April 2, 1963 C. A. SCHURR 3,084,310

CONTROL CIRCUIT

Filed Dec. 14, 1959 2 Sheets-Sheet 1

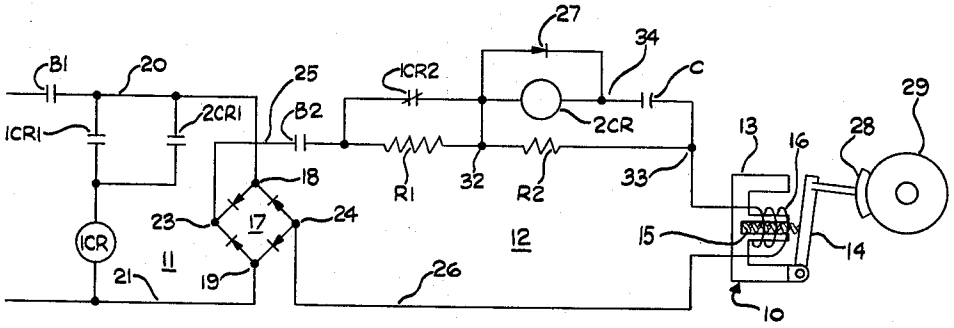


Fig. 1

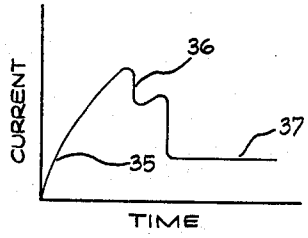


Fig. 2

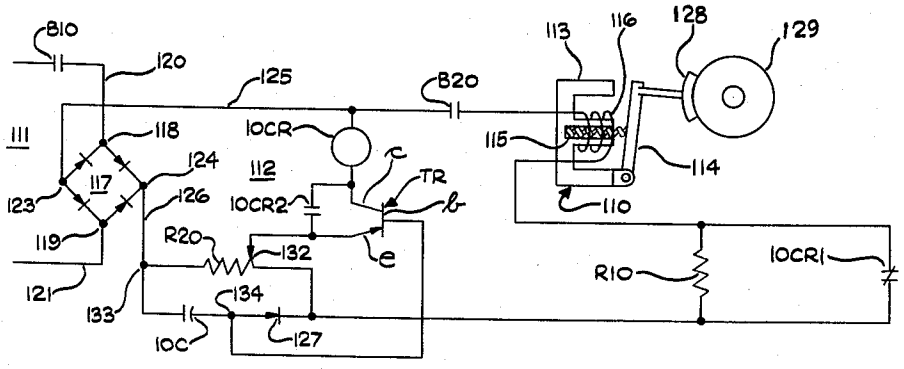


Fig. 3

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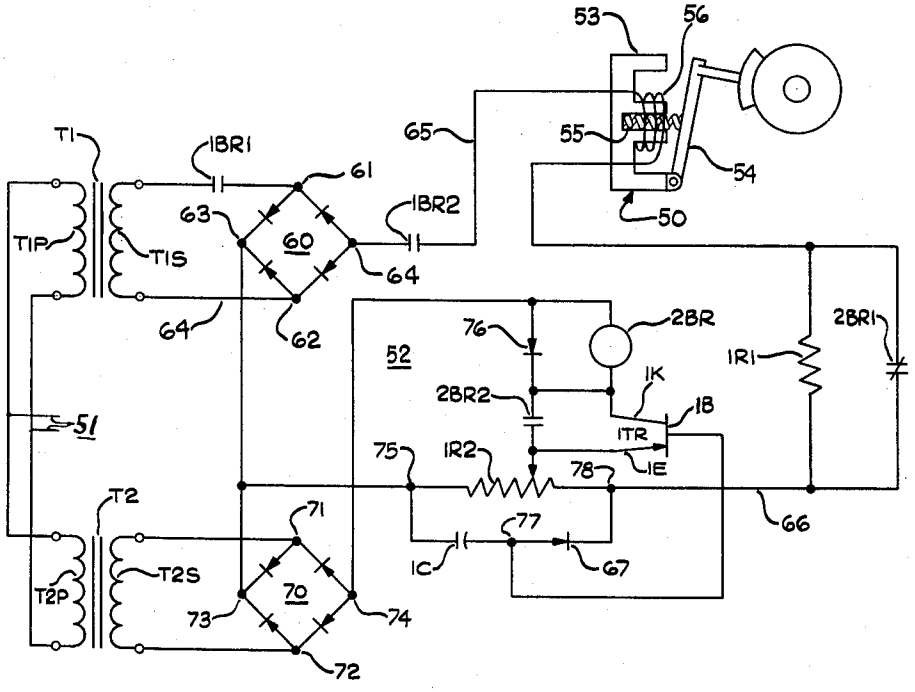


