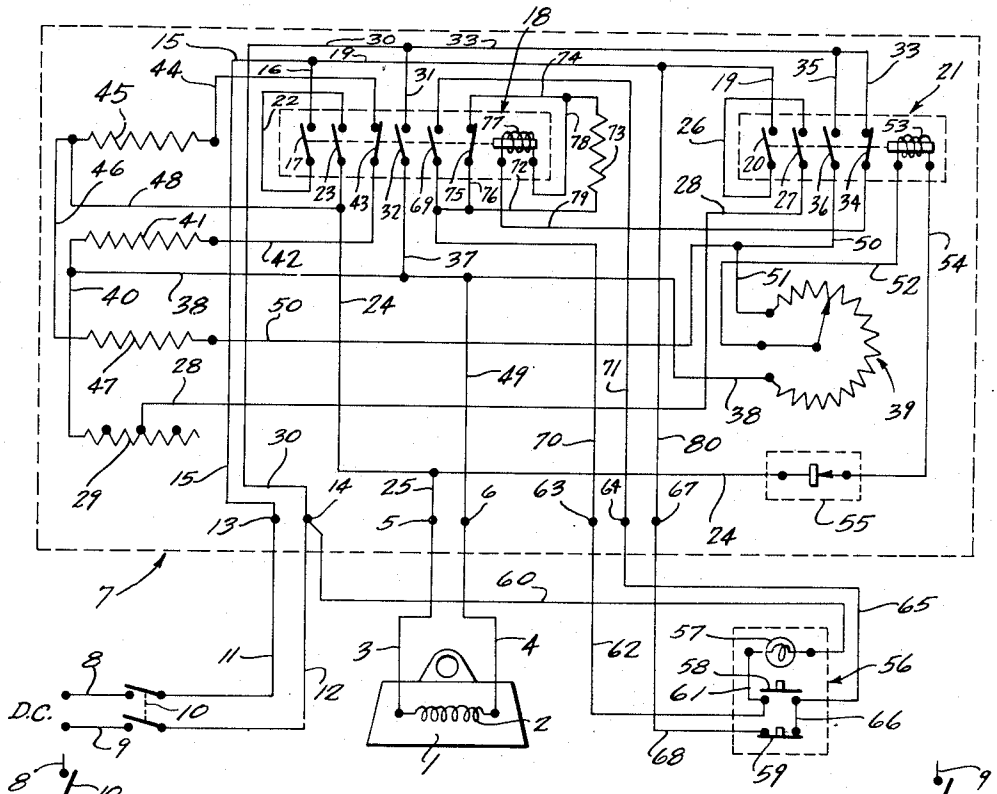
Aug. 4, 1953 W. J. HUDSON 2,648,033

MAGNET CONTROL

Filed Sept. 24, 1951 2 Sheets-Sheet 1

Fig. 1



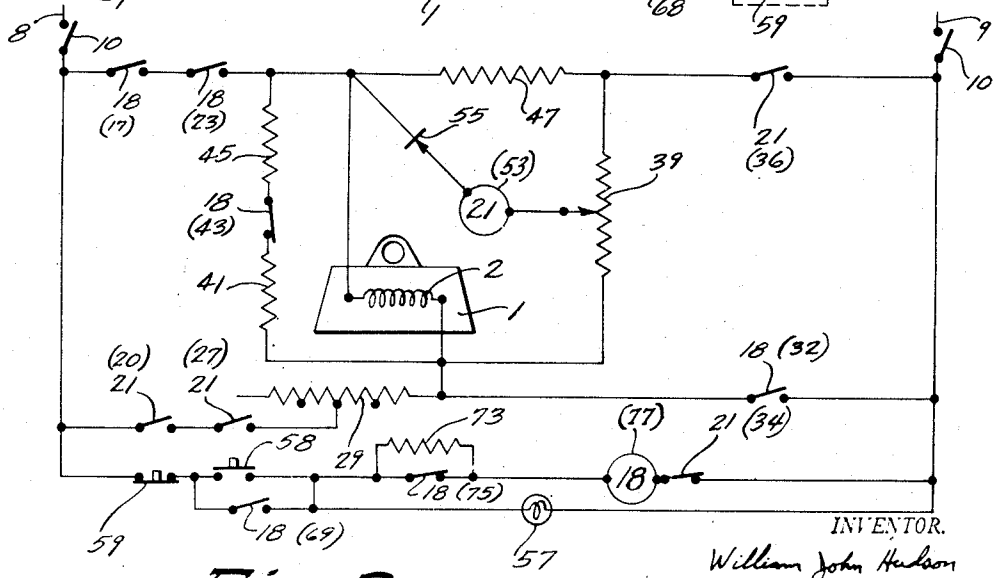


Fig. 2

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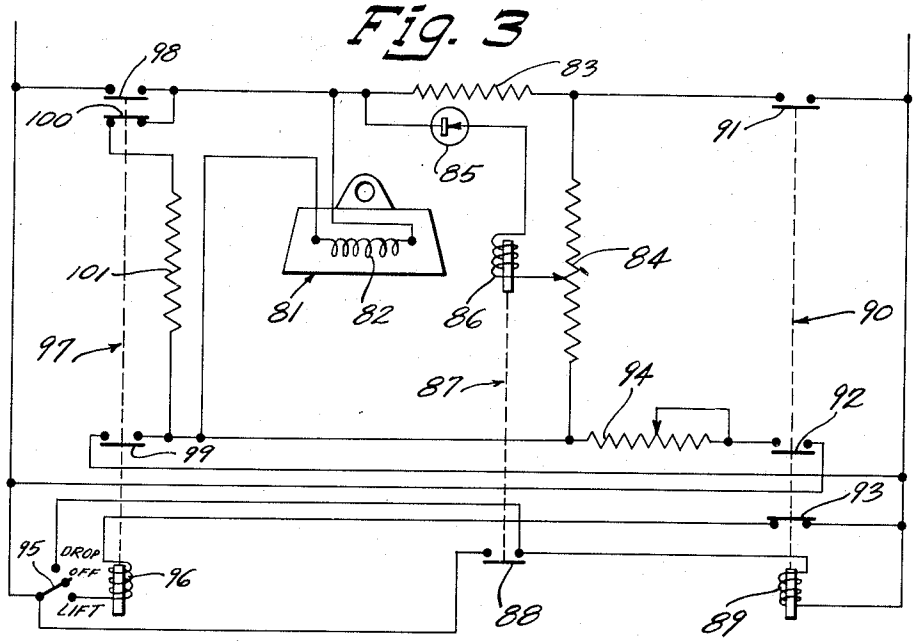
Fig. 3



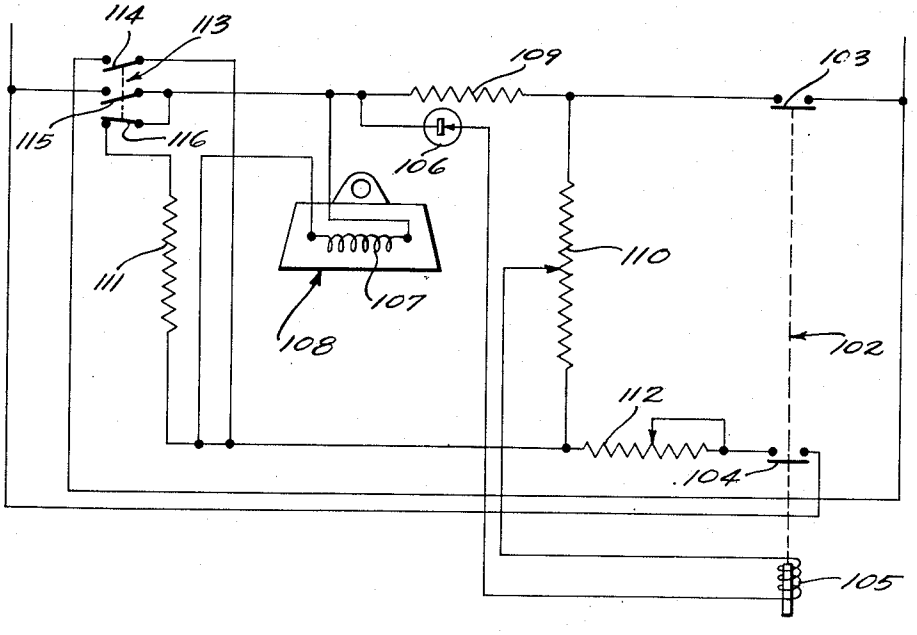


Fig. 4

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UNITED STATES PATENT OFFICE

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MAGNET CONTROL

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Application September 24, 1951, Serial No. 248,014

9 Claims. (Cl. 317—153)

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This invention relates to control circuits for electro-magnets such as lifting magnets and it more specifically resides in a control circuit having switch means adapted to connect a magnet to be controlled to a power source for energization and having a bridge network incorporating the magnet within an arm thereof, the bridge net work being connected to the power source during periods of deenergization of the magnet through switch means operative in response to conditions of unbalance within the bridge due to voltages of self-induction within the magnet that occur upon opening the switch means for energization and the bridge network upon connection to the power source impresses upon the magnet a voltage the polarity of which is reversed from that impressed during energization thereof.

Upon opening an inductive circuit, in which direct current is flowing, voltages of self-inductance due to the sudden collapse of current within the inductive elements of the circuit may greatly exceed the impressed voltage values. Further if such inductive elements comprise windings related to magnetic material, the retentivity characteristics thereof may cause a substantial residual magnetization to prevail after the interruption of energizing current. Such phenomena are undesirable in the use of inductive apparatus such as lifting magnets and control circuits for use with such inductive apparatus are employed to limit peak voltage values of self-inductance and to minimize residual magnetism.

