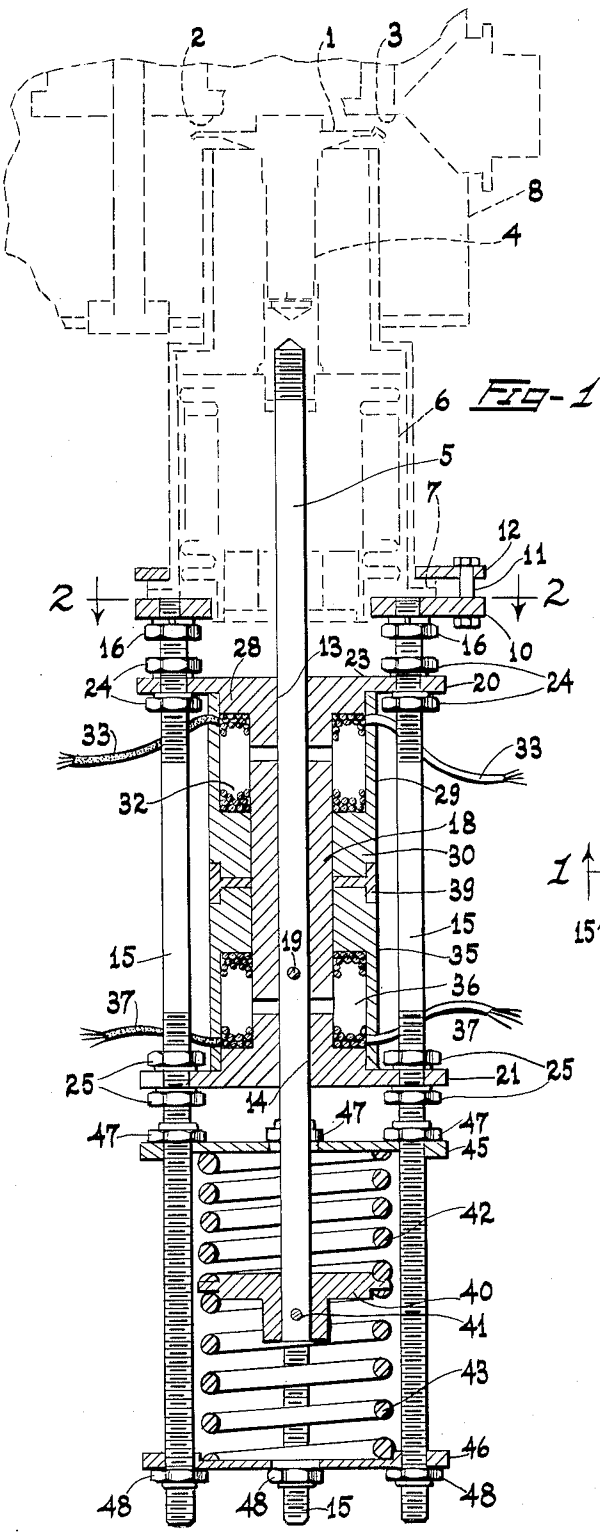
Nov. 16, 1965 W. N. LINDSAY 3,218,409

ELECTROMAGNETIC ACTUATOR

Filed Nov. 7, 1960



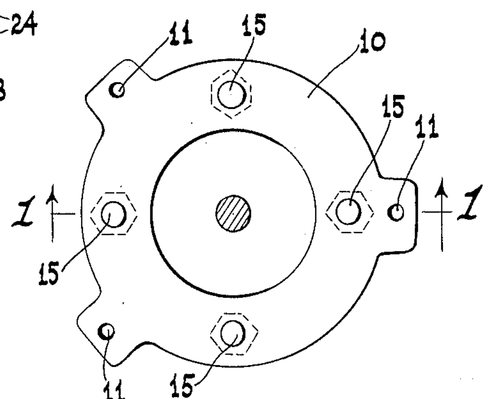


FIG-2

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3,218,409
Patented Nov. 16, 1965

3,218,409

ELECTROMAGNETIC ACTUATOR

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Filed Nov. 7, 1960, Ser. No. 67,668
8 Claims. (Cl. 200—98)

This invention relates to electromagnetic actuators and has as one of its objects the provision of high speed yet controlled motion to vacuum switches and the like.

