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Blum

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[54] **ELECTRO-MECHANICAL ACTUATOR**

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[51] **Int. Cl.** **F15b 13/16;** F15b 9/03

[58] **Field of Search** 60/545, 570; 91/43, 459; 92/13.6

[56] **References Cited**

UNITED STATES PATENTS

2,715,389	8/1955	Johnson	60/545
2,927,432	3/1960	Parry	60/545
3,156,160	11/1964	Meyer et al.	92/13.6
3,605,562	9/1971	Larsen	91/459

FOREIGN PATENTS OR APPLICATIONS

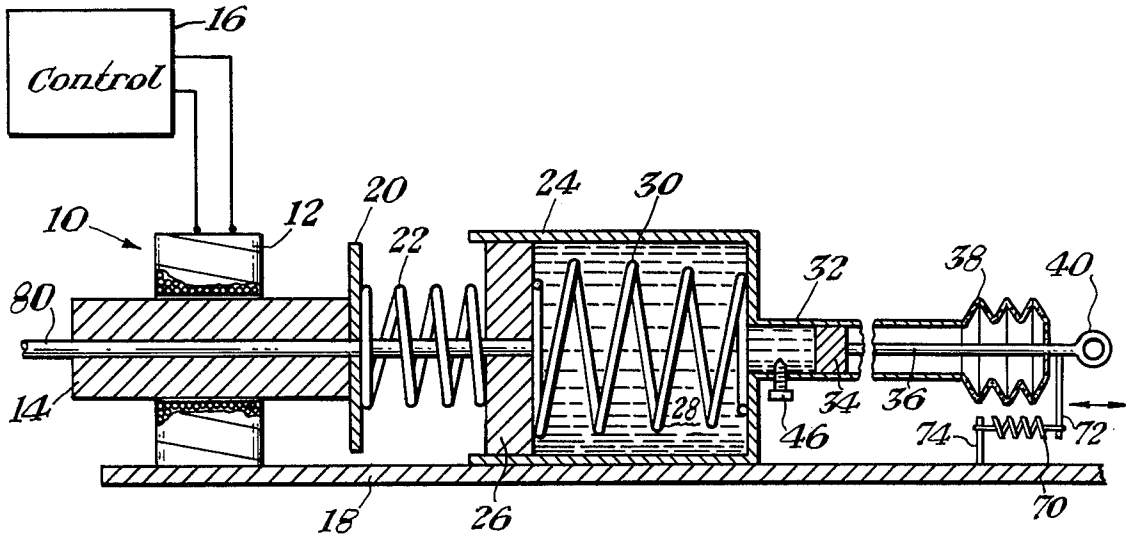
2,117,466	10/1971	Germany	60/545
344,198	3/1960	Switzerland	60/545

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[57] **ABSTRACT**

An electro-mechanical actuator for providing linear reciprocal motion which translates the short, abrupt linear stroke of a solenoid into a longer stroke of more uniform force on an actuating rod. The linear motion of the solenoid armature is coupled through a large spring adjacent a piston lying in a first chamber filled with a hydraulic fluid. A second chamber in communication with said first chamber houses a smaller diameter piston having an actuating rod disposed from one side. An accordion-like chamber adjacent the rod seal protects the seal from dust or damage.

