

Jan. 15, 1952

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2,582,564

HYDRAULIC PUMPING JACK FOR IN-THE-WELL PUMPS

Filed Nov. 1, 1950

2 SHEETS—SHEET 1

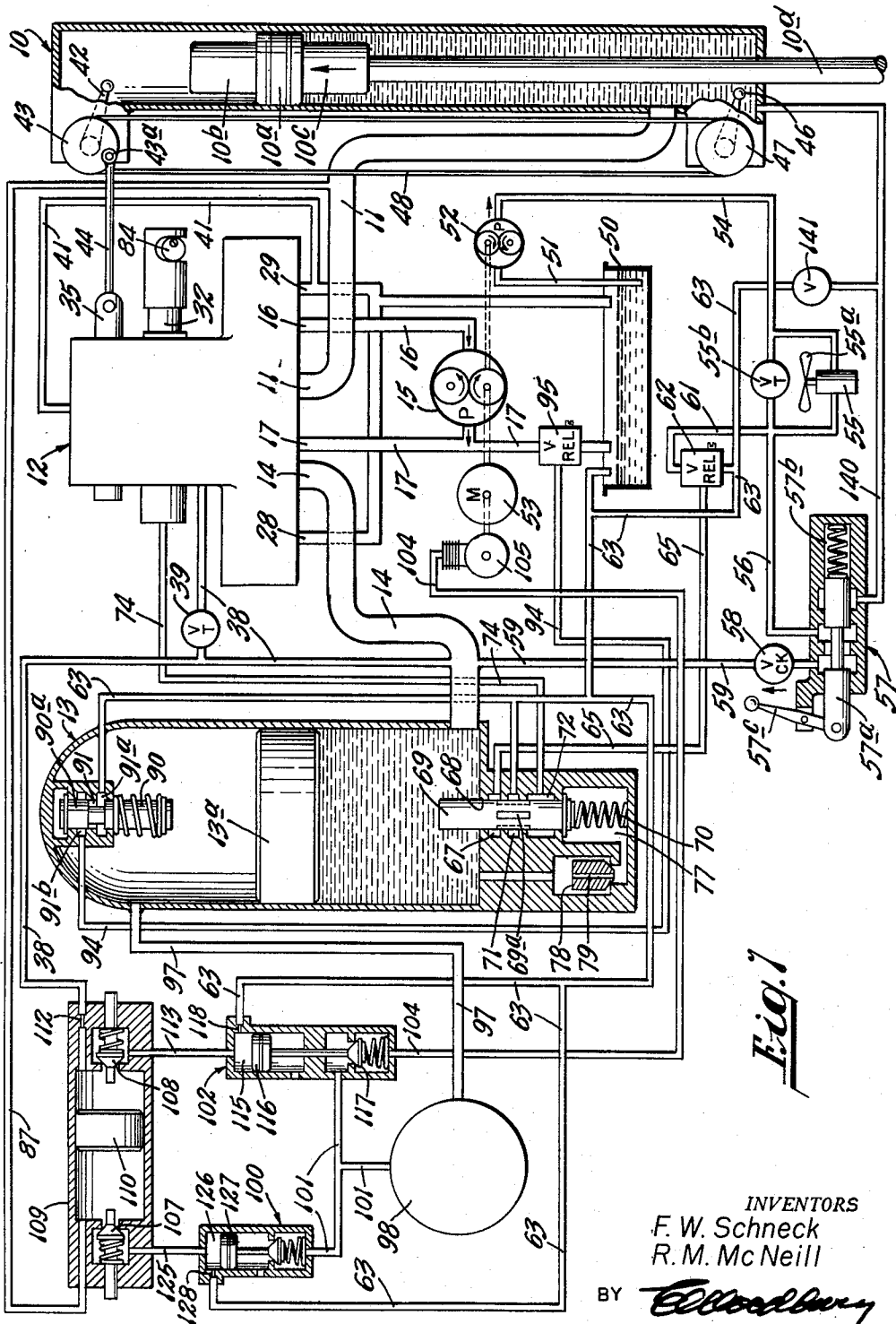


Fig. 1

INVENTORS
F. W. Schneck
R. M. McNeill

BY *Edwards*
ATTORNEY

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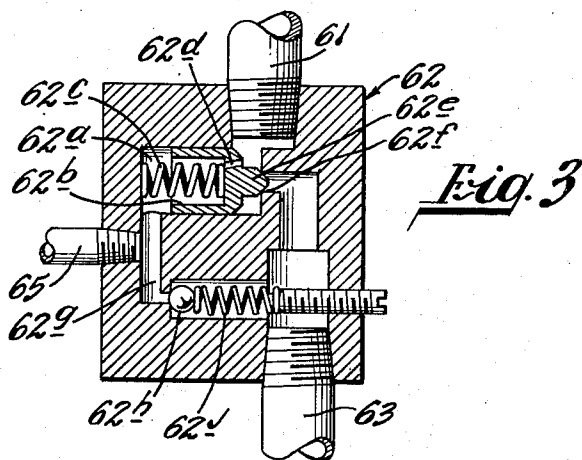
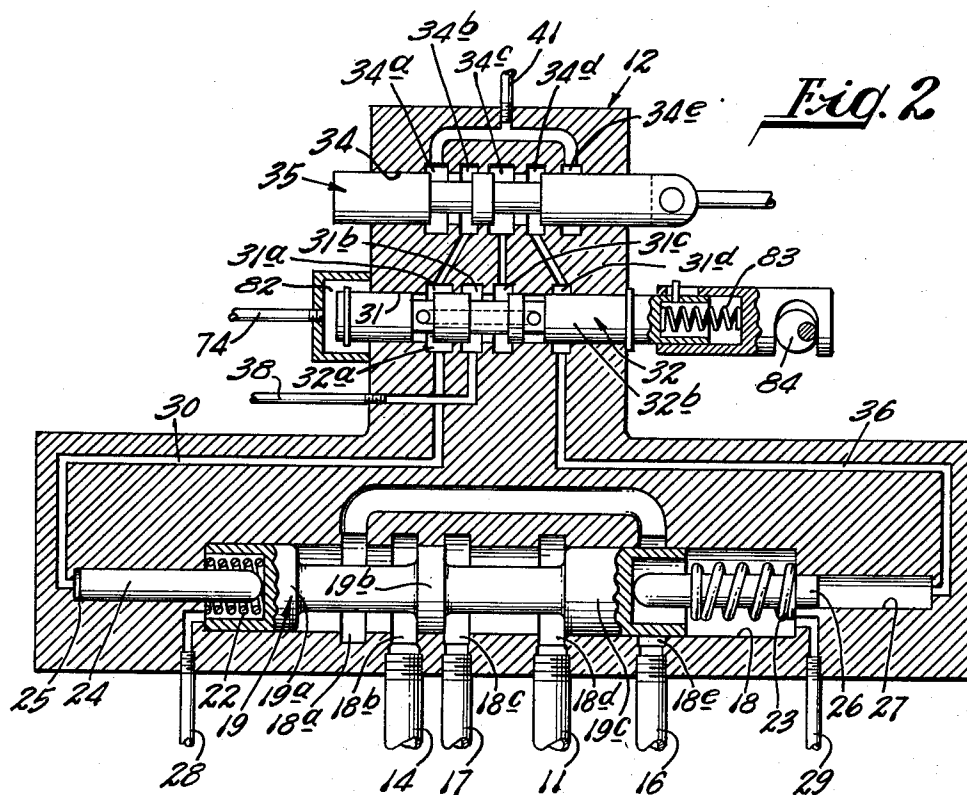
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2 SHEETS—SHEET 2



