

July 10, 1951

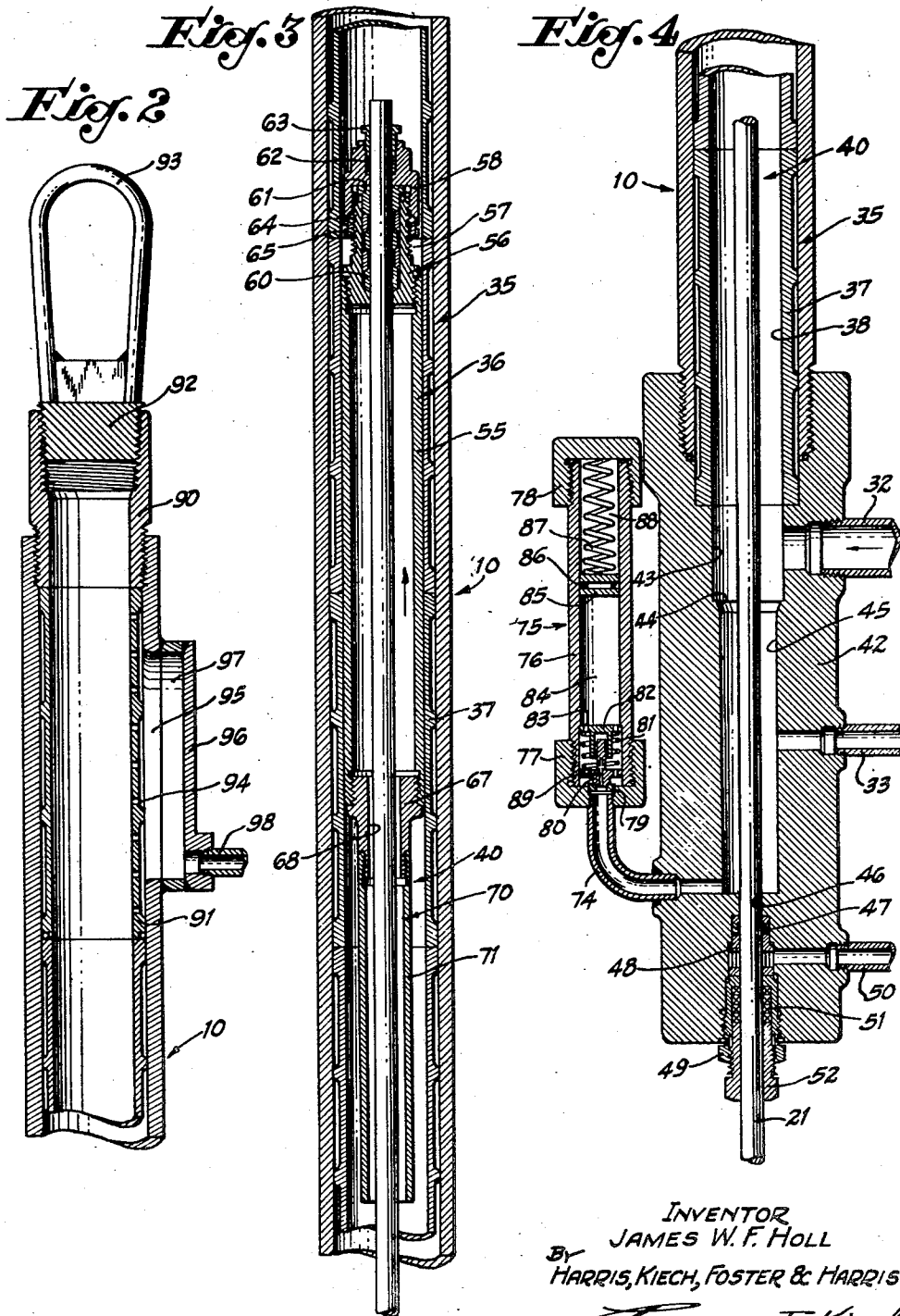
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2,560,441

HYDRAULIC PUMPING SYSTEM

Filed Oct. 2, 1944

4 Sheets-Sheet 2



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Fig. 5

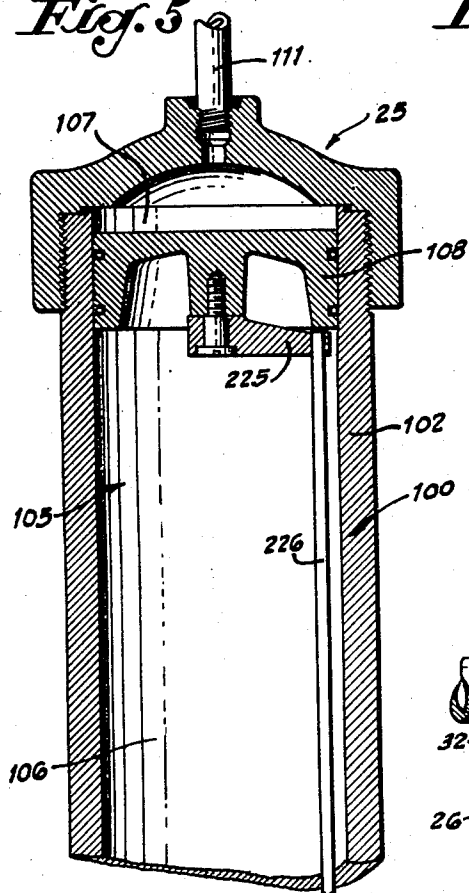
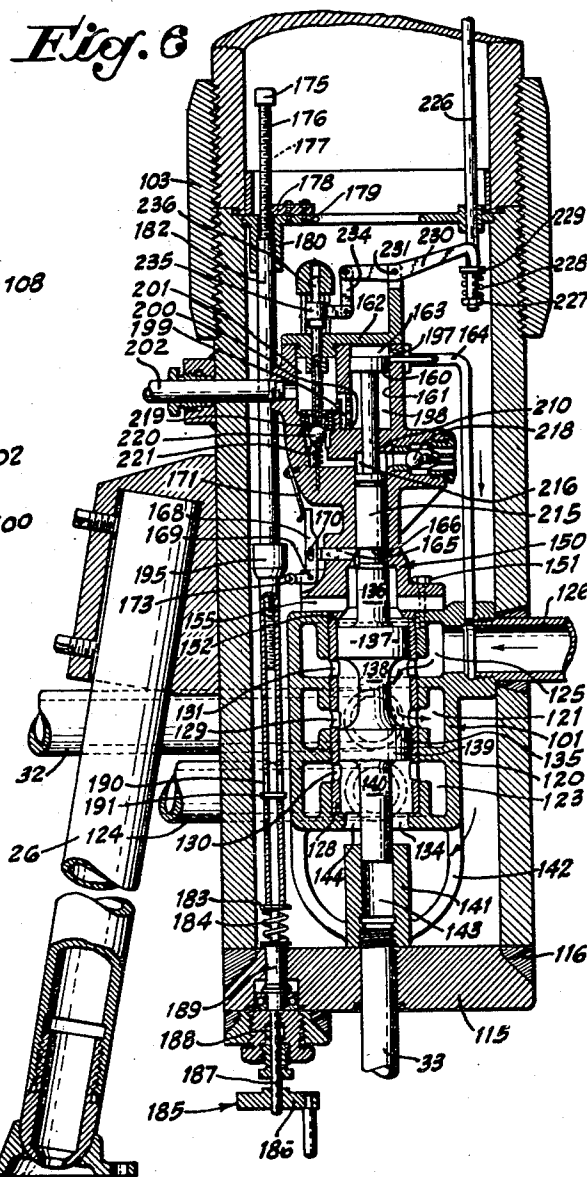


