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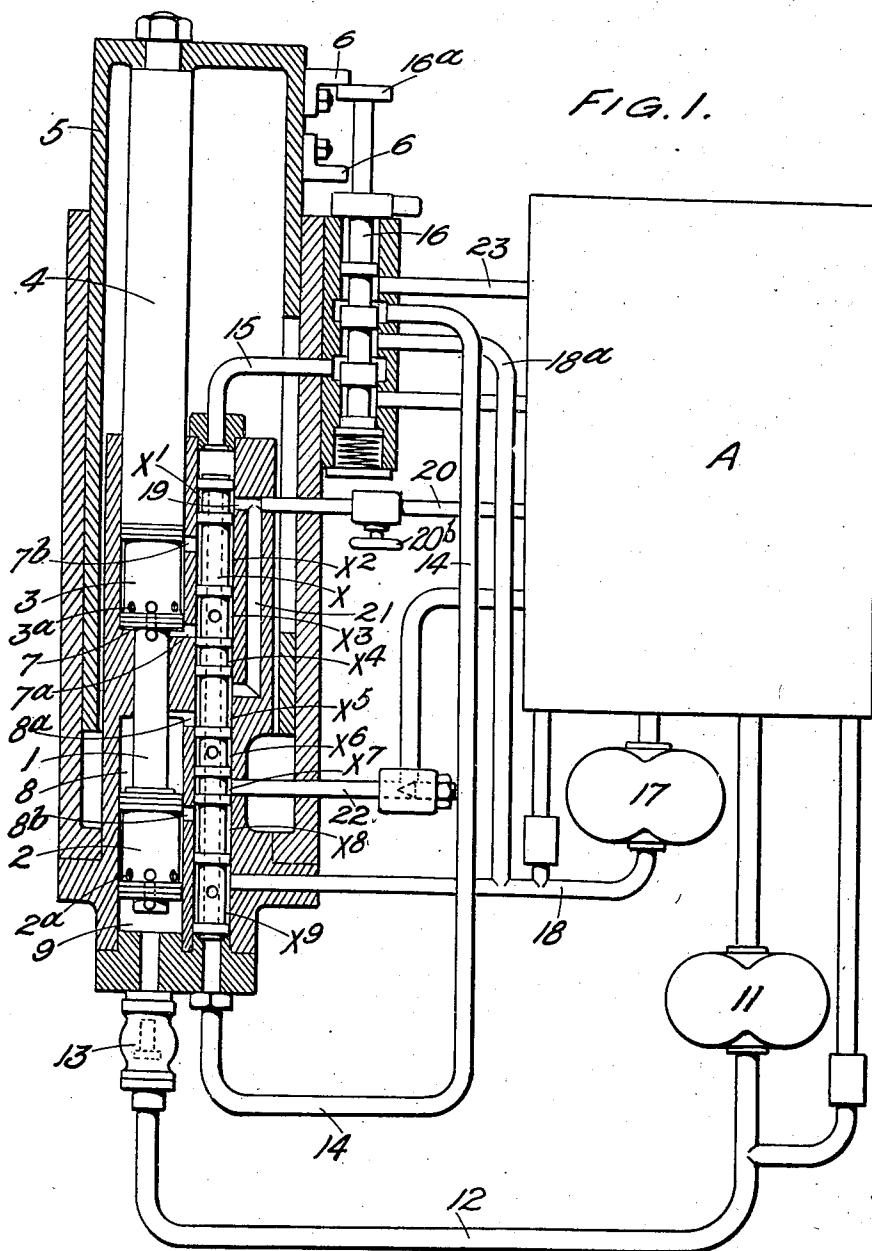
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2,216,486

HYDRAULICALLY OPERATED RECIPROCATING MECHANISM

Filed Sept. 6, 1938

3 Sheets-Sheet 1



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Oct. 1, 1940.

