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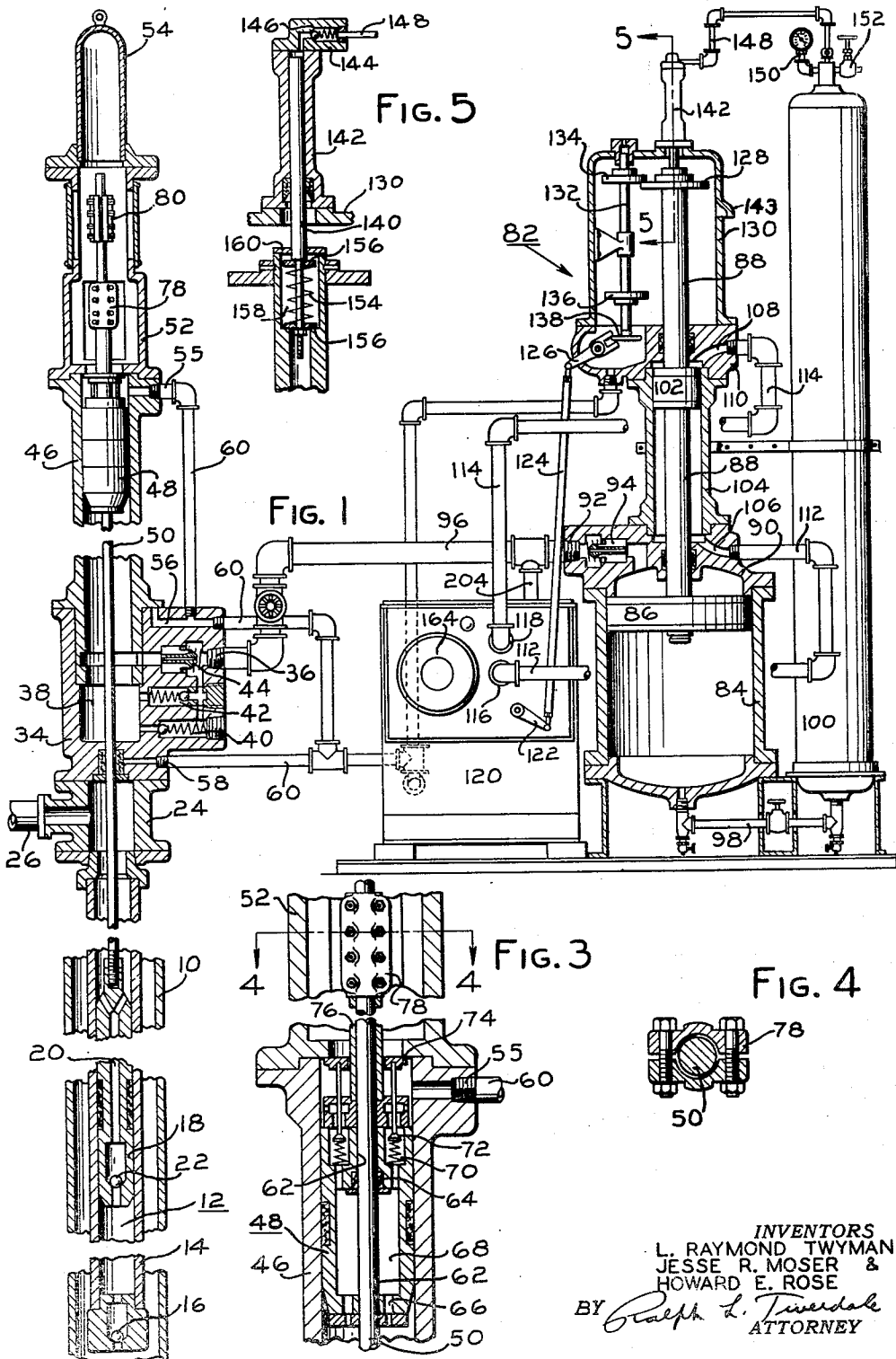
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POWER TRANSMISSION

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2 Sheets-Sheet 1



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POWER TRANSMISSION

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This invention relates to power transmissions, particularly to those of the type comprising two or more fluid pressure energy translating devices one of which may function as a pump and another as a fluid motor.