Lifting magnets, when in operation, are seldom at rest other than at initial moments of lift and attraction of a load, and for effective operation it is desirable that release of all the load be effected promptly at the will of the operator. Otherwise, deposit of the load may not be pin pointed as desired and a scattering thereof will result. To gain the desired operation the energizing or magnetizing current should be decreased rapidly and the retentivity of both the magnet core of the magnet and of the load must be compensated for by a demagnetization accomplished by a reversal of current flow that reduces residual magnetism to a value ineffective for support of the load. It has been the practice heretofore to provide in the control circuit a switching arrangement such as to join the device to be controlled with a discharge path to conduct current caused by voltages of self-inductance thus aiming to limit peak voltage. It has further, heretofore, been the practice to join the device to the power source for a short duration

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with the polarity reversed from that of the initial energization or magnetization with the aim of causing the desired demagnetization necessary for a clean break of the load from the magnet.

The aims above mentioned have been accomplished with some measure of success by manual switching in which the operator is called upon to judge the time during which the demagnetizing currents of reverse polarity are to be applied to the inductive device. However, if the residual flux in the device and load is not adequately diminished the load may not be released in its entirety and the amounts released may drop spasmodically. On the other hand, a prolonged application of demagnetizing current may build up a reverse magnetization flux of value sufficient to retain some part or all of the load, thereby hindering effective operation. Since the degree of magnetization obtained is partially dependent both upon magnetic properties of the load and the particular magnet, even an experienced operator will have considerable difficulty.

The magnet being inductive, the rate of demagnetization of residual due to an adequate reverse current is dependent upon the magnitude of an adequate reverse voltage and the duration of its application. Thus, a large reverse polarity voltage applied for a short duration will have the same effect as a smaller voltage applied and maintained for a longer interval. Consequently a control circuit for lifting magnets and the like should, for optimum performance, provide for a rapidly building reverse current which is terminated at a precisely determined value. It is an object of this invention to provide a control which, while retaining the advantages of protection against the adverse effects of peak voltages of self induction, may be adjusted to provide rapid build up of reverse current and precise and prompt termination of the same at the value desired.

It is another object of this invention to provide a magnet control circuit having the foregoing advantages which will operate to produce the desired results without dependence upon the skill of the operator.

It is a further object of this invention to provide a control circuit having the foregoing advantages in which the magnet to be controlled is connected with a discharge circuit separate from the power source.

These and other objects and advantages of this invention will appear in the description to follow. In the description reference is made to the accompanying drawings in which there is shown

by way of illustration and not of limitation certain forms in which this invention may be embodied.

In the drawings:

Fig. 1 is a circuit diagram of a control circuit for a lifting magnet in which one form of the circuit of this invention may be embodied,

Fig. 2 is a schematic circuit diagram of the circuit shown in Fig. 1 the component elements being arranged in across the line form for purposes of simplification,

Fig. 3 is a circuit diagram of another form of a magnet control circuit of this invention, and

Fig. 4 is a circuit diagram of still another form of a magnet control circuit of this invention.

Referring now to the drawings, there is shown in Fig. 1 a lifting magnet 1 having a core of magnetic material in which is embedded an inductive winding 2. The magnet 1 is of well known form commonly employed in connection with hoists and cranes for the purpose of handling magnetic materials. The winding 2 is connected by leads 3 and 4 to terminals 5 and 6 of a controller unit 7, outlined in Fig. 1 by dotted lines. A direct current power source, represented by the leads 8 and 9, is connected through a main switch 10 by input leads 11 and 12 to the power input terminals 13 and 14 of the controller unit 7.

Lead 15 connected at one end of input terminal 13 branches at its other end into lead 16 joined to a normally open contact 17 of a lift contactor generally designated by the numeral 18 and into lead 19 joined to a normally open contact 20 of a drop contactor generally designated by the numeral 21. From the contact 17 a lead 22 extends to one side of contact 23 of the contactor 18 and from the opposite side of the contact 23 a lead 24 runs to a point of juncture with a lead 25 which joins in turn with terminal 5, connected through the lead 3 to the magnet coil 2. From the contact 20 a lead 26 extends to one side of contact 27 of the contactor 21 and from the opposite side of the contact 27 a lead 28 runs to one of the tapped terminals of a resistor 29.

A lead 30 is connected at one end to the input terminal 14 and branches at its other end into a lead 31 connected to a normally open contact 32 of contactor 18 and into a lead 33 that is connected to a normally closed contact 34 of the contactor 21. Joined to the lead 33 is a short lead 35 that is connected at its opposite end to a normally open contact 36 of the contactor 21.

From the contact 32 a lead 37 extends to and joins with a lead 38 which is connected at one end to an end terminal of a potentiometer 39 and at the opposite end to a lead 40 which in turn is connected between the fixed terminal of the resistor 29 and one end of a resistor 41. From the opposite end of resistor 41 a lead 42 extends to a normally closed contact 43 of the contactor 18 and a lead 44 joined to the opposite side of the contact 43 leads to one side of a resistor 45. From the opposite side of the resistor 45 a lead 46 extends to one side of a resistor 47 and a lead 48 which is also connected to the resistor 45 is joined with the lead 24. The resistors 45 and 41 form part of a path in shunt with the winding 2 which is completed by a lead 49 extending between the terminal 6 and the lead 38.

Joined to the right hand terminal of the resistor 47 is a lead 50 which runs to and joins with one side of the contact 36 of the contactor 21. Branching from the lead 50 is a lead 51 which is connected to the upper terminal of the potentiometer 39.