Fig. 4

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CONTROL CIRCUIT

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8 Claims. (Cl. 317—123)

The present invention relates to a control system responsive to a diminution in magnitude of current flowing through a coil which establishes magnetic flux in relatively movable magnetizable members and more particularly to a control system which instantaneously reduces the magnitude of current flowing through the coil at the instant the magnetizable members touch each other.

Electromagnetic devices provided with a stationary pole piece which supports an energizing coil operate because energization of the coil establishes a magnetic flux path through the stationary pole piece and through the armature. When the armature is spaced from the pole piece, there is an air gap in this flux path and when the armature is seated against or touches the pole piece, the flux path is free of an air gap, or at least has a considerably smaller air gap. The term "free of an air gap" as used herein is meant to include those occasions wherein there is no air gap between the pole piece and the armature as well as those occasions wherein the air gap has been reduced from a relatively large air gap to a relatively small air gap. Electromagnetic devices of this type are commonly used in contactors, relays, and electromagnetically operated brakes.

It is well known that the magnitude of current required to initiate movement of an armature to seat the armature against the stationary pole piece of an electromagnetic device is greater than the magnitude of current required to maintain the armature in the seated position. Also, the armature will seat faster if a large initial current is used than if a small initial current is used. When the electromagnetic device is a brake, it is apparent that the brake's speed of operation may be increased if large initial currents, which, if permitted to be maintained, would overheat the coil, are initially impressed on the coil to cause the armature to move toward the stationary pole piece. After the armature touches the pole piece to provide a flux path free of air gaps, the maximum magnitude of current may be reduced to prevent overheating the coil winding because less current is required to maintain the armature in seated or touched relationship with the stationary pole piece, and also to reduce the length of time required for flux decay thereby improving drop-out characteristics of the electromagnetic device.

In the past, various types of relays and other timing circuits have been used to effect a reduction in the maximum magnitude of current after the armature has seated or touched the stationary pole piece. All of these prior devices operate after a lapse of time or after a predetermined current has been reached and none of them operate in response to any change in electrical conditions resulting from the seating of the armature against the pole piece. It is thus apparent that because they operate sometime after seating of the armature, the initial heavy current is allowed to flow through the winding for a period of time after the armature seats and a period of time longer than necessary. In addition, it was found necessary to adjust the timing circuits every time the device was adjusted. To eliminate this unnecessarily long period of time, the required adjustments always presented the danger of reducing the maximum possible magnitude of current flowing through the coil prior to seating of the armature and the resultant failure of the device because the armature was not touching the stationary pole piece.

Thus, one of the problems is that of providing a device

which automatically reduces the maximum possible magnitude of current flowing through the coil at the instant the armature seats against or touches the stationary pole piece. Therefore, one of the objects of the present invention is to provide a solution to that problem and to overcome the deficiencies in prior attempts to solve the problem.

Another object of the present invention is to provide means for inserting a current limiter in series with the coil of an electromagnetic device at the instant the armature touches the stationary pole piece.

Another object of the invention is to provide a circuit, responsive to the back E.M.F. generated by movement of the armature relative to the coil of an electromagnetic device, which may be used to effectively insert a current limiting device in series circuit with the coil.

A further object of the invention is to provide means responsive to a change in the characteristics of the flux path established by the coil of an electromagnet for automatically interposing a current limiting device in the energizing circuit of the flux producing coil.

