Jan. 13, 1942. W. E. SAXE 2,269,787

COUNTERBALANCING APPARATUS

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Fig. 1.

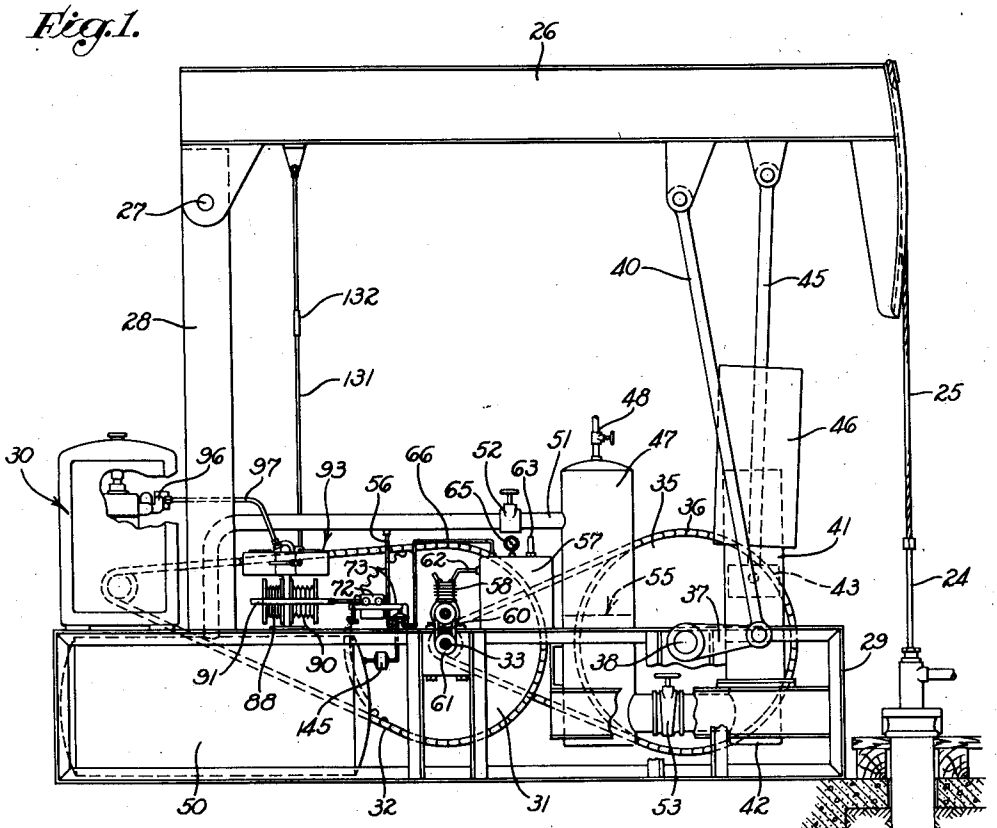


Fig. 4.

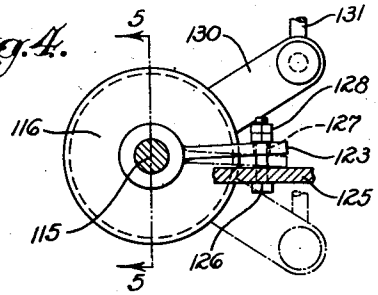


Fig. 5.

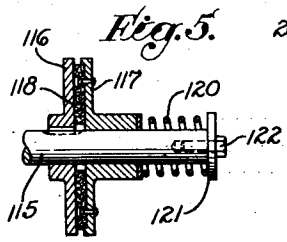
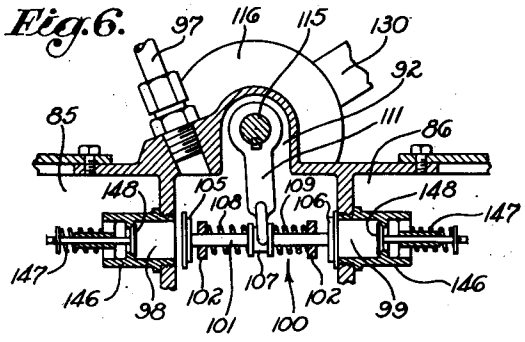


Fig. 6.



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COUNTERBALANCING APPARATUS

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Fig. 2.

