

United States Patent

[11] 3,559,538

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3,296,942	1/1967	Nelson	92/85X
3,323,422	6/1967	Freese	91/409X
3,382,772	5/1968	Kampert et al.	92/85X
3,388,634	6/1968	Madland	91/409X
3,425,498	2/1969	Bick	91/409X

FOREIGN PATENTS

488,918	2/1954	Italy	91/408
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[54] **ACTUATOR**
13 Claims, 6 Drawing Figs.

[52] **U.S. Cl.**..... **92/85,**
91/409

[51] **Int. Cl.**..... **F01b 11/02**

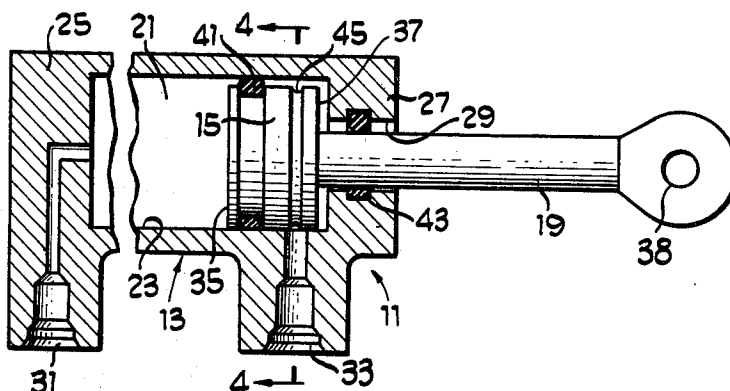
[50] **Field of Search**..... **91/392,**
409, 408; 92/80, 85, 82

[56] References Cited

UNITED STATES PATENTS

1,953,674	4/1934	Dean	91/409
2,152,712	4/1939	Stevens	91/409
2,607,323	8/1952	Kromhout	92/85X
2,695,008	11/1954	Freeman	92/85X
2,935,047	5/1960	Ortman et al.	91/408X

ABSTRACT: A fluid operated piston-type actuator having a movable piston in an operating cylinder including means for deceleration of the piston upon reaching the limit of its stroke. The piston and operating cylinder cooperate to define a contracting deceleration chamber and a restricted orifice flow passage communicating between the deceleration chamber and the fluid discharge conduit. As the piston reaches the terminal portion of its stroke, the passage limits the rate of fluid discharge from the deceleration chamber to control the deceleration of the actuator. The deceleration means is arranged to insure consistent application of the established deceleration properties.