INVENTORS
F. W. Schneck
R. M. McNeill.

BY

Edmundburg

ATTORNEY

UNITED STATES PATENT OFFICE

2,582,564

HYDRAULIC PUMPING JACK FOR
IN-THE-WELL PUMPS

Frederick W. Schneck, Northridge, and Robert
M. McNeill, North Hollywood, Calif., assignors
to Bendix Aviation Corporation, South Bend,
Ind., a corporation of Delaware

Application November 1, 1950, Serial No. 193,381

15 Claims. (Cl. 60—52)

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This invention relates to hydraulic pumping jacks for reciprocating the sucker rods of pumps in deep wells such as oil wells.

An object of the invention is to provide a hydraulic pumping jack that is reliable and efficient and is largely automatic in operation.

Another object is to provide a practicable and simple system for producing a pause or dwell of controllable duration in the movement of the sucker rod at each end of the stroke.

Another object is to provide automatic safety means for stopping the pumping action in response to the development of abnormal conditions in the apparatus that would make continued operation undesirable.

Another object is to provide an effective and reliable system for replenishing hydraulic fluid lost by leakage from the hydraulic circuit.

Another object is to provide automatic interruption of the pumping action in the event of insufficient or excess hydraulic fluid for proper operation and automatic resumption of the pumping action as soon as the fluid supply has been restored to the proper value.

Another object is to provide, in a hydraulic pumping jack incorporating a counterbalance system utilizing compressed gas to balance the power consumption during the up and down strokes of the pump, an automatic control for varying the counter balance gas pressure as necessary to maintain substantially equal power consumption on the up and down strokes of the pump.

Other more specific objects and features of the invention will appear from the description to follow.

Briefly, a system in accordance with the present invention comprises a hydraulic ram connected to the pump sucker rods for lifting and lowering them, a counterbalance containing a supply of hydraulic fluid under a substantially constant pressure, a constantly driven pump, and a main valve for alternately connecting the input for the pump to the counter balance and the output of the pump to the ram to move the ram through its upstroke, and connect the input of the pump to the ram and the output to the counter balance on the downstroke. The main valve is a servo valve actuated by hydraulic pressure under the control of a pilot valve that is mechanically tripped or reversed at the upper and lower ends of the stroke of the ram. The hydraulic actuating mechanism of the main valve consists of a pair of motor pistons which are mechanically separate from the valve, so that each is capable of moving the valve in one direc-

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tion but the valve is capable of moving away from the piston at a more rapid rate. Furthermore, the valve is provided with a centering spring, and pressure fluid is supplied to the pilot valve through a restricted passage, but an exhaust line of unrestricted dimensions returns exhaust fluid from the pilot valve to the reservoir. The result is that when the pilot valve is reversed, pressure fluid is supplied at a slow rate, because of the restriction, to the piston at one end of the main valve, tending to move the latter through its stroke. However the centering spring moves the main valve into neutral position faster than the pressure fluid supplied through the restricted passage can move it. The result is that the main valve is quickly moved into neutral position by its centering spring and holds in neutral position until the motor piston being slowly moved by the pressure fluid flowing through the restricted passage catches up with the main valve and moves it on into its other extreme position. The result is that the main valve moves quickly into neutral position to stop the ram, pauses in neutral position, causing a corresponding pause or dwell in the movement of the ram, and then moves into its other extreme position to start the ram moving in the other direction. This pause or dwell can be varied in length by varying the restriction in the pressure fluid supply to the pilot valve.

There is a constant leakage of hydraulic fluid from the system including the ram, the main valve, and the counter balance, and to compensate for this leakage fluid must be introduced by a replenish system. In accordance with the present invention, the counter balance comprises a cylinder having hydraulic fluid in one end portion and compressed air or gas in the other portion, the two being separated by a free piston in the cylinder. So long as the system contains the proper amount of fluid the free piston reciprocates between certain predetermined limits in the counterbalance cylinder. If the amount of fluid falls below a desired value the free piston moves farther in one direction and contacts and slightly shifts a replenish valve which admits additional fluid from a separate replenish pump. To increase the effectiveness of the replenish valve it is provided with a hydraulic damping system which permits it to return from open to closed position relatively slowly instead of following the free piston as the latter moves on its return stroke.

