

June 26, 1951

S. BREEN ET AL
ELECTRICAL APPARATUS

2,558,670

Filed April 3, 1950

2 Sheets-Sheet 2

Fig. 3

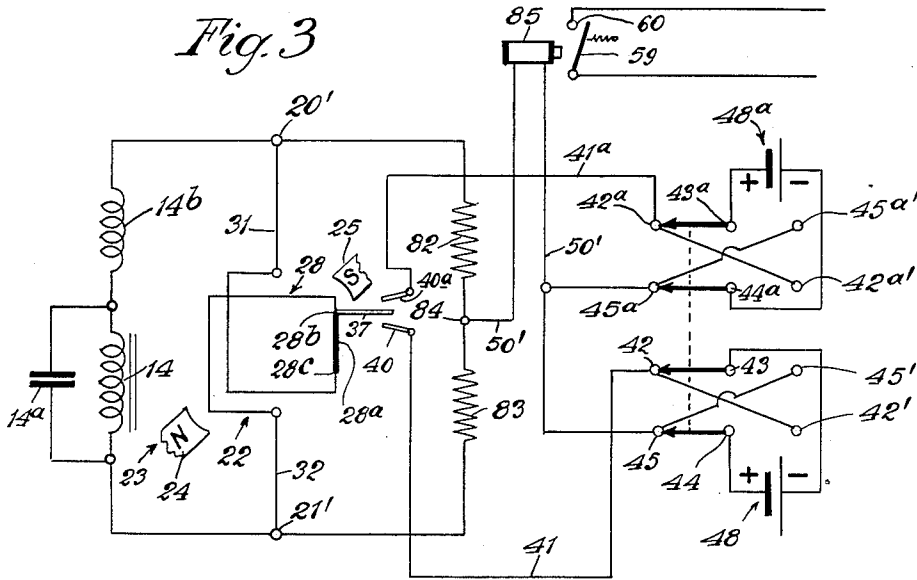
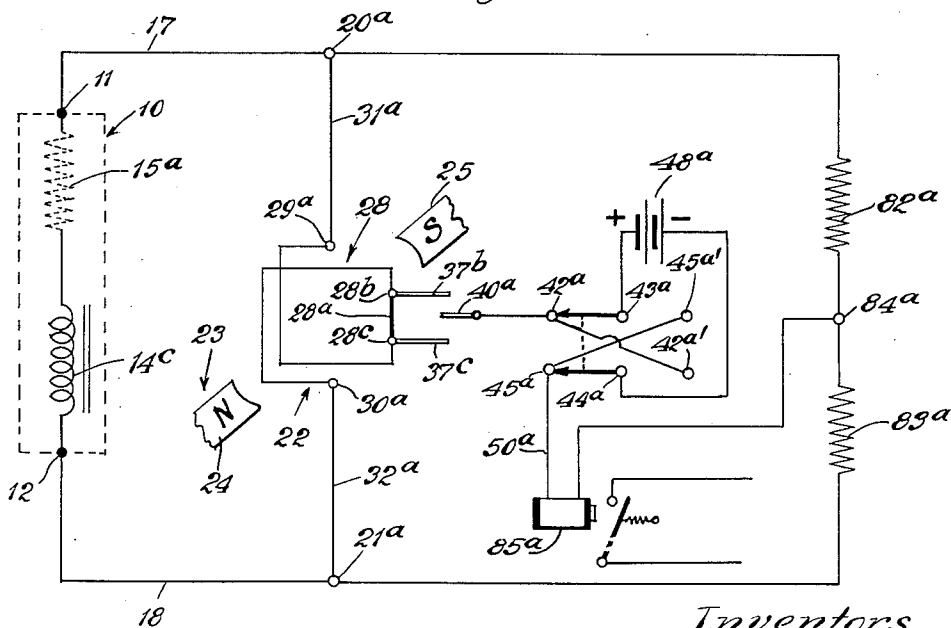


Fig. 4



Inventors
Stanley Breen
Maxwell A. Kerr
by Robert L. Kahn
Attorney

UNITED STATES PATENT OFFICE

2,558,670

ELECTRICAL APPARATUS

Stanley Breen, Geneva, and Maxwell A. Kerr,
Wheaton, Ill., assignors to Operadio Manufac-
turing Co., a corporation of Illinois

Application April 3, 1950, Serial No. 153,552

20 Claims. (Cl. 175—320)

1

2

This invention relates to an electrical apparatus and particularly to a sensitive relay. The sensitive relay to which this invention pertains is adapted to work with sources or generators having an extremely low potential direct current output.

