Nov. 26, 1935. F. F. UEHLING 2,022,097

RECORDING GALVANOMETER

Filed July 11, 1934 2 Sheets-Sheet 1

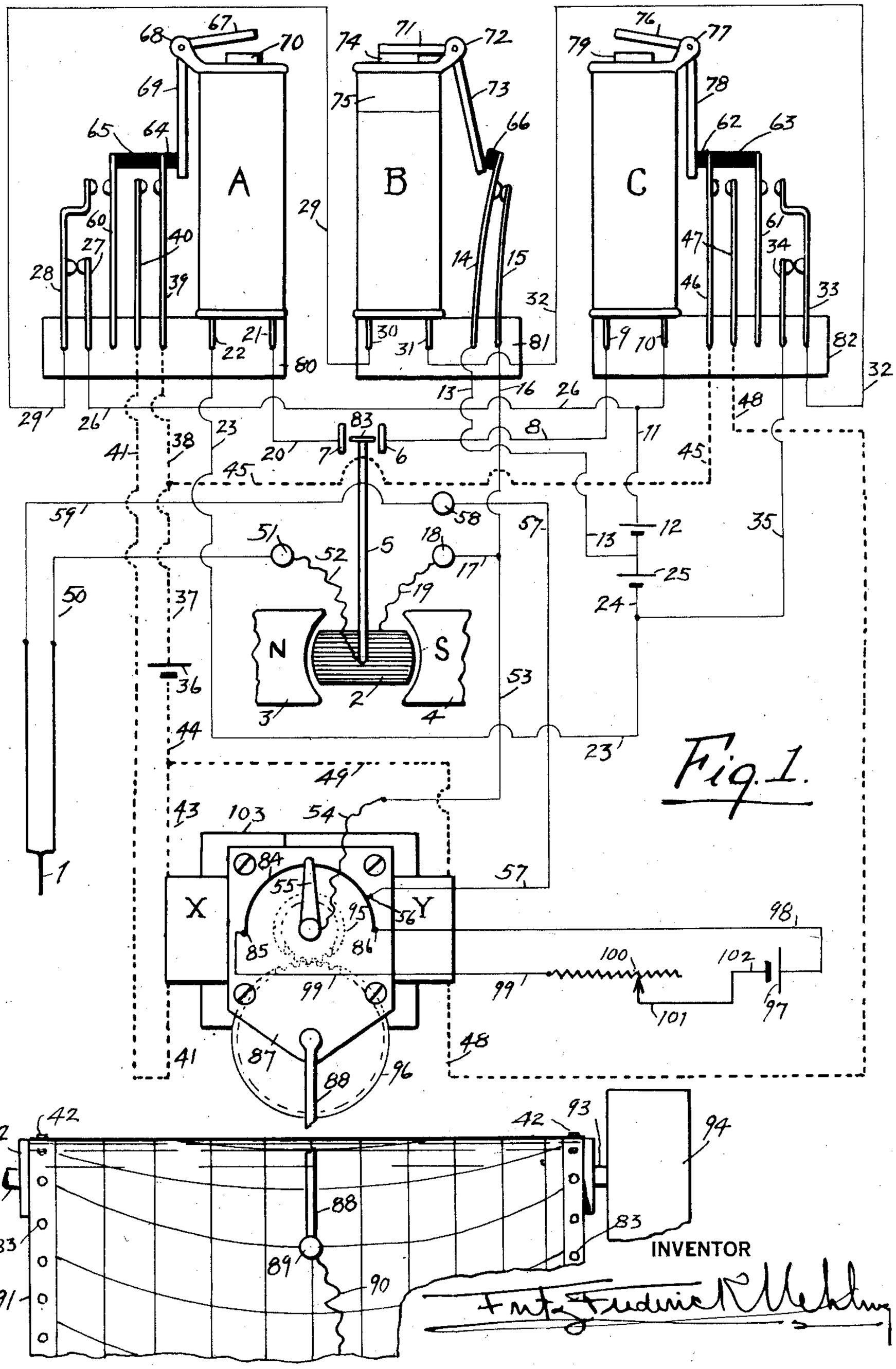

Fig. 1.