8 Claims, 3 Drawing Figures



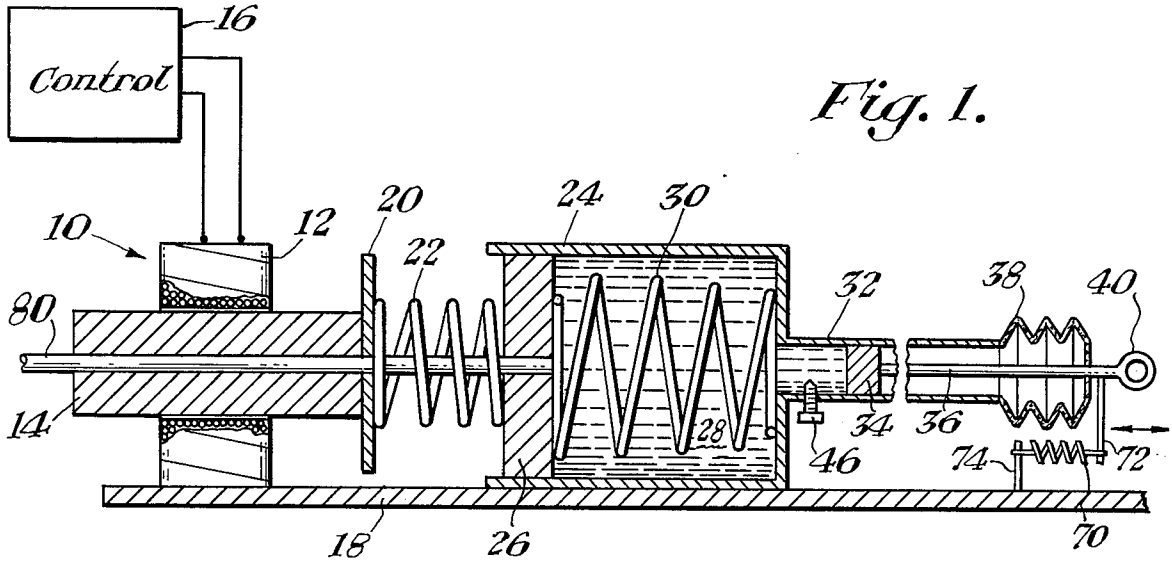


Fig. 1.

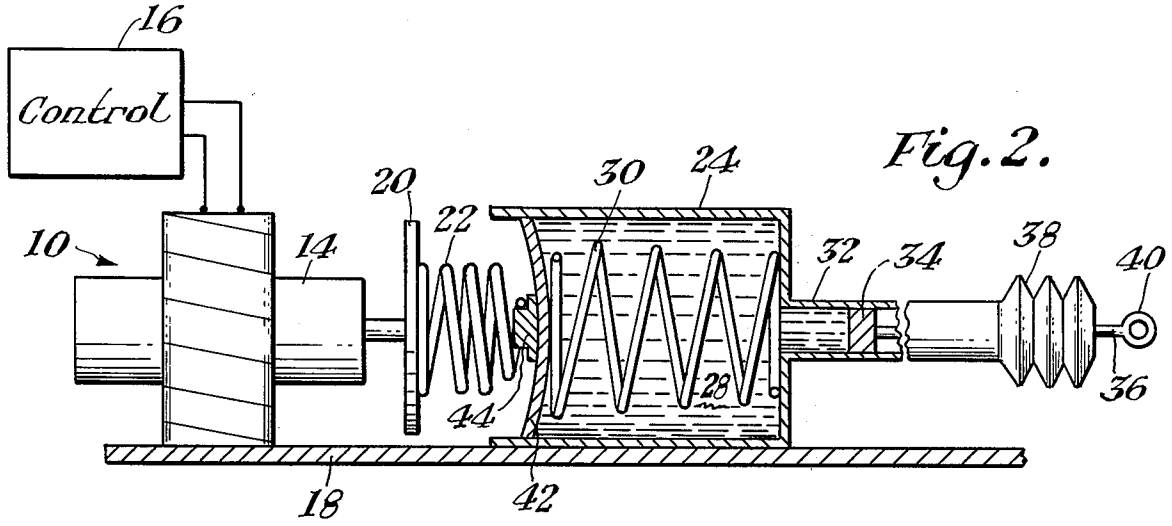


Fig. 2.

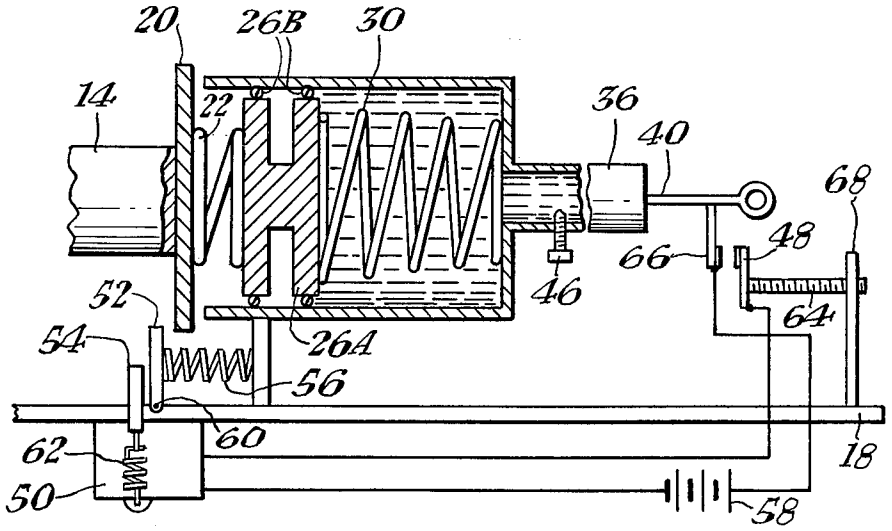


Fig. 3.

