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RELAY WITH TIME DELAY ACTION

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The present invention relates to an electromagnetically actuated relay which, upon energization of the electromagnet, will cause the relay to change its condition and then, automatically and without requiring further manual action, to resume its initial condition after a predetermined period of time.

In many control systems is desired that a circuit be opened or closed promptly upon actuation of the system, that circuit remaining in that condition for a predetermined period of time and then resuming its original condition. The mechanisms employed in the past to accomplish this have been complex, expensive and undependable. It is the prime object of the present invention to provide a simple and reliable device which will satisfy the most rigorous operating requirements.

According to the present invention an electromagnetically energized relay has been produced with a minimal number of moving parts, which occupies substantially no more space than a conventional relay, and which has the desired operating characteristics. The armature which controls the opening and closing of contact pairs is so operatively related to the electromagnet that it will be attracted toward the electromagnet promptly upon energization of the electromagnet and will be caused to move away from the electromagnet a predetermined period of time after it has moved toward the electromagnet, even though the electromagnet is still energized. The device of the present invention may be designed to provide a predetermined fixed time delay between movement of the armature toward and away from the electromagnet, or simple and reliable means may be provided whereby the time delay may be adjusted to a particular value within a predetermined range of values.

To this end the electromagnet is subdivided into a pair of coils having unequal electromagnetic strength, the weaker of the coils being positioned closer to the armature. Each of the coils is provided with a core movable thereinto and out therefrom, and the armature is biased away from the weaker coil with a strength such that it will be moved toward that coil when the coil is energized only when the core associated therewith is within the coil and comparatively close to the armature. Said core is comparatively readily movable into and out from its coil, and hence whenever said coil is energized said core will promptly move thereinto, thus causing the armature to be attracted with sufficient force to be pulled theretoward, the armature then appropriately conditioned the contact pair or pairs with which it is operatively associated. The other and stronger coil will also be energized, but its core, normally biased out therefrom, is retarded in its movement and hence moves into its coil much more slowly than the first mentioned core moves into its coil. The two cores are connected, the connection being such that when the second core has moved a predetermined distance into its coil, which movement will take an appreciable period of time, it will then pull the first mentioned core out of its coil and away from the armature, thereby reducing the electromagnetic attraction exerted on the armature to a

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magnitude less than the armature biasing force, the armature then returning to its original biased position and restoring the contact pair or pairs associated therewith to their original condition. Upon de-energization of the electromagnetic coils, the second mentioned core moves to its biased position outside its coil, thus conditioning the apparatus for a renewed sequence of operations as outlined above by permitting the first mentioned core to once again move into its coil and to remain there until the second mentioned core has once again been drawn within its coil.

In the structure here disclosed both coils are wound about a tube within which the cores are slidable, the tube being filled with a fluid, and preferably a viscous liquid, the first mentioned core being so constructed and arranged relative to the tube that a fairly wide fluid passage is provided from one end thereof to the other, thus permitting that core to move comparatively freely through the tube, the viscous fluid passing through that comparatively wide passage as the core moves and thus offering minimal resistance to its motion. The second mentioned core, the one whose movement is more retarded, is so constructed relative to the tube within which it moves that a comparatively narrow fluid passage is defined from one end of the core to the other, the fluid within the tube having to pass through that narrow passage as the core moves and thus resisting such movement to a marked degree. The first mentioned core, the one which moves more rapidly, may have a wide axial passage directly therethrough, while the second mentioned core, the one which moves less rapidly, may have no passage at all therethrough, but may be sufficiently smaller in diameter than the interior of the tube as to define between itself and the tube the narrow passage above referred to. The relative size of the passages, and particularly the size of the passage from one end to the other of the core which is retarded in movement, in conjunction with the viscosity of the fluid within the tube and the strength of the pull exerted on the second or retarded core by its coil, will determine the time which will elapse between the movement of the armature from its biased position and the return of the armature to its biased position. If desired, a passage external to the tube may be provided communicating between opposite ends of the second or retarded core, the effective diameter of that external passage being adjustable and thus defining a bypass around the retarded core the operative effect of which will permit, within limits, said core to move more or less slowly. In this way the inherent time delay of the device may be adjusted.

Since the moving parts of the present invention are sturdy, few in number, and sealed within the tube, it will be apparent that the device is quite reliable and not subject to dislocation or damage. The effect of ambient temperature on the accuracy of the device, where that is a factor, may be held within acceptable ranges through the use, as a viscous medium within the tube, of any of a number of well known and commercially available fluids the viscosity of which is substantially independent of temperature over a wide range.