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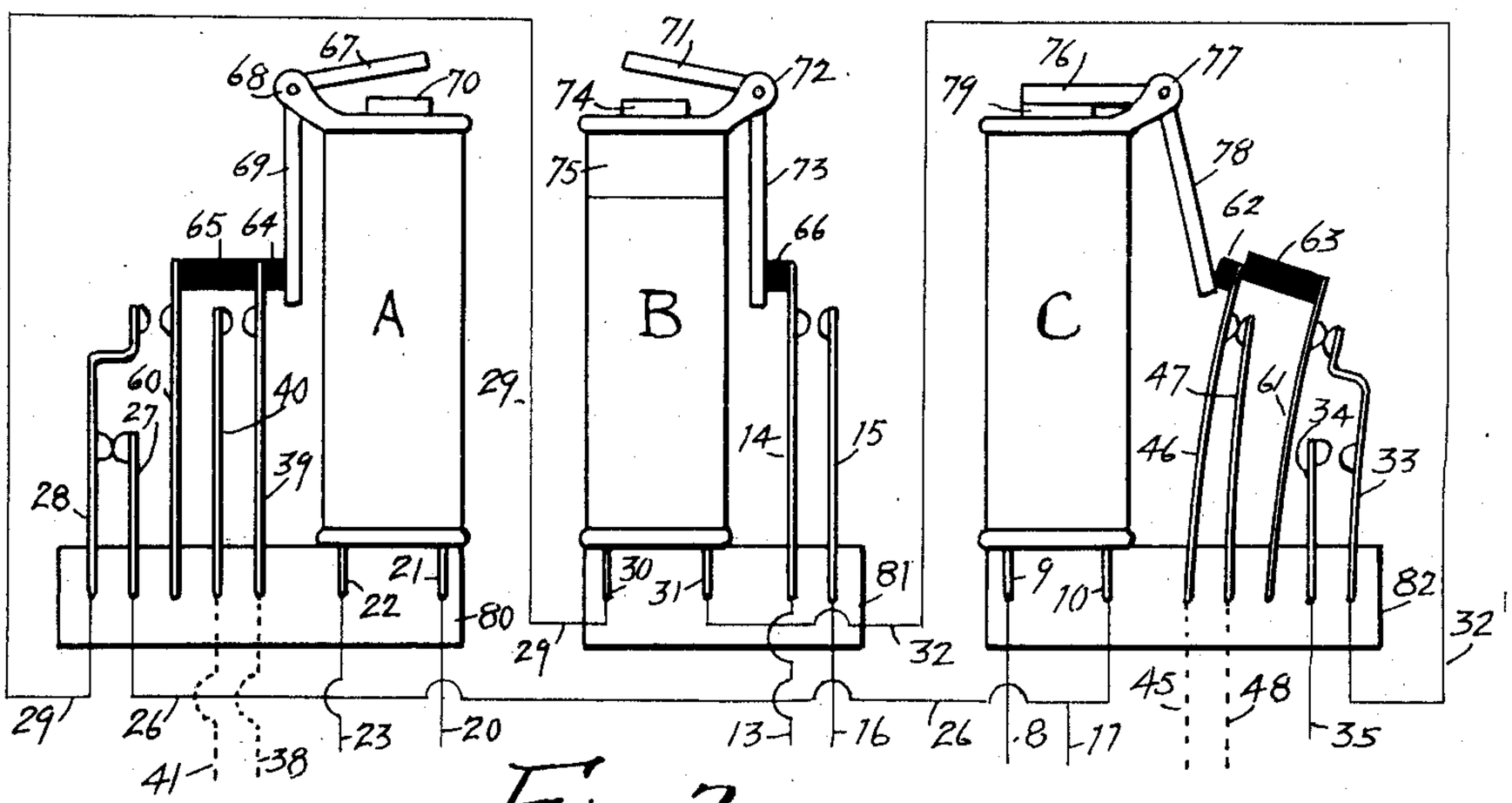

Fig. 2.