Fig. 6



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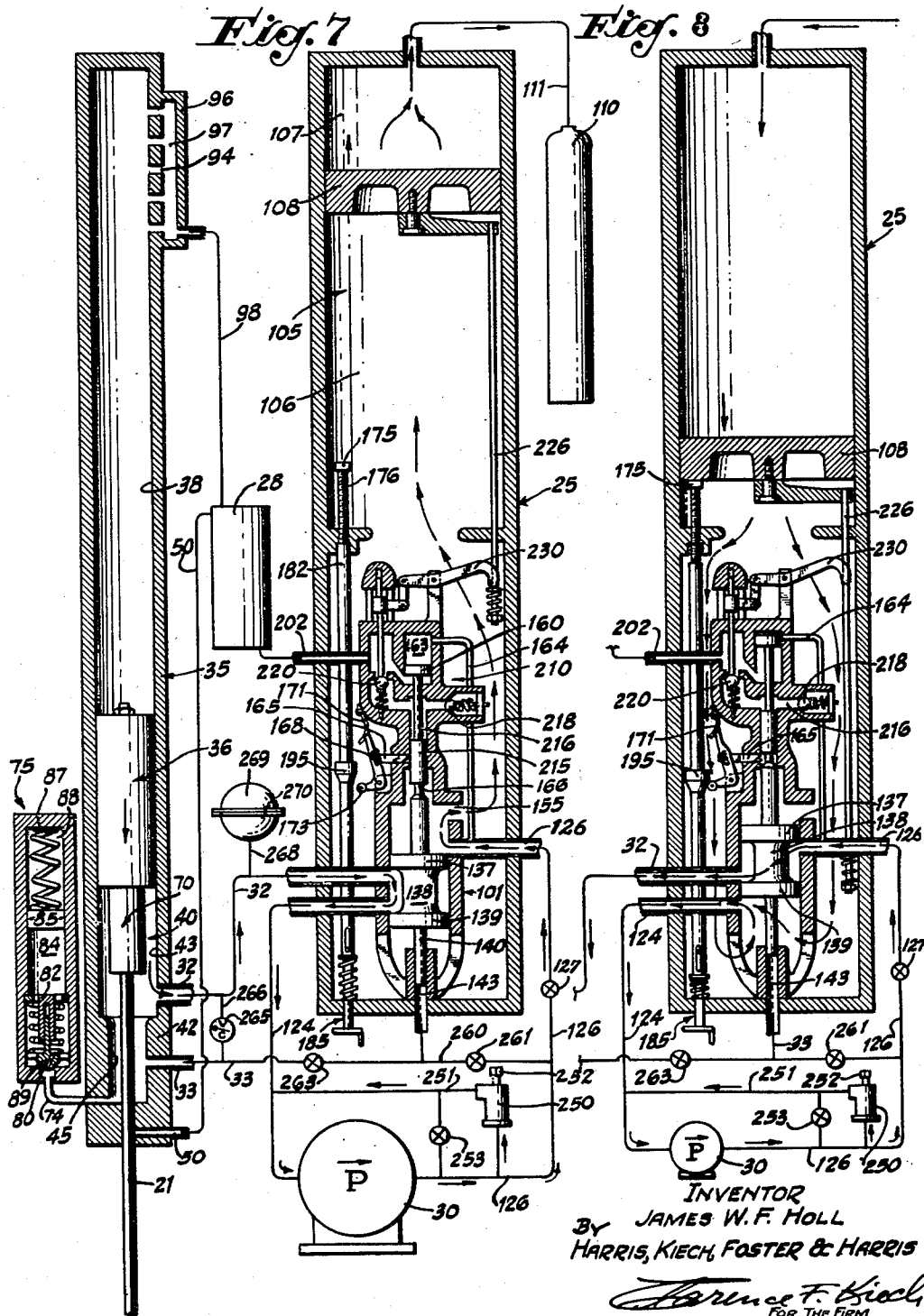
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UNITED STATES PATENT OFFICE

2,560,441

HYDRAULIC PUMPING SYSTEM

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Application October 2, 1944, Serial No. 556,877

24 Claims. (Cl. 60-52)

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My invention relates to a counterbalanced hydraulic pumping structure and component parts thereof, this pumping structure being particularly useful for the reciprocation of a string of sucker rods connected to a well pump. More particularly, the invention relates to a novel hydraulic-pneumatic actuating device including, for example, a pump jack and a counterbalance-control device particularly suited, though not necessarily limited, to the pumping of deep oil wells.

Various proposals have been made to pump deep wells by use of a hydraulic pump jack positioned at the surface of the ground. It is an object of the present invention to provide a novel hydraulically-operated pump jack in which the upper end of the string of sucker rods or a polish rod forming a part thereof can extend directly into the pump jack for connection to the reciprocating piston therein.

Serious accidents have occurred with hydraulic pump jacks of other design upon breakage of the sucker rods or failure of the piping supplying the hydraulic actuating liquid to the jack. Breakage of the sucker rods while hydraulic pressure is applied below the piston has been known to destroy the jack and surrounding equipment by movement of the piston upward from the jack with disastrous results. Failure of the piping supplying the hydraulic actuating liquid to a position below the piston permits the piston to drop under the applied weight of the sucker rods and this often leads to the imposition of destructive stresses, sometimes releasing the sucker rods.

It is an object of the present invention to provide a novel hydraulic pump jack overcoming these difficulties, preferably by providing a suitable cushioning action for stopping the piston either at an extreme upper position or an extreme lower position. Preferably, the invention provides hydraulic shock-absorbing means in this connection.

It is desirable to counterbalance at least a portion of the load imposed on a hydraulic pump jack, for example, all of the weight of the sucker rods and about one-half the weight of the column of liquid being pumped. Any attempt to counterbalance the system by surging the hydraulic actuating liquid into and from a counterbalance chamber containing superimposed and contacting bodies of gas and actuating liquid is open to serious limitations. As the operating pressures are increased, the gas tends to dissolve in, or mingle with, the actuating liquid and this has limited the maximum pressures usable in such a system to about 400 lbs./sq. in. Higher

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actuating pressures are very desirable as they reduce the otherwise large and sometimes impossible size of the pump jack and as they permit pumping from greater depths. Pressures in the present invention are above 400 lbs./sq. in. and usually from 1500-3000 lbs./sq. in.

It is an object of the present invention to provide a pumping system in which a relatively small hydraulic pump jack is operated by an actuating liquid under very high pressures, and in which the counterbalance means avoids any tendency for the gas to dissolve in the actuating liquid.

Still another object of the invention is to provide a counterbalance means employing a compressible gas, and in which this gas is not necessarily trapped in the upper end of the counterbalance chamber. Rather, the invention, in its preferred embodiment, permits some surging of gas into and from the upper end of the counterbalance chamber. In this connection, it is an object of the invention to openly connect a pressure storage vessel to the gas space of a counterbalance means, the pressure vessel being conveniently a bottle of compressed gas which can serve both to pressure the system initially and to act as a surge means into and from which a portion of the gas may flow during the pumping operation. Still a further object of the invention is to provide a pumping system in which the degree of counterbalance may be readily varied.

In the preferred embodiment of the invention, the pump jack is disposed directly above the well, while the counterbalance-control device is positioned a distance therefrom. It is an object of the present invention to operatively connect such a pump jack with the counterbalance-control device exclusively by use of hydraulic lines, thereby avoiding any moving mechanical connections therebetween.

A further object of the invention is to provide a novel valve means for controlling the flow of actuating liquid to and from the pump jack, and to actuate this valve means in response to pressure impulses or variations established in the pump jack.

Another important object of the present invention is to provide a variable-stroke system for pumping wells in which the length of the stroke can be varied without shutting down the equipment.