To the accomplishment of the above, and to such other objects as may hereinafter appear, the present invention relates to an electromagnetically actuated relay or the like as defined in the appended claims and as described in this specification taken together with the accompanying drawings, in which:

Fig. 1 is a side elevational view, partially cross sectioned, showing one embodiment of the present invention in its de-energized state;

Fig. 2 is a top plan view thereof;

Fig. 3 is a view similar to Fig. 1 but showing the position of the parts after the coils have been energized

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and just before the armature is released to return to its biased position, one of the cores being shown in modified form;

Fig. 4 is a view similar to Fig. 1 but showing another embodiment of the present invention utilizing a different type of connection between the cores and having an external bypass by means of which the time delay in the device may be adjusted;

Fig. 5 is a view similar to Fig. 4 but showing the parts thereof in a position corresponding to that of Fig. 3; and

Fig. 6 is a circuit diagram illustrating the manner in which the device may be connected for impulse operation.

Turning first to the embodiment of Figs. 1-3, the relay comprises a frame piece 2 on which any desired number of contacts, generally designated 4, are mounted. The frame 2 may have side arms 5 for mounting purposes. As here disclosed two sets of contacts are provided, each set being defined by opposed fixed contacts 6 and 8 between which a flexibly resilient contact leaf 10 is movable so as to engage one or the other of the fixed contacts 6 and 8, all of the contacts being mounted on the arm 12 of the frame 2 by means of screw 14, insulating bushings 16 being provided between the contacts so as to insulate them from one another and from the frame arm 12. The spring contact 10 is biased so as to normally engage the contact 8. Appropriate electrical connections to the contacts may be made at their terminal portions 18, as is conventional.

An L-shaped armature 20 is pivotally mounted on the frame 2 in any conventional manner, the leg 22 thereof carrying a plate 24 which extends under and is adapted to engage the projecting tips of the spring contacts 10, the resiliency of those contacts 10 serving to bias the armature 20 to its position shown in Fig. 1, in which its leg 26 is moved away from the magnetizable end plate 28 of non-magnetizable tube 30. Coils 32 and 34 are wound on the tube 30, the coil 32 positioned close to the armature leg 26 having a fewer number of turns than the coil 34, the latter being positioned remote from the armature leg 26 and spaced an appreciable distance from the coil 32 by means of spacer ring 35. By way of example, the coil 32 might consist of 8000 turns of wire, while the coil 34 might consist of 12,000 turns. The tube 30 is secured in any appropriate manner, as by welding, to the frame 2.

Slidable within the tube 30 are a pair of cores 32a and 34a operatively associated respectively with the coils 32 and 34. The core 32a has a wide axial passage 36 therethrough, a pin 38 extending across that passage adjacent its lower end. The core 34a has a blind axial aperture 40 extending upwardly from the lower end thereof, a pin 42 extending across the upper end of the aperture 40. A coil spring 44 is connected between the pins 38 and 42, that spring tending to contract and thus pull the cores 32a and 34a toward one another. The core 34a is sufficiently smaller in width than the interior of the tube 30 so as to define a comparatively narrow passage 46 between the sides of the core 34a and the inner surface of the tube 30. A pin 48 extends into the tube 30 between the coils 32 and 34. The tube is filled with a suitable fluid the viscosity of which will determine the rate of movement of the cores 32a and 34a. It is preferred that that fluid be a viscous liquid, and desirably a liquid the viscosity of which is substantially independent of temperature within the range of ambient temperature to which the device may be subjected in use.

The mode of operation of the device is as follows. With the coils 32 and 34 de-energized, as they will be when the device is at rest, the spring 44 will contract and thus pull the cores 32a and 34a toward one another and against the pin 48, those cores then being withdrawn at least to a substantial degree from their re-

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spective coils 32 and 34. The resilient action of the spring contact 10 will cause the armature to pivot so that the armature leg 26 moves away from the end 28 of the tube 30. This position of the parts is shown in Fig. 1.