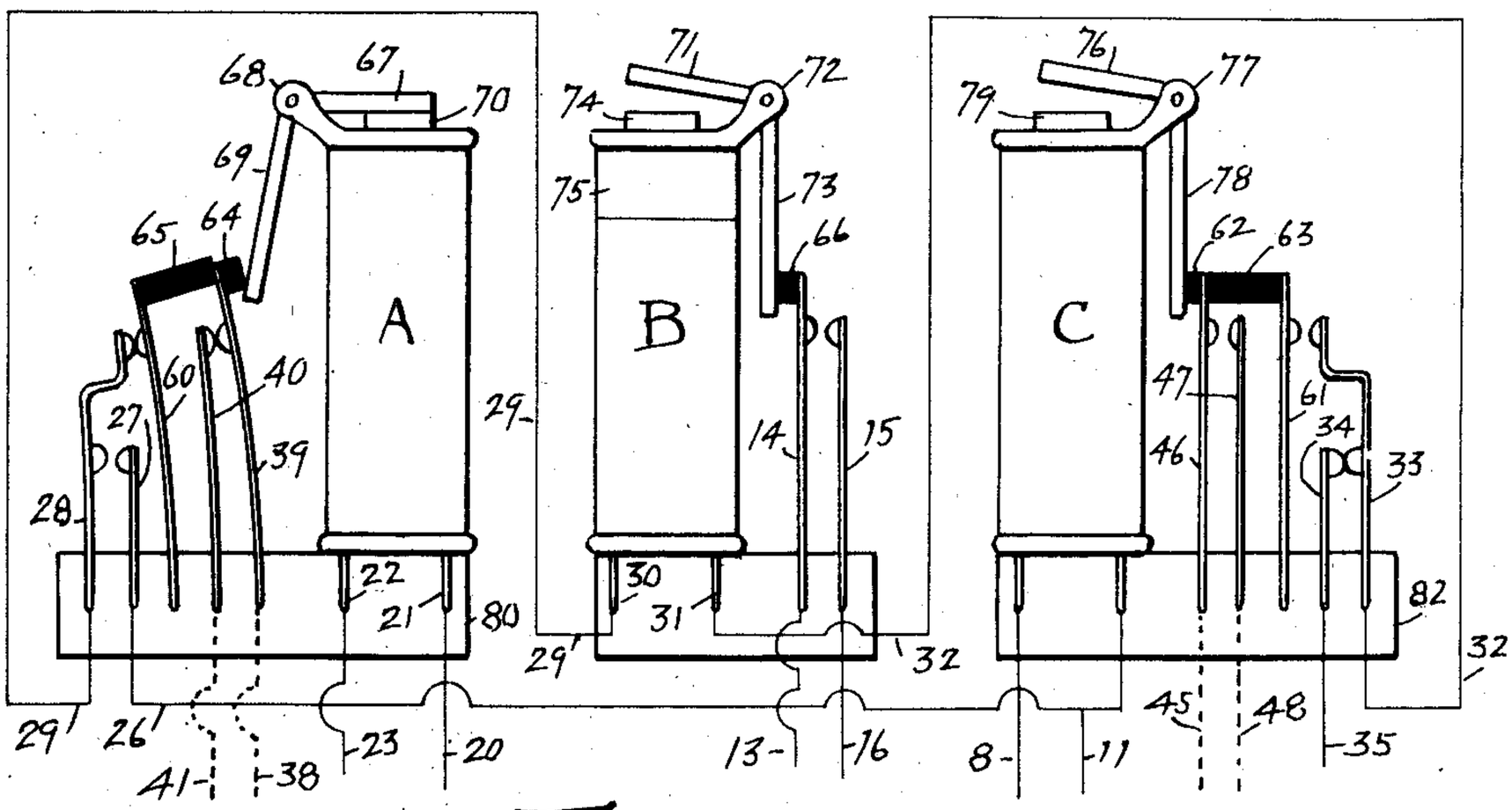

Fig. 3.

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UNITED STATES PATENT OFFICE

2,022,097

RECORDING GALVANOMETER

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Application July 11, 1934, Serial No. 734,645

25 Claims. (Cl. 172—239)

This invention relates to improvements in recording galvanometers of the super-sensitivity type which utilizes the electro-motive force of a thermo-couple or any delicate source of electrical energy as the actuating means. More particularly the invention relates to a novel method of utilizing the indicating needle of the galvanometer for closing a novel combination of circuits through specially designed relays for actuating a potentiometer to balance such electro-motive forces, said actuating means simultaneously operating the recording mechanism.

Figure 1 illustrates diagrammatically all of the essential elements of the invention and their inter-electrical connections; Figure 2 illustrates the relays with their armatures and electric contact points in one of their relative positions; and Figure 3 illustrates the same relays with their armatures and electric contact points in another of their relative positions. Similar numerals refer to similar parts throughout all of the illustrations.

The galvanometer, Figure 1, consists of a usual coil **2**, with an indicating needle **5**, pivoted or suspended between the north and south poles, **3** and **4** respectively, of a permanent magnet. The needle is utilized to close a novel combination of circuits which include the galvanometer, and is therefore electrically connected with one end of the galvanometer coil. A potentiometer which consists of a usual resistance wire **84** and a brush **55**, and which is actuated in a manner to be presently described, may be utilized, for example, to balance the electro-motive force of a thermo-couple **1** through said galvanometer. When the drop across the potentiometer balances the electro-motive force from the couple, the indicating needle **5** will be in its normal position as illustrated. The end of the indicating needle **5** is provided with a contact piece **83** which makes electrical contact with a contact piece **6** or a contact piece **7** depending upon whether the galvanometer is out of balance in one direction or the other. The electric circuit which includes the thermo-couple **1**, the coil **2** of the galvanometer and the potentiometer, starts at the couple, thence through the connecting wire **50**, to a binding post **51**, from binding post **51** through the usual flexible connection **52** to the galvanometer coil **2**, from the galvanometer coil through the flexible connection **19** to the binding post **18**, from the binding post **18** through wires **17**, **53** and **54** to the brush **55**, from the brush **55** through that part of the potentiometer wire **84** between the brush **55** and the point **56**, and thence through wires **57** and **59** back to the couple.

The current through the resistance wire **84** of the potentiometer is furnished by a battery **97** from where it flows through wire **98** to one end of potentiometer resistance wire, thence through the resistance wire, and from the other end of the resistance wire through wire **99**, an adjustable rheostat **100**, and wire **102** back to the battery. The brush **55** of the potentiometer is fastened to a shaft which is in geared connection with the driving shaft of a motor **103** to turn the brush in a clockwise or counter-clockwise direction depending upon whether the coil X of the motor or the coil Y of the motor is energized. The driving shaft of the motor is in geared connection with a pen arm **88** through spur wheels **95** and **96** as illustrated. A pen **89** attached to the pen arm rests against a calibrated chart **91** driven by a clock movement **94**. It thus follows that as the drop across the potentiometer is changed in one direction or the other to balance the electro-motive force of the couple, a record of such changes will be produced on the chart.

The circuit which includes the motor coil X which actuates the pen and potentiometer in one direction, starts at the battery **36** thence through wires **37** and **38** to a switch consisting of contact springs **39** and **40**, from the switch through wire **41** to the coil X and thence through wires **43** and **44** back to the battery. The switch consisting of the contact springs **39** and **40** is operated by means of an electro-magnet A which magnet also operates another switch consisting of contact springs **28** and **27**. These two switches, **39—40** and **27—28**, are kept in their normal positions, as illustrated in Figure 1, by the contact springs **28**, **60** and **39** against the combined tension of which an arm **69** is forced by the magnet A through the insulation pieces **64** and **65** when the magnet is energized. The arm **69** is an integral part of an armature **67** which is pivoted at **68** so that when the armature reacts with the magnet, the springs will be forced to the left thus closing the switch **39—40** and opening the switch **27—28** as illustrated in Figure 3. The purpose of the switch **27—28** and the manner in which the electro-magnet A is energized will be presently described.

