

Nov. 28, 1950

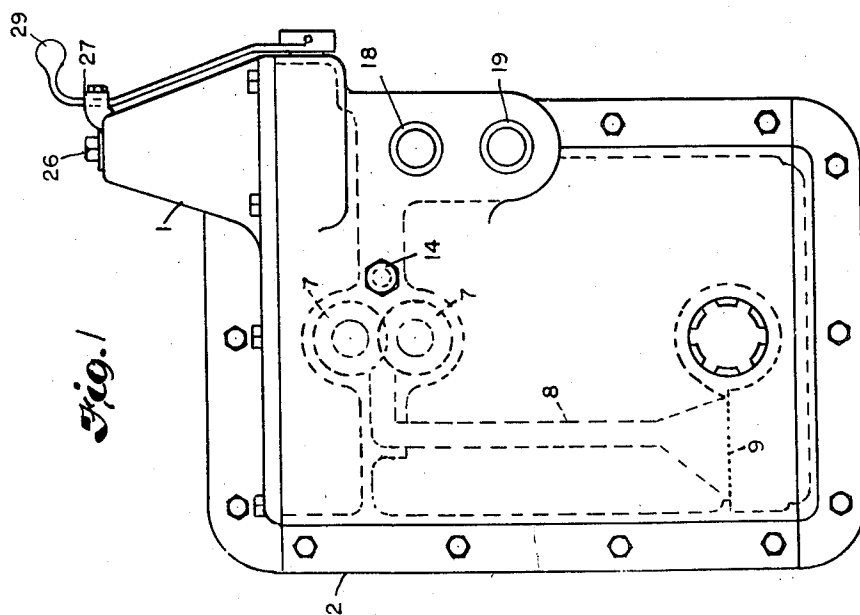
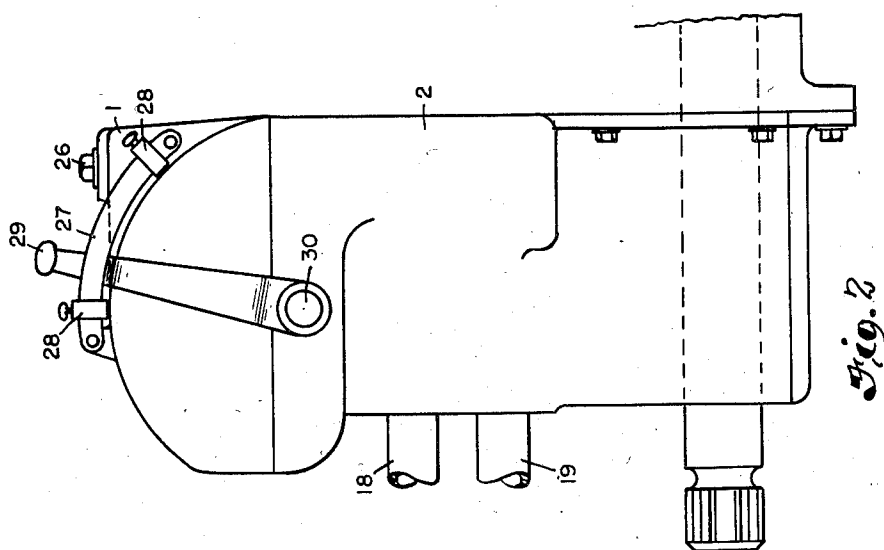
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2,531,428

HYDRAULIC POWER DEVICE POSITIONING CONTROL MECHANISM

Filed Jan. 31, 1947

4 Sheets-Sheet 1



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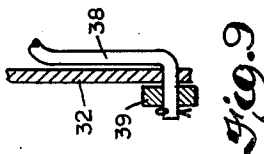
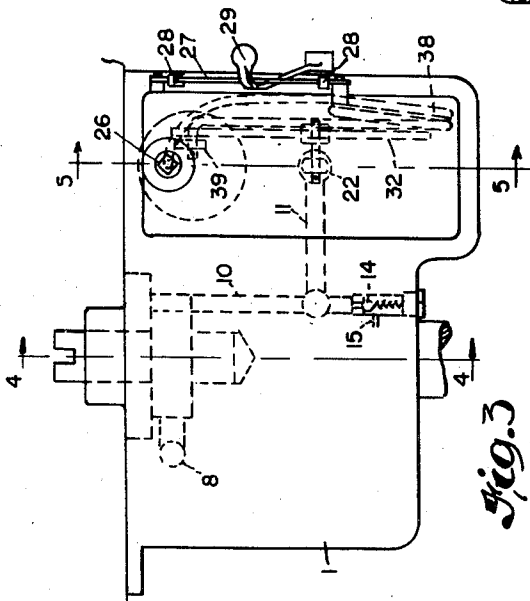
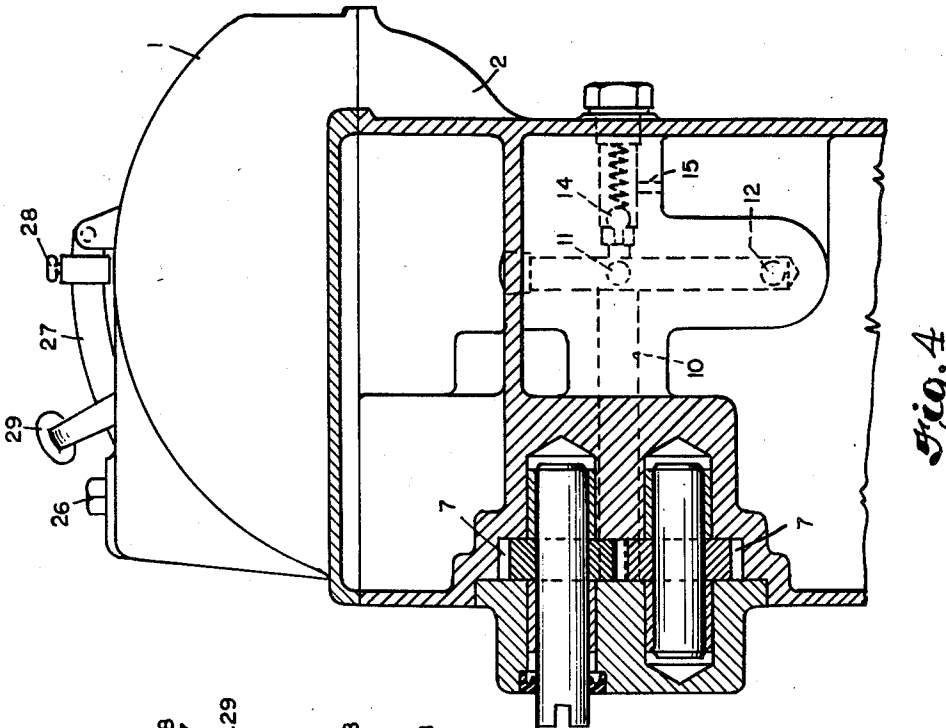
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HYDRAULIC POWER DEVICE POSITIONING CONTROL MECHANISM