Another object of the invention is the provision of an electromagnetic actuator in which the moving element is held securely at its terminal or extreme positions of motion.

A further object of the invention is the provision of an electromagnetic actuator in which high values of acceleration and deceleration of a moving element are obtained with minimum expenditure of external energy.

Another object of the invention is the provision of a relatively simple and inexpensive means for providing quick closing of contacts in a vacuum switch and which means remains effective throughout a relatively large number of actuations of the switch.

A further object of this invention is to provide an electrical relay comprising a switch and an electromagnetic actuator in which the relay contacts are carried upon command at high speed from an open to a closed position with a minimum of contact bounce.

Other objects of the invention will be apparent from the following specification and from the drawings. It will be understood, of course, that the particular embodiment of the invention shown in the drawings and described in the specification should not be taken as restrictive of the invention since various modifications in design will occur to those skilled in the art without departing from the scope of the appended claims.

FIG. 1 is a longitudinal section through the actuator of the invention with certain portions of a vacuum switch, nonessential to the invention, shown in dotted lines. The switch and actuator in combination form an electrical relay.

FIG. 2 is a cross section taken along lines 2—2 of FIG. 1.

In vacuum switches of the type herein contemplated proper design of an actuator must provide for rapid movement of a movable contact into engagement with a fixed contact or contacts and at the same time the actual terminal velocity of the movable contact must be sufficiently low so that impact between the contacts is reduced as much as possible. By the present invention such requirements are adequately provided for by the provision of resilient means automatically controlling the movement of the movable contact throughout its stroke.

In FIG. 1 the dotted line portion indicates a vacuum switch envelope the particular design of which is unimportant but which, in the example shown, includes a shorting bar **1** adapted to be driven into engagement with fixed contacts **2**, **3**. Shorting bar **1** is supported on a ceramic insulator **4** which in turn is carried by one end of a shaft **5**. Conventional bellows **6** secured at one end to shaft **5** and at its other end to base **7** of the envelope **8** serve to permit reciprocal movement of shaft **5** and at the same time exclude atmospheric air from the interior of the envelope.

Secured to base **7** of the envelope is an annular connecting ring **10** which may be provided with a plurality of bolts **11** cooperating with clamping ring **12** for fixedly securing the drive mechanism to the base **7**.

The actuator is supported on four rods **15** which are equally spaced apart and threadedly secured at their corresponding ends to ring **10**. Additional holding effect between rods **15** and ring **10** is effected by means of lock nuts **16**.

An armature **18** of magnetic material is secured by pin **19** to shaft **5** intermediate the ends of the latter. Said armature is adapted to be reciprocated with said shaft **5** relative to rods **15**; and the travel of said armature is limited by a pair of shoe pieces generally designated **20**, **21** respectively which are mounted on rods **15**. Armature **18**, although shown as a single member, can be split intermediate its two ends without significantly modifying its function. In other words, two armatures, each pinned to shaft **5** would serve the same purpose as the single armature shown.

Shoe piece **20** of magnetic material is positioned between the armature **18** and the envelope **8** and includes an annular flange **23** provided with holes for receiving rods **15** therethrough. Said shoe piece may be adjustably positioned perpendicularly to the shaft **5** by means of lock nuts **24**. Similarly shoe piece **21** is positioned on the rods **15** on the opposite side of armature **18** from shoe piece **20** by means of nuts **25**. Shoe pieces **20**, **21** are provided with central holes **13**, **14** through which shaft **5** is slidably received.

Shoe piece **20** is provided with a relatively large central boss **28** which is adapted to receive therearound the side walls **29** of a generally tubular shell **30** of magnetic material which in turn is provided with a relatively heavy end **31** through which armature **18** is slidably received. In the space between shaft **5** and side walls **29**, a wire wound coil **32** is positioned to which current may be supplied through leads **33** by closure of a suitable switch.

A tubular shell **35**, similar to shell **30** is provided on shoe piece **21** and a wire wound coil **36** adapted to be energized through leads **37** and a suitable switch positioned therein. These elements in combination with armature **18** form an electromagnet, as do also elements **20**, **29**, **30**.