Similarly the circuit which includes the motor coil Y which actuates the pen and the potentiometer in the opposite direction, starts at the battery **36** thence through wires **37** and **45** to a switch consisting of contact springs **46** and **47**, from the switch through wire **48** to the coil Y

and thence through wires 49 and 44 back to the battery. The switch consisting of contact springs 46 and 47 is operated by means of an electro-magnet C which magnet also operates another switch consisting of contact springs 33 and 34. These two switches, 46—47 and 33—34, are kept in their normal positions, as illustrated in Figure 1, by the contact springs 33, 61 and 46, against the combined tension of which an arm 78 is forced by the magnet C through the insulation pieces 62 and 63 when the magnet is energized. The arm 78 is an integral part of an armature 76 which is pivoted at 77 so that when the armature reacts with the magnet, the springs will be forced to the right thus closing the switch 46—47 and opening the switch 33—34 as illustrated by Figure 2. The purpose of the switch 33—34 and the manner in which the electro-magnet C is energized will be presently described.

A switch consisting of contact springs 14 and 15 is operated by an electro-magnet B. An armature 71, which is pivoted at 72, has an extension arm 73 which arm forces the contact spring 14 against the contact spring 15 through an insulation piece 66 when the armature reacts with the magnet, thus closing the switch 14—15 when the magnet B is energized, Figure 1. Conversely, when the magnet B is deenergized, the contact spring 14 acts to open the switch and to return the armature 71 to the position illustrated in Figures 2 and 3. The switch 14—15 which is thus operated by energizing and deenergizing the electro-magnet B, is included in both the circuit which includes the electro-magnet C, and the circuit which includes the electro-magnet A, while the circuit through the electro-magnet B includes the switch 27—28 and switch 33—34 in series. The circuit which includes the electro-magnet B and the two switches 27—28 and 33—34 is energized by the two batteries 12 and 25 in series. This circuit starts at battery 12 thence through wires 11 and 26 to the switch 27—28, from the switch through wire 29 to the electro-magnet B, from the electro-magnet B through wire 32 to the switch 33—34, and from the switch through wires 35 and 24 to the battery 25 and thence back to the battery 12. The purpose of this circuit, which includes the electro-magnet B, is to keep the electro-magnet B energized so long as both the electro-magnets A and C are deenergized, Figure 1, thus keeping the switch 14—15 closed. The switch 14—15, as already stated, is included in both the magnet A circuit and the magnet C circuit. It therefore follows that when the magnet A or C is energized, it will be immediately deenergized by the opening of switch 14—15, the opening of which switch is effected by the opening of switch 27—28 or the opening of switch 33—34 which last two mentioned switches, as already stated, are in series with the magnet B. The purpose of this consecutive action will be presently referred to in further detail.

The circuit which includes the electro-magnet A starts at battery 25, thence through wires 24 and 23 to the electro-magnet A, from the magnet A through the wire 20 to the contact piece 7, and when the needle is deflected counter-clockwise against the contact piece 7, the circuit continues through the needle 5, the galvanometer coil 2 and the flexible connection 19 to a binding post 18, from the binding post 18 through the wires 17 and 16 to the switch 14—15, and from the switch through wire 13 back to the battery 25. The closing of this circuit through the needle 5 and the contact piece 7, when the needle is deflected in a counter-clockwise direction, will in the manner which I am about to describe, energize the electro-magnet A, thus forcing the armature 67 into the position illustrated by Figure 3, in which position the switch 39—40 will be closed, and the switch 27—28 simultaneously opened. When the needle is thus deflected against the contact piece 7, it will close the circuit, (already traced) which includes the battery 25, the galvanometer and the electro-magnet A. Obviously, the delicate force of a galvanometer needle, when only slightly deflected, is so small that the contact resistance between the needle and the contact piece 7 will be too great to permit sufficient current to flow from the battery to actuate the electro-magnet. The battery 25 is however of such polarity that whatever current does flow through the circuit will tend to deflect the needle in a counter-clockwise direction against the contact piece 7. Thus the slightest contact between the needle and the contact piece 7 will cause some current to flow through the pivoted coil 2 to force the needle tighter against the contact piece 7. The greater the pressure of the needle against the contact piece 7, the greater will be the flow through the coil 2 thus continuously increasing the pressure between the needle and the contact piece 7 until sufficient current flows through the circuit to actuate the armature 67. The closing of the switch 39—40, thus effected, will energize the motor, in the manner previously stated, to actuate the brush 55 in a counter-clockwise direction thus increasing the drop across the potentiometer to bring the galvanometer needle back to its normal position as illustrated. Simultaneously, however, the switch 27—28 is opened by the armature 67 which in the manner already stated deenergizes the electro-magnet B which changes the switch 14—15 to the position illustrated in Figures 2 and 3 thereby opening the circuit which includes the battery 25, the galvanometer coil 2 and the electro-magnet A. The opening of this circuit will relieve the pressure between the needle 5 and the contact piece 7 as caused by the energy from the battery 25, thereby permitting the needle to find its position with respect to the difference between the electromotive force of the couple and the drop across the potentiometer in its new position. The opening of the switch 14—15 will, however, also deenergize the electromagnet A thereby permitting the switches 27—28 and 39—40 to return to their normal positions as illustrated in Figure 1 which, in the manner already stated, will again energize the electro-magnet B to close the switch 14—15 and simultaneously open the circuit to the motor. If the new position of the potentiometer as caused by the momentary closing of the switch 39—40 is sufficient to deflect the needle to its normal or null position as illustrated, no further action will occur. On the other hand if the galvanometer is still out of balance in the same direction as above described, the cycle will repeat itself until the needle has again been established in its null position as illustrated in Figure 1.