When the coils 32 and 34 are energized, and they are preferably energized substantially simultaneously, as by being connected in series or in parallel with one another, the electromagnetic pull of the coil 32 (and of the coil 34 to whatever degree it may be effective) on the armature leg 26 is insufficient to cause the armature leg 26 to approach the tube end 28, the biasing force exerted on the armature 20 by the resilient contacts 10 being in excess of the electromagnetic pull thereon, it being borne in mind that the core 32a is withdrawn from the coil 32 and is comparatively remote from the armature leg 26. At the same time the coil 32 will attract the core 32a and tend to cause it to slide downwardly within the tube 30 into the coil 32. The comparatively wide axial passage 36 through the core 32a permits the core 32a to move rapidly downwardly in response to the pull exerted thereon by the coil 32 and against the action of the spring 44. As the core 32a moves into the coil 32 the electromagnetic pull on the armature leg 26 increases, and when the core 32a has moved into the coil 32 to a predetermined degree, the electromagnetic pull on the armature leg 26 will come to exceed the biasing force exerted on the armature 20 by the spring contacts 10, the armature then pivoting in a clockwise direction to the position shown in Fig. 3, the armature leg 26 coming up against the coil end 28 and the armature-carried plate 24 bending the spring contacts 10 so as to cause them to disengage from the fixed contacts 8 and engage with the fixed contacts 6, all as illustrated in Fig. 3.

Movement of the armature 20 to its position shown in Fig. 3 is substantially instantaneous with, or at any rate follows very promptly upon, the energization of the coils 32 and 34. At the same time, the coil 34 being energized, the core 34a is pulled upwardly thereby. However, the coil 34a can move upwardly only quite slowly, because the passage 46 between its upper and lower ends, through which the fluid in the tube 30 must flow when the core 34a moves, is quite narrow, and the viscous fluid within the tube 30 can flow therethrough only at a very slow rate. This is to be compared with the rapid rate at which the fluid can pass through the comparatively wide passage 36 in the core 32a. As the core 34a rises the spring 44 is extended, an increasing upward pull being exerted thereby on the core 32a, this spring pull, however, initially being less than the attractive force exerted on the core 32a by the coil 32. However, after a predetermined period of time dependent upon the viscosity of the fluid within the tube 30, the size of the narrow passage 46 between the upper and lower ends of the core 34a, and the size of the coil 34 and hence the magnitude of the pull which it exerts on the core 34a, the core 34a will have moved upward into the coil 34 to the position shown in Fig. 3, the spring 44 then having been extended so that its upward pull on the core 32a is just about equal to the downward pull exerted by the coil 32 on the core 32a. A moment after the parts have assumed their position shown in Fig. 3, the core 34a will have been pulled upwardly an additional distance, it being remembered that the coil 34 is stronger than the coil 32. The spring 44 will be further stretched, it will pull up on the core 32a with a force exceeding the attractive action of the coil 32 thereon, and the core 32a will then be pulled or snapped upwardly by the spring 44 out of the coil 32 and away from the armature leg 26, the core 32a moving fairly rapidly because of its wide passage 36 through which the fluid can readily flow. As soon as the core 32a has moved away from the armature leg 26, the electromagnetic attraction exerted on that leg 26 by the coil 32 falls be-

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low the biasing force exerted on the armature 20 by the spring contacts 10, and the armature will pivot in a counter-clockwise direction to its position shown in Fig. 1, even though the coils 32 and 34 remain energized, thus disengaging the contacts 10 from the contacts 6 and permitting them to once again engage with the contacts 8. It will also be understood that as soon as the core 32a has been pulled away from the magnetizable end plate 28, the air gap formed between them will so decrease the magnetic pull between them that the core 32a will continue to be pulled rapidly upward even though the spring 44 has contracted somewhat.

The core 32a will move upwardly, urged by the spring 44, until it engages with the pin 48. The core 34a will remain in its raised position until such time as the coil 34 is de-energized, after which the spring 44 will cause the core 34a to drop, the cores 32a and 34a then resuming their position shown in Fig. 1 and the device being ready for another actuation.

If a rapid resetting of the device is desired, the core 34a may be constructed as shown in Fig. 3, an axial passage 78 being provided therein adapted to be sealed by ball 80, acting as a check valve. When the core 34a moves upwardly the ball 80 will be seated firmly on the upper end of the passage 78, closing the same and permitting fluid to flow only through the narrow passage 46 between the sides of the core 34a and the sides of the tube 30. The core 34a can then move only very slowly. However, when the core 34a is urged downwardly, the ball 80 will be lifted from its seat at the upper end of the passage 78 and fluid will be permitted to flow through the passage 78, thus permitting the core 34a to move downwardly more rapidly than it can move upwardly. It will be understood that the valve 80 is here shown in semi-schematic manner, any appropriate means being provided to prevent escape of the ball 80 from its operative position when the core 34a moves downwardly.