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4 Sheets-Sheet 2



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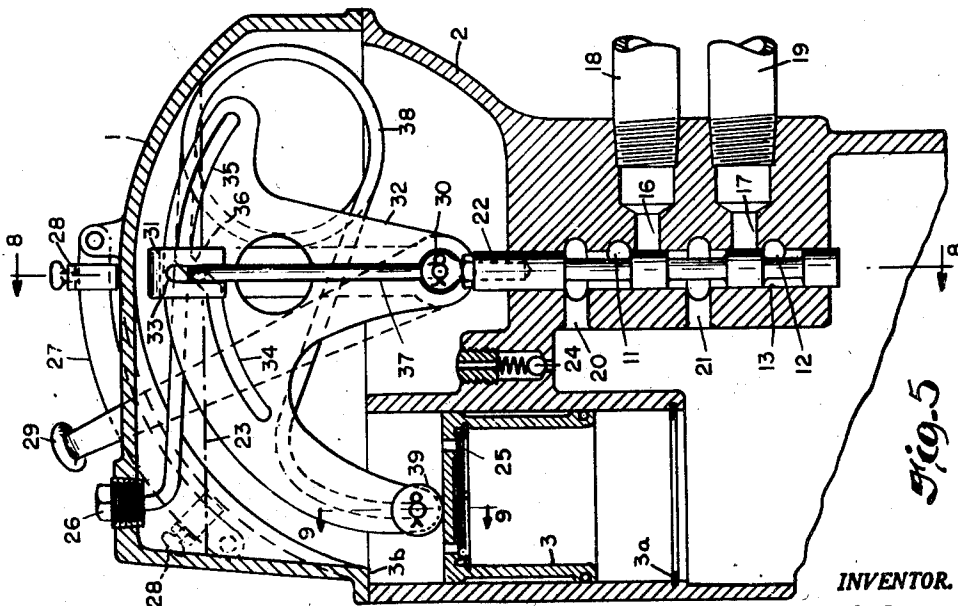
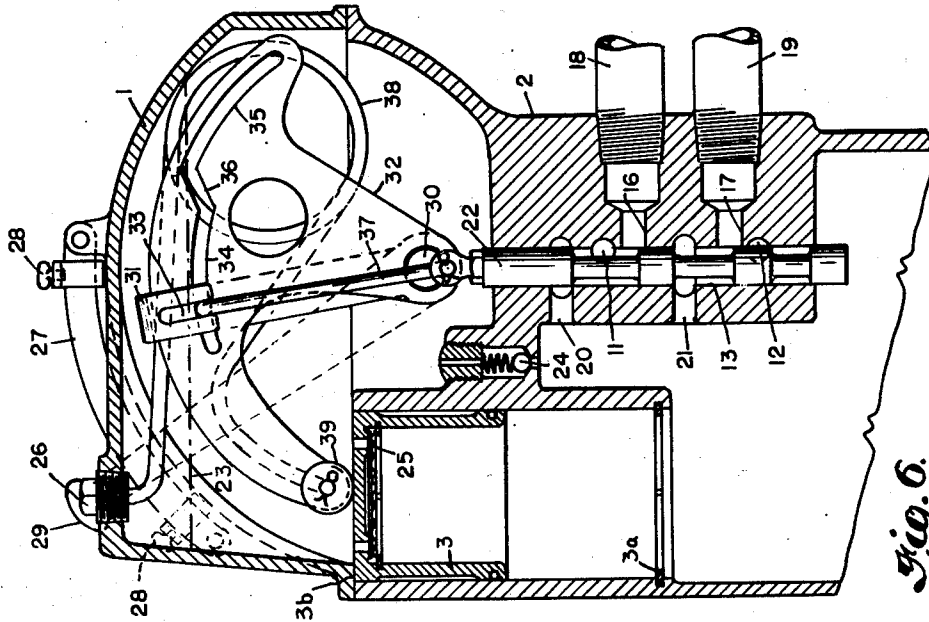
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HYDRAULIC POWER DEVICE POSITIONING CONTROL MECHANISM

