24 mounted in a recess in the wall thereof to maintain a seal between the sliding members. The top of the member 21 has an opening to allow the rod 23 to pass therethrough and is sealed by the packing gland 26. Also in the top portion of the chamber 21 are the passages 27 and 29 which are controlled by the needle valve member 28. Mounted on top and integral with the member 21 is a chamber 32 having a piston 30 reciprocal therein with a piston ring 31 mounted in the piston to provide a seal between the chamber wall and the piston. The piston 30 is connected to the rod 23 and moves in conformity with the head 22. The chambers 21 and 32 may be filled with gas under pressure or the chambers can be made of the same size and capacity and liquid may be used with a corresponding increase in the size of the passages 27 and 29. Also a pressure source may be attached to each chamber to replace any gas which may have leaked out of the chamber, as indicated at 33 and 34.

In operation of the compressible device shown in Fig. 3 as the pitman begins to elongate, the head 22 is forced into the chamber 21, thus compressing the gas in chamber 21. Since the piston head 30 is connected to rod 23 it will move back in chamber 29 thus reducing the pressure on the gas in this chamber and providing a place for the gas from chamber 21 to flow. The gas will flow through passages 27, needle valve 28 and passage 29 into chamber 32. The flow will be so regulated that the gas in chamber 21 will act as a cushioning medium for the pitman. The chambers are made of different sizes and capacities to allow the pitman to come back to a fully expanded condition in a smaller interval of time than the time interval for the elongation of the pitman. Since the greatest stresses occur on the upstroke of the plunger, more compressibility is needed in the pitman on this stroke, so a greater amount of gas is needed in chamber 21 when these stresses occur.

Returning to Fig. 4 it can be seen that the pitman D is in its fully open condition and is shortened. Fig. 5 shows the pitman starting to lengthen thus compressing the compressible means. The pull of the crank arm is sufficient to lengthen the pitman somewhat. Fig. 6 shows the crank arm at its greatest accelerated speed with the pitman still elongating but with plenty of space left in the compressible means to allow for the impact shock when the plunger strikes the liquid in the pump chamber. Figs. 7 and 8 show the crank arm during the second half of the upstroke of the plunger and when the crank arm is decelerating in speed. When the crank arm has reached the bottom of its cycle, the plunger is at the top of the chamber and the pitman is fully elongated. It is to be noted that while the diagrams show a gradual elongation of the pitman throughout the whole upstroke of the plunger, the complete elongation of the pitman can occur at any point in the down cycle of the crank arm in which the impact stresses are occurring. This completes the description of that one-half of the crank cycle in which the crank is imparting upward motion

to the rods and plunger. It is this half of the crank cycle in which the fluid is lifted and in which the greatest stresses occur.

In the other one-half of the crank cycle the rods are either in tension from their own suspended weight or if the rate of imparted motion exceeds, at any part of the cycle, that rate which is a result of the acceleration of gravity together with the combined retarding forces, the rods will be in compression. Since the rods and plunger do not fall freely in a pumping well they are often in compression. If only the stress of compression were involved in this the downstroke, very little destruction would result, but the stresses on this stroke are more complicated than those of the upstroke and although not as great, may contribute more to rod and equipment destruction. In the analysis of the source of stress on the upstroke it was necessary to analyze the motion of the plunger since the majority of the stresses on the upstroke had their origin either in the static or dynamic load imposed upon the plunger. In the analysis of stress on the upstroke, friction was not considered because relatively, it would contribute very little to the stress condition.