Similarly the circuit which includes the electro-magnet C starts at battery 12, thence through wire 11 and connection 10 to the electro-magnet C, from the magnet C through wire 8 to the contact piece 6, and when the needle is deflected clockwise against the contact piece 6, the circuit continues through the needle 5, the galvanometer coil 2 and the flexible connection 19 to the binding post 18, from the binding post 18 through wires 17 and 16 to the switch 14—15, and from

the switch through wire 13 back to the battery 12. The closing of this circuit through the needle 5 and the contact piece 6 when the needle is deflected in a clockwise direction, will in the manner which I am about to describe, energize the electro-magnet C, thus forcing the armature 76 into the position illustrated in Figure 2, in which position the switch 46—47 will be closed, and the switch 33—34 simultaneously opened. When the needle is thus deflected against the contact piece 6, it will close the circuit (just traced) which includes the battery 12, the galvanometer and the electro-magnet C. Obviously, the delicate force of a galvanometer needle, when only slightly deflected, is so small that the contact resistance between the needle and the contact piece 6 will be too great to permit sufficient current to flow from the battery to actuate the electro-magnet. The battery 12 is however of such polarity that whatever current does flow through the circuit will tend to deflect the needle in a clockwise direction against the contact piece 6. Thus the slightest contact between the needle and the contact piece 6 will cause some current to flow through the pivoted coil 2 to force the needle tighter against the contact piece 6. The greater the pressure of the needle against the contact piece 6, the greater will be the flow through the coil 2 thus continuously increasing the pressure between the needle and the contact piece 6 until sufficient current flows through the circuit to actuate the armature 76. The closing of the switch 46—47, thus effected, will energize the motor in the manner previously stated, to actuate the brush 55 in the opposite or clockwise direction thus decreasing the drop across the potentiometer to bring the galvanometer needle back to its normal position as illustrated. Simultaneously, however, the switch 33—34 is opened by the armature 76 which, in the manner already stated, deenergizes the electro-magnet B which changes the switch 14—15 to the position illustrated in Figures 2 and 3 thereby opening the circuit which includes the battery 12, the galvanometer coil 2 and the electro-magnet C. The opening of this circuit will relieve the pressure between the needle 5 and the contact piece 6 as caused by the energy from the battery 12 thereby permitting the needle to find its position with respect to the difference between the electro-motive force of the couple and the drop across the potentiometer in its new position. The opening of the switch 14—15 will, however, also deenergize the electro-magnet C thereby permitting the switches 46—47 and 33—34 to return to their normal positions as illustrated in Figure 1 which, in the manner stated, will again energize the electro-magnet B to close the switch 14—15 and simultaneously open the circuit to the motor. If the new position of the potentiometer as caused by the momentary closing of the switch 46—47 is sufficient to deflect the needle to its normal or null position as illustrated, no further action will occur. On the other hand if the galvanometer is still out of balance in the same direction as above described, the cycle will repeat itself until the needle has again been established in its null position as illustrated in Figure 1.

It thus follows that so long as the galvanometer is out of balance in a counter-clockwise direction, so that the needle 5 is intercepted by the contact piece 7, the electro-magnet A will be alternately energized and deenergized thus giving electrical impulses to the motor from the battery 36 through the switch 39—40. These impulses will continue until the motor has shifted the brush 55 sufficiently in a counter-clockwise direction for the potentiometer to balance the electro-motive force from the couple, thereby bringing the galvanometer needle 5 back to its normal position as illustrated.

Similarly it follows that so long as the galvanometer is out of balance in a clockwise direction, so that the needle 5 is intercepted by the contact piece 6, the electro-magnet C will be alternately energized and deenergized thus giving electrical impulses to the motor from the battery 36 through the switch 46—47. These impulses will continue until the motor has shifted the brush 55 sufficiently in a clockwise direction for the potentiometer to balance the electro-motive force from the couple, thereby bringing the galvanometer needle 5 back to its normal position as illustrated.

In order to provide the most suitable length or duration of the electrical impulses to the motor to operate the potentiometer in one direction or the other, provision is made to delay the release of the armature 71 when the magnet B is deenergized. Although this may be accomplished in a number of different ways, I have illustrated a commonly used copper mass or slug 75 located at the armature end of the magnet. The eddy currents produced in the slug when the circuit through the magnet is opened will retard the dissipation of the magnetic influence on the armature thus establishing an appreciable time element between the instant in which either of the switches 27—28 or 33—34 is opened and the instant in which the switch 14—15 is opened.

I claim:

1. In a device of the class described, the combination with a galvanometer having a rotatably mounted coil, of means for energizing the coil, an indicating needle which is deflected by the coil when the coil is energized, a contact piece with which the needle makes electrical contact when deflected by the coil in a given direction, a switch, electrical means which when energized opens the switch and which when deenergized closes the switch, a second switch actuated by a second electrical means so that when the second electrical means is energized the second switch is closed and when deenergized said switch is open, an electrical circuit which includes the coil, the needle, the contact piece, the first electrical means, and the second switch, and a second electric circuit which includes the second electrical means and the first switch.

