Feb. 7, 1961 P. L. PECCHENINO 2,970,571

HYDRAULIC STEPPING MECHANISM

Filed June 20, 1958 2 Sheets-Sheet 1

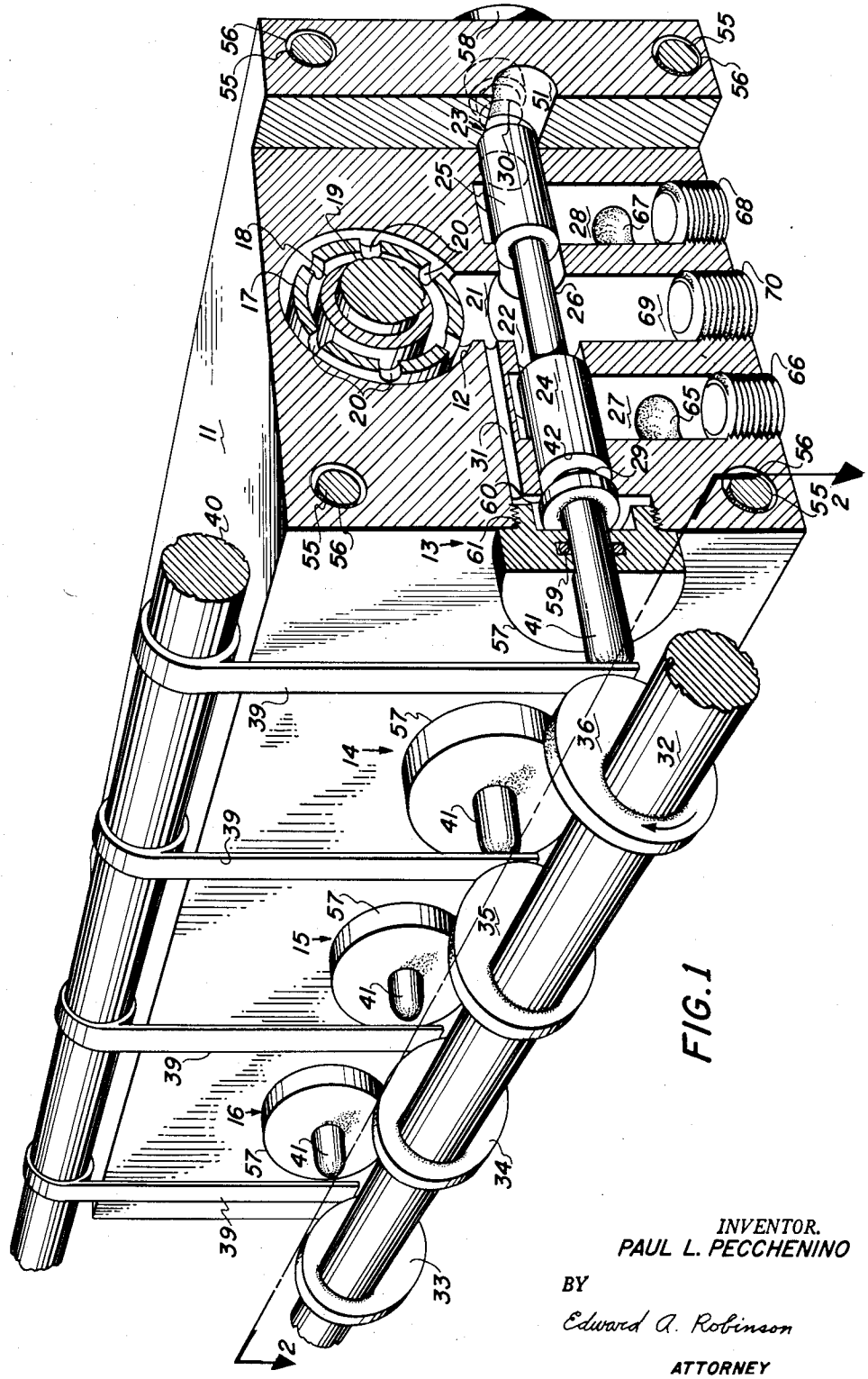


FIG. 1

