Oct. 1, 1963 D. D. MUSGRAVE 3,105,925

ELECTROMECHANICAL ACTUATORS WITH PERMANENT MAGNETS

Filed June 11, 1962

FIG. 1.

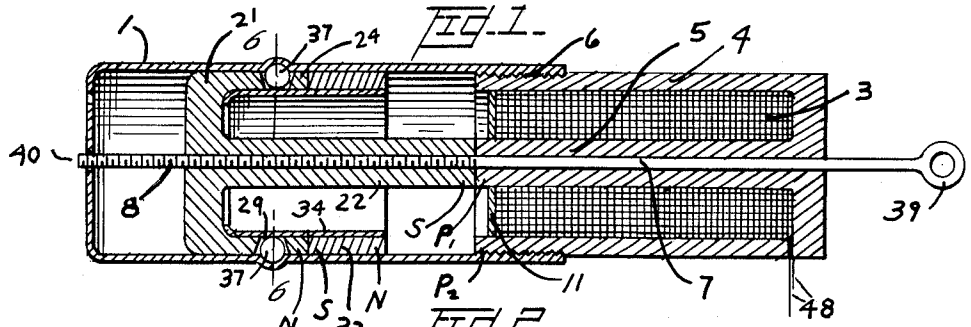


FIG. 2.

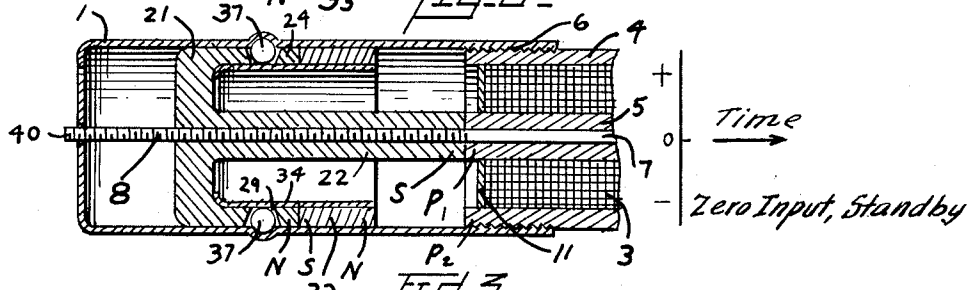


FIG. 3.

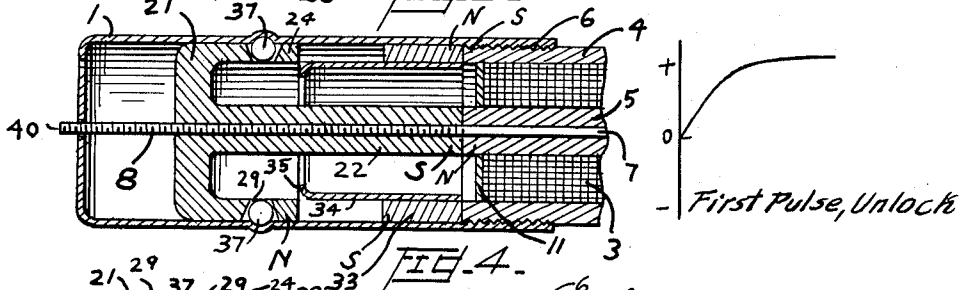


FIG. 4.

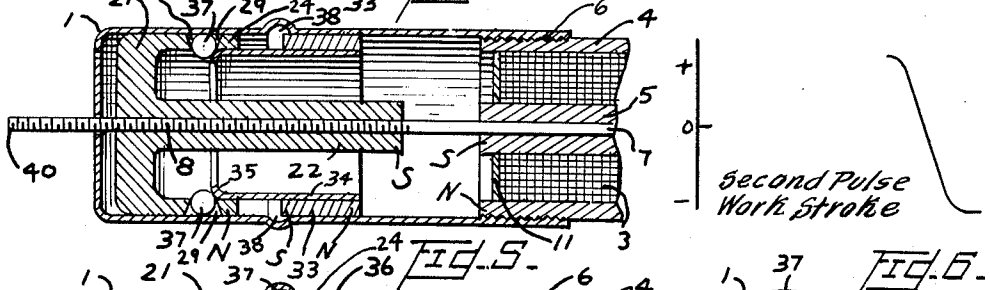


FIG. 5.