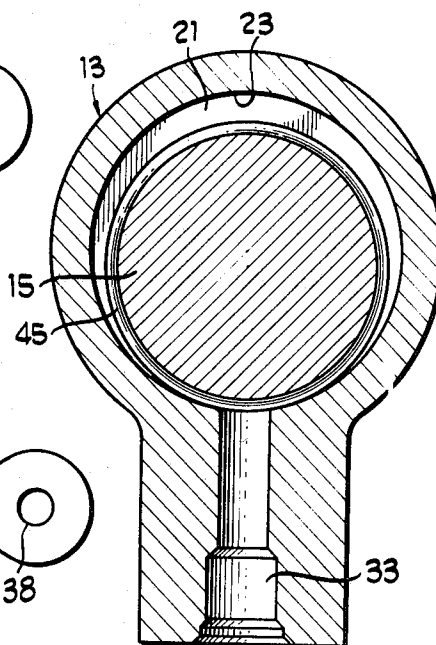
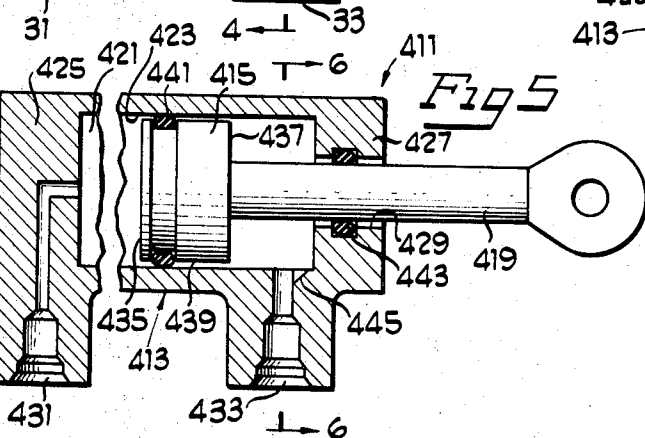
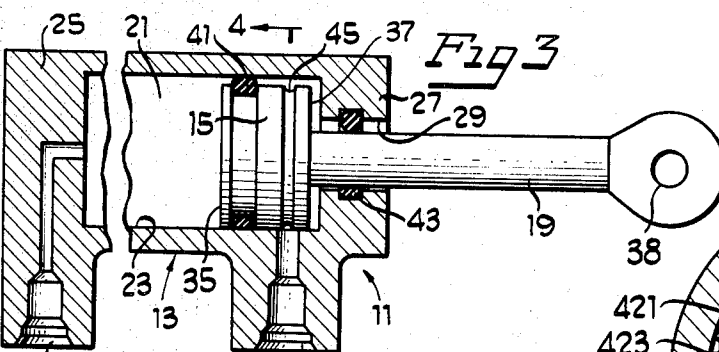
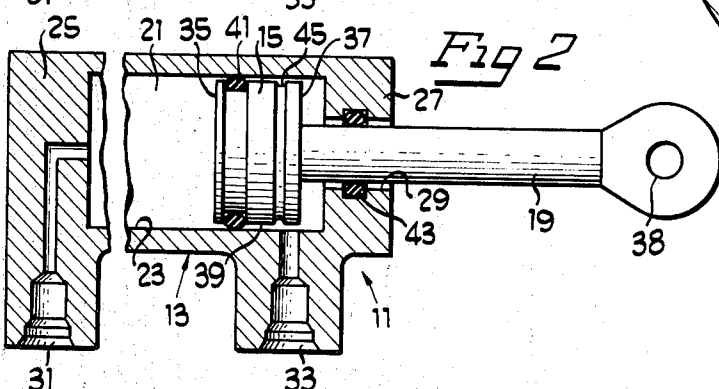
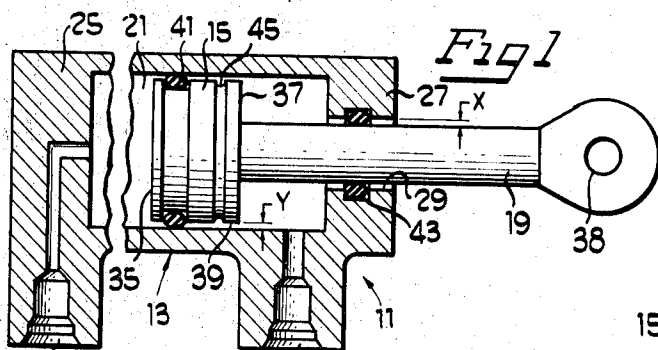


Fig 4

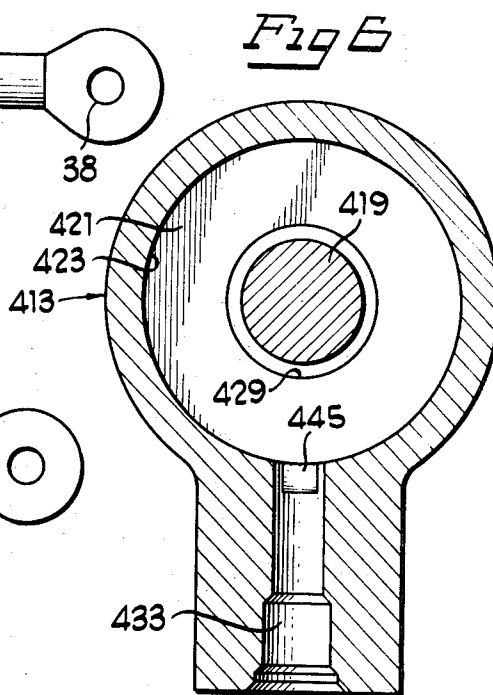


Fig 6

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ACTUATOR

BACKGROUND OF THE INVENTION

This invention relates to fluid operated piston-type actuators. More particularly, it relates to piston-type actuators including means for controlling deceleration as the actuator nears the terminal portion of its stroke.

