Aug. 7, 1945. C. J. KOPP 2,380,973

CONTROL FOR FLUID OPERATED MOTORS

Filed Aug. 11, 1943 4 Sheets-Sheet 1

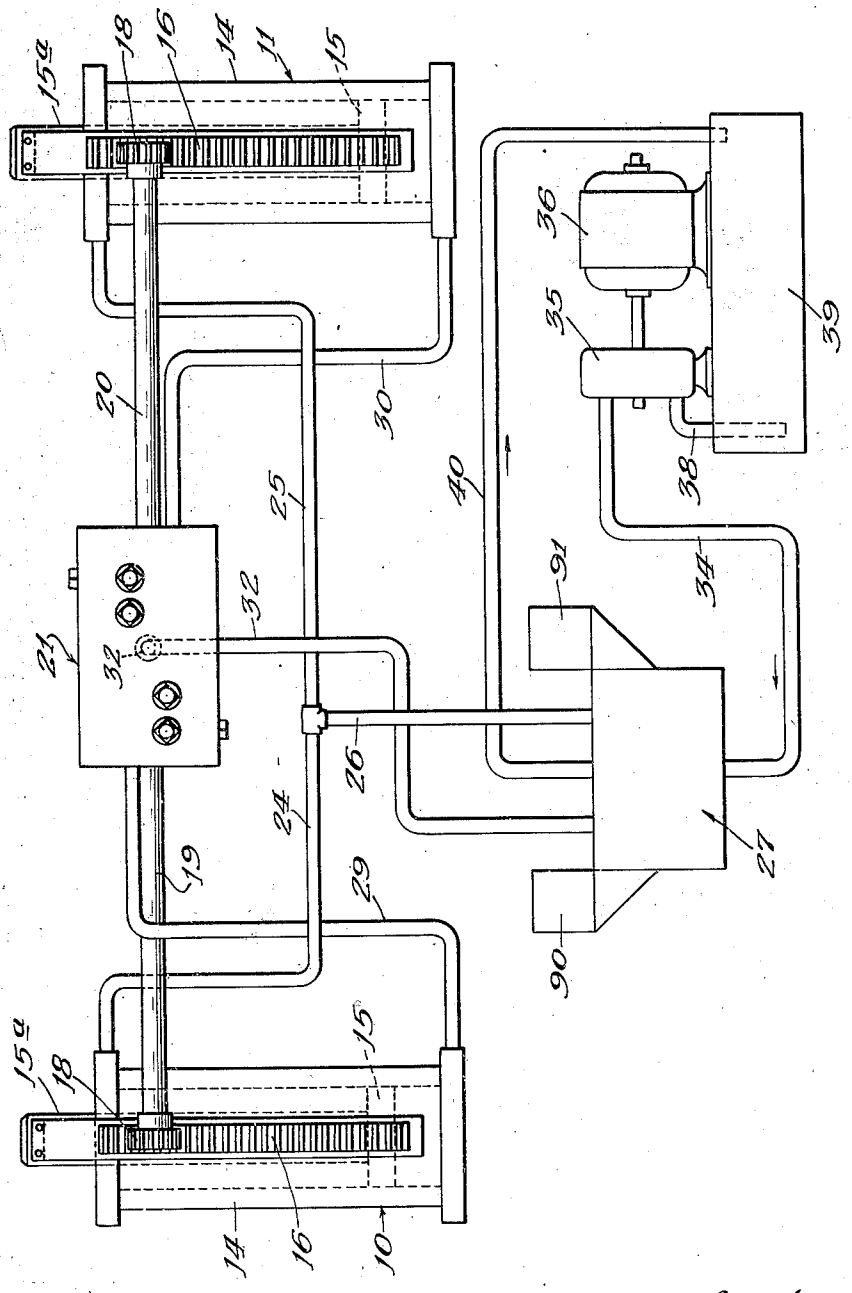


Fig. 1.

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Filed Aug. 11, 1943 4 Sheets-Sheet 2

Fig. 2.

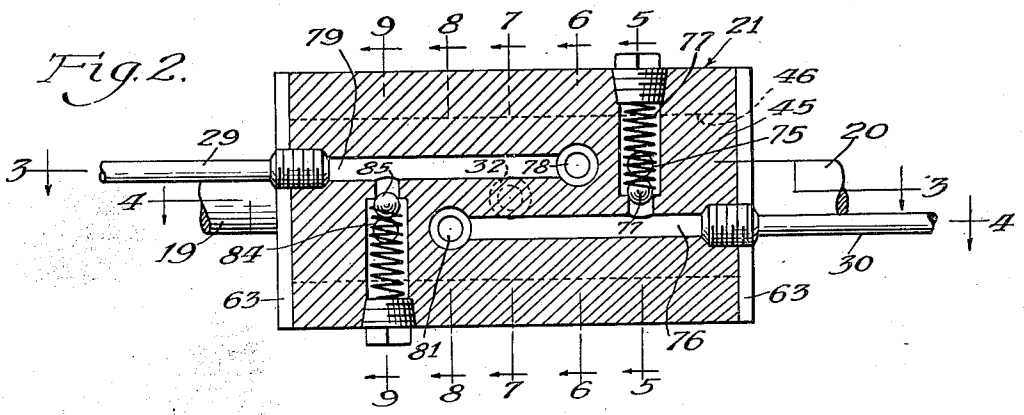


Fig. 3.