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4 Sheets-Sheet 3



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HYDRAULIC POWER DEVICE POSITIONING CONTROL MECHANISM

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4 Sheets-Sheet 4

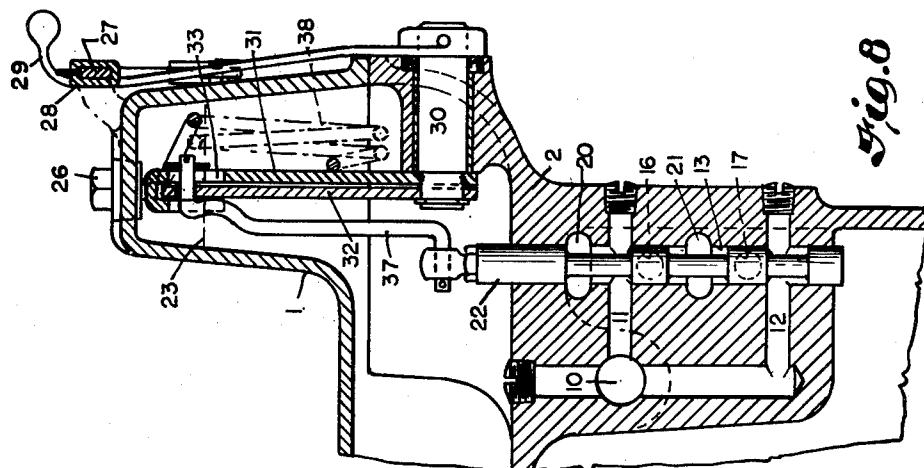


Fig. 8

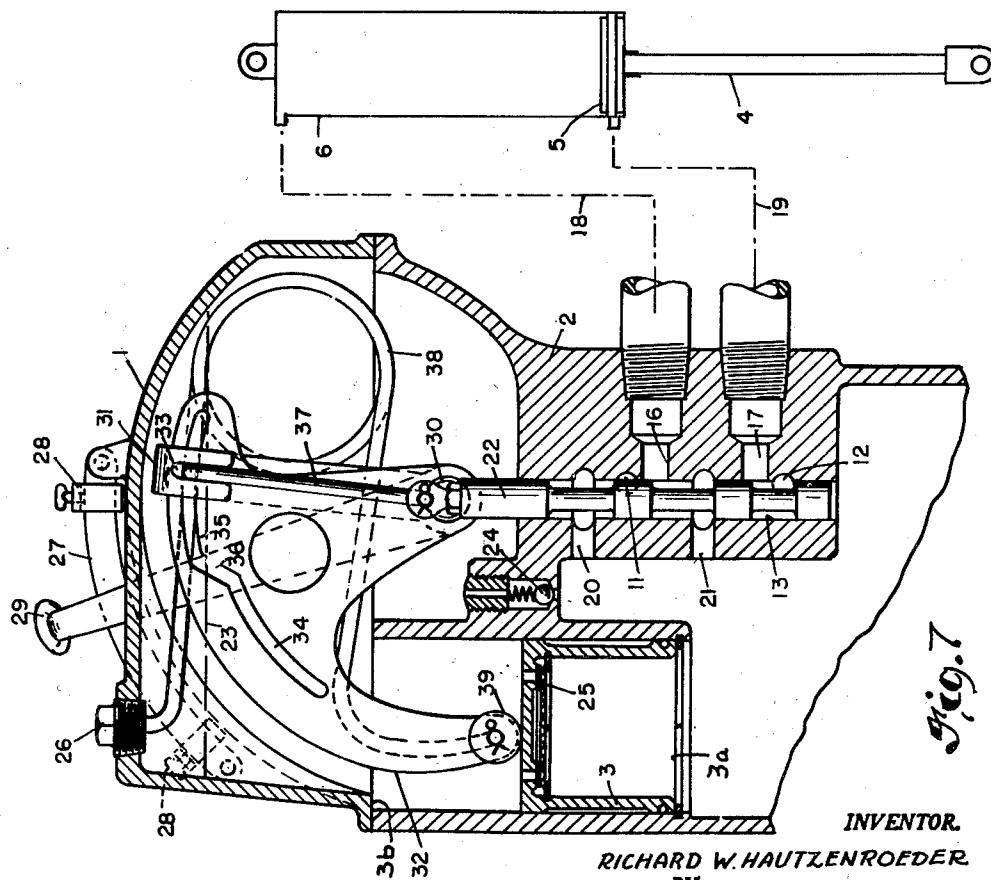


Fig. 7

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UNITED STATES PATENT OFFICE

2,531,428

HYDRAULIC POWER DEVICE POSITIONING
CONTROL MECHANISM

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Application January 31, 1947, Serial No. 725,639

15 Claims. (Cl. 60—52)

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The present invention, while relating generally as indicated to a hydraulic power device positioning control mechanism, is more particularly concerned with a novel form of hydraulic system in which the control mechanism therein is selectively operable to effect movement of the movable element of a power device to any preselected position, said mechanism and power device constituting the entire hydraulic system and being spaced apart and connected to one another only by a pair of fluid conduits.

It is, therefore, one principal object of this invention to provide a hydraulic control mechanism of the character referred to which is adapted to be located remotely from the power device to be controlled thereby and which has no connection with the latter other than the conduits for transmitting hydraulic fluid thereto and therefrom.

It is another object of this invention to provide a closed hydraulic system containing a predetermined amount of hydraulic fluid which comprises a power device having a movable element therein which, when moved, effects variation in the capacity of the system in accordance with the amount of movement thereof and a remotely located control mechanism which is responsive to such variation in capacity to interrupt movement of said element when it reaches a predetermined position as selected by manipulation of said control mechanism during the initiation of the movement of said element.

It is another object of this invention to provide means in a closed hydraulic system for maintaining a predetermined amount of fluid therein.

It is another object of this invention to provide a hydraulic control mechanism which has novel means therein for correlating the operation of a control valve with the movement of the movable element of a power device for automatically interrupting movement of said movable element when it reaches a position preselected by said means.