Normally only small amounts of replenish fluid are required from time to time, and the total quantity of fluid in the system does not drop

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below a value to permit full stroke operation of the ram. However it is conceivable that as a result of some abnormal condition the quantity of fluid in the system might drop below that necessary to permit the ram to make its full stroke. In such event the free piston in the counterbalance cylinder will move the replenish valve beyond its normal position, and, in accordance with the invention, there is provided an auxiliary, hydraulically actuated valve between the pilot valve and the main valve which returns the main valve to neutral in the event the free piston in the counter balance is moved beyond its normal limit. However, continued operation of the replenish pump should normally restore the quantity of fluid, thereby moving the free piston away from the replenish valve and permitting it to move back into normal position, which in turn releases the auxiliary valve and permits the ram to resume its operation. The pumping action is therefore automatically interrupted only as long as there is insufficient fluid, and when the normal amount of fluid has been restored operation is automatically resumed.

The air pressure in the counterbalance cylinder is supposed to balance the weight of the sucker rod and half the weight of the column of oil that is lifted by the pump, and when the pressure is at the optimum value the load on the prime mover is the same on the upstroke as during the downstroke. It is possible however for the load on an oil well pump to vary during the course of operation. Such variation may for example be produced by a variation in the amount of gas in the oil being pumped. To maintain equal load on the prime mover during the up and down strokes of the ram, the air pressure in the counterbalance should be correspondingly varied. In accordance with the present invention the air pressure in the counterbalance is automatically controlled in response to the load on the pump. This is accomplished by providing an auxiliary cylinder having a free piston therein and connected at one end to the ram line and at the other end to the counterbalance line. This auxiliary cylinder can be relatively small so that it shunts relatively little fluid from the pump, and the connection at one or both ends of the cylinders can contain restricted passages which permit only small rates of flow into opposite ends of the cylinder. As long as the counterbalance air pressure is at the proper value to perfectly balance the load on the ram, the time of the upstroke is the same as the time of the downstroke, and the pressure differential applied by the pump between the counterbalance and the ram is the same on both strokes. Under these conditions, the free piston in the auxiliary cylinder travels back and forth between predetermined limits. However, if the load on the ram should increase, the pressure differential across the pump will be somewhat greater on the upstroke than on the downstroke, and the upstroke will require shortly longer time than the downstroke. The result of this is that more fluid will be admitted to one end of the auxiliary cylinder than to the other, which will gradually move the average position of the free piston toward one end of the auxiliary cylinder. Appreciable drift of the free piston beyond its normal stroke limit causes it to open a valve to admit air under pressure to the counterbalance chamber and raise the mean air pressure to a value such as to balance the increased load on the ram. When this balance has been restored, the free piston will again move between

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its normal stroke limits. On the other hand, if the load on the ram should lighten, the free piston would gradually drift in the opposite direction and after appreciable movement beyond its usual stroke limit in this direction it contacts and opens a valve that releases some air from the counterbalance chamber. In this way, an approximately perfect balance between the counterbalance pressure and the pump load is automatically maintained.

A full understanding of the invention may be had from the following description read in connection with the drawing, in which:

Fig. 1 is a schematic diagram of a complete system in accordance with the invention;

Fig. 2 is a detailed schematic diagram of the main valve, the pilot valve, and the cut-off valve; and

Fig. 3 is a detailed schematic diagram of a pressure relief valve that is employed in the system.

Referring to Fig. 1, the apparatus therein disclosed comprises a ram 10 connected by a ram line 11 to a main valve assembly 12, a counterbalance cylinder 13, the lower fluid-filled portion of which is connected by a supply line 14 to the main valve assembly 12, and a main pump 15 driven by a prime mover 53 and having an inlet line 16 and an outlet line 17 connected to the main valve assembly 12. During normal operation the valve assembly 12 functions to alternately connect the inlet line 16 to the ram line 11 while connecting the outlet line 17 to the counterbalance or supply line 14, and vice versa, to raise and lower a piston 10a in the ram 10 which piston is connected by a piston rod 10d to the polish rod of a pump (not shown).

Main valve and operation thereof

Referring to Fig. 2, the main valve assembly 12 includes a main valve cylinder 18 containing a shiftable valve element or piston 19 reciprocable therein. The valve piston 19 has three lands 19a, 19b and 19c which cooperate with ports in the valve cylinder 18 to control the flow of fluid between the pump and the ram and counterbalance cylinders. Thus cylinder ports 18a and 18e are connected to the pump inlet line 16. Cylinder port 18b is connected to the supply line 14. Cylinder port 18c is connected to the pump outlet line 17, and cylinder port 18d is connected to the ram line 11.

The valve piston 19 is shown in extreme left position, in which the supply line 14 is connected to the pump inlet line 16 and the ram line 11 is connected to the pump outlet line 17, so that fluid is pumped from the counterbalance cylinder into the ram to elevate the ram piston.

When the main valve piston 19 is in mid (neutral) position, the land 19b thereon is positioned between the cylinder ports 18c and 18d. This connects the cylinder port 18a directly to the cylinder port 18e, permitting fluid to flow freely from the pump outlet line 17 into the pump inlet line 16. However, the port 18d is completely blocked by the piston lands 19b and 19c so that the ram is held stationary. In neutral position the pump outlet and inlet lines 17 and 16 respectively, in addition to being connected to each other, are connected to the supply line 14.

In the right end position of the valve piston 19, the port 18a is blocked by the piston land 19a, and the supply line 14 is connected by the ports 18b and 18c to the pump outlet line 17. At the same time, the pump inlet line 16 is con-

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nected by the ports 18e and 18d to the ram line 11 so that fluid is pumped from the ram to the counterbalance cylinder to lower the ram piston.

Centering springs 22 and 23, respectively, are provided at opposite ends of the valve piston 19 for moving it into its central neutral position whenever it is not held in one or the other end position by hydraulic motor means next to be described. This motor means comprises a motor piston 24 in a small motor cylinder 25 extending from the left end of the valve cylinder 18, and a motor piston 26 in a small motor cylinder 27 extending from the right end of the valve cylinder 18. The opposite ends of the valve cylinder 18 are vented to the reservoir by exhaust lines 28 and 29, respectively. Hence there is never any pressure fluid in the ends of the cylinder 18 to act upon the piston 19. The outer end of the motor cylinder 25 is connected by a passage 30 and by a port 31a in an auxiliary valve cylinder 31 to a port 34b in a pilot cylinder 34 of a pilot valve consisting of the cylinder 34 and a piston 35. The outer end of the motor cylinder 27 is connected by a passage 36 and a port 31d in the auxiliary valve cylinder 31 to a port 34d in the pilot valve cylinder 34. The pilot valve port 34c is normally connected by the auxiliary valve cylinder ports 31c and 31b to a line 38 connected through a throttling valve 39 (Fig. 1) to the supply line 14 extending to the counterbalance cylinder, so that pressure fluid is supplied from the counterbalance cylinder to the port 34c. The other two ports, 34a and 34e of the pilot valve, are connected by an exhaust line 41 to the reservoir. In Figs. 1 and 2 the pilot valve piston 35 is in leftmost position, in which it applies pressure fluid from the line 38 to the right motor cylinder 27 of the main valve and connects the exhaust line 41 to the left motor cylinder 25, to hold the main valve in leftmost position as shown.