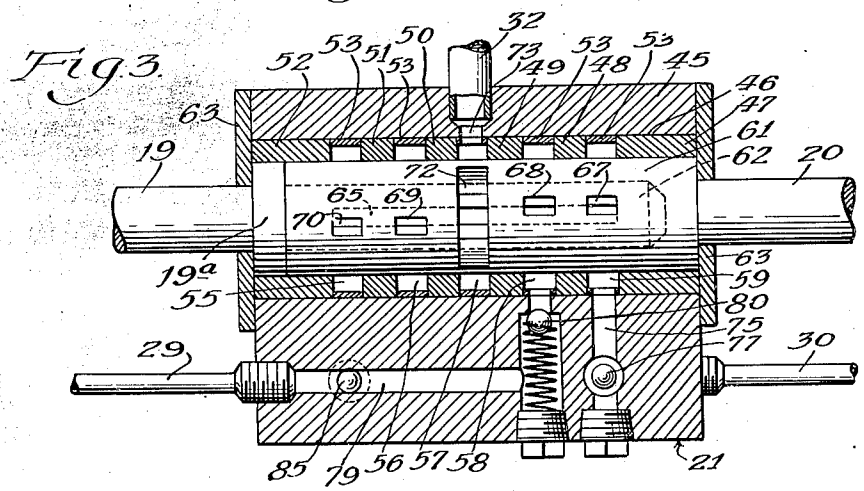
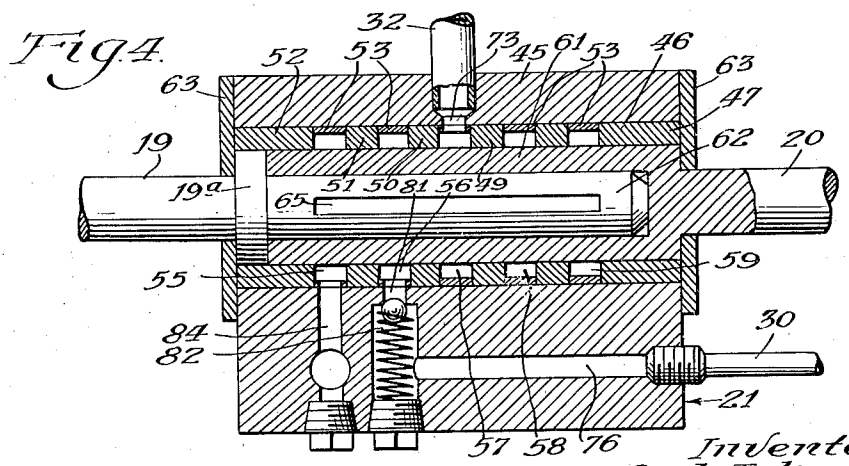


Fig. 4.



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Filed Aug. 11, 1943 4 Sheets-Sheet 3

Fig. 5.

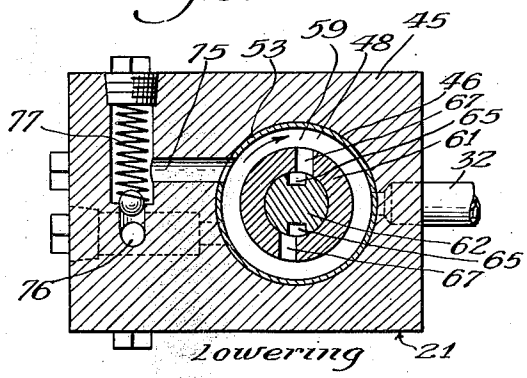


Fig. 6.

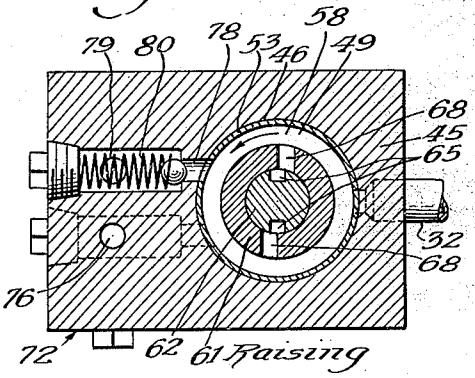


Fig. 7.

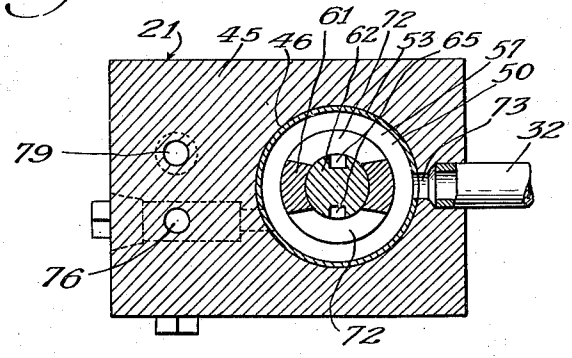


Fig. 8.