Other objects and a fuller understanding of the present invention may be had by referring to the appended claims defining the present new, novel and useful invention or discovery, to the following description of a specific means or method contemplated by the inventor for carrying out his invention, and to the acompanying drawings in which:

FIGURE 1 is a schematic diagram of an electromagnetic brake provided with a stationary pole piece, a movable armature, a coil and a coil energizing circuit incorporating the present invention;

FIGURE 2 is a chart illustrating the magnitude of current in the coil energizing circuit for the time of movement of the positioning of the armature relative to the stationary pole piece;

FIGURE 3 is a wiring diagram of an alternate form of the invention; and

FIGURE 4 is a wiring diagram of another alternate form of the invention.

The following description of the attached drawings and the accompanying claims jointly set forth one or more modifications incorporating the present invention and the advancement in the art of control devices. As used throughout the present description and claims, the specific terms used to identify the parts or components have been arbitrarily chosen to indicate to others commercially available parts or components which may be readily obtained to carry out the specific mode of the invention as described herein, and they are to be interpreted in their broad sense wherein they include electrically or mechanically equivalent components which will provide the same functions as those mentioned herein.

Insofar as possible, any relay used in the invention is illustrated with its coil represented by a circle and with the contacts operated thereby represented by parallel lines. The individual sets of contacts and their operating coils are identified in the drawings either by letters or a combination of letters and numbers with the reference to a respective coil or contacts being identified by the reference character of the other plus a suffix. It is further noted that where convenient, the letters used as reference characters or identification for a relay coil or relay contacts are to some extent an abbreviation of the function performed by the respective relay in the control system.

In FIGURE 1, there is illustrated an electromagnet used in an electromagnetic brake **10** which is energized from a source of power **11** by means of a control circuit **12**. The brake **10** has a stationary flux conductive pole piece **13** and a movable flux conductive armature **14** which is movable toward the stationary flux conductive pole piece **13**, against a force exerter or spring **15**,

upon establishment of a magnetic flux in the stationary flux conductive pole piece **13** by an energizable coil **16**, which is electromagnetically associated with the stationary flux conductive pole piece **13**. Current flows through the energizable coil **16** to provide a flux in the flux conductive pole piece **13** while the energizable coil **16** is energized from the source of power **11**. Movement of the armature **14** relative to the stationary pole piece generates a back E.M.F. in the energizable coil **16**. This back E.M.F. reaches a maximum as the armature **14** seats against the stationary pole piece **13**.

The source of power **11** may be a direct current source or, as illustrated, may comprise a rectifier bridge **17**, having a pair of input terminals **18** and **19** interconnected by a pair of lines **20** and **21** respectively to any suitable source of alternating current. Interposed in the line **20** is a set of normally open contacts **B1** which may be closed to permit the flow of current between an alternating current source and the rectifier bridge **17**. Interconnected between the lines **20** and **21** is a series connection consisting of a set of normally open relay contacts **1CR1** and a relay coil **1CR** which is energizable to close those contacts **1CR1**. Shunting the set of contacts **1CR1** is a set of normally open relay contacts **2CR1**, which may be closed by energization of a relay coil **2CR**.

The energizable coil **16** of the electromagnet **10** is connected across a pair of output terminals **23** and **24** of the rectifier bridge **17** by means of a pair of leads **25** and **26** so that the direct current output of rectifier bridge **17** will flow through the energizable coil **16**. Interposed in the lead **25** is a set of normally open contacts **B2**, a resistor **R1** and a resistor **R2**, all of which are connected in series. Shunting the resistor **R1** is a set of normally closed relay contacts **1CR2** openable by the energization of the relay coil **1CR**. Shunting the resistor **R2** is a series circuit comprising a capacitor **C** and a relay coil **2CR**. A uni-directional current conducting device **27** is connected in shunt with the relay coil **2CR**. The individual rectifiers in the rectifier bridge **17** are poled to pass current in a direction starting from the bridge **17** through the lead **25**, the contacts **B2**, the resistor **R1** or the relay contacts **1CR2**, the resistor **R2**, the energizable coil **16** and the lead **26** and to prevent the flow of current in a direction reverse thereto. Uni-directional device **27** is poled so that current also flows therethrough to charge capacitor **C**.

