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FAST ACTING FLUID ACTUATOR

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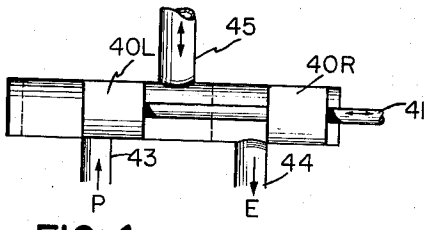


FIG. 4

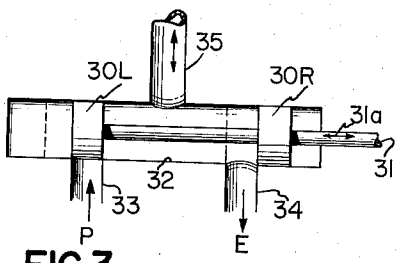


FIG. 3

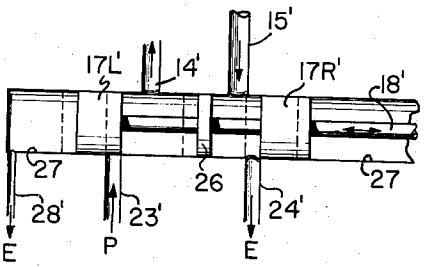


FIG. 2

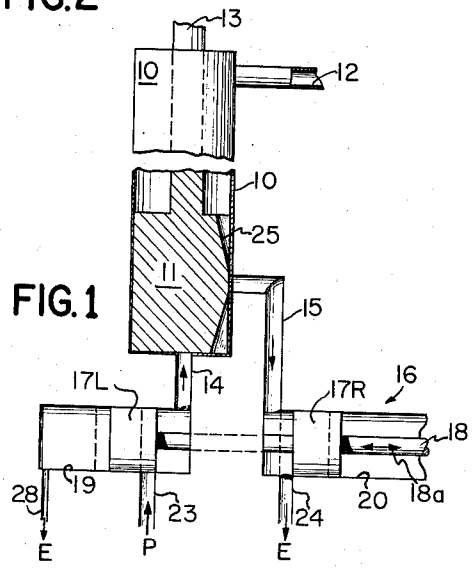


FIG. 1

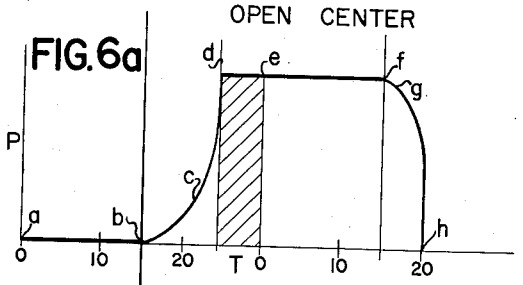


FIG. 6a

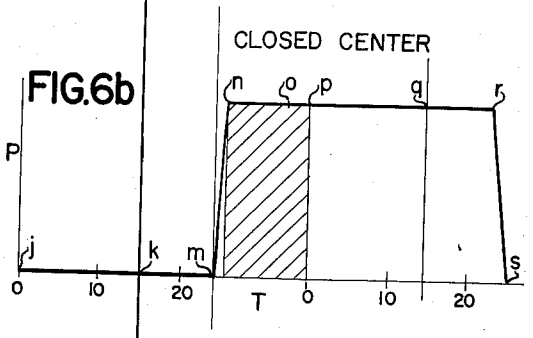


FIG. 6b

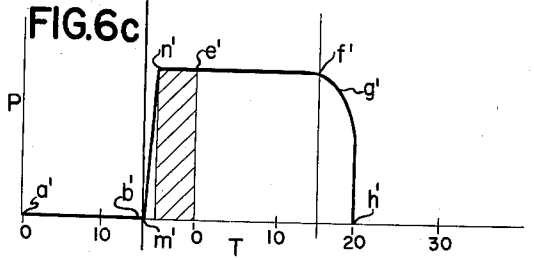


FIG. 6c

FIG. 6

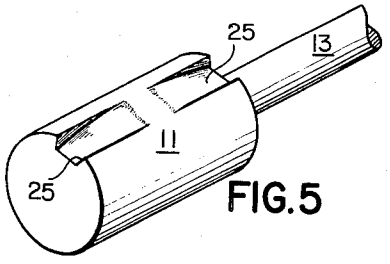


FIG. 5

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FAST ACTING FLUID ACTUATOR

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This invention pertains to fluid actuators and more particularly to a fluid actuator having a sharp acceleration in its driving stroke as well as a high speed return stroke to provide an overall high speed operation particularly useful in computers employing positioning systems using aggregative volumes of fluid, sometimes referred to as the so-called "glob adders."