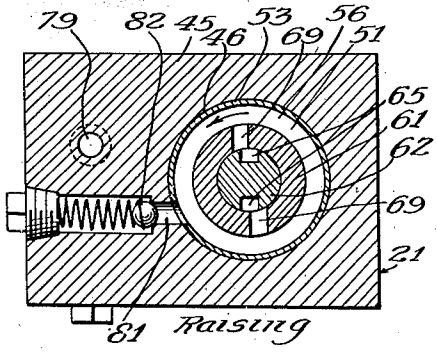
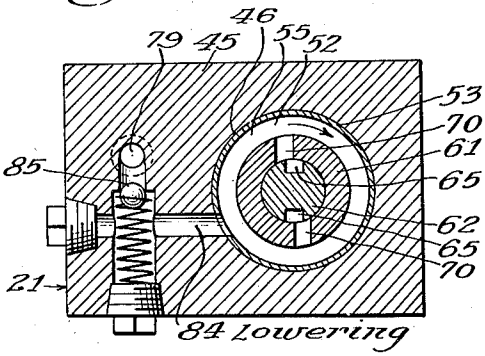


Fig. 9.



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Aug. 7, 1945. C. J. KOPP 2,380,973

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Filed Aug. 11, 1943 4 Sheets-Sheet 4

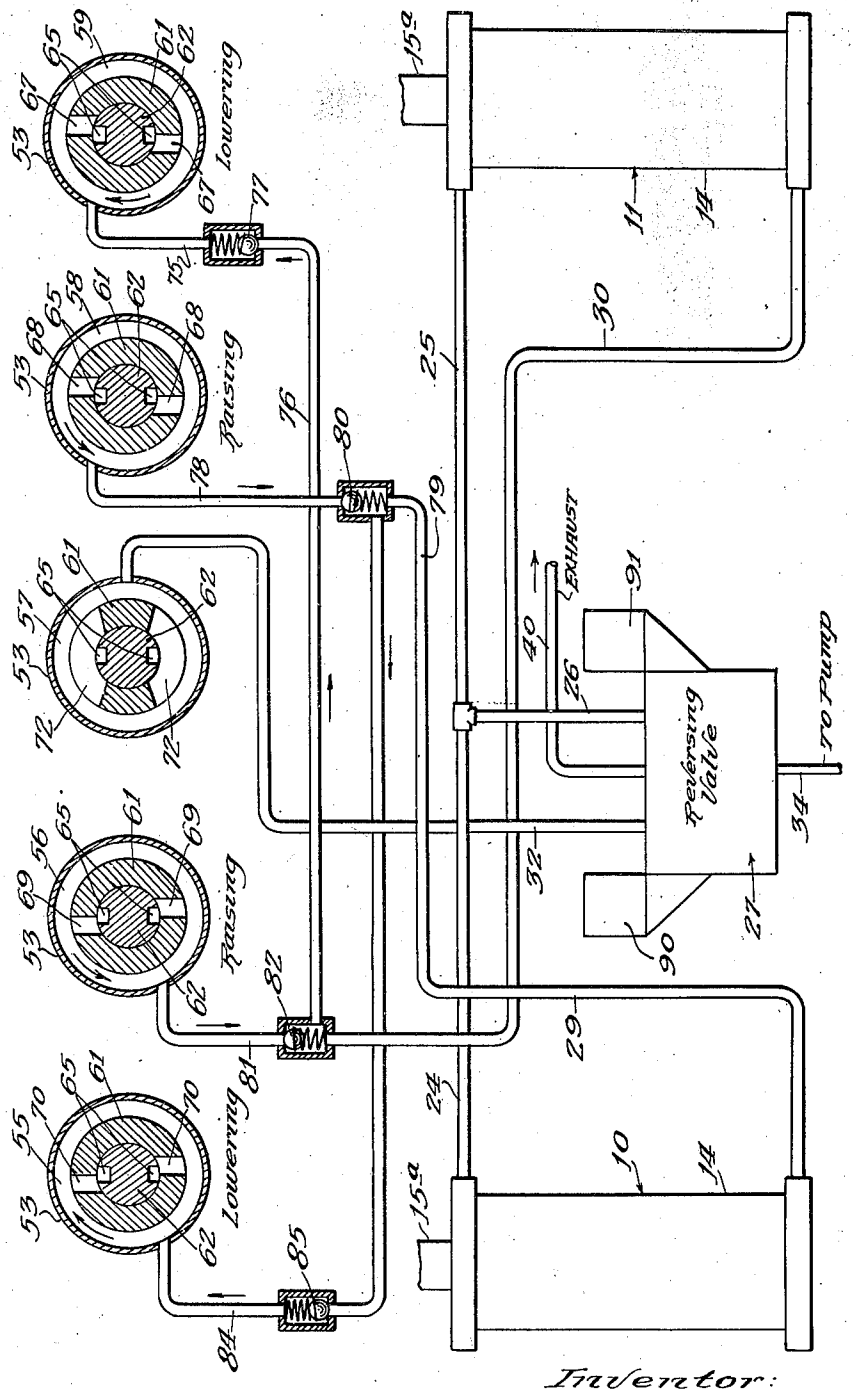


Fig. 10.