Referring to Fig. 1, when the ram piston 10a approaches its uppermost position an actuator 10b on the upper end of the piston contacts a control lever 42 connected to a pulley 43 having a crank pin 43a thereon which is connected by a connecting rod 44 to the pilot valve piston 35, so that final upward movement of the piston rocks the lever 42 and the connecting rod 44 to shift the pilot valve piston 35 into its rightmost position. Referring back to Fig. 2, this movement of the pilot valve connects the pressure line 33 through ports 34c and 34b to the left motor cylinder 25, and connects the exhaust line 41 through ports 34e and 34d to the right motor cylinder 27. The lines 36 and 41 offer a path of low resistance for the flow of fluid from the motor cylinder 27 back to the reservoir, so that the centering spring 22 can quickly restore the main valve piston 19 into neutral position, in which the ram line 11 is blocked, and the pump lines 16 and 17 are short-circuited. Therefore, the ram piston 10a is held at the upper end of its stroke. During this initial movement of the main valve piston 19 by the centering spring 22 back into neutral position, the valve piston 19 runs away from the motor piston 24, which is moving only slowly because of the throttling effect of the throttle valve 39 (Fig. 1) in the pressure supply line 38. Eventually, the motor piston 24 catches up with the valve piston 19 and carries the latter from neutral position into extreme rightmost position, in which the pump outlet line 17 is connected to the counterbalance or supply line 14 and the pump inlet 16 is connected to the ram line 11,

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to reverse the movement of the ram piston and start it on its downward stroke.

Referring back to Fig. 1, as the ram piston 10a approaches its lowermost position, a lower actuator 10c thereon contacts a lever 46 connected to a pulley 47 which is coupled by a belt 48 to the pulley 43, and final movement of the piston 10a into lowermost position rocks the lever 46, the pulleys 47 and 43, and the connecting rod 44, to shift the pilot valve piston 35 back into its leftmost position in which the original connections as shown in Fig. 2 are restored. Hence, the left motor cylinder 25 is now connected to exhaust, the right centering spring 23 is effective to quickly move the main piston 19 back into neutral position, again blocking the ram line 11, and causing the ram piston to pause or dwell in its lower end position until the pressure fluid supplied through the metering or throttling valve 39 to the right motor cylinder 27 causes the motor piston 26 to overtake the valve piston 19 and carry it into extreme left position as shown in Fig. 2 thereby completing a cycle of operation.

The provision of the centering springs 22 and 23 in combination with the low resistance passage from one of the motor cylinders 25 to exhaust while providing throttled flow of pressure fluid to the other motor cylinder provides a simple and effective way of producing a pause or dwell at each end of the stroke of the ram piston and the extent of the dwell can be adjusted by regulating the throttling valve 39.

Replenish system

It will be observed from the foregoing description that the main pump 15 simply circulates fluid back and forth between the lower end of the counterbalance cylinder 13 and the lower end of the ram 10. In such systems, it is usually impractical to prevent a constant slight leakage of fluid which would eventually result in depletion of the fluid supply. Hence it is necessary in a practical system to provide for the frequent replenishment of small quantities of fluid to the system to compensate for that lost by leakage.

In the present system, referring to Fig. 1, fluid is supplied from the reservoir 50 through an intake pipe 51 to a replenish pump 52 which may be constantly driven by the same prime mover 53 that drives the main pump 15. A substantially constant flow of fluid is delivered by the replenish pump 52 through a line 54 and a fan motor 55 to a line 56, which is connected through a manually controlled valve 57 and a check valve 58 and a line 59 to the main supply line 14, which is permanently connected to the lower end of the accumulator cylinder 13. Normally, fluid is freely bypassed from the line 56 to the reservoir through a line 61, a relief valve 62, and a return line 63.

The fan motor 55 drives a fan 55a which is used to supply cooling air for the equipment and is of no importance in connection with the rest of the hydraulic circuit. The motor 55 is bypassed by a throttle valve 55b which is used to regulate the speed of the motor 55.

The replenish pump 52 delivers a substantially constant flow of fluid through the fan motor 55 and the bypass valve 55b and thence (normally) through the pipe 61 and the normally open relief valve 62 and return line 63 back to the reservoir 50. As long as the relief valve 62 is open, no pressure is developed in the line 56 and hence no flow can occur through the check valve 58

o the replenish pipe 59 leading to the supply line 14.

The valve 62 is of the pilot type which remains open in response to free flow through a pipe 61 leading therefrom, but closes in response to stoppage of free flow through the pipe 61. When conditions are such as to require replenishment, the pipe 61 is closed, causing the valve 62 to close and build up sufficient pressure in the line 56 to pass fluid through the check valve 58 into the supply line 14.

Referring to the schematic illustration of the relief valve 62 shown in Fig. 3, pressure fluid from the pipe 61 is applied to a cylinder 62a containing a piston 62b that is urged to the right by a spring 62c. The piston 62b is provided with a bleed hole 62d therein which permits a slow flow of fluid from the cylinder 62a past the piston 62b and to the pipe 61. If the other end of pipe 61 is closed, pressure builds up in the left end of the cylinder 62a so that the pressures on the two ends of the piston 62b are balanced and the piston is held in its rightmost position as shown in Fig. 3 by the spring 62c. In this position a poppet 62e on the right end of the piston 62b closes a seat 62f leading to the pipe 63, so that no fluid can flow into the pipe 63. However if the other end of pipe 61 is open, so that the small flow of fluid through the bleed hole 62d cannot build up pressure in the left end of the cylinder 62a, then the pressure acting on the right end of the piston 62b is sufficient to overcome the force of the spring 62c and move the piston 62b to the left thereby carrying the poppet 62e clear of the seat 62f and permitting free flow of fluid from the pipe 61 through the valve to the pipe 63.