From the mid terminal of the potentiometer 39 connection is extended through a lead 52 with the operating coil 53 of the contactor 21 and thence through a lead 54 and a rectifier 55 with the lead 24.

A push button control station 56 indicated by a broken line enclosure in Fig. 1 comprises a pilot light 57, a normally open manually closeable lift contact button 58 and a normally closed manually opened drop contact button 59. From the right hand side of the light 57 a lead 60 extends to the power input terminal 14. The left hand side of the light 57 is joined by a lead 61 to the left hand side of the lift button 58 and a lead 62 also connected to the left hand side of the lift contact button 58 is joined to a terminal 63 of the controller panel 7. The right hand side of the lift contact button 58 is connected to a terminal 64 on the panel 7 through a lead 65 and additionally joined through a lead 66 to one side of the drop contact button 59. The opposite side of the drop contact button 59 is joined to a terminal 67 of the panel 7 through a lead 68.

Terminal 67 of controller 7 is joined through lead 80 with lead 15 and thence with the power source. The terminal 63 is joined to one side of a normally open contact 69 of the contactor 18 through a lead 70 and the terminal 64 is joined to the other side of the contact 69 through a lead 71. From the lead 70 a lead 72 extends to the lower end of a resistor 73 and a lead 74 leads from the upper end of the resistor 73 to one side of a normally closed contact 75 of the contactor 18. The other side of the contact 75 is joined to the lead 72 through a short lead 76. To complete the controller circuit the operating coil 77 of the contactor 18 is joined through lead 78 to the lead 74 and through lead 79 to the contact 34 of the contactor 21.

In order to facilitate description of the mode of operation of the practical embodiment of the invention shown in Fig. 1, the circuit thereof has been redrawn in Fig. 2 in simplified form. In simplifying, certain leads of the practical embodiment have been consolidated. For this reason reference numerals have been omitted from the leads. Contactor coils and contacts shown in Fig. 2 are designated by the general designating numerals employed in Fig. 1 for the contactors as a whole and accompanying each is the specific numeral, enclosed in parentheses, that is employed in Fig. 1 for the designation of the particular coil or contact.

In operation the apparatus shown in Figs. 1 and 2 is first activated by closing line switch 10 placing the direct current power supply across the contacts of the normally open lift push button 58 of the control station 56. To initiate the magnetization of the lifting magnet 1 the operator depresses the normally open lift push button 58 of the controller station 56. A circuit through power line 8, switch 10, leads 11, 15, and 80, normally closed push button 59, lead 66, the depressed button 58, leads 62, 70 and 76, normally closed contact 75 of the contactor 18, leads 74 and 78, winding 77 of the contactor 18, lead 79, normally closed contact 34 of the contactor 21, leads 33, 30 and 12, switch 10 and power line 9 is thus completed to energize the winding 77 and pick-up the contactor 18. The contacts 17, 23 and 32 close to place the winding 2 of the magnet 1 across the direct current power source and contact 43 opens to remove the resistors 41

and 45 from closed circuit with the magnet winding 2.

The energizing circuit for the magnet 1, thus established extends from the lead 8 and the switch 10 through leads 11, 15 and 16, contacts 17 and 23, leads 24, 25 and 3, the magnet winding 2, the leads 4, 49, 38 and 37, the contact 32 and the leads 31, 30 and 12 to the switch 10 and the power line 9. The polarity applied is such that the rectifier 55 blocks current from the winding 53 of the contactor 21 and a large total resistance value is provided in resistor 47 and mainly in potentiometer 39 so as to allow only a small current drain therethrough.

Upon closure of the contactor 18 contact 69 closes to establish a maintaining circuit after release of the button 58, while the contact 75 of the contactor 18 opens to place the resistor 73 in circuit with the coil 77 to limit the current therethrough after pick-up of the contactor 18. Closure of either or both of contacts 58 and 69 causes lamp 57 to be lit, to indicate the lift condition.

For the purpose of demagnetizing and controlling magnetism and the rate of decay of flux and consequently peak induced voltages a discharge circuit is provided and provision is made for application of reverse current to the winding 2 under the automatic control of a four armed four cornered bridge circuit of which the magnet coil 2 forms part of one arm.

By referring to Fig. 2 the makeup of the discharge and bridge circuits may be more clearly discerned. The discharge circuit comprises the resistors 45 and 41, the contact 43 and associated leads. The magnet winding 2 forms, in conjunction with the discharge circuit, one arm of the bridge. A second arm for the bridge circuit is formed by the resistor 47 and the remaining two arms by the two sections of the potentiometer 39. The resistances of the latter two arms may be relatively varied by movement of the slider of potentiometer 39. The responsive circuit of the bridge, which joins the corner of the bridge formed by the slider of the potentiometer 39 to the diagonally opposite corner at the junction of resistor 47 and winding 2, comprises the rectifier 55, the coil 53 of the contactor 21 and associated leads.