INVENTOR.
PAUL L. PECCHENINO

BY
Edward A. Robinson
ATTORNEY

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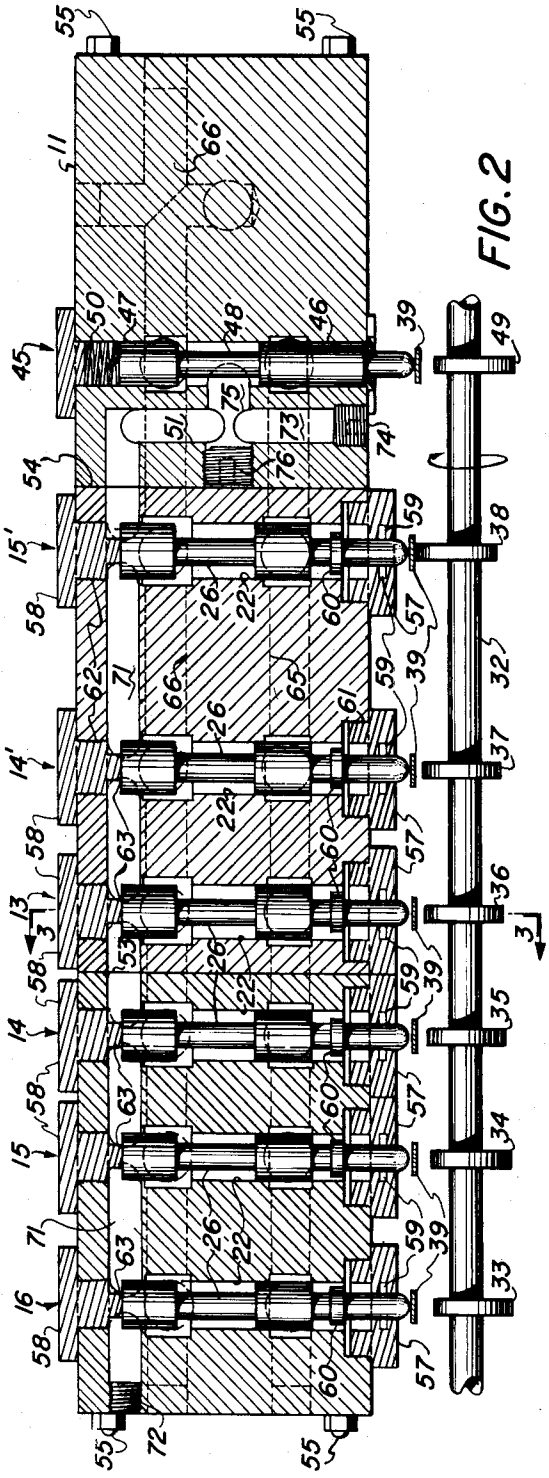