2. In a device of the class described, the combination with a galvanometer having the usual rotatable coil, of a movable element actuated by the coil, means for energizing the coil, a contact piece with which the movable element makes electric contact when the coil is energized in one direction, a second contact piece with which the movable element makes electric contact when the coil is energized, in the opposite direction, a switch, a second switch, electrical means which when energized opens the first switch and closes the second switch, and when deenergized, closes the first switch and opens the second switch, a third switch, a fourth switch, a second electrical means which when energized opens the third switch and closes the fourth switch, and when deenergized, closes the third switch and opens the fourth switch, a fifth switch, a third electrical means for closing the fifth switch when energized and opening said switch when deenergized, an electric circuit which includes the gal-

vanometer coil, the movable element, the first contact piece, the first electrical means and the fifth switch, a second electric circuit which includes the galvanometer coil, the movable element, the second contact piece, the second electrical means and the fifth switch, a third electric circuit which includes the first switch, the third electrical means, and the third switch, a motor, a fourth electric circuit which includes the second switch for operating the motor in one direction, and a fifth electric circuit which includes the fourth switch for operating the motor in the opposite direction.

3. In a device of the class described, the combination with a galvanometer coil, of a movable element actuated by the coil, a contact piece with which the movable element makes electric contact when the coil is energized in one direction, a second contact piece with which the movable element makes electric contact when the coil is energized in the opposite direction, a switch, a second switch, electrical means which when energized opens the first switch and closes the second switch, and when deenergized closes the first switch and opens the second switch, a third switch, a fourth switch, a second electrical means which when energized opens the third switch and closes the fourth switch, and when deenergized closes the third switch and opens the fourth switch, a fifth switch, a third electrical means for closing the fifth switch when energized and opening said switch when deenergized, an electric circuit which includes the galvanometer coil, the movable element, the first contact piece, the first electrical means and the fifth switch, a second electric circuit which includes the galvanometer coil, the movable element, the second contact piece, the second electrical means and the fifth switch, a third electric circuit which includes the first switch, the third electrical means and the third switch, a motor, a fourth electric circuit which includes the second switch for operating the motor in one direction, a fifth electric circuit which includes the fourth switch for operating the motor in the opposite direction, a variable potentiometer actuated by the motor, a thermo-couple, and a sixth electric circuit which includes the potentiometer, the thermo-couple and the galvanometer coil.

4. In a device of the class described, the combination with a galvanometer coil, of an indicating needle actuated by the galvanometer coil, a contact piece with which the needle makes electrical contact when said needle is deflected in one direction, a battery for energizing the galvanometer coil to force the needle tightly against the contact piece, a thermo-couple for independently energizing the galvanometer coil, a variable potentiometer for balancing the electromotive force of the couple, a motor for actuating the potentiometer in one direction, an electric circuit which includes the motor, a switch for opening and closing the circuit, electrical means which, when energized, closes the switch and when deenergized opens the switch, a second electric circuit which includes the electrical means, the galvanometer coil, the needle, the contact piece and the battery, a second switch for opening and closing the second circuit, a second electrical means which, when energized, closes the second switch and when deenergized opens said switch, a third circuit which includes the second electrical means, a third switch in the third circuit which is opened by the first electrical means when energized and closed by said electrical means when deenergized, a second contact piece with which the needle makes electrical contact when deflected in the opposite direction, a second battery for energizing the galvanometer to force the needle tightly against the second contact piece, a second motor for actuating the potentiometer in the opposite direction, a fourth circuit which includes the second motor, a fourth switch for opening and closing the fourth circuit, a third electrical means which, when energized, closes the fourth switch and, when deenergized, opens said switch, a fifth switch for opening and closing the third circuit, said fifth switch being opened by the third electrical means when energized and closed by said electrical means when deenergized, and a fifth circuit which includes the third electrical means, the galvanometer coil, the needle, the second contact piece, the second battery and the second switch.

5. In a device of the class described, the combination with a galvanometer having the usual pivoted coil, of a source of electric energy, the electro-motive force of which is measured by the galvanometer, an electric circuit which includes the galvanometer coil and the source in parallel, a switch actuated by the galvanometer coil for closing the circuit, a second switch in the circuit, electrical means which, when energized, closes the second switch, and when deenergized, opens said switch, a relay in the circuit, an independent circuit which includes the electrical means, and a third switch in the independent circuit which switch is opened by the relay when energized and closed by the relay when deenergized.

6. In a device of the class described, the combination with a galvanometer having the usual pivoted coil, of a source of electric energy, the electro-motive force of which is measured by the galvanometer, an electric circuit which includes the galvanometer coil and the source in parallel, a switch actuated by the galvanometer coil for closing the circuit when the coil is energized in one direction, a second electric circuit which includes the galvanometer coil and the source in parallel, a second switch actuated by the galvanometer coil for closing the second circuit when the coil is energized in the opposite direction, a third switch included in both the first and second circuits, electrical means which, when energized, closes the third switch and when deenergized opens said switch, a relay in the first circuit which opens a fourth switch when energized and closes it when deenergized, a second relay in the second circuit which opens a fifth switch when energized and closes it when deenergized, and a third circuit which includes the fourth switch, the fifth switch and the electrical means.