The discharge and bridge circuits are brought into play upon depressing the normally closed push button contact 59 of the control station 56 to open the energizing circuit of the coil 77 of the contactor 18. Upon relaxation of the contactor 18 the contact 43 thereof which is arranged to close a slight interval before the opening of either of the contacts 17, 23 and 32 joins the discharge resistors 41 and 45 in shunt relation with the magnet winding 2 through the circuit comprising leads 3, 25, 24 and 48, the resistor 45, lead 44, the contact 43, the lead 42, the resistor 41 and the leads 40, 38, 49 and 4. High voltages of self-inductance of the winding 2 are thus isolated from the voltage source and a discharge path comprising the resistors 41 and 45 is provided to limit the peak voltage values appearing across the winding 2.

The self-induced voltages occurring on discharge are of reversed polarity as to which the rectifier 55 is conducting. The self-induced voltage thus causes current to flow through the responsive circuit element of the bridge. The current path involved leads from the magnet winding 2 through leads 4, 49 and 38, part of the potentiometer 39 to the slider thereof, and thence

through lead 52, coil 53 of contactor 21, lead 54, rectifier 55, and leads 24, 25 and 3 to the return terminal of the winding 2. Contactor 21 is thus activated and the closure of contacts 20, 27 and 36 now occurs to connect the bridge circuit to the power source at the two diagonally opposite corners of the ends of potentiometer 39. While this condition prevails contact 34 is maintained open to ensure non-operation of the contactor 18 in case of an attempted operation of the push button 58.

With the power source thus applied to the bridge circuit current is urged to flow through the bridge arms comprising resistor 47 and magnet winding 2 in a direction reverse from that pursued in the winding 2 during the energizing or lift operation. A reverse current is thus caused to flow during the subsiding of self-induced voltages. The circuit provided extends from the power line 8 and switch 10 through leads 11, 15 and 19, contacts 20 and 27, lead 28, tapped resistor 29, leads 40, 38, 49 and 4, to the magnet winding 2, and thence through leads 3, 25, 24, 48 and 46, resistor 47, lead 50, contact 36, leads 35, 33, 30 and 12 to switch 10 and power line 9.

Values may be chosen for the resistor 47 and the potentiometer 39 such that by proper adjustment of the slider of the potentiometer 39 there will be no current flow through the responsive arm of the bridge after transients have subsided and upon a constant voltage being impressed across the power terminals of the bridge. The current flow through the bridge arms will be dependent upon the respective resistance values and by the use of well known computation the ratios of resistances may be set to achieve this balanced condition. This circuit condition may be referred to as a steady state condition of balance and within limits the value of constant impressed voltage may be altered without causing current flow in the responsive arm when the bridge is so adjusted. However, with the bridge so adjusted, upon breaking the lift or energizing circuit for the winding 2 the large self-induced voltages upset the bridge to initially activate the contactor 21 as hereinbefore noted and to cause an unbalance of the bridge when reverse polarity potential is applied to the bridge through the contactor 21.

As the transient voltage of self-induction decreases the voltage across the winding 2 approaches the value of that across the lower portion of the potentiometer 39 and at the instant of equal potentials across these two bridge arms the current flow in the respoonsive arm will cease. In use this momentary or instantaneous balance occurs at a position of adjustment of potentiometer 39 which does not necessarily coincide with the position of adjustment for steady state balance which may only be achieved in the absence of the transient discharge potential. Adjustment is, however, so chosen that instantaneous balance is approached only after some reverse current is established in winding 2 and at this point the contactor 21 will relax and the deenergizing reverse potential will then be removed from the bridge, the circuit again being readied for a lift operation. Both the drop out voltage and time lag of the contactor 21 will affect the response of the circuit and adjustment may be made accordingly.

The magnitude of reverse current at the time of drop out of the contactor 21 is influenced by the reverse voltage impressed on the bridge circuit. The greater the impressed reverse voltage the greater the demagnetizing effect will be. To

control the magnitude of this current the tapped resistor 29 is provided. Thus, for any given setting of the potentiometer 39 a change in value of the resistor 29 will effect a change in magnitude of reverse current at the moment of instantaneous balance. Thus the operator is provided with means for adjustment to meet differences in retentivity of various loads being handled.

Additional control of the circuit may be had through movement of the slider of the potentiometer 39. The setting of potentiometer 39 influences the promptness with which instantaneous balance is arrived at for any given setting of the resistor 29. With a given load, as the slider is moved upward the instantaneous balance will occur sooner but the magnitude of reverse current will be smaller. Likewise, a downward movement of the slider of potentiometer 39 will prolong the duration of application of demagnetizing current and increase the magnitude of the same. Thus, if the operator is handling a low retentivity low reluctance load, a more prompt and certain release of the same may be obtained if desired. The range of adjustability thus provided is such as to make the control circuit of this invention adaptable to various magnets and the varying conditions of installation which may be encountered without need for special engineering for each separate installation.

If it is desired that either manual or automatic control of the demagnetizing operation be made available, the circuit of this invention may be modified as shown in Fig. 3. In this form of the circuit an electromagnet 81 having a winding 82, similar to the magnet 1 of Figs. 1 and 2, forms part of an arm of a bridge circuit that is also similar to that of Figs. 1 and 2. A resistor 83 and a potentiometer 84 form the other three arms of the bridge circuit and a rectifier 85 and a relay coil 86 of a relay 87 form the responsive arm of the bridge. The relay 87 has a set of normally open contacts 88 in circuit with a contactor coil 89 of a contactor 90 which has normally open contacts 91 and 92 and normally closed contacts 93. Between one corner of the bridge circuit and the normally open contacts 92 is a variable resistor 94.