The electromagnetic brake **10**, including the coil **16**, is illustrated in a set position in which it has a brake shoe **28** secured to the movable flux conductive armature **14** and frictionally engaging a wheel **29** to prevent rotation of the wheel **29**. The brake shoe **28** is maintained against the wheel **29**, so long as the energizable coil **16** is de-energized, by the force exerter or spring **15** which exerts force against the movable flux conductive armature **14** in a direction opposite to the force of the flux established by energizing the coil **16**.

When it is desired to withdraw the brake shoe **28** from the wheel **29**, the contacts **B1** and **B2** are closed. This closing of the contacts **B1** and **B2** initiates a flow of current through the lines **20** and **21** and through the rectifier bridge **17**. Upon the closing of the contacts **B1** and **B2**, the magnitude of the current begins to increase and the current flows through the normally closed contacts **1CR2** and the small resistor **R2**. The capacitor **C** becomes charged because there is a negligible voltage drop across the rectifier and because of the voltage between one point **32**, located between the resistors **R1** and **R2**, and another point **33** which is located between the resistor **R2** and the electromagnetic brake **10**. The potential at a point **34**, located between the uni-directional device **27** and the capacitor **C**, will be substantially the same as that at the point **32**.

As illustrated by a first portion **35** of the curve in FIGURE 2, the magnitude of the current continues to increase for a period of time, and until it has provided sufficient flux to move the movable flux conductive armature **14** toward the stationary flux conductive pole piece **13**. At the instant the armature **14** moves toward or touches the pole piece **13**, there is a dip or sudden decrease in the energizing current as represented by a portion **36** of the curve in FIGURE 2. Simultaneously, and because of the dip resulting from the seating of the armature **14**, there is also a corresponding decrease in voltage between the points **32** and **33**. As a result, and because of the blocking action of the uni-directional device **27**, the point **34** is now at a higher potential than point **32**. Immediately a current flows from capacitor **C** through the relay coil **2CR** and causes the relay coil **2CR** to close relay contacts **2CR1**. This closing of relay contacts **2CR1** effects energization of the relay coil **1CR** and thereby the closing of relay contacts **1CR1** and the opening of the relay contacts **1CR2**.

It is apparent that because relay contacts **1CR2** shunt resistor **R1**, the resistor **R1** will be effectively added in series with the resistor **R2** and energizable coil **16** by the opening of relay contacts **1CR2**. In this way, the object of effectively adding current limiting means in series with the energizing coil, or of effectively limiting the magnitude of current flowing through energizable coil **16** when the conductive armature **14** touches pole piece **13**, has been attained. Also, this limiting of current is responsive to the change in current flow in the energizable coil **16**. Following the addition of the current limiting features, a magnitude of current flows as illustrated by a portion **37** of the curve in FIGURE 2. The maximum magnitude possible for this current is lower than that which would flow if resistor **R1** had remained shunted by the contacts **1CR2**.

In the alternate form of the invention illustrated in FIGURE 3, an electromagnetic brake **110** is energized from a source of power **111** by means of a control circuit **112**. The brake **110**, being the same as brake **10**, has a stationary flux-conductive pole piece **113** and a movable flux-conductive armature **114** which is urged away from pole piece **113** by a spring **115** and moved toward stationary flux-conductive pole piece **113** upon establishment of magnetic flux in the flux-conductive pole piece **113** by an energizable coil **116** which is electromagnetically associated with flux conductive pole piece **113**. Current flows through energizable coil **116** to provide flux in the flux conductive pole piece **113** while the energizable coil **116** is energized from source of power **111**.