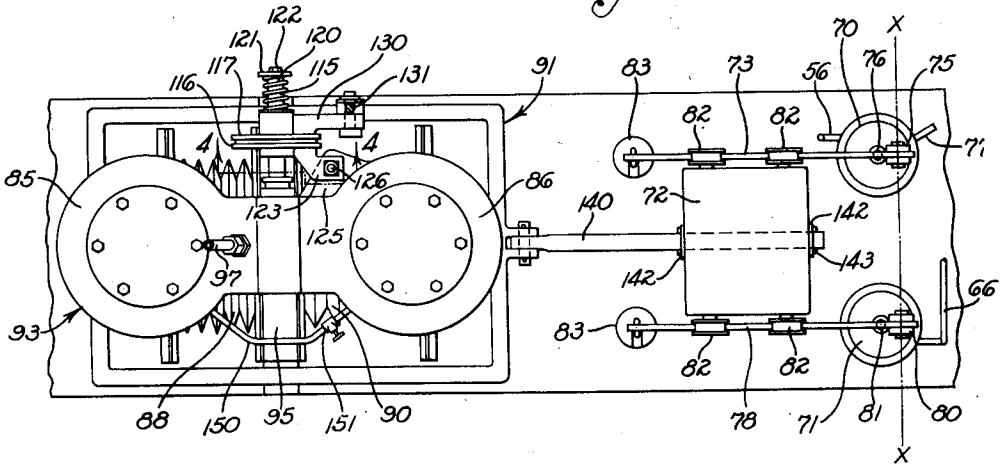
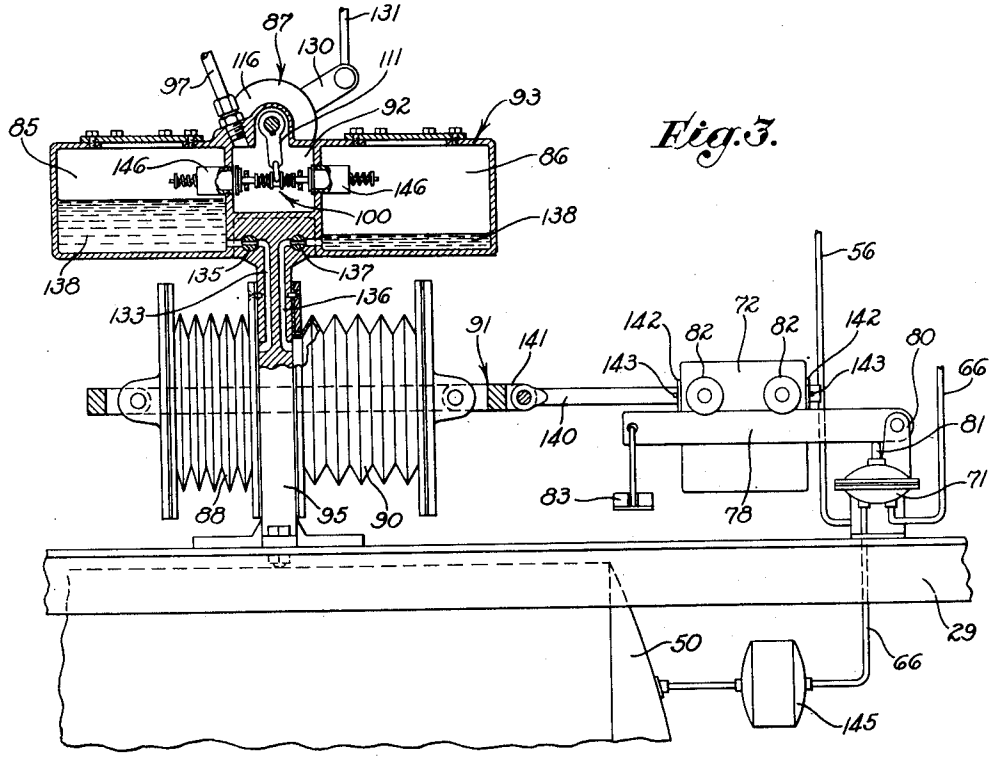


Fig. 3.



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COUNTERBALANCING APPARATUS

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Fig. 7.

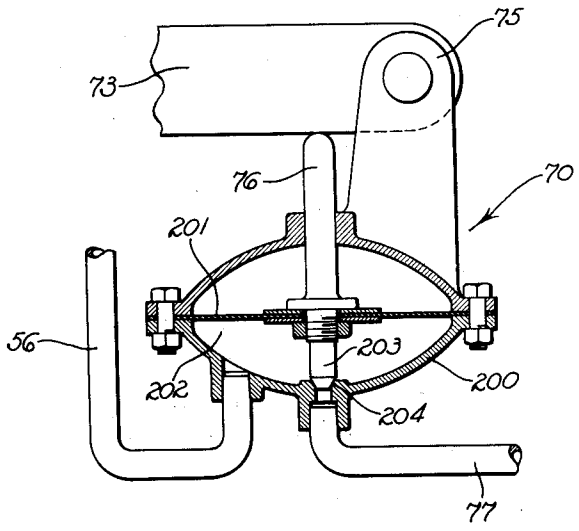
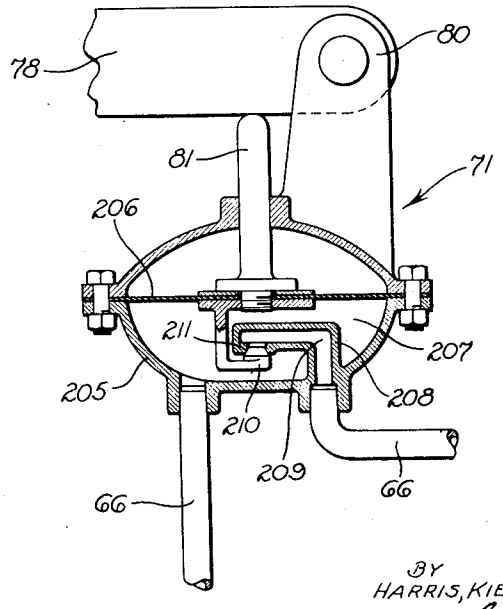


Fig. 8.



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Patented Jan. 13, 1942 2,269,787

UNITED STATES PATENT OFFICE

2,269,787

COUNTERBALANCING APPARATUS

Walter E. Saxe, Alhambra, Calif.

Application April 9, 1940, Serial No. 328,662

12 Claims. (Cl. 60—18)

My invention relates to apparatus for counterbalancing the load on a prime mover, such as the load imposed by a reciprocating member, and is directed specifically to means for automatically varying the counterbalancing force to follow changes in the magnitude of the load.

Since my invention is applicable with exceptional advantages to the problem of automatically counterbalancing pumping apparatus for oil wells, I elect to direct my disclosure to an embodiment of the apparatus for oil well pumping. Those skilled in the art, however, will find sufficient guidance herein for embodying the invention in other apparatus for other purposes.