A manually operable switch 95 is employed as shown having three positions of its selector arm designated as "lift," "off" and "drop." Joined to the "lift" contact of the switch 95 is a coil 96 of a contactor 97 that has normally open contacts 98 and 99 and normally closed contacts 100. A discharge resistor 101 is in shunt circuit relation with the magnet winding 82 through the normally closed contacts 100, similarly as the resistors 41 and 45 in Figs. 1 and 2 are in shunt with the magnet winding 2.

The operation of the circuit shown in Fig. 3 is initiated by placing the selector arm of the switch 95 in "lift" position to energize coil 96 of the contactor 97. Contacts 98 and 99 close to place the magnet winding 82 across the power source and the contacts 100 open to remove the resistor 101 from shunt with the winding 82.

To automatically demagnetize the magnet 81 the selector arm of the manual switch 95 is placed in "off" position. Contactor 97 is then deenergized and contacts 100 close slightly before contacts 98 and 99 open to remove the winding 82 from the line. Similarly as in the circuit of Figs. 1 and 2 the self-induced voltages of the winding 82 cause a current flow in the responsive arm of the bridge circuit and the relay 87 is activated to close the contacts 88. Closure of contacts 88 causes the coil 89 to be placed across the power source and to be energized so as to close contacts 91 and 92. Closing contacts 91 and 92 places the bridge circuit across the power supply to apply a reverse demagnetizing current to the winding 82. The automatic operation of the bridge is similar to that described in reference to Figs. 1 and 2. Upon an instantaneous balance prevailing in the bridge circuit relay 87 relaxes and the circuit is ready for the next "lift" operation.

If for any reason the operator desires manual control of the demagnetization he may place the selector arm of the switch 95 in "drop" position instead of "off" position. The effect of the relay 87 is thus circumvented to the extent that the energization of contactor 90 may be manually prolonged as long as desired by holding the switch 95 in the "drop" position.

Fig. 4 depicts a controller circuit in accordance with this invention in which but one contactor is utilized and in which the "lift" contactors of Figs. 1, 2 and 3 are replaced by a manual switch. The single contactor 102 has normally open contacts 103 and 104 and corresponds to the contactor 21 of Figs. 1 and 2 and the contactor 90 of Fig. 3. Coil 105 of the contactor 102 forms part of the responsive arm of a bridge circuit along with a rectifier 106. This bridge circuit is like that of the others heretofore described, having a magnet winding 107 of a magnet 108 forming part of one bridge arm and a resistor 109 and a potentiometer 110 forming the other arms. A discharge resistor 111 in shunt relationship with magnet winding 107 and a reverse current control resistor 112 are connected as shown and are similar to those of the preceding circuits.

A manual switch 113 with normally open contacts 114, 115 and normally closed contact 116 is connected so as to control admission of power and the closure of the discharge circuit. Moving the switch contacts upward closes contacts 114 and 115 and opens contacts 116 to connect the magnet winding 107 across the power source and to remove the discharge resistor 111 from shunt relation with the winding 107.

For release of the load the switch 113 is placed in the position shown, the ensuing deenergization and demagnetization of the magnet 108 is entirely automatic and proceeds in a manner similar to that described for circuits of Figs. 1, 2 and 3. The resistor 111 provides a shunt path to carry the currents caused by self-induction and acts to limit peak voltage values. The bridge action and its effect upon the contactor 102 is the same as that discussed in connection with Figs. 1, 2 and 3.

I claim:

1. In a control circuit for an inductive electromagnet a bridge network comprising a pair of terminals for connection to the coil of the inductive electromagnet to be controlled to form a first bridge arm, a set of three circuit impedances joined to one another and said first bridge arm serially to form a four armed bridge loop with junctions interposed between the arms to provide a pair of diagonally opposite input junctions and a pair of diagonally opposite reference junctions, and a responsive bridge arm including an unidirectional current valve and a control relay means having a coil connected serially between said pair of diagonally opposite reference junctions, said relay means having coil controlled

normally open contacts; an energizing circuit comprising switch means and current entry and current exit leads joining said pair of magnet terminals through said switch means when closed to a direct current source of predetermined polarity, said leads being oriented with respect to the polarity of said source and said current valve to render the latter non-conductive in relation to the potential imposed through said switch means by said source and conductive with respect to self-induced potential generated in said first bridge arm upon opening of said switch means; and a deenergizing circuit including said control relay means contacts joining the input junctions of said bridge network to said direct current potential source to apply a potential of reversed polarity to said first bridge arm when said relay means contacts are closed by excitation resulting from self-induced voltage in said first bridge arm.

2. In a control circuit for an inductive electromagnet a bridge network comprising a pair of terminals for connection to the coil of the inductive electromagnet to be controlled to form a first bridge arm, a set of three circuit impedances joined to one another and said first bridge arm serially to form a four armed bridge loop with junctions interposed between the arms to provide a pair of diagonally opposite input junctions and a pair of diagonally opposite reference junctions, and a responsive bridge arm comprising a unidirectional current valve and a control relay means having a coil connected serially between said pair of diagonally opposite reference junctions, said relay means having coil controlled normally open contacts; energizing circuit switch means having two sets of contacts one set of which is closed when the other is open; an energizing circuit comprising a set of said switch means contacts and current entry and current exit leads joining said pair of magnet terminals through said set of contacts when closed to a direct current source of predetermined polarity, said leads being oriented with respect to the polarity of said source and said current valve to render the latter non-conductive in relation to the potential imposed through said set of contacts by said source and conductive with respect to self-induced potential generated in said first bridge arm upon opening of said set of contacts; a discharge impedance; a discharge circuit comprising said discharge impedance and the second set of said switch means contacts joined serially between said set of magnet terminals; and a deenergizing circuit including said control relay means contacts joining the input junctions of said bridge network to said direct current potential source to apply a potential of reversed polarity to said first bridge arm when said relay means contacts are closed by excitation resulting from self-induced voltage in said first bridge arm.

3. In a control circuit for an inductive electromagnet a bridge network comprising a pair of terminals for connection to the coil of the inductive electromagnet to be controlled to form a first bridge arm, a resistance and a potentiometer having a movable mid-tap joined to one another and said first bridge arm serially to form a four armed bridge loop with junctions interposed between the arms which junctions comprise a pair of diagonally opposite input junctions composed of the junctions between the first bridge arm and the potentiometer and between the resistance and the potentiometer and a pair of diagonally opposite reference junctions composed of the potentiometer mid-tap and the junction between the said first bridge arm and said resistance, and a responsive bridge arm comprising a unidirectional current valve and a control relay means having a coil connected serially between said pair of diagonally opposite reference junctions, said relay means having coil controlled normally open contacts; an energizing circuit comprising switch means and current entry and current exit leads joining said pair of magnet terminals through said switch means when closed to a direct current source of predetermined polarity, said leads being oriented with respect to the polarity of said source and said current valve to render the latter non-conductive in relation to the potential imposed through said switch means by said source and conductive with respect to self-induced potential generated in said first bridge arm upon opening of said switch means; and a deenergizing circuit including said control relay means contacts joining the input junctions of said bridge network to said direct current potential source to apply a potential of reversed polarity to said first bridge arm when said relay means contacts are closed by excitation resulting from self induced voltage in said first bridge arm and to cause demagnetization current of increasing value to flow in said first bridge arm whereby instantaneous balance of said bridge network is had for a predetermined value of first bridge arm current in accordance with the setting of the mid-tap for said bridge network potentiometer to deenergize said control relay means coil.

4. In a control circuit for an inductive electromagnet a bridge network comprising a pair of terminals for connection to the coil of the inductive electro-magnet to be controlled to form a first bridge arm, a set of three circuit impedances joined to one another and said first bridge arm serially to form a four armed bridge loop with junctions interposed between the arms to provide a pair of diagonally opposite input junctions and a pair of diagonally opposite reference junctions, and a responsive bridge arm comprising a unidirectional current valve and a control relay having a coil connected serially between said pair of diagonally opposite reference junctions, said relay having coil controlled normally open contacts; an energizing circuit comprising switch means and current entry and current exit leads joining said pair of magnet terminals through said switch means when closed to a direct current source of predetermined polarity, said leads being oriented with respect to the polarity of said source and said current valve to render the latter non-conductive in relation to the potential imposed through said switch means by said source and conductive with respect to self-induced potential generated in said first bridge arm upon opening of said switch means; a deenergizing relay having a coil and normally open contacts operated thereby; a deenergizing circuit including said deenergizing relay contacts joining the input junctions of said bridge network to said direct current potential source to apply a potential of reversed polarity to said first bridge arm when said deenergizing relay contacts are closed; a first circuit for said deenergizing relay coil connecting said deenergizing relay coil to a potential through said control relay contacts when closed; and a second circuit for said deenergizing relay coil including manual switch means joining said deenergizing relay coil to a potential through said switch means when closed.

5. In a control circuit for an inductive electromagnet a pair of terminals for connection to the coil of the inductive electro-magnet to be controlled; an energizing circuit cimprising switch means and current entry and current exit leads joining said pair of magnet terminals through said switch means when closed to a direct current source of predetermined polarity; a bridge network comprising a first bridge arm including said pair of terminals, a set of three circuit impedances joined to one another and said first bridge arm serially to form a four armed bridge loop with junctions interposed between the arms to a pair of diagonally opposite input junctions and a pair of diagonally opposite reference junctions, and a responsive bridge arm including control relay means having a coil connected between said pair of diagonally opposite reference junctions, said relay means having coil controlled normally open contacts; circuit means in said bridge network acting to preclude energization of said coil of said control relay means upon closure of said energization circuit and rendering said relay means coil conductive with respect to self-induced potential generated in said first bridge arm upon opening of said switch means; and a deenergizing circuit including said control relay means contacts joining the input junctions of said bridge network to said direct current potential source and oriented with respect to said current entry and current exit leads of said energizing circuit to apply a potential of reversed polarity to said first bridge arm when said relay means contacts are closed by excitation resulting from self-induced voltage in said first bridge arm.