A typical "glob adder" will usually include several pistons, each of which is designed to displace a predetermined coded volume or "glob" of liquid into a common manifold which in turn leads to a slave piston coupled to any suitable mechanism requiring positioning. Thus, by selectively displacing combinations of these volumes, the slave piston can be driven a distance corresponding to the total volume of liquid displaced. Where "glob adders," as described, are used in data processing machines they must operate fast enough so as not to become a handicap to the speed of the overall data processing operation which usually functions at electronic speeds. Therefore, the pistons of the adder unit must be quickly displaceable between their limits of operation, i.e., actuation and reset of these pistons must occur as quickly as possible to keep up with the rest of the data processing operation. In the past, one of two types of valves have generally been employed to actuate the adder pistons, i.e., an "open center" spool valve or a "closed center" spool valve. The former has the disadvantage that fluid pressure is lost to sump during actuation, thereby imparting a slower driving movement to the driven piston. However, the "open center" valve gives an immediate and precipitous drop in pressure during the return or "reset" stroke of the adder unit piston. Using the "closed" center valve, the actuating pressure driving the adder unit piston builds up very rapidly once it begins, but the valve stroke is twice as long as that in an open center valve and hence there is delay in initiating actuation. According to the present invention the advantages of both "open" and "closed" center valves have been combined while eliminating the disadvantages of each.

Therefore, it is an object of the present invention to provide an improved fluid actuator.

It is a more particular object of the present invention to provide a fluid actuator having a sharp pressure buildup on its driving stroke with a minimum amount of delay in commencing such buildup.

It is another object of the present invention to provide a fluid actuator capable of both a high speed driving and return stroke.

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 schematic elevation view of the invention, partly in section.

Fig. 2 shows an alternative embodiment of the spool valve of the invention.

Figs. 3 and 4 show an open center valve and a closed center valve of the prior art.

Fig. 5 is a perspective view of the actuator piston of the invention.

Fig. 6 is a composite graph of three small interrelated graphs, Figs. 6*a*, 6*b* and 6*c* schematically showing the plot of pressure, P, against time, T, for an open center valve, a closed center valve, and the fluid actuator of the present invention respectively.

Referring to the open center valve of Fig. 3 and to its operational characteristic shown in Fig. 6*a*, it is comprised of a pair of spools **30**, designated **30L** and **30R** respectively, formed integrally on a shaft **31** which can be driven leftward to the dotted position shown within a valve cylinder **32**. Shaft **31** is driven by an electromagnetic solenoid connected thereto and represented schematically by arrow **31***a*. Cylinder **32** is provided with a fluid pressure supply port **33** and an exhaust port **34** for passing fluid to and from a pipe **35** which drives a suitable actuator piston (not shown) coupled thereto. The displacement of spools **30** the righthand position shown in Fig. 3 causes the lefthand spool **30L** to completely cover port **33** and the righthand spool **30R** to completely open port **34**. This is the starting position for a cycle of operation and is represented as point *a* on the graph of Fig. 6*a*.

Starting at point *a*, a cycle is commenced by energizing solenoid **31***a*. However, a short period elapses between energizing solenoid **31***a* and the start of movement by spools **30**. This initial movement of spools is represented as point *b* and therefore the distance *a* to *b* defines what can be described as "solenoid dead-time" which has been conventionalized as one standard amount throughout the following descriptions and graphs of Figs. 6*b* and 6*c* to enable a comparison to be made therebetween. This "dead-time," of course, will vary between various solenoids as well as with other suitable valve control devices utilized for the purpose. As soon as shaft **31** begins its leftward movement (point *b*), port **33** commences opening while port **34** is closing. However, the fluid pressure in pipe **35** will not commence any substantial increase until port **34** has become approximately three quarters closed (point *c*) due to the fact that up to this point fluid entering cylinder **32** has been escaping directly through port **34** to sump, in lieu of forcing its way up pipe **35**. Hence, the pressure buildup in pipe **35** commences rather gradually, becoming fairly substantial starting approximately at point *c* and continuing to point *d*, which represents the full pressure condition of the open center valve of Fig. 3, i.e., the dotted position thereshown. Thus, the spool movement time is represented by the distance along coordinate T between point *b* and point *d*. After an indeterminate period which includes the balance of the actuator piston's stroke and a suitable dwell, solenoid **31***a* is reversed starting with energization at point *e* resulting in initiation of spool movement to the right (in Fig. 3) starting at point *f*. A substantial drop in pressure occurs after spool **30R** has opened port **34** about a quarter of the way (point *g*) and continues until it has returned to sump pressure, ordinarily one atmosphere (point *b*). Thus, as will become clear from a comparison with the closed center valve to be described below, the open center valve has a rather quick overall return time, i.e., point *e* to point *h* but has an extended overall actuating time, point *a* to point *d*. Also it is to be noted that the open center valve provides an undesirable "surge" of fluid directly into the sump each time it is actuated.

