Sept 10, 1957 J. T. L. BROWN ET AL 2,806,186

RELAY ADJUSTING SET

Filed March 24, 1954 6 Sheets-Sheet 1

FIG. 1

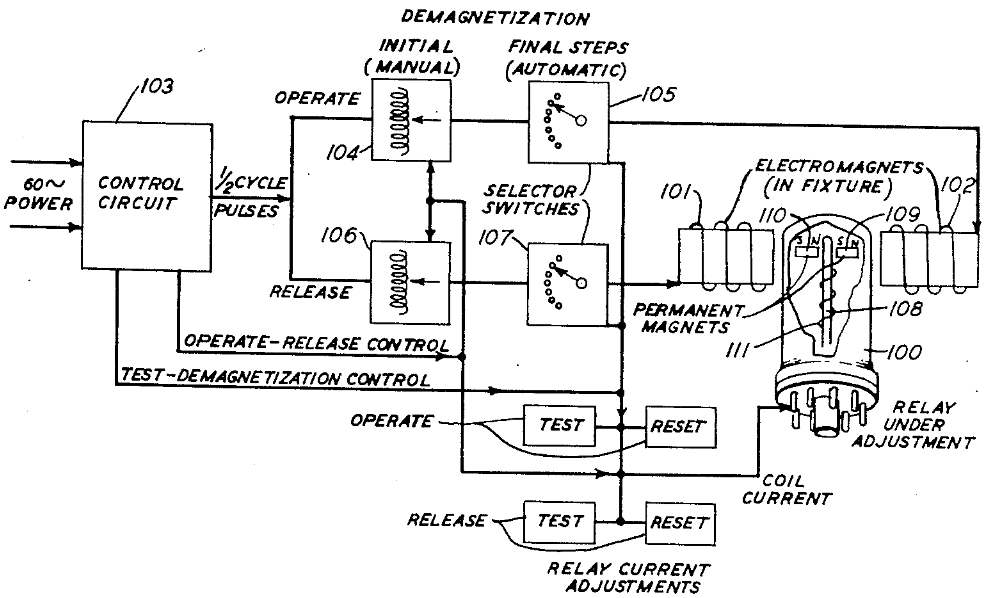


FIG. 2

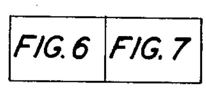
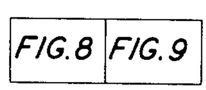


FIG. 3



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RELAY ADJUSTING SET

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FIG. 4

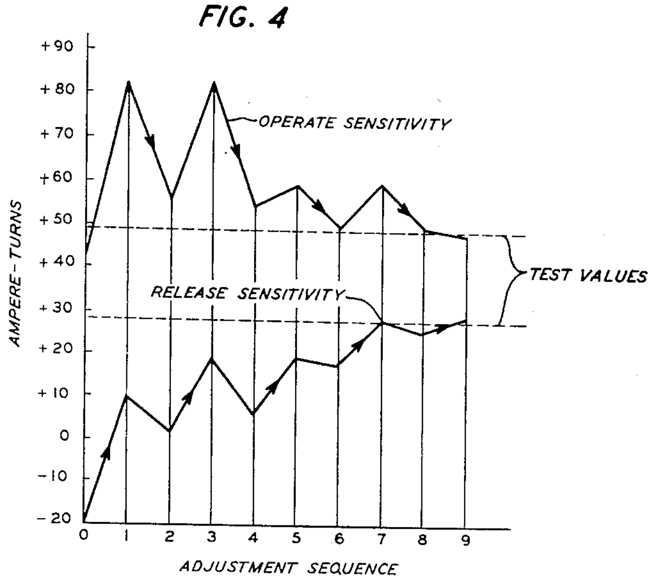
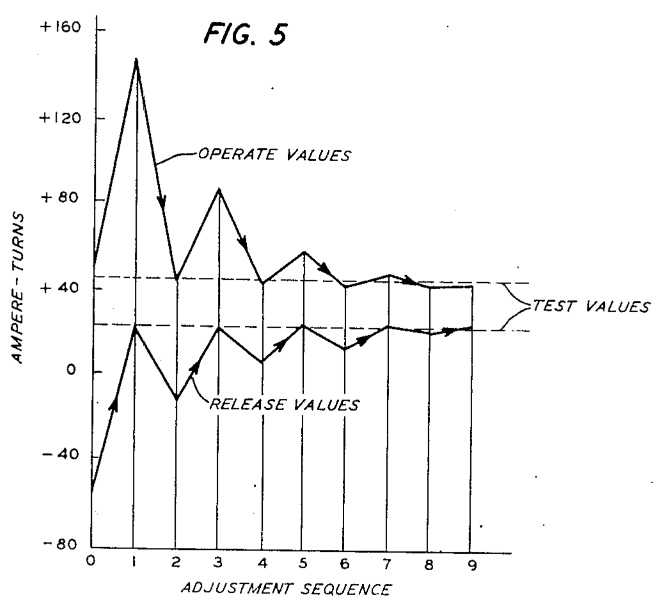


FIG. 5



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RELAY ADJUSTING SET

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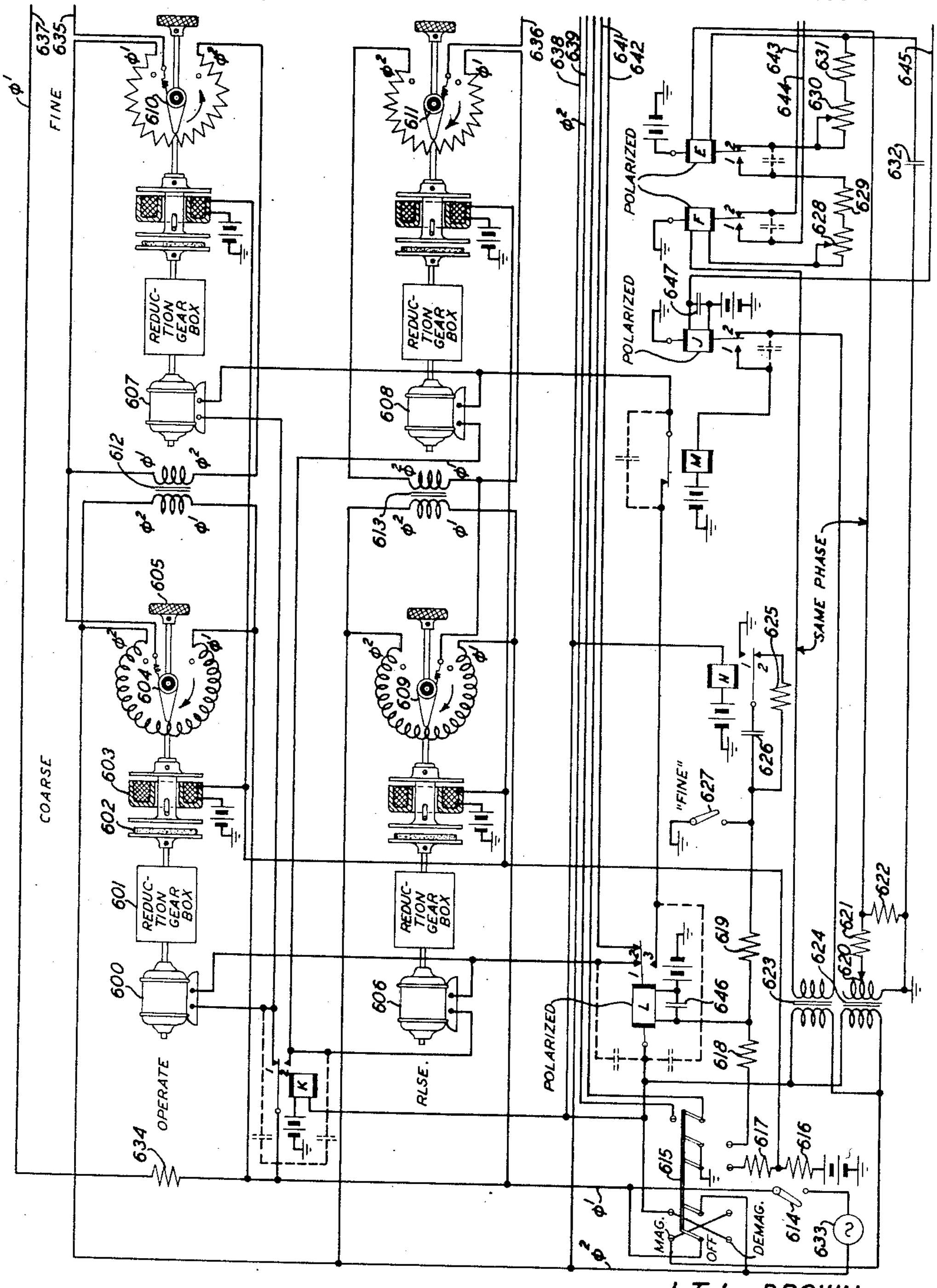

FIG. 6

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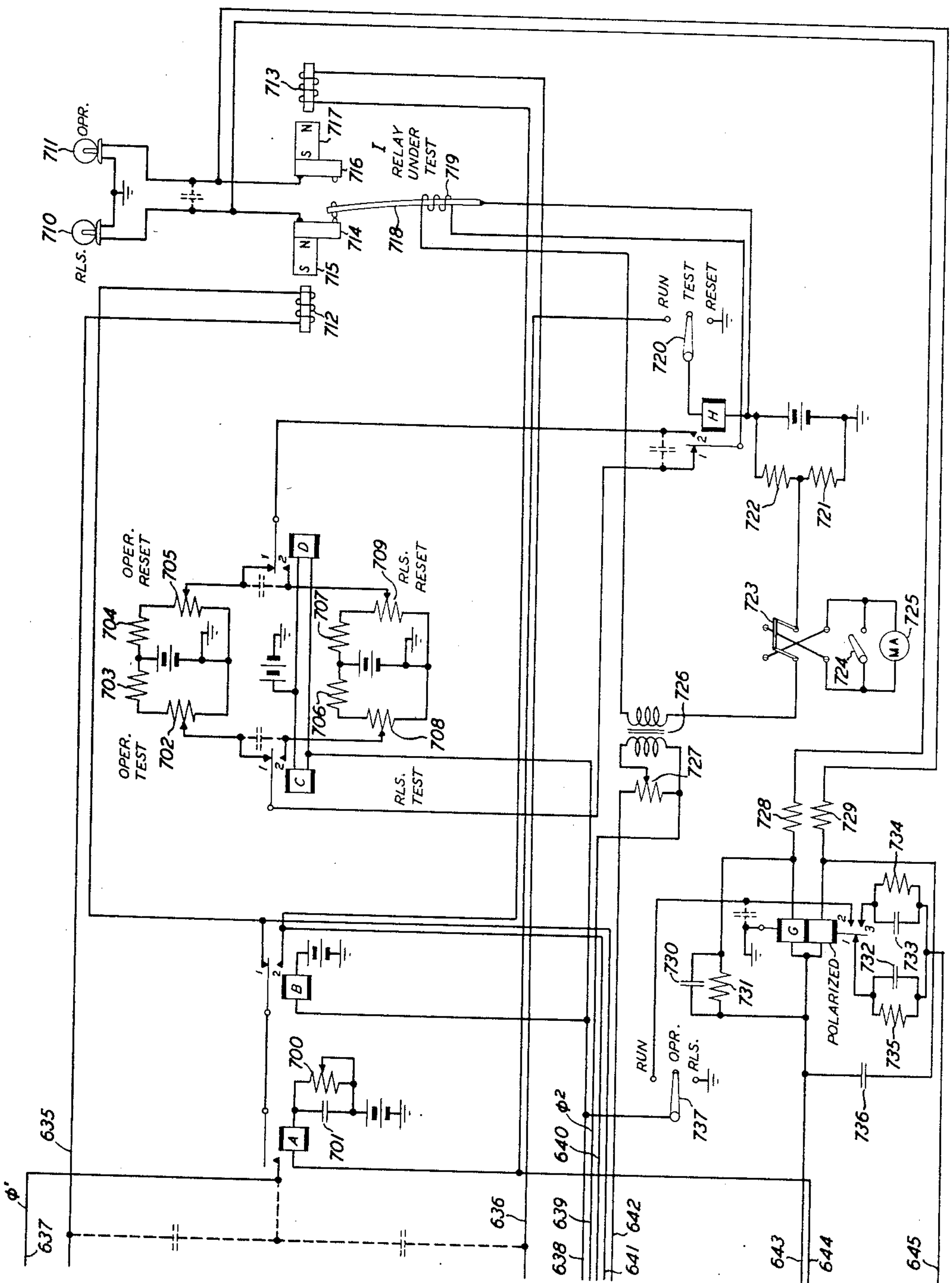