6. In a control circuit for an inductive electromagnet a pair of terminals for connection to the coil of the inductive electro-magnet to be controlled; energizing circuit switch means having two sets of contacts one set of which is closed when the other is open; an energizing circuit comprising one set of said switch means contacts and current entry and current exit leads joining said pair of magnet terminals through said pair of switch means contacts when closed to a direct current source of predetermined polarity; a bridge network comprising a first bridge arm including said pair of terminals, a set of three circuit impedances joined to one another and said first bridge arm serially to form a four armed bridge loop with junctions interposed between the arms to provide a pair of diagonally opposite input junctions and a pair of diagonally opposite reference junctions, and a responsive bridge arm including control relay means having a coil connected between said pair of diagonally opposite reference junctions, said relay means having coil controlled normally open contacts; circuit means in said bridge network acting to preclude energization of said coil of said control relay means upon closure of said energizing circuit and rendering said relay means coil conductive with respect to self-induced potential generated in said first bridge arm upon opening of said set of contacts in said energizing circuit; a discharge impedance; a discharge circuit comprising said discharge impedance and the second set of said switch means contacts joined serially between said set of magnet terminals; and a deenergizing circuit including said control relay means contacts joining the input junctions of said bridge network to said direct current potential source and oriented with respect to said current entry and current exit leads of said energizing circuit to apply a potential of reversed polarity to said first bridge arm when said relay means contacts are closed by excitation resulting from self-induced voltage in said first bridge arm.

7. In a control circuit for an inductive electromagnet a pair of terminals for connection to the coil of the inductive electro-magnet to be controlled; an energizing circuit comprising switch means and current entry and current exit leads joining said pair of magnet terminals through said switch means when closed to a direct current source of predetermined polarity; a bridge network comprising a first bridge arm including said pair of terminals, a set of three circuit impedances joined to one another and said first bridge arm serially to form a four armed bridge loop with junctions interposed between the arms to provide a pair of diagonally opposite input junctions and a pair of diagonally opposite reference junctions, and a responsive bridge arm having circuit means operable to preclude current flow in the bridge arm and a control relay means having a coil connected serially between said pair of diagonally opposite reference junctions, said relay means having coil controlled normally open contacts; said circuit means being oriented with respect to said energizing circuit to preclude energization of said relay means coil upon closure of said energizing circuit and to render said coil conductive with respect to self-induced potential generated in said first bridge arm upon opening of said switch means; and a deenergizing circuit including said control relay means contacts joining the input junctions of said bridge network to said direct current potential source and oriented with respect to said current entry and current exit leads of said energizing circuit to apply a potential of reversed polarity to said first bridge arm when said relay means contacts are closed by excitation resulting from self-induced voltage in said first bridge arm.

8. In a control circuit for an inductive electromagnet a pair of terminals for connection to the coil of the inductive electro-magnet to be controlled; an energizing circuit comprising switch means and current entry and current exit leads joining said pair of magnet terminals through said switch means when closed to a direct current source of predetermined polarity; a bridge network comprising a first bridge arm including said pair of terminals, a set of three circuit impedances joined to one another and said first bridge arm serially to form a four armed bridge loop with junctions interposed between the arms to provide a pair of diagonally opposite input junctions and a pair of diagonally opposite reference junctions, and a responsive bridge arm including contact closing means having an operating coil connected between said pair of diagonally opposite reference junctions, said contact closing means having normally open coil controlled contacts and being oriented with respect to said energizing circuit to preclude energization of said coil to actuate said contacts upon closure of said energizing circuit and to render said coil conductive with respect to self-induced potential generated in said first bridge arm for contact closure upon opening of said switch means; and a deenergizing circuit including said contacts joining the input junctions of said bridge network to said direct current potential source and oriented with respect to said current entry and current exit leads of said energizing circuit to apply a potential of reversed polarity to said first bridge arm when said contacts are closed by excitation

resulting from self-induced voltage in said first bridge arm.

9. In a control circuit for an inductive electro-magnet a pair of magnet terminals for connection to the coil of the inductive electro-magnet to be controlled; a bridge network comprising a first bridge arm including said magnet terminals joined between a first input junction and a first responsive junction, a set of three resistances joined serially between said first input and responsive junctions to form a four armed bridge loop with said first bridge arm, said resistances being joined to one another at junctions diagonally opposite said first input and responsive junctions to form a pair of diagonally opposite input junctions and a pair of diagonally opposite responsive junctions, and a responsive bridge arm including a relay control means coil joined between said responsive bridge junctions, said coil having coil controlled normally open contacts; an energizing circuit comprising switch means and connecting leads joining said magnet terminals to a direct current potential source through said switch means when closed; and a deenergizing circuit comprising said relay control means contacts and connecting leads joining said bridge network at said input junctions to the direct current potential source through said relay control means contacts when closed.

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