In FIG. 1 armature **18** is shown in an intermediate position between shoe piece **20** and shoe piece **21**; and it may be noted at this point that armature **18** may be reciprocated into engagement with shoe piece **20** by energizing coil **32** and into engagement with shoe piece **21** by energizing coil **36**. Engagement of the armature with shoe pieces defines the terminal positions of the moving elements of the actuator.

Between the two shoe pieces **20**, **21**, there is positioned an annular non-magnetic member **39** thus effecting a separation between each coil and its associated shell and shoe piece. It will be noted that the various parts above described may readily be assembled and drawn tightly together into a unitary assembly by means of nuts **24**, **25**.

At the outer end of shaft **5**, remote from the envelope **8**, the shaft is provided with a collar **40** which is secured by pin **41**. Bearing against opposite sides of collar **40** are the corresponding ends of a pair of helical springs **42**, **43**. The opposite ends of said springs abut against a pair of plates **45**, **46** respectively, which in turn are threadedly secured to rods **15** and tightened relative thereto by locknuts **47**, **48**.

The effect of springs **42**, **43** is to exert equal and opposite resilient forces on shaft **5** so that armature **18** assumes the normal inoperative position shown in FIG. 1 centrally between shoe pieces **20**, **21**. The shorting bar **1**, of course, assumes an inoperative position clear of contacts **2**, **3**.

It will of course be apparent that the force exerted by spring **42** is in opposition to the force exerted by spring **43** plus the force exerted by the atmosphere on the interior of the bellows so that the total forces exerted are equal and opposite.

It will be apparent that if collar **40** is displaced from its neutral position shown in FIG. 1 toward plate **46** and released, the assembly that includes shaft **5**, bellows **6**, armature **18** and springs **42** and **43** will resonate or oscillate with simple damped periodic motion between positions on opposite sides of the neutral position shown, until frictional effects finally stop such movement. It will further be apparent that the period of oscillation may be readily determined from known formulae taking into account the effective mass of the oscillating assembly and the stiffness of the springs **42**, **43**.

The preferred speed of closing of switch contacts **1** being arrived at and the effective mass of the movable elements being known, it is then merely neecssary to determine the characteristics of springs **42**, **43** which will produce a half period of oscillation necessary to effect closing or opening in the desired interval of time.

In operation the coil **36** is energized to retract collar **40** away from envelope **8**. Then coil **36** is deenergized and coil **32** energized so that contacts **1** approach contacts **2**, **3** at the predetermined speed and when engagement of the contacts is effected the magnetic force developed between armature **18** and shoe piece **28** by flow of current through coil **32** holds the contacts in engagement. The reason that the above described operation may be carried out without undesirable bouncing of the movable contacts is that the terminal velocity of the movable contacts is relatively low because springs **42**, **43** tend to restrain the contacts to periodic motion which, of course, results in a low terminal velocity at each end of the stroke.

An important feature of the invention resides in the fact that after a relatively large flow of current has been passed through coil **32** for a few milliseconds to supply to the moving mass the energy it loses by windage losses and bearing friction, thereby causing the moving mass to complete its full stroke, the current flow may be markedly reduced by conventional control of energizing circuits, while still causing a strong holding or "latching" effect as a result of the rapid increase in magnetic force with decrease in air gap between armature **18** and shoe piece **28**. The reduction in current flow obviates undesirable heating effects and furthermore permits a fast release of armature **18** as a result of the lesser amount of stored energy in the magnetic structure.

The larger holding or "latching" forces prevent rebound of the armature and the other movable parts, and greatly minimize bounce in the switch contacts.

One particular method to hold a linear actuator at its limits of stroke has been described in this specification. Other methods both mechanical and electrical in nature may be used. One of these is described in my copending application Serial No. 43,382, now Patent No. 3,035,139.

I claim:

1. In a vacuum switch, a vacuumized envelope and a switch element in said envelope mounted for movement between open and closed positions, an actuating rod secured to said switch element and extending outside said envelope, an armature of magnetic material carried by said rod, a pair of magnetic coils operatively associated with said armature for urging said rod to open and closed positions respectively corresponding to said open and closed positions of said switch, spring means urging said rod to an intermediate position between said open and closed positions at all times, whereby the speed of said rod is accelerated upon energizing said coils to urge said rod from open to closed positions and vice versa.