The source of power **111** comprises a rectifier bridge **117** having a pair of input terminals **118** and **119** interconnected by a pair of lines **120** and **121** respectively to any suitable source of alternating current. Interposed in the line **120** is a set of normally open contacts **B10** which may be closed to permit flow of power between an alternating current source and the rectifier bridge **117**. The energizable coil **116** is connected across a pair of output terminals **123** and **124** of the rectifier bridge **117** by means of a pair of leads **125** and **126** so that the direct current output of the rectifier bridge **117** will flow through the energizable coil **116**. Interposed in the lead **126** is a resistor **R10** and a resistor portion **R20** all of which are connected in series. Shunting resistor **R10** is a set of normally closed relay contacts **10CR1** openable by energization of a relay coil **10CR**. Shunting the resistor **R20** is a series circuit comprising a capacitor **10C** and a unidirectional current conducting device or rectifier **127**. The individual rectifiers in rectifier bridge **117** are poled to pass current in a direction starting from the output terminal **124** of the rectifier bridge **117** and through the lead **126**, the resistor **R20**, the resistor **R10** or the contacts **10CR1**, the energizable coil **116**, and the contacts **B20** and to prevent the flow of current in a direction reverse thereto. Uni-directional device **127** is poled so that current also flows therethrough to charge capacitor **10C**.

The relay coil **10CR** is connected in series with a collector *c* and an emitter *e* of a transistor TR and that

series connection of the relay coil 10CR and transistor TR is connected across the leads 125 and 126, with the emitter *e* being connected to a point 132 located between the extreme ends of the resistor R20 and the resistor R10. In this instance, the exact electrical position of the point 132 is adjustable and emitter *e* is connected to the resistor R20. In the circuit of FIGURE 3, if there is a momentary interruption of power which allows relay 10CR to drop out, and power is immediately restored before the brake releases, 10CR will remain open and the brake will burn up unless point 132 is located so as to maintain a bias on the transistor proportional to current. Shunting the collector *c* and the emitter *e* is a set of normally open contacts 10CR2 which close upon energization of the relay 10CR to create a holding circuit for relay 10CR.

The brake 110 is illustrated in a set position in which it has a brake shoe 128 secured to a movable flux conductive armature 114 and frictionally engaging a wheel 129 to prevent rotation of the wheel 129. The brake shoe 128 is maintained against the wheel 129 by a spring 115 so long as the energizable coil 116 is de-energized. The circuit thus provides several points, namely the point 132 and points 133 and 134, similar to the points 32, 33 and 34 in FIGURE 1. The point 133 is located at the connection of the resistor R20, and one side of the capacitor 10C, to the line 126. The point 134 is located at the interconnection between the capacitor 10C and the unidirectional device 127, and is connected to the base *b* of transistor TR.

When it is desired to withdraw the brake shoe 128 from the wheel 129, the contacts B10 and B20 are closed. This closing of the contacts B10 and B20 initiates current flow through the lines 120 and 121 and the rectifier bridge 117. The current is rectified in the rectifier bridge 117 so that a direct current flows in a direction through the lead 126, the resistor R20 and the contacts 10CR1, the energizable coil 116, the contact B20 and the lead 125 in that named order.

When the contacts B10 and B20 are first closed, the potential of point 134 is substantially equal to that of point 132 so that with no voltage existing between the base *b* of the transistor TR and point 132, there will be only a minimum current flowing through the relay coil 10CR. This current is not sufficient to cause coil 10CR to open contacts 10CR1 and close contacts 10CR2. When the brake seals i.e. when armature 114 seats against or touches pole piece 113, the potential at point 134 will suddenly become more negative than the potential at point 132. This change in potential immediately causes the transistor TR to conduct sufficient current through 10CR between the lead 125 and 126 to cause it to open the normally closed contacts 10CR1 and close contacts 10CR2. Opening contacts 10CR1 introduces the series economy resistor R10 conductively into the circuit in series with coil 116 to thereby reduce the magnitude of current flowing through energizable coil 116. Resistor R10 is of a value relative to the characteristics of energizable coil 116 such that current flowing through energizable coil 116 after armature 114 has seated against pole piece 113 and contacts 10CR1 have opened is sufficient to hold the brake released by holding armature 114 against core 113 and against the force of the spring 115.

In the alternate form of the invention as illustrated in FIGURE 4, an electromagnetic brake 50 is energized from a source of power 51 by means of a control circuit 52. The brake 50 has a stationary flux conductive pole piece 53 and a movable flux conductive armature 54 which is urged away from the pole piece 53 by a spring 55 and moved towards the stationary flux conductive pole piece 53 by the energizable coil 56 when the coil is energized from a source of power 51.

