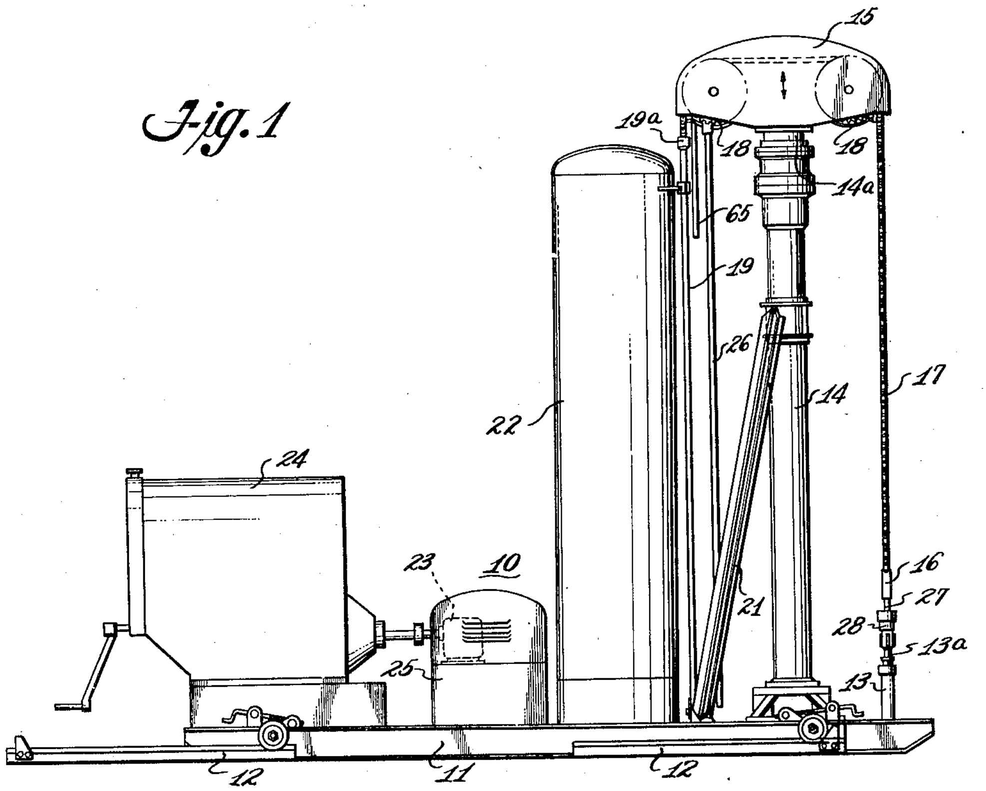
Oct. 23, 1951 P. E. NOLL ET AL 2,572,748