FIG. 2

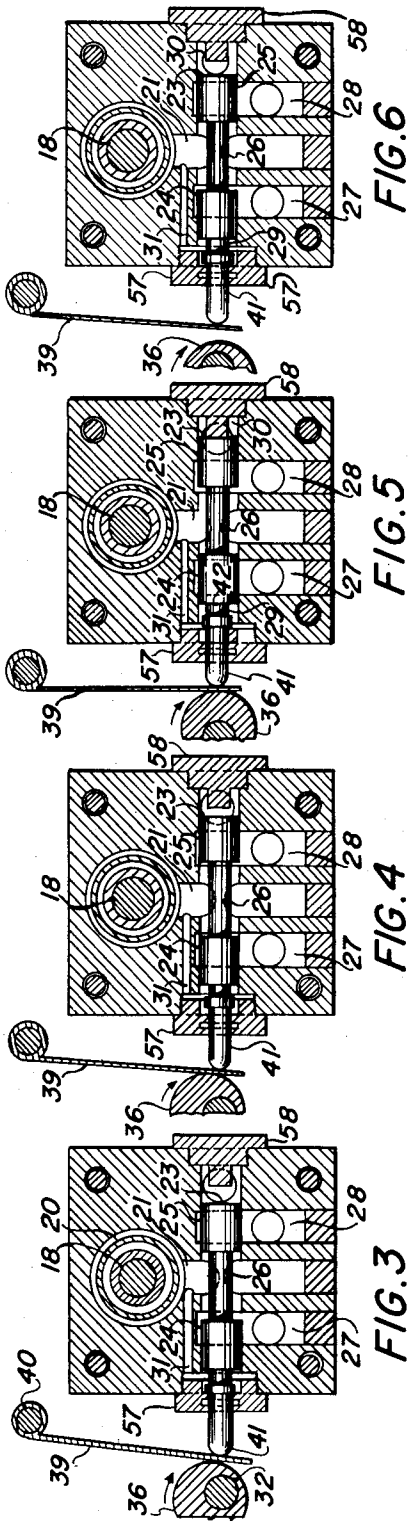


FIG. 6 FIG. 5 FIG. 4 FIG. 3

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HYDRAULIC STEPPING MECHANISM

Paul L. Pecchenino, San Jose, Calif., assignor to International Business Machines Corporation, New York, N.Y., a corporation of New York

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6 Claims. (Cl. 121—38)

This invention relates to a hydraulic drive mechanism for stepping or providing incremental movements in a timed sequence, and more particularly this invention relates to a bistable valve for hydraulically controlling such a stepping mechanism.

An object of this invention is to provide an improved hydraulic stepping drive mechanism including a plurality of bistable valves which may be sequentially activated for causing a device such as a piston adder to expand in steps and which may thence be simultaneously reset by applying hydraulic pressure to return all of the valves to an initial condition.

A further object of this invention is to provide an improved hydraulic valve having two stable conditions such that it will remain closed until mechanically actuated and thence will remain open until restored to the closed position by hydraulic pressure.

According to a preferred embodiment of this invention, each of the hydraulic valves includes a spool having spaced apart enlarged sections to form a cavity for passing hydraulic fluid therethrough. In an initial or reset position, the cavity provides a hydraulic connection for exhausting fluid from an actuating cylinder of a piston adder. A cycle of operation is commenced by a sequencing cam which engages and moves the valve spool from the first position thereby closing an exhaust port and slightly opening a pressure port to admit fluid under pressure into the central cavity and to the actuating device. Fluid under pressure is then conducted from the central cavity to an expandable end cavity whereupon the pressure drives the spool to a second position completely uncovering the pressure port. The valve spool is held in the second position by continued hydraulic pressure until an auxiliary reset valve is opened to admit hydraulic fluid under pressure into a second end chamber to drive the valve spool back to the first position where it will remain until again actuated by the cam in another cycle of operation.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings which disclose, by way of example, the principle of the invention and the best mode which has been contemplated of applying that principle.

In the drawings:

Fig. 1 is a perspective view of the stepping mechanism of this invention with a section taken through one of the control valves associated with the piston adder.

Fig. 2 is a horizontal section along the plane 2—2 of Fig. 1 somewhat reduced in size.

Figs. 3, 4, 5 and 6 are all similar vertical sections along the plane 3—3 of Fig. 2 and illustrating a control valve during a cycle of operation with the valve spool shown in various positions.

As shown in Fig. 1, the hydraulic stepping mechanism comprises a cylinder block 11 having a longitudinal bore 12 for containing a piston adder and having a plurality of bistable control valves 13, 14, 15 and 16. A piston

adder is positioned in the bore 12, which is similar in arrangement to a piston adder shown in Fig. 1 of U.S. Patent 2,197,867, and may include a sleeve 17 extending through the bore 12 with a plurality of pistons such as 18 mechanically linked together with piston rods such as 19. The sleeves 17 may include ports 20 which hydraulically connect to an actuator port 21 from each of the control valves 13 through 16. As described in Patent No. 2,197,867, the incremental stepping movement is accomplished by successively applying pressure to the spaces between adjacent pistons within the sleeve 17 such that the pistons successively expand or move apart by increments of displacement determined by the linkage coupling the adjacent pistons together.