ELECTRO-MECHANICAL ACTUATOR

BACKGROUND OF THE INVENTION

This invention relates generally to an energy translating device, and more specifically to a device for converting the short duration, short distance, abrupt linear force of a solenoid into a longer duration, longer distance, more uniform force to provide linear motion adjustable both in time and distance.

In the past, several different devices have been utilized to achieve a reciprocal motion to accomplish a variety of tasks including opening and closing, switching and in general any type of linear movement from a first point to a second point and back to the first point under the command of appropriate signals, usually electronic. The use of a standard rotary electric motor has been found to be quite complex and expensive in that it requires gearing reduction and elaborate electronic control devices. Solenoids provide for linear motion; however, they have been found undesirable as actuators because they provide a very abrupt motion of non-uniform velocity and force with very little ability for adjusting or controlling the movement over a given path. The primary advantages of a solenoid are that it will respond to very short duration electrical pulses which may be generated from many different types of electronic devices and it is a relatively inexpensive power source. The utilization of hydraulic translators increases the complexity of the system in that they ordinarily require pumps, pipes and motors which are not easily actuated by short electronic pulses. Hydraulic translators do provide for accurate linear movement control of great force.

Applicant's invention utilizes the advantages while eliminating the disadvantages of the solenoid and hydraulic system by converting the linear movement produced by the solenoid in response to a short duration electronic pulse into the more uniform, longer stroke, linear motion of the hydraulic piston. Applicant's device is non-complex in structure and operation and does not require additional pumps, valves or gear reduction.

BRIEF DESCRIPTION OF THE INVENTION

An electro-mechanical hydraulic actuator for translating the abrupt linear motion of a solenoid into a longer duration, more uniform linear motion comprising a solenoid means, a resilient mechanical energy storing means coupled adjacent one end of said solenoid armature along the axis of the solenoid armature, a hydraulic fluid reservoir having a first chamber in communication with a second chamber, said first chamber having a movable member housed within said first chamber and in communication with said mechanical energy storage means, a piston disposed within said second chamber, a fluid medium disposed in said first and in said second chambers, an actuating rod connected to said second chamber piston disposed along the longitudinal axis of said piston, said rod having its opposite end disposed without said second chamber.

In operation, the solenoid armature is connected to a mechanical energy storing device, such as a large spring, at one end along the axis of motion. The spring in turn is connected to a piston or diaphram in communication with a hydraulic cylinder. Movement of the solenoid in response to a single electronic pulse will depress the spring which stores the mechanical energy and slowly presses against the piston. This provides pressure in the hydraulic system which forces a second piston in a chamber of smaller cross-sectional area to move along the second chamber axis. A latching means is connected in communication with the spring to prevent the spring from pushing back against the armature when current to the solenoid is turned off. The latch is necessary whenever a short duration pulse is utilized as the primary power source. An actuating rod coupled to the second piston thus provides uniform linear motion along the longitudinal axis of the rod. A fluid seal is provided between the chamber walls and the piston circumference to prevent leakage of hydraulic fluid.

It is an object of this invention to provide an electro-mechanical hydraulic actuator which is responsive to a short electrical pulse to provide linear motion of increased duration.

It is another object of this invention to utilize a solenoid to provide electro-mechanical linear motion and to translate the solenoid motion into a longer stroke of uniform force in response to a short electronic pulse.

And still yet another object of this invention is to translate the abrupt and non-uniform movement of a solenoid into a longer duration, more uniform linear motion in a simple and efficient manner.

And still yet another object of this invention is to provide an electro-mechanical hydraulic actuator having adjustable stroke distance and adjustable stroke velocity.

In accordance with these and other objects which will be apparent hereinafter, the instant invention will now be described with particular reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a side, elevational view partially in cross-section of Applicant's invention.

FIG. **2** shows a side view in elevation partially cutaway of an alternate embodiment of Applicant's invention.

FIG. **3** shows an alternate embodiment of Applicant's invention utilizing a latching means.

PREFERRED EMBODIMENT OF THE INVENTION

Referring now to the drawings and in particular FIG. **1,** Applicant's invention is shown comprising a conventional solenoid **10** having toroidal wiring **12** disposed about solenoid armature **14.** The toroidal wiring **12** generates a magnetic field in response to a signal from electronic control device **16** to provide the necessary electro-magnetic field through armature **14,** which is a conventional armature. Adjacent one end of the armature **14** is a vertically oriented plate **20** connected rigidly on one side to the end face of the armature. The opposite face of the plate **20** is connected to a large helical spring **22** having its coils arranged to absorb mechanical energy along the longitudinal axis of the armature. The spring is rigidly connected to the exterior face of piston **26** which is housed within a large cylinder **24.** The piston is sealed about its circumference to prevent leakage of hydraulic fluid contained in chamber **28** within cylinder housing **24.** Piston return spring **30** may be enclosed within the piston cylinder housing **28** to return piston **26** to its initial starting position. The larger diameter cylinder chamber **28** is in hydraulic communication with a smaller diameter cylinder chamber formed by housing **32** containing a second smaller di-