FIG. 7

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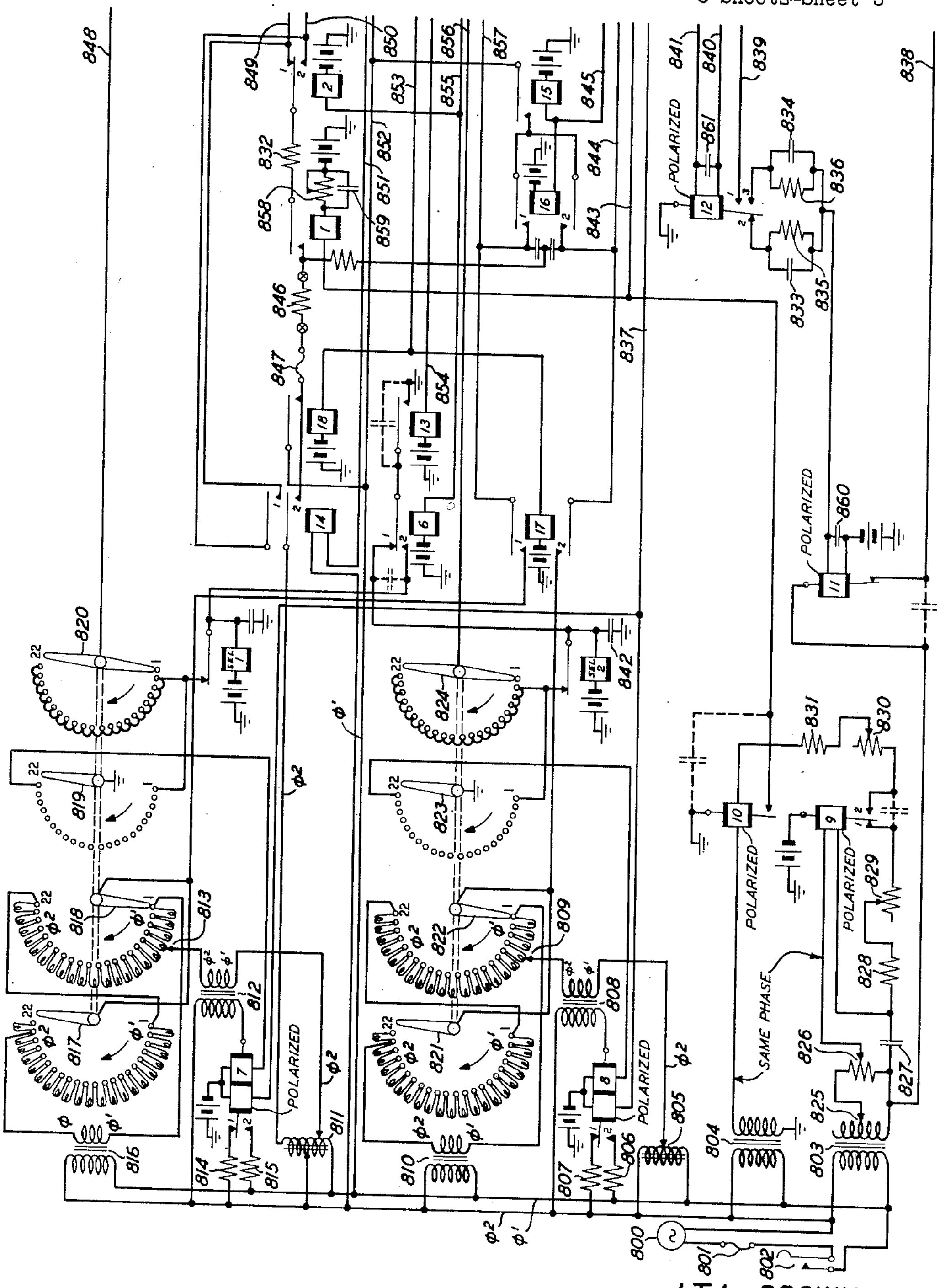

FIG. 8

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RELAY ADJUSTING SET

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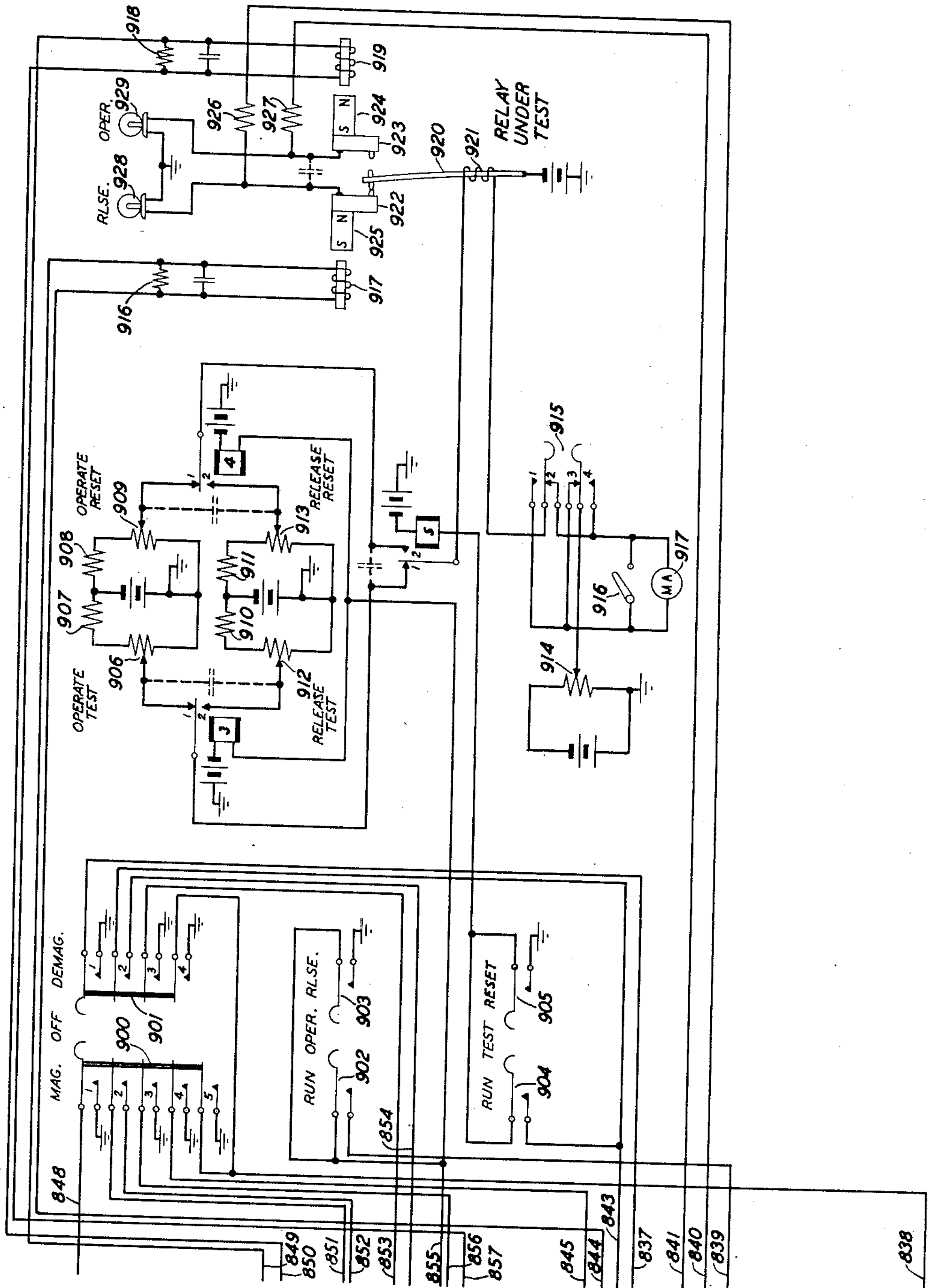

FIG. 9

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United States Patent Office

2,806,186

Patented Sept. 10, 1957

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RELAY ADJUSTING SET

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Application March 24, 1954, Serial No. 418,412

12 Claims. (Cl. 317—157)

This invention relates generally to relay test circuits and more particularly to a test set for automatically testing and adjusting the permanent magnet bias of polar relays having permanent magnet polarization or bias affecting the armature movement thereof in addition to the usual energizing means such as a coil or coils.

Specifically, the present invention relates to a circuit for automatically adjusting the permanent magnet bias of a relay which includes an energizing winding and at least one contact and a permanent magnet and a magnetic armature movable in operable relation to said contact under the influence of the combination of the magnetic field produced by energization of said winding and the magnetic field of said magnet.

An object of the invention is to improve the art of adjusting such relays.

A particular object of the invention is to improve the means whereby the adjustments of interest are made to a polar relay of the totally enclosed type, which, due to its sealed construction, precludes the usual manual adjustment familiar to the art.

The general method employed is disclosed and claimed in Patent 2,590,228 to J. T. L. Brown of March 25, 1952. This method is described therein as used, by way of example, to adjust the magnetic bias of a polar relay of the sealed, mercury type, such as is shown in Patent 2,609,464 to J. T. L. Brown and C. E. Pollard, Jr. of September 2, 1952, and which has a movable armature arranged to make contact with either of two contacts and all sealed in a glass envelope containing mercury fed by capillary action to the contact areas and which has a permanent magnet attached to each contact outside of the envelope and an energizing coil surrounding the envelope. This relay is also described, along with its characteristics and performance, etc., in an article "Balanced polar mercury contact relay," by J. T. L. Brown and C. E. Pollard, in the November 1953 issue of "The Bell System Technical Journal."

Another type of relay which can be adjusted by means of the present invention and according to the method of the Brown patent is the type of relay shown in Patent 2,577,602 to E. T. Burton of December 4, 1951, which, again, is a sealed, mercury type of polar relay but which has only one magnet biasing only one set of the contacts with which the armature cooperates.

It will be appreciated by those skilled in the art that many other types of relays may be adjusted by means of the present invention and that the above are merely exemplary.

These polar relays are magnetically polarized in order that a specified magnitude and polarity of current in the energizing winding will cause the armature to move from one contact to the other. The two directions of motion are commonly referred to as the "operate" and the "release" directions, and this terminology will be used throughout subsequent discussion, description, specification and, where necessary, claims. The magnitude and/or polarity of current to do either job may be anything

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desired, within the capabilities of the relay structure of course. The current or currents specified for a particular relay are generally referred to as the operate and release "sensitivities" of the particular relay in question. The main purpose of the present invention is to effect automatically, quickly and accurately any desired such sensitivity value or values for a particular relay.

The general steps of the method employed, as set forth in the Brown patent and in the Brown-Pollard article, are as follows in order to adjust a balanced polar relay (magnetic bias on both contacts) to any desired pair of sensitivity values:

1. Magnetize the two magnets fully by a flux directly across them.

2. With the armature starting from one side, progressively decrease the magnetization on that side in small steps until the armature just operates to the other side on the final current value desired for this direction of operation (which may be the "operate" direction).

3. With the armature starting on the other side, progressively decrease the magnetization on that side in small steps until the armature just operates from that side on the final current value desired for this second direction of operation (which may be the "release" direction).

4. Repeat steps 2 and 3 alternately until the relay just operates in both directions on the two respective current values desired.

Steps 3 and 4 are necessary in a balanced polar relay because the force on the armature is affected by both magnets and an adjustment of the magnetic strength of one of them will upset the effect of the other. In the case of the unbalanced polar type of relay, such as in the Burton patent and having only one magnet, the procedure would presumably be complete after step 2.

In the disclosed embodiments of the present invention, means are provided for performing step 1 by manual manipulation of circuit means. Steps 2, 3 and 4 are thereafter performed by the circuit automatically in response to a manual manipulation which amounts to a start signal. In more detail, the disclosed embodiments of the invention provide means for performing the above method steps as follows:

1. By the manipulation of a switch to a "magnetizing" position, a relay circuit applies a selected polarity of half-cycle alternating current as magnetizing pulses to electromagnets, which pulses thereby over-magnetize both of the bias magnets of the relay.

2. By the manipulation of said switch to a "demagnetizing" position, the relay circuit selects the other polarity of half-cycle alternating current to be applied to one electromagnet at a time thereby to demagnetize one or the other of the bias magnets at one time under the control of a relay control circuit and a selector. This control circuit causes the test relay armature to operate to one side, say the "operate" side, applies a "test" current to the relay, applies a relatively low demagnetizing pulse of specified magnitude of the selected half cycle as determined by the selector to the associated electromagnet, applies a "reset" current to the test relay to force the armature to operate to the said one side, applies a "test" current to said test relay and detects whether or not the armature of the test relay moves to the other side in response to said test current. If the armature does not so move, then the control circuit causes the selector to preselect a slightly larger magnitude of demagnetizing current and applies this slightly larger demagnetizing pulse to the associated electromagnet and then repeats the rest of the above procedure. If the armature does move, then the control circuit will adjust itself to be able to go through the same procedure on the other side, say the "release" side, using the other

electromagnet, of course, and starting the magnitude of demagnetizing pulses at a specified low value of demagnetizing current as before.