Mechanical actuators are utilized to provide physical mm movement in response to the application of hydraulic pressure to one or the other side of a reciprocal piston. They include an operating shaft connected to the piston and extending from the operating cylinder into association with a mechanical mechanism. Normally, these actuators have some means for decelerating the piston and shaft as the piston nears the terminal portion of its stroke. These deceleration means, often referred to as "snubbers," provide controlled deceleration to prevent damage associated with impact of the piston with the cylinder end wall.

Generally, deceleration is provided by trapping a portion of the hydraulic fluid being discharged from the cylinder by virtue of movement of the operating piston toward one end wall and causing the fluid to pass through a restricted orifice to convert the kinetic energy to heat.

Deceleration means existing prior to this invention were complex in nature and required either separately formed passages in the operating cylinder, nonmetallic seals exposed to substantial pressure differentials, assemblages of separate elements, or check valves in the discharge line. As a result, machining and assembly procedures were complex and functional weaknesses prevalent.

In addition, in many forms of prior deceleration means, accurate control of the size of the restricting orifice, both during machining of the actuator components and during operation, was extremely difficult. As a result, desired deceleration rates were difficult to establish and maintain. A typical example of this problem is illustrated by the commonly used deceleration means which includes a buffer chamber associated with the operating cylinder and a buffer piston associated with the movable piston. The diametral clearance between the buffer chamber and buffer piston establishes the restricting orifice size and rigid control of manufacturing and assembly tolerances is necessary to provide desired performance.

The present invention is directed to an improved form of piston-type actuator which includes a deceleration means which eliminates these prior inherent design faults. The deceleration means of the present invention does not require separately formed passages in the operating cylinder, check valves in the discharge conduit, separately formed elements associated with the piston or cylinder, or nonmetallic seals exposed to extreme pressure differentials.

It further provides accurate control of the piston deceleration rate while minimizing the complexity of providing and maintaining a restricted orifice flow path of desired size.

SUMMARY OF THE INVENTION

Very generally the present invention is directed to a fluid operated piston-type actuator including means for decelerating the piston during the terminal portion of the stroke. The actuator includes a reciprocable piston disposed in an operating cylinder and movable in response to the application of fluid pressure to one or the other side of the piston. The piston and cylinder, during the terminal portion of the stroke, define a deceleration chamber which traps a quantity of operating fluid. The piston and cylinder further define a restricted orifice flow path communicating between the deceleration chamber and discharge conduit which controls the rate of flow of the fluid to provide the decelerating force.

One embodiment of the invention includes a peripheral groove formed in the piston communicating between the deceleration chamber and the discharge conduit. Another embodiment includes a groove formed in the operating cylinder which cooperates with the piston peripheral surface to define the restricted flow path.

The scope of the invention further contemplates the provision of diametral clearance between the piston peripheral surface and the cylinder and between the operating shaft and cylinder in a relationship such that transverse shifting of the piston with respect to the cylinder is accommodated to the extent that intimate contact between the portions of the piston and cylinder defining the restricted orifice flow path is assured to provide consistent application of the desired deceleration properties.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional elevational view of a fluid operated piston-type actuator embodying the principles of the present invention.

FIGS. 2 and 3 are cross-sectional elevational views of the apparatus shown in FIG. 1 illustrating certain elements of the apparatus moved to different operating positions.

FIG. 4 is a cross-sectional elevational view of the apparatus of FIG. 1 taken generally along the line 4-4 of FIG. 3.

FIG. 5 is a cross-sectional elevational view of a fluid operated piston-type actuator illustrating a slightly modified form of the invention.

FIG. 6 is a sectional view of the apparatus of FIG. 5 taken generally along the line 6-6 of FIG. 5.

DETAILED DESCRIPTION

Turning now to the drawings, FIGS. 1 through 4 illustrate a fluid operated piston-type actuator illustrative of the principles of the present invention.

The actuator, generally designated 11, includes an operating cylinder 13, a reciprocable piston 15, and an operating shaft 19.

The operating cylinder 13 defines an elongated operating chamber 21 within which is disposed the reciprocable piston 15 and which includes an inner cylindrical surface 23 and end walls 25 and 27. The end wall 27 includes an aperture 29 through which the operating shaft 19 extends.