Each of the valves 13 through 16 is formed by a transverse bore 22 extending through the block 11 and having a valve spool 23 slidable therein. The spool is arranged with two portions of enlarged diameter 24 and 25 and with an intermediate portion of reduced diameter 26 forming a cavity or chamber centrally disposed and always connecting with the actuation port 21. The central cavity will pass hydraulic fluid between the actuation port 21 and either an exhaust port 27 or a pressure port 28, depending upon the position of the valve spool 23.

In addition to the shiftable central cavity, two cavities 29 and 30 are formed at the ends of the valve spool 23; these cavities are expandable and compressible as the valve spool 23 moves. A bore or opening 31 is provided in the block 11 to permit the passage of hydraulic fluid from the central cavity to a first of the end cavities 29. The sequencing and timing of the various valves is accomplished by a cam shaft 32 which carries therewith a plurality of cams or eccentrics 33 through 38, each cam being associated with a particular valve. A plurality of dogs 39 are pivotally mounted on a shaft 40 (see Fig. 1) and function to minimize the frictional wear upon a protruding end 41 of each of the valve spools 23. At the beginning of each cycle of operation, each of the valve spools 23 is in a first position (to the left in Figs. 1 and 3), and the central cavity provides a fluid connection between the actuation port 21 and an exhaust port 27. Likewise, the passage 31 permits the first end chamber or cavity 29 to stand at reduced or exhaust pressure. In such condition, each of the valves is stable, there being no force tending to move the valve spool away from the first position.

At first it was thought wise to include a compression spring in the second end cavity 30 to bias and retain the valve spool 23 in the first position for guarding against a possible shifting due to vibration effects and the like. However, actual practice has proved the biasing spring to be unnecessary, and therefore it has been eliminated from the structure and is not shown in the drawings.

The cycle of operation is commenced by the cams 33 through 38 which rotate and sequentially depress or move the various valve spools 23. As each valve spool 23 moves from the first position, the exhaust port 27 is closed and nearly simultaneously the pressure port 28 is uncovered by the enlarged portions 24 and 25 of the valve spool 23. When the pressure port 28 is uncovered, hydraulic fluid under pressure passes into the central chamber of the valve, and thence to the actuation device through the port 21. Simultaneously, hydraulic fluid under pressure passes through the conduit 31 to the first end cavity 29 and a net pressure is exerted against an end surface of the spool 42, see Fig. 1. This pressure causes the spool 23 to shift toward the right (as shown in Fig. 5). Therefore, it will be appreciated that the valve spool 23 will be driven to a second position and held in place by hydraulic fluid under pressure which

has been passed into the first end cavity 29. The valve then remains open in a second stable condition until a subsequent reset operation.

As shown in Fig. 2, the hydraulic stepping mechanism may include six control valves 13, 14, 15, 16, 14' and 15' and a reset valve 45. The reset valve 45 is of conventional design having a spool with two enlarged end sections 46 and 47 and a central cavity surrounding a reduced center section 48. After all of the control valves have been sequenced by the cams 33 through 38, and the initial stepping operation has been completed, a further cam 49 mechanically moves the spool of the valve 45 against the restraining force of a compression spring 50, whereupon the enlarged section 46 closes over an exhaust port while the enlarged section 47 opens a pressure port to admit fluid under pressure into the central cavity surrounding the reduced portion 48. A fluid conduit 51 connects between the valve 45 and all of the control valves for passing the fluid under pressure into the second end cavity 30 of each control valve. The fluid in the second end cavity 30 may exert pressure against an effective area of each spool 23 which is greater than the area of the surface 42, and therefore a net force is provided to move each of these spools from the second position to the first position. Subsequently, the cam 49 releases the valve 45 and the compression spring 50 thence causes the spool to close off the pressure port and to open the conduit 51 to exhaust.