Still a further object of the invention is to provide a novel auxiliary pump which automatically comes into operation to compensate for leakage of actuating liquid from the system.

Further objects and advantages of the inven-

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tion will be evident to those skilled in the art from the following exemplary embodiment.

Referring to the drawings:

Figure 1 is a side elevational view of the invention shown in its relationship to a well;

Figures 2, 3, and 4, are, respectively, vertical sectional views of the upper, intermediate, and lower portions of the pump jack;

Figures 5 and 6 are, respectively, vertical sectional views of the upper and lower portions of the counterbalance-control device of the invention;

Figure 7 is a simplified and somewhat diagrammatic representation of the pump jack and the counterbalance-control device showing the valve means and piston means of the latter in one position; and

Figure 8 is a similar simplified and somewhat diagrammatic representation of the counterbalance-control device with the valve means and piston means in another position.

As best shown in Figure 1, the invention includes generally a pump jack 10 with means comprising a plurality of posts 11 resting on a platform 12 or other foundation for mounting the jack above an oil well 14. This oil well is shown as including the usual casing 15 in which hangs a pump tubing 16 extending to a conventional reciprocating pump 18 actuated by the usual string of sucker rods 20, including a polish rod 21. As the polish rod is moved up and down, a column of oil rises in the pump tubing 16 and discharges through a head 22 in the usual manner. It is the purpose of the pump jack 10 to reciprocate the string of sucker rods hydraulically and with any desired, and preferably adjustable, stroke length.

Generally speaking, the invention includes also a counterbalance-control device 25 positioned any desired distance from the pump jack 10 and mounted above the platform 12, as by three posts 26. A reservoir containing actuating liquid under atmospheric pressure is indicated by the numeral 28 and, if desired, may be mounted at a position above the platform 12 by a suitable support 29.

By means to be later described, a high pressure pump 30 causes actuating liquid to surge from the counterbalance-control device 25 to and from the pump jack 10. It is a feature of the invention that the operative connection between the pump jack 10 and the counterbalance-control device 25 is exclusively hydraulic. Generally speaking, only two hydraulic lines need interconnect these elements, for example a surge pipe 32 and a control pipe 33. While Figure 1, for clarity, shows such pipes as extending above the platform 12, it will be understood that these pipes can extend along or beneath the platform.

The details of the pump jack are shown best in Figures 2, 3, and 4. In addition, the left-hand portion of Figure 7 shows, considerably simplified, the mechanism of the pump jack. Referring particularly to Figures 2, 3, and 4, the upper end of the polish rod 21 extends directly into a main cylinder 35 where it is connected to a main or operating piston 36 of the pump jack 10. The main cylinder 35 is preferably equipped with sectional liners 37 providing a cylindrical passage 38. The space within the cylindrical passage 38 below the piston 36 comprises a variable-volume operating chamber 40 into and from which the actuating liquid surges through surge pipe 32 to reciprocate the main piston 36.

The lower end of the main cylinder 35 is threaded to an auxiliary cylinder 42 providing

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a seat for the lower end of the sectional liner 37 and providing a bore 43 of the same diameter as the cylindrical passage 38. A tapered shoulder 44 leads to an auxiliary bore 45 of smaller diameter than the cylindrical passage 38 of the main cylinder 35, the control pipe 33 openly communicating with the auxiliary bore 45. The lowermost end of the auxiliary cylinder 42 is closed except for an opening 46 enlarged to receive a chevron-type packing 47 compressed by a passaged follower 48 which is, in turn, engaged by a threaded gland 49 to seal the polish rod 21 as it reciprocates. The passages of the follower 48 communicate with a pipe 50 conducting any leakage of actuating liquid to the reservoir 28. The gland 49 is, in turn, counter-bored to receive packing rings 51 compressed by a threaded gland 52.

The main piston 36 is preferably, though not necessarily, hollow and the upper end of the polish rod 21 extends axially therethrough and is adjustably connected thereto. The preferred form of piston is shown in Figure 3 as including a piston sleeve 55 having an external diameter only a few thousandths of an inch smaller than the internal diameter of the cylindrical passage 38 so that no intervening piston rings are required. The upper end of the piston sleeve 55 is threaded to a piston head 56 having a threaded neck 57 engaged by a correspondingly threaded cap 58 which is, in turn, bored and counterbored to receive the upper end of the polish rod 21 which terminates a short distance thereabove. While any suitable means can be employed for adjustably clamping the polish rod to the piston, the preferred structure includes offset clamping rings 60 providing tapered surfaces, as shown, and disposed in the counterbore of the piston head 56. Alternate clamping rings 60 are pressed against the piston head 56, while intervening rings are pressed against the polish rod 21 when a follower 61 is moved downwardly in the counterbore, as by tightening the cap 58. In addition, the counterbore of the cap 58 carries a packing 62 compressed by a gland 63 to prevent leakage. Also, leakage between neck 57 and cap 58 is prevented by compression of a small packing gland 64 by a nut 65 threaded to the neck 57.

The lower end of the piston sleeve 55 is internally threaded to receive a piston head 67 providing a bore 68 of larger diameter than the polish rod 21. Depending from and threaded to the lower end of this piston head 67 is an auxiliary piston 70 comprising a piston sleeve 71 having an external diameter only a few thousandths of an inch smaller than the auxiliary cylinder 45. As the main piston 36 nears the lower end of its stroke, the auxiliary piston 70 enters the auxiliary bore 45 of the auxiliary cylinder 42 to entrap actuating liquid therein. Any further downward movement of the main and auxiliary pistons will create a pressure impulse in the auxiliary cylinder. If a hollow piston structure is employed, as suggested in Figure 3, the interior thereof will form a part of the space in which the liquid is entrapped, this interior being completely filled with the liquid. The auxiliary cylinder 42 and the auxiliary piston 70 form a hydraulic actuator for moving the valve means to be later described.

Communicating with the lower end of the auxiliary cylinder 42 by way of a pipe 74 is an accumulator 75 providing a pipe 76 closed by heads 77 and 78. The accumulator 75 cooper-

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ates with the auxiliary cylinder and piston in forming a cushion means for the piston structure when at or nearing the lowermost position thereof during movement in a normal zone of reciprocation or during abnormal downward motion as might occur upon breakage of the surge line 32 with the weight of the sucker rods imposed on the piston. The head 77 threadedly receives the pipe 74 and carries a seat 79 engaged by a valve member 80. This valve member is urged resiliently into engagement with the seat 79 by a spring 81 compressed between the valve member 80 and a fixed plate 82 drilled at 83 to provide access to a chamber 84 filled with actuating liquid below a piston 85 suitably sealed by a piston ring 86. This piston is urged resiliently downward by a spring 87 compressed between the piston and the head 78. Between the piston and the head 78 is a space 88 in which a body of gas may be entrapped to aid the action of the spring 87. Upon the occurrence of a pressure impulse in the auxiliary cylinder 42, a portion of the entrapped actuating liquid will flow through the pipe 74, lifting the valve member 80 against the spring 81 and tending to raise the piston 85. Upon later reduction in pressure in the auxiliary cylinder 42, the valve member 80 will seat but auxiliary liquid may flow back to the auxiliary cylinder 42 through a restricted passage 89 of the valve member 80, the restriction controlling the rate of return flow.

The main cylinder 35 is of a height determined by the maximum desired length of stroke. The extreme upper end of this main cylinder 35 receives a collar 90 engaging the uppermost section of the liner 37, this uppermost section being indicated by the numeral 91. The upper end of the collar 90 receives a plug 92 closing the upper end of the main cylinder, and a bail 93 is connected to this plug.