7. In a device of the class described, the combination with a potentiometer, of means for changing the drop across the potentiometer, a reversible motor for actuating the changing means, a circuit for operating the motor in one direction, a second circuit for operating the motor in the opposite direction, a switch in the first circuit which is closed by an electrical means when energized and opened when said means is deenergized, a second switch in the second circuit which is closed by a second electrical means when energized and opened when said means is deenergized, a galvanometer coil, a third circuit which includes the galvanometer coil and the first electrical means, a third switch actuated by the galvanometer coil to close the third circuit when the coil is energized in one direction, a fourth circuit which includes the

galvanometer coil and the second electrical means, a fourth switch actuated by the galvanometer coil for closing the fourth circuit when the coil is energized in the opposite direction, a fifth switch included in both the third and fourth circuits for opening either of these circuits, a third electrical means which closes the fifth switch when energized and opens said switch when deenergized, a sixth switch which is opened by the first electrical means when energized and closed by said means when deenergized, a seventh switch which is opened by the second electrical means when energized and closed by said means when deenergized, a fifth electric circuit which includes the sixth switch, the seventh switch, and the third electrical means a thermo-couple for energizing the galvanometer coil, and sixth circuit which includes the couple, the galvanometer coil and the potentiometer.

8. In a device of the class described, the combination with a relay, a switch which is closed by the relay when energized and opened when deenergized, a second switch which is opened by the relay when energized and closed when deenergized, a second relay, a third switch which is closed by the second relay when energized and opened when deenergized, a fourth switch which is opened by the second relay when energized and closed when deenergized, a third relay, a fifth switch which is closed by the third relay when energized and opened when deenergized, a galvanometer, a sixth switch which is closed by the galvanometer when the galvanometer is deflected in one direction, a seventh switch which is closed by the galvanometer when the galvanometer is deflected in the opposite direction, a variable potentiometer, electrical means for actuating the potentiometer in one direction, a second electrical means for operating the potentiometer in the opposite direction, a thermo-couple, a circuit which includes the thermo-couple, the galvanometer, and the potentiometer, a second circuit which includes the galvanometer, the sixth switch, the first relay and the fifth switch, a battery in the second circuit with the proper polarity to deflect the galvanometer in one direction, a third circuit which includes the galvanometer, the seventh switch, the second relay, and the fifth switch, a second battery in the third circuit with the proper polarity to deflect the galvanometer in the opposite direction, a fourth circuit which includes the second switch, the third relay, and the fourth switch, a fifth circuit which includes the first electrical means, and the first switch, and a sixth circuit which includes the second electrical means and the third switch.

9. In a device of the class described, the combination with a galvanometer, of a battery circuit with the proper polarity to deflect the galvanometer in a clockwise direction, a switch actuated by a clockwise motion of the galvanometer for closing the battery circuit through the galvanometer, a second battery circuit with an opposite polarity to deflect the galvanometer in a counter-clockwise direction, a switch actuated by a counter-clockwise motion of the galvanometer for closing the second battery circuit through the galvanometer, a system of relays actuated by either the first or second battery circuit to open the actuating circuit, and a thermocouple included in both battery circuits in parallel with the galvanometer.

10. In a device of the class described, the combination with a galvanometer, of a battery circuit for deflecting the galvanometer in a clockwise direction, a second battery circuit for deflecting the galvanometer in a counter-clockwise direction, a switch actuated by the clockwise motion of the galvanometer to close the first battery circuit through the galvanometer, a second switch actuated by the counter-clockwise motion of the galvanometer to close the second battery circuit through the galvanometer, a relay in the first battery circuit, a third switch which is closed by the relay when deenergized and opened when energized, a second relay in the second battery circuit, a fourth switch which is closed by the second relay when deenergized and opened when energized, a switch for opening either of the battery circuits said switch being closed by an electrical means when said means is energized and opened when deenergized, a circuit for energizing the electrical means, said circuit including the third and fourth switches in series, a thermo-couple, and an independent circuit which includes the galvanometer and the couple.

11. In a device of the class described, the combination with a galvanometer coil, of a thermo-couple for energizing the coil, a relay for closing an auxiliary circuit when energized and opening said circuit when deenergized, a switch which is opened by the relay when energized and closed by the relay when deenergized, a battery for energizing the relay, a circuit which includes the thermo-couple, the relay and the battery, a pair of electric contacts actuated by the galvanometer coil for closing the circuit through the relay and the couple, means for shunting part of the battery energy from the relay circuit through the galvanometer coil, a second relay in a second circuit which circuit is opened and closed by the switch, and a second switch in series with the first relay and the battery, said switch being closed by the second relay when energized and opened thereby when deenergized.

12. In a device of the class described, the combination with a galvanometer coil, of a thermo-couple for energizing the coil, a relay for closing an auxiliary circuit when energized and opening said circuit when deenergized, a switch which is opened by the relay when energized and closed by the relay when deenergized, a battery with a given polarity for energizing the relay, a circuit which includes the relay, the couple and the battery, a pair of electric contacts actuated by the galvanometer coil for closing the circuit through the relay and the battery, means for shunting part of the battery energy from the relay circuit through the galvanometer coil, a second relay for closing a second auxiliary circuit when energized and opening said circuit when deenergized, a second switch which is opened by the second relay when energized and closed by the relay when deenergized, a second battery with opposite polarity for energizing the second relay, a second circuit which includes the second relay, the thermo-couple and the second battery, a second pair of electric contacts actuated by the galvanometer coil for closing the circuit through the second relay and the second battery, means for shunting part of the second battery energy from the second relay circuit through the galvanometer coil, a third switch included in both the first and second relay circuits, a third relay for closing the third switch when the relay is energized and opening said switch when deenergized, said third relay being included in a third circuit which circuit may be opened by either the first or second switches.