In addition to opening in response to free flow of fluid through the pipe 61, the valve 62 will open in response to a predetermined excess pressure in the line 61 even though the pipe 61 is closed. Thus the left end of the cylinder 62a is connected by a passage 62g to a ball relief valve seat closed by a ball valve 62h actuated by a spring 62j. Pressure in excess of the predetermined value lifts the ball valve 62h off its seat, permitting flow of fluid from the left end of the cylinder 62a so that a pressure is developed against the right end of the piston to open the poppet 62e and permit free discharge of fluid from the pipe 61 through the pipe 63 back to the reservoir. The pilot valve 62h is provided purely for safety reasons to prevent the pressure from rising to an excessive value in the event of an abnormal condition. Normally it remains closed.

Referring back to Fig. 1, the pipe 65 connects to a port 67 in a valve cylinder 68 formed in the lower end of the counterbalance cylinder 13 and containing a valve piston 69 which is normally held in an upper limit position by a spring 70. In this position, longitudinal grooves 69a in the valve piston 69 connect the port 67 to a port 71 next below the port 67 and to a port 72 next below the port 71. The port 71 is connected to the return pipe 63 leading back to the reservoir. The port 72 is connected by a pipe 74 to a chamber in the main valve assembly 12, the purpose of which will be described later.

The operation of the replenish system is as follows: It will be observed that as long as the valve piston 69 is in its uppermost position as shown in Fig. 1, the pipe 65 is connected by the port 67, the groove 69a, and the port 71 to the return pipe 63 so that no pressure is developed in the pipe 65. Under these conditions, the pop-

pet 62e (Fig. 3) in the valve 62 remains open to freely bypass fluid from the pipe 61 to the return pipe 63 so that insufficient pressure is built up in the pipe 56 to exceed the pressure in the main supply line 14. Therefore the check valve 58 remains closed and there is no replenishment of the fluid supply.

Now let it be assumed that as a result of a leakage of fluid from the system, the total quantity of fluid in the ram 10, the ram line 11, the supply line 14, and the counterbalance cylinder 13 diminishes until eventually during the final movement of the ram piston 10a on an upstroke the liquid level in the lower part of the counterbalance cylinder 13 becomes so low that a free piston 13a separating the liquid from the gas contacts the upper end of the piston 69 and depresses it. A very slight depression of the piston 69 carries the grooves 69a out of registration with the port 67, isolating the latter and permitting pressure to build up in the pipe 65. This closes the relief valve 62 causing the pressure to build up in the pipe 56 to a value exceeding the pressure in the supply line 14 so that fluid flows from the pipe 56, through the valve 57 and the check valve 58 and the pipe 59 into the supply line 14.

The piston 69 will be depressed a slight amount on each downward stroke of the free piston 13a until the quantity of fluid in the system has been restored to its normal value causing the free piston 13a to no longer contact the replenish valve piston 69.

It is desirable in practice to cause the valve piston 69 to remain in depressed position longer than it would normally be held down by the free piston 13a. To produce this result, the lower end of the valve cylinder 68 is connected to a chamber 77 which is connected by a check valve 78 with the lower end of the counterbalance cylinder 13. During downward movement of the valve piston 69, the fluid displaced by the entry of the piston into the chamber 77 is freely displaced therefrom past the check valve 78 into the counterbalance cylinder 13. However when the free piston 13a moves upward again, and the valve piston 69 tends to follow it, rapid return of the fluid in the counterbalance cylinder, a compensating pressure in the chamber 77 being built up only slowly by flow of fluid through a bleed passage 79 in the check valve poppet 78. The spring 70 is not stiff enough to draw a vacuum in the chamber 77. As a result of the delayed return of the valve piston 69 by the check valve 78 only a few depressions of the valve piston 69 by the free piston 13a are normally necessary to so restore the quantity of fluid in the system as to prevent further contact of the free piston 13a with the valve piston 69.

Conceivably, during a period of inactivity, a relatively large amount of fluid might leak out of the system, so that when the unit is first started up there is insufficient fluid contained within the counterbalance cylinder 13 and the ram 10 to produce a full upstroke of the ram piston 10a without fully depressing the free piston 13a in the counterbalance. This could cause cavitation of the main pump 15 due to a lack of fluid on the input side thereof. Apparatus is therefore provided for centering the main valve in the event the free piston 13a drops materially below the normal upper position of the valve piston 69. The mechanism for automatically centering the main valve is controlled by

means of the port 72 in the valve cylinder 68. During a normal replenish operation, the upper ends of the vertical grooves 69a in the valve piston 69 never drop below the port 71, so that the port 72 is always connected to the return line 63 and no pressure can be built up in the port 72 and the pipe 74. However, if the fluid supply in the system should drop so low that the free piston 13a in the counterbalance cylinder could approach its lower limit position, thereby preventing all further delivery of fluid to the supply line 14, the valve piston 69 will be depressed to such an extent that the grooves 69a therein connect the port 72 with the chamber 77, which in turn is always connected by the bleed passage 79 with the counterbalance cylinder. This supplies pressure fluid to the pipe 74 leading to the main valve assembly 12.

Referring now to Fig. 2, the piston 32 of the auxiliary valve is exposed at its left end to the pressure of fluid in a chamber 82 to which the pipe 74 is connected. A rise in pressure in the pipe 74 and the chamber 82 moves the piston 32 to the right to the limit of its travel, compressing a spring 83 in a mechanical link which connects the piston 32 with an eccentric 84 that is manually rotated through 180° to start and stop the apparatus. Movement of the valve piston 32 to the right causes a land 32a thereon to completely block the pressure fluid supply port 31b thereby preventing the admission of pressure fluid to either of the main valve operating motors 24 and 27. Another land 32b on the piston uncovers port 31d thereby interconnecting ports 31a and 31d which are connected by the passages 30 and 36 respectively to the motor cylinders 25 and 27. One or the other of the centering springs 22 or 23 thereupon immediately restores the main valve piston 19 to neutral position, in which the ram line 11 is blocked and the pump inlet pipe 17 is connected to the pump inlet line 16.