HYDRAULIC PUMPING UNIT

Filed Nov. 6, 1948 3 Sheets-Sheet 1

Fig. 1



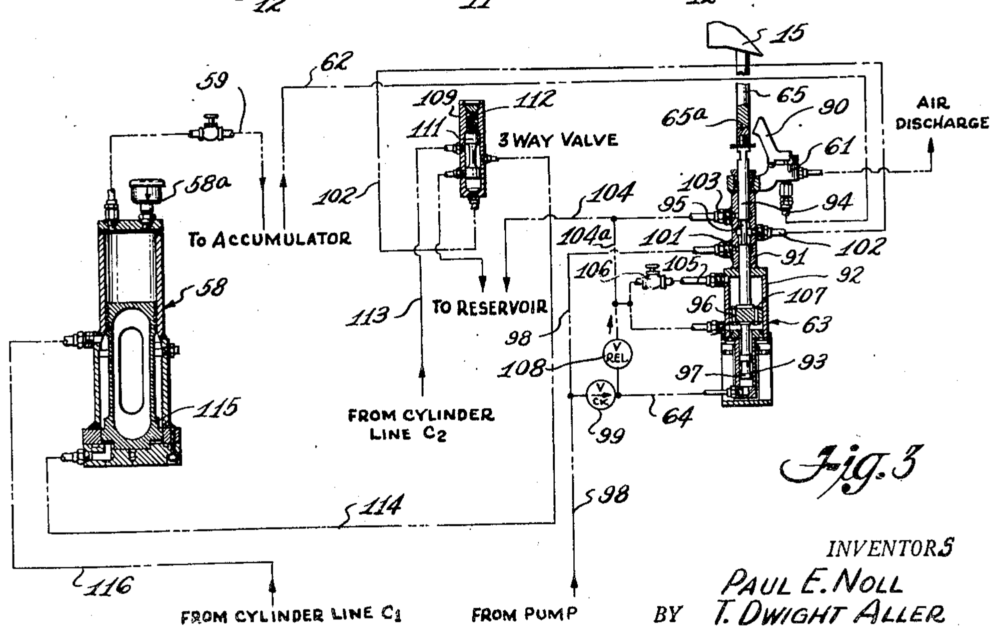


Fig. 3

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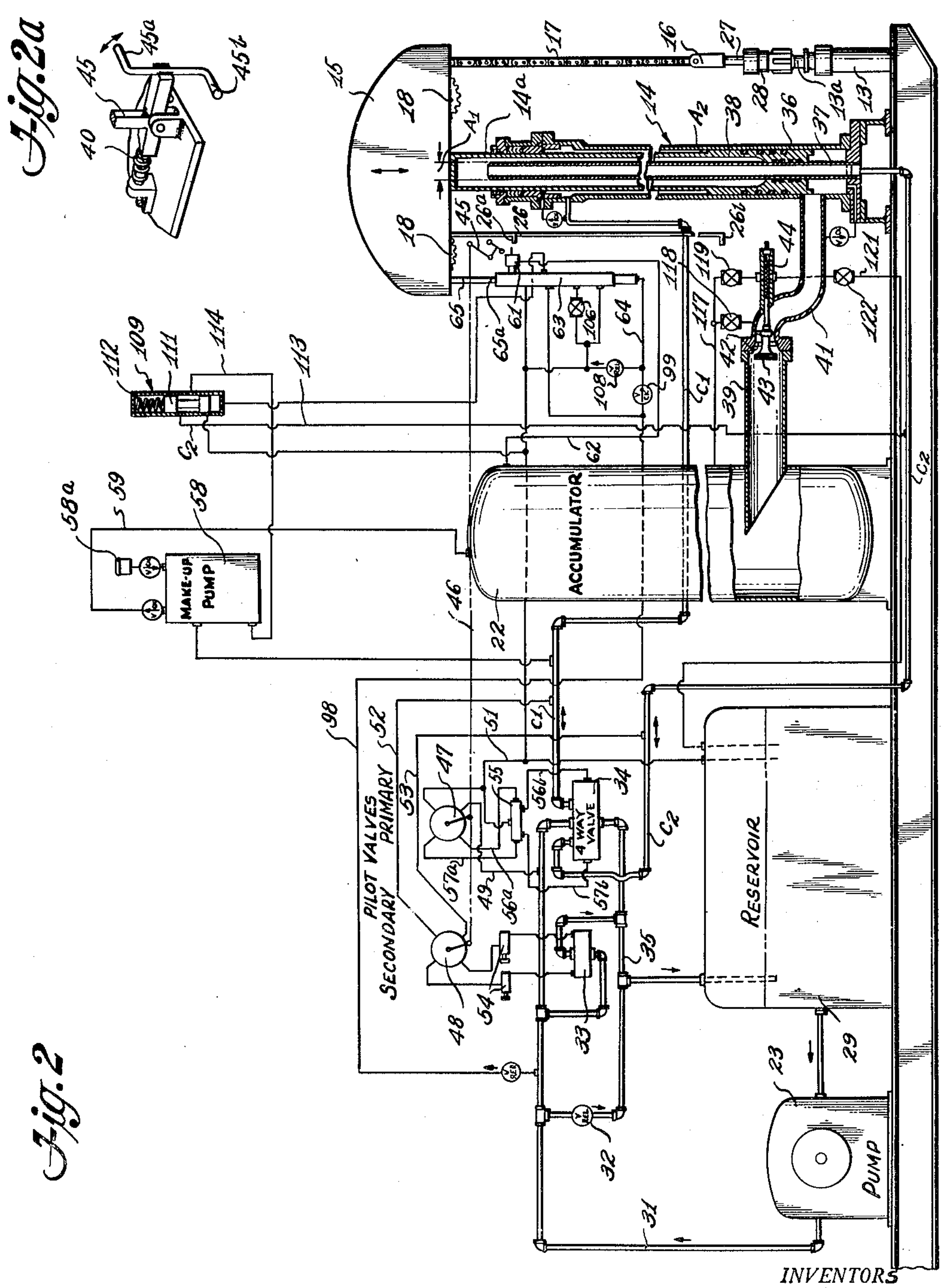

Fig. 2a

Fig. 2

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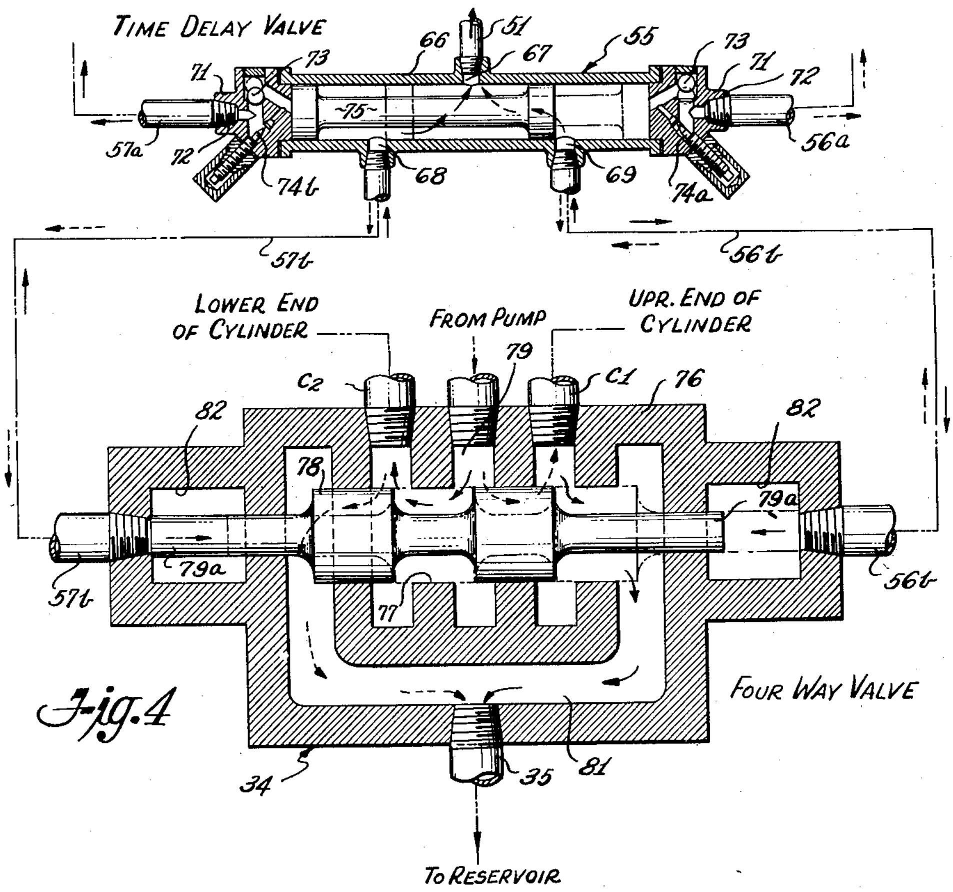