The closed center valve of Figs. 4 and 6*b* is similar to the open center valves except that its spools **40** are

twice as thick as spools 30 due to the fact that ports 43 and 44 are never open at the same time. Thus, to pressurize the pipe 45 shaft 41 is driven commencing at point *k*, leftward to the dotted position shown in Fig. 4. This action causes spool 40R to close port 44 entirely (point *m*) before spool 40L commences to uncover port 43, thereby building up the pressure in pipe 45 quite abruptly (to point *n*) once it begins. Maximum pressure is reached before spools 40 have been moved to their maximum displacement, which occurs by time *o*. Thus, in operation actual movement time of shaft 41 is substantially twice that of shaft 31 while the total elapsed time required to reach full pressure is approximately the same for both. However, in the closed center valve, the pressure buildup is much more rapid once commenced, i.e., point *m* to *n* than in the open center valve (*b* to *d*). The overall return time commencing after indeterminate time as described above, at point *p* includes a period of solenoid "dead-time" (*p* to *q*) plus one half the total actual movement time of shaft 41 (*q* to *r*) followed by a pressure drop (*r* to *s*) substantially as rapid as the pressure buildup during the driving stroke (*m* to *n*).

As stated above, fast overall actuating and return times are highly desirable in data processing machine applications as described above. Therefore, as can be seen by referring to Fig. 6*c*, the high speed features of both the open center and closed center valves have been incorporated into the structure of the present invention while at the same time removing most of the time lags of the two valves.

Referring to Fig. 1, the present invention is there shown comprising an actuator cylinder 10 containing a movable piston 11 therein, best shown in Fig. 5. Piston 11 is pressure biased to the position shown in Fig. 1 by fluid entering via a hose 12 connected to the upper end of cylinder 10. A strong spring, of course, could serve the same purpose. Where piston 11 performs a "glob adder" function as described above, it would normally not be provided with an output shaft. However, the foregoing actuating and reset requirements as described, are obviously not unique to the application mentioned and hence piston 11 in the drawings has been provided with an output shaft 13 for use in the more usual positioning situations. At the lower end of cylinder 10 there is provided a fluid pressure inlet 14 and a fluid pressure outlet 15 for admitting and exhausting fluid to and from cylinder 10 respectively. The flow of fluid via inlet 14 and outlet 15 is controlled by the position of a spool valve designated generally by the arrow 16 which includes a pair of spools 17L and 17R mounted upon a shaft 18 driven by a suitable actuating device, such as an electromagnetic solenoid, represented schematically by the arrow 18*a*. Spools 17L and 17R operate within their own valve cylinders 19 and 20 respectively. Cylinder 19 is connected to a pressure source represented by the letter P via a conduit 23 whereas cylinder 20 is connected so as to exhaust fluid from cylinder 10 via a conduit 24 into a sump, represented by the letter E. Cylinder 19 is also provided with a small return or "bleed" line 28 leading to sump E for keeping cylinder 19 drained. Finally, as best seen in Fig. 5, piston 11 has been provided with a pair of tapered damping slots 25 which decelerate the emovement of piston 11 at each end of its stroke by gradually reducing the fluid flow via outlet 15 and hose 12 respectively as piston 11 arrives thereat.

In operation, shaft 18 is actuated leftwardly to the dotted position shown, thereby uncovering conduit 23 and closing conduit 24. With the arrangement shown, there is no way for fluid to escape directly from conduit 23 to conduit 24 except by passing through cylinder 10 which in turn causes piston 11 to be driven upwardly without the usual gradual pressure buildup commonly associated with the open center valve described above. By the time piston 11 has moved sufficiently to uncover outlet 15, spool 17 has had time to close conduit 24 thus maintaining the pressure built up beneath piston 11, thereby driving piston 11 quickly to the upper end of cylinder 10. As piston 11 approaches the upper end of cylinder 10, fluid exhausting via hose 12 against the bias pressure therein is gradually reduced by the upper slot 25 in piston 11 until the periphery of piston 11 seals the opening to hose 12 thereby stopping piston 11 at that point. Thus, it can be seen by referring to Fig. 6 that the short "throw" (and resultant reduced actuation time) of an open center valve has been combined with the abrupt pressure buildup of a closed center valve, to increase the overall speed of actuation of piston 11, as shown in Fig. 6*c*.