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, a pitman, and a walking-beam. When the crank arm, in its rotation, is nearly vertical, the component of its movement parallel to the direction of travel of the walking-beam and the pump plunger is relatively small, and therefore the load on the prime mover when the crank is in this position is also 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 the load on the prime mover is then most influenced by the load on the walking-beam. If no counterbalance is employed, it is evident that on the upstroke of the string of sucker rods, when the crank arm is horizontal, the prime mover is subjected to its greatest load, being required at that time to lift with greatest velocity the walking-beam, the string of sucker rods, and all of the liquid being elevated in the well tubing; while on the downstroke, the walking-beam and string of sucker rods fall by gravity, subjecting the prime mover to little or no load.

As disclosed in my Patent No. 2,122,871, issued July 5, 1938, effective counterbalancing in an oil well pumping apparatus may be achieved by compressing air on the downward stroke of the walking-beam to store energy and releasing such energy to assist the prime mover on the upward stroke. By proper adjustment of such apparatus, I am able to equalize the burden on the prime mover during the downward stroke with the burden on the prime mover during the upward stroke for increased efficiency and longer life of the pumping apparatus.

I have found, however, that in the case of many wells, the load during the upstroke of the sucker rod does not remain constant but may vary gradually and, over a period of hours, may be considerably altered. This change may come about through operation of various factors. The fraction of water contained in the oil may change, resulting in a heavier or lighter column of liquid to be raised; or change in the fraction of gas contained in the oil may change the weight of the column of liquid. Moreover, in those wells situated adjacent the ocean, the well pressure and the load on the sucker rod are found to change with the tide. In such installations, it is desirable to vary the counterbalancing force as the load on the sucker rod varies, to make the burdens on the prime mover equal during the upward and downward strokes of the sucker rod. To do this ordinarily requires close attendance to the apparatus, a requirement to be avoided.

In my copending application, Serial No. 228,536, filed September 6, 1938, now Patent No. 2,196,816, entitled "Method and apparatus for automatically counterbalancing pumping apparatus on oil wells," I disclose and generically claim a method and apparatus for varying a counterbalancing force in such apparatus as may be required for equalization under conditions of changing load. The underlying concept is that of comparing the upstroke stage with the downstroke stage of the pumping cycle with respect to force exerted or work done, or some factor that is correlated with force or work and causing any significant differences between the two stages with respect to the selected factor or factors to be brought into effect in a cumulative manner to change the magnitude of the counterbalancing force until equalization is restored at a new level of values. If the emphasis is on force as a factor, the apparatus may be designed to equalize the maximum operative forces of the two stages respectively; whereas by bringing into effect time as a factor along with force, the equalization may be between work performed on the upstroke and work performed on the downstroke regardless of relative magnitudes of force involved. In both cases it may be said that the end sought is equalization of loads on the prime mover.

The present disclosure illustrates the fact that automatic counterbalancing may be achieved by integrating some factor related directly to the prime mover, including such factors as pressure, temperature, amperage, fuel or other energy input, by-product, etc. Such factors are to be distinguished from driving torque, driving pressure, and other forms of applied force that may

be identified in the mechanism for transmitting energy from the prime mover to the load.

An object of the present invention is to base the required automatic operation on one of the factors related directly to a prime mover, the particular prime mover chosen for illustration being an internal combustion engine, and the particular factor selected being the intake pressure of the engine. The manner in which I make the counterbalancing force responsive to the pressure in the intake manifold of an engine will clearly indicate how in other forms of my invention counterbalancing control may be based on other factors relating to an internal combustion engine, or on factors associated with a steam engine, an electric motor, or other form of prime mover.

Other objects and advantages of my invention will be apparent from consideration of the following detailed description and the accompanying drawings.

In the drawings:

Fig. 1 is a side elevation of the preferred form of my automatic counterbalancing apparatus, a portion of the apparatus being broken away for clarity;

Fig. 2 is a plan view on an enlarged scale of a portion of the apparatus shown in Fig. 1;

Fig. 3 is a side elevation of the mechanism shown in Fig. 2, the view being partly in section;

Fig. 4 is a fragmentary section taken as indicated by the line 4—4 of Fig. 2;

Fig. 5 is a section taken as indicated by the line 5—5 of Fig. 4;

Fig. 6 is an enlarged sectional detail of Fig. 3;

Fig. 7 is an enlarged section of a valve employed in the preferred form of my apparatus; and

Fig. 8 is a similar view of a second valve employed in the apparatus.

The drawings illustrate my invention as applied to the pumping apparatus for an oil well 20. The well 20 has a casing 21 and a pump tubing 22 in the lower end of which a pump plunger 23 is reciprocated by a string of sucker rods 24. The sucker rods 24 extend upwardly through the pump tubing to above the surface of the earth and are attached by suitable means, such as a cable 25, to the working end of a walking-beam 26, the other end of the walking-beam being mounted upon a pivot 27 carried by a fulcrum frame 28. This assembly is arranged in such manner that rocking of the walking-beam results in reciprocation of the pump plunger 23 through a pumping cycle comprising an upwardly directed pumping stroke and a downwardly directed return stroke. The fulcrum frame 28 and the remainder of the pumping and counterbalancing apparatus are preferably mounted on an under frame 29.

In the form of pumping apparatus illustrated in the drawings, a prime mover 30 in the form of an internal combustion engine drives a relatively large sprocket 31 through a chain 32, the sprocket being mounted on and keyed to a countershaft 33. A small sprocket (not shown) that is also keyed to the countershaft 33 drives a second large sprocket 35 through a chain 36, and the large sprocket 35 in turn drives a crank arm 37 on a second countershaft 38. Attached to the crank arm 37 and operatively connected with the walking-beam 26 is a pitman 40, the described apparatus being adapted to raise and lower the walking-beam once for every revolution of the crank arm 37.