Generators of the type having a search coil operating in the earth's field, as one example, provide a direct or slowly varying current of minute value at low potential. Such currents in extreme cases may be measured in microamperes with potentials in microvolts. In connection with such devices, it is desirable to provide a relay which will respond to the output of such a generator and close a second relay circuit for supplying current to a final load.

Vacuum tube amplifiers for such purpose are not satisfactory. One reason is that a conventional vacuum tube amplifier is inherently unsuitable for operation on slowly varying or direct currents. Even elaborate means to balance the amplifier and prevent drift still make the operation of such amplifiers erratic and unreliable. Secondly, is the fact that a vacuum tube amplifier requires a cathode circuit continuously energized. In certain types of apparatus, such as portable apparatus for field use or apparatus having long stand-by periods, the matter of a power supply for energizing a cathode circuit is a serious problem and renders a vacuum tube amplifier impractical.

This invention provides an electromagnetic relay having a part movable in response to a current for controlling the relay. While extremely sensitive moving coil galvanometers are known, the application of such devices for relay purposes is beset with difficulties. This is particularly true if the movable element is to carry a movable contact cooperating with a fixed contact forming part of a relay circuit. Since moving coil galvanometers are sensitive and have very weak forces normally generated therein, it follows that the movable element is unlikely to make good contact between the fixed and movable contacts.

The most sensitive type of galvanometer is the moving coil type having current leads and torsion suspension combined into one structure. The movable contact will naturally move with the coil and may have a separate lead therefor or use the moving coil leads. Having more than two leads for the movable part of the galvanometer renders the structure impractical and impairs the sensitivity. If two leads are used in a conventional manner, a serious drawback becomes apparent. When the relay circuit is estab-

lished, the IR drop across the galvanometer coil system, including suspension, becomes large in comparison to the E. M. F. normally developed by the original generator as a search coil. Hence the entire movable coil system becomes a source of E. M. F. which may exceed the safe value to be impressed across the original generator as a search coil with disastrous results to the latter.

This invention provides a construction utilizing a movable coil type of galvanometer whereby the movable element, when it reaches a predetermined position, is adapted to lock itself closed so that firm contact is established between the fixed and movable relay contacts. The invention further provides means whereby relay currents are prevented from flowing into the generator, thus removing the possibility of damage to the generator due to excessively large currents. This invention further provides means whereby the coil will unlock itself when desired and open the relay circuit in preparation for a new relay operating cycle. A galvanometer embodying the invention utilizes the full sensitivity of the instrument and, apart from the movable contact arm, does not have elements upon the movable coil which detract either electrically or mechanically from the sensitivity of the galvanometer.

The invention, in general, is characterized by a combination of a novel galvanometer structure and a novel circuit for the galvanometer. The galvanometer is of the moving coil type operating in a constant magnetic field. The movable coil is preferably, though not necessarily, suspended in a torsion type of mounting. The mounting also functions to lead currents to the movable coil. The movable coil carries at least one movable contact in the form of a thin wire extending therefrom. This contact is connected to the movable coil at any place desired between the end and center of the coil. Two movable contacts may be thus carried and be connected symmetrically on opposite sides of the center point of the movable coil. While the movable contact may be connected to the terminal of the movable coil, it is preferred to make the connection to an intermediate eccentric point on the coil proper. The amount of eccentricity of the contact tap on the coil will be determined by other considerations which will be apparent in connection with a detailed description of the invention.

The eccentricity of the contact tap on the movable coil is with reference to the electromagnetic properties of the coil. Thus the center of the movable coil will be that point which will divide the coil electromagnetically into equal and oppo-

site coil parts. While such a coil center is near the geometrical wire center, it is not necessarily coincident, due to departure from theoretically perfect winding. Hence the term coil center will be used here with reference to the electromagnetic effects and not the geometrical center or resistance center unless expressly stated.