ameter piston **34.** The chamber **32** is elongated and has connected to it a collapsible, rod covering **38** which acts as a dust cover and permits linear movement along its longitudinal axis. Coupled to one face of piston **34** along its longitudinal axis of chamber **32** is an actuating rod **36** having a coupling eye **40** attached outside the chamber housing **32.** The actuating rod **36** is rigidly coupled to the end of the rod covering **38.** A guide rod **80,** rigidly connected to piston **26** passing through axial aperatures in armature **14** and plate **20,** insures that the surface of piston **26** remains normal to the direction of movement.

In operation, a current from control **16** creates a magnetic field about toroidal wiring **12** causing the permanent magnet or armature to move along its longitudinal axis in a conventional manner. The mechanical kinetic energy of the moving armature is then received and stored as potential energy in spring **22** and is uniformly released against piston **26** forcing the piston **26** deeper into the hydraulic chamber **28.** Pressure in the hydraulic fluid within chamber **28** then acts against piston **34** driving it axially along the chamber **32.** This provides uniform linear motion to rod **36** and any other device coupled to the connecting eye **40.** As the rod moves linearly, the rod covering **38** will expand or contract linearly.

To provide linear reciprocal motion, a control signal drives the solenoid armature back in the opposite direction which will reverse the direction of operation of Applicant's device. An additional solenoid coil may be utilized to return the armature to the initial position. Spring **22** in conjunction with return spring **30** will pull the piston **26** back out to its initial starting position. Rod **36** is coupled by arm **72** to a return spring **70** anchored to base **74,** the spring action returning the rod and piston **34** to its initial position.

In an alternate embodiment shown in FIG. **2,** solenoid **10** with its armature **14** and connecting plate **20** is coupled to spring **22** as shown previously. However, spring **22** is connected to a coupling plate **44** rigidly in contact with a flexible diaphram **42** which is deformable when a force on spring **22** is applied to the connecting plate **44.** As the diaphram expands, fluid moves the piston **34** and thus rod **40.**

In both embodiments, the return spring **30** is utilized to aid in returning the piston or the diaphram to its initial position upon cessation of the driving force or initiating reciprocal motion back to the initial starting point.

The time period of the actuating rod linear stroke is dependent upon the viscosity of fluid, internal friction, and the stiffness of spring **22,** which must be chosen to absorb the amount of energy which the stroke of the solenoid will produce. Also, the relative sizes of the larger diameter hydraulic cylinder **28** and the smaller diameter cylinder **32** and their respective piston cross-sectional areas are selected to produce the length of the actuating rod stroke. A gate **46** may be utilized to regulate the velocity of the rod **40** by varying the fluid flow rate (variable friction or drag) to the piston **34.**

The electronic control device **16** provides the necessary electrical signals to actuate Applicant's invention, including electrical current sufficient to drive the solenoid **10.** An advantage of Applicant's device is that very short pulses to drive the solenoid may be employed to drive a slow moving actuator which eliminates abrupt control movement as found in the solenoid itself.

FIG. **3** shows an alternate embodiment of Applicant's invention which includes a latching mechanism to hold the plate **20** at a predetermined position so that when the control pulse to the armature winding has passed, the spring **22** will not push the armature back out of position. The latching mechanism is comprised of a latching plate **52** which is coupled by pivot **60** to the supporting structure **18.** A spring **56** resiliently holds the latching plate **52** in a substantially upright position. A latching rod **54** engages the mid-portion of the latching plate **52** and is movable from a first position below and not in contact with the latching plate to a second position behind and engaged in contact with the plate **52** to prevent pivotal motion of plate **52** in a direction toward the armature. The latching rod **54** is coupled to a return spring **62** and solenoid **50** which positions the latching rod vertically in accordance with electrical signal from battery **58** which is connected through a switch **48.** FIG. **3** shows the device after the latching rod **54** has been pushed up by spring **62** and prevents the latching plate **52** from pivoting in the direction of the armature **14.** The spring **22** has received mechanical energy from the armature and has forced the cylindrical piston **26** to move linearly to a predetermined point. When the rod engages adjustable contact **48,** power to the solenoid **50** forces the latching rod **54** downward to a position below and out of contact with the plate **52** allowing the armature **14** and spring **22** to move back to the initial position.