As in my issued patent, first above-mentioned, I preferably counterbalance the pumping apparatus by counterbalancing means that includes a cylinder 41 secured at its lower end to a housing 42 with which it freely communicates. Reciprocable within the cylinder 41 is a piston 43 having a connecting rod 45 pivotally connected thereto. As a protective cover for the cylinder 41 the connecting rod 45, by preference, carries a hood 46. The housing 42 normally communicates with a compression and expansion chamber 47 having a normally closed release valve 48 and the chamber 47 in turn normally communicates with a relatively large additional chamber 50 through a pipe 51 and valve 52. The valve 52 and a valve 53 between the cylinder 41 and the chamber 47 are ordinarily open unless the walking-beam is to be disconnected from the sucker rod, or the various units of the apparatus are to be isolated for some other reason.

Normally a liquid 55, preferably oil, fills the housing 42 and extends upward to present a surface in contact with the piston 43 in the cylinder 41 and a second surface in contact with a gas within the chamber 47, the gas being, by preference, compressed air and filling the remaining space in the chamber 47 and the whole of the space in the chamber 50. The chambers 47 and 50, the housing 42, and the cylinder 41 thus constitute a chamber that contains gas and liquid and is closed by the movable piston 43.

In normal operation, as the walking-beam is moved down, the piston 43 forces liquid out of the cylinder 41 and housing 42 into the chamber 47, compressing the gas in the chambers 47 and 50 and requiring the prime mover to exert a torque on the downward stroke of the walking-beam, which torque is determined by the dimensions of the gas space, the stroke of the piston, and the initial pressure of the gas in the compression space. The use of a relatively large chamber 50 to provide a relatively large compression space results in a relatively small change in gas volume upon movement of the piston 43, and therefore results in a relatively small change in gas pressure throughout the cycle of movement of the piston. On the upward stroke the gas in the chambers 47 and 50 acts upon the piston 43 to help raise the walking-beam, at the same time expanding to its original volume. The present form of my invention is adapted to automatically seek equality of work required by the prime mover to raise the walking-beam on its upstroke with work required of the prime mover on the downstroke of the walking-beam. It is contemplated that whenever work performed by the prime mover on the upstroke of the walking-beam exceeds the work performed by the prime mover on the downstroke of the walking-beam, gas will be added to the counterbalancing system to raise the counterbalancing pressure and that, on the other hand, when greater work is expended on the downstroke of the walking-beam than on the upstroke, gas will be released from the counterbalancing system automatically.

The means for lowering the counterbalancing pressure may be simply a valve controlled release pipe connected at any suitable point to the counterbalancing apparatus, for example, a valve controlled release pipe 56 connected to the pipe 51 and controlled by automatic means to be described hereinafter.

For raising the gas pressure in the counterbalancing system when required, I may provide a high pressure reservoir 57 in which a reserve

body of air is held available at a pressure exceeding the range of counterbalancing pressures for the given installation. To maintain the reserve air at the required pressure, any suitable pump means may be employed. The drawings show a reciprocating air pump 58 that is continuously driven through the medium of a belt 60 from a sheave 61 on the countershaft 33. In my preferred arrangement the pump has a compression ratio corresponding to the required pressure in the reservoir 57 and is in continuous communication with the reservoir through a pipe 62 so that the pump delivers air into the reservoir whenever the reservoir pressure tends to drop but at other times the air in the air pump is merely expanded and contracted without displacement into the reservoir 57. The reservoir 57 may be provided with a safety valve 63 and pressure gauge 65 and connects with a high pressure pipe 66 through which air may be transmitted to the counterbalancing apparatus when required, the high pressure pipe leading, for example, to the chamber 50 and being controlled by an automatic valve described below.

Although various types of controllable arrangements may be employed to govern flow through the two pipes 56 and 66, I contemplate the employment of a well-known type of pressure regulating valve. Such a valve involves the application of a mechanical force exerted by a spring or weight in opposition to the pressure of the fluid controlled by the valve, the critical pressure at which the valve operates to release fluid varying with the magnitude of the applied force. In my preferred arrangement I rely upon a weight rather than spring means to oppose the fluid pressure, and I prefer an arrangement in which the operation of the two required valves is varied by movement of a single weight towards and away from a fulcrum axis. Thus, as best shown in Fig. 2, I provide a pressure regulating valve 70 for the release pipe 56 and a second pressure regulating valve 71 for the high pressure pipe 66 and I provide a single weight 72 common to the two valves, which weight is movable towards and away from a fulcrum axis x—x.