The operation of each of the control valves may be seen from Figs. 3 through 6 wherein the valve spool 23 is shown at various points or positions. Fig. 3 illustrates the valve in an initial stage of operation, and it may be noted that the enlarged portion 25 of the spool 23 covers and seals off the pressure port 28 while the other enlarged portion 24 fails to completely seal off the exhaust port 27. In Fig. 3, the cam 36 has mechanically engaged the extending end 41 and is moving the valve spool 23 from the first position, but since the exhaust port 27 remains uncovered, the control valve is still closed and the actuation device 18 remains at the low sump or exhaust pressure. In Fig. 4, the cam 36 has advanced and shifted the valve spool 23 to seal off the exhaust port 27 whereupon the pressure port 28 is about to be opened. Fig. 5 shows the cam 36 progressed still further forcing the valve spool 23 from the first position completely sealing the exhaust port and opening the pressure port 28. With the pressure port 28 opened, hydraulic fluid under pressure will pass into the central chamber of the valve surrounding the reduced portion 26 and will thence pass through the actuation port 21 to the actuating device 18. Simultaneously, the fluid under pressure will pass through the hydraulic conduit 31 to the first end chamber 29 whereupon the pressure exerted against the surface 42 will move the valve spool 23 to the right (as illustrated in Fig. 5) thereby expanding the end chamber 29 while compressing the second end chamber 30. As shown in Fig. 6, the valve spool 23 has shifted to a second position (to the right) under the driving force of hydraulic pressure within the first end chamber 29 such that the extending end 41 has disengaged from the cam 36. The dog 39 may continue to follow the extending end 41, or it may lay against the cam 36, its position being immaterial.

As shown in Figs. 1 and 2, the cylinder block 11 may be sectionalized to facilitate manufacture, and the various sections may be butted together in joints 53 and 54 which may be accurately machined to retain oil pressure or which may include gaskets. Studs or bolts 55 may extend longitudinally through drilled holes 56 thereby holding the various sections of the cylinder block 11 together in a single rigid mass. The actuating device 18 may be assembled separately in the sleeve 17 and may have enlarged portions or circular gaskets for preventing hydraulic fluid from circulating longitudinally of the cylinder block through the bore 12 from the various actuator ports 21. As shown in Figs. 1 and 2, each of the valves is included in a transverse bore through the cylinder block, which bore is closed at the ends by caps or plugs 57 and 58. The cap 57 closes the first end of the bore and partially forms the first end cavity 29 of each valve, and therefore an opening is provided for the outward extending end 41 of the valve spool 23 and included therewith is an oil seal ring 59. The valve spool 23 is provided with an end collar 60 which functions merely as a stop to limit the travel of the valve spool 23. Each of the valve caps 57 and 58 are secured in place by threads 61 and 62. The end chamber 29 at the first end of the bore is enlarged by counter boring prior to the threading operation, and therefore the threads 61 of the cap 57 are of a greater diameter than the threads 62 of the cap 58. The plug 58 associated with each of the control valves is engaged in the end of the bore 22 by the threads 62 and is provided with an inwardly extending stop 63 (see Fig. 2). The stop 63 engages the end of the spool 23 and limits the travel thereof as the spool moves to the second position.

As shown in Fig. 1, the conduit or passage 31 may be formed by drilling a hole parallel with the principal bore of the valve from the enlarged counterbored end and into the actuation port 21. Thus, the conduit 31 may be formed in the cylinder block 11 by a straight drilling operation which will afford economy in manufacture. It must be pointed out, however, that the means for passing oil from the central cavity of each valve to the first end cavity may be accomplished by methods other than the straight drilled hole 31 as shown in Fig. 1. One such alternative may be to drill a hole through the enlarged portion 24 of the valve spool 23, and therefore it must be appreciated that the hydraulic means for passing oil to the first end chamber 29 may be associated with either the cylinder block 11 or with the valve spool 23. A further possible alternative to the drilled hole 31 may be the simple scoring of the valve spool along the enlarged diameter portion 24 or the scoring of the cylinder wall of the bore over the equivalent area. However, if this alternative is employed, further means must be provided to isolate the exhaust port 27 from the scored channels which would replace the conduit 31.