3. At the completion of a demagnetization cycle on the release side, the control circuit will switch to the operate side and continue again because the adjustment of the release side will have caused an error in the previous operate side adjustment.

4. This procedure is continued back and forth on the operate and release sides until the detecting means in the relay control circuit indicates (such as by the rapid alternate flashing of two lamps associated with each side of the relay) that the armature travels in the right direction upon the proper sensitivity or test current being applied respectively to the test relay winding.

A feature of the present invention is the provision of a circuit for automatically adjusting the permanent magnet bias of a relay of the general type referred to herein.

A particular feature of the present invention is the provision of the necessary relay control circuits, current or voltage selector means, and predetermined test current value source or sources whereby the above adjustment procedure is performed automatically.

The invention is described in the following detailed description as embodied in exemplary circuitry shown on the drawings of which the following are general descriptions:

Fig. 1 shows in block diagram form a functional layout of a typical adjusting set arranged for demagnetization;

Fig. 2 illustrates how to arrange Figs. 6 and 7 to disclose a complete circuit according to one embodiment of the invention;

Fig. 3 illustrates how to arrange Figs. 8 and 9 to disclose a complete circuit according to another embodiment of the invention;

Fig. 4 shows a curve or graph or plot of test data applicable to the circuit of Figs. 6 and 7, which showing is referred to in the detailed description as an aid to understanding the functioning of the circuit of Figs. 6 and 7.

Fig. 5 shows data similar to that of Fig. 4 but associated with the circuit of Figs. 8 and 9;

Figs. 6 and 7 disclose the details of one complete embodiment; and

Figs. 8 and 9 disclose the details of another complete embodiment.

Fig. 1 shows a functional block diagram layout of an automatic relay adjusting set embodying the present invention. The relay under adjustment, relay **100**, is shown with its case broken open to show the armature **108** with an energizing coil **111** surrounding the armature **108** and two contact elements **109** and **110** each comprising a permanent magnet. The relay **100** is placed within a suitable fixture which carries two electromagnetic magnetizing-demagnetizing coil arrangements, such as **101** and **102**. A control circuit **103** is arranged to select under certain circumstances specified polarities of half-cycle pulses of the alternating-current power and to apply these over the operate or the release path through respective initial and final steps of power magnitude selectors **104**, **105**, **106** and **107** to one or both of the electromagnets **101** and **102**. The control circuit **103** also, at certain times, exercises an operate-release control and a test reset control over the operation of the test circuit in cooperation with certain test relay current adjustment circuits which apply predetermined test and reset current values for the operate and release directions of motion of the armature **108** of relay **100**.

Briefly, the operation of the circuit is as follows. Assuming that the release direction of motion of the armature **108** is from contact **109** to contact **110** and that the operate direction is the reverse and assuming that the armature of relay **100** is initially in contact with the operate contact **110**, the relay current adjustment circuits are first set such that when an operate or release test or reset current is desired to be transmitted through the coil **111** of relay **100**, these values will be those which are specified for the relay under adjustment. The selector switches **105** and **107**, comprising a fine adjustment, will be set at their minimum voltage values. The variacs **104** and **106**, comprising the coarse adjustment, will be set at some predetermined relatively high value of voltage output. In response to the operation of a manual switch, the power control circuit **103** will apply to both of the electromagnets **101** and **102** a few half cycles of specified polarity (say the positive half cycles) of the alternating-current power, whereby each of the relay contacts comprising permanent magnets **109** and **110** is overmagnetized. Thereafter, the coarse controls **104** and **106** are manually readjusted to a selected minimum voltage position and the control circuit **103** will select the variac **106**, the selector switch **107** and the electromagnet **101**, and will cause relatively low level reverse polarity half-cycle pulses of demagnetizing current to be applied to the electromagnet **101** for the purpose of partially demagnetizing the magnet contact **110** of relay **100**. While this particular half cycle of demagnetizing current is being applied to the electromagnet **101**, the release reset current value will be applied to the winding **111** of relay **100** to insure that the armature **108** remains in contact with the operate contact magnet **110**. As soon as this half-cycle demagnetizing pulse is finished, the control circuit **103** will cause the release test current value to be applied to the winding **111** to determine whether or not the armature **108** will transfer from contact **110** to contact **109**. Normally, in response to the first demagnetizing pulse, the armature **108** will not perform as required, whereupon the control circuit **103** causes the release power selector to adjust itself to a slightly increased amount of demagnetizing voltage and to apply this increased demagnetizing voltage again to the electromagnet **101** simultaneously with the previously-mentioned value of release reset current being applied to the winding **111**. As soon as this second demagnetizing pulse is finished, the release test current is again applied to the winding **111**. This procedure is repeated until such time as the armature **108** will travel from the operate contact magnet **110** to the release contact magnet **109** as an indication that the magnet **110** has been demagnetized to a sufficient extent to permit the armature **108** to travel to the release contact **109** in response to the predetermined value of release test current.

The control circuit **103** detects the travel of the armature **108** from the operate contact **110** to the release contact **109** in response to the preselected value of release test current. Thereupon the control circuit **103** switches its power control from the release to the operate side thereby enabling the variac **104** and selector **105** to apply demagnetizing pulses only to the electromagnet **102**. The above procedure, whereby successively increasing increments of half-cycle demagnetizing pulses are applied to electromagnet **101**, is repeated with respect to electromagnet **102** except that the reset and test relay current adjustment circuits which are used are the operate values instead of the release values. Sooner or later the armature **108** will move in response to the operate test current from the release contact magnet **109** over to the operate contact magnet **110** as an indication that the magnet **109** has been demagnetized to the necessary extent.

The last-mentioned adjustment of the magnet **109** necessarily causes an error in the previous adjustment of the magnet **110** because of their proximity and their joint influence over the action of the armature **108**. It is, therefore, necessary, upon the movement of the armature **108** from the release contact **109** to the operate contact **110**, to again repeat the demagnetizing procedure with respect to the magnet **110**.

This process continues back and forth until the control circuit **103** detects that the adjustment of the two magnets **109** and **110** is relatively close to the desired final adjustments with respect to their starting condition, and thereupon may, according to one embodiment of the invention, bring into play the fine adjustment selector switches 105 and 107 to the exclusion of the coarse adjustments comprising the variacs 104 and 106. Thereupon, under the control of the fine adjustments, the testing set proceeds to a conclusion whereby each of the magnets 109 and 110 is successively and alternatively adjusted until the armature 108 "buzzes" back and forth from contact 109 to contact 110, and vice versa, immediately in response to the application to the winding 111 of the respective operate and release test current values without any further demagnetization. This represents a condition, as detected by the control circuit 103, indicating that the relay 100 has been properly adjusted and that the test is completed.

Thereafter, another relay may be placed in the electromagnet fixture and the selector switches or variacs reset to their starting position and a new test procedure followed.

Fig. 4 illustrates in a general manner what happens during the various adjustment sequences according to the embodiment of the invention wherein a shift is provided between coarse and fine power control which is in the embodiment of Figs. 6 and 7. At sequence 0, the release sensitivity and the operate sensitivity of the test relay are respectively −20 ampere turns and +43 ampere turns. This represents the condition of over-magnetization of both magnets prior to the demagnetizing procedure.

The first series of adjustments, whereby the magnet 110 (the operate magnet contact) is demagnetized until the armature moves to the release contact 109 in response to the preselected value of release test current, places the relay under test in a condition where the respective release and operate sensitivities are +10 and +82 ampere turns. Thereupon, an adjustment sequence is effected upon the operate contact magnet 109, at the conclusion of which the respective release and operate sensitivities are +3 and +56.

Thereafter, the circuit alternatively causes an adjustment sequence to the release and to the operate sides. At the ninth adjustment sequence time the release sensitivity of the relay is +30 and the operate sensitivity is +47, these being assumed as the final adjustment sensitivities of the relay.

Somewhere, approximately in the neighborhood of the fourth or fifth or sixth sequence, the circuit will automatically shift from coarse to fine adjustment.

Fig. 5 is an illustration of what happens during the various adjustment sequences of a test circuit according to another embodiment of the invention, such as disclosed in Figs. 8 and 9, wherein there is no shift from a coarse to a fine power adjustment, but wherein the entire procedure is controlled under a fine adjustment situation. In this case, each of the release and operate demagnetizing adjustment sequences will bring the particular contact magnet being operated upon to its respective test value. Each time, however, due to the interaction of the two magnets, the successive adjustments of opposite sides will upset the previous adjustment of the other side. Eventually, however, as was the case in Fig. 4, the final adjustment at approximately adjustment sequence time nine will approach the desired final test values.

In Figs. 4 and 5 it will be appreciated that each of the lines on the curves marked with a black arrow represents one entire adjustment sequence on the particular release or operated side, as indicated, and that each one of these adjustment sequences may involve any number of separate consecutive demagnetizing pulses and reset and test current tests for that side. Figs. 4 and 5 merely represent what the release and operate sensitivities of a test relay would be if taken out of the test set and checked to ascertain what these sensitivities are at the end of each adjustment sequence. Of course, the test set embodying the present invention does not actually provide ampere turn sensitivity values for the relay at these specific times, but continues with the automatic adjustment sequences until such time as the relay under test "buzzes" to and from the operate and release contacts in rapid sequence under the control of the respective operate and release test currents, without the necessity of any further demagnetization.

In the embodiment of Figs. 6 and 7 the relay I in Fig. 7 is the relay under test and is shown as including an armature 718, an energizing winding 719, an operate contact 716 with an associated permanent magnet 717 and a release contact 714 with an associated permanent magnet 715. Located adjacent to the respective magnets 717 and 715 are the magnetizing-demagnetizing coils 713 and 712. The armature 718 of the relay under test, relay I, is shown in contact with the release contact 714. The armature 718 of this type of relay will be in contact with one or the other of its contacts 714 and 716 and the showing of armature 718 in contact with the release contact 714 is merely illustrative of a suitable starting position.

With the double-pole double-throw switch 723 in one or the other of its two positions and with switch 724 open, a circuit is completed from the voltage divider comprising resistance 721 and 722 across the battery, into switch 723 through milliammeter 725, out of switch 723, through the secondary of transformer 726, the winding 719 of relay I, contact 1 of relay H, contact 1 of relay C to potentiometer 702 comprising part of a voltage divider including potentiometer 702 and resistance 703 across a battery. By observing the milliammeter 725 and by adjusting the potentiometer 702, the predetermined desired value of operate test current may be set up by potentiometer 702. By operating switch 720 to the reset position, relay H will be operated in a circuit extending from ground over switch 720 and through the winding of relay H to negative battery. This switches the circuit of the winding 719 of relay I to extend over contact 2 of relay H and contact 1 of relay D to potentiometer 705 which comprises part of a voltage divider including resistance 704 in series with potentiometer 705 across a battery. By moving the double-pole double-throw switch 723 to the proper position and by adjusting potentiometer 705, the preselected value of operate reset current may be adjusted.

Leaving switch 720 in the reset position and operating switch 737 to the release position holds relay H operated and operates relays N and K of Fig. 6 and relays B, C and D of Fig. 7. The operation of relays N, K and B are not significant at the moment. Relays C and D are operated in a circuit extending from ground over switch 737, conductor 638 through the windings of relays C and D in parallel to negative battery, whereupon relays C and D operate. With the switch 723 in the appropriate position, a circuit is now completed through the milliammeter 725 and the secondary of transformer 726, the winding 719 of relay I, contact 2 of relay H and contact 2 of relay D to the potentiometer 709 comprising part of the voltage divider, including resistance 707 and potentiometer 709 across battery. By observing the milliammeter 725 and by adjusting potentiometer 709, the preselected value of release reset current may be properly set up.

By maintaining switch 737 in its release position and moving switch 720 back to its test position, relay H will be released, whereupon the previously described circuit through the winding 719 of relay I is switched over contact 1 of relay H and contact 2 of relay C to the potentiometer 708, by means of the adjustment of which the release test value of current may be set up, at the conclusion of which switch 720 may be momentarily placed in its reset position to apply the release reset value of current to the winding 719 to insure that the armature 718 thereof ends up in contact with the release contact 714. Thereupon, switches 737 and 720 may be returned to their respective operate and test positions leaving the armature 718 in the position shown in Fig. 7.