An important feature of the invention resides in the provision for constructing a winding so that an eccentric tap for a movable contact may be substantially at the resistance center of the winding so that the direct current resistance of the parts of the complete winding on opposite sides of the tap are substantially equal. This may be true even though two movable contacts are provided. This effect is obtained by forming that part of the movable coil at the electrical or resistance center for equal distances on both sides of the center up to the movable contact tap or taps of wire having lower resistance than the remainder of the movable coil. In so disposing the low resistance section of the movable coil, it is assumed that the geometric center and ohmic resistance or electrical center of the coil are coincident. In practice, these two points are close enough so that satisfactory results are obtained.

By virtue of the above expedient, the galvanometer movable contact (or contacts, if two are used) is electromagnetically eccentric of the winding but electrically is substantially centered. Hence the galvanometer coil is substantially symmetrical for ohmic resistance as seen from the movable contact or contacts and coil terminals.

The relay circuit in which the galvanometer operates has a source of constant potential, such as a battery, and a three wire type of load. By virtue of the arrangement of the relay circuit source of potential and three wire load in the relay circuit and the inclusion in the circuit of suitable balancing means, it is possible to provide a substantially perfect electrical balance across the terminals of the galvanometer when the load relay circuit is closed. As previously pointed out, the movable coil may be balanced for IR drop. The torsion suspension leads, however, may vary from instrument to instrument so that resistance balancing means external to the galvanometer are preferable. When balance at the galvanometer terminals is obtained substantially no current from the load relay circuit will flow through the generator.

Where two fixed relay contacts are provided, it is possible to utilize a center zero type of instrument, thus rendering the instrument independent of polarity of the generator. Normally, the generator must be connected in such a manner that current of proper polarity actuates the galvanometer coil in the direction so that the relay contacts approach each other.

In order that the invention may be understood, it will now be explained in connection with the drawings wherein Figure 1 is a diagrammatic view showing one form of the invention and Figures 2 to 4 inclusive are diagrammatic views showing modified forms of the invention.

Referring first to Figure 1, generator 10 of any desired type is shown, this generator having terminals 11 and 12 and furnishing, at desired times or under predetermined conditions, a current whose intensity is normally measured in microamperes at a potential as low as several microvolts. Such a generator, for example, may consist of coil 14 of wire with or without a suitable ferromagnetic core and adapted to function as

an exploring coil. Such a generator will have an internal resistance represented by resistor 15. This generator, in addition, may also have inductance and capacitance, these two properties of the generator being unimportant for the purposes at hand.

Terminals 11 and 12 of the generator are connected by wires 17 and 13 to terminals 20 and 21 of a galvanometer generally indicated by numeral 22. Galvanometer 22 is preferably of the suspension type although the conventional spiral hair spring D'Arsonval type of galvanometer may be used. Inasmuch as both types of galvanometers are well known and highly developed, a detailed description of the galvanometer itself is not deemed to be necessary.

Galvanometer 22 has suitable permanent magnet system 23 having poles 24 and 25 respectively. In practice, the magnet would have suitable pole pieces of soft iron shaped in a particular manner to distribute the flux from the magnet over a predetermined angular extent, all well known in the art. Cooperating with the magnet is movable coil winding 28 which may consist of any desired number of turns on a suitable form. Coil 28 has terminals 29 and 30 attached to suspension wires 31 and 32, these wires being aligned and consisting of flexible, elastic good conducting material such as gold, tungsten, copper, bronze or any other material. Wires 31 and 32 may be tensioned by suitable means not shown, in a manner well known in the art with suitable adjusting means so that moving coil 28 normally has a predetermined zero position.

Between one of the galvanometer terminals and the suspension wire, in this case between terminal 21 and wire 32, there is provided electrical balancing means consisting of variable resistor 33 and variable inductor 34 shunted by variable resistor 35 and variable capacitor 36 for a purpose which will be apparent later. In some instances, it may be possible to eliminate either or both resistors or the inductor or combine the two in one unit. In the case of a D'Arsonval type of meter, the conventional spiral springs would replace the suspension wires.

Movable coil 28 carries movable relay contact 37. This contact may consist of a fine wire extending outwardly from the coil so that this wire moves over a predetermined path when coil 28 moves in response to a current passing through the same. Movable contact 37 is connected to point 23b on coil 28 somewhat off electromagnetic center 28a of the coil so that coil 28 is divided into two portions. In practice, coil 28 may consist of a number of turns of wire, as 25 turns for example. Between points 28a and 28b there may be part of a turn or a number of turns.