Fig. 1 further illustrates a simplified manufacturing method of providing the valves with exhaust and pressure ports 27 and 28 as well as with an actuator port 21. The ports 27 and 28 are provided by drilling and machining spaced apart holes into the valve bore 22 from a side external to the block 11. A longitudinal hole or bore 65 connects with a sump or low pressure source of hydraulic fluid and is positioned to intersect each of the bores forming the exhaust ports 27. These bores are then provided with plugs 66 at each valve location. Similarly, a longitudinally extending pressure conduit 67 connects with all of the pressure ports 28 which are likewise closed by plugs 68. In the case of the actuator port 21, a hole 69 is drilled upwardly intermediate to the pressure and exahust ports. However, the hole 68 intersects with and extends through the bore 22 continuing upwardly into the bore 12 of the actuation device, when a plug 70 is provided at the lower end of the hole 69 the connection remains to the actuator device solely.

To provide a fluid conducting means from the reset valve 45 to the second end cavity of each of the control valves, a longitudinal bore 71 is drilled through each of the sections of the block 11 containing the control valves. A plug 72 will close off the bore 71 at one end thereof. At the section containing the reset valve 45, the block is provided with a transverse bore 73 connecting with the bore 71 and having a plug 74 closing one end thereof. A short longitudinally extending bore 75 intersects the transverse bore 73 and connects with the central cavity of the reset valve 45. A plug 76 is provided to retain the fluid pressure without resorting to a special seal at the joint 54 between the sections of the block 11. All of the aforementioned plugs 66, 68, 70, 72, 74 and 76

are threaded into their respective openings and may be provided with a socket into which an Allen wrench may be inserted such that the plugs will be flush with and will not protrude outwardly from the cylinder block **11**.

A cycle of operation is initiated as the cams **33** through **38** rotate and successively engage and move the valve spools **23** of the various control valves. As each valve spool is moved from the first stable position (to the left in Figs. 1, 3, 4, 5 and 6) the exhaust port thereof is sealed off and fluid under pressure is admitted to the central cavity. This fluid under pressure is bypassed through the conducting means **31** to the first end chamber **29** whereupon the spool **23** is caused to move by hydraulic action to a second position (to the right as shown in Fig. 5). The operation of each valve is timed or sequenced by the cam associated therewith, and therefore can be accurately and critically adjusted by adjusting the position of the particular cams upon the cam shaft **32**. As shown in Fig. 1, the valve **13** has its spool **23** moved to a critical firing position wherein the exhaust port **27** is covered and wherein the pressure port **28** is about to be uncovered. When the cam **36** moves the valve spool **23** slightly further, the hydraulic fluid under pressure from the port **28** will be passed through the central cavity and the conduit **31**, and will cause the valve to snap fully open and remain in a second stable state. Thus, by properly orienting all of the cams **33** through **38**, the successive valves may be caused to operate in succession with precise timing to advance the actuating mechanism in precise timed steps. After the actuation mechanism has completely expanded, the cam **49** operates the reset valve **45** and all of the control valves are reset simultaneously. The timing of the reset operation is not critical.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to the preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. A bistable valve for controlling flow of hydraulic fluid to actuate a device, said valve comprising a valve body having a bore therein, a spool movable within the bore having enlarged and reduced portions forming a centrally disposed cavity and two end cavities, means hydraulically connecting the central cavity to the actuating device, an exhaust port associated with the bore and positioned to hydraulically connect with the central cavity when said spool is in a first position, a pressure port associated with the bore and positioned to hydraulically connect with the central cavity when the spool is moved from the first position, a means hydraulically connecting the central cavity with a first of the end cavities whereby the spool will be hydraulically urged to a second position to pass fluid under pressure to the actuating device, and means for cyclically admitting fluid under pressure into the second end cavity to return the spool to the first position.