One advantage of the use of a spring 44 to interconnect the cores 32a and 34a is that said spring 44 produces a snap action, the core 32a being pulled upwardly at a rate exceeding the upward rate of movement of the core 34a. A drawback to the use of a spring 44 is that the time delay built into the device is dependent in part upon the strength of that spring, and hence the spring 44 must be carefully calibrated and the time delay will change if the spring should age. Accordingly, in the embodiment of Figs. 4 and 5, a different type of connection between the cores 32'a and 34'a is provided, that connection comprising a linkage of the lost motion type. A link 50 is secured to the pin 42 in the core 34'a, that link extending through the wide axial passage 36 in the core 32'a and having an elongated slot 52 within which the pin 38 on the core 32'a is slidable, that pin 38 being appropriately positioned axially of the passage 36 in order to permit the cores 32'a and 34'a to function as described, that is to say, the core 32'a should be initially movable down into the coil 32 without any restriction by the link 50 and, with the core 32'a within the coil 32 and against the tube end 28, the core 34'a should be free to move upwardly, pulling the link 50 along with it, to a predetermined degree, as shown in Fig. 5, before it will positively lift the core 32'a. In the embodiment of Figs. 4 and 5 a spring 54 is active between the upper end of the tube 30 and the core 34'a so as to bias the core 34'a downwardly against the pin 48, a recess 56 being provided at the upper end of the core 34'a into which the lower end of the spring 54 is adapted to fit, the upper end of the tube 30 being provided with a comparable recess 58 for the upper end of the spring 54.

It is preferred, although it is not essential, that another spring 60 be active between the tube bottom 28 and the core 32'a so as to bias that core upwardly, said core be-

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ing provided with a recess 62 into which the upper end of the spring 60 is received.

The embodiment of Figs. 4 and 5 discloses another modification of the present invention which, if desired, could also be incorporated into the embodiments of Figs. 1-3. An external pipe 64 communicates between the upper end of the tube 30 and a portion of the tube 30 below the core 34'a, the pipe 64 thus defining a bypass around the core 34'a through which the fluid in the tube 30 may flow. A screw 66 is provided in the tube 64 for the purpose of varying the effective diameter thereof and thus throttling the flow of fluid therethrough. With the screw 66 threaded all the way into the pipe 64 so as to close it completely, the device will operate in the same manner as the embodiment of Figs. 1-3. With the screw 66 threaded out so as to permit fluid to flow through the pipe 64, it will be appreciated that the core 34'a will be permitted to move upwardly at an increased rate when attracted by the coil 34, the amount of that increase being determined by the amount to which the screw 66 is withdrawn from the pipe 64. In this way the time delay of the device may be adjusted within limits.

Fig. 6 illustrates a typical circuit arrangement by means of which the device of the present invention may be impulse operated. The coils 32 and 34 are connected in series, one end of the coil 34 being connected to power line 68 and the other end thereof being connected to power line 70 via manually actuated switch 72. The lower end of the coil 32 is also connected by lead 74 to contact 8a, contact 10a, normally disengaged therefrom, being connected by lead 76 to the other side of the switch 72. Contacts 8b and 10b are connected to the circuit to be controlled, it being desired to open that circuit for a predetermined period of time each time that the switch 72 is closed, even if the switch 72 be held closed only for an instant. Of course, by substituting the contact 6b for the contact 8b the external circuit could be held closed for that predetermined period of time.

As soon as the switch 72 is closed the coils 32 and 34 are energized and, because the core 32a is readily movable, the armature 20 is substantially instantaneously pivoted in its clockwise direction as viewed in Fig. 1 so as to close the circuit between contacts 8a and 10a and open the circuit between contacts 6b and 10b. The closing of the contacts 8a and 10a short-circuits the switch 72, so that even if that switch is released and opened the coils 32 and 34 will remain energized. After the core 34a has pulled the core 32a upwardly away from the armature leg 26, the armature will return to its position shown in Fig. 1, the circuit between contacts 8a and 10a will be opened, and the coils 32 and 34 will be de-energized.

From the above it will be apparent that the relay of the present invention is compact, simple and dependable, that it takes up substantially no more room than a relay of conventional construction, and that the time delay between the movement of the armature 20 away from its biased position and back to its biased position may either be fixed in the design and construction of the unit, as in the embodiment of Figs. 1-3, or may be adjustable within limits, as in the embodiment of Figs. 4 and 5.

While but a limited number of embodiments of the present invention have been here disclosed, it will be apparent that many variations may be made therein, all within the spirit of this invention as defined in the appended claims.