2. In a vacuum switch, a vacuumized envelope and a switch element in said envelope mounted for movement between open and closed positions, an actuating rod secured to said switch element and extending outside said envelope, an armature of magnetic material carried by said rod, a first magnetic coil associated with said armature for urging said rod to a closed position corresponding to the closed position of said element, a second magnetic coil for urging said rod to an open position corresponding to an open position of said element, and spring means urging said rod to an intermediate position between said open and closed positions at all times, whereby the speed of said rod is accelerated toward closed position when said second coil is deenergized and said first coil is energized.

3. In a vacuum switch, a vacuumized envelope and a switch element in said envelope mounted for movement between open and closed positions, an actuating rod secured to said switch element and extending outside said envelope, an armature of magnetic material carried by said rod, a first magnetic coil associated with said armature for urging said rod to a closed position corresponding to the closed position of said element, a second magnetic coil for urging said rod to an open position corresponding to an open position of said element, spring means urging said rod to an intermediate position between said open and closed positions at all times, whereby the speed of said rod is accelerated toward closed position when said second coil is deenergized and said first coil is energized, and first and second shoe pieces associated with said first and second coils respectively and adapted to engage said armature for limiting the movement of the latter away from said intermediate position.

4. In a vacuum relay, a vacuumized envelope and a switch element in said envelope mounted for movement between open and closed positions, an actuating shaft secured to said switch element, an electromagnet adapted to urge said switch element to a closed position, a second electromagnet adapted to urge said switch element to an open position, and spring means to urge said switch element to an intermediate position between said open and closed positions at all times whereby upon actuation by said magnets the switch element is moved rapidly from one position to the other with low terminal velocity.

5. In a vacuum relay, a vacuumized envelope and a switch element in said envelope mounted for movement between open and closed positions, an actuating shaft secured to said switch element, electromagnetic actuated means to urge said switch element to a closed position, a second electromagnetic actuated means to urge said switch element to an open position, and spring means urging said shaft to an intermediate position between said open and closed positions at all times whereby upon energization of said one electromagnet and deenergization of said second electromagnet said switch element is moved rapidly from one position to the other with low terminal velocity, said one electromagnet upon partial deenergization holding said switch element in closed position during the resonating action of said spring.

6. An actuator for moving a switch contact from open to closed position, comprising a pair of opposed electromagnets, an amature operatively arranged with both electromagnets, means operatively connecting the switch contact to the armature, spring means operatively disclosed with relation to said armature and restraining its movement in either direction from a neutral position, whereby said armature moves from said neutral position in a direction away from closed position and then reverses and moves toward closed position upon energizing one electromagnet and concurrently deenergizing the other electromagnet.

7. In a vacuum relay, a vacuumized envelope, a switch element in said envelope mounted for movement between open and closed positions, an actuating shaft secured to said switch element and extending outside said envelope, an armature of magnetic material carried by said shaft, a first wire wound coil associated with said armature to urge said shaft to a closed position corresponding to the closed position of said element, a second wire wound coil for urging said shaft to an open position corresponding to an open position of said element, spring means urging said shaft to an intermediate position between said open and closed positions at all times, whereby said shaft is caused to move toward closed position when said second coil is deenergized and said first coil is energized, and first and second shoe pieces associated with said first and second coils respectively for limiting the movement of said armature away from said closed and opened position.

8. In combination, a vacuumized shell, a fixed contact in said shell, a movable contact in said shell, a shaft connected to the movable contact and movable in one direction to close the contacts and in the opposite direction to open them, a bellows hermetically interposed between the shaft and the wall of the shell, a pair of opposed electromagnets adjacent the shaft, an armature fixed on the shaft and responsive to both electromagnets, stop means for limiting movement of the shaft and armature in closing and opening movements thereof and fixed with relation to the electromagnets, and spring means interposed between said shaft and said stop means and urging said shaft to an intermediate position between open and closed positions at all times.

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