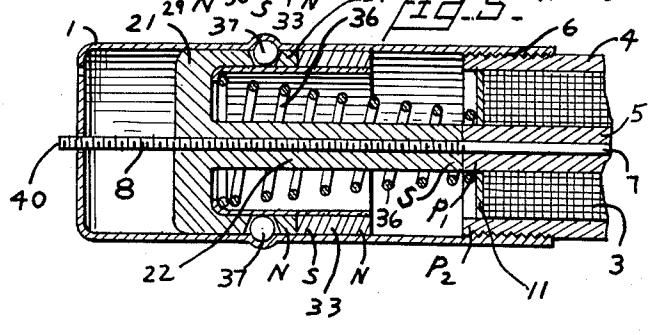
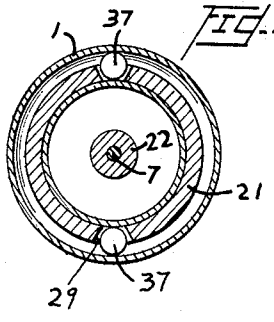


FIG. 6.



United States Patent Office

3,105,925
Patented Oct. 1, 1963

3,105,925

ELECTROMECHANICAL ACTUATORS WITH PERMANENT MAGNETS

Daniel D. Musgrave, 8201 Caraway St., Cabin John, Md.

Filed June 11, 1962, Ser. No. 201,596
4 Claims. (Cl. 317—171)

This invention relates to a safety actuator of the electromagnetic type. Such devices are useful where mechanical actuation must be controlled from a distant station, as they dispense with mechanical moving parts between the control station and the actuator, using electrical conductors instead. Because of their low cost, ease of installation, and simplicity, electromagnetic actuators are widely employed in military, industrial, and aeronautical equipment, and probably will be widely used in space projects. As a result of long usage and development they can be expected to function upon signal when situated in any normal environment.

Equal importance must be attached to another kind of reliability, that is, safety against inadvertent functioning. This is particularly true when the control pertains to a power plant or a weapon system, for in such applications inadvertent operation may set off a disaster of catastrophic proportions. In any such installation of a control actuator, careful consideration must be given to safeguards against human error, environmental conditions, and combinations of circumstances which might result in inadvertent actuation.

The hazards associated with electric actuation are difficult to evade completely, particularly because electrical energy is not visible and under some circumstances can be transmitted without a physical conductor. The energy levels specified for intentional actuation must be kept reasonably low to avoid excessive time lag between control and actuation. The constantly increasing usage of electric and electronic equipment provides more and more sources from which electrical energy may unintentionally be introduced into actuator circuits.

Important sources of extraneous electrical energy which are recognized as particularly dangerous to circuits controlling high-energy devices are lightning, static charges, galvanic action and radio-frequency energy. Very little can be done about lightning, but careful design can largely circumvent danger from static and galvanic action. The problem of radio-frequency energy is severe, particularly because modern emitters, such as radar equipment, transmit in a concentrated beam.

The above discussion pertains to typical hazards but it is not exhaustive, nor should it be considered limiting.

In consideration of the aforesaid situation, the principal object of this invention is to provide an electromagnetic actuator which is relatively immune to typical extraneous electricity.

Another object is to provide such an actuator which will not depend on a power supply to remain in a safe condition.

Another object is to provide an actuator so designed that inadvertent changing of polarity of control conductors will not cause unintentional functioning.

These and other objects of the present invention will be apparent upon reference to the following specification, taken in connection with the accompanying drawings, wherein:

FIGURE 1 is a longitudinal section of an actuator which is an embodiment of this invention.

FIGURE 2 is a portion of the actuator shown in FIGURE 1 with a chart showing electrical input to the actuator.

FIGURE 3 is the same portion as shown in FIGURE 2, but with some parts relatively displaced, and with a chart showing the electrical input causing the displacement.

FIGURE 4 shows the same portion of the actuator with additional relative displacement of parts and with a chart showing the electrical input causing the further displacement.

FIGURE 5 shows the same portion of the actuator with an alternate feature using an additional part.

FIGURE 6 is a cross-section of the actuator shown in FIGURE 1 and taken in the plane indicated by the numerals 6—6 on FIGURE 1.

Referring to FIGURE 1 there is shown an actuator having a hollow, cylindrical jacket 1, made of brass or some other material of low magnetic permeability, and affixed by threads 6, to a cylindrical frame 4. Frame 4 may be made of any material that will retain only a slight amount of residual magnetism when subjected to a magnetic field. Soft iron would be a suitable material for frame 4.