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2,380,973

CONTROL FOR FLUID OPERATED MOTORS

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Application August 11, 1943, Serial No. 498,139

7 Claims. (Cl. 60—97)

This invention relates to control apparatus for fluid operated pistons, adapted to be utilized for controlling movement and/or positioning of various members or mechanisms, such as for example the height of a platen of a press, or the bed of a milling or boring machine. More particularly the present invention is directed to apparatus for simultaneously controlling the movement of a plurality of pistons which are connected for moving various elements, or machines.

It has long been a problem to properly control the simultaneous operation of a plurality of fluid actuated pistons when said pistons are utilized, as for example, for raising or lowering various elements or parts of a machine. The simultaneous operation of a plurality of pistons necessitates great care and skill, as well as the consumption of a substantial amount of time.

One of the objects of the present invention is to provide a novel control for simultaneously operating a plurality of fluid operated pistons for maintaining substantially synchronized or balanced movement of the piston elements.

Another object is to provide a novel control of the character indicated wherein a main control valve is adapted to be actuated in direct response to the differential of the rates of movement of two interconnected pistons for proportionately varying the rate of flow of fluid to the pistons, and thereby automatically causing substantially balanced or equalized movement of the piston elements.

A further object is to provide an improved control of the character indicated by virtue of which the rate of movement of a plurality of interconnected pistons serves to automatically effect adjustments of a main control valve so as to maintain substantially uniform, balanced movement of the piston elements.

Still another object is to provide a novel two-directional fluid control valve for a fluid system comprising a pair of cooperating telescoping valve elements, each connected to a separate rotatable shaft, and wherein a small amount of relative rotation of one shaft with respect to the other instantly effects adjustment of the valve elements by virtue of which said shafts are caused to rotate in substantial synchronism with each other.

Other objects and advantages of this invention will be apparent from the following description, taken in connection with the accompanying drawings in which:

Fig. 1 is a schematic illustration of my novel control apparatus for a pair of fluid operated pistons.

Fig. 2 is a vertical section through the control valve per se.

Fig. 3 is a section through the control valve, taken as indicated on line 3—3 of Fig. 2.

Fig. 4 is a section through the control valve, taken substantially as indicated on line 4—4 of Fig. 2.

Figs. 5 to 9 inclusive are vertical transverse sections through the control valve, taken substantially as indicated respectively at lines 5—5, 6—6, 7—7, 8—8 and 9—9 on Fig. 2.

Fig. 10 is a diagrammatic illustration of the control apparatus represented in Fig. 1 of the drawings.

The control apparatus herein disclosed may utilize fluid in the form of gas or a liquid, and for purpose of illustration the present invention will hereinafter be described as being operated by liquid, such as oil.

In Fig. 1 of the drawings I have shown a pair of fluid operated motors, designated generally at 10 and 11, disposed in upright position, each comprising a cylinder 14 and a piston element 15, reciprocably movable within the cylinder 14. The upper end of each piston rod 15a of the piston elements is rigidly attached to a vertically disposed toothed rack 16, mounted for slidable guided vertical movement, on the outer wall of the cylinder 14. Meshed with each of said racks is a pinion 18. Said pinions are rigidly mounted on the outer ends of a pair of axially aligned, rotatable shafts 19 and 20, which are operably associated with a main control valve designated generally at 21.

The control valve 21 is constructed so as to maintain substantially synchronized or balanced rotation of the two shafts 19 and 20 and by virtue of which the piston elements of the respective motors 10 and 11 are caused to be raised or lowered in relatively synchronized relation to each other. It is to be understood that the upper ends of the piston rods 15a may be operably connected to the machine bed or other object to be moved or supported thereby.

The control valve is a hydraulically balanced unit and is operable by hydraulic pressure without having to overcome any resistance caused by pressure within it. Such an arrangement is particularly important if the control valve were operated by means other than racks and pinions, such as a cable and drum, a Selsyn motor, or other means which might not be capable of transmitting large amounts of power.

As shown in Fig. 1 of the drawings, the upper ends of the chambered portion of the cylinders 14 are interconnected by a duct or conduit, formed in two sections, as indicated at 24 and 25 which are joined to a conduit 26, connected to a conventional reversing valve indicated generally at 27. The lower ends of the chambers of the cylinders are connected by ducts or conduits 29 and 30, for the respective pistons 10 and 11, to the main control valve 21. The main control valve is interconnected with the reversing valve by a duct or conduit indicated at 32. Oil is supplied to the system through the reversing valve 27, by a conduit 34, connected to a pump 35, driven by a motor 36, for supplying oil through means of a conduit 38, from a storage tank 39. The reversing valve 27 is also connected by conduit 40 to the storage tank 39, to provide a return duct for the oil from the system to the source of supply.