A cushioning means is also provided for stopping the main or operating piston 36 during any adverse upward motion, for example, should the sucker rods break while high pressure actuating liquid is present in the operating chamber 40 below the piston. The preferred cushion means is shown in Figure 2 as comprising a plurality of vertically-aligned openings 94 in the uppermost liner section 91, these openings being progressively closed by the main piston as it moves upward. The openings 94 may register with corresponding openings of the main cylinder 35 or with a vertical passage 95 closed by a structure 96 to form a chamber 97. Actuating liquid entering the chamber 97 may drain therefrom through a pipe 98 extending to the reservoir 28.

Normal leakage past the main piston 36 maintains a column of actuating liquid above this main piston. Above this column of liquid is an air-filled space into and from which air may surge as the column of actuating liquid respectively lowers and raises. The height of the column of liquid will depend upon the distance between the openings 94 and the top of the piston when in its uppermost position. Any leakage past the main piston tending to increase the height of this column will drain through the openings 94 to the reservoir 28. If the string of sucker rods should break and the main piston move rapidly upward beyond its normal zone of reciprocation, the level of the column of liquid will rapidly rise and force from the upper end of the main cylinder substantially all of the entrapped air except that residual volume of air

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which remains entrapped above the uppermost opening 94. This rise of the piston permits flow of actuating liquid through all of the openings 94 until such time as the piston covers these openings in sequence during continued upward movement. Such successive covering of the openings reduces the number remaining for conducting actuating liquid from the upper end of the main cylinder 35 and acts as a very effective shock absorber for gradually slowing down the upward movement of the piston. The pressure on the column of liquid and on the residual body of air above the uppermost opening 94 increases during this progressive throttling. When the pressure above the piston equals the pressure of the actuating liquid in the operating chamber 40 below the piston, taking into consideration the weight of the sucker rods still supported by the piston, the upward motion of the piston will stop. Such a system prevents disastrous blowing of the piston from the upper end of the pump jack upon breakage of the sucker rods.

Referring particularly to Figures 5 and 6, the counterbalance-control device 25 includes, in general, a counterbalance means 100 and a valve means 101. The counterbalance means 100 includes a cylinder 102, preferably formed of aligned sections joined by a coupling 103. Within the cylinder 102 is a counterbalance chamber 105 providing a lower portion or space 106 containing a body of actuating liquid and an upper portion or space 107 containing a compressible means in pressure-transferring relationship with the body of actuating liquid. Preferably, this compressible means comprises a compressible gas separated from the actuating liquid by a movable piston means 108, which moves up and down as the actuating liquid surges into and from the space 106 of the counterbalance chamber 105. As the piston means 108 rises, the gas in space 107 is compressed. In addition, I prefer to provide for surging a portion of the gas into and from the space 107. This is accomplished by one or more pressure storage vessels 110 (Figure 1) openly communicating with the space 107 through a pipe 111 so that the pressure in the storage vessels is always equal to the pressure in the space 107, disregarding pressure drops due to flow of gas along the pipe 111. The preferred type of pressure storage vessel is a conventional steel container or bottle employed for storage of gases under pressure. One or more of such bottles can be connected to the pipe 111 and suitable valves 112 opened to pressure the system and to provide an enlargement of the space 107 communicating therewith through a more restricted pipe 111.

It is preferred, though not necessary to the invention, to dispose the valve means 101 in the lower portion of the counterbalance chamber 105. In this event, the valve means 101 may be surrounded by actuating liquid retained in the space 106 by a lower head 115 for the cylinder 102, this head being suitably welded thereto as indicated by the numeral 116.

The details of the preferred valve means 101 are best shown in Figure 6, while the various positions thereof are best shown in Figures 7 and 8. Referring particularly thereto, the valve means 101 includes a housing 120, partitioned to define an intermediate chamber 121 upon which the surge pipe 32 opens; a lower chamber 123 upon which opens a pipe 124 leading to the intake of the pump 30; and an upper chamber 125 upon which a pipe 126 opens. This pipe 126 leads to

the discharge of the pump 30 and provides a normally-open valve 127. The housing 120 is drilled to receive a liner 128 providing a plurality of ports 129 opening on the intermediate chamber 121, a plurality of ports 130 opening on the lower chamber 123, and a plurality of ports 131 opening on the upper chamber 125. The interior of this liner 128 provides a valve chamber 134 in which slides a movable valve element, indicated generally by the numeral 135. This valve element provides an upper plunger 136, an upper valve piston 137, a neck 138, a lower valve piston 139, and a lower plunger 140. The neck 138 is of such length as to space the valve pistons 137 and 139 a distance to lie on opposite sides of ports 129 and 131 or ports 129 and 130. The lower plunger 140 makes a piston fit with a cylinder 141 carried by arms 142 depending from the housing 120. The plunger 140 cooperates with the cylinder 141 in providing a valve-actuating chamber 143, with which the control pipe 33 openly communicates to supply actuating pressure for hydraulically moving the valve element 135 from a lower position (shown in Figure 7) to an upper position (shown in Figures 6 and 8). The lower plunger 140 is sufficiently smaller than the housing 120 to provide an intake port 144 constantly open to the actuating liquid in the space 106 of the counterbalancing chamber 105.

At the upper end of the housing 120 is a head structure 150 secured to the housing by bolts 151. These bolts extend through a flange of the head structure 150, this flange providing a collar 152 extending into the bore of the housing 120 to engage the upper end of the liner 128. The inner diameter of the collar 152 is larger than the upper plunger 136 to define an annular space cooperating with radial grooves in the lower end of the head structure 150 to define a discharge port 155 opening on the actuating liquid in the space 106 of the counterbalance chamber 105.

The movable valve element 135 is biased toward lower position by any suitable means. In the preferred embodiment, this biasing force is hydraulically applied by means of a biasing piston 160 at the extreme upper end of the upper plunger 136, this piston moving in a cylinder 161 provided at the extreme upper end of the head structure 150 and closed by a cover structure 162 to provide a chamber 163 above the biasing piston 160. This chamber 163 communicates through a pipe 164 with some portion of the system in which the pressure normally is substantially the same as in the valve-actuating chamber 143; for example, it may communicate with the pipe 126, as shown. The biasing piston 160 is of slightly larger diameter than the lower plunger 140, thus normally exerting a downward force on the movable valve element 135.

Downward movement of the valve element 135 under this biasing force is prevented a certain times in the cycle of operation by a latch 165 engaging a shoulder 166 formed by an annular depression in the upper plunger 136. This latch slides in a correspondingly shaped radial opening in the head structure 150 and is actuated by a bell crank 168 pivoted at 169 to the head structure 150. The operative connection between the latch 165 and the bell crank 168 is through a pin 170 carried by the latch and extending in a vertically elongated opening of the vertical arm of the bell crank. A spring 171 biases the latch 165 inwardly. A horizontal arm of the bell crank 168 carries a roller 173. Any downward movement of this roller withdraws the latch 165 and releases

the valve element 135 to move downward under the hydraulic biasing force.

Means is preferably provided for operating the latch 165 to release the valve element 135 in response to movement of a predetermined, and preferably adjustable, amount of actuating liquid from the counterbalance chamber 105. This can be accomplished by operatively connecting the latch 165 to be actuated by the piston means 108 as it moves downward to a desired position. The preferred structure for accomplishing this result and for providing a readily accessible adjustment for the length of the stroke of the pump jack will now be described.

Referring particularly to Figure 6, a contact member 175 is carried at the upper end of a relatively long threaded rod 176. This threaded rod provides a longitudinal slot 177 traversing the threads and into which extends a keeper 178 carried by an annular supporting member 179 supported between the sections of the cylinder 102. The keeper 178 permits vertical movement of the threaded rod 176 up and down in the space 106 of the counterbalance chamber 105 but prevents rotation of this threaded rod. The annular supporting member 179 carries a depending collar 180 counterbored to slidably and rotatably receive the upper end of a tube 182 extending downwardly to a position just above the lower head 115, where it is in engagement with a washer 183. A compression spring 184 urges this tube 182 resiliently upward into the counterbore of the collar 180.