It is another object of this invention to provide a hydraulic control mechanism of unitary package form which includes therein a pressure providing means, a fluid chamber, a control valve, a follower movable in such chamber, means interconnecting the follower and valve so that movement of the former actuates the latter, and manually operable means for controlling the valve and for varying the amount of movement of the follower prior to its effecting actuation of the valve as aforesaid.

Other objects and advantages of the invention

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will become apparent as the following description proceeds.

To the accomplishment of the foregoing and related ends, said invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In the drawings:

Fig. 1 is a rear elevation view of one form of hydraulic control mechanism;

Fig. 2 is a right-hand side elevation view of the control mechanism illustrated in Fig. 1;

Fig. 3 is a top plan view of the control mechanism illustrated in Fig. 1;

Fig. 4 is a vertical cross section view of the pump portion of the mechanism taken along line 4—4, Fig. 3;

Fig. 5 is a vertical cross section view through the control valve and follower portion of the mechanism taken along line 5—5, Fig. 3;

Figs. 6 and 7 are views similar to Fig. 5 except illustrating two other positions of the control valve, the follower and the mechanism interconnecting said valve and follower;

Fig. 8 is a vertical cross section view through the control valve and the actuating mechanism therefor taken along line 8—8 of Fig. 5; and

Fig. 9 is a cross section view of that portion of the actuating member which engages the follower, such section having been taken along line 9—9, Fig. 5.

Briefly outlined, the hydraulic system reduced to its simplest form comprises a power device and a control mechanism which are connected to one another by a pair of fluid conduits. The power device is in the form of a hydraulic jack or the like in which movement of the piston and piston rod therein effects unequal displacement of fluid thereinto and therefrom in accordance with the displacement of the piston rod. The control mechanism includes a pump, a control valve selectively operable between a position connecting said conduits to the pressure and suction sides, respectively, of the pump and a position isolating the power device, in which latter position the pump discharge passes through the valve to the pump inlet, a follower movable in response to the displacement of the piston rod of the jack and means interconnecting the follower and the valve to effect actuation of the valve. The interconnecting means is arranged so that the control

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valve may be shifted to a desired position to initiate movement of the piston within the jack in a desired direction and is further formed to provide a variable lost motion connection whereby the follower will effect actuation of the control valve only after the piston has moved a predetermined amount as selected by the amount of such lost motion.

Referring now to the drawing, the aforesaid control mechanism is shown as comprising upper and lower housings 1 and 2 which together define upper and lower chambers. Movable in a bore formed in the partition wall between such chambers is a follower member 3. The diameter and the length of the bore in which the follower 3 is movable is such that when the follower moves from its upper limit, as shown in Fig. 6, to its lower limit, as shown in Fig. 7, the fluid capacity of the lower chamber and thus of the fluid system will vary an amount equal to the displacement of the piston rod 4, see Fig. 7, during movement of the piston 5 from one end to the other end of cylinder 6.

As best shown in Fig. 4, the front of lower housing 2 is formed with a pump chamber for receiving the pump elements 7 which are herein illustrated as elements of a conventional gear pump. One of the elements 7 has a shaft keyed thereto which projects exteriorly of the housing 2 for connection with a drive shaft, not shown. A passage 8 in housing 2, see Figs. 1 and 3, leads from the bottom of the lower chamber to the suction side of the pump chamber. A suitable strainer 9 may be provided at the lower end of passage 8. A passage 10, see Figs. 3 and 4, leads from the pressure side of the pump chamber to two branches 11 and 12 which intersect an elongated bore 13 in the housing at longitudinally spaced points. In passage 10 is a relief valve 14 which is adjusted to by-pass the pump discharge to the lower chamber through a passage 15 whenever the pressure of the fluid in passage 10 exceeds a predetermined maximum.

Also intersecting bore 13 at points between the passages 11 and 12 are the passages 16 and 17 which respectively lead, by means of suitable flexible conduits 18 and 19, to the head and rod ends of the cylinder 6. Still other spaced passages 20 and 21 lead from the bore 13 to the lower chamber.

Slidable in bore 13 is a spool valve 22 which is formed with several cylindrical enlarged portions which are closely fitted into bore 13 so as to make sealed engagement therewith. The axial spacing of such cylindrical portions of said spool 22 in relation to the aforesaid passages which intersect bore 13 is such that the spool may be shifted to any one of the following three positions:

1. To that shown in Fig. 5 wherein the passages 16 and 17 are cut off to thus lock the piston 5 in cylinder 6 against movement in either direction and the pump discharge flows through passages 11 and 20 to the lower chamber;

2. To that shown in Fig. 6 wherein the pump discharge flows through passages 11 and 16 to the head end of cylinder 6 to thus extend the jack and wherein the fluid displaced from the rod end of cylinder 6 flows through passages 17 and 21 to the lower chamber; and

3. To that shown in Fig. 7 wherein the pump discharge flows through passages 12 and 17 to the rod end of cylinder 6 to thus retract the jack and wherein the fluid displaced from the

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head end of cylinder 6 flows through passages 16 and 21 to the lower chamber.

The spool valve herein illustrated is of a form (usually denoted "open center" type) such that the pump operates under pressure only during actuation of the power device, such pressure varying in accordance with the resistance to movement of said power device but not exceeding that for which the relief valve 14 is set. At all other times, the pump is unloaded by said valve to an extent that it need only overcome the internal circuit resistance. Thus, substantial savings in power are realized by using such an "open center" type valve.