The main control valve 21 includes a body 45 formed with a cylindrical bore 46 in which there is forcibly fitted a plurality of rings designated at 47, 48, 49, 50, 51 and 52 which are axially spaced apart by rings designated at 53, the internal diameter of which is substantially greater than the internal diameter of the other rings, so as to provide five annular chambers designated as 55, 56, 57, 58 and 59. Snugly fitted within the bore of the rings 47 to 52 inclusive is a pair of cooperating telescopic valve elements designated at 61 and 62. The valve element 61 is in the nature of a sleeve, formed as an integral part of the shaft 20, and telescoped within the sleeve 61 is the valve element 62, which is the terminal portion of the shaft 19. The valve elements are maintained in position within the valve body by end plates 63, abutting against a shoulder formed at the rear end of the sleeve 61, and against a collar 19a fixed on the shaft 19. The valve element 62 is formed with a pair of diametrically opposite, longitudinally extending passageways 65, which are in the form of keyway slots, terminating in approximate alignment with the outer walls of the end chambers 55 and 59.

The sleeve 61 is provided with four pair of axially spaced apart ports 67, 68, 69 and 70, with the ports of each pair disposed in diametrically opposed relation to each other, as seen in Figs. 5, 6, 8 and 9 inclusive of the drawings. When the shafts 19 and 20 are rotating in synchronized relation to each other, the ports 67 to 70 inclusive are in semi-registration with the respective passageways 65 of the valve element 62. The ports 67 to 70 inclusive are open to and disposed in registration respectively with the annular chambers 59, 58, 56 and 55.

The sleeve 61 is also provided with a pair of diametrically opposite transverse slots 72, located at substantially the center of the length thereof, in registration with the annular chamber 57, so as to provide direct communication between the passages 65 and a main port 73 formed in the valve body, and to which is connected the conduit 32.

The valve body is provided with separate ports and ducts for communication with the respective chambers in registration with the ports 67 to 70 inclusive. As may be seen in Fig. 5 of the drawings, the chamber 59, which is in registration with the valve port 67, opens into a port 75, which is in one-way communication with a duct 76, the latter being connected to the conduit 30. Interposed between the ducts 75 and 76 is a one-way ball check valve designated generally at 77. In Fig. 6 of the drawings it will be noted that the chamber 58, which is in registration with the ports 68, is in open communication with a port 78, which is in one-way communication with a duct 79, connected to the conduit 29. A one-way ball check valve designated generally at 80 interconnects the port 78 and duct 79.

In Fig. 8 of the drawings it will be noted that the chamber 56, in registration with the ports 69, is in direct communication with a port 81, which in turn is connected to the duct 76, connected to conduit 30, with a one-way ball check valve, indicated generally at 82, interposed in the duct 81 so as to provide a one-way passage for the flow of oil in the system. In Fig. 9 of the drawings the chamber 55, in registration with the ports 70, is in direct communication with a port 84, which in turn is connected to the duct 79, with a one-way ball check valve, indicated generally at 85, interposed to provide a one-way passage of flow of oil.

For convenience, and for a more clear understanding of this invention, it may be here mentioned that the valve structure indicated in Fig. 5, controls the flow of oil to effect lowering of the piston element of the motor 11. The valve structure represented in Fig. 9, serves as the control for the lowering of the piston element of the motor 10, and the valve arrangements represented in Figs. 6 and 8, respectivelv control the raising of the piston elements of the motors 10 and 11.

The reversing valve indicated generally at 27 may be understood to be of the spring centered type and normally has ports thereof so disposed that oil is caused to flow from the conduit 34, directly into the conduit 40 so as to form a closed fluid system. The reversing valve may be operated in any convenient manner, and as herein shown by a pair of solenoids 90 and 91. It is to be understood that these solenoids may be separately and selectively energized by suitable switch means, not shown, for adjusting the reversing valve to either of two main positions of adjustment. For example, it may be assumed that when the solenoid 90 is energized the ports of the reversing valve are so adjusted that oil is pumped through the conduit 34 into the conduit 32, through the main control valve 21, and through the conduits 29 and 30, to the lower ends of the cylinders 14 of said motors 10 and 11, for raising the piston elements. In this position of adjustment of the reversing valve, the conduit 26 is, then through a suitable port arrangement of the reversing valve, in direct communication with the exhaust conduit 40, so as to permit the oil in the upper end of the cylinders, above the piston elements to be expelled and returned to the storage reservoir 39. When solenoid 90 is deenergized and the other solenoid 91 is energized, the reversing valve then assumes a position of adjustment wherein oil is pumped through the conduit 34 into the conduit 26, and thence into the respective conduits 24 and 25, into the upper ends of the chambers of the cylinders 14, for causing lowering of the pistons 15 within their respective cylinders. To accommodate such lowering action the oil in the lower ends of the chambers of the cylinders is caused to flow through the conduits 29 and 30 into the main control valve 21, from whence it flows through the conduit 32, which will then be in direct communication with the exhaust conduit 40, for returning the oil to the reservoir 39. The control valve 21, at this time will func-

tion to equalize the lowering of the pistons by controlling the exhaust oil from the cylinders.