The invention is more particularly concerned with a power transmission system for use in oil well pumping for operating the type of pump in which a sucker rod string is utilized in the well to operate the pumping plunger or barrel at the bottom of the well. Hydraulically operated well pumping units of this class have been known for many years and have recently come into more extensive use. Pumping units of this class provide many advantages over the conventional walking beam type of pump jack, among them being a greater length of stroke and consequent reduction in the pump losses due to stretching of the sucker rod as well as the advantage of more precisely controlled acceleration and deceleration at opposite ends of the stroke resulting in longer sucker rod life due to less violent shock imposed upon the sucker rod string at reversal.

Hydraulic pumping units of this class have heretofore been constructed with hydraulic counterbalancing means either of the air-loaded type or of the weight-loaded type. Where it is desired to operate the pump at relatively high speed, the air-loaded type presents some advantage permitting higher speed of reversal due to the lower inertia of the moving parts. One difficulty which the air-loaded type of counterbalance has heretofore presented is the high cost of providing air containers capable of holding the high pressures at which it is desirable to operate the hydraulic parts of the circuit. Present A. S. M. E. code regulations covering air pressure vessels require construction which is considerably more costly in the higher pressure ranges above 400 pounds per square inch so that considerable economy can be effected while complying with such code regulations if the apparatus can be designed for air pressures below this value. On the other hand, in the hydraulic parts of the mechanism an operating pressure of only 400 pounds necessitates more costly construction than is possible at higher pressures of the order of 1,000 pounds.

It is an object of the present invention to provide an improved well pumping system of the hydraulically counterbalanced type which permits the use of high pressure hydraulic power apparatus and medium pressure air containers thus permitting maximum economy of construction throughout the apparatus.

Another problem which has heretofore increased the cost of construction of hydraulic well pumping apparatus has been the necessity of making up leakage losses in the hydraulic parts of the circuit as well as in the air chamber of the counterbalance mechanism.

It is an object of the present invention to provide an improved pumping system wherein replenishing of hydraulic fluid and of compressed air is readily accomplished by inexpensive mechanism and automatically throughout the continued operation of the device.

A further object is to provide a hydraulic well pumping apparatus with an improved means for adjusting the position of the sucker rod relative to that of the work piston in order to obtain maximum pumping efficiency in the pumping barrel at the bottom of the well.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein a preferred form of the present invention is clearly shown.

In the drawings:

Figure 1 is a side view partly in section of an oil well pumping apparatus incorporating a preferred form of the present invention.

Figure 2 is a diagrammatic sectional view of the hydraulic power supplying means for the apparatus in Figure 1.

Figure 3 is a fragmentary sectional view showing the work piston on a larger scale.

Figure 4 is a cross section on line 4—4 of Figure 3.

Figure 5 is a cross section on line 5—5 of Figure 1.

Referring now to Figure 1, there is shown a well comprising a casing 10 having a pump 12 at the bottom thereof. The latter may be of any conventional type and, for example, may consist of a stationary barrel 14 having the usual check valve or "standing valve" 16 at the bottom and a reciprocable plunger 18 having the usual central passage 20 and check valve 22 at the bottom thereof. At the top of the well there is secured to the top of the casing a discharge head 24 having the usual outlet 26 for the discharge of the oil delivered by the well pump.

Positioned on top of the discharge head 24 is a cylinder head casting 34 having a connection 36 for hydraulic operating fluid extending into cylinder end chamber 38 at a point somewhat above the bottom thereof. A suitable spring-loaded relief valve 40 permits discharge of oil out of the chamber 38 to the connection 36 when the

piston, later to be described, has closed off the point of communication between connection 36 and the upper part of chamber 38. A check valve 42 permits free flow from connection 36 into chamber 38 when the piston is below the normal inlet connection.