Fig. 4

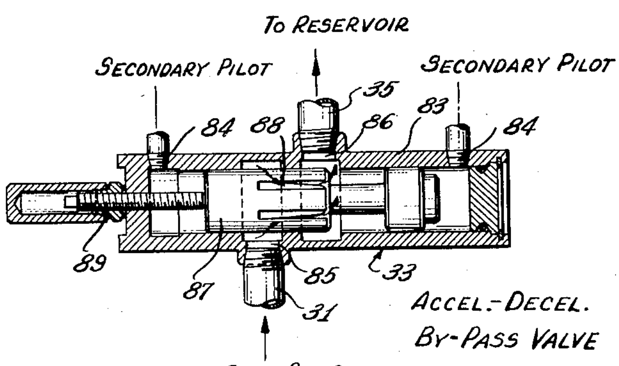

Fig. 5

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HYDRAULIC PUMPING UNIT

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Application November 6, 1948, Serial No. 58,714

9 Claims. (Cl. 60—52)

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Our invention relates to hydraulic pumping units, and has particular reference to a precise control circuit for controlling the actuation of a ram in a hydraulic cylinder, which ram may be used for example to actuate a reciprocating mechanical pump disposed in an oil well.

The principal components of our hydraulic system are similar to those disclosed in patent application Serial No. 668,942, filed May 10, 1946, in the names of Paul E. Noll, Charles W. Crawford, T. Dwight Aller, and Albert R. Rethey, and which issued as Patent No. 2,504,218, April 18, 1950. In general, a prime mover drives a pump which takes hydraulic fluid from a reservoir and delivers it under pressure to a four-way valve. The valve alternately connects opposite ends of a hydraulic cylinder to the pressure fluid and to exhaust, to cause the piston in the cylinder to be reciprocated. The ram connected to the piston may be coupled directly or indirectly to a pump, and for oil well pumping may be coupled to the upper end of a string of sucker rods, the lower end of which may be connected to a pump disposed deep within an oil well. An accumulator is customarily provided to assist on the pumping stroke of the unit and thereby reduce the maximum pressure required from the pump and in addition substantially equalize the pressure required from the pump on the pumping stroke and the return stroke of the ram; that is, on the return stroke the pressure of the accumulator opposes the pump pressure.

Our invention includes a novel circuit for controlling the reversal of the hydraulic ram at the ends of each stroke. Due to the inertia of the sucker rod string and the column of oil being lifted, stresses of serious consequence may be imposed on the rods by rapid reversals at the ends of each stroke. It is highly desirable, therefore, that the rods be decelerated and accelerated very gradually, particularly at the lower reversal. This gradual deceleration and acceleration may be accomplished in accordance with our invention by by-passing pressure fluid at the extremes of travel of the ram so that the volume of the fluid passing through the four-way control valve is reduced, thus gradually slowing the ram to a stop.

In order to permit close spacing of the subsurface oil pump, thus reducing its clearance and improving its efficiency, it is essential that the lower reversal point of the pumping unit at the surface remain substantially constant. In our pumping unit, no positive stop or cushion is employed to establish the reversal point, but instead

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the piston is hydraulically suspended throughout the reversal. Since the counterbalance pressure tends to assist in decelerating the ram at the bottom reversal, variation in that pressure might cause variation in the reversal point. We regulate precisely the lower end point of travel of the piston by maintaining the counterbalance pressure within close limits by building up or relieving gas pressure according to whether there is over-travel or under-travel of the piston with respect to a preselected bottom reversal point. Thus the counterbalance pressure is utilized as a control medium for end reversal point, and our invention provides apparatus for continuously and automatically controlling this pressure.

It is therefore an object of our invention to provide gradual acceleration and deceleration of the ram in a hydraulic actuating cylinder by shunting or by-passing pressure fluid.

Another object of our invention is to provide a hydraulic pumping unit incorporating a by-pass action and a four-way valve energized at the same time by means of a single mechanical element associated with the stroke of the actuating ram.

A further object of our invention is to provide a hydraulic actuating unit with a by-pass valve and a four-way valve wherein a time delay device is coupled with the four-way valve to permit synchronized actuation of the by-pass valve and the four-way valve to effect deceleration, reversal, and acceleration.

A further object of our invention is to provide a hydraulic pumping unit incorporating a counterbalancing device of the compressed gas type, with means for automatically maintaining the gas pressure.

Still another object of our invention is to provide a hydraulic actuating unit in which the piston is hydraulically suspended throughout its reversals and in which means are provided to prevent variation in the lower reversal point.

Another object of our invention is to provide a hydraulic pumping unit in which variation of the lower reversal point is prevented by automatically increasing or reducing the counterbalance pressure according to whether the piston tends to over-travel or under-travel a preselected reversal point.

It is also a feature of our invention to provide an automatic flow-control valve in the counterbalance circuit to prevent damage to the unit in case of breakage of the rod string.

Other objects and advantages of our invention will be apparent in the following description and claims, considered together with the accompanying drawings, in which:

Fig. 1 is an elevation view of a presently preferred embodiment of our hydraulic pumping unit as connected to the sucker rods of an oil well pump;

Fig. 2 is a circuit diagram of a presenty preferred hydraulic circuit embodying our invention and also illustrating the actuating cylinder in section;

Fig. 2*a* is a perspective view of an illustrative actuating mechanism for operating the primary and secondary pilot valves of Fig. 2, which mechanism is illustrated schematically in Fig. 2;

Fig. 3 is a circuit diagram of the accumulator pressure control circuit illustrating the circuit components in section;

Fig. 4 is an enlarged sectional view of an illustrative time delay valve and a four-way valve to which the time delay valve is connected; and

Fig. 5 is a sectional view through an illustrative by-pass valve that may be utilized in the circuit of Fig. 2.