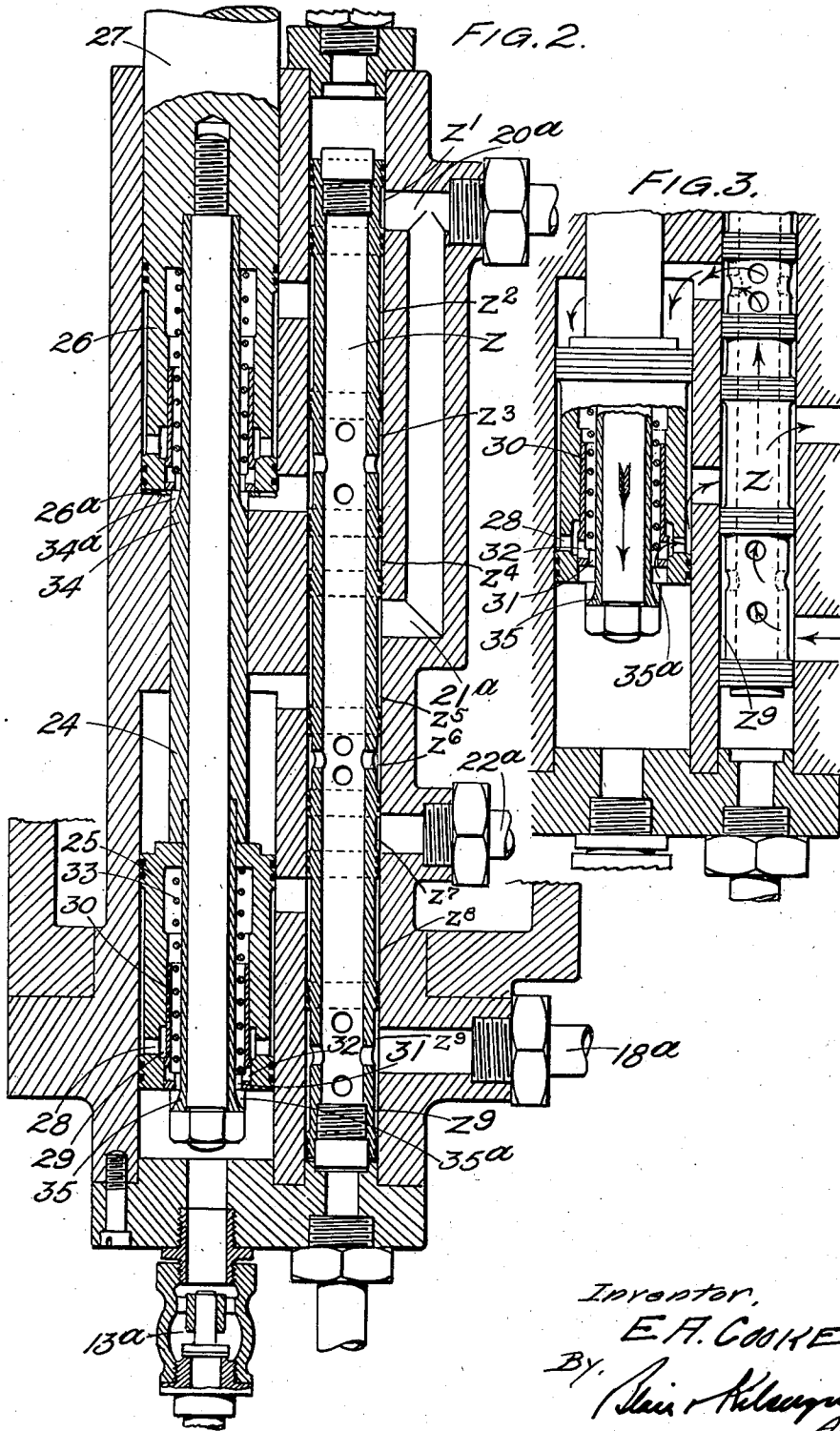
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Filed Sept. 6, 1938

3 Sheets-Sheet 2



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Oct. 1, 1940.