Concentric with frame 4 is core 5, which is also made of some material which will retain only a small amount of residual magnetism. The frame and core may be made integral, or as separate pieces suitably joined together.

Within the space between frame 4 and core 5 is wound coil 3, which is a typical electromagnetic coil terminating in a pair of conductor leads 43. (For purposes of clarity only a simplified coil is shown. The exact construction of the typical electromagnet coil is well known and need not be detailed here.) The turns of coil 3 must be suitably insulated. A closure disk 11 is affixed by any convenient method in the open end of frame 11 to protect coil 3 in the well-known manner.

Core 5 is bored along its longitudinal axis to accommodate a slidable rod 7, made of brass or some other material of low magnetic permeability. Rod 7 may be provided with suitable arrangements for mechanical connection with a driven or controlled device. As an example only, it is shown provided with a ring end 39 and a threaded end 40. In relation to frame 4 and jacket 1 (which will be assumed to be fixed) the ring end and threaded end furnish relative pulling or pushing motion respectively, as will be explained more in detail later.

A permanent magnet 21, having a threaded longitudinal bore, encompasses rod 7, engaging with threads 8. Magnet 21 is thus affixed to and is capable of moving with rod 7 as will be explained later. Magnet 21 has a central portion 22 and a rim portion 24, the maximum diameter of which is slightly less than the interior diameter of jacket 1.

Formed in rim portion 24 are tapered holes 29 which accommodate balls 37. The dimensions of the holes are so chosen relative to the diameter of the balls that the balls may be inserted into the holes flush with the exterior of rim portion 24 as shown in FIGURE 4. It will be noted in FIGURE 4 that the balls cannot pass completely through holes 29.

Formed in jacket 1 is an annular recess 38 which is

profiled closely to an arc having a radius slightly greater than that of balls 37. Recess 38 can therefore accommodate a portion of each ball 37 as shown in FIGURES 1, 2, 3, 5 and 6.

Slidable within jacket 1 is a hollow cylindrical permanent magnet 33 to which is attached by any convenient method a hollow cylindrical latch 34, preferably made of some material of low magnetic permeability. Latch 34 is longer than magnet 33 and its protruding portion may slide inside rim portion 24 and block holes 29 thus maintaining balls 37 in contact with annular recess 38 as shown in FIGURES 1, 2, 3, 5 and 6. The protruding portion of latch 34 is provided with an internal lip 35 which serves as a cam to position balls 37 when the latch slides toward the balls. FIGURE 5 shows an alternate construction in which a spring 36 is added to the arrangement shown in FIGURE 1. Spring 36 bears against closure disk 11 and lip 35 of latch 34 and tends to urge latch 34 away from coil 3, that is, to its latched position.

Operation: In FIGURE 1 the actuator is in its standby status, awaiting a signal to operate. (The output of mechanical actuation will be accomplished by a sliding movement of rod 7, to the left, relative to jacket 1 and frame 4.) In FIGURE 1 it may be noted that such movement is physically blocked by the engagement of magnet 21 with jacket 1 by means of balls 37. As magnet 21 is threaded to and slidable with rod 7, the continued engagement of magnet 21 with jacket 1 will prevent actuation.

It will also be noted in FIGURE 1 that a portion of latch 34 is encompassed within rim portion 24 of magnet 21, and is physically preventing balls 37 from moving inward to disengage from annular recess 38. So long as the latch remains in the position shown in FIGURE 1, linear actuation is prevented.

The polarity of permanent magnets 21 and 33 is indicated by the letters N and S, and will be the same in all views. The poles of the electromagnet are identified as P_1 and P_2, and their polarity will depend on the current in coil 3. (The invention would work as well with the polarities of the permanent magnets reversed, and those shown for illustration should not be considered limiting.)

In FIGURE 1 it is assumed that no current is flowing in coil 3, but the S pole of magnet 21 is adhering to P_1. The S pole of magnet 33 is adhering to the N pole of magnet 21, and there is a distinct air-gap between the N pole of magnet 33 and P_2 of the electromagnet.

FIGURE 2 shows the same mechanical and magnetic conditions as FIGURE 1, and it includes a chart showing electrical input to coil 3. (The electrical input shown is zero and the arrow indicates the direction of time.)

In FIGURE 3, the distant control station (not shown) is sending an unlocking signal to coil 3. For illustrative purposes it will be assumed that coil 3 is so wound that a positive input has caused P_2 to become an S pole of sufficient intensity to exert an attraction for the N pole of magnet 33 sufficient to move it to the position shown in FIGURE 3. It will be noted that latch 34 is now clear of rim portion 24 and is no longer preventing inward movement of balls 37.