It will be seen, therefore, that if the apparatus is started with insufficient fluid in the system the following sequence of operation takes place: The ram piston 10a starts its upstroke and due to the insufficient supply of fluid in the system the free piston 13a in the counterbalance drops into its lowermost position before the ram piston has completed its upstroke. The resultant large depression of the valve piston 69 by the free piston 13a closes the relief valve 62 as previously described so that the replenish pump develops full pressure in the line 56 to deliver fluid through the check valve 58 to the supply line 14, thereby beginning to restore the fluid supply. At the same time the application of pressure fluid from the chamber 77 through the grooves 69a in the valve piston 69 to the port 72 and the pipe 74 shifts the main valve into neutral position as previously described, thereby short-circuiting the main pump 15 and blocking the ram line 11 to hold the ram piston 10a in whatever position it had been lifted to at the time the free piston 13a in the counterbalance reached its lowermost position. The action of the replenish pump gradually increases the amount of fluid in the counterbalance cylinder 13, lifting the free piston 13a therein and permitting rise of the valve piston 69. This rise will, after a period of time, carry the grooves 69a in the piston 69 clear of the chamber 77 but the pressure previously built up in the line 74 will be maintained until further rise of the grooves 69a connects the port 72 to the return port 71. This releases the pressure in the pipe 74 permitting the auxiliary

valve piston 32 (Fig. 2) to be restored by the spring 83 and permitting the pilot valve to again take control and shift the main valve into position to cause the main pump 15 to again deliver fluid from the supply line 14 to the ram line 11. The ram piston 10a will thereupon be again lifted until the free piston 13a in the counterbalance cylinder again depresses the valve piston 69 to repeat the cycle of operations. The overall result is that the ram piston 10a is lifted by small increments during the replenish of fluid to the system, until the ram piston reaches the upper end of its stroke and trips the lever 42 causing the reversal of the main valve and the commencement of the downstroke. The next succeeding upstroke will ordinarily be completed in normal fashion except in the event of a very abnormal condition producing insufficient leakage of fluid from the system during one cycle of operation to cause the free piston 13a to fully depress the valve piston 69 on the next succeeding downstroke.

Conceivably, through some accident, the system could be overfilled with fluid, in which event, during the upstroke of the free piston 13a it would rise beyond its usual limit position, and such abnormal rise is utilized to release some fluid from the system. Thus excessive upward movement of the free piston 13a will cause it to contact and elevate a valve piston 90 reciprocable in a valve cylinder 91, the latter containing two ports 91a and 91b which are normally blocked from each other by a land 90a on the piston 90. The port 91a is connected to the return pipe 63 and the port 91b is connected to the pilot pipe 94 of a relief valve 95 connected to the pump outlet pipe 17. The construction of the valve 95 may be identical with the valve 62, as shown in Fig. 3. The valve 95 is normally closed, but will open either to abnormal pressure in the pump outlet line 17 or to release of pressure from the pilot line 94. Pressure will be maintained in the pilot line 94 as long as the port 91b is blocked by the piston land 90a. However if there is excess fluid in the system, causing the free piston 13a to lift the valve piston 90 and interconnect the port 91a to the port 91b, pressure is immediately relieved in the pilot line 94, causing the valve 95 to open and discharge fluid from the system until the free piston 13a is lowered sufficiently to permit the valve piston 90 to restore it to its normal position, again blocking the port 91b.

Counterbalance air pressure regulator

As was described in the introduction, the air pressure above the free piston 13a should be such as to produce equal loading of the main pump 15 during the up and down strokes of the ram. It is also desirable that the air pressure above the free piston 13a vary as little as possible during each stroke. To this end the air chamber of the counterbalance cylinder 13 is connected by a pipe 97 to an air tank 98 which is preferably of large volume compared to the volume of the counterbalance cylinder 13. The air pressure in the tank 98 is controlled by an exhaust valve 100 connected thereto by a pipe 101 and by a supply valve 102 which is adapted to connect the pipe 101 to a pipe 104 leading to an air compressor 105 which may be connected to and driven by the same prime mover 53 that drives the main pump 15 and the replenish pump 52. Both of the valves 100 and 102 are normally closed, but the valve 100 is opened to relieve the

air pressure in the event it is too high, and the valve 102 is opened to admit more air from the compressor 105 in case the pressure is too low. These valves 100 and 102 are actuated by pilot valves 107 and 108, respectively, in opposite ends of a cylinder 109 containing a free piston 110. The left end of the cylinder 109 is connected by a pipe 87 to the ram line 11, and the right end of the cylinder 109 is connected by the pipe 38 to the supply line 14. It will be observed therefore that during the upstroke of the ram 10 the pressure developed by the main pump 15 is applied to move the free piston 110 to the right, and that during the downstroke of the ram the pressure developed by the pump is applied to move the free piston 110 to the left. It is desirable that the cylinder 109 be of small dimensions so as not to bypass any more fluid from the main pump than is necessary. To permit this, flow into and out of the right end of the cylinder is restricted by a bleeder passage 112 in the right end of the cylinder.

As long as the air pressure in the tank 98 and in the upper end of the counterbalance cylinder 13 is at its optimum value, the pressure differential developed by the main pump 15 will be the same on both the up and down strokes of the ram, and the time of the upstroke will equal the time of the downstroke. While this condition is maintained, the free piston 110 in the cylinder 109 will move back and forth through a fixed distance between end limits that are well spaced from the ends of the cylinder 109. However if the mean air pressure in the counterbalance cylinder is insufficient to balance the load on the ram, the pressure differential applied across the free piston 110 during the upstroke of the ram will be greater and will be of longer duration than the pressure differential applied in the opposite direction during the downstroke of the ram. The result will be that the free piston 110 will work toward the right end of the cylinder 109 and will contact and trip the valve 108 thereby permitting some of the pressure fluid in the right end of the cylinder 109 to flow through a pipe 113 into a cylinder 115 in the valve 102 where it will develop a pressure to move a piston 116 and open a poppet valve 117 to admit air from the compressor 105 through the pipe 104 and through the pipe 101 to the air tank 98. The pressure fluid in cylinder 115 will leak out through a bleed passage 118 to the return line 63, so that the valve 117 will automatically close shortly after the free piston 110 has moved away from the valve 108. However, on successive movements of the free piston 110 into its right end position, the valve 108 will be opened to again open the valve 117, until the air pressure in the tank 98 and in the counterbalance cylinder 13 has been restored into proper balance with the load on the ram 10a, whereupon the free piston 110 will again ride clear of the valve 108.