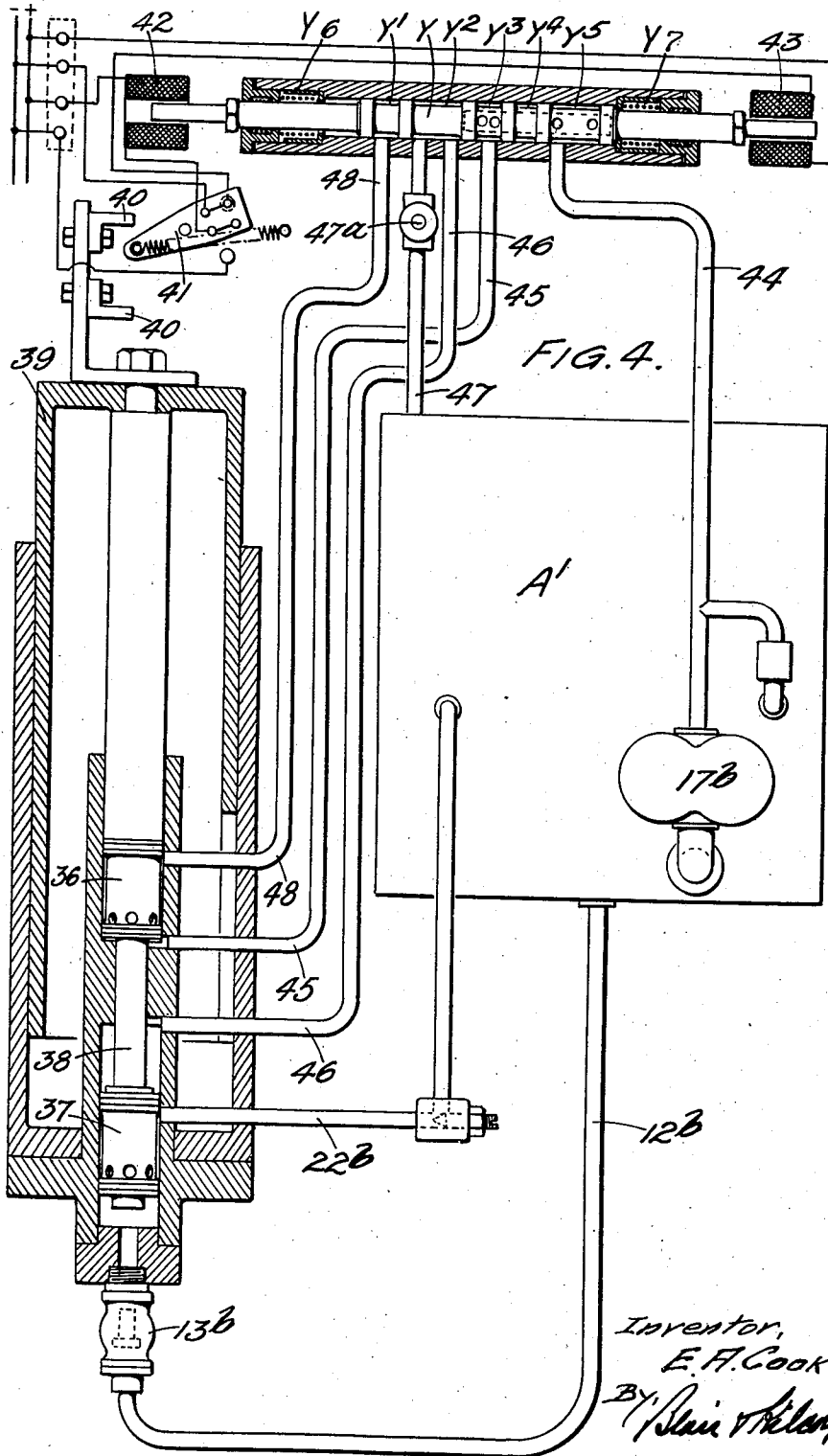
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UNITED STATES PATENT OFFICE

2,216,486

HYDRAULICALLY OPERATED RECIPROCATING MECHANISM

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Application September 6, 1938, Serial No. 228,719
In Great Britain September 17, 1937

12 Claims. (Cl. 121-45)

This invention relates to hydraulically operated reciprocating mechanism and in particular to mechanism by which a vertical reciprocation is imparted to some movable element, for example, part of a machine tool, having an appreciable weight.

The object of the invention is to provide a mechanism which will have a smooth reciprocating movement, free from shocks on reversal and with an up and down stroke of constant velocity or with very small limits of variation in velocity between them. A further object of the invention is to provide a mechanism which is independent of any pipe lines or circuits which are not incorporated in the apparatus to which the mechanism is applied and which will not be subject to air locks or other causes of disturbance.