The connection 36 is also provided with a velocity limiting valve 44 normally spring biased to the open position illustrated and arranged to close the connection 36 except for the small central bore in the valve 44 whenever the velocity of flow from chamber 38 to connection 36 exceeds a predetermined value. This is merely a safety device and operates only in the event of a broken connection.

Rigidly mounted in the casting 34 is a long work cylinder 46 within which is slidably mounted a piston 48. The latter is slidably mounted for adjusting purposes on a sucker rod 50 which extends into the well and carries plunger 18 at its lower end. On top of the work cylinder 46 there is mounted a member 52 provided with two pairs of access doors, one pair above the other, and carrying at its upper end a long cylindrical closure member 54 for protection of the upper end of the sucker rod 50. Suitable leakage drains are provided at 55, 56 and 58 and are connected by conduits 60 with the oil reservoir to be later described.

The construction of the piston 48 and its associated clamping mechanism is illustrated in Figures 3 and 4 from which it will be seen that the piston has a central bore 62 packed at 64 through which the sucker rod 50 extends. The piston is formed with one or more passages 66 at its lower end which communicate through a central chamber 68 with valved passages 70 normally closed by poppet valves 72. The latter have their operating stems connected to a ring-74 above the piston and which is adapted to contact a shoulder at the bottom of the member 52 whenever the piston 48 is in its uppermost position as shown in the drawings. There is thus provided a passage between the upper and lower sides of piston 48 when valves 72 are open. As soon as the piston 48 is lowered slightly, the valves 72 will close by the action of their associated springs, thus effectively sealing this passage through the piston.

The piston 48 is provided with an upwardly extending sleeve 76, immediately above which is mounted a split clamp 78 on the sucker rod 50. Thus the sucker rod 50 is supported by means of the clamp 78 resting on the sleeve 76. Spaced above the clamp 78 is a second clamp 80 which during normal operation serves merely as a safety precaution to catch the sucker rod in the event of slippage of clamp 78. For the purpose of adjusting the sucker rod relative to the piston 48, the clamp 80 may be utilized as a temporary support for the sucker rod by inserting a U-shaped temporary support underneath the clamp 80 and resting on the bottom edges of the upper access doors in member 52. The clamp 78 may then be released and the piston 48 and clamp lowered to the desired extent after which the clamp 78 may be again tightened. Thereafter the piston 48 and sucker rod 50 may be raised together to release the weight of the rod from the temporary support, and clamp 80 may then again be adjusted to a position correspondingly spaced from the new position of clamp 78.

Mounted on a suitable base at one side of the well is a combined hydraulic power and air counterbalancing unit generally designated 82. The counterbalancing means comprises a vertical cylinder of considerably larger diameter but of 75

equal fluid displacement to that of the cylinder 46 and designated 84. Slidably mounted in the cylinder 84 is a piston 86 having an upwardly extending rod 88 which extends through a packed opening in the upper cylinder head 90. The cylinder head 90 incorporates a connection 92 which communicates through a second velocity valve 94 with the space in cylinder 84 above piston 86. The connection 92 is connected to the work cylinder at connection 36 by a conduit 96. The space below piston 86 is adapted to contain air under pressure and connects by a conduit 98 with a larger air bottle 100. Suitable drain cocks are provided as shown for draining any condensate or oil leakage that may seep into the bottom of cylinder 84 and air bottle 100.

It will be seen that the conduit 96 connecting work cylinder 46 and counterbalance cylinder 84 forms what is hereinafter termed "a secondary circuit" so that as piston 48 moves downwardly oil will be displaced from work cylinder 46 into the top of counterbalanced cylinder 84 thus providing a single-acting liquid column connecting the pistons 48 and 86 for simultaneous movement. In this secondary circuit it will also be seen that the bottom face of piston 48 constitutes a work ram while the upper face of piston 86 constitutes a counterbalance ram.