The pressure regulating valve 70 has a control lever 73 that is fulcrumed in a bracket 75 on the valve and continuously presses down on a plunger 76 that in turn presses against a diaphragm within the valve in opposition to fluid pressure from the counterbalancing system, the principle of the valve operation being well known in the art. When this pressure regulating valve is open it releases counterbalancing gas to the atmosphere through a short discharge pipe 77. As shown in Fig. 7 the valve 70 includes a housing 200 that is spanned by a diaphragm 201, the diaphragm forming with the housing a valve chamber 202. The above mentioned plunger 76 is operatively connected to the diaphragm 201, and mounted on the lower side of the diaphragm is a valve member 203 in the valve chamber 202. Normally the valve member 203 is retained in a valve seat 204 to cut off the discharge pipe 77. The previously mentioned release pipe 56 for lowering the counterbalancing pressure of the system is in communication with the valve chamber 202 to permit the counterbalancing pressure to be exerted against the diaphragm 201 in opposition to pressure from the plunger 76. Whenever the gas pressure in the valve chamber 202 predominates over whatever downward force is transmitted through the plunger 76, the diaphragm is moved upward to unseat the valve member 203 and thereby permit gas to be released from the counterbalancing system through the pipe 77. It is apparent that the magnitude of the downward force exerted through the plunger 76 determines the critical pressure in the counterbalancing system at which the valve 70 automatically opens. In like manner the pressure regulating valve 71 has a control lever 78 in a vertical plane parallel to the vertical plane of the control lever 73, the control lever 78 being fulcrumed in a bracket 80 to press downward against a plunger 81. The valve 71 may be constructed as shown in Fig. 8. In this construction a housing 205 is spanned by a diaphragm 206 that defines with the housing a valve chamber 207. A hollow portion 208 extends inwardly from the housing 205 into the valve chamber 207 and is formed with a valve passage 209 that communicates with the high pressure reservoir 57 through the right-hand pipe 66. Mounted on the diaphragm 206 to move therewith is a valve member 210 which is normally positioned in a valve seat 211 closing off the valve passage 209, the arrangement being such that gas pressure in the valve chamber 207 against the diaphragm 206 tends to maintain the valve member 210 in closed position. The left-hand pipe 66 communicates directly with the valve chamber 207 so that unseating of the valve member 210 permits flow through the pipe line 66 to the counterbalancing system. It is apparent that whenever the gas pressure in the valve chamber 207 derived from the counterbalancing system drops sufficiently to permit the plunger 81 to flex the diaphragm downward, high pressure gas is introduced into the counterbalancing system and the critical pressure in the counterbalancing system at which gas will be introduced is determined by the force transmitted to the plunger 81 from the control lever 78.

The weight 72 is provided with four flanged supporting wheels 82, two of which on each side of the weight rest upon one of the control levers 73 and 78. By virtue of the described arrangement, movement of the weight 73 towards the fulcrum axis x—x lowers the pressure point of the counterbalancing system at which the valve 70 opens to release compressed air from the counterbalancing system and also lowers the pressure point at which the valve 71 opens to feed high pressure air into the system. Preferably, a relatively small pressure differential is maintained between the two valves, say, a differential of two pounds per square inch, so that the valve 70 always opens at a higher pressure in the counterbalancing system than the valve 71. At the end of each of the control arms or levers 73 and 78, I provide what I call a "tare" weight 83 that may be employed not only to provide the required pressure differential between the two valves, but also to compensate for any minor irregularities in the system.

The present embodiment of my invention is based on the conception of measuring the intake pressure of the engine 30 over the period of the upstroke of the walking-beam 26, measuring the intake pressure of the engine over the period of the downstroke of the walking-beam, accumulating the differential of these measurements over successive pumping cycles and shifting the weight 72 in accordance with or in response to the accumulated differential, the movement of the weight being in a direction to obviate the differential by changing the counterbalancing pressure. It will be apparent to those skilled in the

art that various arrangements may be made to vary the position of the weight 72 in response to the intake pressure or other characteristic or factor of the engine in various practices and embodiments of my invention. The principal parts of the arrangement relied upon for control in the present disclosures are: an upstroke vacuum chamber 85; a downstroke vacuum chamber 86; a valve operating means generally designated 87; an upstroke bellows 88; a downstroke bellows 90; and a yoke or frame 91 that controls the previously mentioned weight 72 in response to the two bellows 88 and 90.

The function of the upstroke vacuum chamber 85 is to house a body of air at a pressure representing the intake pressure of the engine 30 integrated over the period of the upstroke of the walking-beam, and the function of the downstroke vacuum chamber 86 is to represent the intake pressure on the downstroke of the walking-beam in the same manner. The two vacuum chambers 85 and 86, together with an intermediate valve chamber 92, are provided by a housing, generally designated 93, that is integral with and is supported by a standard 95 mounted on the under frame 29 of the apparatus. The valve chamber 92, which is sealed off from the atmosphere, is in continuous communication with an intake manifold 96 of the engine 30 through a suitable pipe 97. The valve chamber 92 has ports 98 and 99 communicating with the vacuum chambers 85 and 86 respectively, and, as best shown in Fig. 6, encloses a valve assembly, generally designated 100, for controlling the two ports.

The valve assembly 100 includes a valve stem 101 slidingly mounted in a pair of stationary supports 102, the valve stem having a valve member 105 on one end to control the port 98 and having a valve member 106 on the other end to control the port 99. The central portion of the valve stem 101 has an enlargement 107 between a pair of opposed helical springs 108 and 109, and the enlargement is circumferentially grooved for engagement by a forked rocker arm 111. When the forked arm swings in one direction to shift the valve stem 101 longitudinally against the resistance of the spring 109, the valve member 105 closes the port 98, and when the valve stem 101 is moved in the opposite direction by the rocker arm in opposition to the spring 108, the valve member 106 closes the port 99.

The forked rocker arm 111 is keyed to a shaft 115 that extends outward through the wall of the valve chamber 92, the shaft being journaled in the chamber wall in an airtight manner. As best shown in Figs. 4 and 5 a friction disc 116 is keyed to the shaft 115 outside of the valve chamber 92 and a complementary friction disc 117 is rotatably and slidingly mounted on the shaft for cooperation with the first friction disc, suitable facing 118 preferably being provided on at least one of the discs. To urge the friction disc 117 against the friction disc 116 a suitable helical spring 120 may be mounted on the shaft in compression between the disc 117 and a circular plate 121 that is secured to the end of the shaft by a suitable cap screw 122. While the construction of the valve assembly 100 is such that it will limit the oscillation of the rocker arm 111 and thereby limit oscillation of the shaft 115, I prefer to rely upon other limiting means to avoid excessive pressure against the valve springs 108 and 109. The limiting means may include, for example, a radial arm 123 on the friction disc 116, a flange 125 extending outwardly from the housing 93, and a bolt 126 extending upward from the flange through an oversize aperture 127 in the radial arm 123. On downward movement the radial arm is stopped by the flange 125 and on upward movement the arm is stopped by a pair of nuts 128 on the bolt 126, the range of movement permitted being sufficient to permit the rocker arm 111 to alternately close the ports of the two vacuum chambers 85 and 86.