The upper end of the tube 182 is internally threaded to receive the threaded rod 176. Correspondingly, if the tube 182 is turned, the contact member 175 is moved vertically. Means is preferably provided for turning the tube 182 from a position outside the counterbalance-control device 25. This adjustment means is indicated generally by the numeral 185 and includes a hand wheel or crank 186 rotating a rod 187 extending through a packing gland 188 and thence through a spool 189 vertically slidable in the lower head 115. The upper end of the rod 187 extends through the spring 184 and into the lower end of the tube 182, where it carries a transverse pin 191 extending outwardly through vertically elongated slots 190 of the tube 182. Correspondingly, turning of the rod 187 will turn the tube 182 to move the threaded rod 176 and the contact member 175 vertically. When the piston means 108 lowers to engage the contact member 175, any additional downward movement of the piston means will depress the threaded rod 176 and the tube 182, compressing the spring 184. This downward movement of the tube 182 is permitted by the vertically elongated slots 190 thereof. Such slight downward motion of the tube 182 is made to actuate the latch 165 by attaching a collar 195 to the tube. When the lower beveled surface of this collar engages the roller 173 of the bell crank, the latch 165 is withdrawn and the valve element 135 is released to move into its lower position.

Means is preferably provided for hydraulically cushioning the movement of the valve element 135. The biasing piston 160 can serve as a part of this means by moving upwardly a sufficient distance to partially or completely close the port opening on the pipe 164. Complete closure is preferred, as shown in Figure 6, and any upward motion of the biasing piston beyond the position where it closes this port is slowed down and cushioned by use of a small restricted passage 197

communicating between the chamber 163 and the pipe 164. Correspondingly, upward motion of the biasing piston 160 beyond this closing position can take place at a rate determined by the rate at which actuating liquid can flow from the chamber 163 to the pipe 164 through the restricted passage 197.

Below the biasing piston 160 within the cylinder 161 is a chamber 198. The walls of this chamber provide a large port 199 and a small port 200 opening on a chamber 201 which, in turn, communicates through a pipe 202 with the reservoir 28. Both of the ports 199 and 200 are available for discharge of actuating liquid from the chamber 198 during lowering of the biasing piston 160 until this piston covers the port 199, after which its downward motion is retarded and cushioned by restricted discharge through the smaller port 200. The actuating liquid thus discharged from the chamber 198 returns to the reservoir 28.

The invention comprehends also the provision of means for automatically replenishing any leakage of actuating liquid from the system. To accomplish this result, an auxiliary pump means, generally designated by the numeral 210, is employed to move actuating liquid from the reservoir 28 into the counterbalance chamber 105 to compensate for such leakage. Means is preferably provided for preventing operation of this auxiliary pump means when a normal amount of actuating liquid is in the system.

The preferred structure of the auxiliary pump means is best shown in Figures 5 and 6. Here, the auxiliary pump means is actuated by movement of the valve element 135 under the control of the piston means 108. That portion of the upper plunger 136 above the shoulder 166, and indicated by the numeral 215, comprises a piston movable in a cylindrical space of the head structure 150 to define a variable-volume space 216. Discharge from this space into the counterbalance chamber 105 is through a spring-loaded valve 218 preventing any return flow. Actuating liquid may enter the space 216 from the reservoir 28, pipe 202, and chamber 201 through an intake valve including a seat 219 and a ball 220 urged resiliently toward the seat by a spring 221. If these spring-operated intake and discharge valves of the auxiliary pump were otherwise unrestrained in their motion, an increment of the actuating liquid would be discharged into the counterbalance chamber 105 upon each reciprocation of the movable valve element 135.

To make the auxiliary pump responsive to leakage, the lower end of the piston means 108 carries a hinged arm 225 to which is connected a rod 226 journaled in the annular supporting member 179 and extending to a position therebeneath. The lowermost end of the rod carries a nut 227, a spring 228, and a washer 229. Sufficient upward movement of the rod 226 brings the washer 229 into contact with a lever 230 pivoted at 231 to a portion of the cover structure 162, thus moving a link 234 downward. This link is pivoted to a collar 235 mounted on a rod 236 journaled in the cover structure 162 and extending downwardly to the ball 220. The parts are so arranged as to press the ball 220 downward each time the piston means 108 nears the extreme upper end of its stroke and so long as a normal amount of actuating liquid is in the system. However, any leakage from the system will cause the piston means 108 to rise less than its normal amount, thus permitting the ball 220 to remain

seated under the action of the spring 221. Under the former circumstance, a rise in the piston 215 will merely surge actuating liquid rearwardly through the intake valve, now held open by the rod 236. Under the latter circumstance, namely, a deficient rise in the piston means 108, a rise in the piston 215 will force an increment of the actuating liquid through the discharge valve 218 into the counterbalance chamber 105.

The operating pump 30 is of the high pressure type to produce a discharge pressure almost invariably above 400 lbs./sq. in. and usually much higher, for example, 1500-3000 lbs./sq. in. Its maximum discharge pressure is usually predetermined by the setting of a spring-loaded by-pass valve 250 mounted in a line 251. The spring-loading of this valve is controlled by turning a member 252. A portion of the pumped actuating liquid may flow continuously through the by-pass line 251 under control of the valve 250, or this by-pass flow may take place only when the discharge pressure becomes excessive. A manually-operated valve 253 may communicate with the pipe 126 and the by-pass line 251 for manual control of the by-passed liquid. For purpose of starting the pumping system, a pipe 260 providing a valve 261 is connected between the pipe 126 and the control pipe 33, the latter pipe in turn providing a normally-open valve 263.

A check valve 265 is disposed in a pipe 266 interconnecting the surge pipe 32 and the control pipe 33, permitting flow from the former to the latter. Further, the surge pipe 32 communicates through a pipe 268 with a container 269, preferably providing a diaphragm 270 separating an air-containing space above the diaphragm from a space below the diaphragm opening on the pipe 268. This device acts as an air cushion to absorb any shock load created during operation of the system.

The mode of operation of the complete system can best be described with reference to Figures 7 and 8, assuming that the system has been pressured and is in operation. Figure 7 shows the pump jack nearing the lower end of its stroke and shows the element 135 of the valve means 101 in its lower position. At this time, the entrapped actuating liquid is flowing from the operating chamber 40 because of the downward motion of the main piston 36 induced by the weight of the sucker rods. This actuating liquid moves through surge pipe 32, intermediate chamber 121, and port 129 into the space around the neck 138 to discharge through port 130, lower chamber 123, and pipe 124 to the intake of pump 30. Here, the actuating liquid is additionally pressured and discharged through pipe 126, whence it flows through upper chamber 125, ports 131, and discharge ports 155 into the space 106 of the counterbalance chamber 105. Correspondingly, the piston means 108 is rising at a rate proportional to the downward movement of the main piston 36 of the pump jack and the gas in space 107 is being compressed, a portion of this gas flowing through the line 111 to compress substantially equally the gas in the pressure vessel 110. At this time, the valve element 135 is hydraulically biased in a downward direction because the pressure in the chamber 163 above the biasing piston 160 and tending to move the valve downwardly is substantially greater than the pressure in the valve actuating chamber 143 tending to move the valve upwardly, the chamber 163 being connected to the discharge of pump 30 through pipe 164, and the chamber 143 being at pump-intake pressure

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through the control line 33 opening on the auxiliary cylinder 42, which at this time is open to the main operating chamber 40.