The weight of the sucker rod 50 exerts a constant force tending to keep the work ram in contact with the liquid column beneath it while the air under pressure in bottle 100 and the lower part of cylinder 84 exerts another constant force tending to keep the piston 86 moved upwardly into contact with the liquid column above it. Preferably the air pressure in cylinder 84 is maintained at a value where the upward force on piston 86 is greater than necessary to support the weight of sucker rod 50 but less than that necessary to lift that weight plus the weight of the producing oil column standing above check valve 22 in the well. Under this condition it will be seen that the mechanism thus far described tends to hold piston 48 in any position which it should happen to rest since the weight of the sucker rod alone is unable to overcome the air pressure in cylinder 84, it being noted that standing valve 16 supports the weight of the producing oil column. Likewise, there is no tendency to lift the work ram 48 because the pressure in cylinder 84 is insufficient to overcome the weight of both the sucker rod and the oil column in the well.

If the air pressure in cylinder 84 is maintained at an average value midway between that necessary to support the sucker rod only and that necessary to lift both the sucker rod and the oil column, then it will be seen that an equal amount of force is necessary to drive the work ram and counterbalance ram upwardly or downwardly. The effective area of work ram 48 is preferably so designed that the air pressure required in the counterbalance does not exceed the A. S. M. E. code rating of 400 pounds per square inch for a medium pressure vessel.

For the purpose of driving the work ram on its pumping and return stroke, a separate power drive is provided for one of the two rams, in this case, the counterbalance ram. For this purpose the piston rod 88 carries a smaller piston 102 which is slidable in a smaller cylinder 104 carried on the end casting 90 of cylinder 84. The piston 102 and cylinder 104 thus constitute a double-acting hydraulic motor whereby the counterbalance ram 86 may be positively reciprocated by the admission to and exhaust of fluid from the opposite end of the cylinder 104.

Connections 106 and 108 in the head castings 98 and 110, respectively, communicate by pipes 112 and 114 with the power supply connections 116 and 118 of a power fluid supply unit 120. The details of the unit 120 will be described hereafter in connection with Figure 2. For the present purposes it is sufficient to state that the unit is adapted to deliver fluid alternately through connections 116 and 118 while at the same time withdrawing returning fluid through the opposite connections. The direction of fluid flow through the unit 120 is controlled by a lever 122 which is connected by a link 124 with a lever 126 pivoted in the end casting 110.

The piston rod 88 extends through the casting 110 and is provided with a flange 128 at its upper end. The projecting upper end of piston 88 is enclosed in a housing 130 which also supports a sliding control rod 132 carrying flanges 134 and 136 at its upper and lower ends. At its extreme lower end the control rod 132 carries a flange 138 which coacts with the slotted end of lever 126 whereby the rod 132 may operate the latter. Thus when the piston rod 88 is at the upper limit of its stroke the flange 128 contacts flange 134 to lift the control rod 132 and depress the link 124. At the lower limit of the stroke the flange 128 contacts flange 136 to reverse the position of the control linkage members. Either or both of the flanges 134 and 136 may be adjustably mounted on the control rod 132 for changing the length of stroke of piston rod 88.

For the purpose of automatically and continuously replenishing the compressed air supply in bottle 100 the upper end of piston rod 88 carries a plunger 140 adapted to enter an air compressor cylinder 142 secured to the top of casing 130. The length of cylinder 142 is somewhat shorter than the normal minimum stroke of piston rod 88 so that at the lower position of the latter the plunger 140 is completely out of the cylinder 142. A vent louver at 143 permits entry of air into the housing 130. The cap 144 which closes the upper end of cylinder 142 is provided with a discharge check valve 146 which communicates by a pipe 148 with the upper end of the air bottle 100. A suitable pressure gage 150 and blow-off cock 152 may be provided at the top of the bottle 100.