Fluid communication conduits 31 and 33 are provided in the operating cylinder which direct operating fluid to the operating chamber 21 adjacent its opposite ends. These conduits are in fluid communication with a source of fluid under pressure (not shown) such as a hydraulic pump or the like, which provides pressurized fluid as necessary at one or the other end of the operating chamber to move the operating piston toward one or the other end wall 25 or 27 to extend or retract the operating shaft 19. While the fluid source contemplated is a hydraulic system, any other suitable fluid system may be utilized.

In the illustrated embodiment, the fluid communication conduit 33 extends through the inner cylindrical surface 23 of the operating chamber 21 at a point spaced from the end wall 27. This relationship is necessary to provide the deceleration means of the present invention as will become apparent shortly. The opposite fluid communication conduit 31 extends through the end wall 25 into communication with the operating chamber 21. If deceleration of the actuator operating shaft in both directions of travel were desired, the conduit 31 would be disposed, with respect to end wall 25, in a manner similar to the relationship of the conduit 33 with the end wall 27.

The piston 15 is disposed in the operating chamber 21 and divides the chamber into two separate portions which are either contracting or expanding depending upon the direction of piston movement. It includes a pair of transverse, generally planar surfaces 35 and 37 which are acted upon by the pressurized fluid entering one or the other portions of the operating chamber to extend or retract the operating shaft 19. The operating shaft 19 is disposed generally coaxially of the piston 15 and chamber 21 and is secured to the piston at the surface 37.

The piston 15 further includes an outer peripheral surface 39 which is disposed in closely spaced sliding relation to the inner cylindrical surface 23 of the operating cylinder 21.

The peripheral surface 39 includes a groove adjacent the transverse planar surface 35 within which is disposed an O-ring seal 41 which provides an essentially fluid tight seal between the portions of the chamber on opposite sides of the piston 15. A second O-ring seal 43 is disposed in an appropriately formed groove in end wall 27 to provide an essentially fluid tight seal with the operating shaft 19. O-ring seals 41 and 43, as can be seen in FIGS. 3 and 4, also function as compressible biasing means urging the piston 15 away from the surface 23. The operating shaft 19 is provided with a connector 38 at its free end. The shaft is connected to a movable mechanism (not shown) at the connector to transmit movement of the operating shaft to the mechanism to perform a desired function.

In accordance with the present invention, the outer peripheral surface 39 is provided with a circumferential groove 45 disposed adjacent the transverse planar surface 37. This groove cooperates with the inner cylindrical surface 23 of the operating cylinder 13 to define a restricted orifice flow path as will be explained. The cross-sectional area of the groove, which may be readily formed by simple machining techniques, establishes the orifice size and consequently the deceleration rate. Desired deceleration properties may therefore be easily established.

Extension and retraction of the operating shaft 19 and the consequent movement of the mechanical mechanism to which it is attached is accomplished by applying a pressurized fluid to one or the other of the fluid communication conduits 31 and 33. At the same time, the other of the fluid communication conduits is connected to low pressure such as the sump of the fluid system to allow fluid trapped in the contracting portion of the cylinder to escape. For example, to extend the operating shaft 19, the fluid communication conduit 31 is connected to a source of high pressure and the fluid communication conduit 33 is connected to low pressure. The pressurized fluid acts upon the transverse planar surface 35 and urges the piston toward the end wall 27. The fluid trapped between the planar surface 37 and end wall 27 is expelled from the cylinder through the conduit 33. This contracting portion of the operating chamber was previously filled with fluid during retraction of the operating shaft when high pressure fluid was admitted through the fluid communication conduit 33.

As the piston 15 moves to the position shown in FIG. 2, the outer peripheral surface 39 begins to cover the fluid communication conduit 33. This reduces the effective orifice area of the conduit 33 and fluid flow from the chamber becomes restricted. The transverse planar surface 37, end wall 27 and the portion of the inner cylindrical surface 23 between the conduit 33 and end wall 27 define a deceleration chamber containing a quantity of trapped fluid.