General description

A presently preferred commercial actuating unit is illustrated in Fig. 1, wherein a pumping unit **10** is mounted on a frame **11** that may roll on rails **12** when it is desired to withdraw the unit as a whole from the vicinity of an oil well having a flow tubing **13** projecting above the ground. The pumping unit **10** includes a vertically disposed hydraulic actuating cylinder **14** with an actuating piston or ram **14*a*** axially slidable therein and a T-shaped sprocket head **15** mounted on the top end of the ram. Over a pair of horizontally spaced sprockets **18** is trained a chain **17**, one end of which is anchored at **19*a*** to a dead-end rod **19** and the other end of which is attached to a polish rod **27** by means of a clevis **16**. The actuating cylinder **14** is supported in an upright position by means of inclined braces **21**.

The actuating ram **14*a*** is operated by hydraulic fluid under pressure supplied by a pump **23**, and also from an accumulator **22**. The pump may be driven by any suitable prime mover, such as an internal combustion engine **24** or an electric motor. Suitable control valves are disposed within a reservoir **25** positioned under the pump **23**, and the pressure fluid control valve operating mechanism is actuated by a trip rod **26** secured to the sprocket head **15**.

The clevis **16** on the chain **17** is coupled to a polish rod **27** acting as the terminal section of a string of sucker rods passing downwardly through the flow tubing **13*a*** to contact a reciprocating pump (not shown) disposed below the oil level within the oil well. A stuffing box **28** secured to the top end of the tubing **13*a*** seals off the polish rod **27** from the flow tubing **13** to prevent leakage therefrom, and a suitable connection (not shown) to the flow tubing **13** leads the pumped oil to a suitable reservoir or tank. Thus the entire hydraulic pumping unit **10** causes a pumping action by means of the reciprocation of the sprocket head **15** by the actuating ram **14*a*** which causes the chain **17** to raise and lower the polish rod **27** to thereby actuate the pump within the oil well and lift a column of oil in the flow tubing **13** to the earth's surface.

The details of the hydraulic circuit of the pumping unit **10** of Fig. 1 are illustrated in Fig. 2. There it will be noted that the pump **23** receives hydraulic fluid from a reservoir **29** and

delivers the fluid under pressure to an outlet pipe **31** connected to a relief valve **32**, a by-pass valve **33**, and a four-way valve **34**. An exhaust or return conduit **35** connects these three valves to the reservoir so that the same hydraulic fluid may be continuously circulated. The four-way valve **34** is actuated to connect two cylinder lines **C1** and **C2** alternately to pressure and to exhaust, and accordingly reciprocates the actuating ram **14*a*** inasmuch as these conduits are connected to opposite ends of the cylinder **14**. The hydraulic ram unit comprises a stationary outer shell **36** having a concentrically mounted tube **37** projecting upwardly therein, to the lower end of which is attached the pressure line **C2**. A tubular piston **38** integrally formed on the lower end of the ram **14*a*** makes a sealing engagement with the interior of the shell **36** and the exterior of the tubing **37** and reciprocates therebetween, the closed upper end of the ram **14*a*** being attached to the sprocket head **15**. Thus the effective lifting area for pumped fluid is the outside diameter of the central tube **37**, which area may be designated as **A1**. The effective return stroke area of the piston **38** is the annular space between the ram **14*a*** and the outer shell **36**, to which the pressure supply line **C1** communicates, and which area is designated as **A2**. The area **A2** is preferably and usually made smaller than the area **A1** so as to effect a rapid return of the piston as compared to the working stroke speed of travel, assuming a constant delivery output from the pump **23**.

The piston **38** is normally urged upwardly by means of pressure existent within the accumulator **22** acting on the bottom of the piston **38**. Thus the accumulator **22** may be provided with an outlet tube **39** coupled to a flow tube **41** that communicates with the interior of the cylinder shell **36**. The coupling of the flow tube **41** with the outlet tube **39** is enlarged to form a valve seat **42** for a surge poppet valve **43** normally urged to an open position by means of a compression spring **44**. Thus a normal flow of hydraulic fluid from the accumulator to the ram will not cause operation of the poppet valve **43**, but if the chain **17** should break or the string of sucker rods should break, release of a load would cause rapid rise of the piston **38** with a consequent rapid flow from the accumulator. This rapid flow would in turn cause the poppet valve **43** to seat, thus stopping flow from the accumulator through tubes **39** and **41**, and causing the piston **38** to move to its upper end position at a slow rate of speed regulated by valve **118**. Thus breakage due to the piston striking the packing gland at the upper end of the shell **36** is avoided. In passing, it should be noted that the accumulator **22** is of the usual type wherein a gas under pressure occupies the upper portion of the accumulator to act upon a hydraulic fluid disposed in the bottom part of the accumulator tank.

As previously mentioned, our control circuit obtains a deceleration at the end of each stroke and a gradual acceleration at the beginning of each stroke by means of by-passing pressure fluid to exhaust, thereby diverting from the four-way valve its normal volumetric fluid supply and also decreasing pressure to the four-way valve. Thus the ram **14*a***, at the end of each stroke, receives a decreasing supply of fluid under pressure, thus causing it to slow down to a stop. In this way the momentum of the loads being carried is gradually decreased so as to provide a smooth reversal with minimum rod stresses. While it would be possible to provide two projections on the trip rod **26** adjacent each end so that the by-pass valve could be operated prior to the operation of the four-way valve, we prefer to initiate the action of both valves at the same time by a single projection at each end.