When it is desired to return piston 11 to its original position as shown in Fig. 1, shaft 18 is actuated to the right thereby exhausting fluid from cylinder 10 via outlet 15 and conduit 24 while at the same time closing conduit 23 to cut off the pressure to inlet 14. This action produces a return stroke characteristic for piston 11 comparable to that shown for the open center valve. Again, as in the actuating stroke, piston 11 on its return stroke will be damped in the same way by the gradual reduction in fluid flow via outlet 15 due to the action of the lower slot 25. Referring to Fig. 6, it will be seen that the graph there drawn has purposely omitted this damping characteristic for purposes of clarity in explanation. Further, it is to be understood that these graphs are somewhat schematic as shown, for purposes of emphasizing the comparisons being made, in that rather abrupt unrealistic angular corners are shown in the traces thereof.

Referring to Fig. 2, an alternative embodiment of the valve structure of Fig. 1 is there shown which has the advantage of being easier to manufacture and assemble. It comprises a shaft 18′ having a pair of spools 17′ similar in structure and function to those shown in Fig. 1 plus an intermediate spool 26 for isolating conduit 23′ from conduit 24′ during the actuation of shaft 18′ which in this way prevents the direct passage of fluid from pressure, P, to exhaust E. As thus arranged, a single valve cylinder 27 can be drilled into a housing to form a pair of movable chambers positionable to couple or decouple pressure and exhaust to cylinder 10. Also, as provided in Fig. 1 there is a small return or "bleed" channel 28′ arranged to the left of spool 17L′ for draining and maintaining the left end of valve cylinder 27 free of fluid. The operation of the embodiment shown in Fig. 2 is substantially the same as that shown in Fig. 1 and therefore has not been described.

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 fluid actuator comprising a cylinder, a first source of fluid under pressure, a second source of fluid under pressure, the pressure of said second source being less than the pressure of said first source, first coupling means for coupling and decoupling said first pressure source to to said cylinder, second coupling means for coupling and decoupling said cylinder to said second pressure source to define a fluid path from said first pressure source to said second pressure source through said cylinder, said first coupling means being hydraulically isolated from, but operatively associated with, said second coupling means and arranged to couple said first source to said cylinder while said second coupling means is decoupling said cylinder from said second source and vice versa, and

a piston longitudinally displaceable within said cylinder, said piston being arranged to substantially decouple said cylinder from said second pressure source temporarily until said second coupling means has substantially decoupled said cylinder therefrom, whereby a rapid acceleration is imparted to said piston upon coupling said first pressure source to said cylinder.

2. A fluid actuator comprising a closed cylinder, a first source of fluid under pressure, a second source of fluid under pressure, the pressure of said second source being less than the pressure of said first source, first coupling means for coupling and decoupling said first pressure source to said cylinder, second coupling means for coupling and decoupling said cylinder to said second pressure source to define a fluid path from said first pressure source to said second pressure source through said cylinder, said first coupling means being hydraulically isolated from and operatively associated with said second coupling means and arranged to couple said first source to said cylinder while said second coupling means is decoupling said cylinder from said second source and vice versa, and a piston longitudinally displaceable within said cylinder, said piston being arranged to interrupt said path through said cylinder at one extreme of its displacement to temporarily substantially decouple said cylinder from said second pressure source until said second coupling means has substantially decoupled said cylinder therefrom, whereby a rapid acceleration is imparted to said piston upon coupling said first pressure source to said cylinder.

3. A fluid actuator comprising a closed cylinder, a source of fluid under pressure, means for supplying fluid from said pressure source to said cylinder, a sump, means for exhausting fluid from said cylinder to said sump to provide a fluid channel through said cylinder, a first valve means for controlling said fluid supply to said cylinder, a second valve means for controlling said fluid passing from said cylinder, said first valve means being operatively associated with said second valve means and arranged to couple said pressure source to said cylinder while said second valve means decouples said sump from said cylinder and vice versa, and a piston longitudinally displaceable within said cylinder and arranged to substantially decouple said cylinder from said sump temporarily until said second valve means has substantially decoupled said cylinder from said sump, whereby a rapid acceleration is imparted to said piston.