Coil 28 normally would be of fine copper wire such as #40 as an example. However, between points 28b and 28c on the winding, these points being symmetrical to center point 28a, it is preferred to use wire having substantially less resistance per unit length than is true of the winding as a whole. Thus if coil 28 is of #40 wire, then wire 28b—28c may be of #34 or #36 wire. If #34 wire is used, the resistance will be $\frac{1}{2}$ that of the #40 wire, the wire section doubling for each two steps in wire gauge. The low resistance part 28b—28c may be of silver to further reduce the resistance, although the gain is ordinarily not worth the expense.

The departure of point 28b from electrical center 28a of coil 28 depends in some measure upon the amount of relay current flowing in the

relay circuit when closed, the amount of current which the galvanometer winding can safely carry, the amount of force necessary for locking and unlocking the relay contacts and the convenience of locating a suitable spot on the winding to which a connection may be made.

Cooperating with movable relay contact 37 is fixed relay contact 40, connected by wire 41 to terminal 42 of double pole double throw reversing switch 39. This switch has terminals 43 and 44 going to suitable movable contacts. The movable contacts cooperate with fixed contacts 42 and 45 at one switch position and contacts 42' and 45' at the other position of the switch. Movable contact terminals 43 and 44 are connected to the terminals of a source of potential for the relay circuit, this being conveniently shown as battery 43, terminal 44 being connected to the positive terminal and terminal 43 being connected to the negative terminal, as an example. The polarity of the connections, as will be readily apparent, is unimportant and is given merely by way of illustration.

Terminal 45 of the switch is connected by wire 50 to intermediate terminal 51 of a three wire load. This load, as shown here, consists of windings 52 and 53 having common intermediate terminal 51 and outer terminals 54 and 55 respectively. Terminal 54 is connected by wire 56 to terminal 20 while terminal 55 is connected by wire 57 to terminal 21. Windings 52 and 53 are the windings of load relay 52, these windings being so arranged that when current from terminal 51 goes through windings 52 and 53 as shown, the magnetic fields created by the two windings will aid each other. Load relay 59 is a conventional relay and has contacts 59 and 60 of usual construction going to a utilization circuit of any type whatsoever, contacts 59 and 60 being adapted to handle comparatively heavy currents.

The resistances of windings 52 and 53 of relay 58 are preferably substantially greater than the resistance of winding 23. This has the effect of preventing excessive loading of generator 10.

The operation of the relay system is as follows: Assume that double pole double throw switch 39 is in the position shown and the galvanometer coil is at rest. Now assume that generator 10 becomes active and generates current with terminal 11 being positive and terminal 12 being negative. Current will flow from terminal 11 along wire 17 to terminal 20 through the moving coil portion of the galvanometer to terminal 21 and back along wire 18 to terminal 12 of the generator. Movable coil 28 of the galvanometer begins to respond to this current, it being understood that the polarity of the current is such that movable contact 37 approaches fixed contact 40. Assume that movable contact 37 reaches fixed contact 40. Even though contacts 37 and 40 do not close tightly nevertheless, some current from relay battery 43 will flow. A circuit for this current may be traced as follows: From the negative terminal of battery 43 to terminal 43, terminal 42, relay contact 40, relay contact 37, tap 28b of coil 28, terminal 20, wire 32, resistor 33 and inductor 34 to terminal 21, wire 57, through winding 53 of the load relay, center terminal 51, wire 50 to terminal 45 and then to the positive terminal of the battery. An additional circuit through which relay current will flow ex-

tends from the negative terminal of battery 43 through to movable contact 37 of the galvanometer, then tap 28b of coil 28 and up to terminal 20 of the galvanometer and then through winding 52 of the load relay and then back to the positive terminal of the relay circuit battery.

Whether this initial current is strong enough to operate load relay 58 is unimportant. The initial current from the relay battery passing along wire 56 is of the same polarity as current from generator 10 as far as its effect upon that part of the coil between 28b and 29 is concerned. The current going along wire 57 to terminal 30 and tap 28b opposes the generator current in the galvanometer coil. Thus the eccentricity of connection of movable contact 37 causes the currents from the load relay battery to have unequal and opposing effects upon the galvanometer coil. Thus as shown, current from wire 56 passes through more than one-half of coil 28 and since it aids the current from generator 10, it will be noted that coil 28 will tend to close contacts 37 and 40 tightly against each other. As soon as sufficient current passes through the two contacts in the galvanometer, load relay 58 will be operated to close its contacts 59 and 60.