The latching mechanism is necessary whenever a short duration electrical pulse initiates abrupt movement of armature **14** compressing spring **22.** Without the latching mechanism, the spring would push back against the armature forcing it back to its initial position, thereby not actuating rod **40.** With the latching mechanism, however, the mechanical energy that is stored in spring **22** will then slowly push against piston **26** forcing the rod to move. Thus, the latching is only necessary whenever a continuous current is not available to solenoid **10.** Spring **56** holds the latching plate **52** in an upright position so that it may properly engage armature plate **20.** The pivotal action on the latching plate **52** allows the armature plate **20** to pass over it, thereby allowing it to be engaged on the armature side of the plate **20.** Other means may be employed for the latching mechanism such as pure mechanical or combination electro-mechanical system. A choke cable (not shown) may be mechanically connected to the latching arm **54** to manually disengage the latching mechanism.

An adjustable mechanical screw **64** is utilized to regulate the distance that the actuating rod **40** moves. The screw **64** is threadably connected to adjustable contact **48** and the distal end rotates in and is supported by rigid static structure **68.** The linear distance of contact **48** from structure **68** is adjusted by turning screw **64.** Contact **66** is rigidly mounted to rod **40.** Whenever contact **66** engages contact **48,** power is supplied to solenoid **50** releasing the latching bar **54,** thus stopping the motion of rod **40.**

In the embodiment of FIG. **3,** a floating piston **26A** is employed with dual O-ring seals **26B** to prevent leakage of the hydraulic fluid if the force on spring **22** is not symmetrically applied to piston face **26A.**

It should be noted that one end of the spring **22** may be connected to a rack and pinion mechanism, as is

well known in the art. The speed of the rack may be varied by connecting said pinion to an escapement mechanism as is well known in the art. The distance of movement of the rack may be lengthened over the movement of the stroke of solenoid **10.** This may be accomplished by an ordinary gear means or linkage means that are common in the art.

The instant invention has been shown and described herein in what is considered to be the most practical and preferred embodiment. It is recognized, however, that departures may be made therefrom within the scope of the invention and that obvious modifications will occur to a person skilled in the art.

What I claim Is:

1. An electro-mechanical actuating device responsive to an electrical current for providing a uniform, longer duration actuating stroke comprising:

a solenoid;

an electrical current means coupled to said solenoid for actuating said solenoid armature;

a means connected to said armature for storing mechanical energy;

a fluid actuated linear motion translating means connected to said energy storage means for translating said stored energy received from said solenoid armature movement into uniform linear motion;

a connector means connected to said fluid actuated translating means.

2. An actuating device, as in claim **1,** including:

means coupled to said translating means for adjustably varying the rate at which mechanical energy is translated from said energy storage means.

3. An actuating device, as in claim **1,** wherein:

said fluid actuating translating means includes a hydraulic closed system including a first chamber, a second chamber in fluid communication with said first chamber, a movable first piston coupled within said first chamber forming a sealed closure along one end of said first chamber, a second movable piston coupled within said second chamber, a fluid medium disposed within said first chamber and said second chamber communicating therebetween, said first chamber having a different piston surface area than said second chamber piston area, said first piston being coupled to said mechanical energy storage means, connector means coupled to said second piston.

4. An actuating device, as in claim **3,** wherein:

said energy storage means is a spring.

5. A device for converting a high force, short distance, short duration, non-uniform motion of a solenoid to a relatively lower force, longer distance, longer duration, more uniform and adjustable motion along an actuating rod comprising:

a solenoid;

control means coupled to said solenoid providing energization of said solenoid;

a spring coupled to said solenoid, said solenoid having an armature movable in a linear direction, said spring coupled to said end face of said armature;

a hydraulic system including a first hydraulic chamber, a first piston movably disposed within said chamber, said first piston coupled to said spring, a second chamber, a second piston disposed within said chamber, said first chamber and said second chamber within fluid communication, an actuating rod coupled to said second piston, said rod responsive to the motion of said second piston which is actuated by movement of said first piston within said first chamber in response to mechanical energy stored in said spring received from said solenoid armature.

6. A device, as in claim **5,** including:

means coupled to said hydraulic system for variably adjusting the velocity of said second piston.

7. A device, as in claim **5,** including:

a means coupled to said rod for adjusting the distance movable of said rod.

8. A device, as in claim **5,** including:

a latching means coupled to one side of said spring to prevent spring movement toward said armature after the control signal to said solenoid has passed; and

latch control means connected to said latching means for controlling the latching means.

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