I claim:

1. A relay comprising a frame, an armature mounted thereon, operatively connected to a pair of contacts and movable between contact opening and closing positions, and an electromagnet assembly on said support and operatively associated with said armature, said electromagnet assembly comprising a pair of coils each having a core associated therewith and movable therinto and out therefrom, one coil and associated core being close to said

armature and the other being remote therefrom, said armature being biased away from said one coil and being attracted theretoward against said biasing force only when said one core is positioned within its coil and said coil is energized, said other core being biased to a position outside its coil, said one coil being weaker than said other coil, said one core being more freely movable into and out from its coil than is said other core with respect to its coil, means for energizing said coils, and a connection between said cores effective, when said other core has been moved by its coil thereinto to a predetermined extent, to cause said one core to move out of its associated coil against the action of said coil, thereby causing said armature to move away from said one coil even though that coil remains energized.

2. In the relay of claim 1, means for varying the degree to which the movement of said other core is retarded.

3. A relay comprising a frame, an armature mounted thereon, operatively connected to a pair of contacts and movable between contact opening and closing positions, and an electromagnet assembly on said support and operatively associated with said armature, said electromagnet assembly comprising a tube extending from a point close to said armature, a first coil on said tube close to said armature, a second coil on said tube spaced from and having a greater electromagnetic effect than said first coil, first and second cores movable within said tube and operatively associated respectively with said first and second coils, said first core being more freely movable than said second core within said tube, said armature being biased away from said one coil and being attracted theretoward against said biasing force only when said first core is positioned within said first coil and said coil is energized, means biasing said second core out of said second coil, means for energizing said coils, and a connection between said cores effective, when said second core has moved into said second coil to a predetermined extent, to move said first core out of said first coil and away from said armature, thereby causing said armature to move away from said first coil even though that coil remains energized.

4. In the relay of claim 3, means for varying the degree to which the movement of said other core is retarded.

5. The relay of claim 3, in which said connection between said cores comprises a spring.

6. The relay of claim 3, in which said connection between said cores comprises a spring, said tube having an internal projection between said cores and said spring biasing both said cores against said projection and out of their respective coils.

7. The relay of claim 3, in which said tube is filled with a fluid, a relatively wide fluid passage being defined from one end of said first core to the other, a relatively narrow fluid passage being defined from one end of said second core to the other.

8. The relay of claim 7, in which said fluid is a viscous liquid.

9. In the relay of claim 7, a bypass around said second core through which said fluid is adapted to flow, and means for adjusting the freedom of fluid flow through said bypass.

10. The relay of claim 3, in which said connection between said cores comprises a spring, and in which said tube is filled with a fluid, a relatively wide fluid passage being defined from one end of said first core to the other,

a relatively narrow fluid passage being defined from one end of said second core to the other.

11. The relay of claim 3, in which said connection between said cores comprises a spring, said tube having an internal projection between said coils and said spring biasing both said cores against said projection and out of their respective coils, and in which said tube is filled with a fluid, a relatively wide fluid passage being defined from one end of said first core to the other, a relatively narrow fluid passage being defined from one end of said second core to the other.

12. The relay of claim 11, in which said fluid is a viscous liquid.

13. In the relay of claim 11, a bypass around said second core through which said fluid is adapted to flow, and means for adjusting the freedom of fluid flow through said bypass.

14. The relay of claim 3, in which said connection between said cores comprises a lost motion linkage.

15. The relay of claim 3, in which said connection between said cores comprises a lost motion linkage, and a spring active on said second core so as to urge it out of its coil, thereby defining said biasing means active on said second core.

16. The relay of claim 3, in which said connection between said cores comprises a lost motion linkage, said tube having an internal projection between said coils, and a spring active on said second core so as to urge it out of its coil and against said projection.

17. In the relay of claim 3, said connection between said cores comprising a lost motion linkage, a spring active on said second core so as to urge it out of its coil, said tube being filled with a fluid, a relatively wide fluid passage being defined from one end of said first core to the other, a relatively narrow fluid passage being defined from one end of said second core to the other.

18. In the relay of claim 3, said connection between said cores comprising a lost motion linkage, said tube having an internal projection between said cores, and a spring active on said second core so as to urge it out of its coil and against said projection, thereby defining said biasing means active on said second core, and said tube being filled with a fluid, a relatively wide fluid passage being defined from one end of said first core to the other, a relatively narrow fluid passage being defined from one end of said second core to the other.

19. The relay of claim 18, in which said fluid is a viscous liquid.

20. In the relay of claim 18, a bypass around said second core through which said fluid is adapted to flow, and means for adjusting the freedom of fluid flow through said bypass.

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