The portion of the outer peripheral surface 39 of the piston 15 exposed at the fluid communication conduit 33 is subjected to the relatively low pressure existing in that conduit. The remainder of the peripheral surface is exposed to high pressure both from the source of fluid under high pressure entering through the conduit 31 and from the quantity of fluid being compressed between the transverse planar surface 37 and the end wall 27. These two sources of fluid under pressure enter the clearance between the outer peripheral surface of the piston 15 and the inner peripheral surface 23 of the operating cylinder 13. As a result and as illustrated in FIGS. 3 and 4, the piston is caused to shift transversely toward the communication conduit 33 eliminating essentially all clearance between the piston peripheral surface 23 at that area. This in turn maximizes the clearance between these two surfaces at a location spaced 180° from the position of the conduit 33.

Trapped fluid in the defined deceleration chamber passes through the clearance between the piston outer peripheral surface and the inner cylindrical surface 23 into the groove 45 circumscribing the piston 15. This groove defines with the inner cylindrical surface of the operating chamber 21 a restricted orifice flow path communicating between the

deceleration chamber and the fluid communication conduit 33. This flow path limits the rate of flow from the chamber and thereby provides controlled deceleration of the piston 15 and operating shaft 19.

The desired deceleration flow rate is easily established by sizing of the peripheral groove 45. Transverse shifting of the piston toward the fluid communication conduit 33 eliminates essentially all clearance between the piston and cylinder at that area and the critical cross-sectional area of the passage defined by the groove 45 and the inner cylindrical surface is essentially equal to the cross-sectional area of the groove. Therefore, accurate control of desired flow rate may be established when machining the groove 45 in the piston 15 and consistent provision of the desired flow orifice size is always insured during operation.

It is important to note that in order to insure adequate transverse shifting of the piston 15 toward the fluid communication conduit 33 the clearance designated x in FIG. 1 between the operating shaft 19 and the aperture 29 must be greater than the clearance designated y between the piston peripheral surface 39 and the inner cylindrical surface 23.

Further, the peripheral groove 45 must be disposed with respect to the transverse planar surface 37 in a relationship such that as the piston moves toward the wall 27, the passage defined by the groove 45 comes into communication with the fluid communication conduit 33 before the outer peripheral surface 39 of the piston completely covers the conduit 33 so that a communication passage between the deceleration chamber and conduit 33 will always exist.

When the operating shaft is to be retracted the fluid communication conduit 33 is placed in communication with high pressure and the conduit 31 is placed in communication with low pressure. The portion of the outer peripheral surface 39 of the piston 15 covering the conduit 33 is therefore exposed to higher pressure than the remainder of the peripheral surface causing the piston to shift transversely away from the conduit and maximize the clearance at that area. Therefore incoming high pressure fluid is free to enter the portion of the operating chamber 21 defined by the piston transverse planar surface 37, inner cylindrical surface 23 and end wall 27 to urge the piston toward the end wall 25.

If deceleration in the direction of operating shaft retraction is desired, a second groove such as the groove 45 must be provided upon the piston on the opposite side of the O-ring seal 41. Also, the fluid communication conduit 31 must be disposed in relation to the end wall 25 as the fluid communication conduit 33 is disposed with respect to the end wall 27.

Turning now to FIGS. 5 and 6, there is shown a slightly modified form of the invention. In this embodiment there is provided a fluid operated piston-type actuator generally designated 411 including an operating cylinder 413, a reciprocable piston 415 and an operating shaft 419.

The cylinder 413 is essentially identical to that of the embodiment of FIGS. 1 to 4 and defines an operating chamber 421. It includes an inner cylindrical surface 423 and end walls 425 and 427. The end wall 427 includes an aperture 429 which receives the operating shaft 419.

Fluid communication conduits 431 and 433 are provided as in the previously described embodiment. The conduit 433 extends through inner cylindrical surface 423 at a point spaced from the end wall 427.

The piston 415 divides the chamber 421 into two separate portions. It includes a pair of transverse, generally planar surfaces 435 and 437. The operating shaft 419 is connected to the piston 415 at the surface 437.

The piston further includes an outer peripheral surface 439 disposed in closely spaced sliding relation to the inner cylindrical surface 423 of the operating cylinder 413. The peripheral surface includes a groove within which is disposed an O-ring seal 441 which provides an essentially fluid tight seal between the separated portions of the chamber. A similar O-ring seal is provided between the end wall 427 and the operating shaft 419.