To place the circuit in condition for automatic operation, switch 724 is closed to short-circuit the meter 725 and switches 737 and 720 are placed in their respective "run" positions. In this condition, all relays in the circuit of Figs. 6 and 7 are in the conditions as shown.

In Fig. 6, upon the closure of switch 614, the alternating-current source of power 633 is applied over the two bus bars marked Φ_1 and Φ_2 which extend to the similarly marked terminals of the variacs 604 and 609, to the primaries of transformers 612 and 613 and to potentiometers 610 and 611. The manual adjustment knobs, such as 605 for variac 604, may be moved to adjust the variacs and potentiometers 604, 609, 610 and 611 to their minimum voltage positions corresponding with phase Φ_1. This manual adjustment is permitted by virtue of the fact that the magnetic clutch arrangements, such as comprising the electromagnet 603 and the friction clutch 602 associated with the variac 604, are not energized.

With these various initial settings of the coarse and fine power selection controls for the operate and release sides, it will be noted that the wiper of the variac 609 carries zero voltage with respect to phase Φ_1 and applies it to the Φ_1 terminal of the potentiometer 611, whereupon the wiper of potentiometer 611 carries zero voltage with respect to Φ_1 and applies it over conductor 636 into Fig. 7 to the right side of the electromagnet 713, the left side of the magnet of winding 713 extending back to contact 2 of relay B. Similarly, in Fig. 6, the wiper of variac 604 carries zero voltage with respect to Φ_1 and applies it to the Φ_1 terminal of the potentiometer 610, whereby the wiper of potentiometer 610 carries zero voltage with respect to Φ_1 and applies it over conductor 635 into Fig. 7 to the left side of the winding of electromagnet 712, the right side of the winding thereof extending back to contact 1 of relay B.

In Fig. 6, the Φ_1 phase of the alternating-current power bus extends through resistance 634 and over conductor 637 into Fig. 7 to the contact of relay A. It will, therefore, be apparent that, when relay A is operated, the Φ_1 phase of the alternating-current power will be applied from conductor 637 over the contact of relay A to the armature of relay B, whereupon, depending upon whether relay B is released or operated, the Φ_1 phase will extend over contact 1 or 2 thereof and through the respective electromagnet 712 or 713 to conductor 635 or 636, extending back into Fig. 6 to the coarse and fine power selector controls associated with the respective electromagnets 712 and 713, namely, the operate and release controls. It will further be appreciated that whatever increment of power may have been selected by the power control circuit of Fig. 6 with respect to phase Φ_1 will thereupon be applied over conductor 635 or 636 to the associated magnetizing-demagnetizing electromagnet 712 or 713. In Fig. 6 the directions of increasing increments of power with respect to phase Φ_1 are indicated by arrows associated with the wipers of the variacs and potentiometers comprising the coarse and fine power increment selection means.

The first operation in initiating the relay adjustment cycle is a preselected manual setting of the wiper of variac 604 by means of the knob 605 to a position which represents a substantial amount of alternating-current voltage on the wiper of variac 604 with respect to its Φ_1 terminal. A similar setting is made of the variac 609. This, then, will apply this amount of alternating-current power to conductors 635 and 636 extending into Fig. 7 through the electromagnets 712 and 713 back to the contacts 1 and 2 of relay B, one or the other of which will extend to the armature of relay A.

The magnetize-demagnetize switch 615 will now be operated to its upper or magnetize position, causing a number of things to happen as follows:

1. At its right outer switch blade, the switch 615 interconnects conductors 640 and 641, which, as will be seen in Fig. 7, amounts to short-circuiting contacts 1 and 2 of relay B. This, as will be appreciated, places the electromagnets 712 and 713 in parallel between their respective power source conductors 635 and 636 and the contact 1 of relay B which, when relay A is operated, will extend back over conductor 637 into Fig. 6 and through resistance 634 back to the Φ_1 phase of the alternating-current power source.

2. With the switch 615 in its upper or magnetizing position, phase Φ_2 of the alternating-current power source 633 is extended over the left inner blade of switch 615 to the swinger armature of relay L, to the winding of relay K, to the primary windings of transformers 623 and 624, to the winding of relay N, and over conductor 638 into Fig. 7 to the windings of relays B, C and D. The only significant connections in this respect are that phase Φ_2 is connected to transformers 623 and 624 and to the swinger armature of relay L.

3. A circuit is completed from phase Φ_2 on the armature of relay L, over contact 2 of relay L, conductor 642 into Fig. 7 through the potentiometer 727 to phase Φ_2 on the conductor 639 extending back into Fig. 6. No alternating-current power is, therefore, applied to the transformer 726 when the switch 615 is in its upper or magnetizing position.

4. The phase Φ_2 extends from the armature of relay L over the contact 1 thereof to the right-hand terminals of the operate and release drive motors 600 and 606. The left-hand terminals of these drive motors extend to respective contacts 1 and 2 of relay K and over the armature of relay K, depending upon whether relay K is released or operated, back to the phase Φ_1 bus. The right-hand terminals of the fine power control motors 607 and 608 extend over the contact of relay M back to contact 3 of relay L. It is thus apparent that with relay L in the position shown in Fig. 6, the coarse motors 600 and 606 are enabled for operation and the fine control motors 607 and 608 are disabled. The converse is true, as will be pointed out in subsequent description, when relay L is operated so that its armature makes contact with its contact 3.

Variac 620 selects a suitable quantity of alternating-current voltage from the secondary of transformer 624, a portion thereof appearing across the resistance 622 in the voltage divider comprising resistance 621 and 622 and being applied to the series circuit including the winding of relay E and condenser 632. This causes a specified level of alternating current to flow in this circuit through the winding of relay E, the level of which is too low to cause the relay E to operate on the alternating current alone. However, it will be noted that negative battery (positive terminal grounded) is applied over the armature of relay E and the contact 2 thereof, through potentiometer 630 and through resistance 631, through the winding of relay E and to ground through resistance 622. Also, it will be noted that condenser 632 shunts the lower side of the winding of relay E to ground. In this position of relay E, the condenser 632 will acquire a charge at a rate determined by the setting of the potentiometer 630. The circuit variables are chosen, preferably, so that the maximum value of direct current which may flow through the winding of relay E is by itself less than the operate value of current for relay E.

As the direct current flowing in the winding of relay E increases (as the charge on condenser 632 increases), it is arranged that at some suitable point on this exponential direct-current curve the alternating current injected into the relay circuit will be sufficient such that the sum of the alternating current and the exponentially increasing direct current will be sufficient to operate relay E. When this happens, the armature of relay E moves from its contact 2 to its contact 1. This removes the direct-current charging circuit for condenser 632 and permits condenser 632 to discharge in the circuit including resistance 622 and the winding of relay E. The voltage across capacitor 632 will, therefore, decrease at an exponential rate determined by the resistance in this discharge path. Since this resistance is fixed for any one setting of the variac 620, the time constant of the discharge circuit for condenser 632 is substantially constant. When the discharge current in this circuit, including the winding of the relay E, has decreased to a sufficient extent, the summation of the alternating and direct currents through the winding of relay E will be such as to permit relay E to again release, whereupon the armature of relay E again makes contact with its contact 2 to cause the above-described cycle to repeat itself.

Potentiometer 630, as above explained, changes the time constant in the charging circuit for condenser 632, thereby varying the amount of time from a specified starting point at which relay E will operate. Potentiometer 630, therefore, may be termed as a "Percent Make Control"; that is, it will control the amount of time when the armature of relay E is in contact with its contact 1 as compared to the total amount of time including the latter plus the amount of time when the armature of relay E is in contact with its contact 2.

At the instant that the armature of relay E makes contact with its contact 1, a circuit is completed from negative battery, armature of relay E, contact 1 of relay E, resistance 629, potentiometer 628, winding of relay F, secondary winding of transformer 623, contact 2 of relay J to ground. The phasing of transformers 623 and 624 is arranged such that the upper side of the winding of relay F carries the same phase of alternating current as the upper winding of relay E, as indicated on Fig. 6 by the notation "Same Phase." Potentiometer 628 simultaneously adjusts the levels of the alternating and direct currents which are permitted to flow through the winding of relay F and thereby adjusts the instant at which the composite current through the winding of relay F first reaches the operate value, at which time the armature of relay F will transfer from its contact 2 to its contact 1.

When relay F transfers to its contact 1, a circuit is completed from ground over the armature and contact 1 of relay F to conductor 644 extending into Fig. 7, through the winding of relay A, and to negative battery through a parallel circuit of condenser 701 and potentiometer 700, and conductor 644 extends over the run positive of switch 720 to operate relay H for a purpose to be described later. The condenser 701 in the circuit of relay A presents an instantaneous short circuit across the potentiometer 700 and permits relay A to operate very quickly upon the grounding of conductor 644. Sooner or later, depending upon the setting of potentiometer 700, condenser 701 will acquire a sufficient charge to cause relay A to release.

The settings of the potentiometer 628 in the circuit of relay F and potentiometer 700 in the circuit of relay A may be considered, respectively, as pulse start and pulse end potentiometers, whereby the specific instant with respect to the alternating-current wave form at which relay A will operate is determined by potentiometer 628 and the specific instant of the release of relay A compared to the same alternating-current wave form is determined by the setting of potentiometer 700.

The net effect of this relaxation oscillator type of relay circuit is that relay E will operate and release at a rate which is preferably a subharmonic of the alternating-current frequency (but broadly may be any integral multiple of the cycle time of the alternating-current wave form), such as four or five times per second as compared to a 60-cycle source of alternating current and such that relay A may be operated and released at the specified instants with respect to the alternating-current wave form.

As previously described, the phase Φ_1 of alternating-current power in Fig. 6 is applied through resistance 634 and over conductor 637 to the contact of relay A. When relay A is operated, the phase Φ_1 is extended from conductor 637 over the contact of relay A and over contact 1 or 2 or both of relay B to the electromagnet 712 or 713 or both, and back over conductor 635 or 636 or both, to the wiper or wipers of the fine power control potentiometers 610 or 611 or both, to apply a pulse of alternating-current power to one or the other or both of these electromagnets during the time when relay A is operated. An oscilloscope may be connected across the resistance 634 to observe the alternating-current half cycle of power which is transmitted through the contact of relay A. With such a continuous indication, the various adjustments, such as the variac 620 and potentiometers 630, 628 and 700, may be adjusted such that the portion of alternating-current power delivered through the closed contact of relay A may be exactly a positive or negative half cycle more or less.

The previously described relaxation oscillator type of power control circuit involving relays E, F and A, etc. is disclosed and claimed as a power control circuit in the application of C. E. Pollard, Jr., Serial No. 418,396, filed on March 24, 1954, now Patent No. 2,781,459 issued February 12, 1957. A more detailed and more precise description of the operation of this power control circuit is provided therein.

Therefore, with the switch 615 in the upper or magnetizing position, selected polarity half cycles of the alternating-current power (the magnitude of which is determined by the settings of the variacs 604 and 609) are transmitted through the contact of relay A over contact 1 of relay B to the right side of the winding of electromagnet 712 and over conductor 641 into Fig. 6, over the right outer blade of switch 615, and back over conductor 640 into Fig. 7, to the left side of the winding of electromagnet 713 and in parallel back over conductors 635 and 636 to the wipers of the fine power control potentiometers 610 and 611, out over the respective Φ_1 terminals thereof to the wipers of the respective coarse power control variacs 604 and 609, to the preselected portion of alternating-current voltage at which they are set.

These selected polarity half-cycle pulses of power are considered as magnetizing pulses, whereby each of the permanent magnets 715 and 717 associated with the release and operate contacts 714 and 716 of relay I (the relay under test) are overmagnetized.

After the operator is satisfied that sufficient time has been allowed for these magnetizing pulses to take effect (actually only one pulse is necessary), the switch 615 may be transferred from its upper to its lower or demagnetizing position. As an incident to this operation, the variacs 604 and 609 will be manually adjusted to a low value toward their Φ_1 terminals. This causes a number of effects, as follows:

1. The phase of the alternating-current power applied to the primaries of transformers 623 and 624 is reversed. This, as will be appreciated, will cause the power pulses which are transmitted through the contact of relay A to be of the reverse polarity from those previously described. These new power pulses will be referred to as demagnetizing pulses.

2. Phase Φ_1 will be applied over the left outer blade of switch 615 to the armature of relay L and thence over contact 2 thereof and conductor 642 to the top of potentiometer 727, whereby alternating current will be transmitted through transformer 726 to be injected in series with the previously described direct-current reset and test values preselected by the potentiometers 702, 705, 708 and 709.

3. The right outer blade of switch 615 removes the short circuit across conductors 640 and 641, which removes the short circuit across contacts 1 and 2 of relay B in Fig. 7. This permits relay B to select by its release or operation which of the two electromagnets 712 and 713 will be permitted to receive demagnetizing pulses transmitted over the contact of relay A.

4. A circuit is completed from ground, over the right inner blade of switch 615, through resistance 617 and to battery through the windings of all of the magnetic clutch magnets, such as magnet 603 associated with the operate coarse power control mechanism. This causes all of the clutches, such as clutch 602, to engage, whereby the respective drive motors, if energized, will cause the associated wipers of the variacs 604 and 609 and potentiometers 610 and 611 to move from their Φ_1 terminals toward their Φ_2 terminals at a fairly slow rate depending upon the speed of the associated motor and the amount of gear reduction in the respective reduction gear boxes, such as reduction gear box 601 for motor 600.

5. A circuit is completed from ground, over the right middle blade of switch 615, through resistance 618 to negative battery through the winding of relay L. The condenser 646 across the winding of relay L will acquire a voltage charge, the value of which, however, is insufficient to cause the relay L to operate, but which is sufficient to cause the relay L to stay operated once it is operated by other means.

Simultaneously with the operation of relay F from its No. 1 contact to its No. 2 contact which, as previously explained, operates relay A by applying ground to conductor 644, relay H is also operated by an extension of conductor 644 over the run position of switch 720. Relay H, in operating, applies the operate reset value of current from potentiometer 705 over contact 1 of relay D and contact 2 of relay H, through winding 719 of the test relay I, through the secondary of transformer 726 and through switches 723 and 724 to the connection of resistances 721 and 722. As previously explained, this value of operate reset current will insure that the armature 718 of relay I remains in contact with its contact 714 during the time when relay A is operated to apply a demagnetizing pulse to the electromagnet 712. The magnitude of this demagnetizing pulse as previously explained, will be determined by the position of variac 604 as it moves slowly from its Φ_1 terminal toward its Φ_2 terminal under the control of motor 600, which at this time is connected to the alternating-current source of power over contact 1 of relays K and L.

Relay A will release, terminating the application of a demagnetizing pulse to the electromagnet 712, at a time determined by the setting of potentiometer 700, as previously described. As soon as relay F releases to its contact 2, relay H will release. The release of relay H, therefore, occurs during the time when relay A is also released, which represents the time interval between applications of demagnetizing pulses to electromagnet 712. Relay H, in releasing, completes a circuit from the potentiometer 702 over contact 1 of relay C, contact 1 of relay H, through the winding 719 of the test relay I, through the secondary of transformer 726, etc., to apply to the winding 719 of relay I the prescribed value of operate test current. As previously explained, this value of operate test current is the value which will make the armature 718 of relay I transfer from contact 714 to contact 716 of relay I when the permanent magnet 715 has been properly demagnetized. Due to the injection, by means of transformer 726, into this test current circuit for relay I of a suitable quantity of alternating current, the armature 718 will accomplish the prescribed transfer earlier in the demagnetizing cycle of permanent magnet 715 than it otherwise would if the alternating current were not superimposed upon the direct current in this circuit of the winding 719. That is, as the relays usually under adjustment are capable of operating or releasing in less than a half cycle of the superimposed alternating current, the latter permits the relay to operate or release whenever the composite current passes through a value about equal to the respective direct-current sensitivities.

If the armature 718 of relay I does not accomplish the required transfer, no changes in the circuit operation occur and the relay A is again operated along with relay H to apply another demagnetizing pulse to the electromagnet 712, this time of a slightly increased magnitude due to the fact that during the intervening time the variac 604 has moved farther from its Φ_1 terminal thereby selecting a slightly increased magnitude of demagnetizing current. Upon the operation of relay H, as before, the preselected value of operate reset current is applied to the winding 719 of relay I to insure that the armature 718 remains in contact with the release contact 714 of relay I. Thereafter, as soon as the relay A has released and relay H has released, as evidence of the fact that the demagnetizing pulse is over, relay H again being released once again applies the selected operate test value of current to the winding 719 of relay I.

This process continues until such time as the armature 718 of relay I transfers to its operate contact 716 during the time interval between applications of demagnetizing pulses to the electromagnet 712. When this transfer takes place, a circuit is completed from negative battery over the armature 718 of relay I, contact 716, resistance 729, to the right side of the lower winding of relay G, through the lower winding of relay G and to conductor 643 extending to ground over contact 2 of relay F. It will be noted that condenser 736 shunts the lower winding of relay G thereby causing a slight delay in the operation of relay G, after which delay the armature of relay G will be operated to make contact with its contacts 2 and 3.

Upon the movement to the right of the armature of relay G, ground is extended over the armature thereof and over contact 3 of the relay G, through condenser 733 and over conductor 645 to the upper side of the winding of relay J. This ground pulse augments the charge existing on condenser 647, whereby the relay J will cause its armature to transfer from contact 2 to contact 1, where the armature of relay J will remain for a short period of time depending upon the amount of time the condenser 733 requires to obtain a charge. After this short interval of time, relay J will release again to its contact 2. During the time that relay J is operated to its contact 1, relay M will be operated in an obvious circuit for a purpose to be described later. Relay J, in operating for a short period of time, immobilizes the circuit of relay F, thereby permitting the armature of relay F to remain in contact with its contact 2, and thus preventing the immediate reoperation of relays A and H when relay E continues to oscillate.

Relay G, in operating its armature to the right, also completes a circuit from ground over its contact 2, through the run position of switch 737, to conductor 638 which, in an obvious manner, causes the operation of relays B, C and D. The grounding of conductor 638 in Fig. 6 causes the operation of relays N and K. Relay N, in operating, applies a ground pulse over its contact 1 through condenser 626 and through resistance 619 to the left side of the winding of relay L. Condenser 626 will very quickly, however, acquire a charge which then removes the additional pulse from the winding of relay L, and relay L is arranged such that this single pulse will not cause it to operate. Relay K, in operating, transfers the phase Φ_1 of alternating-current power from its contact 1 to its contact 2 thereby stopping the operation of motor 600 and starting the operation of motor 606. Furthermore, during the time when the armature of relay G is in contact with its contacts 2 and 3, the previously charged condenser 732 associated with contact 1 of relay G will discharge through resistance 735.

After relay J of Fig. 6 releases, after its momentary operation as previously described, the circuit for relay F is again completed and the relaxation oscillator relay circuit comprising relays E and F again comes into play to cause the operation of relay A of Fig. 7 to again apply a demagnetizing pulse over its contact. However, with relay B operated, this demagnetizing pulse, the magnitude of which is determined by the now continually slowly increasing value of alternating-current voltage selected by the variac **609** under the control of motor **606**, will be transmitted over contact **2** of relay B to the electromagnet **713**. During the interval of time when relay A is operated, relay H will again be operated, as previously described, and a circuit will be completed from the release reset potentiometer **709** over contacts **2** of relays D and H to apply to the winding **719** of relay I the predetermined value of release reset current whereby the armature **718** of relay I is forced to remain in contact with the operate contact **716** of relay I.

During the interval between the magnetizing pulses when relays A and H are released, as above described, a circuit is completed from the release test potentiometer **708** over contact **2** of relay C and contact **1** of relay H, whereby the predetermined value of release test current is applied to the winding **719** of relay I to determine whether or not the armature **718** will transfer back to the release contact **714**. As previously explained, this release test current is augmented again by the portion of alternating current transmitted through transformer **726**.

If the armature **718** does not transfer back to contact **714**, the above-described demagnetizing process is repeated whereby another demagnetizing pulse is transmitted to the electromagnet **713**. This, as will be obvious from previous description, will be of a slightly increased magnitude due to the fact that the variac **609** has been moving slowly under the control of motor **606** toward its Φ_2 terminal.

Sooner or later armature **718** will accomplish the desired transfer, by which time a circuit is completed from negative battery, through the armature **718** of relay I, over contact **714** of relay I and through resistance **728** to the right side of the upper winding of relay G. Relay G will operate in the same manner as previously described, after a short delay caused by the short-circuiting effect of condenser **730**, to move its armature from the right to the left, thereby releasing relays B, C, D, N and K. This, as will be obvious at this point, reverts the entire control circuit again to the condition whereby demagnetizing pulses will again be applied to the electromagnet **712** associated with the release contact **714** of relay I.

This back-and-forth procedure will continue under the control of the coarse variacs **604** and **609**, as controlled by their respective motors **600** and **606**, until the relay G operates to and releases from its contact **2** at a sufficiently rapid rate such that relay N of Fig. 6 is operated and released at a fairly fast rate, whereby a succession of ground pulses are applied over contact **1** and relay N to the winding of relay L. Relay J is also operated and held operated by the rapid pulsing of the G relay over its contacts 3 and 2. This immobilizes the F relay and operates the M relay, thereby to stop the demagnetizing procedure. Such a rapid pulsing of the winding of relay L will cause the condenser **646** in shunt thereof to acquire a sufficiently increased charge to cause relay L to operate its armature into engagement with its contact **3**. Relay L, in operating its armature into engagement with its contact **3**, remains in this position because the steady charge on condenser **643** is now sufficient to accomplish this holding effect. Relay L, in so operating, causes the power circuit for motors **600** and **606** to be opened and causes the power circuit for motors **607** and **608** to be completed, in an obvious manner, over contact 3 of relay L and the contact of relay M (at such time as relay M releases upon the release of relay J into engagement with contact 2 of relay J as previously described). The operation of relay L, in addition to bringing into operation the fine power control in the upper right portion of Fig. 6 instead of the coarse control as previously effected, also removes from contact **2** of relay L the previously-described circuit whereby the transformer **726** in Fig. 7 receives alternating-current power. This causes the "buzzing" of the relay I to cease, whereupon relays M and J release and relays N and G cease to "buzz." This means that during the remaining part

of the relay adjustment there will no longer be any alternating current superimposed upon the test currents injected into winding **719** of relay I and the circuit may continue its automatic operation as the wipers of the fine power control potentiometers **610** and **611** move slowly from their Φ_1 terminals toward their Φ_2 terminals to apply very small, but nevertheless increasing amount of alternating-current demagnetizing pulse power to the two electromagnets **712** and **713**.

Eventually, a point will be reached where the armature **718** of relay I will even more rapidly and more quickly transfer back and forth between contacts **716** and **714**, and vice versa, of relay I and to in turn cause relay G to switch quickly back and forth between its contacts **1** and **3**, whereupon sufficiently frequent pulses will be applied to conductor **645** to cause relay J to remain operated in the position where contact **1** of relay J is grounded continuously. This causes a continuous operation of relay M thereby to open at its contact the operating circuit for motors **607** and **608** to stop any further demagnetizing procedure.

This condition is visually indicated by the two lamps **710** and **711** in Fig. 7 which, under this condition, will flash back and forth in a very rapid fashion, thereby indicating to the operator that the demagnetizing procedure for adjusting relay I has come to a proper conclusion. At this point, the operator will move switch **615** to the off-position and will remove relay I from the electromagnet fixture preparatory to repeating the above test on a new relay.

Before beginning a new test, the operator will readjust the fine potentiometers **610** and **611** to their minimum or Φ_1 positions and may or may not return the variacs **604** and **609** to their starting positions. In Fig. 6 the "fine" switch **627** may be manually closed, if desired, assuming that a coarse setting of the variacs **604** and **609** has been predetermined. This will cause the immediate operation of relay L, as will be obvious, such that only the motors **607** and **608** controlling the fine power control will be effective.

The embodiment of the invention disclosed in Figs. 8 and 9 performs substantially the same relay adjusting job as that described previously in connection with Figs. 6 and 7. The embodiment of Figs. 8 and 9 differs from the embodiment of Figs. 6 and 7 in a number of deails, the differences of major significance being as follows:

1. The means whereby successively increasing increments of demagnetizing current are supplied from the source of alternating-current power comprises a pair of step-by-step switches shown in the upper left portion of Fig. 8. These switches are self-normalizing and, therefore, need not be manually readjusted to their starting positions prior to each relay adjustment cycle.

2. There is no coarse control over the increments of demagnetizing pulse magnitude. The total excursion of the step-by-step selectors provide equal increments of power throughout the entire test and no alternating current is superimposed on the relay test currents.

3. A number of additional control relays are provided as will be apparent from subsequent description.

In reference to Fig. 9, the relay under test is shown in the right-hand portion in the same manner as previously discussed with respect to Fig. 7. With the main power switch **802** in Fig. 8 unoperated and with the magnetizing switch **900** and demagnetizing switch **901**, run switch **902** and run switch **904** also unoperated, the various operate and release currents of the reset and test values may be set up on the potentiometers **906**, **909**, **912** and **913** in substantially the same manner as described in connection with the circuit of Figs. 6 and 7.