As soon as the auxiliary piston 70 enters the auxiliary bore 45 of the auxiliary cylinder 42, it entraps a portion of the actuating liquid therein and quickly increases the pressure in the auxiliary cylinder to a value greater than the discharge pressure of the pump 30. This increase in pressure, herein termed a pressure impulse, is transmitted through the control line 33 to the valve actuating chamber 143 and is sufficient to overcome the hydraulic bias of the valve element 135, thus moving this valve element, with a cushioned motion previously described, into the upper latched position shown in Figure 8. This opens a path for the actuating liquid to discharge from beneath the piston means 108 through the intake port 144 at the bottom of the valve means 101, thence through ports 130, lower chamber 123, and pipe 124 to the intake of pump 30. The intake pressure of the pump is thus determined by the pneumatic pressure above the piston means 108, and the pump additionally pressures the actuating liquid and discharges the same through the pipe 126, through the upper chamber 125, and ports 131 along the space between upper and lower valve pistons 137 and 139 to discharge through ports 129, chamber 121, and surge line 32 to the operating chamber 40 of the pump jack. Correspondingly, the piston means 108 in the counterbalance chamber moves downward while the main piston 36 of the pump jack moves upward. As soon as the auxiliary piston 70 is removed from the auxiliary bore 45 of the auxiliary cylinder 42, the pressure in the valve actuating chamber 143 remains equal to the discharge pressure of the pump 30. The pipe 164 also transmits this discharge pressure to the chamber 163 above the biasing piston 160. However, due to the fact that the piston 160 is slightly larger in size than the lower plunger 140, the valve is biased in a downward direction, though downward motion is restrained by the latch 165.

As the main piston 36 nears the upper end of its desired stroke, the piston means 108 in the counterbalance chamber 105 will lower to engage the contact member 175 and, immediately thereafter, the parts will be in the position shown in Figure 8. A slight additional downward motion of the piston means 108 will release the latch 165, permitting the valve element 135 to move to its lower position under the biasing action just mentioned. Actuating liquid will then tend to discharge from the operating chamber 40 beneath the main piston 36, through the valve means 101, and into the space 106 of the counterbalance chamber 105, as previously defined.

Each time the valve element 135 moves downward, the piston 215 of the auxiliary pumping means 210 draws an increment of actuating liquid from the reservoir 28 into the chamber 216. As the piston means 108 moves toward its normal uppermost position, the rod 226 rocks the lever 230 and depresses the ball 220, as previously described, so that, when the valve element 135 moves upward, the liquid in the chamber 216 merely surges back into the atmospheric-pressure reservoir 28. However, if leakage has taken place from the system and the piston means 108 does not move upward a sufficient distance to actuate the ball 220, it is quite apparent that upward motion of the valve element 135 will expel the increment of actuating liquid through the spring-

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loaded discharge valve 218 and into the space 106 below the piston means 108. This expulsion of an increment of actuating liquid will continue until the piston means 108 depresses the ball 220.

Each time the piston structure of the pump jack reaches its lower desired position in which the auxiliary piston 70 enters the auxiliary bore 45 of the auxiliary cylinder 42, the development of excessive pressures in the auxiliary cylinder is prevented by the accumulator 75. Thus, when the pressure in the auxiliary cylinder becomes greater than that required to actuate the valve means 101, the excess pressure is relieved by a rise in the valve member 80 and flow into the accumulator 75. Should the auxiliary piston 70 move downward sufficiently to close the control pipe 33, the only escape from the auxiliary cylinder 42 is into the accumulator 75, with a consequent cushioning action, as previously mentioned. Each time the auxiliary piston 70 starts to rise in the auxiliary cylinder 42, the actuating liquid thus temporarily in the accumulator 75 flows rearwardly at a rate determined by the restricted passage 89. To prevent any possibility of the pressure in the auxiliary cylinder 42 dropping substantially below the pressure in the operating chamber 40 and thus possibly exerting an excessive force on the latch 165, the check valve 265 is provided to permit flow from the surge line 32 into the auxiliary cylinder 42.

It will be readily apparent that the main piston 36 normally reciprocates to a predetermined lower position while the piston means 108 of the counterbalance means reciprocates to a predetermined upper position, assuming no leakage. At the same time, the maximum upper position of the main piston 36, and thus the stroke of the pump jack, is determined by the lower position of the piston means 108 of the counterbalance means and by the instant of engagement with the contact member 175. Correspondingly, by turning the adjustment means 185 to raise or lower the contact member 175, the stroke of the pump jack can be varied. It is a feature of the present invention that this adjustment can be made during the operation of the system so that the maximum production of which the well is capable can be obtained by adjustment during the operation of the pump and without requiring shut-downs in which equilibrium conditions in the well would change.

It will be apparent, also, that the degree of counterbalancing can be varied merely by changing the pneumatic pressure above the piston means 108. In this connection, the system is pressured when starting and additional counterbalancing pressures can be applied merely by increasing the pneumatic pressure in the space 107. This can be accomplished, for example, by permitting the gas to surge normally into one of the pressure vessels 110 and employing the other pressure vessel to increase the gas pressure if and when desired.

It is a feature of the invention that the pump 30 is discharged alternately between the operating chamber 40 and the counterbalance chamber 105, thus making the pump work constantly and avoiding periods of inaction or periods of extensive by-pass. At the same time, the intake of the pump is shifted alternately from the counterbalance chamber 105 to the operating chamber 40, and this additionally tends to equalize the load on the pump from time to time. Correspondingly, the pump 30 is not subjected to ex-

treme variations in load during the continued operation of the system.

In initially starting the system with the main piston 36 in a lowermost position, it is desirable to apply pump pressure directly to the valve actuating chamber 143 to lift the valve means 101. This is accomplished by closing the valves 127 and 263 and momentarily opening the valve 261 to raise the valve element 135 into latched position.

While the invention has been particularly described with reference to reciprocation of a string of sucker rods connected to a deep well pump, it will be apparent that it is useful in other connections, particularly where a variable-stroke reciprocating motion is desired or where a bias on the operating piston is to be partially or completely counterbalanced. It will be apparent, also, that some of the features of the invention are novel irrespective of their combination with the remainder of the equipment shown. For example, many of the features of the invention are novel irrespective of whether a pneumatic counterbalance is employed, though the complete system has been found most advantageous in the pumping of deep oil wells.

Various changes and modifications can be made without departing from the spirit of the invention as defined in the appended claims.

I claim as my invention:

1. In a counterbalanced hydraulic pumping unit for reciprocating a string of sucker rods connected to a well pump, the combination of: a hydraulic pump jack including means for mounting same directly above said well, said pump jack including a cylinder and an operating piston movable therein, said piston and cylinder defining a variable-volume operating chamber filled with actuating liquid and said piston being adapted for operative connection to said string of sucker rods; a counterbalance means remote from said pump jack and comprising a counterbalance chamber providing one portion containing a body of actuating liquid and another portion containing a compressible means in pressure-transferring relationship with said body of actuating liquid; hydraulic means forming the exclusive operative connection between said pump jack and said counterbalance means and including pipe means for surging the actuating liquid from the counterbalance means to said operating chamber and later from said operating chamber to said counterbalance means to reciprocate said piston, said hydraulic means including a hydraulic control line extending from said pump jack; valve means controlling said pipe means; and hydraulic pressure impulse means included in said pump jack at the bottom thereof and connected by said hydraulic line to said valve means to actuate said valve means as said piston approaches the end of its stroke in one direction.