Thus the trip rod **26** is provided with an upper projection **26***a* and a lower projection **26***b* to act on a bell crank **45** illustrated in more detail in Fig. 2*a* wherein it will be noted that one arm of the bell crank is bifurcated and the fork tips offset as at **45***a* and **45***b*. Accordingly the two projections or fingers **26***a* and **26***b* are disposed in different vertical planes so that the lower projection **26***b* will contact only tip **45***a*, and the upper projection **26***a* will contact only the other tip **45***b*. Thus the fingers **26***a* and **26***b* contact a tip and operate the bell crank to one extreme position or the other, at which position the tip will be disposed out of the path of travel of the particular actuating finger so that the finger passes the bell crank. Upon the next reciprocation the finger that had just actuated the bell crank and traveled past it would again travel past the bell crank without operating it, but the other tip of the bell crank would be in the line of travel of the other finger or projection. From the foregoing it will be apparent that the neutral position illustrated in Fig. 2*a* is never achieved as a rest position, inasmuch as the bell crank **45** should be in one extreme position or the other. This attainment of an extreme position that will rotate the tip just actuated out of the path of travel of the acuating finger may be assisted by an over-center compression spring **40** contacting a portion of the bell crank **45**.

We also prefer to operate the by-pass valve **33** and four-way valve **34** by means of pilot valves rather than by direct mechanical actuation. The bell crank **45**, for this purpose, is connected by a link **46** to the control handles of a primary pilot valve **47** and a secondary pilot valve **48**. Both the pilot valves **47** and **48** are simple four-way valves, and are illustrated as being of the rotary type. The primary valve **47** is connected to pressure and to exhaust by means of conduits **49** and **51**, respectively, thus giving a unidirectional supply to the primary pilot valve. The secondary pilot valve **48** is, by contrast, connected by conduits **52** and **53** to the cylinder lines **C1** and **C2** so as to obtain alternating pressure and exhaust connections. The cylinder lines of the secondary pilot **48** are connected through metering valves **54** to opposite ends of the pressure-driven by-pass valve **33**. The cylinder lines **56***a* and **57***a* of the primary pilot valve **47** are connected, however, to opposite ends of a time delay or relay valve **55** which, after a time period of an appreciable duration, supplies pressure and exhaust to opposite ends of the four-way valve **34** through lines **56***b* and **57***b*.

From the foregoing description it will be apparent that a single finger **26***a* or **26***b* on the trip rod **26** may initiate the actuation of the by-pass valve **33** and the four-way valve **34** at the same time, but because of the interposition of the time delay valve **55**, the actuation of the four-way valve **34** will be delayed until immediately following the traverse of the by-pass valve **33**. Furthermore, as will be apparent from an inspection of Fig. 5, the by-pass valve **33** has a time-graduated capacity so that at the end of the delay period of the time delay valve **55**, the by-pass valve **33** will be passing substantially all of the output of the pump **23**. The time delay valve **55** is controlled by adjustments indicated in Fig. 4 to control its rate of speed, and the meter valves **54** in the circuit of by-pass valve **33** are also manually adjusted so that the time of full flow of the by-pass valve **33** will coincide with the period of the time delay valve **55**. Also the position of trip fingers **26***a* and **26***b* on trip rod **26** may be adjusted in conjunction with the valves to give an acceleration and deceleration travel of any desired length.

The control of the pressure in the accumulator **22** is also illustrated diagrammatically in Fig. 2. Thus if there is a deficient pressure within the accumulator **22**, a make-up pump **58** is automatically operated to pump air into a line **59** connected to the accumulator **22**. On the other hand, if the gas pressure of the accumulator is excessive, a blowdown valve **61** is operated automatically to release air or other gas from the accumulator **22** through a conduit **62**. The main control element of the accumulator pressure circuit is a stroke control valve **63** which is urged upward by hydraulic fluid under pressure supplied by a conduit **64** and which is mechanically driven downwardly by the sprocket head **15** acting through a vertically disposed drive rod **65**, the top end of which is positioned so as to be engaged by the head **15** as it nears the lower extremity of the stroke.

Detail description of power clutch

The detail construction of the power circuit may be explained with reference to Figs. 4 and 5, as well as to Fig. 2. Referring to Fig. 4, it will be noted that the time delay valve **55** includes a barrel **66** having an exhaust port **67** and two cylinder ports **68** and **69**. The exhaust line **51** is connected to the port **67**, and the cylinder lines **57***b* and **56***b* are connected to the ports **68** and **69**, respectively. The opposite ends of the barrel **66** are closed with identical caps **71**, including pipe fittings **72** communicated by means of check valves **73** to the interior of the barrel **66**. The check valves are by-passed by adjustable needle or metering valves **74***a* and **74***b*. A double-landed spool **75** is slidably disposed within the barrel **66** to reciprocate between the two end caps **71**. When pressure fluid from primary pilot valve **47** is applied at one end of the time delay valve **55**, for example the left end, it flows through the check valve **73** to the interior of the barrel **66**, forcing the spool **75** to the right, and the fluid trapped at the right end of the valve is forced outwardly through the meter valve **74***a*. When the spool has moved to the right sufficiently to uncover port **68**, there will be a direct communication between the left hand line **57***a* and its associated line **57***b*, and the pressure fluid will pass through line **57***b* to shift four-way valve **34**. The length of time delay between the application of pressure fluid to the left hand end of the time delay valve **55** and the shifting of the four-way valve **34** is governed by the rate of metering of exhaust fluid through the meter valve **74***a*. As the spool **75** moves to the right, the line **56***b* will be communicated to the exhaust line **51**. When the pressure from the primary pilot valve **47** is reversed, the valve moves to the position illustrated in full outline in Fig. 4, communicating the line **57***b* to exhaust and interconnecting lines **56***a* and **56***b*. The time delay as the valve spool moves to the left is governed by the rate of metering of exhaust fluid through the meter valve **74***b*.