2. A bistable valve mechanism for controlling flow of hydraulic fluid for cyclically actuating a device, said valve mechanism comprising a valve body having a bore therein, a spool movable within the bore having enlarged and reduced portions forming a centrally disposed cavity and two end cavities, means hydraulically connecting the central cavity with the actuating device, a pressure port and an exhaust port spaced apart along the bore, said exhaust port being positioned to connect with the central cavity when the spool is in a first position within the bore, said pressure port being positioned to connect with the central cavity when the spool is in a second position, a cam means for cyclically engaging and moving the spool from the first position, means hydraulically connecting the central cavity with a first of the end cavities whereby fluid under pressure is admitted into the first end cavity to move and hold the spool in the second position in response to the cam means, and means for cyclically admitting fluid under pressure into the second end cavity to return the spool to the first position, and a reset means including a hydraulic connection to the second end cavity whereby fluid under pressure will return the spool to the first position.

3. A bistable valve mechanism for controlling flow of hydraulic fluid for cyclically operating a device, said valve mechanism comprising a valve body having a bore therein, a spool movable within the bore having enlarged and reduced portions forming a central cavity movable with the spool and two end cavities expandable as the spool moves, said valve body having three ports connecting with and spaced along the bore, a first of the ports hydraulically connecting with the actuating device and positioned at the central cavity, a second of the ports connecting with a low pressure source for exhausting hydraulic fluid and positioned to connect with the central cavity only when the spool is in a first position in the bore, the third port connecting with a high pressure source and positioned to connect with the central cavity when the spool is moved from the first position, said valve body having a fluid conduit connecting between the bore at the central cavity and a first of the end cavities for passing fluid under pressure to expand the first end cavity and drive the spool to a second position when the spool is initially moved away from the first position.

4. A hydraulic stepping mechanism comprising an actuation device, a plurality of control valves hydraulically associated with the actuation device, a rest valve, and a sequenching device mechanically coupled to the control valves and to the reset valve, each of said control valves including a movable valve spool having enlarged and reduced portions forming a shiftable central cavity and two end cavities which expand and contract oppositely as the valve spool is moved, the central cavity of each control valve being hydraulically connected to the actuation device, exhaust means associated with each control valve for exhausting fluid from the central cavity when the spool is in a first position, pressure means associated with each control valve for passing fluid under pressure into the central cavity when the spool is moved from the first position, said sequenching device being operable to move the spools of the control valves in a timed sequence and thence to operate the reset valve, each of the control valves having hydraulic means connecting the central cavity with a first of the end cavities whereby each valve spool is hydraulically driven to and held at a second position when the sequenching device initiates movement thereof, said reset valve being hydraulically connected to the second end cavity of all of the control valves and being operable to pass fluid under pressure thereto whereby the valve spools of all of the control valves are hydraulically driven back to the first positions.

5. A hydraulic stepping mechanism comprising a cylinder block containing an actuation device, a plurality of control valves and a reset valve, each of the control valves being formed from a bore in the cylinder block and having a movable valve spool with enlarged and reduced portions forming a shiftable central cavity and two end cavities which expand and contract oppositely as the spool moves, said cylinder block having a hydraulic connection between the actuation device and the central cavity of each control valve, said cylinder block having an exhaust conduit connecting with each valve at the central cavity when the spool is in a first position, said cylinder block having a pressure conduit connecting with each valve at the central cavity when the spool is moved from the first position, said cylinder block having a conduit associated with each valve for passing fluid from the central cavity to a first of the end cavities for moving and holding the spool in a second position after the spool

has been initially moved from the first position, said cylinder block having a conduit connecting the reset valve to the second end cavity of each of the control valves for returning each of the valve spools to the first position when the reset valve is operated.

6. The hydraulic stepping mechanism in accordance with claim 10 wherein each of the valve spools extends outwardly of the cylinder block and wherein a cam shaft is provided having thereon a separate cam operatively associated with each of the valve spools, each of the cams being mechanically coupled to engage and move a respective valve spool to provide a timing sequence for

causing an initial movement of the spool from the first position whereupon hydraulic fluid under pressure admitted to the first end cavity will move and retain the spool in a second position.

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UNITED STATES PATENT OFFICE

CERTIFICATION OF CORRECTION

Patent No. 2,970,571 February 7, 1961

Paul L. Pecchenino

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 33, for "rest" read -- reset --; column 7, line 7, for the claim reference numeral "10" read -- 5 --.

Signed and sealed this 13th day of June 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

UNITED STATES PATENT OFFICE

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