2. In a counterbalanced hydraulic pumping unit for reciprocating a string of sucker rods connected to a well pump, the combination of: a hydraulic pump jack including means for mounting same directly above said well, said pump jack including a cylinder and an operating piston movable therein, said piston and cylinder defining a variable-volume operating chamber filled with actuating liquid and said piston being adapted for operative connection to said string of sucker rods; a counterbalance means remote from said pump jack and comprising a counterbalance chamber providing one por-

tion containing a body of actuating liquid and another portion containing a compressible means in pressure-transferring relationship with said body of actuating liquid; a pump means; pipe means communicating with said operating chamber; a fluid-actuated valve means adjacent said counterbalance means and connected to said pipe means for controlling the flow of actuating liquid therethrough, said valve means alternately connecting said pump to force actuating liquid from said body to said operating chamber through said pipe means and then connecting said operating chamber and said body for movement of actuating liquid through said pipe means from said operating chamber to said body; and means comprising a hydraulic actuator associated with and positively operated by said pump jack and a hydraulic line connecting said actuator to said valve means for actuating said valve means when said operating piston reaches a predetermined position in said cylinder.

3. A combination as defined in claim 2, in which said pipe means and said hydraulic line are the only operative connection between said pump jack and its associated hydraulic actuator on the one hand and the counterbalance means and its adjacent valve means on the other hand.

4. In a counterbalanced hydraulic pumping unit for reciprocating a string of sucker rods connected to a well pump, the combination of: a hydraulic pump jack comprising a cylinder and an operating piston reciprocable therein, said operating piston being adapted for operative connection to said string of sucker rods; a counterbalance means remote from said pump jack and comprising a counterbalance chamber providing one portion containing a body of actuating liquid and another portion containing a compressible means in pressure-transferring relationship with said body of actuating liquid; means for surging actuating liquid between said pump jack and said counterbalance means, said means including valve means and including means for moving actuating liquid from said body to said cylinder of said pump jack when said valve means is in a first position and for moving actuating liquid from said cylinder of said pump jack to said body when said valve means is in a second position; means responsive to a decrease in the amount of actuating liquid in said counterbalance chamber for moving said valve means from said first position to said second position; and means responsive to the position of said piston in said cylinder for moving said valve means from said second position to said first position, said last-named means responsive to the position of said piston including a hydraulic actuator in the lower end of said pump jack for developing a pressure impulse when said operating piston reaches a predetermined position in said cylinder, and means for delivering said pressure impulse to said valve means to move same from said second position to said first position.

5. In a counterbalanced hydraulic pumping unit for reciprocating a string of sucker rods connected to a well pump, the combination of: a hydraulic pump jack for reciprocating said sucker rods; a counterbalance means remote from said pump jack and comprising a counterbalance chamber containing a body of actuating liquid and a compressible means in pressure-transferring relationship with said body of actuating liquid; means for surging actuating liquid from said counterbalance chamber to said pump

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jack and from said pump jack to said counterbalance chamber to reciprocate said sucker rods; valve means to control the direction of flow of surging liquid to and from said counterbalance chamber; means to actuate said valve hydraulically for flow of liquid in one direction with respect to said counterbalance chamber; means operable to actuate said valve hydraulically for flow of liquid in the opposite direction with respect to said chamber; latch means to control movement of said valve means for flow of said liquid in one direction; means for tripping said latch means; and means associated with said counterbalance means for adjusting said tripping means and thereby varying the stroke of said hydraulic pump jack during continued operation thereof.

6. In combination with a hydraulic pump jack connected to reciprocate a string of sucker rods, a counterbalance-and-control device including: a counterbalance chamber containing a body of actuating liquid, a compressible means, and a movable piston means for transferring pressure between said body of actuating liquid and said compressible means; a hydraulic line for connecting said pump jack with said counterbalance chamber; a continuously operating one-way drive pump for forcing actuating liquid from said counterbalance chamber to said pump jack to reduce the volume of actuating liquid in said counterbalance chamber and to move said piston means in one direction; a valve means in said line and controlling the return flow of actuating liquid from said pump jack to said counterbalance chamber, said return flow moving said piston means in the other direction; a contact member in the path of travel of said piston means; control means between said contact member and said valve means providing for movement of said valve means when said piston means engages said contact member; and a hydraulic control line connecting the lower end of said pump jack with said valve means to shift said valve means by a pressure impulse produced by said pump jack at the limit of its downstroke.

7. A combination as defined in claim 6, including an adjustment means for changing the position of said contact member with respect to said piston means to control the time of operation of said valve means relative to the position of said piston means.

8. A combination as defined in claim 6, in which said valve means includes a movable element biased to move in a given direction in opposition to said pressure impulse, and in which said means for operatively connecting said contact member and said valve means includes a latch means for restraining motion of said biased movable element and means for releasing said latch means when said piston means engages said contact member.

9. In combination with a hydraulic pump jack connected to reciprocate a string of sucker rods, a counterbalance-and-control device including: a counterbalance chamber carrying a body of actuating liquid, counterbalancing means, and a movable piston means for transferring pressure between said body of actuating liquid and said counterbalancing means; a pump for forcing actuating liquid from said counterbalance chamber to said pump jack to reduce the volume of actuating liquid in said counterbalance chamber and to move said piston means in one direction; valve means controlling the return flow of actuating liquid from said pump jack to said counter-

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balance chamber, said return flow moving said piston means in the other direction, said valve means including a movable element biased to move in a given direction; a contact member in the path of travel of said piston means; and control means between said contact member and said valve means providing for movement of said valve means when said piston means engages said control contact member, said means including latch means for restraining motion of said biased movable element and means for releasing said latch means when said piston means engages said contact member.

10. In combination with a hydraulic pump jack connected to reciprocate a string of sucker rods, a counterbalance-and-control device including: a counterbalance chamber containing a body of actuating liquid, a compressible means, and a movable piston means for transferring pressure between said body of actuating liquid and said compressible means; a pump for forcing actuating liquid from said counterbalance chamber to said pump jack to reduce the volume of actuating liquid in said counterbalance chamber and to move said piston means in one direction; a valve means controlling the return flow of actuating liquid from said pump jack to said counterbalance chamber, said return flow moving said piston means in the other direction; an auxiliary pump means for delivering additional actuating liquid to said counterbalance chamber; control means for said auxiliary pump means; and means for interconnecting said control means and said piston means to render said auxiliary pump means inoperative during reciprocation of said piston means in a normal zone of said counterbalance chamber and for rendering said auxiliary pump means operative to supply additional actuating liquid to said counterbalance chamber when said piston means reciprocates to a position out of said normal zone due to leakage of actuating liquid.

11. In a counterbalanced hydraulic pumping unit for reciprocating a string of sucker rods connected to a well pump, the combination of: a hydraulic pump jack comprising a cylinder and an operating piston reciprocable therein and cooperating therewith in defining a variable-volume operating chamber, said operating piston being adapted for operative connection to said string of sucker rods to be biased in one direction by the weight of and the load imposed on said string of sucker rods; a counterbalance means for counterbalancing at least a part of the weight of said sucker rods and the load imposed thereon, said counterbalance means comprising a counterbalance chamber containing a body of actuating liquid, a compressible gas, and a movable piston means separating said gas and said liquid while transferring pressure therebetween, said piston means preventing the tendency of said gas to dissolve in said actuating liquid if in contact therewith at high pressures; pipe means for surging actuating liquid from said counterbalance chamber to said operating chamber and then from said operating chamber to said counterbalance chamber while under sufficiently high pressure that a substantial portion of said gas would tend to dissolve in said actuating liquid if in contact therewith; valve means controlling said pipe means; a hydraulic line extending between said pump jack and said valve means; and hydraulic pressure impulse means included in the bottom of said pump jack and connected by said

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hydraulic line to actuate said valve means as said piston approaches the end of its downstroke.

12. A combination as defined in claim 11, including a pressure vessel containing gas under pressure and a pipe openly communicating between said pressure vessel and said gas in said counterbalance chamber whereby said gas is compressed and expanded and also surged into and from said pressure vessel as said piston means reciprocates.