It is contemplated that the friction disc 117 will be oscillated in synchronism with the up-and-down strokes of the walking-beam 26 in such manner that at the initiation of each of the strokes, the rocker arm 111 will move to open one of the vacuum chamber ports and simultaneously close the other port. The desired synchronism and extent of oscillation on the part of the friction disc 117 may be obtained by operatively connecting the friction disc with any of various moving parts of the pumping apparatus, but I prefer simply to operate the friction disc directly from the walking-beam 26. In the particular construction shown in Figs. 1, 4, and 5, the friction disc 117 has a radial arm 130 that is operatively connected to the walking-beam 26 by a connecting rod 131. Preferably, the connecting rod 131 is adjustable in length, being fabricated in two sections that are oppositely threaded into an interconnecting adjustment sleeve 132.

The yoke or frame 91 is of rectangular construction and movably surrounds the standard 95 below the two vacuum chambers. The previously mentioned metal bellows 88 that cooperates with the upstroke vacuum chamber 85 is confined between one face of the standard 95 and the corresponding end of the surrounding frame 91, and the bellows is in communication with the vacuum chamber 85 through a fluid passage 133 formed in the standard. Preferably, a suitable valve 135 is provided to restrict flow through the fluid passage 133 to whatever extent may be desired. The second metal bellows 90 that cooperates with the downstroke vacuum chamber 86 is in like manner mounted on the opposite face of the standard 95 between the standard and the corresponding end of the frame 91, and the second metal bellows communicates with the vacuum chamber 86 through a second fluid passage 136 having a valve 137. The fluid occupying the two vacuum chambers and the two bellows may be air, but for the sake of a desirable dashpot action I prefer to fill each of the two bellows and partially fill each of the corresponding vacuum chambers with bodies 138 of suitable liquid, such as light oil. The dashpot action arising from the inertia and viscosity of the oil may be controlled by adjustment of the valves 135 and 137. It is apparent that the relative longitudinal dimensions of the two bellows will determine the position of the frame 91 and that movements of the frame may be readily transmitted to the weight 72 by suitable means such as a rod 140. Since the weight 72 should be permitted to cant from side to side as well as to rise and fall, the rod 140 may be pivotally connected to a bracket 141 on the end of the frame 91 and rotatably embraced by the weight 72. As shown in Fig. 3, the weight 72 may be confined between a pair of washers 142 secured by cotter pins 143.

The operation of the automatic control mechanism may be readily understood from the foregoing description. At initiation of the upstroke of the walking-beam 26 the valve assembly 100

is shifted to open the port 98 to place the upstroke vacuum chamber 85 in communication with the intake manifold 96 of the engine through the valve chamber 92 and the pipe 97. Upon initiation of the subsequent downstroke of the walking-beam, the valve mechanism 100 shifts in the opposite direction to close the port 98 and open the port 99 to place the downstroke vacuum chamber 86 in communication with the engine intake through the valve chamber 92 and pipe 97. Since the upstroke vacuum chamber 85 is in communication with the engine intake substantially continuously throughout the upstroke of the walking-beam, the pressure in the vacuum chamber 85 tends to follow the intake pressure of the engine during the upstroke of the walking-beam. In like manner the pressure in the vacuum chamber 86 tends to follow the intake pressure of the engine during the downstroke of the walking-beam. So long as the pressure in the vacuum chamber 85 is substantially equal to the pressure in the vacuum chamber 86, there is substantially no tendency for oil to flow in either direction through either of the fluid passages 133 and 136. If the prevailing pressure in one of the vacuum chambers drops below the prevailing pressure in the other vacuum chamber, oil will tend to flow upward into the vacuum chamber having a relatively low pressure. For example, if the pressure in the upstroke vacuum chamber 85 drops relative to oil pressure in the chamber 86, oil will tend to flow into the chamber 85 from the metal bellows 88, and by virtue of the rectangular frame 91 interconnecting the two metal bellows, the second metal bellows 90 will tend to expand and thereby cause oil to flow downward from the second vacuum chamber 86. In other words, the two bodies of oil 138, although isolated from each other, tend to act as one body, oil flowing out of one vacuum chamber and simultaneously flowing into the other vacuum chamber at the same rate. Whenever the vacuum chamber pressures become unbalanced, the automatic control mechanism tends to shift the weight 72 to an equilibrium position at which there is pressure equalization between the two vacuum chambers 85 and 86.

Since the time factor is brought into effect by arranging for each of the vacuum chambers to be in continuous communication with the engine intake throughout the period of the pump stroke represented by the vacuum chamber, it is apparent that average pressures rather than maximum or minimum pressures are balanced between the two vacuum chambers and therefore the mechanism tends to equalize the work performed by the engine on the two strokes.

For improved operation, various refinements may be incorporated in the described arrangement. For example, a choke chamber 145 may be interposed in the high pressure pipe 66 between the chamber 50 and the pressure regulating valve 71 to dampen surges of pressure transmitted to the pipe 66 from the counterbalancing body of gas. In a typical situation, for example, the gas pressure in the counterbalancing system will vary from 146 to 154 pounds in the operating cycle of the apparatus. If the choke chamber is provided with suitably restricted ports, the pressure transmitted to the pressure regulating valve 71 will remain rather close to the average pressure of 150 pounds throughout the operating cycle of the mechanism. Such a choke chamber, then, avoids unnecessary operation of the two pressure regulating valves 70 and 71 and also permits a relatively low pressure differential between the two valves.