It will be evident that the galvanometer contacts will remain in locked position now independently of the condition of generator 10. Now assume that it is desired to open the galvanometer contacts and restore the system to the position shown. To do this, it is necessary to operate double pole double throw switch 39 so that terminals 43 and 44 are connected to terminals 45' and 42' respectively. It will be observed that this reverses the polarity of battery 43 with respect to the coil of the galvanometer and load relay 58. As far as load relay 58 is concerned, the direction of current is unimportant but it is obvious that the direction of current flowing through coil 28 is important. Thus, if the net effect of currents flowing through galvanometer coil 28 is reversed, coil 28 will tend to move contact 37 away from fixed contact 40. Hence, sufficient force can be generated to open these contacts even though some sticking may occur. Thereafter, the reversing switch may be returned to its original condition and the galvanometer is ready to operate anew.

It will be observed that any difference in potential between terminals 20 and 21 will result in current flow through generator 10. It is desirable to limit such potential differences as may exist to the order of that developed across the generator by virtue of generator operation. During steady state conditions, existing while contacts 37 and 40 are open or closed, a high degree of balance across terminals 20 and 21 may be readily attained. This is true even if part 28b-28c of the coil is not of lower resistance than the remainder of the coil. Thus any difference in resistance between tap 28b and terminal 20 on the one hand and tap 28b and terminal 21 on the other hand, solely through the winding and suspension, can be compensated for by resistor 33. Hence, after steady state conditions have been reached with the galvanometer contacts closed, the potential difference across 20 and 21 may be made zero or small enough so that generator 10 will not be damaged.

It is clear that transients will be generated in the galvanometer system when the galvanometer contacts open or close. An important cause of the transients is believed to reside in the mutual

inductance between the parts of the movable coil considered with reference to a tap whose contact is just closing or opening. Thus if contact 37 is just closing against fixed contact 40, the entire movable coil may be considered as consisting of one part from terminal 29 to tap 28b and the other part from tap 28b to terminal 30. Obviously, the two parts of the entire coil are electromagnetically coupled and have mutual inductance. Upon initial closure of the contacts, the mutual inductance has some effect upon the coil tending to move the contacts together more closely. At the same time, the transient or transients generated in the coil result in a potential difference at the galvanometer terminals apart from the resistance drop in the coil. This transient may cause a surge in generator coil 14. By choosing proper values for resistor 35, capacitor 36 as well as inductor 34, a low pass filter may be provided to suppress transients. A condenser across the generator winding may also help.

When the reversing switch is opened, the mutual inductance effects have some tendency to generate forces to move the coil in a direction to open the contacts. While this may be relied upon in some instances, it is preferred to move the switch to the reversing position. The combination of transient effects and positive actuation of the movable coil suffice to move the coil quickly into contact opening position.

The transient effects resulting from opening the reversing switch are generally more powerful than from contact closure. Thus after contact closure, opening of the reversing switch will cause the current to decay at a sharper rate than is true of the current increase at contact closure. However, the rates of current rise and decay may be assumed to be of the same order so that a low pass filter will generally be effective against all transients.

It is clear from the foregoing, that the polarity of generator 15 is important when connecting the generator to the galvanometer system. For certain purposes, it may be desirable to have a system wherein the polarity of the generator is not important. This is shown in Figure 2 wherein similar parts carry similar numbers. In this modification, movable contact 37 is connected as before to tap 28b of coil 28. A low resistance conductor is between points 28b and 28c. In the system shown in Figure 2, the suspension system for movable coil 28 is adjusted so that the normal zero position of the winding is the same as in a zero center type of instrument. In such an instrument, current in one direction will cause the coil to move one way while current in reverse direction will cause the coil to move the other way.

