May 1, 1945. C. O. GIBBON 2,375,100

ELECTROMAGNETIC RELAY

Filed June 6, 1941 2 Sheets-Sheet 1

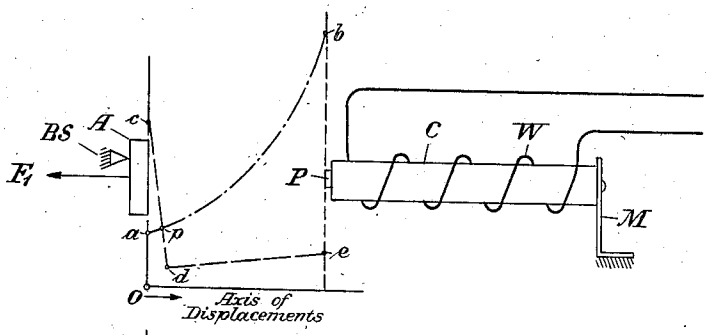


Fig. 1

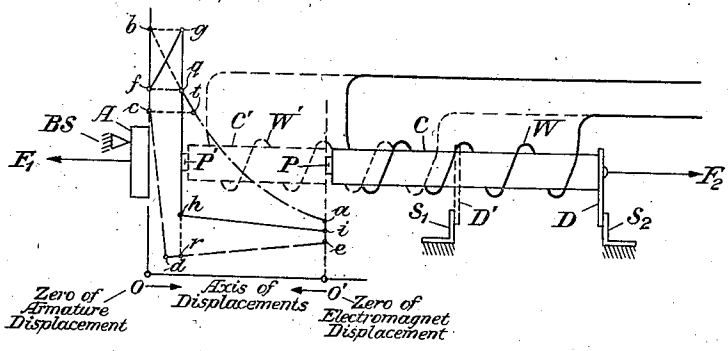


Fig. 2

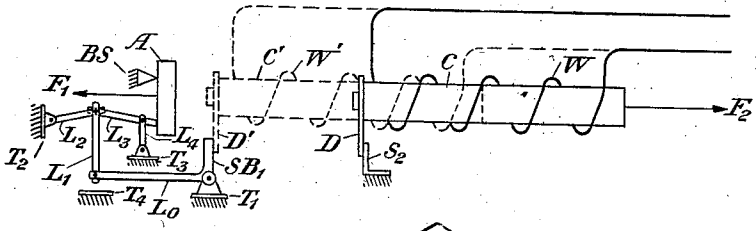


Fig. 3

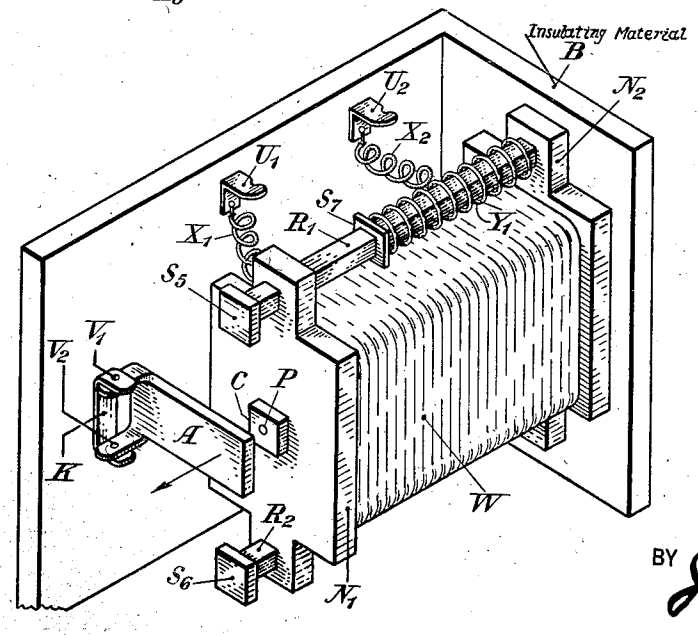


Fig. 4

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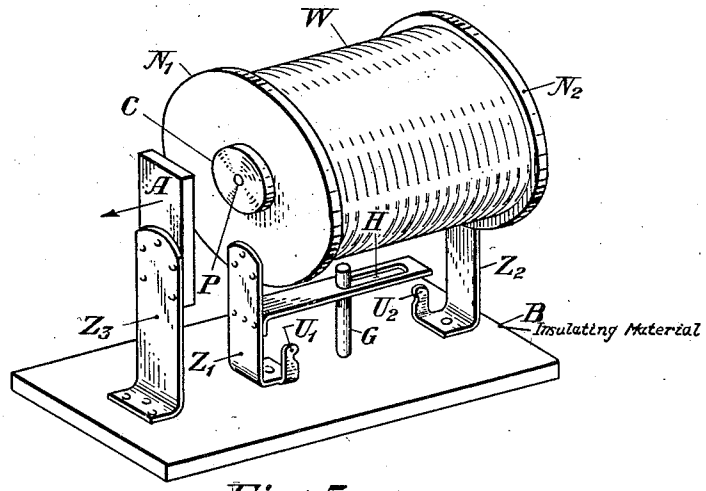


Fig. 5

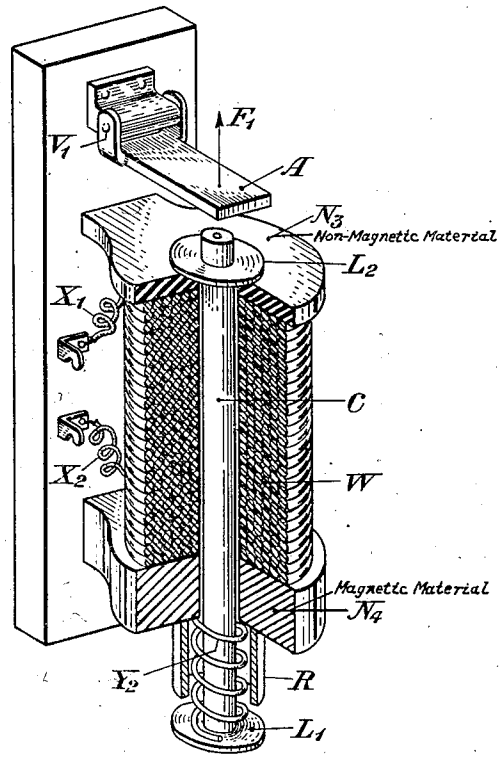


Fig. 6

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ELECTROMAGNETIC RELAY

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Application June 6, 1941, Serial No. 396,798

9 Claims. (Cl. 175—336)

This invention relates to electromagnetic relays and, more particularly, to electromagnetic relays (and like devices) in which the armature and the magnetic structure for attracting the armature are both movable.

There are at present many forms of electromagnetic relays which comprise a stationary electromagnetic structure including, for example, a core of magnetic material and a coil of wire wrapped around the core, and a movable armature of magnetic material which may be attracted to the electromagnet when the electromagnet is energized. Upon the deenergization of the electromagnet the armature is returned to its former or starting position under the influence of some external force such as gravitation or a spring, or other means. In such electromagnetic relays the core and the coil wound thereabout are both stationary and the armature alone is movable. In accordance with this invention not alone is the armature movable in the direction of the electromagnet, but either the core of the electromagnet, or the core and its coil, are movable in the direction of the armature.

This invention may have special application where the armature is coupled to a load which cannot be started in motion by the electromagnetic fields present in relays of the prior art. In accordance with this invention, the core of the electromagnet (or the core and its coil) is advanced toward the armature immediately after the coil is energized, thereby increasing the intensity of the magnetic field acting upon the armature sufficiently to overcome the high initial resistance to the armature's motion. The armature is then started in motion. The core of the electromagnet (or the core and its coil) is thereafter returned to its initial position while the coil remains energized and carries the armature with it to the armature's fully operated position. The armature is returned to its original position only after the coil is deenergized.

This invention will be better understood from the detailed description hereinafter following when read in connection with the accompanying drawings in which Figure 1 represents schematically some of the elements of the prior art, and the characteristics of these elements, as they may be utilized in the practice of this invention; Fig. 2 shows schematically one embodiment of the invention in which both the core and coil of the electromagnet of the relay are simultaneously movable; Fig. 3 represents another embodiment of the invention for initiating the motion of the relay armature after the electromagnet of the relay is energized; Fig. 4 illustrates one form of arrangement shown in perspective, for displacing the entire electromagnet toward the armature; Fig. 5 illustrates another form of the invention which has the same function as the arrangement of Fig. 4; and Fig. 6 shows a different embodiment in which the core of the electromagnet is movable but its coil remains stationary.

Referring to Fig. 1 of the drawings, there are illustrated the core C and the winding W of the electromagnet of a relay, the core being held stationary by being fixedly mounted upon a bracket M. The core C, as is well known, is formed of magnetic material, preferably of a material which retains a minimum of residual magnetism after the core is deenergized. If desired, the core C may have a plug P at its left-hand terminal, as shown, this plug being of brass, copper, or other non-magnetic material to prevent retention or sluggish or erratic release of the relay armature A due to residual magnetism or "freezing" when the current through the coil W is reduced to a nullity. The armature A is, of course, formed also of a similar magnetic material and is mounted in any well known manner so as to be movable by the attraction of the electromagnet when the latter is energized. The armature A is moved toward the core C upon the energization of the electromagnet; and under the influence of an external force, such as a spring, the armature is returned to its initial or starting position, and comes to rest against the back-stop BS when the electromagnet is deenergized. The retarding force acting upon the armature is designated F_1, and in relays of the prior art this retarding force may be in the form of a spring as already stated. It is essential, however, that the force exerted upon the armature A by the field established by the electromagnet be greater than the retarding influence acting upon the armature A so as to initiate the movement of the armature when the electromagnet is energized. This is well understood in the art. The spacing between the armature A and the core C is somewhat exaggerated in the drawings in order to illustrate the principles of the prior art as they relate to the principles of this invention and for convenience in graphing the forces which are brought into play in this invention.

In Fig. 1 the curve *ab* represents the force of attraction between the armature A and the electromagnet, of which core C is a part, when the electromagnet is energized. The forces of attraction are plotted as ordinates and the arma-

ture displacements, that is, distances the armature moves toward the electromagnet from its initial position against back-stop BS, are plotted as abscissae. According to the curve *ab*, when the armature A is in the position shown in Fig. 1, the attractive force is at its least value, i. e., the value represented by the ordinate of point *a*. As the armature is brought closer to the core C the attractive force, being of a magnitude which is proportional to the ordinate at which the armature A is positioned, is also increased. When armature A reaches its limiting position against the plug P of core C, the attractive force is at its greatest value, corresponding to the ordinate of point *b*. The changing force represented by curve *ab* displays the variation which is characteristic of such electromagnetic systems, the attractive force being least when the armature is in its unoperated position, increasing as the armature travels toward the electromagnet and reaching its greatest value when the armature A is in its fully operated position.

Let us assume now that the force F_1, or forces acting upon the armature A have a characteristic such as that shown by curve *cde*. This curve is shown to have an irregularity at *d*. Such an irregularity may be due to the fact that two or more forces are simultaneously coacting on the armature A, for example, one a relatively large force tending to hold the armature in its unoperated position, and the other a continuously acting force which exerts a retarding influence upon the armature A even after it is started in motion. The larger force may have a characteristic somewhat resembling that of the portion *cd* of the curve *cde*, whereas the continuously acting retarding force may be that due to a spring having a characteristic such as *de*. Although the curve *cde* is shown with its irregularity at *d*, the curve may be a continuous curve without any irregularity, and it may have any shape whatsoever. It is to be noted that the curve *ab* intercepts the curve *cde* at point *p*, and point *p* will be a critical point when considered in connection with the factors involved in this invention. At all points to the left of *p* the retarding force acting upon the armature A exceeds the attractive force between the armature A and the electromagnet. Under such conditions the electromagnet when energized is incapable of imparting any motion to armature A through its initial travel path.

In order to overcome such a condition, it is necessary to increase the attractive force between the armature A and the electromagnet from a value 0*a* to some value greater than 0*c*. This can be accomplished, for example, by substituting a more powerful electromagnet for the one heretofore considered, or by substantially reducing the initial separation between the armature A and the electromagnet, or by some combination of these expedients. Any appreciable reduction in the separation between the armature A and the core C might, however, be objectionable from a design standpoint because a predetermined minimum armature travel distance may be required. Moreover, any substantial increase in the power of the electromagnet may be p rohibited by space and cost limitations. According to the present invention there is provided an arrangement for increasing the attractive force between the armature and the electromagnet without recourse to a more powerful electromagnet and without reducing the armature travel distance.

Fig. 2 shows the winding W of the electromagnet mounted upon the core C, the core being separated from the armature A by the same distance as in Fig. 1. The retarding force F_1 acting upon the armature A is the same as that considered in connection with Fig. 1. The electromagnet, however, is movable through any desired portion of the initial distance separating the core C and the armature A. This travel distance may be controlled by suitable positioning of the stops S_1 and S_2. The electromagnet may be coupled to a spring (not shown) which exerts a retarding force F_2 (upon the electromagnet), as shown in the drawing. The movement of the electromagnet in the direction of the retractive force F_2 may be limited in some well known manner, as, for example, by engagement of the approaching dog D, which is suitably attached to and moves with the electromagnet, with the back stop S_2. Under influences of forces to be subsequently described, the electromagnet is free to move toward the armature A until, when the approaching dog reaches the position D' (shown in dotted lines), it engages the fixed forward stop S_1, thereby arresting the electromagnet in its most advanced position as indicated by the dotted lines. It will be apparent, of course, that both the core C and the coil W are moved back and forth as a unitary structure according to the forces which are brought into play in this relay structure.

The curve *hi* represents the force F_2 which tends to hold the electromagnet against the back-stop S_2. This retractive force is at its minimum value when the electromagnet is deenergized and its core is at its most extreme position at the right. The retractive force F_2 increases and reaches its maximum value as the spring tension increases with the displacement of the electromagnet toward its most extreme position at the left. This is a well known phenomenon of a spring or similar tension system. As in Fig. 1, the curve *ab* represents the mutual attraction between the electromagnet and the armature A; but here, to aid in explaining the principles of the invention, the forward displacements of the electromagnet, that is, distances the electromagnet moves towards the armature from its initial position, are plotted as abscissae to the left of the reference zero point 0', so that the position of curve *ab* in Fig. 2 is reversed with respect to its position in Fig. 1. Inasmuch as the forces represented by curve *ab* exceed at all points the corresponding forces represented by curve *hi* then, when the electromagnet is energized, the force exerted by the electromagnet will overcome the retarding force F_2 and hence the electromagnet will move toward armature A against this retarding force F_2.

Assume, also, that the armature A is held fixed in position until the electromagnet reaches its most advanced position at the left. At the most advanced position the attractive force between armature A and the electromagnet which is along curve *ab* will be that represented by the ordinate of point *q* on curve *ab*. Inasmuch as this attractive force exceeds the retarding force acting on armature A which is represented by the ordinate of point *c* on curve *cde*, if the armature now be permitted to move and the electromagnet be assumed to be held fixed in its advanced position the armature will move towards the electromagnet. This motion will continue until the armature comes into contact with the non-magnetic plug P' of the core. During this motion of the armature A the force of attraction exerted between the armature and the electromagnet will

increase as the separation between them decreases, this ascending force of attraction being represented by the curve *fg*, which is merely the corresponding portion *qb* of curve *ab* reversed. At the end of this motion this force of attraction will be that represented by the ordinate of point *g* on curve *fg*. At the same time the force F_1, resisting the motion of the armature A is that represented by point *r* on curve *cde*, while the retractive force F_2 seeking to return the electromagnet to its initial position is that represented by point *h* on curve *hi*. Inasmuch as the value of the retractive force F_2 represented by point *h* exceeds the value of the resisting force F_1 represented by point *r*, and, moreover, since all values of F_2 represented by points between *h* and *i* along curve *hi* exceed the values of F_1 represented by corresponding points between *r* and *e* along curve *cde*, if the electromagnet now be permitted to move it will be returned to its initial position. Since the force of mutual attraction represented by point *g* on curve *fg* persists and exceeds the foregoing values of F_2, the electromagnet, in returning to its initial position, will carry the armature A with it. The armature A will thus be carried to its fully operated position. The arrangement in Fig. 2 is thus readily distinguished from prior art electromagnet schemes in which the armature is the only moving element.

In explaining the operation of the arrangement of Fig. 2, it has been assumed that first the armature A and then the electromagnet consisting of core C and winding W were momentarily held in immovable positions. These assumptions were, of course, made merely to avoid other considerations such as the effects of inertia, the forces due to acceleration, etc., and to simplify the explanation of the operation of the invention. In fact, as the electromagnet moves toward the armature A, due to the energization of the electromagnet, the attractive force between the armature A and the electromagnet rises, as shown by the curve *ab*, and when the point *t* on this curve is reached the mutual attractive force exceeds the retarding force acting on armature A. Consequently, the armature A starts its motion toward the electromagnet almost instantly after point *t* is reached by the moving electromagnet. The component forces continuously acting on the armature A and the electromagnet, while the electromagnet is energized, are so adjusted that the electromagnet reverses its direction of travel and carries the armature A with it to its fully operated position while the electromagnet remains energized. If, in the meantime, the electromagnet becomes deenergized, not alone will the electromagnet return to its initial or unoperated position at the right, but the armature A will also return to its initial or unoperated position at the extreme left.

Fig. 3 shows an arrangement for utilizing the kinetic energy of the moving electromagnet to inaugurate the displacement of the armature A. Here the fixed stop S_1 of Fig. 2 is replaced by a bell crank SB_1 pivoted in a fixed mounting T_1. One arm of this bell crank is positioned to engage the projecting dog D mounted on the electromagnet when it reaches the advanced position D' shown in dotted lines. The other arm L_0 of the bell crank is connected through a link L_1 to operate an expanded toggle consisting of a link L_2 pivoted in a fixed mounting T_2 and a link L_3 pivoted in another link L_4, which in turn is pivoted in the fixed mounting T_3 as shown. The blow delivered to the bell crank SB_1 by the moving electromagnet when the latter is energized is thus converted into a force which acts to move the armature toward the electromagnet. The advanced motion of the electromagnet is limited by the arms L_0 and L_1 encountering the fixed element T_4.

Fig. 4 shows in perspective another arrangement for carrying out the principles of this invention. Here the coil W is supplied with current through two flexible leads X_1 and X_2, which extend to terminals U_1 and U_2, respectively. The coil ends N_1 and N_2 are slidable along two bars R_1 and R_2. The advance motion of the coil W is limited by stops S_5 and S_6 which engage the coil end N_1 when the electromagnet, after being energized, has advanced to a predetermined position. Interposed between the coil end N_2 and the element S_7 which is fixed to bar R_1 is a spring Y_1. This spring is under continuous compression but the compression is increased as the electromagnet W advances with the energization of the electromagnet W. The compression of spring Y_1 introduces the retarding force which is continuously acting on the electromagnet W to return the electromagnet to its original or starting position.

The core C of the electromagnet is shown in the center of the coil W with the non-magnetic plug P at its center. The armature A of the relay is pivoted at points V_1 and V_2, which are mounted in a support bracket K. The armature A has a continuously acting (and other) retarding force applied thereto, as already explained.

Thus when current flows through the coil W, a magnetic field is established by the electromagnet which moves the electromagnet, including its core C, to its forward position at the left, the stops S_5 and S_6 limiting the forward movement of the electromagnet. The compression in the spring Y_1 is increased as the element N_2 advances with the electromagnet. Thereafter the armature A is started in motion toward the electromagnet. While current still energizes the coil W of the electromagnet, the electromagnet is returned to its former or initial position, carrying with it the armature A. The armature A will come to rest when it either strikes a back stop (not shown), or when the electromagnet has reached its starting position. The armature A will remain in its fully operated position until the current through the electromagnet has been interrupted.

Fig. 5 shows a somewhat different embodiment of the invention in perspective. Here the coil W is likewise supported between its ends N_1 and N_2, which are mounted on supports Z_1 and Z_2, respectively. The supports Z_1 and Z_2 are carried on a plate B of insulating material. The supports Z_1 and Z_2 are preferably made of spring-like material, such as phosphor-bronze, for example, and they are fastened at the plate B to lugs U_1 and U_2 to which the current carrying conductors are connected. The support Z_1 also carries a slotted member H within which is located an immovable bar G, which is also supported by the plate B in any well-known manner. The armature A is also carried by a similar support Z_3 mounted on the plate B.

When the coil W of the electromagnet is energized, the electromagnet, including its core C, will be moved to its advanced position at the left, advancing the core C toward the armature A against the retarding influence of supports Z_1 and Z_2. The right-hand end of the slot in member H, upon reaching post G, will limit the motion of the electromagnet as the electromagnet moves toward the armature A. After the electromagnet

has advanced through a predetermined distance, the armature A will be started in motion against its retarding forces toward the electromagnet. Thereafter the electromagnet will be returned to its former position as determined by the left-hand end of the slot of member H meeting post G, while the electromagnet remains energized, and the armature A will reach its fully operated position. The armature will be released only when the current through coil W is stopped. The spring restoring force for armature A is provided by support Z_3. Likewise the supports Z_1 and Z_2 provide the retarding force acting on the electromagnet.

Fig. 6 shows a different arrangement in which the core C of the electromagnet is movable, but the coil W is stationary. Here the upper end of the coil N_3 is made of some non-magnetic material such as fiber, wood, etc., while the lower end N_4 may be made of a magnetic material. A disc L_1 is attached to the lower end of the core C. A spring Y_2 is interposed between disc L_1 and the end N_4 of the coil W. The upward limit of movement of the core C is reached when the disc L_1 engages a tubular member R, the spring Y_2 being compressed in this upward movement. The downward movement of the core C under the influence of the spring Y_2 is restricted by a member L_2, which is also carried by the core C and engages the upper end N_3 of the coil W.

When current is supplied through the leads X_1 and X_2 to the coil W, the magnetic field established between the coil W and the armature A will be so great as to move the core C upwardly toward the armature A against the retarding influence of the spring Y_2. The upward movement of the core C will be arrested when the disc L_1 engages the tube R. In the meantime the armature A will be moved toward the core C against its retarding force F_1. The core C will, moreover, return to its former position while the coil W remains energized, the lower limiting position of the core C being reached when the stop L_2 engages the member N_3. When the core C has returned to its initial position, the armature A will remain in its fully operated position until the current through the coil W is interrupted.

Although the various electromagnetic systems shown in this specification have been described as electromagnetic relays, they need not be used to open and close circuits in response to the movement of the armature back and forth between its limiting positions. These various arrangements may be employed to produce mechanical motion to overcome large initial operating forces whether or not as part of electrical circuits.

While this invention has been shown and described in certain particular embodiments merely for the purpose of illustration, it will be understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. An electromagnetic relay structure comprising a movable coil of wire, a movable core associated with said coil of wire, a movable armature, said coil and said core being advanced toward said armature upon said coil being energized, said armature being advanced toward said core after said core has reached a predetermined point, said coil and said core being returned to their original positions while said coil of wire remains energized.

2. An electromagnetic relay structure comprising a movable coil of wire, a movable core associated with said coil of wire, and a movable armature, said coil and said core being advanced toward said armature upon the energization of said coil of wire, said armature being advanced toward said core after said core has reached a predetermined point, said coil and said core being returned to their original positions and said armature being advanced further in the direction of said core while said coil of wire remains energized.

3. An electromagnetic relay comprising a movable electromagnet and a movable armature, said electromagnet being advanced toward said armature when said electromagnet becomes energized, said armature being advanced toward said electromagnet to contact said electromagnet after said electromagnet has advanced a predetermined distance, said electromagnet being returned to its starting position while said electromagnet remains energized, said armature remaining in contact with said electromagnet during the return travel of said electromagnet, said armature being returned to its starting position when said electromagnet becomes de-energized.

4. In an electromagnetic relay, the combination of an electromagnet having a movable coil and core, a movable amature, and a spring to retard the movement of said armature, the coil and core of said electromagnet being advanced toward said armature upon the energization of said electromagnet, said armature being moved toward said coil and core only after said coil and core have advanced a predetermined distance, said coil and core being returned to their initial positions while said electromagnet remains energized, said armature being released to return to its original position under the influence of said spring upon the de-energization of said electromagnet.

5. In an electromagnet relay, the combination of an armature, continuously acting means for retarding the movement of said armature, an electromagnet having a movable coil and core, continuously acting means for retarding the movement of said coil and core, the coil and core of said electromagnet being advanced toward said armature upon the flow of current through said electromagnet, said armature being advanced toward said coil and core in response to the increased magnetic field resulting from the closer proximity of said core to said armature, said coil and core being returned to their original positions and said armature being further advanced toward said coil and core while current continues to flow through said electromagnet.

6. In an electromagnetic relay, the combination of an armature under load, and an electromagnet, the position of said electromagnet being advanced with respect to said armature when said electromagnet becomes energized so that said armature will be in a stronger magnetic field, said armature being moved toward said electromagnet under the influence of said stronger magnetic field, said electromagnet being returned to its original position while it remains energized.

7. An electromagnetic relay comprising an armature, and an electromagnet, said armature being unattracted toward said electromagnet when said electromagnet is de-energized, said electromagnet being advanced toward said armature when said electromagnet becomes energized, said armature being moved toward said electromagnet after said electromagnet has advanced a predetermined distance toward said armature, said electromagnet being returned to its original position while it remains energized, said armature being

returned to its original position after said electromagnet becomes de-energized.

8. An electromagnetic relay structure comprising a movable electromagnet, and a movable armature, the said electromagnet being moved toward said armature when said electromagnet becomes energized, said armature being advanced toward said electromagnet after said electromagnet has reached a predetermined position, said electromagnet being returned to its original position while it remains energized and carrying said armature with it to its fully operated position, said armature being released and returned to its original position when said electromagnet becomes de-energized.

9. In an electromagnetic relay structure, the combination of a movable armature, means to resist the movement of said armature, and a movable electromagnet, said electromagnet being advanced toward said armature when said electromagnet becomes energized, said armature being advanced toward said electromagnet when the spacing between said armature and said electromagnet has been reduced to a predetermined size, said electromagnet being returned to its original position while it remains energized and carrying said armature with it to its fully operated position, said armature being released and returned to its original position under the influence of said resisting means when said electromagnet becomes de-energized.

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