A further refinement may be the provision of a check valve 146 for each of the vacuum chamber ports 98 and 99 to control the communication of each of the vacuum chambers with the valve chamber 92. Each of the check valves 146 may be of familiar construction in which, as best shown in Fig. 6, a spring 147 continuously urges a valve member 148 into closed position, the valve member being disposed to open in response to preponderance of pressure within the vacuum chamber over the pressure in the valve chamber 92. When such check valves are used, each of the vacuum chambers remain sealed regardless of action of the valve assembly 100 so long as pressure in the vacuum chamber is below the pressure in the valve chamber 92. Under such an arrangement, some anomalous action on the part of the internal combustion engine preventing development of the usual vacuum on one of the pump strokes will not cause corresponding anomalous action on the part of the automatic control mechanism, because in such event the corresponding check valve will remain closed to maintain the degree of vacuum in the corresponding vacuum chamber that truly represents the load on the engine. Some means, however, is desirable to permit air to enter each vacuum chamber because otherwise the pressure in a vacuum chamber would not drop to reflect a drop in the actual load on the engine. A simple bleeder port of relatively small cross section for each of the two vacuum chambers would suffice, but I prefer instead to provide an equalizing by-pass 150 having a small adjustment valve 151 so that whenever there is a difference in pressure between the two vacuum chambers, air flows at a relatively slow rate from the chamber of relatively high pressure to the chamber of relatively low pressure. By using one by-pass common to the two vacuum chambers instead of individual bleeder ports for the chambers, I avoid any problem of providing equal rates of leakage from the chambers under equal pressure differentials It will be readily appreciated that the rate of equalizing flow through the by-pass 150 must be relatively low to make the control mechanism sufficiently sensitive to changes in pressure in the intake manifold of the engine. The addition of the two check valves 146 and the by-pass serves to reduce the tendency of the control mechanism to hunt.

In my previously mentioned copending application the mechanism for automatically varying the counterbalance pressure is responsive to the energy output of the prime mover or to the energy transmitted through some operative connecting means between the prime mover and the well pump. In my present arrangement, however, the automatic means is responsive to a factor that varies with the energy input of the prime mover. More specifically, the present embodiment of the invention responds to a factor associated with the fuel consumption of the engine. Other factors associated with the fuel consumption that might be relied upon for automatic control could be found in carburetion or in the exhausting of fuel from the engine. If the prime mover were an electric motor, a corresponding factor associated with the energy input would be the amperage of the energizing current.

The preferred form of my invntion disclosed in specific detail herein for the purpose of illustration and to teach the principles involved will suggest to those skilled in the art various changes, modifications, and substitutions under my inventive concept. I reserve the right to all such changes, modifications, and substitutions that come within the scope of my appended claims.

I claim as my invention:

1. In an apparatus in which a prime mover has a characteristic associated with and varying with the prime mover input and in which the prime mover reciprocates a loaded member through a power stroke and a return stroke, the combination therewith of: adjustable counterbalancing means adapted to derive energy from said prime mover on said return stroke and to deliver said energy to said member on the subsequent power stroke thereby to substantially equalize the loads on the prime mover on the two strokes; and means responsive to said characteristic to vary the adjustment of said counterbalancing means to increase or decrease the magnitude of said derived energy as the load on said member is increased or decreased.

2. In an apparatus in which a prime mover reciprocates a loaded member through a power stroke and a return stroke, and in which means involved in the fuel consumption of the prime mover varies when the load on the prime mover varies, the combination therewith of: adjustable counterbalancing means adapted to derive energy from said prime mover on said return stroke and to deliver said energy to said member on the subsequent power stroke thereby to substantially equalize the loads on the prime mover on the two strokes; and means responsive to said variable means to change the adjustment of said counterbalancing means to increase or decrease the magnitude of said derived energy as the load on said member is increased or decreased.

3. In an apparatus having a prime mover for reciprocating a loaded member through a power stroke and a return stroke, and including a course for fluid flow through said prime mover involving the consumption of fuel by the prime mover, the combination therewith of: adjustable counterbalancing means adapted to derive energy from said prime mover on said return stroke and to deliver said energy to said member on the subsequent power stroke thereby to substantially esualize the loads on the prime mover on the two strokes; and means responsive to pressure at a point in said fluid course to vary the adjustment of said counterbalancing means to increase or decrease the magnitude of said derived energy as the load on said member is increased or decreased.

4. A combination as set forth in claim 3 in which said prime mover is an internal combustion engine and said point in said fluid course is at the engine intake.

5. In an apparatus in which a prime mover reciprocates a loaded member through a power stroke and a return stroke, and in which some means responds to the load imposed on the prime mover, the combination therewith of: a fluid-pressure system for applying a counterbalancing force to a moving part of said apparatus for substantial equalization of loads on said prime mover during said strokes; regulating means for said system responsive to an applied regulating force, said regulating means being adapted to admit fluid into the system to increase said counterbalancing force when said applied force is increased and to release fluid from the system to decrease the counterbalancing force when said applied force is reduced; weight means to apply the regulating force to said regulating means, said weight means being movable in one direction to increase the applied force and movable in the opposite direction to decrease the applied force; a first fluid-pressure means responsive to said load-responsive means during the power strokes and adapted to urge said weight means in the direction to increase said applied regulating force; and a second fluid-pressure means responsive to said load-responsive means during the return strokes to urge said weight means in the direction to decrease said applied regulating force.