13. In combination with a hydraulic pump jack having piston and cylinder means connected to reciprocate a string of sucker rods, a counterbalance-and-control device including: a counterbalance chamber for receiving a body of actuating liquid and counterbalancing means; a pump for forcing actuating liquid from said counterbalance chamber to said pump jack to reduce the volume of actuating liquid in said counterbalance chamber; reciprocating valve means controlling the return flow of actuating liquid from said pump jack to said counterbalance chamber, the body of actuating liquid in said chamber increasing and decreasing in step with the reciprocations of said pump jack; auxiliary pump means for supplying additional actuating liquid to said counterbalance chamber, said auxiliary pump means including a piston connected with said reciprocating valve means for actuation therewith, a cylinder in which said piston operates, and a valve controlled discharge port for discharging liquid into said counterbalance chamber when said valve means is moved in one direction; means to limit the supply of liquid to said counterbalance chamber by said auxiliary pump means; and means supplying liquid to said auxiliary pump means.

14. A combination as in claim 13 including: a hydraulic line connected to one extremity of said cylinder to supply impulse pressure from said pump jack at one end of its stroke to said reciprocating valve means to actuate the same in one direction; and means connected with said pump to supply actuating pressure to move said reciprocating valve means and said piston of said auxiliary pump means in the opposite direction.

15. A combination as in claim 13 including a hydraulic line connected to one extremity of said cylinder to supply impulse pressure from said pump jack at one end of its stroke to said reciprocating valve means whereby to actuate said valve means in one direction and at the same time actuate said auxiliary pump piston.

16. A combination as in claim 13 including: a counterbalance piston in said chamber; and means actuable by said counterbalance piston adjacent one end of its stroke to render said auxiliary pump means ineffective when a predetermined amount of actuating liquid is present in said counterbalance chamber.

17. A combination as in claim 13 wherein said means supplying liquid to said auxiliary pump includes a check valve, said combination including: a counterbalance piston in said chamber; and means actuable by said counterbalance piston means to hold said check valve open during actuation of said auxiliary pump piston when said counterbalance chamber contains a predetermined amount of actuating liquid.

18. A combination as in claim 13 which includes: a counterbalance piston in said chamber; a check valve in said liquid supply means; and control means for said check valve and responsive to movements of said counterbalance piston.

19. In a counterbalanced hydraulic pumping

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unit for reciprocating a string of sucker rods connected to a well pump, the combination of: a hydraulic pump jack comprising a cylinder and an operating piston reciprocable therein, said operating piston being adapted for operative connection to said string of sucker rods; a counterbalance means remote from said pump jack and comprising a counterbalance chamber providing a portion for a body of actuating liquid; pipe means connecting said jack cylinder with said counterbalance chamber; continuously operating pump means for forcing actuating liquid between said cylinder and said chamber; reciprocating valve means for controlling the direction of flow of actuating liquid being moved by said pump means; means included in said pump jack for producing a pressure impulse at the end of the stroke of said operating piston in one direction; a hydraulic control line connecting said pressure impulse means with said reciprocating valve means to move said valve in one direction at said end of said stroke; pressure supply means connected with said pump means for moving said reciprocating valve means in the opposite direction; and means for controlling said supply means.

20. A combination as in claim 19 wherein said means to control said supply means includes a latch to hold said reciprocating valve means in position after being moved by said pressure impulse, said combination also including: a counterbalance piston in said counterbalance chamber; and means actuable by said counterbalance piston to release said latch when said counterbalance piston approaches the end of its corresponding stroke.

21. In a counterbalanced pumping unit for reciprocating a string of sucker rods connected to a well pump, the combination of: a hydraulic pump jack comprising a cylinder and an operating piston reciprocable therein, said operating piston being adapted for operative connection to said string of sucker rods, said pump jack including at its lower end auxiliary piston means and cylinder means to entrap a portion of actuating liquid from said cylinder and impart a pressure impulse thereto at the end of the downstroke of said operating piston and also to limit and cushion the downstroke of said operating piston; counterbalancing means removed from said pump jack and comprising a counterbalance chamber; pipe means connecting said jack cylinder with said counterbalance chamber; pump means for forcing actuating liquid to and from said counterbalance chamber; valve means connected with said pump means and controlling the flow of liquid between said chamber and said jack cylinder; and a hydraulic control line connecting said auxiliary cylinder means with said valve means whereby said valve means is actuated by pressure impulse produced in the lower portion of said pump jack when said piston is cushioned by said auxiliary piston and cylinder means at the lower end of said stroke.

22. A combination as in claim 21 including: an auxiliary pump cylinder; and an auxiliary piston in said auxiliary cylinder and adapted to introduce make-up liquid into said counterbalance chamber from said auxiliary pump cylinder, said auxiliary piston being connected with said valve means and operable with said valve means by said pressure impulse from said pump jack.

23. In a counterbalanced hydraulic pumping

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unit for reciprocation of a string of sucker rods connected to a well pump, the combination of: a hydraulic pump jack comprising a cylinder and an operating piston reciprocable therein and cooperating therewith to define a variable-volume operating chamber, said operating piston being adapted for operative connection to said string of sucker rods to be biased in one direction by the weight of and the load imposed on said string of sucker rods; a counterbalance means comprising a counterbalance chamber providing one portion containing a body of actuating liquid and another portion containing a compressible means in pressure-transferring relationship with said body of actuating liquid; a high-pressure pump for said actuating liquid; a valve means acting when in a first position to connect the discharge of said pump to said operating chamber of said pump jack and to connect the intake of said pump to said body of actuating liquid thus forcing actuating liquid from said body into said operating chamber of said pump jack to move said operating piston against its bias, and acting when in a second position to connect the intake of said pump to said operating chamber of said pump jack and to connect the discharge of said pump to said body of actuating liquid thus moving actuating liquid from said operating chamber of said pump jack to said body of actuating liquid; means responsive to the amount of actuating liquid in said counterbalance chamber for moving said valve means from said first position to said second position; and hydraulic means interconnecting said pump jack and said valve means for moving said valve means from said second position to said first position, said pump jack including means for producing a pressure impulse adjacent the end of its downstroke, said interconnecting hydraulic means connecting said pressure impulse means with said valve means for operation of the latter.

24. In combination with a hydraulic pump jack connected to reciprocate a string of sucker rods, a counterbalance-and-control device including: a counterbalance chamber containing a body of actuating liquid, a compressible means, and a movable piston means for transferring pressure between said body of actuating liquid and said compressible means; a pump for forcing actuating liquid from said counterbalance chamber to said pump jack to reduce the volume

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of actuating liquid in said counterbalance chamber and to move said piston means in one direction; a valve means controlling the return flow of actuating liquid from said pump jack to said counterbalance chamber, said return flow moving said piston means in the other direction, said piston means thus reciprocating from one end position to another end position in step with the reciprocations of said pump jack; control means for operatively interconnecting said valve means and said piston means when in one end position; an auxiliary pump means for supplying additional actuating liquid to said counterbalance chamber; and means responsive to a variation in the position of said piston means for operating said auxiliary pump means to supply additional actuating liquid to said counterbalance chamber, said auxiliary pump means including a piston connected with said valve means for actuation therewith, a cylinder in which said piston operates, means to supply fluid to said cylinder, and a valve for discharge of fluid from said cylinder into said counterbalance chamber when said valve means is moved in one direction.

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Certificate of Correction

Patent No. 2,560,441

July 10, 1951

JAMES W. F. HOLL

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 7, line 29, for "counterbalancing" read *counterbalance*; line 61, for "a certain" read *at certain*; column 16, line 9, strike out "control" and insert the same after "said", same line;

and that the said Letters Patent should be read as corrected above, so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of September, A. D. 1951.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.