With the release switch **903** and the reset switch **905** both unoperated, relays **3**, **4** and **5** will be in the position shown on Fig. 9. Whereupon, by manipulating switch **915** in one direction or the other depending upon the polarity of current to be read by meter **917** (assuming switch **916** to be open), adjustment of the potentiometer **906** permits the predetermined value of operate test current to flow in a circuit extending from the wiper of potentiometer **906**, contact **1** of relay **3**, contact **1** of relay **5**, winding **921** of the relay under test, contact **1** or **2** of switch **915**, meter **917**, contact **3** or **4** of switch **915** to the wiper of potentiometer **914** and thence to battery. The meter **917** will indicate when the adjustment of potentiometer **906** has been set at the prescribed value of operate test current. Now, with switch **903** closed, operating relays **3** and **4** in an obvious circuit to ground over the contact of switch **903**, the potentiometer **912** will be effective over contact **2** of relay **3** and contact **1** of relay **5** to set up the prescribed value of release test current. With switch **903** operated, switch **905** is also operated, thereby operating relay **5** in an obvious circuit, the potentiometer **913** may be adjusted whereby it is effective over contact **2** of relay **4** and contact **2** of relay **5** to adjust the prescribed value of the release reset current. Now with switch **905** operated and switch **903** released, thereby maintaining relay **5** operated and releasing relays **3** and **4**, potentiometer **909** is effective by means of contact **1** of relay **4** and contact **2** of relay **5** to establish the prescribed value of operate reset current. Switches **903** and **905** may then be released and switch **916** may now be closed to short-circuit the meter **917**.

Upon the closure of the main power switch **802** in Fig. 8, alternating-current power is applied from the source **800** thereof, through fuse **801** and switch **802**, to the two alternating-current power lines designated phase Φ_1 and phase Φ_2. This applies power to the primary windings of transformers **816**, **810**, **804** and **803** and also applies alternating-current power to variacs **811** and **805**.

To accomplish the initial over-magnetization of the permanent magnets **925** and **924**, associated with the respective release and operate contacts **922** and **923** of the relay under test, the magnetizing switch **900** will be closed causing the following operations:

1. Relays **15** and **16** of Fig. 8 will be operated in a circuit extending from ground over contact **4** of switch **900** and over conductor **845** to the windings of relays **15** and **16**.
2. A circuit is completed from ground over contact **5** of switch **900**, conductor **838** into Fig. 8 and over the contact of relay **11** to place ground on the bottom terminal of the secondary winding of transformer **803**.
3. Grounds are extended over contacts **1** and **3** of switch **900** and over respective conductors **848** and **856** extending into Fig. 8 to the respective wipers **820** and **824** of the two step-by-step selectors.
4. A circuit is completed for operating relay **14** in Fig. 8 extending from the phase Φ_2 power line through the winding of relay **14**, conductor **851**, contact **2** of switch **900**, conductor **852**, back to the phase Φ_1 power line.

Relay **9** in Fig. 8 operates in the same fashion as previously described for relay E in Fig. 6; that is, relay **9** will oscillate its armature back and forth between its contacts **1** and **2** at a rate which is preferably a subharmonic of the alternating-current frequency (such as three to five cycles per second as compared to a 60-cycle source). The rate at which relay **9** oscillates is determined primarily by the settings of the variac **825** and the potentiometer **826**, both comprising, in effect, a frequency adjustment. The amount of time when the armature of relay **9** dwells at its contact **2**, as compared to the total amount of time when it dwells against contact **2** and contact **1**, is adjustable by means of the percent make potentiometer **829**.

Each time relay **9** operates its armature against its contact **2**, relay **10** will be operated by a combination of alternating and direct currents, and it will operate at an instant with respect to the alternating-current wave form determined by the adjustment of the pulse start potentiometer **830**.

Each time relay **10** operates and grounds its contact, ground is applied to the winding of relay **1** and over conductor **843** into Fig. 9. Relay **1** will thereupon operate and will stay operated for a short interval of time depending upon the setting of the pulse stop potentiometer **858**, which adjusts the time constant of the circuit whereby condenser **859** will acquire a charge sufficient to cause relay **1** to release.

The various adjustments comprising variac **825**, frequency potentiometer **826**, percent make potentiometer **829**, pulse start potentiometer **830** and pulse stop potentiometer **858** are preferably made with an oscilloscope connected across the terminals of resistance **846**, such that the relay **1** will close its contact when the alternating-current wave form goes through zero in one direction and will open its contact when the alternating-current wave form goes through zero in the other direction; that is, the contact of relay **1** will be closed only during a selected polarity half cycle (more or less) of the alternating-current power, all as previously described with respect to relay A of Fig. 7.

During the operation of relay **1**, a circuit is completed from the phase Φ_1 power line over the contact of relay **15**, in parallel over contacts **1** and **2** of relay **16**, over conductors **857** and **844** into Fig. 9, to the respective right and left sides of the windings of the electromagnets **919** and **917**, back over respective conductors **850** and **849**, to the respective contacts **2** and **1** of relay **2**. It will be noted that the contacts **1** and **2** of relay **2** are short-circuited by means of contact **1** of the operated relay **14**. Therefore, no matter what position relay **2** may be in, the circuit continues over the armature thereof through resistance **832**, over the contact of relay **1**, through resistance **846** and fuse **847** and over contact **2** of relay **14** to the top terminal of the variac **811**, which will carry phase Φ_2 of the alternating-current power. Selected half cycles of a specified polarity of the alternating-current power are, therefore, applied to both of the electromagnets **917** and **919** to over-magnetize them.

In the event that the two stepping switches are not in the positions shown in Fig. 8, the grounds on conductors **848** and **856** in Fig. 8 will be extended over the respective wiper arms **820** and **824** and over the contacts of the respective stepping magnets SEL1 and SEL2 to operate them. Immediately upon being operated, these respective stepping magnets SEL1 and SEL2 open their own operating circuits, thereby releasing and advancing the associated wiper arms one step in the directions shown by the arrows. It will be appreciated that, for instance, the wiper arms **817**, **818**, **819** and **820** are associated with the stepping magnet SEL1 and that the wiper arms **821**, **822**, **823** and **824** are associated with the stepping magnet SEL2. Each of these stepping switches continues to step automatically until position **22** is arrived at, whereupon ground will extend over the wipers **819** and **823** to battery through the right-hand windings of the respective relays **7** and **8**. These relays **7** and **8** will thereupon operate their armatures into the positions shown in contact with their respective contacts **1**. If the respective stepping switches are initially in the position shown, the respective relays **7** and **8** will therefore nevertheless be in the position shown. It will be noticed that with relays **7** and **8** in the positions shown the primary windings of transformers **812** and **808** are short-circuited so that no alternating-current voltage or current is induced into the secondaries of these transformers.

The magnetizing switch **900** will now be released preparatory to setting the circuit into automatic operation for demagnetizing the two permanent magnets **925** and **924** of the relay under test, thereby releasing relays **15** and **16**, removing ground from the wipers **820** and **824** of the stepping switches, releasing relay **14** and removing ground from conductor **838** thereby stopping the oscillation of relay **9**, etc.

To initiate the demagnetizing procedure, switches **902** and **904** are placed in their run positions and the demagnetizing switch **901** is closed. The closure of the demagnetizing switch **901** accomplishes the following things:

1. Ground is extended over contact **4** of switch **901** to conductor **838** to cause the relay **9**, etc., to start oscillating.

2. Ground is extended over contact **3** of switch **901** to conductor **853** extending into Fig. 8 to cause the operation of relays **17** and **18**.

3. Ground is extended over contact **1** of switch **901** to conductor **837** extending into Fig. 8 and to battery through the left-hand windings of relays **7** and **8**. This does not cause relays **7** and **8** to operate, but will hold them operated if they are caused to operate when and if the respective step-by-step wiper arms **819** and **823** ground the terminals **22** of their respective contact arcs, as previously described.

4. The conductor **843** in Fig. 8, which is grounded each time relay **10** is operated, is extended in Fig. 9 over the contact of switch **904** to the winding of relay **5** and is extended over contact **2** of switch **901** to conductor **854** extending back into Fig. 8 to the winding of relay **13**. Therefore, each time that relay **10** is operated (operating relay **1** as previously described) relay **5** will operate to cause the operate or release reset value of current to be applied to the relay under test and relay **13** will be operated to extend a pulsing ground over its contact and over contact **1** or **2** of relay **6** to the respective stepping magnet SEL2 or SEL1 in Fig. 8. As soon as the ground is removed from conductor **843** in Fig. 8, when relay **10** releases, relays **5** and **13** likewise will release, thereby respectively calling into operation the operate or release test value of current for the relay under test and permitting the operated stepping magnet SEL1 or SEL2 to release to advance the associated stepping switch one position.

With the relay under test in the position shown in Fig. 9, that is, with its armature **920** in contact with its release contact **922**, a circuit will have been completed for causing the relay **12** of Fig. 8 to operate into the position shown with its armature in contact with its contact **2**. This circuit extends from battery, armature **920** of the relay under test, contact **922**, resistance **926**, conductor **840** through the winding of relay **12**, conductor **841**, resistance **927** to ground through the operate lamp **929**. The operate lamp **929** will not light in this circuit due to the impedance in series therewith. The release lamp **928** will light, being directly connected to battery over contact **922** and armature **920** of the relay under test. The fact that the release lamp **928** is lit indicates to the operator the situation of the relay under test. With relay **12** in the position shown, ground is removed from its contact **1** and from conductor **839**, which extends over the contact of switch **902** to relays **3** and **4** of Fig. 9 and over conductor **855** into Fig. 8 to the windings of relays **2** and **6**. These relays **3**, **4**, **2** and **6**, therefore, will be released and in the positions shown in the drawing.

Under this condition a circuit is completed each time relay **1** is operated to apply a reverse polarity (that is, reverse with respect to the magnetizing pulses) of alternating-current power to the electromagnet **917** associated with the permanent magnet **925** which comprises part of the release contact **922** of the relay under test. This circuit extends from the phase Φ_1 power line in Fig. 8 over the contact of relay **18**, through fuse **847** and resistance **846**, contact of relay **1**, resistance **832**, contact **1** of relay **2**, conductor **849**, through the winding **917** of the electromagnet, conductor **844**, contact **2** of relay **17**, wiper arm **822**, wiper **809**, the secondary of transformer **808** and the wiper of variac **805**, back to the phase Φ_2 side of the power line. It will be noted that the polarity of this circuit is reversed from that previously described in connection with the magnetizing part of the procedure. In view of the fact that the primary of transformer **808** is short-circuited over contact **1** of relay **8** (it will be noted that shorted or energized transformer **812** represents a substantially constant impedance), the only voltage available in this demagnetizing path is the voltage available from the variac **805**, and the small amount of voltage represented by the position of the wiper **809** which is of no particular significance except that it may be adjusted to one position or the other for purposes of balancing out small differences between transformers, such as **812** and **816** or **808** and **810**. Simultaneously, with the closure of the contact of relay **1**, as previously explained, conductor **843** is grounded by the operation of relay **10**, whereupon relay **5** is operated over the contact of switch **904**. This causes the operate reset value of current to be applied on potentiometer **909** to the winding **921** of the relay under test to insure that the armature **920** remains in contact with contact **922**.

As soon as relay **10** releases, relay **5** will release, thereby causing the operate test value of current to be applied from potentiometer **906** to the winding **921** of the relay under test. In the meantime, relay **13** had been operated and released once thereby causing the stepping magnet SEL2 to operate and release once, advancing the associated wiper arms one step.

If the armature **920** of the relay under test does not transfer to its contact **923**, another demagnetizing pulse will be applied to the electromagnet **917** upon the reoperation of relay **10**. This demagnetizing pulse will be of slightly increased magnitude as determined by the advance of one step of the wiper arm **822**. Simultaneously with the application of this next demagnetizing pulse to the electromagnet **917**, relay **5** is reoperated to again apply the operate reset value of current to the winding **921** of the relay under test. As soon as relay **10** releases, relay **5** is released to cause the operate test value of current to be applied to the winding **921**. In the meantime, the stepping magnet SEL2 is again reoperated and released to cause the wiper arms associated therewith to advance still another step.