It may be understood that if desired, suitable limit switches may be employed for controlling the maximum and minimum position of adjustment of the piston elements, which would correspond to the limits of movement of the members to be controlled by the pistons, such as the platen of a press, or the bed of a machine. Such limit switches could be connected in series with the respective solenoids **90** and **91**, so that when the pistons arrived at their uppermost limit of adjustment, the actuated solenoid would be deenergized so as to permit the reversing valve **27**, to again assume its normal spring centered position of adjustment, at which time oil will then be pumped from the conduit **34** directly into the exhaust conduit **40**, for return to the reservoir **39**, and a proper quantity of oil will be sealed in the system, so as to support the pistons at such position of adjustment.

It is also to be understood that if desired the pump motor may be controlled by relay circuits, connected in circuit with the respective solenoids and limit switches, so that the motor **36** functions only when one of the solenoids is energized and the limit switches are closed.

Operation of control valve

In the diagrammatic showing of the different valve structures of the main control valve in Fig. 10, it will be noted that the sections of the valve, reading from right to left, correspond to the sections disclosed respectively in Figs. 5 to 9 inclusive.

If it be assumed now that the reversing valve **27** is adjusted by actuation of solenoid **90**, so as to cause raising of the piston elements in their respective cylinders, the oil is supplied from the conduit **34** directly to the conduit **32**, and enters the chamber **57** of the main control valve. Oil then flows into slots **72** of the sleeve valve element **61**, into passageways **65**, in the inner valve element **62**, from whence it flows through the ports **68** and **69** (see Figs. 6 and 8), into the chambers **58** and **56**, into the respective ducts **78** and **81** which are in direct one-way communication with the conduits **29** and **30** respectively, so as to supply oil to the lower portion of the cylinders of the respective motors **10** and **11**. It will be noted that at this time oil cannot flow through the ports **67** and **70** because of the one-way ball check valves **77** and **85**. When the reversing valve is so adjusted the oil at the upper ends of cylinders **14** is permitted to return through the conduits **24**, **25**, and through the conduit **26**, to the exhaust conduit **40**, for return to the storage reservoir **39**. If during the raising action of the two pistons one of the pistons tends to travel faster than the other, as for example the piston element in the motor **11**, this will cause the shaft **20** to rotate a slight amount relatively to the shaft **19**. This, as may be observed from Fig. 6 of the drawings, would cause the sleeve **61** to rotate, in counterclockwise direction, slightly in excess of the rate of rotation of the valve element **62**, which would cause the ports **68** to increase their registration with the passageways **65**, while at the same time it would cause the ports **69**, as seen in Fig. 8 of the drawings, to decrease the extent of their registration with said passageways **65**. Thus a greater proportion of the available oil supplied through the duct **32** would be supplied through ports **68** into duct **79** and conduit **29** to the lower end of the cylinder of the motor **10**, and a reduced quantity of oil would be supplied to the lower end of the cylinder of motor **11**. By virtue of this arrangement the two motors are almost instantly brought into synchronized adjustment, or relationship, so that they constantly tend to move in equalized or balanced relation to each other.

When the piston elements of the respective motors **10** and **11** are caused to be lowered by the readjustment of the reversing valve **27**, by actuation of solenoid **91**, as above described, the oil is supplied through the conduit **34**, directly into the conduit **26**, for feeding the oil through the conduits **24** and **25**, into the upper end of the cylinder chambers. The oil at the bottom of the chambers, below the piston elements, is then forced through the respective conduits **29** and **30** into the main control valve **21** and the oil from the conduit **29** passes through the ball check valve **85**, through the duct **84** into the chamber **55**, surrounding the ports **70** through which the oil then feeds into the passageways **65**, and the oil from the conduit **30** feeds into the duct **76**, and through the one-way check valve **77** and duct **75** into the chamber **59**, surrounding the ports **67**, and then discharges into the passageways **65**. The oil is then discharged from the passageways through the slots **72**, port **73** into conduit **32**, for return through the reversing valve **27**, to the storage supply tank **39**.

In the event one of the piston elements tends to travel downwardly at a rate of speed, in excess of the other, it will result in relative rotation of the shafts **19** and **20** with respect to each other, and by virtue of which adjustment of the ports **67** and **70** with respect to the passageways **65** is effected in the same manner as above described in connection with the raising of the pistons, that is, the main control valve **21** becomes adjusted for proportionately increasing the flow of oil from the piston which is moving the slower of the two, while at the same time reducing the quantity of oil flowing from the other piston which is traveling at the higher rate of speed. During the lowering operation oil cannot flow through the ports **68** and **69** because of the one-way ball check valves **80** and **82**.

It will be noted that full oil pressure is exerted and utilized at all times for controlling movement of the pistons. Hence the arrangement may be termed a constant pressure variable volume system as distinguished from systems wherein the pressure is varied for controlling the operation of a pump or other parts of the system.

While I have herein shown and described a preferred embodiment of my invention, manifestly it is capable of modification and rearrangement without departing from the spirit and scope thereof. I do not, therefore, wish to be understood as limiting this invention to the precise embodiment herein disclosed, except as I may be so limited by the appended claims.