The source of power 51 includes a transformer T1 and a rectifier bridge 60. Transformer T1 has a primary T1P and a secondary T1S. The rectifier bridge 60 has a pair of input terminals 61 and 62, interconnected to the opposite ends respectively of transformer secondary T1S, and a pair of output terminals 63 and 64. Interposed between one end of transformer secondary T1S and the input terminal 61 is a set of normally open contacts 1BR1 which may be closed to permit flow of power from the power source 51 to the rectifier bridge 60. The energizable coil 56 is connected across the output terminals 63 and 64 of the rectifier bridge 60 by means of a pair of leads 65 and 66 so that the direct current output of the rectifier bridge 60 will flow through the energizable coil 56. Interposed in the lead 65 is a set of normally open contacts 1BR2 closable along with the closing of contacts 1BR1 to effect energization of energizable coil 56. Interposed in the lead 66 is a resistor 1R1 and a resistor 1R2 all of which are connected in series. Shunting the resistor 1R1 is a set of normally closed relay contacts 2BR1 openable by energization of a related relay coil 2BR in a manner which will later be described. Shunting the resistor 1R2 is a series circuit comprising a capacitor or condenser 1C and a uni-directional device or rectifier 67. The individual rectifiers in rectifier bridge 60 are poled to pass current, starting from the bridge 60, in a direction through the lead 66, resistors 1R2 and 1R1, or contacts 2BR1, coil 56, lead 65, and contacts 1BR2 and to prevent the flow of current in a direction reverse thereto. Uni-directional device 67 is poled so that current also flows therethrough to charge capacitor 1C.

In FIGURE 4, and because the voltage used to energize the brake is generally fairly high in comparison to the voltage ratings of transistors, a separate voltage source is used to power the relay coil 2BR. The relay coil 2BR is energized from power source 51 by a circuit including a transformer T2, having a primary T2P connected to power source 51 and a secondary T2S, and rectifier bridge 70. The energization of coil 2BR is controlled by a transistor 1TR responsive to current flow through leads 65 and 66. The rectifier bridge 70 has input terminals 71 and 72 connected to their respective ends of secondary T2S and output terminals 73 and 74 connected in a loop circuit for energizing relay coil 2BR. This loop circuit, starting at outlet 74, comprises outlet 74, relay coil 2BR, collector 1K of transistor 1TR, emitter 1E of transistor 1TR, at least a portion of resistor 1R2 and output terminal 73 of rectifier bridge 70. The output terminal 73 is maintained at the same electrical potential as the output terminal 63 and the interconnected end of resistor 1R2 since these three points are electrically tied together to provide a voltage point 75 on one side of capacitor 1C and at the extreme end of resistor 1R2. Shunting relay coil 2BR is a protective rectifier 76 and shunting collector 1K and emitter 1E is normally open set of relay contacts 2BR2 which interlock relay coil 2BR when it is energized. The emitter 1E is adjustably connected to the resistor R2 at some point at or between the ends thereof.

The transistor TR has a base 1B electrically connected to a point 77 located between condenser 1C and the unidirectional device 67 and on the side of the condenser opposite the voltage point 75. FIGURE 4 shows the emitter 1E of the transistor 1TR connected to the resistor 1R2 at a point which puts a positive bias on the transistor proportional to current in the brake coil energizing circuit and in lead 66. With proper adjustment of this point along the resistor 1R2, this bias will cause the transistor to conduct and energize the relay coil 2BR when the current in lead 66 has reached its maximum. Normally the transistor 1TR operates when the current in lead 66 dips during the time the armature 54 of the brake 50 is operating. However, if, because of a momentary open circuit, or for some other reason, the transistor should not be triggered by this dip, the relay coil 2BR will be energized because the transistor 1TR will be triggered by the bias described above.