An illustrative four-way valve **34** for operation with the system is also indicated in Fig. 4. This valve includes a main housing 76 having a central bore 77 in which is disposed a double-landed spool 78, which spool is provided with projecting ends 79a that act as pistons. The housing 76 has two cylinder ports formed therein to which the lines C1 and C2 are connected, and also has a central pressure port 79 disposed between the two cylinder ports. Exhaust fluid is discharged through a bifurcated exhaust passage 81 to which the exhaust pipe 35 is connected. The housing 76 also has cylinder chambers 82 formed at either end thereof communicating with the actuating lines 56b and 57b. In the position illustrated, cylinder line C2 is connected to pressure port 79, whereas cylinder line C1 is connected to exhaust conduit 35. If the pressure and exhaust in actuating conduits 56b and 57b are reversed, the spool 78 will slide toward the right to reverse this condition of flow.

An illustrative construction for the by-pass valve 33 is shown in Fig. 5, wherein it will be noted that a housing 83 has ports 84 at each end to communicate with the lines from the secondary pilot valve 48. The housing 83 also is provided centrally with axially spaced ports 85 and 86 communicated to the pressure pipe 31 and to the exhaust pipe 35, respectively. A double-headed piston 87 is disposed within the housing 83 to move in response to the direction of application of pressure and exhaust at the ports 84, and has one head slotted with tapering grooves 88 to provide a condition of graduated flow from pipes 31 to 35 as the piston 87 moves in the bore. The rate of speed of movement of the piston 87 may be carefully regulated by the meter valves 54 (Fig. 2). An adjustable threaded stop 89 is provided to establish the maximum flow conditions through the valve when the piston 87 is at the full flow position illustrated. As previously mentioned, the secondary pilot valve which operates the by-pass valve 33 has its inlet and exhaust pressures reversed by reversal of the four-way valve 34 due to the connection to lines C1 and C2. For this reason the spool 87 will be returned to a non-flow or non-by-pass condition shortly after the four-way valve has been operated.

Detail description of accumulator pressure control circuit

The detail construction of the accumulator pressure control circuit is illustrated in Fig. 3, wherein the parts previously identified in connection with Fig. 2 are illustrated, including the main control element, the stroke control valve 63, as well as the make-up pump 58 and the blowdown valve 61. The stroke control valve 63 includes a valve housing 91, a dashpot housing 92, and an actuating cylinder housing 93 arranged end-to-end in axial alignment. A central stem 94 passes through all three housings and has a reduced portion 95 at the valve housing 91, a check valve piston 96 disposed in the dashpot housing 92, and a piston head 97 disposed within the actuating cylinder 93. Pressure is supplied to the valve 63 by means of the conduit 64, previously identified, communicating with the fluid pressure pipe 31, which pressure fluid passes through a check valve 99 to the actuating cylinder 93 to force the stem 94 upwardly. A branch conduit 98 supplies pressure fluid to a port 101 in the valve housing 91. A second port in the housing 91 is connected to a conduit 102, and a third port 103 is connected to a conduit 104 leading to the reservoir 29.

The dashpot 92 of the valve 63 is the central control element of the valve 63 and is provided with an external metering circuit including a conduit 105 and a metering valve 106. The dashpot piston 96 is apertured to permit passage of liquid therethrough on the down-stroke, but has a check valve 107 which closes the aperture on the up-stroke to give rise to the dashpot action. The normal lower position of the stem 94 with the dashpot piston 96 is illustrated in Fig. 3, and it will be noted that it is spaced an appreciable amount from the bottom of the containing cylinders. It will also be noted that in this position, the pressure port 101 remains covered by the stem 94.

As stated previously, deficiency of gas pressure in the accumulator will tend to permit the ram to over-travel its normal point of reversal. Accordingly, the sprocket head 15 in contacting the drive rod 65 will drive it and the stem 94 below its normal position due to the fact that the entire hydraulic cylinder is permitted to drop below its predetermined lower point. The driving of the piston 96 below its normal lower point will cause communication between the pressure port 101 and the conduit 102, causing pressure fluid to flow through that conduit to a three-way valve 109, causing a spool 111 in that valve to be raised, as illustrated, against the compression of a spring 112. In the illustrated position, pressure fluid from cylinder line C2 will be communicated by a conduit 113 through the valve 109 to a conduit 114 connected to the bottom end of the hydraulically actuated make-up pump 58. Inasmuch as pressure will exist in the cylinder line C2 on the up-stroke of the actuating ram 14a, this pressure will cause a piston 115 within the pump 58 to rise, thus compressing air and forcing it outwardly through the conduit 59 to the accumulator 22. At the time that cylinder line C2 is under pressure cylinder line C1 will be subject to exhaust, and accordingly a conduit 116 connected to the exhaust will permit the piston 115 to move freely upwardly. Upon the downstroke of the actuating ram 14a, fluid under pressure will pass through the line 116 to act on the pump piston 115, forcing it downwardly because the three-way valve 109 will then be in its rest position because the rise of the stem 94 will close off the pressure port 101 and open exhaust port 103. The spool 111 of the three-way valve will then communicate the conduit 114 to the reservoir. The over-travel of the ram 14a will continue, and the make-up pump will deliver a charge of air to the accumulator on each stroke until accumulator pressure has been returned to normal.