A groove 445 is provided in the inner cylindrical surface 423 which extends from the fluid communication conduit 433 toward the end wall 427.

High pressure applied at the conduit 431 causes the piston 415 to move toward the end wall 427 urging fluid from the contracting portion of the chamber 421 through the fluid communication conduit 433.

As the piston covers the conduit 433 the transverse planar surface 437, end wall 427 and the portion of the inner cylindrical surface 423 between the conduit 433 and end wall 427 define a deceleration chamber containing a quantity of trapped fluid.

As a portion of the outer peripheral surface 439 of the piston 415 becomes exposed to low pressure at the communication conduit 433 the piston is caused to shift transversely to minimize the clearance between the peripheral surface 439 and the inner cylindrical surface 423 at the area of the conduit 433. Thus, the only communication between the deceleration chamber and fluid communication conduit 433 is through the groove 445. Because of the minimization of piston-to-cylinder clearance the size of the groove as provided during initial machining defines the restricted area flow path between the deceleration chamber and the fluid communication conduit 433. Desired deceleration characteristics can therefore be readily provided and consistent application of the deceleration properties over prolonged periods of operation insured.

This later embodiment of the invention includes an additional advantage. The groove 445 is formed at an angle with respect to the inner cylindrical surface 423 in the direction of operating shaft extensions. Therefore as the piston peripheral surface 439 covers a greater portion of the groove the cross-sectional area of the restricted area flow path is reduced. Since the velocity of the piston, and therefore the piston load mass becomes reduced as the piston nears the wall 427, a relatively constant deceleration rate may be provided.

As can be seen, a fluid operated piston type actuator has been provided which includes an effective means for decelerating the piston as it nears the terminal portion of its stroke.

Various features of the invention have been particularly shown and described in connection with the illustrated embodiments disclosed, however, it must be appreciated that various modifications may be made without departing from the spirit and scope of the invention.

I claim:

1. A fluid operated piston-type actuator comprising:
 - an operating cylinder defining an operating chamber having a longitudinal axis;
 - a reciprocable piston disposed in said chamber such that a clearance is defined between said piston and said cylinder;
 - said piston being movable in response to fluid pressure acting thereon;
 - compressible biasing means disposed between said piston and said cylinder spacing said piston away from said cylinder;
 - an operating shaft connected to said piston extending outwardly of said chamber through said operating cylinder;
 - means for decelerating said piston in at least one direction of travel including a deceleration chamber defined by said piston and cylinder trapping a quantity of fluid and a restricted orifice flow path defined by said piston and cylinder communicating between said deceleration chamber and a source of low fluid pressure; and
 - said piston being responsive to the flow of fluid through said restrictive orifice flow path to shift transverse to said axis thereby compressing said biasing means to further restrict the flow of fluid through said restricted orifice.
2. A fluid operated piston-type actuator as claimed in claim 1 wherein:
 - said piston includes an outer peripheral surface; and
 - said means defining said restricted orifice flow path includes a circumferential groove extending about said outer

peripheral surface which groove communicates with said source of low fluid pressure.

3. A fluid operated piston-type actuator as claimed in claim 2 wherein: said operating cylinder includes an inner cylindrical surface;

said outer peripheral surface of said piston is disposed in closely spaced sliding relation to said inner cylindrical surface;

said circumferential groove of said piston; and

said inner cylindrical surface of said cylinder define said restricted orifice flow path.

4. A fluid operated piston-type actuator as claimed in claim 3 wherein:

said cylinder includes an end wall and said pump includes a fluid communication conduit extending through said inner cylindrical surface adjacent said end wall in spaced relation thereto;

movement of said piston toward said end wall causing said outer peripheral surface of said piston to close said fluid communication conduit;

said piston, said end wall and said inner cylindrical surface of said cylinder thereby defining said deceleration chamber; and

said restricted orifice flow path defined by said circumferential groove in said piston and said inner cylindrical surface providing communication between said deceleration chamber and said fluid communication conduit.