For the sake of convenience the upper face of a piston will be referred to as an upper piston face while the under face of a piston will be referred to as an under piston face.

According to the present invention the reciprocating mechanism comprises two pistons mounted on a common rod and operating in separate cylinders, a supply of high pressure liquid being admitted from a high pressure circuit alternately to one under piston face and one upper piston face of the same effective area to cause reciprocation of the pistons while a supply of low pressure liquid from an independent low pressure circuit is admitted to the other under piston face as the pistons move upwards.

The two chambers to which the high pressure liquid is admitted alternately will be referred to as the working chambers.

The flow of liquid in the high, and in some cases also in the low pressure circuit, is controlled by one or more valves, the arrangement being such that the high pressure liquid flowing to the two working chambers does so without change of direction when the direction of movement of the pistons changes while the liquid in the low pressure circuit always flows in the same direction.

Preferably the high pressure liquid is admitted alternately to the under face of the upper piston and the upper face of the lower piston while the independent supply of low pressure liquid is admitted to the under face of the lower piston as the pistons rise.

It will be seen that the low pressure liquid provides the necessary resistance to overcome the effect of gravity upon the weight of the reciprocating elements and it will be understood that pressures in the high and low pressure circuits and the rate at which the high pressure liquid

and the low pressure liquid is allowed to escape is determined in accordance with the speed of reciprocation desired, the weight of the reciprocating elements and other factors.

The main valve is conveniently of the piston type and is reciprocated in a suitable cylinder adjacent to the working cylinders so as to control ports in the latter, the movements of this valve being effected by apparatus under the control of the working pistons. Thus this main valve may itself be hydraulically reciprocated by liquid pressure conveniently controlled by means of a pilot valve which is also preferably of the reciprocating piston type and is actuated by means of adjustable stops carried by or connected to a part of the movable element to which reciprocating movement is imparted by the working pistons.

The main valve may be provided with cushioning means to eliminate shock at the end of each stroke.

In some cases the pilot valve may be omitted and reciprocation of the main valve may be effected by means of solenoids, the circuits of which are alternately closed by means of a reversing switch actuated by the stops on the member to which reciprocation is imparted. In such a case the main valve can be simplified, and instead of being arranged in a chamber adjacent to the working cylinders, may be at any point convenient to the various pipe lines through which the high and low pressure liquid is circulated. Further, the high pressure liquid can be supplied to and exhausted from the lower cylinder through the same valve port and the low pressure exhaust pipe may remain permanently open to the lower cylinder.

In the simplest construction the annular space between the two faces of each working piston is in constant communication with the ports in the lower piston face, but in a preferred arrangement these parts are controlled by sleeve valves incorporated in the working pistons, by which pressure liquid is only admitted to the annular space around each piston when this liquid is being exhausted or discharged thereby.

Three alternative constructions are illustrated somewhat diagrammatically in the accompanying drawings, in which—

Figure 1 shows in sectional elevation a pair of working pistons controlled by a main valve and a pilot valve, the various circuits being diagrammatically shown,

Figure 2 is a vertical section on an enlarged scale of an alternative construction of working pistons provided with sleeve valves,

Figure 3 is a similar view of the lower working piston in its upper position during the discharge of low pressure liquid, and

Figure 4 is an elevation, partly in vertical section, showing an electrically operated main valve and a modified arrangement of high and low pressure circuits.

The arrangement illustrated in Figure 1 comprises a common piston rod 1 carrying a lower piston 2 and a similar upper piston 3, each operating in separate coaxial chambers. The movements of these pistons are transmitted to a ram 4 which, in effect, constitutes an extension of the upper piston 3 and carries a jacket or casing 5 to the upper end of which are secured adjustable stops 6 for controlling the pilot valve in the manner hereafter described.

The space 7 below the under face of the upper piston 3 and the space 8 above the upper face of the lower piston 2 constitute the high pressure working chambers while the space 9 below the piston 2 constitutes the low pressure chamber, to which low pressure liquid is admitted.

Mounted in a cylindrical bore, adjacent and parallel to the working pistons, is a main valve X of the piston type which is reciprocated to control the admission of high pressure liquid to and the escape of this liquid from the two working chambers, and also to control the escape of low pressure liquid from the chamber 9, as hereafter more fully described.

The low pressure liquid which may be supplied from a tank A by means of a pump 11 is at a much lower pressure than the high pressure liquid. It exerts no appreciable force on the upwardly moving pistons and is supplied through a separate supply pipe 12 provided with a non-return admission valve 13. When the piston 2 descends, the low pressure liquid escapes through an outlet port, hereafter described, controlled by the main valve X and so provides the necessary resistance to counteract the effect of gravity on the reciprocating element 5 and any member it may support.

In the construction shown, the main valve X is hydraulically reciprocated by means of a column of liquid alternately admitted through pipes 14 and 15 to opposite ends of the main valve chamber and this liquid column is controlled by means of a pilot valve 16 which is actuated by the adjustable stops 6 secured to the reciprocating element 5. The pilot valve may be at any convenient point on the machine without special reference to the position of the main valve.

The upper cylinder inlet port 7a is formed near the lower end of the upper cylinder, and the upper outlet port 7b is above it and communicates at all times with an annular recess in the upper piston 3. Ports and passages 3a in the piston 3 establish communication between the annular recess surrounding the piston and the upper working chamber 7. At the upper end of the lower working chamber 8 is a port 8a through which high pressure liquid is admitted and exhausted, and the port 8b in the lower working chamber enables low pressure liquid to be exhausted when it passes through passages 2a in the lower piston into the annular space surrounding this piston.

The above ports 7b, 7a, 8a, 8b communicate with the chamber in which the main valve X reciprocates and are controlled by the main valve as follows. The valve X comprises a hollow rod with closed ends carrying a series of spaced pistons which divide the valve chamber into a series

of spaces X^1 — X^5 , X^1 being the uppermost and X^5 being the lowest. Ports in the hollow valve rod establish communication between the interior of the rod and the spaces X^3 , X^4 and X^5 . The delivery side of the high pressure pump 17 communicates through the pipe 18 with the annular space X^3 and high pressure liquid is also supplied to the spaces X^4 and X^5 . The space X^2 is at all times in communication with the upper outlet port 7b, and when the valve moves upwards from the position shown in Figure 1, can also be brought into communication with an upper relief port 19 communicating with the liquid tank A (from which both high and low pressure pumps are supplied) by means of a pipe 20 containing a throttle 20b. The space X^5 is in constant communication, through a lower relief passage 21, with the relief pipe 20 of the high pressure circuit and can be brought into communication with the combined inlet and outlet port 8a of the lower working chamber 8. The space X^3 communicates with the low pressure outlet pipe 22 only when the valve X is raised from the position shown, whereupon the low pressure fluid passes back to the tank A through the pipe 22.

The dimensions of the spaces and position of the various ports is such that when the valve X is in its lower position, as shown, the space X^3 communicates with the upper inlet port 7a allowing high pressure liquid to enter the upper working chamber 7 and the space X^2 lies wholly below the upper relief port 19 which is closed, as it communicates only with the annular space X^1 while the outlet port 8b is similarly closed. The space X^4 communicates with the combined inlet and outlet port 8a in the lower working chamber and with the lower end of the relief passage 21. The working pistons 2 and 3 are therefore moved upwards by the high pressure liquid admitted to the upper working chamber 7 and low pressure liquid is admitted through the non-return valve 13 without exerting any appreciable force on the pistons.

When the valve X is in its upper position, the space X^2 communicates with the upper outlet port 7b and with the upper relief port 19 through which high pressure liquid in the upper working chamber 7 can be discharged through the port 3a; the space X^4 communicates with the upper inlet port 7a which is thus closed; space X^5 communicates with the combined inlet and outlet port 8a through which high pressure liquid is thus delivered to the lower working chamber 8, and the space X^3 communicates with the low pressure outlet port 8b and with the passage 22 leading back to the tank A through which the low pressure liquid in the chamber 9 can be discharged. With the valve in this position, the working pistons again descend at a rate determined by the throttling resistance in the pipes 20 and 22. This movement of the main valve is controlled by the pilot valve which is reciprocated by engagement between the stops 6 and a head 16a formed on the rod of the pilot valve 16. High pressure fluid is supplied to the pilot valve through a pipe 18a and returns to the tank A by a pipe 23. When the pilot valve is in the position shown, high pressure fluid from the pilot valve chamber is admitted into the upper end of the main valve chamber through the pipe 15; but when the pilot valve is raised the port leading to the pipe 15 is closed and liquid is admitted to the main valve chamber through the pipe 14. At each end of its stroke the movements of the main valve are cushioned as some of the liquid is trapped between

the plug at the end of the valve and the recess into which these plugs enter. The flow of high pressure liquid and hence the speed of reciprocation is controlled by means of the throttle 20b in the exhaust pipe 20, the low pressure discharge pipe 22 being also provided with a throttle, indicated in dotted lines, which will not generally require adjustment after being initially set. The general arrangement described enables a supply tank to be used which is open to the atmosphere and hence air is not trapped in the system and close control can be obtained even when comparatively heavy elements are to be reciprocated.

The alternative construction illustrated in Figures 2 and 3 shows working pistons provided with sleeve valves to control the ports in the pistons but intended for use with a similar main valve and with high and low pressure circuits as already described. It will thus be seen that the main valve Z is provided with pistons which divide it into nine annular chambers Z¹—Z⁹, already described, high pressure liquid being admitted to the hollow bore of the main valve by a pipe 18a and discharged through passages 21a and 20a. Low pressure liquid is admitted to the lower working piston through a non-return valve 13a and returned through a pipe 22a.

A common connecting rod 24 is provided with a lower working piston 25 and an upper working piston 26 to which is connected the ram 27 and a member similar to the casing 5 shown in Figure 1. Instead of the annular space surrounding each working piston communicating with the under piston face by means of ports which are constantly open, as in the construction last described, each of the working pistons is provided with a sleeve valve. The pistons are similar in this respect and the following description is intended to read only on the lower of these two similar pistons. The piston 25, as before, is provided with an annular recess in which are formed a number of radial holes 28 communicating with an annular groove 29 formed in the bore of the piston. Mounted to slide in the piston bore is a sleeve 30 having at its lower end an inwardly projecting flange 31 which is cut away so as to permit fluid to pass between the sleeve and the piston rod, and also provided with a number of radial apertures 32. The interrupted flange 31 forms an abutment for a coiled spring 33 and the downward movement of the sleeve is limited by a suitable shoulder formed on the spacer 34 (for the upper piston) or 35 (for the lower piston). Grooves 34a and 35a are formed in the shoulders so that fluid is free to pass into the bore of the piston even when the sleeve is in its lowest position. As the opposite ends of each sleeve 30 are of different effective areas, very little extra force is required to compress the light spring 33 in order to connect the apertures 32 with the holes 28 in the piston and thus to place the annular recess surrounding the piston in communication with the underside of the piston, as shown in Figure 3.

These sleeve valves 30 are intended to permit the lower piston face and the top and bottom piston rings to be used to the best advantage and to prevent piston creep. The construction provides each piston with a self-contained low pressure valve so that the cut-off X⁶ and X⁷ can be eliminated and the low pressure fluid can be evacuated from the lower cylinder without passing through the reversing valve.

On the underface of the piston 26 a small flange or projection 26a is shown so that there is an

annular clearance below the piston. Practically the whole area of this piston face is therefore exposed to pressure should the piston assume the position shown in Figure 2.

In practice, springs of different strength will be employed for the upper and lower pistons but for the purpose of this description the two constructions may be regarded as generally similar. The operation of the main valve and the way in which it cooperates with the ports in the working chambers is in accordance with the description already given with reference to Figure 1, but it will be seen that instead of the pressure liquid having constant access to the annular space surrounding each working piston, by the provision of the sleeve valves, communication is only established with such annular spaces when the pressure liquid is being exhausted or discharged.

In the simplified construction illustrated in Figure 4, the upper and lower working pistons 36 and 37 are mounted on a common connecting rod 38 and are provided with sleeve valves, as in the construction illustrated in Figures 2 and 3. The reciprocating jacket or casing 39, which is connected to the working pistons, is provided with adjustable stops 40, but instead of these stops actuating a pilot valve, as in the constructions already described, they operate a spring-controlled reversing switch 41 by which the circuits of the solenoids 42 and 43 are alternately closed so as to bring about the reciprocation of a simplified main valve. This valve Y is somewhat diagrammatically shown as mounted in a suitable housing adjacent to the switch 41, although, of course, the valve can be in any suitable position.

The valve comprises a hollow rod with closed ends, carrying a series of spaced pistons which divide the valve chamber into five spaces Y¹, Y², Y³, Y⁴, Y⁵. Ports in the hollow valve rod establish communication between the interior of the rod and the spaces Y⁵ and Y³. When the valve is in the position shown, high pressure fluid from the pump 17b enters the valve chamber through the pipe 44 and, passing through the ports in the valve rod, flows through the pipe 45 to the under working face of the upper piston 36. This causes the working pistons to rise, and the low pressure liquid enters the lower cylinder through the pipe 12b and non-return valve 13b. The high pressure liquid above the lower working cylinder is discharged through the pipe 46 into the valve chamber and thence by the pipe 47 back to the liquid tank A¹. A throttle 47a is provided in the pipe 47 by which the rate of flow of the high pressure liquid and hence the speed of reciprocation can be controlled.

Upward movement of the working pistons brings the stop 40 into contact with the operating member of the pivoted reversing switch, so that the circuit of the solenoid 43 is opened, the solenoid 42 is energised, and the valve rod is thus moved towards the left. As a result, high pressure liquid is admitted into the upper end of the lower cylinder through the pipe 46, the low pressure liquid, owing to the operation of the sleeve valve which the piston 36 contains, being returned through the pipe 22b to the tank A¹. The high pressure liquid below the upper piston 36 passes through the sleeve valve in that piston to the pipe 48 and thence through the pipe 47 back to the liquid tank A¹. The reversing switch is then again swung over so that the cycle of operations is repeated.

It will be seen that in the construction last described the low pressure pump is eliminated

and the low pressure circuit depends upon the head of liquid in the tank.

The valve illustrated is provided at either end with a spring-loaded sleeve Y⁶—Y⁷ adapted to limit the movement of the valve and to cushion its movement prior to being brought to rest, but it is to be understood that the construction is given by way of example only and that the drawings are of a relatively diagrammatic character.

It will further be appreciated that the invention is capable of a number of applications and although the constructions above described are particularly suitable for use with a machine tool such, for example, as an abrasive wheel, the invention is not limited to such use and many of the constructional details may be varied in accordance with the particular purpose to which the invention is put.

What I claim as my invention and desire to secure by Letters Patent is:

1. Hydraulically operated reciprocating mechanism comprising two working cylinders, an operating piston in each cylinder, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, means for admitting and exhausting high pressure liquid alternately to one under face of the lower piston and one upper piston face area so as to cause reciprocation of the pistons, an independent low pressure liquid supply circuit, and means for admitting low pressure liquid to the under piston face as the working pistons move upwards, and means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the pistons to counteract the effect of gravity on the pistons.

2. Hydraulically operated reciprocating mechanism comprising two working cylinders, an operating piston in each cylinder, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, a main valve adapted to control the supply and exhaust of high pressure liquid alternately to one under piston face and one upper piston face of the same effective area so as to cause reciprocation of the pistons, an independent low pressure liquid supply circuit, and means for admitting low pressure liquid to the under face of the lower piston as the working pistons move upwards, and means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the pistons to counteract the effect of gravity on the pistons.

3. Hydraulically operated reciprocating mechanism comprising two working cylinders, an operating piston in each cylinder, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, means for admitting and exhausting high pressure liquid alternately to one under piston face and one upper piston face of the same effective area so as to cause reciprocation of the pistons, an independent low pressure liquid supply circuit, means for admitting low pressure liquid to the under face of the latter piston as the working pistons move upwards, means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the pistons in order to counteract the effect of gravity on the pistons, and throttling means for restricting the passage of high pressure liquid as it is exhausted whereby the speed of reciprocation can be controlled.

4. Hydraulically operated reciprocating mechanism comprising two superimposed working cylinders, an operating piston in each cylinder, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, a main

valve adapted to control the supply and exhaust of high pressure liquid alternately to the under face of the upper piston and to the upper face of the lower piston, an independent low pressure liquid supply circuit, and means for admitting low pressure liquid to the under face of the lower piston as the working pistons move upwards, and means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the pistons to counteract the effect of gravity on the pistons.

5. Hydraulically operated reciprocating mechanism comprising two superimposed working cylinders, an operating piston in each cylinder, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, a main valve adapted to control the supply and exhaust of high pressure liquid alternately to the under face of the upper piston and to the upper face of the lower piston, an independent low pressure liquid supply circuit and means for admitting low pressure liquid to the under face of the lower piston as the working pistons move upwards and means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the pistons to counteract the effect of gravity on the pistons, the main valve being adapted also to control a port in the lower cylinder through which low pressure liquid is discharged.

6. Hydraulically operated reciprocating mechanism comprising two superimposed working cylinders, an operating piston in each cylinder, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, a main valve of the piston type adapted to control the supply and exhaust of high pressure liquid alternately to the under face of the upper piston and to the upper face of the lower piston, an independent low pressure liquid supply circuit, and means for admitting low pressure liquid to the under face of the lower piston as the working pistons move upwards, said main piston valve also controlling the exhaust port through which low pressure liquid is discharged from the lower cylinder, and means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the pistons to counteract the effect of gravity on the pistons.

7. Hydraulically operated reciprocating mechanism comprising two superimposed cylinders, an operating piston in each cylinder, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, means for alternately admitting said high pressure liquid to one under piston face and one upper piston face of the same effective area, means by which the high pressure liquid is discharged in the same direction from both cylinders when the direction of movement of the pistons changes, means for supplying low pressure liquid from an independent source to the under face of the lower piston as the pistons move upwards, means for exhausting, without change of direction, the low pressure liquid as the pistons descend and throttling means to restrict the flow of low pressure liquid as it is exhausted to counteract the effect of gravity on the pistons.

8. Hydraulically operated reciprocating mechanism comprising two working cylinders, an operating piston in each cylinder having a space surrounding the piston, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, a main valve adapted to control the supply and exhaust of high pressure liquid alternately to one under piston face and to

one upper piston face, a low pressure liquid supply admitted to the under face of the latter piston as the working pistons move upwards, a sleeve valve in each working piston adapted to permit a flow of liquid between each under piston face and the space surrounding the piston when the pressure on the under face of the piston is greater than that in the space surrounding the piston, and means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the piston to counteract the effect of gravity on the pistons.

9. Hydraulically operated reciprocating mechanism comprising two working cylinders, an operating piston in each cylinder having a space surrounding the piston, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, a main valve adapted to control the supply and exhaust of high pressure liquid alternately to one under piston face and to one upper piston face, a low pressure liquid supply admitted to the under face of the latter piston as the pistons move upwards, a sleeve valve in each working piston adapted to permit a flow of liquid between each under piston face and the space surrounding the piston, when the pressure on the under piston face is greater than that in the space surrounding the piston, means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the piston to counteract the effect of gravity on the pistons, each of said sleeve valves comprising a sleeve mounted to reciprocate in a bore formed in the working piston, one end of the sleeve being of larger effective area than the other end.

10. Hydraulically operated reciprocating mechanism comprising two working cylinders, an op-

erating piston in each cylinder having a space surrounding the piston, a common piston rod connecting the two pistons, a high pressure liquid supply circuit, a main valve adapted to control the supply and exhaust of high pressure liquid alternately to one under piston face and to one upper piston face, a low pressure liquid supply admitted to the under face of the latter piston as the pistons move upwards, a spring controlled sleeve valve in each working piston adapted to permit a flow of liquid between each under piston face and the space surrounding the piston when the pressure on the under piston face is greater than that in the space surrounding the piston, means for restricting the flow of low pressure liquid as it is exhausted during the downstroke of the piston to counteract the effect of gravity on the pistons, each sleeve valve comprising a sleeve mounted to reciprocate in a bore formed in the working piston, the lower end of the sleeve being of larger effective area than its upper end.

11. Hydraulically operated reciprocating mechanism as claimed in claim 10 in which the main valve controls only the high pressure fluid circuit and a sleeve valve included in the lower working piston controls the discharge of the low pressure liquid.

12. Hydraulically operated reciprocating mechanism as claimed in claim 7 in which the high pressure liquid circuit is controlled by the movements of a piston valve and the admission and discharge of low pressure liquid is controlled independently respectively by a non-return inlet valve and by a sleeve valve mounted in the lower working piston.

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