Cooperating with movable contact 37 are fixed contacts 40 and 40a on opposite sides, these two contacts being arranged so that the movable contact can close against one or the other, depending upon the direction of coil movement. Fixed contact 40 is connected to contact 42 of double pole double throw reversing switch 39 exactly as in Figure 1. Fixed contact 40a is connected by wire 41a to the corresponding contact 42a of double pole double throw reversing switch 39a. The two reversing switches are the same and are connected in the same manner, the corresponding part carrying the letter a with the exception that battery 43a has its positive terminal connected to contact 43a whereas in the lower reversing switch, contact 43 is connected to the negative terminal of this reversing switch.

As clearly indicated, the two reversing switches are tied to be simultaneously operated.

The operation of the modified system is as follows: If the polarity of terminal 11 of the generator is positive as in Figure 1, then the action of the system is exactly the same as in Figure 1, coil 28 moving clockwise as seen in Figure 2 to close a circuit with contact 40. If, however, the polarity of generator 15 is reversed, coil 28 will move anti-clockwise and contact 37 will approach contact 40a. When contacts 37 and 40a touch, current from battery 43a will act in the same manner as from battery 43 in Figure 1, the polarity of 43a being such that coil 28 is driven to close contact 37 against contact 40a more tightly.

The operation of the system as far as the load or secondary relay is concerned, is the same as in Figure 1 and needs no explanation. In order to unlock the contacts with the system shown in Figure 2, it will be necessary to throw the two reversing switches from the position during relay operation, such as shown in Figure 2, for example, to the reverse position.

Referring now to Figure 3, a further modification is shown. The galvanometer is generally the same as in Figure 2, having one movable contact operating between fixed contacts. However, terminals 20' and 21' of the galvanometer are connected directly to the coil suspension and do not have any resistors, capacitors or inductors as in lead 32 of Figure 1. Instead, generator coil 14 has condenser 14a across it and is in series with inductor 14b across galvanometer terminals 20' and 21'. Terminals 20' and 21' are connected to resistors 82 and 83 having common junction 84. Wire 56' is connected through conventional relay 85 to junction 84. The galvanometer load here is still of the three wire type, consisting of resistors 82 and 83 and relay 85. Resistors 82 and 83 are not necessarily equal and may be proportioned relatively the same as the resistances from tap 28b to terminals 20' and 21'.

This system may be considered as a bridge with galvanometer parts 28b—20' as one arm, 28b—21' as a second arm, resistor 82 as a third arm and resistor 83 as a fourth arm. The diagonal across 20' and 21' is formed by the generator and inductor in series. A difference in potential is impressed across the second diagonal from movable contact 37 and junction 84 when the galvanometer contacts are closed. For perfect operation, the bridge arms should be so related that the bridge is substantially balanced across 20' and 21'. As has been previously pointed out, this balance may be substantially achieved for steady state conditions by choosing proper values for resistors 82 and 83. By proper design of the first diagonal containing the generator and inductor, a low pass filter effect is provided.

It will be noted that the system illustrated in Figure 3 resembles the system of Figure 2 in requiring two sets of batteries in the galvanometer relay circuit. This may be undesirable. Referring now to Figure 4, a modification is shown wherein only one battery is necessary.

This system has generator 14c connected in series with resistor 15a (which resistor may be the resistance of 14a) across galvanometer terminals 20a and 21a. These terminals are connected directly to suspension elements 31a and 32a going to terminals 29a and 30a of coil 28. Coil 28 is the same as in Figure 1 except that it carries two movable contacts 37b and 37c at points 28b and 28c respectively. The part of the

coil between these contact taps preferably has a lower resistance than the remainder of the coil. Contacts 37b and 37c cooperate with stationary contact 43a. Contact 43a is connected to contact 42a of a double pole double throw switch having contacts 42a, 42a', 45a, 45a'. movable contacts 43a and 44a. This switch is connected as in Figure 1 so that battery 48a may have its polarity reversed. From contact 45a, wire 50a goes to relay 85a, the other terminal of this relay going to junction 84a of resistors 82a and 83a. Resistors 82a and 83a are connected to galvanometer terminals 20a and 21a.

It is clear that the galvanometer is the center zero type. Coil 28 will move irrespective of the polarity of the generator. Normally the one fixed contact 43a will be between the two movable contacts. Whichever way the coil will move, contact closure will result in locking action. By simply opening the double pole double throw switch, contact opening may result due to the action of the mutual inductance of the coil parts, as previously described. However, throwing the switch to the other position to reverse the battery will be found generally preferable and more reliable.