The upper chamber previously referred to constitutes a reservoir which may be periodically filled with fluid up to a level indicated by the dot-dash line 23, such filling being accomplished by removing the plug 26 at the upper end of housing 1. Between the upper and lower chambers are two valves 24 and 25, the former of which is in the nature of a pressure relief valve which spills over the excess fluid in the system into the upper chamber whenever the fluid in the system expands in volume as by an increase in the temperature thereof and the latter of which is in the nature of a suction relief valve to admit fluid from the upper chamber to the lower chamber whenever the fluid in the system decreases in volume as by thermal contraction or exterior leakage of fluid from the system as by the springing of leaks in the conduits or joints or in the piston rod packing, etc. The operation of valves 24 and 25 is set out in greater detail in the ensuing description.

Whenever movement of the piston 5 is initiated by the shifting of spool valve 22, the follower 3 will move as previously indicated in response to the displacement of the piston rod 4. In order to preselect the position to which the piston 5 will move, it is necessary that the movement of the follower 3 to a predetermined position be operative to shift the spool valve 22 to the position of Fig. 5 wherein the movement of the piston is interrupted. The interconnecting means between follower 3 and spool valve 22 for accomplishing such actuation of the latter will now be described in detail.

The upper housing 1 has mounted thereon a quadrant 27 which has suitable adjustable stops 28 thereon which may be adjusted along the quadrant to positions corresponding with the extreme positions to which it is desired to shift the piston 5 in cylinder 6. Said quadrant 27 may also have suitable markings thereon corresponding with the various in-between positions of the piston 5. An operating handle 29 is pivotally connected to lower housing 2 about an axis coinciding with that of quadrant 27 for swinging between the stops 28 or to any other position therebetween.

Handle 29 is non-rotatably connected to one end of a shaft 30 which extends into the upper chamber. Non-rotatably secured to that end of shaft 30 which extends into the upper chamber is a yoke arm 31 which has a rebent outer end which embraces the outer periphery of a cam plate 32, said cam plate lying adjacent the arm 31 and being rotatably mounted on said shaft 30. Said arm also has an elongated slot 33 in its outer rebent end extending in a radial direction relative to the axis of shaft 30. Such slot 33 is of radial extent corresponding with the radial difference between the arcuate slots 34 and 35 formed in the cam plate 32. Slots 34 and 35 are concentric

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about the axis of shaft 30 and are connected to one another by an intermediate cam slot 36. Passing through the slots in the cam plate 32 and in the yoke arm 31 is the upper lateral end of a valve operating rod 37 which has its lower lateral end pivotally connected to the upper end of spool valve 22.

A spring member 38 which has its opposite ends bearing against the plug 26 and the follower 3 tends to constantly urge the follower 3 downwardly and thereby constantly maintain the fluid system under some pressure even when the pump is not operating. One end of the spring 38 passes through an opening in the cam plate 32 and has a roller 39 thereon, which roller engages the follower 3. With the spring end so passing through the cam plate 32, the cam plate 32 will be caused to swing about shaft 30 in response to the movement of follower 3.

With the parts positioned as shown in Fig. 5, the movable piston element of the jack is locked in its mid-position. When the piston is so positioned, the follower 3 will likewise be disposed in a mid-position and the cam slot 36 in the cam plate 32 will be engaged with the upper lateral end of rod 37, such engagement having either raised or lowered the spool valve 22 to the position shown depending upon the position from which the piston was shifted to such mid-position.

In Fig. 6, the piston 5 is at the head end of the cylinder and the handle 29 has been shifted in a counter-clockwise direction from a position adjacent the upper stop 28 to the position shown. Such shifting of the handle causes the yoke arm 31 and valve actuating rod 37 to rotate relative to cam plate 32 and during such relative rotation the cam slot 36 is operative through the rod 37 to move the spool valve 22 downwardly to the position shown. In this position the upper lateral end of rod 37 is in engagement with the arcuate slot 34 in cam plate 32. With the spool valve 22 shifted downwardly as shown fluid under pressure from the pump will flow through passages 11 and 16 to the head end of the cylinder to effect downward movement of the piston therein. The displacement from the rod end of the cylinder flows through the passages 17 and 21 to the lower chamber and suction side of the pump. During movement of the piston the follower 3 will move downwardly under the influence of spring 38, such movement of the follower 3 being directly in response to the displacement of the piston rod. The follower 3 and thus the cam plate 32 move until the cam slot 36 engages the valve actuating rod 37. When such engagement occurs the spool valve 22 will be raised to the position shown in Fig. 5 to thus interrupt any further movement of the piston and to lock the piston until such a time that handle 29 is either rotated still further in a counter-clockwise direction or else rotated in a clockwise direction from the position shown in Fig. 6.

On the other hand, should the piston 5 be at the rod end of cylinder 6 and the handle 29 and yoke arm 31 rotated clockwise from a position adjacent the lower stop 28 to a position such as shown in Fig. 7, the cam slot 36 will be operative to raise the spool valve 22 from the position of Fig. 5 to that of Fig. 7. In such latter position the upper lateral end of the valve operating rod 37 will be disposed in the arcuate slot 35. With the spool valve 22 so shifted, fluid under pressure flows through passages 12 and 17 to the rod end of cylinder 6 to thus move the piston 5 upwardly toward the head end of the cylinder. During

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such movement of the piston the larger displacement of fluid from the head end of the cylinder as determined by the displacement of the piston rod 4 will cause a proportionate upward movement of follower 3. In turn, the upward movement of the follower 3 causes clockwise rotation of the cam plate 32 relative to yoke arm 31 and rod 37 until finally the cam slot 36 engages rod 37 to force the spool valve 22 downwardly to the piston movement interrupting position of Fig. 5.

It will be observed that as the piston approaches the position selected by the yoke arm 37, the engagement of cam slot 36 with arm 37 will gradually move spool valve 22 to a position closing off the pressure supply to the cylinder, thereby effecting shockless interruption of the movement of the piston. It will be understood that the stops 28 may be used for holding the handle 29 in any selected position or, if desired, any other means may be employed which frictionally resist inadvertent shifting of the handle from a selected position as by vibration or the like and during engagement of the cam slot 36 with the rod 37.