4. A fluid actuator comprising a closed cylinder, a source of fluid under pressure, means for supplying fluid from said pressure source to said cylinder, a sump, means for exhausting fluid from said cylinder to said sump to provide a fluid channel through said cylinder, a first valve means for controlling said fluid supply to said cylinder, a second valve means for controlling said fluid passing from said cylinder, said first valve means being operatively associated with said second valve means and arranged to couple said pressure source to said cylinder while said second valve means decouples said sump from said cylinder and vice versa, and a piston longitudinally displaceable within said cylinder and arranged to interrupt said channel at one extreme of its displacement to substantially decouple said cylinder from said sump temporarily until said second valve means has substantially decoupled said cylinder from said sump, whereby a rapid acceleration is imparted to said piston.

5. A fluid actuator comprising a cylinder, a piston arranged to move between a first and second position within said cylinder, a fluid inlet within said cylinder for admitting fluid under pressure to said cylinder, a fluid outlet in said cylinder for exhausting said fluid from said cylinder, valve means operable in one condition to simultaneously open said inlet and close said outlet to drive said piston from said first position, said outlet being arranged with respect to said cylinder to be maintained temporarily closed by said piston when positioned at said first position to prevent said fluid from exhausting therethrough as said valve means begins opening said inlet, thereby allowing said valve means time to substantially close said outlet before said piston can move sufficiently to open said outlet to direct substantially all of said fluid against said piston to impart a rapid acceleration thereto from said first position.

6. A fluid actuator comprising an actuator cylinder, a piston movable within said actuator cylinder between a first and second position, a valve cylinder, an inlet channel and an outlet channel coupling said cylinders, means for supplying fluid under pressure via said valve cylinder to said inlet, means for exhausting fluid from said outlet via said valve cylinder, piston means defining a pair of isolated movable chambers within said valve cylinder, said chambers being interposed between and arranged in a first condition to simultaneously couple said inlet to said fluid supply means while decoupling said outlet to said fluid exhaust means and operable in a second condition to reverse said first condition, one end of said outlet channel being located in the interior wall of said cylinder so as to be maintained temporarily closed by the side of said piston when positioned at said first position to prevent said fluid from exhausting through said outlet channel as said chambers commence entry into said first condition, thereby allowing said valve means time to substantially close said outlet before said piston can move sufficiently to open said outlet to direct substantially all of said fluid against said piston to impart a rapid acceleration thereto from said first position.

7. A fluid actuator comprising a cylinder, a piston arranged to move between a first and second position within said cylinder, means for applying a bias force to said piston tending to maintain said piston at said first position, a fluid inlet within said cylnder for admitting fluid under pressure to said cylinder, a fluid outlet in said cylinder for exhausting said fluid from said cylinder, valve means operable in a first condition to open said inlet and close said outlet to drive said piston from said first position, said outlet being arranged with respect to said cylinder to be maintained temporarily closed by said piston when positioned at said first position to prevent said fluid from exhausting therethrough as said valve means begins opening said inlet, thereby allowing said valve means time to substantially close said outlet before said piston can move sufficiently to open said outlet, said valve means being operable also in a second condition to close said inlet while opening said outlet to return said piston to said first position under the action of said biasing force, whereby a rapid acceleration is imparted to said piston in each direction of its travel.

8. The invention according to claim 7 wherein said outlet is formed in the interior side wall of said cylinder and wherein said piston includes an elongated taper slot in its peripheral surface oriented lengthwise of said piston to provide damping of said piston in the region of said outlet.

9. A fluid actuator comprising a cylinder, a piston movable within said cylinder between a first and second position therein, means for applying a bias force to said piston tending to maintain said piston at said first position, a fluid inlet in said cylinder, a fluid outlet in said cylinder, means for supplying fluid under pressure to said inlet, means for exhausting fluid from said outlet, coupling means interposed between said fluid supply means and said inlet and between said fluid exhaust means and said outlet, said coupling means being operable in a first condition to couple said inlet to said fluid supply means while decoupling said outlet from said fluid exhaust means and operable in a second condition to reverse said first condition, said outlet being further positioned with respect to said cylinder and said piston so as to be maintained temporarily closed by the side of said piston when said piston is located at said first posi-

tion to prevent fluid from passing directly from said inlet to said outlet before said coupling means has substantially fully closed said outlet as said first condition commences to rapidly accelerate said piston from said first position to said second position and as said second condition commences to rapidly reduce the fluid pressure within said cylinder to permit said bias force to rapidly accelerate said piston from said second position to said first position.

10. The invention according to claim 9 wherein said coupling means comprises a spool valve and valve cylinder defining a pair of isolated movable chambers.

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