In general, where extreme sensitivity is desired, the galvanometer contacts must be fine and threaded to remain clean. A rugged but sensitive galvanometer construction is possible, utilizing various constructional details well known in the art. Under certain conditions, the entire galvanometer may be immersed in a liquid, as kerosene, so that the contacts will remain clean for long periods of time.

The load must be of the three wire type and the various circuit branches of the load preferably should have the same symmetry when coupled to the galvanometer system and generator as would be required by an electrical bridge. Where a galvanometer coil carries two movable contacts, as in Figure 4, the two contacts may be considered as one for bridge analysis. Thus one arm of the bridge may consist of one coil suspension and the coil part going to the nearest movable contact 37c. The other arm may consist of the other coil part going to the other movable contact, 37b. The part of the coil between contacts 37b and 37c may be considered as a connection having negligible effects on the bridge. Actually, precise analysis would demand that whichever movable contact is closed against the fixed contact, is the bridge point, the temporarily idle movable contact being disregarded.

What is claimed is:

1. A sensitive relay comprising a movable coil type of galvanometer, the movable coil consisting of a winding of wire having end terminals, a contact movable with said coil and connected to a point on said coil electromagnetically off-center, a fixed contact cooperating with said movable contact and touched by said movable contact when said coil has responded a predetermined amount to energization, a three wire load having an intermediate and end terminals, a connection from one terminal of the movable coil to one end terminal of the load, a connection from the other terminal of the movable coil to the other end terminal of the load, a connection including at least one source of potential between the fixed contact and intermediate terminal of the load, a source of minute substantially direct current connected to said coil terminals, said sources of potential and current being properly poled whereby when said movable coil responds

to current and closes the movable contact against the fixed contact, a relay circuit is closed with currents flowing between the movable contact and terminals of the movable coil in opposite directions generating a net electromagnetic coil effect due to the eccentricity of the connection of the movable contact to the movable coil tending to move the coil into tighter contact closing position.

2. The system according to claim 1 wherein only one source of potential is provided, this source being disposed in the circuit branch having the intermediate terminal of the load.

3. The system according to claim 1 wherein only one source of potential is provided in the circuit branch having the intermediate terminal of the load and wherein switching means are provided for reversing the polarity of this source of direct potential, said reversal serving to generate a force in the coil for opening the contacts.

4. The system according to claim 1 wherein one of said coil connections includes impedance balancing means whereby upon closure of the load circuit, no difference of potential due to the source of potential will be present at the terminals of the minute current source when connected thereto.

5. The system according to claim 1 in combination with a source of minute potential.

6. The system according to claim 1 wherein said galvanometer coil has a section symmetrically disposed with respect to the electrical coil center and extending to the movable contact tap, said section having substantially less resistivity than the remainder of the coil.

7. A sensitive relay system comprising a galvanometer of the movable coil type, said galvanometer having a movable coil with terminals, a contact movable with said coil and connected to a point on said coil electromagnetically off-center, said galvanometer being of the zero center type, a pair of fixed contacts, said contacts being on opposite sides of the movable contact and spaced so that said movable contact must move from a zero position in either direction for a predetermined amount of travel to encounter one or the other of said fixed contacts, a three wire load having outer terminals and an intermediate terminal, a source of potential connected between the load intermediate terminal and one fixed contact, a second source of potential connected between the load intermediate terminal and the other fixed contact, the polarity of the fixed contacts being opposite to each other, and connections between the outer terminals of the load and the terminals of the movable coil, said movable coil terminals functioning as terminals for connecting an energizing source of minute current to said system to move said coil from its center zero position in one direction or the other depending upon the polarity of the minute current source, said movable contact when touching a fixed contact completing a load circuit which tends to lock the contacts, the polarity of the potential sources being such that when the movable contact touches a fixed contact, the load current through the movable coil generates a resultant force to lock the contacts together.

8. The system according to claim 7 wherein reversing means are provided for both sources of potential to reverse the polarities whereby unlocking of the contacts is provided.

9. The system according to claim 7 wherein impedance balancing means are connected in the movable coil circuit so that no relay poten-

tial appears across the minute current source when connected.

10. The system according to claim 7 wherein the branch of the system containing the minute current source includes low pass filter means for suppressing transient effects.