Valve 25 in follower 3 is arranged so as to open under a very slight pressure differential between the upper and lower chambers and only when fluid in the system has been lost either by leakage or by volumetric contraction. Therefore, the spring 38 is so proportioned that at all times and in all positions it exerts a pressure on the follower 3 which pressurizes the system an amount sufficient to hold valve 25 closed. If, while the jack is being extended to its maximum, for example, the follower 3 reaches its lowermost position (as shown in Fig. 7), the pressure of spring 38 on follower 3 is transmitted against the follower stop 3a. Now, if there is a deficiency of fluid in the lower chamber and the valve 22 is operated to permit the pump to transfer fluid from the lower chamber to further extend the jack, the drop in pressure caused by the suction of the pump will unseat valve 25 thereby permitting fluid to flow from the upper chamber into the lower chamber or system to make up said deficiency and synchronize follower 3 relative to piston 5.

The fluid pressure in the system which is maintained by spring 38 acting on follower 3 is at all times and in all positions insufficient to unseat relief valve 24 so that any excess of fluid in the system caused by volumetric expansion of the fluid or volumetric decrease in the physical dimensions of the circuit can only be vented when follower 3 is at its uppermost position against the stop 3b formed by housing 1. With the follower engaged with stop 3b, the force exerted by spring 38 only determines the minimum pressure of the system and any excess will be vented through relief valve 24. In this way if the follower 3 reaches its upper limit prior to the jack being fully retracted, a further attempt to fully retract the cylinder by actuation of valve 22 will result in a build-up in pressure in the lower chamber which will cause valve 24 to open to spill over the excess fluid into the upper chamber and to synchronize the follower 3 relative to the piston 5.

It will be observed that the power device motivating pressure in the system is never present in the lower chamber. The pressure in such lower chamber is normally determined by the strength of the spring 38. When, however, the follower 3 reaches either end of its travel and engages a stop, then if the pressure of the fluid in the lower chamber becomes less than that in the upper chamber as when the follower 3 is against the stop 3a, the valve 25 will unseat as

aforesaid and when the pressure is greater than that (the maximum) determined by the setting of valve 24 as when the follower 3 is against shoulder 3b, then the relief valve 24 will unseat. Thus the pressure applied to the lower chamber by the spring 38 is normally sufficient to keep the valve 25 seated but insufficient to unseat valve 24.

Any out of phase relation between follower 3 and piston 5 as caused by expansion or contraction or loss of the fluid is automatically compensated for by valves 24 and 25 at the extreme stroke positions of the follower 3 and therefore under certain conditions of operation it may be necessary to periodically cycle the jack through its entire range in order to restore perfect synchronization of said follower 3 and piston 5. However, it is to be observed that such synchronization will ultimately occur even without such cycling of the jack upon the out-of-phase relationship becoming such that the handle 29 must be actuated to a position beyond the reach of the cam seat 36 in plate 32 in order to effect actuation of the piston 5 to a desired position. When this occurs the piston 5 will be fully retracted or extended to correspond with the uppermost or lowermost position of the follower 3.

One use of the mechanism disclosed herein is for controlling the position of trailing farm implements, the double acting jack or the like being associated with the implements and the control mechanism being mounted on an agricultural tractor for convenient manipulation by the tractor operator. The tractor engine supplies the power for operating the pump which is contained within the control mechanism and all that an operator need do in order to raise and lower the implements to any preselected position is to manipulate the handle 29. The one principal feature of this invention is that there are no connections between the jack and the control mechanism other than the usual hydraulic lines for supplying fluid under pressure to opposite ends of the jack. The above use of this invention is, of course, to be regarded as typical only in that it obviously has utility in remotely controlling the position of any unit which it is desired to control through the movement of the movable part of a fluid motor, such units including movable parts on a machine tool, the wing flaps on an airplane, etc.

While this invention has been described in relation to a hydraulic motor or jack of the piston and cylinder type, it will be apparent to those skilled in the art that other types of motors may be used so long as they effect the necessary unequal fluid displacement thereinto and therefrom during movement of the movable element. As a matter of fact, the principles of operation of this invention may be utilized as a safety cut-off device in conjunction with a jack having rods projecting from opposite ends thereof to cut off the fluid supply thereto when the leakage of fluid from the system exceeds a predetermined maximum. In such a system, the follower 3 normally remains stationary at its upper position during movement of the piston, but should a conduit burst or a serious leak develop in the system, the follower would then move downwardly to effect actuation of the control valve for closing off the pressure supply to the jack, such closing being effected only after a predetermined amount of fluid has been lost. In this way the contents of the entire fluid system would not be lost in trying to actuate a jack in a badly leaking system.

Other modes of applying the principle of the

invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

I therefore particularly point out and distinctly claim as my invention:

1. In a closed hydraulic system filled with fluid, the combination of a pump and a double acting, differential displacement power device dividing said system into separate delivery and return portions respectively establishing fluid communication between said pump and device, a valve in said system controlling flow of fluid between said pump and device, means in fluid communication with said return portion having a follower movable in accordance with the differential displacement of fluid by said device, means interconnecting said follower and valve whereby movement of the former actuates the latter, a fluid supply reservoir associated with said system, and a valve in fluid communication with said return portion and said reservoir permitting flow of fluid into said reservoir in response to the displacement of fluid into said return portion exceeding the differential displacement of fluid by said device.