When the accumulator gas pressure is excessive, the hydraulic ram will tend to under-travel its normal bottom reversal point, and consequently the stem 94 will not be returned to the normal position illustrated. The normal rise of the piston 96 on its dashpot action will cause the upper end of the stem 94 to contact a valve-operating lever 90 to actuate the blowdown valve 61 and thereby relieve gas pressure from the accumulator. The under-travel and resulting blowdown will continue on each stroke until accumulator pressure has been reduced to normal.

Operation

The operation of the power control for our pumping unit may best be described with reference to Figs. 1 and 2. The prime mover 24 may first be energized, causing the pump 23 to be actuated, drawing fluid from reservoir 29 and delivering it to pipe 31. The pump may be of any suitable type that develops a requisite pressure, but we prefer to use a constant-speed, constant-displacement type of pump, protected against overload by relief valve 32.

The operation of the ram 14a is continuous and automatic and is principally effected by the four-way valve 34 which is connected between the pressure line 31 and the exhaust line 35. Accordingly pressure and exhaust alternately exist in the cylinder lines C1 and C2 connected, respectively, to the top and the bottom of the hydraulic cylinder 14. Pressure in line C2 is delivered to the central tube 37 of the ram and acts over the area A1 to lift the ram. Fluid under pressure in the accumulator 22 passes through conduits 39 and 41 to act on the bottom of the piston 38. The entire sprocket head 15 is consequently lifted, causing a two-fold movement of the chain 17 connected by the clevis 16 to the polish rod 27 of the oil well.

When the actuating ram 14a approaches the end of its stroke, the finger 26b on the trip rod 26 connected to the sprocket head 15 engages the bell crank 45, shifting the link 46 and consequently shifting the pilot valves 47 and 48. The pilot valve 47 acts to reverse the four-way valve 34, but this actuation is delayed because of the interposition of the time delay valve 55 in the circuit, as is best illustrated in Fig. 4. The actuation of the by-pass valve 33 is started immediately by delivery of fluid under pressure to the right-hand end (Fig. 5) of the by-pass valve 33, causing its piston 87 to shift to the left to the position illustrated in Fig. 5. This shift is not immediate, however, but is slow in acting due to the control of the rate of exhaust as determined by the setting of the meter valve 54.

The flow of fluid to actuate the by-pass valve 33 to decelerate the ram as its approaches the end of its downstroke can be traced from the cylinder line C1, via pipe 52, secondary pilot valve 48, meter valve 54 at the right, and port 84 at the right into the right end of cylinder 83. The left end of this cylinder is relieved via port 84 at the left, meter valve 54 at the left, secondary pilot valve 48, and pipe 53 to cylinder line C2. The flow to actuate this valve to decelerate the ram as it approaches the end of its upstroke is similar, except that the actuating fluid comes from cylinder line C2 and pipe 53 and the valve is relieved to pipe 52 and cylinder line C1.

The effect of the opening of the by-pass valve 33 is to divert from the four-way valve 34 a part of the normal output of the pump 23. As the hydraulic cylinder approaches its upper stop, an increased amount is by-passed due to the movement of the piston 87 to the left until finally only a small flow of fluid is left for the four-way valve 34. The effect is a gradual slowing of the piston 38 of the ram 14a, causing a slowing of the associated string of sucker rods and the column of oil being lifted to the surface. Thus, reversal of the rods is accomplished gradually at the ends of the stroke, with minimum reversal stresses induced therein. As the ram piston 38 reaches the end of its upward travel, the time delay valve 55 will permit the control fluid from the pilot valve 48 to shift the four-way valve 34, and accordingly this shifting of the valve will take place under a reduced pressure and a reduced fluid flow condition, thus relieving the valve of major loads during movement.

The flow of fluid to actuate the by-pass valve 33 to accelerate the ram as it starts its upstroke can be traced from the cylinder line C2, via pipe 53, secondary pilot valve 48, meter valve 54 at the left, and port 84 at the left into the left end of cylinder 83. The right end of this cylinder is relieved via port 84 at the right, meter valve 54 at the right, secondary pilot valve 48, and pipe 52, to cylinder line C1. The flow to actuate this valve to accelerate the ram as it starts its downstroke is similar, except that the actuating fluid comes from cylinder line C1 and pipe 52 and the valve is relieved to pipe 53 and cylinder line C2.

While we have shown and described the preferred embodiment of our invention, we do not desire to be limited to any of the details shown and described, except as defined by the terms of the following claims.

We claim:

1. A hydraulic pumping unit comprising: a reservoir; a power driven pump receiving fluid from the reservoir; a four-way valve having a pressure port connected to the pump output and having an exhaust port connected to the reservoir; a cylinder containing an actuating ram and being connected to the four-way valve for reciprocation of the ram, a by-pass valve connected between the pump output and the reservoir in parallel with said four-way valve; an automatic actuator for operating the by-pass valve as the ram approaches the end of each stroke in either direction, whereby the fluid delivered to the four-way valve is gradually reduced to decelerate the hydraulic ram prior to reversal and gradually increased to accelerate the ram after reversal; and an automatic actuator for operating the four-way valve at the end of each stroke to cause the reversal of the ram.

2. A hydraulic pumping unit comprising: a reservoir; a power driven pump receiving fluid from the reservoir; a four-way valve connected to the pump output and to the reservoir; a cylinder containing an actuating ram and being hydraulically connected to the four-way valve for reciprocation of the ram; a by-pass valve connected between the pump output and the reservoir in parallel with said four-way valve; a single mechanical actuator mechanically coupled to the ram for movement in response to ram actuation and adapted to initiate operation of the by-pass valve and the four-way valve near the end of each stroke of the ram in either direction; and a time delay mechanism for the four-way valve, whereby the by-pass valve will be first operated to decelerate the hydraulic ram and thereafter the four-way valve will operate to reverse the hydraulic ram, after which the by-pass valve will operate to accelerate the ram in the opposite direction.