6. In an apparatus having a prime mover for reciprocating a loaded member through a power stroke and a return stroke and including a fluid course for fluid flow through said prime mover involving the consumption of fuel by the prime mover, the combination therewith of: adjustable means to apply a counterbalancing force to a moving part of said apparatus to substantially equalize the loads on said prime mover on said strokes; a first means adapted to urge adjustment of said adjustable means in the direction of increased counterbalancing force; and a second means adapted to urge adjustment of said adjustable means in the direction of decreased counterbalancing force, one of said urging means being responsive to pressure in said fluid course during the power strokes of the apparatus and the other of said urging means being responsive to pressure in said fluid course during the return strokes of the apparatus.

7. A combination as set forth in claim 6 in which each of said urging means applies fluid pressure to urge adjustment of said adjustable means and applies the fluid pressure throughout both strokes of the apparatus.

8. In an apparatus having a prime mover for reciprocating a loaded member through a power stroke and a return stroke and including a fluid course for fluid flow through said prime mover involving the consumption of fuel by the prime mover, the combination therewith of: adjustable means to apply a counterbalancing force to a moving part of said apparatus to substantially equalize the loads on said prime mover on said strokes; a first fluid-pressure means adapted to urge adjustment of said adjustable means in the direction of increased counterbalancing force; a second fluid-pressure means adapted to urge adjustment of said adjustable means in the direction of decreased counterbalancing force; and means responsive to a moving part of the apparatus adapted to place one of said urging means in communication with said fluid course on one of said strokes and to place the other of said urging means in communication with said fluid course during the other of said strokes.

9. In an apparatus having a prime mover for reciprocating a loaded member through a power stroke and a return stroke and including a fluid course for fluid flow through said prime mover involving the consumption of fuel by the prime mover, the combination therewith of: a fluid-pressure system for applying a counterbalancing force to a moving part of said apparatus for substantial equalization of loads on said prime mover during said strokes; regulating means for said system responsive to an applied regulating force, said regulating means being adapted to admit

fluid into the system to increase said counterbalancing force when said applied regulating force is increased and to release fluid from the system to reduce the counterbalancing force when said applied regulating force is reduced; means to apply the regulating force to said regulating means to govern the magnitude of said counterbalancing force, said force-applying means being adjustable in one direction to increase the applied regulating force and adjustable in the opposite direction to decrease the applied regulating force; a first means responsive to fluid pressure in said fluid course to urge adjustment of said force-applying means in the direction of increased applied force; a second means responsive to fluid pressure in said fluid course to urge adjustment of said force-applying means in the direction of decreased applied force; and means responsive to a moving part of the apparatus to place said first and second fluid-pressure responsive means alternately in communication with said fluid course on alternate strokes of the apparatus.

10. In an apparatus having a prime mover for reciprocating a loaded member through a power stroke and a return stroke and including a fluid course for fluid flow through said prime mover involving the consumption of fuel by the prime mover, the combination therewith of: adjustable means to apply a counterbalancing force to a moving part of said apparatus to substantially equalize the loads on said prime mover on said strokes; a fluid-pressure chamber representing the power stroke of the apparatus; means to place said chamber in communication with said fluid course during the power stroke of the apparatus and to cut off the chamber from the fluid course during the return stroke of the apparatus; a second fluid-pressure chamber representing the return stroke of the apparatus; means to place said second chamber in communication with said fluid course during the return stroke of the apparatus and to cut off the second chamber from the fluid course during the power stroke of the apparatus; a first means responsive to fluid pressure in one of said chambers to urge adjustment of said adjustable means in the direction of increased counterbalancing force; and a second means responsive to fluid pressure in the other of said chambers to urge adjustment of said adjustable means in the direction of decreased counterbalancing force.

11. In an apparatus having a prime mover for reciprocating a loaded member through a power stroke and a return stroke and including a fluid course for fluid flow through said prime mover involving the consumption of fuel by the prime mover, the combination therewith of: adjustable means to apply a counterbalancing force to a moving part of said apparatus to substantially equalize the loads on said prime mover on said strokes; a fluid-pressure chamber representing the power stroke of the apparatus, said chamber having a relatively small bleeder port; means to place said chamber in communication with said fluid course during the power stroke of the apparatus and to cut off the chamber from the fluid course during the return stroke of the apparatus; a second fluid-pressure chamber representing the return stroke of the apparatus, said second chamber having a relatively small bleeder port; means to place said second chamber in communication with said fluid course during the return stroke of the apparatus and to cut off the second chamber from the fluid course during the power stroke of the apparatus; a first means responsive to fluid pressure in one of said chambers to urge adjustment of said adjustable means in the direction of increased counterbalancing force; and a second means responsive to fluid pressure in the other of said chambers to urge adjustment of said adjustable means in the direction of decreased counterbalancing force.

12. In an apparatus in which a prime mover reciprocates a loaded member through a power stroke and a return stroke, and in which some means responds to the load imposed on the prime mover, the combination therewith of: a fluid-pressure system for applying a counterbalancing force to a moving part of said apparatus for substantial equalization of loads on said prime mover during said strokes; a first regulating means for said system responsive to an applied regulating force and adapted to release fluid from the system when said applied regulating force is decreased; a second regulating means for said system responsive to an applied regulating force and adapted to admit fluid to the system when said applied regulating force is increased; a first weight means adapted to apply regulating force to said first regulating means; a second weight means adapted to apply lesser force to said second regulating means, both of said weight means being adjustable to vary said applied regulating forces; and means responsive to said load-responsive means to vary the adjustments of said two weight means simultaneously to automatically increase the counterbalancing force when the load on said member increases and vice versa.

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