Should the condition be reversed and the air pressure be too high for the ram load, the pressure conditions in the cylinder 109 will be reversed, with the result that the free piston 110 will contact the valve 107 in the left end of the cylinder thereby admitting pressure fluid through a pipe 125 into a cylinder 126 in the valve 100, causing a piston 127 therein to move and open the bleeder valve 100 to relieve air pressure from the tank 98 through the pipe 101. To relieve the pressure in the cylinder 126 after the valve 107 has closed, the cylinder 126 is connected by a bleed passage 128 to the return pipe 63.

Miscellaneous features

The manual valve 57 previously referred to contains a piston 57a which is normally biased by a spring 57b to connect the line 56 to the check valve 58 for replenishing the fluid supply in the counterbalance cylinder 13 under the control of the relief valve 62 as previously described. However, by manipulating a lever 57c the valve piston 57a can be shifted and held against the force of the spring 57b, to connect the pipe 56 to a pipe 140 leading to the lower end of the ram 10. This is used when it is desired to lift the ram under manual control, as when testing or making adjustments.

A normally closed valve 141 connects the pipe 140 to the return pipe 63, and by opening this valve fluid can be released from the lower end of the ram to controllably move the ram piston 10a downwardly.

Although for the purpose of explaining the invention, a particular embodiment thereof has been shown and described, obvious modifications will occur to a person skilled in the art, and we do not desire to be limited to the exact details shown and described.

We claim:

1. In a hydraulic pumping jack for reciprocating the sucker rod of an in-the-well pump: a hydraulic ram adapted to be mechanically connected to the sucker rod for lifting it in response to delivery of pressure fluid to the ram and lowering it in response to release of pressure fluid from the ram; a pump having inlet and outlet ports; a fluid supply line; a ram line for fluid flow to and from said ram; a main valve for controlling fluid flow between said lines and said pump and containing a shiftable valve element movable between first and second end positions through a neutral position, said valve having ports and passages controlled by said shiftable element for connecting the pump inlet port to said supply line and the pump outlet port to said ram line in said first position, blocking said ram line in said neutral position, and connecting said pump inlet port to said ram line and said pump outlet port to said supply line in said second position; restoring means constantly urging said valve element toward neutral position; hydraulic motor means having first and second ports for shifting said valve element into its two respective end positions; a source of pressure fluid; a pilot valve operable between two positions for connecting said first motor port to said pressure fluid source and the said second motor port to exhaust in one position and vice versa in the other positions; means restricting the rate of flow of said pressure fluid to said pilot valve to a value such that the speed at which said motor means tends to shift said valve element is less than the speed at which the element is shifted into neutral position by said restoring means; and over-running drive means mechanically coupling said motor means to said valve element whereby during movement of said motor means by pressure fluid applied thereto the motor means is capable of driving said valve element in one direction but the valve element is movable in the same direction into neutral position by said restoring means at a faster rate than said motor means drives it.

2. A hydraulic pumping jack according to claim 1 in which said shiftable valve element comprises a slide valve, said restoring means comprises a slide valve centering spring, and said motor means comprises a stationary cylin-

der aligned with said slide valve and a piston in said cylinder adapted to abut against said slide valve and drive it in one direction.

3. In a hydraulic pumping jack for reciprocating the sucker rod of an in-the-well pump; a hydraulic ram adapted to be mechanically connected to the sucker rod for lifting it in response to delivery of pressure fluid to the ram and lowering it in response to release of pressure fluid from the ram; a pump having inlet and outlet ports; a fluid supply line; a ram line for fluid flow to and from said ram; a main valve for controlling fluid flow between said lines and said pump and containing a shiftable valve element movable between first and second positions through a neutral position said valve having ports and passages controlled by said valve element for connecting the pump inlet port to said supply line and the pump outlet port to said ram line in said first position, blocking said ram line in said neutral position, and connecting said pump inlet port to said ram line and said pump outlet port to said supply line in said second position; restoring means constantly urging said valve element toward neutral position; said main valve including hydraulic motor means having first and second ports for shifting said valve element into its two respective end positions; a source of pressure fluid; a pilot valve operable between two positions for connecting said first motor port to said pressure fluid source and said second motor port to exhaust in one position, and vice versa in the other position; an auxiliary valve interposed in the fluid lines leading to said pilot valve and having an "on" position in which it completes connections from said pressure source and said motor means to said pilot valve and an "off" position in which it blocks flow of pressure fluid to and connects said motor means to exhaust; and means for manually actuating said auxiliary valve between "on" and "off" positions.

4. A hydraulic jack according to claim 3 including a counterbalance means connected to said fluid supply line for supplying pressure fluid thereto; auxiliary hydraulic motor means responsive to pressure fluid for moving said auxiliary valve from "on" position into "off" position; and means responsive to depletion of the pressure fluid in said counterbalance means below a predetermined limit for applying pressure fluid to said auxiliary hydraulic motor.

5. A hydraulic pumping jack according to claim 4 including a yieldable spring link coupling said auxiliary valve to said manual actuating means whereby said auxiliary motor can override said manual actuating means to shift said auxiliary valve into "off" position while the manual actuating means is in "on" position.