This process continues uninterruptedly until such time as the armature **920** of the relay under test, in response to the application to the winding **921** of the operate test value of current, moves from its contact **922** to its contact **923**. This causes the release lamp **928** to extinguish and the operate lamp **929** to become lighted. This also causes a circuit to be completed from battery over the armature **920**, contact **923**, resistance **927**, conductor **841**, winding of relay **12**, conductor **840**, resistance **926** to ground through the release lamp **928**. This battery pulse applied to the winding of relay **12**, over and above the steady charge maintained on condenser **861**, is sufficient to cause the relay **12** to move its armature from its contact **2** into contact with its contacts **1** and **3**. This movement of the armature of relay **12** causes the charge previously acquired by condenser **833** to be dissipated in resistance **835** and causes a ground pulse to be applied over the armature of relay **12**, contact **3** thereof through condenser **834**, to the winding of relay **11**, which ground, augmenting the charge normally carried by condenser **860**, will cause relay **11** to operate momentarily until condenser **834** can acquire a sufficient charge to cause relay **11** to release. This momentary operation and release of relay **11** opens the circuit between the grounded conductor **838** and the bottom terminal of the secondary winding of the transformer **803**, thereby causing the relay **9** to stop oscillating. Ground is also applied over contact **1** of relay **12** to conductor **839** extending into Fig. 9 and over the contact of switch **902** to operate relays **3** and **4** and extending over conductor **855** into Fig. 8 to operate relays **6** and **2**.

Upon the release of relay **11**, after a momentary delay above mentioned, relay **9** is again permitted to oscillate to again cause relays **10**, **1** and **5** to operate to cause a demagnetizing pulse to be applied to the electromagnet **919**. The circuit for this demagnetizing pulse extends from the phase Φ_1 side of the power line, over the contact of relay **18**, through fuse **847**, resistance **846**, contact of relay **1**, resistance **832**, contact **2** of relay **2**, conductor **850**, through the winding of the electromagnet **919** back over conductor **857**, contact **1** of relay **17**, to wiper **818** of the upper stepping switch and out over the wiper **813**, through the secondary of transformer **812**, back to the wiper of variac **811**. The only voltage available in this demagnetizing pulse circuit is the voltage derived from the wiper arm of variac **811** and the small amount of voltage available due to the position of the wiper arm **813**, by virtue of the fact that relay **7** is short-circuiting the primary of transformer **812**.

Due to the fact that relay **4** is operated during this demagnetizing pulse and due to the fact that relay **5** is also operated, potentiometer **913** will cause the release reset value of current to be applied to the winding **921** of the relay under test to force the armature **920** to remain in contact with the operate contact **923** of the relay under test. As soon as the demagnetizing pulse is over with, as indicated by the release of relay **10**, relay **5** will release and will cause, in combination with the operation of relay **3**, the potentiometer **912** to apply to the winding **921** of the relay under test the prescribed value of release test current. If the armature **920** does not return to contact **922** in response to this value of release test current, then another demagnetizing pulse of slightly increased amplitude is applied to the electromagnet **919**. This increased amplitude of demagnetizing pulse is produced because during the operation and release of relay **10**, conductor **843** is grounded and ungrounded, which in turn causes relay **13** to operate and then to release. The operation and release of relay **13** extends a ground pulse over its contact and contact **2** of relay **6** to the winding of the stepping magnet SEL1, whereupon the stepping magnet SEL1 operates and releases causing the associated wiper arms to advance one step.

This process continues with the armature **920** in contact with the operate contact **923** until such time as the armature **920** transfers to the release contact **922** in response to the prescribed value of release test current, whereupon relay **12** is again operated to cause its armature to make contact with its contact **2**. This momentarily operates relay **11** to stop the oscillation of relay **9**, which stops the application of demagnetizing pulses to the electromagnets and releases relays **3**, **4**, **2** and **6** to revert the relay control circuit to the previously-described condition whereby further demagnetizing pulses may be applied to the electromagnet **917**.

The above-described procedure is repeated back and forth with respect to the electromagnets **917** and **919** until a point is reached where the armature **920** moves back and forth between contacts **922** and **923** immediately in response to each respective application of the release and operate test values of current. This will cause a similar oscillation of relay **12** back and forth between its contacts **2** and **3** whereby a succession of ground pulses is applied to the winding of relay **11** at a sufficiently high rate to maintain relay **11** operated continuously. The continuous operation of relay **11** immobilizes the demagnetizing procedure by causing relay **9** to stop oscillating. The rapid flashing back and forth of the two lamps **928** and **929** provides a visual indication to the operator that the relay under test has arrived at a condition whereby the permanent magnets **925** and **924** have been demagnetized to such an extent that the respective operate and release test values of current prescribed for the relay under test properly cause the armature **920** to perform as prescribed.

The relay under test may now be removed from the circuit and another relay may be placed under test, whereupon the above procedure is repeated, it being appreciated that as soon as the magnetizing switch **900** is operated with the demagentizing switch **901** released, the two stepping mechanism of Fig. 8 will automatically adjust themselves to their normal starting positions.

It is to be understood that the above-described arrangements are merely illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and a contact and a permanent magnet and a magnetic armature movable in operable relation to said contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic field of said magnet, said circuit comprising a source of electric power, switch means having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize said test relay magnet, a power control circuit responsive to the operation of said switch means into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coil from said source, said current pulse being adaptable to over-magnetize said magnet, variable means operable to deliver variable increments of power from said source to said coil under the control of said control circuit, means automatically responsive to the operation of said switch means into its demagnetizing position to cause said control circuit to control said variable means to apply a sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to said coil from said source, said sequence of pulses being adaptable to demagnetize said magnet to successively increasing extents, means automatically operative by said control circuit during the application of each demagnetizing pulse of said sequence to said coil and adaptable to cause said armature to be placed into contact with said contact and automatically operative by said control circuit during the intervals before and after demagnetizing pulses of said sequence are applied to said coil and adaptable to apply to the winding of said test relay a test current of such a magnitude and polarity as would move said armature away from said contact when the permanent magnet bias is properly adjusted by said sequence, and means automatically operative by said control circuit and adaptable to detect the movement of said armature away from said contact.

2. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and a contact and a permanent magnet and a magnetic armature and movable in operable relation to said contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic field of said magnet, said circuit comprising a source of electric power, switch means having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize said test relay magnet, a power control circuit responsive to the operation of said switch means into its magnetizing position to apply at least one pulse of current of magnetizing polarity to said coil from said source, said current pulse being adaptable to over-magnetize said magnet, variable means operable to deliver variable increments of power from said source to said coil under the control of said control circuit, means automatically responsive to the operation of said switch means into its demagnetizing position to cause said control circuit to control said variable means to apply a sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude of said coil from said source, said sequence of pulses being adaptable to deenergize said magnet to successively increasing extents, means automatically operative by said control circuit during the application of each demagnetizing pulse of said sequence to said coil and adaptable to cause said armature to be

placed into contact with said contact, means automatically operative by said control circuit during the intervals before and after demagnetizing pulses of said sequence are applied to said coil and adaptable to apply to the winding of said test relay a test current of such a magnitude and polarity as would move said armature away from said contact when the permanent magnen bias is properly adjusted by said sequence, and means automatically operative by said control circuit and adaptable to detect the movement of said armature away from said contact.

3. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and a contact and a permanent magnet and a magnetic armature movable in operable relation to said contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic field of said magnet, said circuit comprising a source of electric power, a manually operable switch having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize said test relay magnet, a power control relay circuit responsive to the operation of said switch into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coil from said source, said current pulse being adaptable to over-magnetize said magnet, a power selector operable to deliver variable increments of power from said source to said coil under the control of said relay control circuit, relay means in said relay control circuit automatically responsive to the operation of said switch into its demagnetizing position to cause said power selector to apply a sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to said coil from said source, said sequence of pulses being adaptable to demagnetize said magnet to successively increasing extents, means automatically operative by said relay control circuit during the application of each demagnetizing pulse of said sequence to said coil and adaptable to cause said armature to be placed into contact with said contact, relay means in said relay control circuit automatically operative during the intervals before and after demagnetizing pulses of said sequence are applied to said coil and adaptable to apply to the winding of said test relay a test current of such a magnitude and polarity as would move said armature away from said contact when the permanent magnet bias is properly adjusted by said sequence, and means automatically operative by said control circuit and adaptable to detect the movement of said armature away from said contact.

4. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and a contact and a permanent magnet and a magnetic armature and movable in operable relation to said contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic field of said magnet, said circuit comprising a source of electric power, a manually operable switch having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize said test relay magnet, a power control relay circuit including a pulsing relay and responsive to the operation of said switch into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coil from said source under the control of said pulsing relay, said current pulse being adaptable to over-magnetize said magnet, a power selector operative to deliver variable increments of power from said source to said coil under the control of said relay control circuit, means in said relay control circuit including said pulsing relay and a power selector control relay automatically responsive to the operation of said switch into its demagnetizing position to cause said power selector to apply a sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to said coil from said source under the control of said pulsing and selector control relays, said sequence of pulses being adaptable to demagnetize said magnet to successively increasing extents, means automatically operative by said control circuit during the aplication of each demagnetizing pulse of said sequence to said coil and adaptable to cause said armature to be placed into contact with said contact, means in said relay control circuit including a pair of relays and a current control automatically operative by said control circuit during the intervals before and after demagnetizing pulses of said sequence are applied to said coil and adaptable to apply to the winding of said test relay a test current of such a magnitude and polarity as would move said armature away from said contact when the permanent magnet bias is properly adjusted by said sequence, and means automatically operative by said control circuit and adaptable to detect the movement of said armature away from said contact.

5. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and a contact and a permanent magnet and a magnetic armature movable in operable relation to said contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic field of said magnet, said circuit comprising a source of electric power, a manually operable switch having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize said test relay magnet, a power control relay circuit including a pulsing relay and responsive to the operation of said switch into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coil from said source under the control of said pulsing relay, said current pulse being adaptable to over-magnetize said magnet, a power selector operable to deliver variable increments of power from said source to said coil under the control of said relay control circuit, relay means in said relay control circuit including said pulsing relay and a power selector control relay automatically responsive to the operation of said switch into its demagnetizing position to cause said power selector to apply a sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to said coil from said source under the control of said pulsing and selector control relays, said sequence of pulses being adaptable to demagnetize said magnet to successively increasing extents, means automatically controlled by said pulsing relay during the application of each demagnetizing pulse of said sequence to said coil and adaptable to cause said armature to be placed into contact with said contact, means in said relay control circuit including a pair of relays and a variable test current source automatically controlled by said pulsing relay during the intervals before and after demagnetizing pulses of said sequence are applied to said coil and adaptable to apply to the winding of said test relay a test current of such a magnitude and polarity as would move said armature away from said contact when the permanent magnet bias is properly adjusted by said sequence, means automatically operative by said control circuit and adaptable to detect the movement of said armature away from said contact, and means in said relay control circuit responsive to the operation of said detecting means to disable said pulsing relay whereby the demagnetizing procedure is stopped.

6. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and two separate contacts and a permanent magnet associated with each contact and a magnetic armature attracted magnetically in opposite directions towards each contact by respective magnets and movable away from each respective contact under the influence of the com-

bination of the magnetic field produced by the energization of said winding and the magnetic fields of said magnets, said circuit comprising a source of power, switch means having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize each of said test relay magnets, a power control circuit responsive to the operation of said switch means into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coils from said source, said current pulse being adaptable to over-magnetize said magnets, variable means operable to deliver variable increments of power from said source to said coils under the control of said control circuit, means operative at respective odd and even times by said control circuit and adaptable to detect respective movements of said armature away from said odd contact and into contact with said even contact and away from said even contact and into contact with said odd contact, means automatically responsive to the operation of said switch means into its demagnetizing position and under the control of respective even and odd operations of said detecting means to cause said control circuit to control said variable means to apply respective odd and even sequences of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to respective odd and even coils from said source, said sequence of pulses being adaptable to demagnetize respective odd and even magnets to successively increasing extents, means automatically operative by said control circuit during the application of each demagnetizing pulse of respective odd and even sequences to respective odd and even coils and adaptable to cause said armature to be placed into contact with respective odd and even contacts and said latter means automatically operative by said control circuit during the intervals before and after demagnetizing pulses of respective odd and even sequences are applied to respective odd and even coils and adaptable to apply to the winding of said test relay respective first and second test currents of such respective magnitudes and polarities as would move said armature respectively away from said odd contact and into contact with said even contact and away from said even contact and into contact with said odd contact when the permanent magnet bias of respective odd and even magnets is properly adjusted by respective odd and even sequences, and means responsive to immediate odd and even operations of said detecting means pursuant to respective immediately preceding even and odd operations of said detecting means to prevent any further demagnetizing sequences and adaptable to indicate completion of the adjustment of the permanent magnet bias of both magnets.

7. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and two separate contacts and a permanent magnet associated with each contact and a magnetic armature attracted magnetically in opposite directions towards each contact by respective magnets and movable away from each respective contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic fields of said magnets, said circuit comprising a source of power, switch means having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize each of said test relay magnets, a power control circuit responsive to the operation of said switch means into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coils from said source, said current pulse being adaptable to over-magnetize said magnets, variable means operable to deliver variable increments of power from said source to said coils under the control of said control circuit, means operative at respective odd and even times by said control circuit and adaptable to detect the respective movements of said armature away from said odd contact and into contact with said even contact and away from said even contact and into contact with said odd contact, means automatically responsive to the operation of said switch means into its demagnetizing position and under the control of respective even and odd operations of said detecting means to cause said control circuit to control said variable means to apply respective odd and even sequences of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to respective odd and even coils from said source, said sequences of pulses being adaptable to demagnetize respective odd and even magnets to successively increasing extents, means automatically operative by said control circuit during the application of each demagnetizing pulse of respective odd and even sequences to respective odd and even coils and adaptable to apply to the winding of said test relay respective first and second reset currents of such respective magnitudes and polarities as would attract said armature into contact with respective odd and even contacts, means automatically operative by said control circuit during the intervals before and after demagnetizing pulses of respective odd and even sequences are applied to respective odd and even coils and adaptable to apply to the winding of said test relay respective first and second test currents of such respective magnitudes and polarities as would move said armature respectively away from said odd contact and into contact with said even contact and away from said even contact and into contact with said odd contact when the permanent magnet bias of respective odd and even magnets is properly adjusted by respective odd and even sequences, and means responsive to immediate odd and even operations of said detecting means pursuant to respective immediately preceding even and odd operations of said detecting means to prevent any further demagnetizing sequences and adaptable to indicate completion of the adjustment of the permanent magnet bias of both magnets.

8. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and two separate contacts and a permanent magnet associated with each contact and a magnetic armature attracted magnetically in opposite directions towards each contact by respective magnets and movable away from each respective contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic fields of said magnets, said circuit comprising a source of power, switch means having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize each of said test relay magnets, a power control circuit responsive to the operation of said switch means into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coils from said source, said current pulse being adaptable to over-magnetize said magnets, variable means for each coil and operable to deliver variable increments of power from said source to the associated coil under the control of said control circuit, means automatically responsive to the operation of said switch means into its demagnetizing position to cause said control circuit to control a first variable means to apply a first sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to one of said coils from said source, said first sequence of pulses being adaptable to demagnetize the associated magnet to successively increasing extents, means automatically operative by said control circuit during the application of each demagnetizing pulse of said first sequence to said one coil and adaptable to apply to the winding of said test relay a first reset current of such a magnitude and polarity as would attract said armature into contact with the one contact, means automatically operative by said control

circuit during the intervals before and after demagnetizing pulses of said first sequence are applied to said one coil and adaptable to apply to the winding of said test relay a first test current of such a magnitude and polarity as would move said armature away from said one contact and into contact with the other contact when the permanent magnet bias of said one magnet is properly adjusted by said first sequence, means automatically operative at respective odd and even times by said control circuit and adaptable to detect respective movements of said armature away from said one contact and into contact with said other contact and away from said other contact and into contact with said one contact, means automatically responsive to an odd operation of said detecting means at the end of said first sequence to cause said control circuit to control the second variable means to apply a second sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to the other of said coils from said source, said second sequence of pulses being adaptable to demagnetize the other of said magnets to successively increasing extents, means automatically operative by said control circuit during the application of each demagnetizing pulse of said second sequence to said other coil and adaptable to apply to the winding of said test relay a second reset current of such a magnitude and polarity as would attract said armature into contact with the other contact, means automatically operative by said control circuit during the intervals before and after demagnetizing pulses of said second sequence are applied to said other coil and adaptable to apply to the winding of said test relay a second test current of such a magnitude and polarity as would move said armature away from said other contact and into contact with said one contact when the permanent magnet bias of said other magnet is properly adjusted by said second sequence, means effective in response to succeeding respective even and odd operations of said detecting means at the end of succeeding respective even and odd sequences to permit said control circuit to control said first and second variable means alternately to apply succeeding respective odd and even additional sequences of demagnetizing pulses of still increasing magnitude to respective coils from said source, said additional sequences of pulses being adaptable to successively further demagnetize said magnets, and means responsive to immediate odd and even operations of said detecting means pursuant to respective immediately preceding even and odd operations of said detecting means to prevent any further demagnetizing sequences and adaptable to indicate completion of the adjustment of the permanent magnet bias of both magnets.

9. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and two separate contacts comprising permanent magnets and a magnetic armature attracted magnetically in opposite directions towards each contact by respective magnets and movable away from each respective contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic fields of said magnets, said circuit comprising a source of power, a manually operable switch having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize each of said test relay magnets, a power control relay circuit responsive to the operation of said switch into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coils from said source, said current pulse being adaptable to over-magnetize said magnets, a power selector for each coil and operative to deliver variable increments of power from said source to the associated coil under the control of said relay control circuit, relay means in said relay control circuit automatically responsive to the operation of said switch into its demagnetizing position to cause a first power selector to apply a first sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to one of said coils from said source said first sequence of pulses being adaptable to demagnetize the associated magnets to successively increasing extents, relay means in said relay control circuit automatically operative during the application of each demagnetizing pulse of said first sequence to said one coil and adaptable to apply to the winding of said test relay a first reset current of such a magnitude and polarity as would attract said armature into contact with the one contact, relay means in said relay control circuit automatically operative during the intervals before and after demagnetizing pulses of said first sequence are applied to said one coil and adaptable to apply to the winding of said test relay a first test current of such a magnitude and polarity as would move said armature away from said one contact and into contact with the other contact when the permanent magnet bias of said one magnet is properly adjusted by said first sequence, relay means in said relay control circuit automatically operative at respective odd and even times and adaptable to detect respective movements of said armature away from said one contact and into contact with said other contact and away from said other contact and into contact with said one contact, relay means in said relay control circuit automatically responsive to an odd operation of said detecting means at the end of said first sequence to control the second power selector to apply a second sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to the other of said coils from said source, said second sequence of pulses being adaptable to demagnetize the other of said magnets to successively increasing extents, relay means in said relay control circuit automatically operative during the application of each demagnetizing pulse of said second sequence to said other coil and adaptable to apply to the winding of said test relay a second reset current of such a magnitude and polarity as would attract said armature into contact with the other contact, relay means in said relay control circuit automatically operative during the intervials before and after demagnetizing pulses of said second sequence are applied to said other coil and adaptable to apply to the winding of said test relay a second test current of such a magnitude and polarity as would move said armature away from said other contact and into contact with said one contact when the permanent magnet bias of said other magnet is properly adjusted by said second sequence, relay means in said relay control circuit effective in response to succeeding respective even and odd operations of said detecting means at the end of succeeding respective even and odd sequences to control said first and second power selectors alternately to apply succeeding respective odd and even additional sequences of demagnetizing pulses of still increasing magnitude to respective coils from said source, said additional sequences of pulses being adaptable to successively further demagnetize said magnets, and relay means in said relay control circuit responsive to immediate odd and even operations of said detecting means pursuant to respective immedately preceding even and odd operations of said detecting means to prevent any further demagnetizing sequences and adaptable to indicate completion of the adjustment of the permanent magnet bias of both magnets.

10. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and two separate contacts comprising permanent magnets and a magnetic armature attracted magnetically in opposite directions towards each contact by respective magnets and movable away from each respective contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic fields of said magnets, said

circuit comprising a source of power, a manually operable switch having a magnetizing and a demagnetizing position, a magnetizing-demagnetizing coil adaptable to magnetize or demagnetize each of said test relay magnets, a power control relay circuit including a relay controlled by said source to oscillate at a desired rate and including a power relay controlled by said oscillating relay, said relay control circuit responsive to the operation of said switch into its demagnetizing position to apply at least one pulse of current of a magnetizing polarity from said source to said coils under the control of said power relay said current pulse being adaptable to over-magnetize said magnets a power selector for each coil and operable under the control of said relay control circuit to deliver variable increments of power from said source to the associated coil through the agency of said power relay, a dual-condition steering relay in said relay control circuit automatically responsive to the operation of said switch into its demagnetizing position to assume one of its positions thereby to cause a first power selector to apply a first sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude to one of said coils from said source under the control of said power relay said first sequence of pulses being adaptable to demagnetize the associated magnet to successively increasing extents, a group of test current relays controlled by said relay control circuit to at times assume one of four different conditions of operated and released relays of said group, said group automatically operative by said control circuit into a first of its conditions during the application of each demagnetizing pulse of said first sequence to said one coil and adaptable to apply to the winding of said test relay a first reset current of such a magnitude and polarity as would attract said armature into contact with one of said contacts, said group automatically operative by said control circuit into a second of its conditions during the intervals before and after demagnetizing pulses of said sequence are applied to said one coil and adaptable to apply to the winding of said test relay a first test current of such a magnitude and polarity as would move said armature away from its one contact and into contact with the other contact when the permanent magnet bias of said one magnet is properly adjusted by said first sequence, a detecting relay in said relay control circuit automatically operative at respective odd and even times and adaptable to detect respective movements of said armature away from said one contact and into contact with said other contact and away from said other contact and into contact with said one contact, said dual-condition steering relay automatically responsive to an odd operation of said detecting means at the end of said first sequence to control the second power selector to apply a second sequence of pulses of current of a demagnetizing polarity and of successively increasing increments of magnitude from said source to the other of said coils through the agency of said power relay said second sequence of pulses being adaptable to demagnetize the other of said magnets to successively increasing extents, said group automatically operative by said control circuit into a third condition during the application of each demagnetizing pulse of said second sequence to said other coil and adaptable to apply to the winding of said test relay a second reset current of such a magnitude and polarity as would attract said armature into contact with the other contact, said group automatically operative by said control circuit into its fourth condition during the intervals before and after demagnetizing pulses of said second sequence are applied to said other coil and adaptable to apply to the winding of said test relay a second test current of such a magnitude and polarity as would move said armature away from said other contact and into contact with said one contact when the permanent magnet bias of said other magnet is properly adjusted by said second sequence, means including said relay control circuit and said steering relay and said group of relays effective in response to succeeding respective even and odd operations of said detecting means at the end of succeeding respective even and odd sequences to control said first and second power selectors alternately to apply succeeding respective odd and even additional sequences of demagnetizing pulses of still increasing magnitude from said source to respective coils through the agency of said power relay, said addition sequences of pulses being adaptable to successively further demagnetize said magnets, and relay means including said detecting relay means and responsive to immediate odd and even operations of said detecting means pursuant to respective immediately preceding even and odd operations of said detecting means to disable said oscillating relay thereby to prevent any further demagnetizing sequences and adaptable to indicate completion of the adjustment of the permanent magnet bias of both magnets.

11. A circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and a contact and a permanent magnet and a magnetic armature movable in operable relation to said contact under the influence of the combination of the magnetic field produced by energization of said winding and the magnetic field of said magnet, said circuit comprising a source of electric power, switch means having a demagnetizing position, a coil adaptable to magnetically influence said test relay magnet, a power control circuit, selector means operable to deliver increments of power from said source to said coil under the control of said control switch, means responsive to the operation of said switch means into its demagnetizing position to cause said control circuit to control said selector means to apply at least one pulse of current of a demagnetizing polarity to said coil from said source, means operative by said control circuit during the application of said demagnetizing pulse to said coil and adaptable to cause said armature to be placed into contact with said contact and operative by said control circuit after said demagnetizing pulse is applied to said coil for applying to the winding of said test relay a test current of such a magnitude and polarity as would move said armature away from said contact when the permanent magnet bias is properly adjusted, and means operative by said control circuit and adaptable to detect the movement of said armature away from said contact.

12. In a circuit for automatically adjusting the permanent magnet bias of a test relay including an energizing winding and a contact and a permanent magnet and a magnetic armature movable in operable relation to said contact under the influence of the combination of the magnetic field produced by the energization of said winding and the magnetic field of said magnet, said circuit comprising a source of electric power, switch means having a demagnetizing position, a coil adaptable to magnetically influence said test relay magnet, a power control circuit responsive to the operation of said switch means into its magnetizing position to apply at least one pulse of current of a magnetizing polarity to said coil from said source, said current pulse being adaptable to over-magnetize said magnet, variable means operable to deliver variable increments of power from said source to said coil under the control of said control circuit, means automatically responsive to the operation of said switch means into its demagnetizing position to cause said control circuit to control said variable means to apply a sequence of pulses of current of a demagnetizing polarity to said coil from said source, said sequence of pulses being adaptable to demagnetize said magnet, means automatically operative by said control circuit during the application of each demagnetizing pulse of said sequence to said coil and adaptable to cause said arma-

ture to be placed into contact with said contact and automatically operative by said control circuit during the intervals before and after demagnetizing pulses of said sequence are applied to said coil and adaptable to apply to the winding of said test relay a test current of such a magnitude and polarity as would move said armature away from said contact when the permanent magnet bias is properly adjusted by said sequence, and means automatically operative by said control circuit and adaptable to detect the movement of said armature away from said contact.

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