5. A fluid operated piston-type actuator as claimed in claim 3 wherein:

said cylinder includes means defining an aperture through which said operating shaft extends;

said shaft and said aperture being sized to provide clearance therebetween;

said outer peripheral surface of said piston and said inner cylindrical surface of said cylinder being sized to provide clearance therebetween; and

said clearance between said shaft and aperture being greater than said clearance between said outer peripheral surface of said piston and said inner cylindrical surface of said cylinder.

6. A fluid operated piston-type actuator as claimed in claim 4 wherein:

said cylinder includes means defining an aperture through which said operating shaft extends;

said shaft and said aperture being sized to provide clearance therebetween; and said clearance between said shaft and said aperture of said cylinder being greater than said clearance between said outer peripheral surface of said cylinder.

7. A fluid operated piston-type actuator comprising: an operating cylinder defining an operating chamber having an inner generally cylindrical surface and a pair of end walls, one of which includes an aperture;

said operating chamber having a longitudinal axis; a reciprocable piston disposed within said chamber dividing said chamber into separate portions and including an outer peripheral surface disposed in closely spaced sliding relation to said inner generally cylindrical surface;

compressible biasing means disposed between said piston and said cylinder;

said biasing means spacing said piston away from said cylinder;

an operating shaft secured to said piston and extending outwardly of said chamber through said aperture in said one end wall, said shaft being extensible and retractable in response to movement of said piston;

a pair of fluid communication conduits;

said conduits communicating with said chamber on opposite sides of said piston and being adapted to be placed in communication, alternately, with a source of high fluid pressure and a low fluid pressure to effect movement of said piston;

at least one of said fluid communication conduits extending through said inner cylindrical surface adjacent one of said end walls in spaced relation thereto, and deceleration means for decelerating said piston upon reaching the terminal portion of its stroke in at least one direction including a deceleration chamber defined by said piston;

said inner cylindrical surface and said end wall associated with said fluid communication conduit extending through said inner cylindrical surface when said piston moves to a position to cause said outer peripheral surface to close said fluid communication conduit thereby trapping a quantity of fluid in said deceleration chamber;

a restricted orifice flow path defined by said piston and said cylinder communicating between said deceleration chamber and said fluid communication conduit; and said piston being responsive to the flow of fluid through said restricted orifice flow path to shift transverse to said longitudinal axis to further restrict the flow of fluid through said restricted orifice.

8. A fluid operated piston-type actuator as claimed in claim 7 wherein said restricted flow path is defined by means including a circumferential groove formed about said outer peripheral surface of said piston.

9. A fluid operated piston-type actuator as claimed in claim 8 wherein said aperture in said end wall and said operating shaft are sized to provide clearance therebetween, and said outer peripheral surface of said piston and said inner cylindrical surface of said cylindrical surface are sized to provide clearance therebetween, said clearance between said aperture

and said shaft being greater than said clearance between said peripheral surface of said piston and said inner cylindrical surface of said cylinder.

10. A fluid operated piston-type actuator as claimed in claim 1 wherein said operating cylinder includes an inner cylindrical surface, an end wall, and a fluid communication conduit extending through said inner cylindrical surface adjacent said end wall in spaced relation thereto, said cylinder further including a groove formed at said inner cylindrical surface communicating with said fluid communication conduit and extending in a direction toward said end wall, said groove cooperating with said piston to define said restricted orifice flow path.

11. A fluid operated piston-type actuator as claimed in claim 10 wherein said piston includes an outer peripheral surface disposed in closely spaced sliding relation to said inner cylindrical surface of said cylinder, said outer peripheral surface cooperating with said groove to define said restricted orifice flow path.

12. A fluid operated piston-type actuator as claimed in claim 11 wherein said groove formed at said inner cylindrical surface decreases in depth with respect to said inner cylindrical surface in a direction toward said end wall.

13. A fluid operated piston-type actuator as claimed in claim 11 wherein said operating shaft, cylinder and piston are arranged to allow said piston outer peripheral surface to contact said inner cylindrical surface of said cylinder at said fluid communication conduit.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,559,538 Dated February 2, 1971

Inventor(s) Robert E. Holder

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 48, after "therebetween;" cancel "and";
line 50, after "said", second occurrence, insert -- piston
and said inner cylindrical surface of said --.

Signed and sealed this 25th day of May 1971.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents