May 25, 1948. G. C. ARMSTRONG 2,441,984

ELECTRIC CIRCUIT FOR ELECTROMAGNETS

Filed Oct. 12, 1944 2 Sheets-Sheet 1

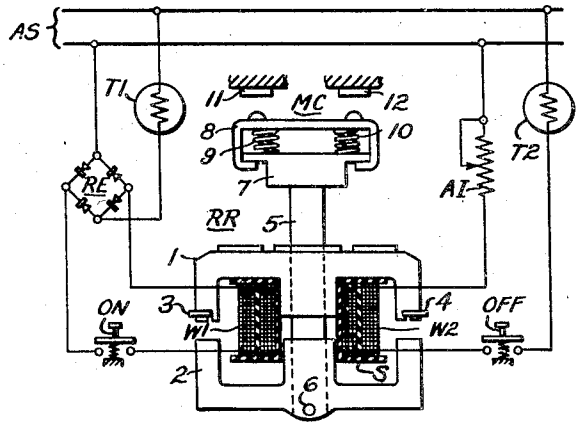


Fig. 1.

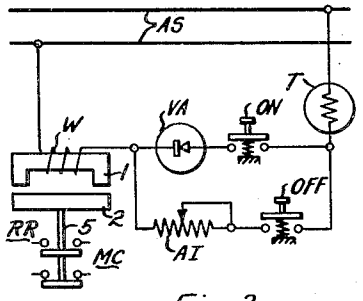


Fig. 3.

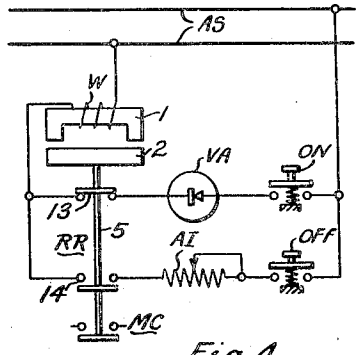


Fig. 4.

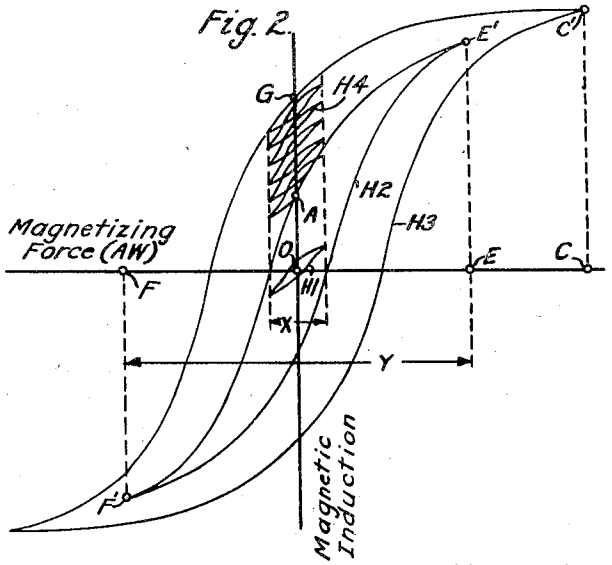


Fig. 2.

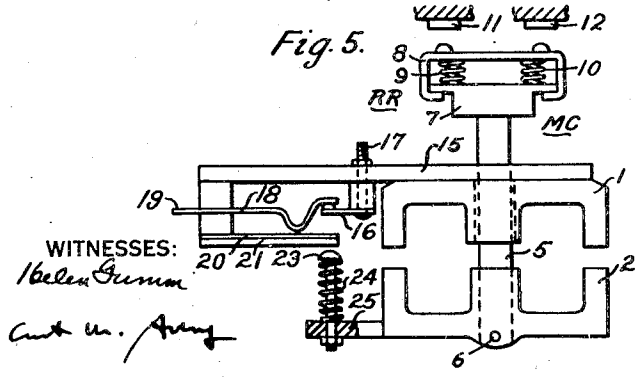


Fig. 5.

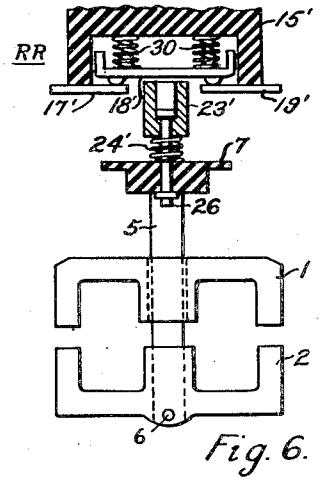


Fig. 6.

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ELECTRIC CIRCUIT FOR ELECTROMAGNETS

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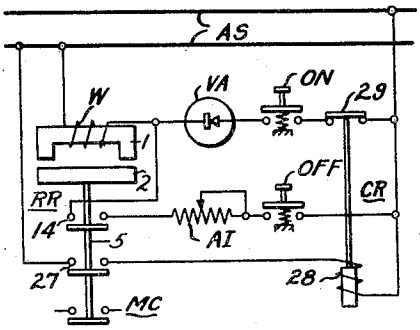


Fig.7

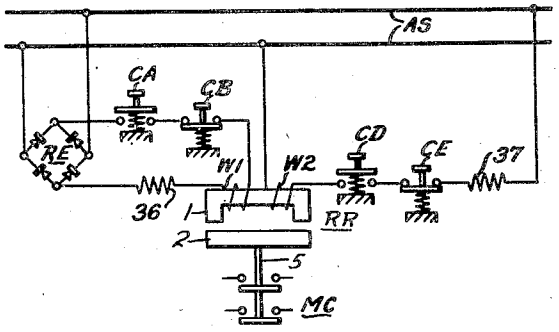


Fig.8

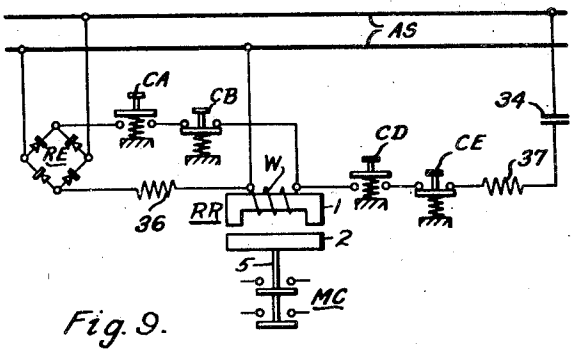


Fig.9.

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ELECTRIC CIRCUIT FOR ELECTROMAGNETS

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5 Claims. (Cl. 175—335)

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My invention relates to control apparatus, in particular contactors, which have an electromagnet capable of holding an armature in attracted position due to retentive magnetism.

In electromagnetic relays and the like devices in which an armature is kept in magnetically attracted position only when and as long as an electric current is passed through the energizing coil of the armature magnet, the magnetic circuit formed by the magnet and its armature consists wholly of substantially non-retentive material. That is, any holding force due to residual magnetism which remains after the cessation of the electric energization is smaller than the biasing force that tends to move the armature away from the magnet. Consequently, the armature is released from the magnet immediately upon termination of the electric current flow. In contrast thereto the electromagnetic apparatus concerned by the present invention are provided with a magnetic circuit which contains magnetizable material of the retentive type so that upon proper magnetization of the circuit, the remaining residual or remanent magnetism is stronger than the armature bias and thus capable of holding the armature sealed against the magnet. Hence, an apparatus of this type has a function similar to that of the so-called "latched-in" contactors and requires special releasing means for causing the armature to drop away from the magnet. To this end, a demagnetizing current is usually applied in order to reduce the residual or remanent magnetism to an amount sufficiently low for being overcome by the armature bias.

Referring to the last-mentioned control apparatus equipped with magnetic circuits of the retentive type, it is an object of my invention to improve such apparatus so as to afford a selection and adjustment of the armature release operation to a desired or most favorable time constant.

Another object of my invention is to provide electromagnetic apparatus of the retentive type which are suitable for operation as time limit relays and permit obtaining a timing period from fractions of a second up to several seconds.

A further object related to the foregoing is to provide electromagnetic time limit devices which in a simple manner afford a change of their timing period within wide limit and without requiring a disassembly of the device and without necessitating a change in the structural parts of the electromagnetic apparatus proper.

These and other objects of the invention will

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become apparent from the following description in conjunction with the drawings, in which:

Figure 1 represents an electromagnetic timing apparatus according to the invention which permits an adjustment of its timing period,

Fig. 2 is explanatory and represents different magnetizing characteristics of a retentive magnetic circuit as embodied by the apparatus shown in Figs. 1 and 3 through 10,

Figs. 3 and 4 illustrate the circuit diagrams of two other embodiments of electromagnetic contact apparatus according to the invention,

Figs. 5 and 6 are schematic illustrations of control relays which are provided with a retarded interlock contact for automatically disconnecting the magnetizing circuit in control apparatus according to the invention,

Figs. 7, 8 and 9 show the circuit diagrams of different relay circuits respectively which also embody the principles of my invention.

Referring to Fig. 1, the electromagnetic contactor, denoted as a whole by RR, has a magnetic circuit which includes a stationary field structure 1 and a movable armature 2. The field structure and the armature are both composed of E-shaped laminations. One or both of the composite bodies 1 and 2 contain a magnetic material of the retentive type. For instance, both bodies may be formed of retentive magnet steel of the type used for permanent magnets. Another way of providing the necessary remanence is to alternate in one or both of bodies 1 and 2 non-retentive and retentive laminations. A simple and preferred design is to compose the field structure 1 entirely of non-retentive laminations and the armature 2 of retentive magnet steel.

The pole ends of the field structure are provided with shading windings 3 and 4. The armature 2 is connected at 6 to a tappet 5 which carries an insulating base 7 for a contact bridge 8. Bridge 8 is vertically displaceable relative to base 7 under compression of contact springs 9 and 10. Two stationary contacts 11 and 12 are provided so as to be connected with each other by the contact bridge 8 when the tappet 5 is lifted by the armature 2. The movable contact assembly as a whole is denoted by MC.

Due to its own gravity and that of the contact assembly, the armature 2 is normally biased away from the field structure 1. The gap between the pole ends of armature and field structure is limited by abutments (not shown) so that the armature remains close enough to the field structure to be lifted when the magnetic circuit of the relay is energized to a sufficient extent.

Two magnetizing coils W1 and W2 are mounted on a spool S which is attached to the field structure 1. The coils surround the center legs of field structure and armature with sufficient play for the armature and the tappet 5 to permit a free upward and downward motion of the movable assembly.

The magnetizing winding W1 is connected through a full-wave rectifier RE with an alternating current source AS. The connection includes a control contact, for instance of the push button type, denoted by ON. The winding W2 is connected to the alternating current source AS through an adjusting impedance device AI, such as an ohmic rheostat, and through a control contact, for instance also of push button type, which is denoted by OFF. The alternating current source AS is preferably of substantially constant voltage. If voltage fluctuations are to be expected, automatic voltage regulators may be employed, for instance, as represented by the ballast resistance tubes T1 and T2.

Assuming that the magnetic circuit of relay RR is demagnetized and hence the armature and appertaining contact assembly MC in the illustrated opening position, the relay can be closed by closing the contact ON. This passes a direct current from rectifier RE through coil W1, and this current is so rated that the magnetic induction produced by winding W1 in the magnetic circuit is strong enough to move the armature 2 and the contact assembly MC upwardly into the closing position. When now the ON contact is released and opened, the residual magnetism or remanence in the magnetic circuit is high enough to maintain the armature in the attracted position. Hence, the contacts remain closed and the relay acts as a latched-in contactor.

In order to release the armature, the OFF contact is actuated, thereby closing an alternating current circuit through coil W2 and impedance device AI. This alternating current is so rated, that it reduces the remanent magnetism gradually and during a multiplicity of alternating current cycles to the low value required for the armature release. The number of cycles necessary for this performance, and consequently the timing period of the relay drop-off, is determined by the adjustment of the impedance device AI. As a result, the time limit of relay RR can be changed to any desired value and within very wide limits merely by changing the slider position of the device AI.

The rating of the magnetic and electric elements required for achieving the just-mentioned adjustability of the timing operation will be understood from the following consideration of the magnetic conditions represented in the diagram of Fig. 2.

Referring to Fig. 2, it should be kept in mind that the armature and the appertaining movable assembly is biased for motion away from the stationary field structure of the magnetic circuit. Hence, in order to seal the armature in its attracted position, the remanent magnetic induction in the magnetizable circuit must be large enough to overcome the biasing force. The diagram of Fig. 2 represents a coordinate system whose abscissa indicates the magnetizing force as represented by the ampere windings of the magnetizing coils, while the ordinate indicates values of the magnetic induction caused in the magnetic circuit by the magnetizing force. Let us assume that a magnetic induction of the value denoted by A is necessary in order to hold the armature

closed against the opening tendency of the armature bias. If the magnetic circuit is magnetized exclusively by means of an alternating current of low magnitude as exemplified by the amplitude X, a magnetizing cycle may be obtained as typified by the hysteresis loop H1 in Fig. 2. With such a low magnetizing current, the magnetic induction produced in the circuit remains always below the value A. Consequently, the field structure 1 will not attract the armature 2.

If the magnetic circuit is not essentially premagnetized and alternating current magnetization applied in accordance with the hysteresis loop H2 so that the magnetizing force varies through the range denoted by Y, i. e., between the positive value E and the negative value F, the magnetic induction passes through the critical value A. Hence, the armature may be attracted and, once attracted, will be held in the attracted position as long as the magnetizing alternating current is effective. However, when the current is switched off, the armature will drop off because the maximum residual magnetism will not be greater than the value A and in all probability will almost always be lower than this value.

If the magnetic relay circuit is magnetized by a substantially higher magnetizing force, for instance, as represented by the value C in Fig. 2, and if upon interruption of the magnetizing current, the residual magnetism is considerably above the value A, for instance, as represented by the value G, the armature will stay sealed. Such a magnetization can be obtained, for instance, by applying a magnetizing direct current to the relay so that the magnetic characteristic reaches the point exemplified by C', and then interrupting the current so that the induction drops to the remanence value G.

The last-mentioned condition is in accordance with the direct-current magnetization obtained in the embodiment of Fig. 1 when the ON contact is temporarily closed. After the opening of the contact, the magnetic condition of the relay is similar to that denoted by value G in Fig. 2, i. e. it exceeds the critical armature sealing value A. When the OFF contact is closed, the alternating-current magnetization applied to the magnet has an amplitude, for instance, as typified by the amplitude value X in Fig. 2. However, since at the closing instant of the alternating-current circuit, the relay is premagnetized to the value G, the ensuing magnetic behavior is similar to that denoted by the magnetizing characteristic H4. That is, the remanence is reduced during each successive cycle of the alternating current. Since the initial remanence G is far in excess of the critical value A and the amplitude of the alternating current is small, many cycles of alternating magnetization are necessary to lower the remanent induction to the value A. Only when this value is reached or surpassed is the magnetic induction lower than necessary for balancing the armature bias, so that the armature drops off.

It will be seen from the foregoing that the number of cycles of the alternating demagnetizing effect depends on the amplitude of the alternating magnetization. Since this amplitude depends on the ampere windings, and hence on the current magnitude of the alternating-current circuit, the number of cycles and hence the period elapsing between the initiation of the demagnetizing effect and the release of the armature can be adjusted by means of the impedance device AI, as described in the foregoing.

I have found by experiments with apparatus of

the type here described, that it is possible in this manner to adjust the time constant of a retentive relay to values from a substantially immediate response to a time limit up to many seconds.

It will be understood from the foregoing that in cases where a certain fixed time limit is desired, the impedance in the opening circuit of the relay may be given a suitable magnitude without provision for changing this magnitude once the apparatus has been assembled or installed.

The embodiment shown in Fig. 3 is equipped with an electromagnetic contactor of the retentive type whose magnetic circuit, shown more schematically than in Fig. 1, is formed by a stationary field structure 1 and an armature 2, one or both of which contain retentive magnetic material for maintaining the armature in sealed position. As described previously, the armature has a tappet 5 for actuating the main contacts MC of the relay. In contrast to the preceding embodiment, a single magnetizing winding W is provided on the field structure 1, both for magnetizing and demagnetizing the magnetic circuit. The winding W is connected to an alternating-current source AS through a voltage stabilizing resistance tube T and two circuit branches. One of these branches contains a valve VA consisting, for instance, of a junction type rectifier and includes a normally open push button or contact marked ON. The second circuit branch contains an adjusting impedance device AI and a control contact marked OFF. When the ON button is depressed, the coil W is energized by intermittent direct current. Upon release of the button, the magnetic circuit retains remanent magnetism considerably in excess of that required for overcoming the armature bias. Consequently, the armature assembly remains in attracted and sealed position. When the OFF button is closed, an alternating current of a small amplitude, as adjusted by the device AI, is passed through the coil W and demagnetizes the magnetic circuit during a number of current cycles in accordance with the desired time limit set by device AI.

In cases where the control contact in the relay closing circuit is apt to remain closed for a period of time longer than that needed, an undue overheating of the relay winding and rectifier or other apparatus can be avoided by inserting an interlock contact which interrupts the magnetizing current under control by the armature. A similar interlock contact controlled by the relay armature may be provided for preventing the energization of the relay opening circuit unless the armature is in the attracted and sealed position. These possibilities are exemplified by Fig. 4.

The embodiment of Fig. 4 is substantially similar to that of Fig. 3 and operates in the manner described in the foregoing, except that the armature and contact assembly includes a normally closed interlock contact 13 and a normally open interlock contact 14. The former is series connected in the relay closing branch of the control circuit while the latter lies in series in the opening branch of this circuit. As long as the armature is in the illustrated open position, a closure of the OFF contact remains ineffective. When the arm contact is closed, the interlock 13 is opened at the end of the armature closing motion.

In order to ascertain that the interlock contact in the relay closing circuit opens only after the magnetic circuit is sufficiently magnetized, a time delay between the sealing moment of the armature and the opening moment of the interlock can be provided for. Figs. 5 to 7 serve to demonstrate two different possibilities of such time delayed interlocks.

According to Fig. 5, the stationary structure 1 of the relay RR is connected by a support 15 with a stationary contact 16 whose terminal is denoted by 17. A movable contact 18 having a terminal 19 is also mounted on support 15. Contact 18 consists of a leaf spring which tends to remain in contact engagement with stationary contact 16. Mounted on support 15 is also a leaf spring 20 in face-to-face relationship to a bar or strip 21 of a material having cold flow properties. That is, this bar consists of a substance which, like thermoplastic and other resinous compositions of suitable consistency, offers a high resistance to sudden deformation but performs a gradual deformation when subjected to continuous stress. These cold flowing materials have the tendency to return into their original condition when released from such stress. In the embodiment shown in Fig. 5 such return motion is further secured by the backing spring 20 mentioned in the foregoing.

The armature assembly is provided with a pin 23 which is biased by a spring 24 and slidably mounted on a holding member 25 attached to the armature assembly. When the armature 2 is attracted so that it seals against the field structure 1, the pin 23 is pressed against the bar 21 under compression of the spring 24. The pressure thus exerted by spring 24 on bar 21 causes the latter to deflect gradually towards the contact 18 until contact 18 is entrained and opens its engagement with contact 16. Consequently, a timed period elapses between the initial sealing moment of the armature and the opening of the contact between terminals 17 and 19.

The appertaining control circuit is not illustrated in Fig. 5, because it may be similar to those shown in the other figures. For instance, the retarded interlock contact according to Fig. 5 may take the place of the interlock denoted by 13 in Fig. 4. That is, the terminals 17 and 19 are then series connected in the direct current branch of the elements VA and ON in Fig. 4.

The relay shown in Fig. 6 has an interlock contact for opening the energizing circuit of the relay coil whose retardation is due to the inertia of a resiliently mounted mass. The relay has a stationary field structure 1 and an armature 2, the latter being provided with a tappet 5 for moving the insulating base 7 of a contact assembly, similar to the design according to Fig. 1. The base 7 carries main contacts (not shown in Fig. 6) and is also provided with actuating means for the interlock contact. These means comprise a pin 26 firmly attached to base 7, a mass 23' slidably mounted on pin 26, and a spring 24' which biases the mass 23' away from base 7 toward a stop formed by pin 26. The interlock contact proper has an insulating base 15' which carries two stationary contacts with terminals 17' and 19' and accommodates a movable contact bridge 18'. Springs 30 serve to bias the bridge 18' toward engagement with contacts 17' and 19'. The energizing coil circuit (not shown in Fig. 6) extends through contacts 17' and 19'. When the relay magnet is energized, the armature 2 is suddenly lifted, while the mass 23', due to its inertia does not follow immediately but compresses first the spring 24' before it is also lifted. As a result, the magnet is sealed before the mass 23' is moved against the bridge contact 18', so that the interlock contact is interrupted

with sufficient delay to secure the desired operation. The springs 24' and 30 are dimensioned so that spring 24' can lift the mass and the contact bridge in opposition to the weaker springs 30.

According to the embodiment shown in Fig. 7, a time delayed interruption of the relay closing circuit is obtained by means of an auxiliary control relay denoted by CR. The closing and opening circuit for relay winding W is substantially similar to that shown in Fig. 4, except that the armature assembly of relay RR is provided with an interlock contact 27 which closes when the armature 2 seals against the field structure 1. This interlock connects the coil 28 of auxiliary relay CR to the alternating-current source AS so that a contact 29 in the closing branch of the circuit is opened later than the closure of contact 27.

The circuit diagram shown in Fig. 8 is similar to that according to Fig. 1, but so modified as to enforce a given sequence of operation of a number of control contacts. Winding W1 of the relay is energized from a rectifier RE through an adjusting resistor 36, a normally open contact CA and a normally closed contact CB. Winding W2 is connected to an alternating-current source AS through an adjusting resistor 37, a normally open contact CD and a normally closed contact CE. The direct and alternating currents in the two circuits are adjusted by means of the impedances 36 and 37 so that neither the direct current nor the alternating current, acting alone, is capable of closing the magnet. Consequently, both contacts CA and CD must be closed before the relay will pick up. After the relay is closed and sealed, contact CB must be opened before contact CE, or the relay will remain closed.

Fig. 9 shows a similar arrangement whose operation is performed in accordance with the one just described with reference to Fig. 8, except that a capacitive resonance circuit, including a capacitor 34, is used in the alternating portion of the control circuit. Furthermore, both the direct current and alternating current circuits are connected to a single relay winding W, so that the superposition of the direct current and alternating current control effects occur in the energizing circuit of the relay winding.

As demonstrated by the variety of embodiments shown and described in this application, it is possible to practice my invention in various ways and to make changes or introduce modifications or additions without departing from the gist and essential features of the invention as set forth in the claims appended hereto.

I claim as my invention:

1. Control apparatus comprising, in combination, a retentive magnetic circuit having a field structure and an armature movable toward and biased away from said field structure, electric control means including direct-current means for magnetizing said circuit so as to cause said field structure and armature to attract each other and to remain attached by remanent magnetic induction of substantially a given value in excess of that required for overcoming the armature bias, and control means disposed for demagnetizing said circuit and comprising an alternating current circuit inductively linked to said magnetic circuit for applying thereto an alternating magnetic induction of lower magnitude than said given excess value of said remanent induction so as to require a multiple number of alternating current cycles from the initiation of the demagnetization to the release of said armature, and an adjustable electric circuit element disposed in said alternating current circuit for varying said number of cycles in order to select a desired timing period.

2. Control apparatus comprising, in combination, a retentive magnetic circuit having a field structure and an armature movable toward and biased away from said field structure, two energizing coils inductively associated with said magnetic circuit, a direct-current relay closing circuit having contact means and being connected with one of said coils in order to produce in said magnetic circuit and under control by said contact means a remanent magnetic induction a substantially given value in excess of that required for sealing said armature in attracted position against its bias, an electric alternating current circuit having contact means and being connected with said second coil for applying to said magnetic circuit an alternating magnetic induction of lower magnitude than said excess value of said remanent induction so as to require a multiple number of alternating current cycles from the initiation of the demagnetization to the release of said armature, and an adjustable impedance device disposed in said alternating current circuit for changing said number of cycles in order to thereby adjust the drop-off timing of said relay.

3. Control apparatus comprising, in combination, a retentive magnetic circuit having a field structure and an armature movable toward and biased away from said field structure, coil means disposed on said circuit for controlling its magnetic condition, alternating current supply means for energizing said coil means, controllable circuit means disposed between said supply means and said coil means and containing a control contact and valve means for producing in said magnetic circuit and under control by said contact a unidirectional magnetic induction of a remanent magnitude in excess of that required for sealing said armature to said field structure against the armature bias, and controllable circuit means disposed between said supply means and said coil means and including an adjustable impedance device rated for applying to said magnetic circuit an alternating magnetic induction of lower magnitude than the excess magnitude of said remanent induction so as to require a multiple number of alternating current cycles from the initiation of the demagnetization to the release of said armature in accordance with a desired timing period.

4. A contactor comprising, in combination, a retentive magnetic circuit including a field structure and an armature movable toward and away from said field structure and biased for motion away from said structure, direct current means inductively associated with said circuit for producing therein a magnetic induction sufficient for attracting said armature toward said structure and holding it by remanent magnetism, a control contact for rendering said direct current means operative, and a time-delayed contact under control by said armature for rendering said current means inoperative upon elapse of a timed period after the attraction of said armature.

5. Control apparatus comprising, in combination, a retentive magnetic circuit having a field structure and an armature movable toward and biased away from said field structure, coil means inductively associated with said magnetic circuit, direct-current circuit means of substantially constant voltage attached to said coil means and hav-

ing a control contact for causing said field structure and armature, when said contact is actuated, to attract each other by magnetic induction substantially a given value in excess of that required for overcoming the armature bias, and control means disposed for demagnetizing said circuit and comprising alternating current means rated for applying to said circuit an alternating magnetic induction of lower magnitude than said given excess value of said induction so as to require a multiple number of alternating current cycles from the initiation of the demagnetization to the release of said armature, and resistance means forming part of said alternating current means for approximately adjusting said number of cycles in accordance with a desired timing period.

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