In the analysis of stress on the downstroke, friction, indirectly, is the source of the majority of the destructive stresses. A study of plunger motion on this stroke would be of little value in the determination of involved stresses. On this stroke, due to the high ratio of longitudinal to cross sectional area of the rods and absence of an immediate supporting medium, the rods will enter a bending stress at such time as the friction at the plunger exceeds the weight of the plunger to the extent that the resulting bending movement will distort the rod column above. Unlike the stress of tension or the stress of compression, the bending stress is not distributed throughout the length of the rods but will be concentrated in a few places and the effect in fore-shortening the stroke may be quite large. The points of bending stress concentration will be at those points that offer the least resistance to bending and repeated bending at these points will soon result in fatigue failure from bending reversals and reversals from tension to compression stress concentrated at the point weakened by bending reversals. Such stress concentration may result in shortening the life of the rods from the application of rod weight alone, but when the rate of applied motion is greater than the rate of motion due to gravity the stress is increased in proportion to the increase of applied power resulting in a rapid progressive failure of the rod structure at the point of stress concentration which is at the point of bending. Further, on the downstroke the working barrel might be partially filled with gas which will offer very little resistance to the downward travel of the plunger but when the gas has been displaced above the working valve, the plunger encounters the liquid at a time when the rate of motion is relatively high and the impact resulting therefrom is transmitted to the point of stress concentration in the rods causing much more rapid failure at this point.

Thus it can be seen from Figs. 9 to 12 that on the downstroke of the plunger the crank arm may be traveling at a speed which is greater than the speed at which the plunger will go down in the chamber, due to the friction force of the plunger with the chamber wall. The stored up energy of the compressible means is employed

during the downstroke to shorten the pitman and thus relieve the rods of the destructive forces set forth above. Fig. 9 shows the crank arm just starting its upstroke and the plunger just starting down on its downstroke. The pitman is starting to shorten, thus allowing the strain to be removed from the rods and the plunger to overcome the friction forces in the chamber. When the crank arm has reached the position in Fig. 10 it is again traveling at its highest speed and the pitman will be coming into its fully open position. By the time the crank arm has reached the position in Fig. 11, the force of gravity on the rods and plunger has imparted a speed to the plunger whereby it has caught up with the speed of the crank arm, and the two move together without any destructive effects on the rods. When the crank arm and plunger have reached the position shown in Fig. 12, we are back to the position of Fig. 4, from which we started and are now ready to lift the plunger again on the upstroke.

Therefore it can be seen that there is here disclosed a pitman which has a main compressible medium so that it will be activated dynamically by the rod motion reversal from down to upstroke. The energy thus transferred to the main compressible medium will be used to move the plunger upward in the early stage of gas compression at the time in the compression period that a relatively small amount of energy is needed to perform this work, thus increasing the volumetric efficiency of the pump. This motion will be imparted to the plunger at the time that the crank is passing over center which is at a time that very little, if any, motion is being imparted to the rods by the crank which allows a greater portion of the crank cycle to be used in doing useful work and dynamic stresses will be reduced because the maximum weight will be applied to the plunger at a lower rate of travel of the plunger. Under this condition the main compressible medium may or may not function according to the characteristics of the well at the end of the upstroke to maintain upward travel of fluid at the

time that the crank has completed that part of its cycle which imparts upward motion to the rods. It is further to be noted that the compressible mediums disclosed are merely representative of compressible mediums which have been found suitable for use. Other compressible mediums may be employed without departing from the spirit of the invention.

It is to be understood that the form of my invention herewith shown and described is to be taken as a preferred example of the same, and that various changes in the shape, size and arrangement of parts may be resorted to, without departing from the spirit of my invention, or the scope of the subjoined claims.

Having thus described my invention, I claim:

1. In a deep well pumping unit of the reciprocal plunger type having rods and a walking beam to reciprocate the plunger with a pitman connected between a power means and the walking beam, said pitman member having a compressible medium mounted therein to absorb stresses from the rods, said compressible medium comprising a pair of telescoping cylinders having a spring mounted therein and two pairs of arms pivotally connected to the ends of the cylinder members on opposite sides thereof with one pair of arms connectable with the walking beam while the other pair connects with the power means.

2. In a deep well pumping unit of the reciprocal plunger type having rods and a walking beam to reciprocate the plunger with a pitman connected between a power means and the walking beam, said pitman member having a compressible medium mounted therein to absorb stresses from the rods, said compressible medium comprising a pair of telescoping cylinders having a spring mounted therein, a bolt member passing through the cylinders to hold the same assembled, spring members mounted on each end of the bolt and without the cylinders and two pairs of arms pivotally connected to the ends of the cylinder members forming the end coupling means for the pitman.

WILBUR J. CRITES.