I claim as my invention:

1. In combination with a fluid operated motor comprising a cylinder and a piston element reciprocably movable in the cylinder, a control for the motor comprising a toothed rack, connected to and movable with the piston element, a pinion meshed with and rotatable incident to such movement of the rack, a control valve comprising a body provided with a main port and spaced apart inlet and outlet ports, check valves in said inlet and outlet ports to permit passage of fluid in only one direction therethrough, two

oppositely extending axially aligned rotatable shafts, one of said shafts having a terminal portion extending into said valve body and constituting a valve element, said shaft portion being provided with an elongated passageway, a sleeve connected to the adjacent end of the other shaft and disposed in said body in surrounding relation to said shaft portion, said sleeve being provided with axially spaced apart inlet and outlet ports normally disposed in registration with said passageway and an opening to provide direct communication between said passageway and main port, said valve body having internal chambers to provide communication between said inlet and outlet ports of the sleeve and the corresponding inlet and outlet ports of the body, one of said shafts being rigidly connected to said pinion, a source of liquid supply, a pump connected to said supply, a reversing valve, duct means connecting the pump to the reversing valve, duct means connecting the reversing valve and main port of the control valve, duct means connecting the reversing valve to one end of said cylinder, duct means connecting the opposite end of the cylinder to the inlet and outlet ports of the valve body, and duct means connecting the reversing valve to the source of fluid supply, whereby the adjustment of the reversing valve to one position, during synchronized relationship of said shafts, causes fluid to enter one end of the cylinder to move the piston element and simultaneously causes the fluid at the opposite end of the cylinder to return to said source of fluid supply, and adjustment of the reversing valve to another position, during synchronized relationship of said shafts, causes fluid to enter said opposite end of the cylinder to move the piston in an opposite direction and causes the fluid at said one end of the cylinder to return to said source of fluid supply.

2. In combination with a fluid operated motor comprising a cylinder and a piston element reciprocably movable in the cylinder, a control for the motor comprising a toothed rack, connected to and movable with the piston element, a pinion meshed with and rotatable incident to such movement of the rack, a control valve comprising a body provided with a main port and spaced apart inlet and outlet ports, check valves in said inlet and outlet ports to permit passage of fluid in only one direction therethrough, two oppositely extending axially aligned rotatable shafts, one of said shafts having a terminal portion extending into said valve body and constituting a valve element, said shaft portion being provided with two circumferentially spaced apart longitudinally extending passageways, a sleeve connected to the adjacent end of the other shaft and disposed in said body in surrounding relation to said shaft portion, said sleeve being provided with dual sets of axially spaced apart inlet and outlet ports normally disposed in registration with said passageways and an opening to provide direct communication between said passageways and said main port, said valve body having internal chambers providing communication between the dual sets of inlet and outlet ports of the sleeve and the corresponding inlet and outlet ports of the body, one of said shafts being rigidly connected to said pinion, a source of fluid supply, a pump connected to said supply, a reversing valve, duct means connecting the pump and reversing valve, duct means connecting the reversing valve and main port of the control valve, duct means connecting the reversing valve to one end of said cylinder, duct means connecting the opposite end of the cylinder to the inlet and outlet ports of the valve body, and duct means connecting the reversing valve to the source of fluid supply, whereby the adjustment of the reversing valve to one position, during synchronized relationship of said shafts, causes fluid to enter one end of the cylinder to move the piston element and simultaneously causes the fluid at the opposite end of the cylinder to return to said source of fluid supply, and adjustment of the reversing valve to another position, during synchronized relationship of said shafts, causes fluid to enter said opposite end of the cylinder to move the piston in an opposite direction and causes the fluid at said one end of the cylinder to return to said source of fluid supply.

3. A two direction fluid control valve comprising a body provided with a main port and spaced apart inlet and outlet ports, check valves in said inlet and outlet ports to permit passage of fluid in only one direction therethrough, two oppositely extending axially aligned shafts, one of said shafts having a terminal portion extending into said valve body and constituting a valve element, said shaft portion being provided with an elongated passageway, and a sleeve connected to the adjacent end of the other shaft and disposed in said body in surrounding relation to said shaft portion, said sleeve being provided with two sets of axially spaced apart inlet and outlet ports adapted to be disposed in substantially semi-registration with the passageway and a separate opening providing direct communication between said passageway and said main port, said valve body being provided with internal chambers providing communication between said inlet and outlet ports of the sleeve and the corresponding inlet and outlet ports of the body, whereby a small amount of relative rotation of one shaft with respect to the other in one direction, during either direction of flow of the fluid, increases the effective registration of one set of inlet and outlet ports of the sleeve with the passageway and decreases the effective registration of the other set of inlet and outlet ports of the sleeve with said passageway, and opposite relative rotation of said shafts, during either direction of flow of the fluid, decreases the effective registration of said one set of inlet and outlet ports of the sleeve with the passageway and increases the effective registration of said other set of inlet and outlet ports of the sleeve with said passageway.