2. In a closed hydraulic system filled with fluid, the combination of a pump and a double acting, differential displacement power device dividing said system into separate delivery and return portions respectively establishing fluid communication between said pump and device, a valve in said system controlling flow of fluid between said pump and device, means in fluid communication with said return portion having a follower movable in accordance with the differential displacement of fluid by said device, means interconnecting said follower and valve whereby movement of the former actuates the latter, a fluid supply reservoir associated with said system, and a valve in fluid communication with said return portion and said reservoir permitting flow of fluid into said reservoir in response to thermal expansion of the fluid in said return portion.

3. In a closed hydraulic system filled with fluid, the combination of a pump and a double acting, differential displacement power device dividing said system into separate delivery and return portions respectively establishing fluid communication between said pump and device, a valve in said system controlling flow of fluid between said pump and device, means in fluid communication with said return portion having a follower movable in accordance with the differential displacement of fluid by said device, means interconnecting said follower and valve whereby movement of the former actuates the latter, a fluid supply reservoir associated with said system, and two valves in fluid communication with said return portion and said reservoir respectively permitting flow of fluid from said return portion into said reservoir and vice versa in response to the volume of fluid in said return portion being increased or decreased more than the differential displacement of fluid by said device.

4. In a closed hydraulic system filled with fluid and including a pump and a double acting, differential displacement motor therein dividing said system into separate delivery and return portions, respectively establishing fluid communication between said pump and motor, said motor including a movable element effecting, upon movement in opposite directions, a differential displacement of fluid between said portions, means in fluid communication with said return portion having a follower movable in response to

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the differential displacement of fluid by said motor, a valve in said system selectively shiftable from a position initiating movement of and pre-selecting the position to which it is desired to move said movable element to a position interrupting movement thereof, said follower upon moving a predetermined amount as selected by shifting said valve to such first-named position engaging said valve to shift the same to such second-named position.

5. In a closed hydraulic system filled with fluid, a pump, a differential displacement motor comprising a cylinder, a piston movable in said cylinder, and a piston rod on said piston projecting through an end of said cylinder, said pump and motor dividing said system into separate delivery and return portions respectively establishing communication between said pump and motor, said piston rod upon movement thereof in opposite directions with said piston being effective to cause a differential displacement of fluid between said portions of said system in accordance with the displacement of said piston rod, means in fluid communication with said return portion having a follower movable in response to the differential displacement of fluid as aforesaid, a valve in said system controlling flow of fluid from said pump to said motor selectively shiftable from a position initiating movement of and pre-selecting the position to which it is desired to move said piston to a position interrupting movement thereof, said follower upon moving a predetermined amount as selected by shifting said valve to such first-named position engaging said valve to shift the same to such second-named position.

6. In a closed hydraulic system filled with fluid, the combination of a pump and a double acting, differential displacement power device dividing said system into separate delivery and return portions respectively establishing fluid communication between said pump and device, a valve in said system controlling flow of fluid between said pump and device, means in fluid communication with said return portion having a follower movable in accordance with the differential displacement of fluid by said device, means interconnecting said follower and valve whereby movement of the former actuates the latter, said last-named means comprising a pair of interengageable swingably mounted members engaging said follower and valve, respectively.

7. In a closed hydraulic system filled with fluid, the combination of a pump and a double acting, differential displacement power device dividing said system into separate delivery and return portions respectively establishing fluid communication between said pump and device, a valve in said system controlling flow of fluid between said pump and device, means in fluid communication with said return portion having a follower movable in accordance with the differential displacement of fluid by said device, means interconnecting said follower and valve whereby movement of the former actuates the latter, said last-named means comprising a pair of interengageable swingably mounted members engaging said follower and valve, respectively, one of said members being constantly urged into engagement with said follower, and the other of said members being swingable to a position providing a lost-motion connection between said members, whereby said follower will move a predetermined amount prior to actuating said valve as aforesaid.

8. In a closed hydraulic system filled with fluid,

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a double acting differential displacement power device in said system having a movable part, and a remotely located control unit in said system connected to said device by a pair of conduits establishing fluid communication between said control unit and device, said control unit comprising a housing formed with a fluid-containing chamber therein, a follower in such chamber movable in response to the differential displacement of said device, a pump in said housing having its inlet end communicating with such chamber, a valve body in said housing including passages leading to the outlet end of said pump, to such chamber, and to such conduits, a valve element in said body selectively shiftable between a position directing fluid under pressure from said pump into one of such conduits to initiate movement of the movable part of said power device and bringing the other of such conduits into communication with such chamber and a position isolating said power device from said control unit, and means interconnecting said follower and valve element whereby movement of the former shifts the latter from such first to second-named position.

9. In a closed hydraulic system filled with fluid, a double acting differential displacement power device in said system having a movable part, and a remotely located control unit in said system connected to said device by a pair of conduits establishing fluid communication between said control unit and device, said control unit comprising a housing formed with a fluid-containing chamber therein, a follower in such chamber movable in response to the differential displacement of said device, a pump in said housing having its inlet end communicating with such chamber, a valve body in said housing including passages leading to the outlet end of said pump, to such chamber, and to such conduits, a valve element in said body selectively shiftable between a position directing fluid under pressure from said pump into one of such conduits to initiate movement of the movable part of said power device and bringing the other of such conduits into communication with such chamber and a position isolating said power device from said control unit, and means interconnecting said follower and valve element whereby movement of the former shifts the latter from such first to second-named position, said last-named means comprising a pair of members having an adjustable lost-motion connection with one another whereby said follower will move a predetermined amount prior to actuating said valve element as aforesaid.

10. In a closed hydraulic system filled with fluid, the combination of a pump and a double acting, differential displacement power device dividing said system into separate delivery and return portions respectively establishing fluid communication between said pump and device, a valve in said system controlling flow of fluid between said pump and device, means in fluid communication with said return portion having a follower movable in accordance with the differential displacement of fluid by said device, means interconnecting said follower and valve whereby movement of the former actuates the latter, said last-named means comprising a pair of members having an adjustable lost-motion connection with one another whereby said follower will move a predetermined amount prior to actuating said valve as aforesaid.