As long as the positive input continues there will be no absolute mechanical locking, as the depth of annular recess 38 is such that the balls may be readily cammed from the recess should magnet 21 slide. However, the actuator in FIGURE 3 is still safe against inadvertent operation for P_1 has become an N pole and is exerting a powerful attraction for the S pole of magnet 21. The condition shown in FIGURE 3 can be maintained at will from the distant control station (not shown), by maintaining the positive input to the coil.

(It should be noted that the dimensions and configuration of the several elements of the device may be varied in practice to produce desired response characteristics. The drawings are not intended to be limiting.)

When the operator at the distant control station decides to actuate, that is, to cause a work stroke of rod 7, he first sends a positive current to coil 3 to cause the unlocked condition shown in FIGURE 3, and then he suddenly reverses the current to the coil. The control might be accomplished by using a battery and a pole-changer connected to leads 48 in the well-known manner.

Upon reversal of the current as shown on the chart in FIGURE 4, P_1 becomes an S pole and repels the S pole of magnet 21, which slides (to the left in the drawing), camming balls 37 out of annular recess 38 as it slides. As rod 7 is threaded to magnet 21 it also moves, providing mechanical actuation at either or both of its ends.

The reversal of the current also causes P_2 to change polarity. It becomes an N pole, repelling the N pole of magnet 33 which slides in the same direction as magnet 21. By selection of dimensions as stated hereinbefore the travel of magnet 21 required to cam balls 37 out of recess 38 can be made less than the travel of magnet 33 and latch 34 required to return the latch to a position blocking the camming of the balls. It is also possible to select dimensions whereby the repulsion of magnet 33 provides additional actuation thrust. This may be seen in FIGURE 4 where lip 35 of latch 34 carried by magnet 33 is exerting a thrust against balls 37. The balls transmit the thrust to magnet 21 which is affixed to slidable rod 7.

In FIGURE 5, spring 36 is interposed between latch 34 and closure disk 11 so as to require an increased pull on magnet 33 to cause unlocking. This might be desirable when the actuator is subject to inertial forces which might cause premature unlocking.

There is thus disclosed a simple electromagnetic actuator which is relatively immune to inadvertent functioning by extraneous electrical energy. It is desired to point out that the principle of the invention disclosed hereinbefore may be applied by means of other mechanical and magnetic arrangements, and that the disclosed embodiment should be considered illustrative rather than limiting.

I claim:

1. In an electromagnetic actuator in combination: a coil adapted for producing an electromagnetic field; a longitudinally bored core of low magnetic retentivity located within said magnetic field of said coil; a diamagnetic actuating rod slidable within said core; a first permanent magnet affixed to said rod and adapted by position to be attracted to or repelled from said core according to the magnetic polarity of said core; a diamagnetic member fixed to said core and having a detent surface; a second permanent magnet slidable relative to said member and adapted by position to be attracted to or repelled from said core according to the magnetic polarity of said core; detent means carried by said first permanent magnet and adapted for engaging said detent surface of said member; blocking means carried by said second permanent magnet and adapted for preventing disengagement of said detent means from said detent surface when said second permanent magnet is at a first position relative to said second permanent magnet; and means for applying an electric current alternately in opposite directions to said coil.

2. The combination set forth in claim 1 and further characterized by said blocking means being spring loaded away from said core.

3. The combination set forth in claim 1 and further characterized by said detent means comprising one or more spheres.

4. An electromagnetic actuator comprising: a coil adapted for producing an electromagnetic field; a core positioned within said field; actuating means normally retained at an inoperative position and movable to an operative position; first movable magnetic means operatively connected to said actuating means and normally magnectically attracted to said core; releasable mechanical detent means normally retaining said actuating means at

said inoperative position; second movable magnetic means having operatively connected thereto blocking means for normally preventing release of said detent means at a position whereat said second magnetic means contacts said first magnetic means; and means for applying an electric current alternately in opposite directions to said coil.

References Cited in the file of this patent

UNITED STATES PATENTS

2,505,904	Matthias et al.	May 2, 1950
2,632,821	Wright et al.	Mar. 24, 1953
3,070,730	Gray et al.	Dec. 25, 1962

FOREIGN PATENTS

1,035,771	Germany	Aug. 7, 1958