The plunger 140 is not rigidly secured to the piston rod 88 but is resiliently attached thereto by means of a compression spring 154 mounted between washers 156 which abut a nut and a shoulder, respectively, on the plunger 140. The upper end of rod 88 is provided with a counter-bore 158 closed by a cap 160, the arrangement being such that the plunger 140 may be moved downwardly relative to rod 88 by any force sufficient to overcome the force of the spring 154. The force of the spring is preferably so adjusted that the desired pressure of air in bottle 100 will overcome the force of the spring 154. Thus there is provided a limit to the degree of compression of air in cylinder 142, and whenever the pressure in bottle 100 is at the desired value the plunger 140 will fail to compress the air in cylinder 142 to the value necessary to open check valve 146. Thus no air will be discharged from cylinder 142, and the energy of compression of the air therein will be returned to the rod 88 on the expansion stroke. In this way it is automatically insured that the pressure in bottle 100 is maintained at the desired value regardless of leakage, but when no make-

up of air is required, no energy is dissipated by the air recompression mechanism.

Referring now to Figure 2, the entire unit 120 is there illustrated and in the form disclosed comprises a fixed displacement unidirectional delivery pump 162 having a suction conduit 168 and a delivery conduit 170. Pump 162 may be driven by any suitable prime mover such as an electric motor 164 mounted on the outside of the casing 166 of the unit 120. The casing 166 forms a main oil reservoir as well as a support for the various parts of the power unit.

The delivery conduit 170 leads to a three-way pilot control valve 172 which is manually controlled from outside the casing 166. In the position shown the valve 172 connects the delivery conduit with a bypass conduit 174 whereby the full delivery of pump 162 is returned to the reservoir. When the valve 172 is moved to the left the delivery conduit 170 is connected to a conduit 180 leading to the pressure port of a conventional four-way valve 182. The customary relief valve 184 may be provided in a branch extending from the conduit 180.

The tank ports of valve 182 connect by a conduit 186 with the conduit 168 thus providing a closed return circuit to the suction side of pump 162. The conduit 168 at its bottom may be provided with a check valve 188 for replenishing purposes in the main power circuit. The cylinder ports of the four-way valve 182 connect by conduits 190 and 192 with the supply connections 116 and 118. The spool of valve 182 is adapted to be shifted by pilot pressure admitted to the end chambers thereof through connections 194 and 196 which are controlled by a conventional four-way pilot valve 198. The latter is operated by the lever 122 previously described. The usual orifices and check valves 200 and 202 may be provided for controlling the speed of shifting of the spool of valve 182.

In order to provide replenishing oil for the secondary circuit a branch conduit 204 (Figure 1) extends from the conduit 96 into the tank 165 and is provided with a check valve 206 at its lower end. The latter serves merely to admit oil to the secondary circuit during the preliminary filling of the apparatus before it is started.

A bleed conduit 208 extends from the conduit 180 to the conduit 204 and incorporates a hydrostatic flow rate controlling valve 210 of conventional construction and a check valve 212. The valve 210 serves to control the rate of flow through conduit 208 to a predetermined constant volume depending upon the setting of the adjustable throttle 214 incorporated in the valve. The flow through bleed-off conduit 208 is also utilized as a source of pilot operating pressure for shifting the main reverse valve 182, and for this purpose a branch conduit 216 extends from conduit 204 to the pressure port of the pilot valve 198.

In operation, with the secondary and power circuits filled with oil and with the air bottle and counterbalance cylinder filled with air at the required pressure, the pump 162 may be started and the power control valve 172 shifted to its lefthand position.

Starting with the parts in the position illustrated, the oil delivered by pump 162 passes through conduits 170, 180 and 192 to connection 118 and continues through conduit 114 and connection 108 to the upper end of cylinder 104. Piston 102 is accordingly forced downwardly discharging oil from the lower end of cylinder 104

through connection 106, conduit 112, connection 116, conduit 130, and conduits 136 and 138 to the inlet side of pump 162. As piston 102 is driven downwardly, the force of the air pressure in the bottom of cylinder 84 is overcome permitting the weight of the sucker rod to drive piston 48 downwardly thus transferring oil in the secondary circuit from work cylinder 46 to counterbalance cylinder 84.