4. A two direction fluid control valve comprising a body provided with a main port and spaced apart inlet and outlet ports, check valves in said inlet and outlet ports to permit passage of fluid in only one direction therethrough, two oppositely extending axially aligned shafts, one of said shafts having a terminal portion extending into said valve body and constituting a valve element, said shaft portion being provided with two circumferentially spaced apart longitudinally extending passageways, and a sleeve connected to the adjacent end of the other shaft and disposed in said body in surrounding relation to said shaft portion, said sleeve being provided with two sets of axially spaced apart inlet and outlet ports normally disposed respectively in substantially semi-registration with said passageways and a separate opening providing direct communication between said two passageways and said main port, said valve body being provided with internal chambers providing communication between

the sets of inlet and outlet ports of the sleeve with the corresponding inlet and outlet ports of the body, whereby a small amount of relative rotation of one shaft with respect to the other in one direction, during either direction of flow of the fluid, increases the effective registration of one set of inlet and outlet ports of the sleeve with said passageways and decreases the effective registration of the other set of inlet and outlet ports of the sleeve with said passageways, and opposite relative rotation of said shafts, during either direction of flow of the fluid, decreases the effective registration of said one set of inlet and outlet ports of the sleeve with said passageways and increases the effective registration of said other set of inlet and outlet ports of the sleeve with said passageways.

5. In combination, a pair of spaced apart hydraulically actuated motors each comprising a cylinder and a piston element reciprocably movable therein, two sets of liquid ducts connected respectively to corresponding ends of the respective cylinders, an equalizing valve connected in one set of ducts, a reversing valve connected in the other set of ducts, a duct interconnecting the equalizing valve and reversing valve, means for supplying liquid, from a source of supply, under pressure to said reversing valve, a return duct connecting the reversing valve to the source of supply, said reversing valve being adapted in one position of adjustment to supply liquid under pressure to a corresponding end of each of said cylinders and causing the liquid at the opposite ends to return to the source of supply, and adapted in another position of adjustment to supply liquid under pressure to said opposite ends of the cylinders and causing the liquid at said corresponding end of each cylinder to return to the source of supply, said equalizing valve comprising two relatively rotatable valve elements for controlling the flow of liquid to and from corresponding ends of the cylinders and between said equalizing and reversing valves, and means operably connecting said valve elements to the respective pistons, said elements being adjustable relatively to each other in response to the differential of the rate of movement of said pistons for proportionally varying the rate of flow of the liquid to or from corresponding ends of said cylinders, whereby to cause substantially equalized movement of said pistons.

6. In combination, a pair of spaced apart hydraulically actuated motors each comprising a cylinder and a piston element reciprocably movable therein, two sets of liquid ducts connected respectively to corresponding ends of the respective cylinders, an equalizing valve connected in one set of ducts, a reversing valve connected in the other set of ducts, a duct interconnecting the equalizing valve and reversing valve, means for supplying liquid, from a source of supply, under pressure to said reversing valve, a return duct connecting the reversing valve to the source of supply, said reversing valve being adapted in one position of adjustment to supply liquid under pressure to a corresponding end of each of said cylinders and causing the liquid at the opposite ends to return to the source of supply, and adapted in another position of adjustment to supply liquid under pressure to said opposite ends of the cylinders and causing the liquid at said corresponding end of each cylinder to return to the source of supply, said equalizing valve comprising two relatively rotatable valve elements telescoped one within the other and provided with suitable ports for communicating with said one set of ducts and with the said duct interconnecting the equalizing valve and reversing valve, means operably connecting said valve elements to the respective pistons, said elements being adjustable relatively to each other in response to the differential of the rate of movement of said pistons for proportionally varying the rate of flow of the liquid to or from corresponding ends of said cylinders, whereby to cause substantially equalized movement of said pistons.

7. In combination, a pair of spaced apart hydraulically actuated motors each comprising a cylinder and a piston element reciprocably movable therein, two sets of liquid ducts connected respectively to corresponding ends of the respective cylinders, an equalizing valve connected in one set of ducts, a reversing valve connected in the other set of ducts, a duct interconnecting the equalizing valve and reversing valve, means for supplying liquid, from a source of supply, under pressure to said reversing valve, a return duct connecting the reversing valve to the source of supply, said reversing valve being adapted in one position of adjustment to supply liquid under pressure to a corresponding end of each of said cylinders and causing the liquid at the opposite ends to return to the source of supply, and adapted in another position of adjustment to supply liquid under pressure to said opposite ends of the cylinders and causing the liquid at said corresponding end of each cylinder to return to the source of supply, said equalizing valve comprising two relatively rotatable valve elements telescoped one within the other and provided with suitable ports for communicating with said one set of ducts and with the said duct interconnecting the equalizing valve and reversing valve, a toothed rack extending longitudinally of each cylinder and operably connected to said pistons for movement therewith, a pinion meshing with each rack, and a pair of axially aligned shafts connected at corresponding ends to said pinions, and their opposite, adjacent ends being fixedly connected to the respective valve elements, whereby the differential rate of movement of said pistons effects relative rotative adjustment of the valve elements for proportionally varying the rate of flow of liquid to or from said corresponding ends of the cylinders to cause substantially equalized movement of said pistons.

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