6. In a hydraulic pumping jack for reciprocating the sucker rod of an in-the-well pump: a hydraulic ram adapted to be mechanically connected to the sucker rod for lifting it in response to delivery of pressure fluid to the ram and lowering it in response to release of pressure fluid from the ram; a pump having inlet and outlet ports; a counterbalance cylinder having a piston therein defining with one end of said cylinder an expansible and contractable counterbalance chamber and means urging said piston to maintain pressure in said chamber; a ram line for fluid flow to and from said ram; a main valve for alternately connecting said pump to deliver fluid from said chamber to said ram and from said ram to said chamber, to reciprocate the

sucker rod; a source of replenish fluid under pressure; a replenish valve and actuating means therefor projecting into said one end of said cylinder adapted to be contacted and moved by said piston in response to movement of the piston toward said one end past a predetermined limit position, for moving said replenish control valve out of normal position; and means for delivering fluid from said replenish fluid source to said chamber in response to said movement of said replenish valve out of normal position.

7. A hydraulic pumping jack according to claim 6 including means for returning said replenish valve to normal position at a predetermined slow speed following movement of said piston away from said actuating means.

8. A pumping jack according to claim 7 in which said replenish valve and actuating means comprises a valve cylinder in said one end of said counterbalance cylinder, a valve piston sealing in said valve cylinder and extending therefrom into said counterbalance cylinder, a spring urging said valve piston into normal position, a passage connecting the outer end of said valve cylinder to said counterbalance cylinder, check valve means permitting free flow through said passage from said valve cylinder to said counterbalance cylinder, and means permitting restricted flow through said passage from said counterbalance cylinder to said valve cylinder.

9. A pumping jack according to claim 6 including pressure-actuated means for moving said main valve into neutral position, and means responsive to movement of said replenish valve away from neutral position beyond the position for delivering fluid from said replenish fluid source to said chamber for delivering pressure fluid to said pressure-actuated means to actuate the latter and move said main valve into neutral position.

10. A pumping jack according to claim 6 in which: said source of replenish fluid comprises a continuously running replenish pump and duct means including a check valve connecting the output of said replenish pump to said counterbalance chamber; a pressure relief valve connecting said replenish pump output to exhaust and having a pilot port, said relief valve opening in response to unimpeded flow from said pilot port to unload said pump and closing in response to stoppage of flow from said pilot port; said replenish valve having a first port connected to said pilot port, a second port connected to exhaust, and means for interconnecting said first and second ports in said normal position of said replenish valve and breaking connection between said first and second ports in response to movement of said replenish valve out of normal position.

11. A pumping jack according to claim 10 in which said replenish valve comprises a valve cylinder and a valve piston reciprocable therein by excess travel of said counter balance piston away from a normal position to the extent of said excess travel, said valve cylinder having progressively longitudinally spaced first, second, third, and fourth ports and said valve piston having a recess interconnecting said first, second and third ports in normal position, interconnecting said second and third ports when slightly displaced from normal position, and interconnecting said third and fourth ports in response to further displacement from normal position; pressure-actuated means for moving said main valve into

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neutral position connected to said third port and a source of pressure fluid connected to said fourth port.

12. In a hydraulic pumping jack for reciprocating the sucker rod of an in-the-well pump: a hydraulic ram adapted to be mechanically connected to the sucker rod for lifting it in response to delivery of pressure fluid to the ram and lowering it in response to release of pressure fluid from the ram; a pump having inlet and outlet ports; a counter balance cylinder having a piston therein defining with one end of said cylinder an expansible and contractable counter balance chamber and means urging said piston to maintain pressure in said chamber; a ram line for fluid flow to and from said ram; a main valve for alternately connecting said pump to deliver fluid from said chamber to said ram and from said ram to said chamber, to reciprocate the sucker rod; and means contacted by said counter balance piston in response to movement thereof a predetermined distance from said one end of said counter balance cylinder for connecting said pump to exhaust in response to said contact.

13. In a hydraulic pumping jack for reciprocating the sucker rod of an in-the-well pump; a hydraulic ram adapted to be mechanically connected to the sucker rod for lifting it in response to delivery of pressure fluid to the ram and lowering it in response to release of pressure fluid from the ram; a counterbalance chamber containing fluid and gas under pressure; valve and conduit means for alternately connecting said pump to deliver fluid from said ram to said counterbalance chamber and vice versa, to reciprocate said ram through a predetermined stroke; a source of replenish gas for said counterbalance chamber; a container having a movable barrier therein dividing it into two variable volume compartments, and means defining two restrictive passages connecting said compartments to said ram and said counterbalance chamber respectively, the flow impedances of said restrictive passages having a predetermined ratio to each other and being of such sizes relative to the size of said container and the mean pressure developed by said pump that the normal stroke of said barrier is less than the free path of travel thereof; a first normally closed valve for connecting said source of replenish gas to said counterbalance chamber; a second normally closed valve for exhausting gas from said counterbalance chamber; first actuating means operable by said barrier in response to overtravel thereof

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into the compartment connected to said counterbalance chamber for opening said first valve; and second actuating means operable by said barrier in response to overtravel thereof into the compartment connected to said ram for opening said second valve.

14. A pumping jack according to claim 13 including a bypass passage in shunt to each of said restricted passages and a check valve in each bypass passage permitting free flow therethrough into the associated compartment while preventing reverse flow.

15. In a hydraulic pumping jack for reciprocating the sucker rod of an in-the-well pump: a hydraulic ram adapted to be mechanically connected to the sucker rod for lifting it in response to delivery of pressure fluid to the ram and lowering it in response to release of pressure fluid from the ram; a counterbalance chamber containing fluid and gas under pressure; valve and conduit means for alternately connecting said pump to deliver fluid from said ram to said counterbalance chamber and vice versa, to reciprocate said ram through a predetermined stroke; a container having a movable barrier therein dividing it into two variable volume compartments, and means defining two restricted passages connecting said two compartments to said ram and to said counterbalance chamber respectively, the flow impedances of said restricted passages having a predetermined ratio to each other and being of such sizes relative to the size of said container and the mean pressure developed by said pump that the normal stroke of said barrier is less than the free path of travel thereof; a normally closed valve for varying the quantity of gas in said counterbalance chamber, and actuating means operable by said barrier in response to overtravel thereof into one of said compartments for opening said normally closed valve.

FREDERICK W. SCHNECK.
ROBERT M. McNEILL.

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