As the piston 102 nears the bottom of its stroke, flange 128 contacts flange 136 shifting the control rod 132, link 124 and lever 122 to shift pilot valve 198 to its opposite or righthand position. Pilot pressure is accordingly admitted to conduit 216, conduit 196, and through check valve 202 to the lefthand chamber of valve 182 shifting the spool of the latter to the right. Oil discharged from the righthand chamber returns to tank through conduit 194 and valve 198, being restricted in its rate of flow, however, by the throttle 200. When the spool of valve 182 has shifted completely to the right the pressure oil from pump 162 is now directed in an opposite direction through the main power circuit beyond the valve 182.

Piston 102 is accordingly driven upwardly displacing oil from the counterbalance cylinder through conduit 96 into the work cylinder 46. Thus the sucker rod and the oil column supported on check valve 22 are lifted, and the oil is discharged to pipe 26. As the piston 102 reaches the upper limit of its stroke flange 128 contacts flange 134 to shift the control linkage into the position illustrated and thus cause a reversal of piston 102 to repeat the cycle.

It will be noted that during a complete downward and upward cycle of movement of the piston 48, the bleed conduit 208 was continuously feeding oil from the power circuit to the secondary circuit at a comparatively slow rate. Nevertheless, during this interval the quantity of oil in the secondary circuit was increased by a small amount so that the piston 48 will reach the top of its stroke before the piston 86 reaches the top of its stroke. As soon as piston 48 reaches the top the ring 74 will contact its shoulder and open valve 72 to bypass a small quantity of oil from the work cylinder into the drain connection 55. Thus it is insured that the secondary circuit is supplied with make-up fluid at a greater rate than necessary to make up for normal leakage, and any excess is automatically returned to the reservoir by the action of the replenishing relief valve 72.

It will be noted that the present apparatus utilizes but a single pump of inexpensive construction which may be of small size. In fact,

the displacement of pump 162 may be but a fraction of the displacement of oil in the secondary circuit. Furthermore, the pump 162 may operate at or near its maximum rated pressure which is in turn several times the pressure prevailing in the secondary circuit. Thus, economies are secured in the apparatus both by operating at an air pressure which admits of economical air containers and by operating at a hydraulic pressure which admits of the most economical pump construction.

This feature of operating the hydraulic power circuit at a higher pressure than the secondary circuit and air reservoir provides a further economy in that it is unnecessary to provide a separate pump for replenishing the secondary circuit, or, alternatively, to provide mechanism for temporarily disrupting the pumping action periodically while permitting the main power pump to replenish the secondary circuit.

While the form of embodiment of the invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

What is claimed is as follows:

1. A transmission system for a reciprocating oil well pump comprising hydraulic work ram means, an air-loaded hydraulic counterbalance ram, a closed coupling circuit connecting the counterbalance ram in free communication with the work ram means, a fluid pressure generating means, means forming a power circuit isolated from the coupling circuit and including said generating means, said power circuit including a double-acting fluid motor mechanically connected to said hydraulic counterbalance ram and driven by said generating means through said power circuit, and means controlled by the position of the counterbalance ram for reversing the flow of fluid through said power circuit.

2. A transmission system for a reciprocating oil well pump comprising single-acting hydraulic work ram means, single-acting, air-biased, hydraulic counterbalance ram means, a closed coupling circuit connecting the counterbalance means in free communication with the work ram means, and a separate reversible power drive mechanically connected to operate the counterbalance ram means, said drive including a double-acting fluid motor and means for alternately supplying pressure fluid to drive said motor in opposite directions, said last means being controlled by the position of the counterbalance ram.

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