11. The system according to claim 7 wherein said galvanometer coil has a section symmetrically disposed with respect to the electrical coil center and extending to the movable contact tap, said section having substantially less resistivity than the remainder of the coil.

12. A sensitive relay system comprising a galvanometer of the movable coil type, said galvanometer having a movable coil with terminals, a pair of contacts movable with said coil and connected to points on said coil electromagnetically off center but generally symmetrically with respect to the electrical center of the coil, said galvanometer being of the zero center type, a fixed contact, said movable contacts being on opposite sides of the fixed contact and spaced so that said movable contacts must move from a zero position in either direction for a predetermined amount of travel to encounter the fixed contact, a three wire load having outer terminals and an intermediate terminal, a source of potential connected between the load intermediate terminal and said fixed contact, connections between the outer terminals of the load and the terminals of the movable coil, said movable coil terminals functioning as terminals for connecting an energizing source of minute current to said system to move said coil from its center zero position in one direction or the other depending upon the polarity of the minute current source, one of said movable contacts, when touching the fixed contact, completing the load circuit, the polarity of the potential source being such that when the load circuit is completed, current through the movable coil generates a resultant force to lock the contacts together.

13. The system according to claim 12 wherein switch means are provided for reversing the polarity of the potential source so that after contact has been established, reversal of the potential source will result in a force being generated in the coil tending to unlock the contacts and move the coil away from contact making position.

14. The system according to claim 12 wherein said load consists of a pair of resistors connected in series across the movable coil and wherein the junction of the resistors is connected to the fixed contact through a load relay.

15. A sensitive relay galvanometer for use with a three wire type of load, said galvanometer being of the movable coil type, said coil having end terminals, at least one contact carried by said coil and movable therewith, a connection between said contact and a point on said coil electromagnetically off-center from said coil, at least one fixed contact cooperating with said movable contact, said galvanometer having its coil terminals for connection to a source of current for moving said coil toward a contact-making position, said galvanometer also having its coil terminals and fixed contact for connection to the end and intermediate terminals respectively of a three wire type load with a source of potential included in the intermediate branch of the load, with the potential source of polarity

being so selected that upon contact closure due to galvanometer coil movement, a force is generated in the galvanometer coil tending to increase the force closing the contacts.

16. The galvanometer according to claim 15 wherein the galvanometer coil has a section symmetrically disposed with respect to the electrical coil center and extending to the movable contact tap, said section having substantially less resistivity than the remainder of the coil.

17. The galvanometer according to claim 15 wherein said galvanometer coil carries two movable contacts, said two contacts being connected to two points on said coil symmetrically disposed with respect to the coil center, said galvanometer being of the zero center type with one fixed contact.

18. The galvanometer according to claim 17, wherein said galvanometer coil has a section symmetrically disposed with respect to the electrical coil center and extending to the points of connection of the movable contacts, said section having substantially less resistivity than the remainder of the coil.

19. A galvanometer system comprising a movable coil type of galvanometer having a movable coil with end terminals, a pair of movable contacts carried by said coil, connections between said contacts and points on said coil symmetrically disposed with respect to the electrical center of the coil, a fixed contact cooperating with said two movable contacts, said galvanometer being of the zero center type, said galvanometer including conducting suspensions for said movable coil, a pair of resistors connected in series with the outer terminals connected to the suspension means so that the two resistors are connected across the coil and suspension means, a branch circuit between the fixed contact and common resistor terminal, said branch circuit including a source of potential and a load relay, said resistors having substantially the same ratio of resistance as one suspension means and the corresponding part of the coil up to the electrical center has to the remaining suspension means and coil part, a source of current connected to the coil terminals through the suspension means for actuating the movable coil toward a contact closing position, the polarity of the potential source being such that when contact is established, current from said potential source passes through the galvanometer winding to generate additional contact closing force.

20. The galvanometer system according to claim 19, wherein said galvanometer coil has a section symmetrically disposed with respect to the electrical coil center and extending to the movable contact taps, said section having substantially less resistivity than the remainder of the coil.

STANLEY BREEN.
MAXWELL A. KERR.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,346,589	Lamb	Apr. 11, 1944
2,357,524	Klepp	Sept. 5, 1944
2,376,808	Ratz	May 22, 1945