11. In a closed hydraulic system filled with fluid, a double acting differential displacement

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power device in said system having a movable part, and a remotely located control unit in said system connected to said device by a pair of conduits establishing fluid communication between said control unit and device, said control unit comprising a housing formed with fluid-containing upper and lower chambers therein, a follower between such chambers movable in response to the differential displacement of said device, a pump in said housing having its inlet end communicating with such lower chamber, a valve body in said housing including passages leading to the outlet end of said pump, to such lower chamber, and to such conduits, a valve element in said body selectively shiftable between a position directing fluid under pressure from said pump into one of such conduits to initiate movement of the movable part of said power device and bringing the other of such conduits into communication with such lower chamber and a position isolating said power device from said control unit, and means in such upper chamber interconnecting said follower and valve element whereby movement of the former shifts the latter from such first to second-named position, said last-named means comprising a pair of members having an adjustable lost-motion connection with one another whereby said follower will move a predetermined amount prior to actuating said valve element as aforesaid.

12. In a closed hydraulic system filled with fluid, a double acting differential displacement power device in said system having a movable part, and a remotely located control unit in said system connected to said device by a pair of conduits establishing fluid communication between said control unit and device, said control unit comprising a housing formed with fluid-containing upper and lower chambers therein, a follower between such chambers movable in response to the differential displacement of said device, a pump in said housing having its inlet end communicating with such lower chamber, a valve body in said housing including passages leading to the outlet end of said pump, to such lower chamber, and to such conduits, a valve element in said body selectively shiftable between a position directing fluid under pressure from said pump into one of such conduits to initiate movement of the movable part of said power device and bringing the other of such conduits into communication with such lower chamber and a position isolating said power device from said control unit, and means in such upper chamber interconnecting said follower and valve element whereby movement of the former shifts the latter from such first to second-named position, and a valve in said housing establishing communication between such chambers in response to increase in the amount of fluid in the portion of the system between said device and the inlet end of said pump exceeding that effected by the differential displacement of said device.

13. In a closed hydraulic system filled with fluid, a pump in said system for circulating fluid therein, a double acting differential displacement motor included in said system having a movable element, a pair of delivery and return conduits connecting said pump and motor, a four-way valve interposed between said pump and motor having a longitudinally shiftable valve element operative when shifted to its end positions to actuate said motor in opposite directions and when shifted to an intermediate position to interrupt operation of said motor, a follower in fluid

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communication in said return conduit movable in accordance with the differential displacement of said motor, and means interconnecting said follower and valve element whereby movement of the former actuates the latter, said means comprising a rod pivotally connected to and settable at a desired angle relative to said valve element, a cam plate swingable in a plane parallel to said rod, and spring means constantly urging said plate into engagement with said follower, said plate being formed with a slot including concentric arcuate end portions interconnected by an intermediate portion intersecting such end portions at an obtuse angle, said rod being formed with a portion engaged in such slot, the pivot axes of said rod and plate being substantially coaxial when such rod portion is engaged in the intermediate portion of such slot.

14. In a closed hydraulic system filled with fluid, a pump in said system for circulating fluid therein, a double acting differential displacement motor included in said system having a movable element, a pair of delivery and return conduits connecting said pump and motor, a four-way valve interposed between said pump and motor having a longitudinally shiftable valve element operative when shifted to its end positions to actuate said motor in opposite directions and when shifted to an intermediate position to interrupt operation of said motor, a follower in fluid communication in said return conduit movable in accordance with the differential displacement of said motor, and means interconnecting said follower and valve element whereby movement of the former actuates the latter, said means comprising a rod pivotally connected to and settable at a desired angle relative to said valve element, a cam plate swingable in a plane parallel to said rod, and spring means constantly urging said plate into engagement with said follower, said plate being formed with a slot including concentric arcuate end portions interconnected by an intermediate portion intersecting such end portions at an obtuse angle, said rod being formed with a portion engaged in such slot, the pivot axes of said rod and plate being substantially coaxial when such rod portion is engaged in the intermediate portion of such slot, the arcuate end portions of such slot when engaged by said rod portion effecting shifting of said valve element to its end positions aforesaid and the intermediate portion of such slot when engaged by said rod portion effecting shifting of said valve element to an intermediate position as aforesaid.

15. In a closed hydraulic system filled with fluid, the combination of a pump and a double acting, differential displacement power device dividing said system into separate delivery and return portions respectively establishing fluid communication between said pump and device, said device including a member movable in opposite directions between definite limits by fluid under pressure and effecting differential displacement of fluid into or from the return portion of the system in accordance with the direction and extent of such movement, a valve in said system controlling flow of fluid between said pump and device, means in fluid communication with said return portion having a follower movable in accordance with the differential displacement of fluid by said device, means interconnecting said follower and valve whereby movement of the former actuates the latter, and means for synchronizing said follower and said movable member comprising stops adapted to be engaged by

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said follower to limit movement of the latter between positions corresponding to the maximum differential displacement of fluid effected by movement of said movable member between its limits of movement, means for operating said valve after said follower engages one of said stops whereby said device may be operated to move said movable member to its limit in one direction to thus synchronize said member and follower, a fluid supply reservoir associated with said system, and two valves in fluid communication with said return portion and said reservoir respectively permitting flow of fluid from said return portion into said reservoir and vice versa in response to

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the differential displacement of fluid from or into said return portion by said movable member during movement of said member after engagement of said follower with one of said stops.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,423,485	Court	July 8, 1947