3. A hydraulic pumping unit comprising: a reservoir; a pump adapted to receive fluid from the reservoir; a four-way valve connected to the pump output and to the reservoir; a hydraulic actuating cylinder; a piston and ram slidable in said cylinder; a pair of cylinder lines connecting the actuating cylinder to the four-way valve so that alternate connection of the lines to pressure and exhaust will cause a reciprocating motion of a piston and ram in the actuating cylinder; a hydraulically operated by-pass valve disposed between the pump output and the reservoir in parallel with said four-way valve and normally

maintained in a closed position; a pilot valve for operating the by-pass valve by means of pressure fluid from the cylinder lines; and an actuator for the pilot valve to operate it a predetermined distance from the end of the stroke in either direction, whereupon the by-pass valve will gradually reduce the fluid supply to the four-way valve prior to reversal of the four-way valve to thereby decelerate the actuating ram, and, after reversal of flow in the cylinder lines by actuation of the four-way valve, will gradually increase the fluid supply to the four-way valve to thereby accelerate the actuating ram.

4. A hydraulic pumping unit as defined in claim 3, including a meter valve interposed between the pilot valve and the by-pass valve to regulate the speed of operation of the by-pass valve.

5. In a hydraulic pumping unit: a source of hydraulic fluid under pressure; an actuating cylinder; a ram in said cylinder; a four-way valve connected to the source and to the cylinder for selective reciprocation of the ram in the cylinder; a by-pass valve connected to the source in parallel with said four-way valve to control the fluid supply available to the four-way valve; a pilot valve connected to the by-pass valve for operating the by-pass valve; a time delay relay valve coupled to the four-way valve; another pilot valve coupled to the time delay valve; and a single actuator for simultaneously actuating both pilot valves a predetermined distance prior to the end of the stroke of the ram in either direction, whereby the by-pass pilot valve will act immediately to commence opening the by-pass valve, but the opening of the four-way valve will be delayed due to the action of the time delay valve.

6. A hydraulic pumping unit comprising: a fluid reservoir; a power driven pump adapted to receive fluid from the reservoir; a hydraulically operated four-way valve connected to the pump output and to the reservoir; a two-way actuating cylinder and ram; cylinder lines connecting opposite ends of the cylinder to the four-way valve for selective reciprocation of the ram; a hydraulically operated by-pass valve connected between the pump output and the reservoir; a primary four-way pilot valve having pressure and exhaust connections to the pump output and the reservoir; a time delay valve coupled to the primary pilot valve and coupled to the four-way valve for actuation of the four-way valve and having adjustments for regulating delay time; a secondary four-way pilot valve having pressure and exhaust connections to the cylinder lines and connections to the by-pass valve, each of which includes a meter valve, for operation of the by-pass valve; and a single actuator for simultaneously operating both pilot valves prior to the end of the stroke of the actuating ram, whereby the by-pass valve will be gradually opened, at a rate dependent upon the setting of the meter valve, to effect a deceleration of the actuating ram, after which the four-way valve will be operated to effect reversal of the actuating ram, following which the four-way valve will supply fluid in opposite sense to the secondary pilot valve to effect gradual closure of the by-pass valve at a rate dependent upon the

setting of the other meter valve to produce acceleration upon beginning of the next stroke.

7. In a hydraulic pumping unit employing an accumulator and a hydraulic actuating cylinder ram having a possible stroke in excess of a pump to be actuated, a control circuit for the gas pressure of the accumulator so as to effect a constant predetermined stroke of the actuating ram comprising: a stroke-control valve whose spool is normally urged in one direction; a drive rod contacted by the actuating ram to return the spool toward a normal position upon each complete cycle of the actuating ram; a power operated make-up pump adapted to deliver gas under pressure to the accumulator; a control circuit for the pump adapted to be operated by movement of the spool past a normal lower position; and a blowdown valve for the accumulator adapted to be operated by the spool when it moves beyond its normal upper position.

8. A hydraulic pumping unit comprising: a reservoir; a constant-volume, power driven pump adapted to receive liquid from the reservoir; a four-way valve; a two-way cylinder connected to the four-way valve and having an actuating ram mounted therein for selective reciprocation; an actuator for the four-way valve operative to reverse the valve at the ends of the stroke of the actuating ram; an accumulator for assisting the pump on the pumping stroke; a stroke-control valve whose spool is urged in one direction by pressure from the pump; a drive rod contacted by the actuating ram to drive the spool in the opposite direction at the end of each cycle of the actuating ram; a make-up pump coupled to the accumulator to deliver gas under pressure thereto; a blowdown valve connected to the accumulator to relieve gas pressure therein; a valve actuated by the stroke-control valve and responsive to the valve spool when driven past its normal position for actuating the pump; and an actuator coupled to the spool for actuating the blowdown valve responsive to the spool rising above its normal limit in response to pressure fluid.

9. A hydraulic pumping unit as defined in claim 8 wherein the make-up pump is hydraulically actuated and is connected to cylinder lines extending from the four-way valve to the cylinder, and wherein the stroke-control valve controls a three-way valve in one of the connections to the cylinder lines so as to selectively operate the make-up pump.

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Certificate of Correction

Patent No. 2,572,748 October 23, 1951

PAUL E. NOLL ET AL.

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

Column 6, line 30, for "*clutch*" read *circuit*;

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 19th day of February, A. D. 1952.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.