To energize the brake, contacts 1BR1 and 1BR2 are closed. Current now flows through the resistor 1R2 and

also starts to charge the capacitor 1C. When the brake armature begins to move in toward seating position, the brake coil 56 begins to generate a back voltage and, as the armature seats, this back voltage increases in magnitude, thus reducing the current as indicated by the portion 36 in FIGURE 2. The back voltage causes the current to decrease thus reducing the voltage drop between the point 75 and a point 78 defined by the interconnection of the ends of the resistors 1R1 and 1R2 and uni-directional device 67. The capacitor 1C was charged to the value of voltage associated with the higher current (portion 35 in FIGURE 2) passing through resistor 1R2. Because of this, the capacitor 1C now causes a current to flow from point 75 to the emitter 1E, through the emitter 1E to the base 1B of the transistor 1TR and back to the point 77, thereby discharging the capacitor 1C. This causes the transistor to operate and conduct current from point 75 through the emitter 1E, the collector 1K, through the relay coil 2BR, the output terminal 74, the rectifier 70, and the output terminal 73 to the point 75. This causes the relay to operate, thereby opening the normally closed contacts 2BR1 and closing the normally open interlock contacts of 2BR2, which hold the relay coil 2BR energized. The normally closed contacts open and electrically insert resistor 1R1 in the coil energizing circuit to limit the current therein to a safe value.

Although this invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and scope of the invention as hereinafter claimed.

What is claimed is:

1. A first magnetizable member, a second magnetizable member movable toward and away from the first member and seatable thereagainst, a circuit, coil means in the circuit and establishing magnetic flux in a flux path in which the flux threads through both members, a direct current source energizing said circuit and causing current to flow therethrough, a current restrictive means, and means responsive to sudden reduction in magnitude of said current flowing in said circuit to interpose said current restrictive means in said circuit between said coil means and said source.

2. The structure as defined in claim 1 wherein said means responsive to said sudden reduction includes a relay coil, a transistor operatively connected to the relay coil for controlling the relay coil and connected in shunt across said coil means, and contacts operable by said relay coil to render said restrictive means effective and ineffective.

3. A control system for a magnetically operated apparatus and comprising a circuit connectable to a source of voltage and including, in series, an operating coil of the device to be controlled, a resistance, and a set of normally closed contacts, a core for said coil, an armature movable toward and away from the core, whereby, upon movement of the armature into predetermined proximity to the core, the magnitude of the current flowing in said circuit diminishes, a rectifier, a condenser, circuit means connecting the rectifier and condenser in series with each other and in shunting relation to the resistance, thereby to cause said condenser to be charged by the current prior to said diminution in said magnitude and to discharge upon said diminution in said magnitude, and means responsive to the discharge of the condenser to open said set of normally closed contacts, and a current limiting resistor shunting said contacts for limiting the magnitude of current flowing in said coil after the opening of said set of contacts.

4. A control system according to claim 3 wherein said last mentioned means includes one relay coil operable when energized to open said set of contacts, and another relay having a coil responsive to discharge of the condenser to cause the energization of said one relay coil.

5. A control system according to claim 3 wherein said last mentioned means comprises transistor controlled relay means.

6. A control system according to claim 3 wherein said last mentioned means includes relay means operable when energized to open said normally closed contacts, a source of power for energizing said relay means, and a transistor responsive to the discharge of said condenser to control the energization of said relay means by said last mentioned source of power.

7. A control system for a magnetically operated apparatus and comprising a circuit connectable to a source of voltage and including an operating coil of a device to be conrtolled, a resistance, a core for said coil, an armature movable toward and away from the core, whereby, upon movement of the armature into predetermined proximity to the core, the magnitude of the current flowing in said circuit diminishes, a set of normally closed contacts, said coil, resistance, and normally closed contacts being series connected in said circuit, a current limiting resistor normally shunting the contacts and operative to limit the magnitude of current flowing in said coil after the opening of said set of normally closed contacts, and means responsive to said diminution in magnitude of said current to open said set of normally closed contacts.

8. A control system according to claim 7 wherein said last mentioned means includes relay means operable when energized to open said normally closed contacts, a source of power for energizing said relay means, and a transistor responsive to said diminution in magnitude to control the energization of said relay means by said last mentioned source of power.

References Cited in the file of this patent

UNITED STATES PATENTS

498,763	Callender	June 6, 1893
1,915,566	Younghusband	June 27, 1933
2,393,192	Ruehrmund	June 15, 1946
2,509,252	Salazar	May 30, 1950
2,638,496	Church	May 12, 1953
2,937,321	Decker et al.	May 17, 1960