13. In a device of the class described, the combination with a galvanometer coil, of an indicating needle actuated thereby, a contact piece against which the needle deflects when the galvanometer coil is energized, a source of electrical energy for deflecting the needle toward the contact piece, a second source of electrical energy for energizing the galvanometer coil, a circuit which includes the galvanometer coil and the second source and which circuit is closed by contact between the needle and the contact piece, a relay in the circuit, a switch which is opened by the relay when energized, a second relay which is energized through the switch, and a second switch which is closed by the second relay when energized and opened thereby when deenergized, said second switch being included in the circuit through the second source.

14. In a device of the class described, the combination with a source of electrical energy, of a second source of electrical energy, a third source of electrical energy, a galvanometer coil permanently connected with the first source, a switch actuated by the galvanometer coil for connecting the galvanometer with the second source, a second switch actuated by the galvanometer coil for connecting the galvanometer with the third source, a relay in circuit with the galvanometer coil and the second source through the first switch, a second relay in circuit with the galvanometer coil and the third source through the second switch, a third relay which is deenergized by either of the first two relays when either of said relays is energized, and a third switch operated by the third relay for disconnecting whichever of the second or third sources may be connected with the galvanometer coil through the first or second switches respectively.

15. In a device of the class described, the combination with a source of electrical energy, of a second source of electrical energy, a third source of electrical energy, a galvanometer coil permanently connected with the first source, a switch actuated by the galvanometer coil for connecting the galvanometer with the second source, a second switch actuated by the galvanometer coil for connecting the galvanometer coil with the third source, a relay in circuit with the galvanometer coil and the second source, a second relay in circuit with the galvanometer coil and the third source, a third relay which is deenergized by either of the first two relays when either of said relays is energized, a third switch operated by the third relay which switch, when the third relay is deenergized disconnects whichever of the second or third sources may be connected with the galvanometer coil through the first or second switches respectively, a potentiometer for balancing the electro-motive force of the first source, an electrical means for adjusting the potentiometer in one direction, a second electrical means for adjusting the potentiometer in the opposite direction, a fourth switch which is closed by the first relay when energized, to actuate the first electrical means and a fifth switch which is closed by the second relay when energized, to actuate the second electrical means.

16. In a device of the class described, the combination with a galvanometer coil, a switch actuated by the galvanometer coil, a battery for deflecting the galvanometer coil in one direction, a circuit which includes the galvanometer coil, the switch and the battery, a second switch actuated by the galvanometer coil, a second battery for deflecting the galvanometer coil in the opposite direction, a second circuit which includes the galvanometer coil, the second switch and the second battery, a relay in the first circuit which, when energized, opens a third switch, a second relay in the second circuit which, when energized opens a fourth switch, a third relay which, when energized, closes a fifth switch which fifth switch is included in both the first and second circuits, a third circuit which includes the third relay and the third and fourth switches, and a fourth circuit for actuating the galvanometer coil independently of the batteries.

17. In a device of the class described, the combination with a galvanometer having a rotatably mounted coil, of a thermo-couple for energizing the coil, a switch, electrical means which, when energized, opens the switch and, when deenergized, closes the switch, an electric circuit which includes the galvanometer coil and the electrical means, a second switch which is actuated by the galvanometer coil, when energized, to close the circuit, a second circuit which includes a second electrical means and which second circuit is opened and closed by the first switch, and a third switch in the first circuit, which third switch is closed by the second electrical means, when energized, and opened thereby when deenergized.

18. In a device of the class described, the combination with a galvanometer having a rotatably mounted coil, of a thermo-couple for energizing the coil, an indicating needle which is deflected by the coil when the coil is energized, a contact piece with which the needle makes electrical contact when deflected by the coil, a switch, electrical means which, when energized, opens the switch and which, when deenergized, closes the switch, an electric circuit which includes the coil, the needle, the contact piece and the electrical means, a second circuit which includes a second electrical means and which second circuit is opened and closed by the switch, and a second switch in the first circuit, which second switch is closed by the second electrical electrical means when energized and opened by said second electrical means when deenergized.

19. in a device of the class described, the combination with a galvanometer consisting of the usual permanent magnet, a coil pivoted between the poles of the magnet and an indicating needle actuated by the coil, of means for energizing the coil, a contact piece with which the needle makes electrical contact when the coil is deflected in a given direction, a switch, a second switch, electrical means for actuating the first and second switches simultaneously, an electric circuit which includes the coil, the needle, the contact piece and the electrical means, a second electric circuit which includes a second electrical means and which second circuit is opened or closed by the first switch depending upon whether the first electrical means is energized or deenergized, a third switch for opening and closing the first circuit, which third switch is opened or closed by the second electrical means depending upon whether the second electrical means is deenergized or energized, and an independent circuit which is opened and closed by the second switch.

20. In a device of the class described, the combination with a galvanometer having the usual pivoted coil, of a movable element actuated by the coil, a contact piece with which the movable element makes electric contact when the coil is energized in one direction, a second contact piece with which the movable element makes elec-

tric contact when the coil is energized in the opposite direction, means for energizing the coil in one direction, means for energizing the coil in the opposite direction, a switch, a second switch, electrical means which, when energized, opens the first switch and closes the second switch, and when deenergized closes the first switch and opens the second switch, a third switch, a fourth switch, a second electrical means which, when energized, opens the third switch and closes the fourth switch and when deenergized, closes the third switch and opens the fourth switch, an electric circuit which includes the galvanometer coil, the movable element, the first contact piece and the first electrical means, a second electric circuit which includes the galvanometer coil, the movable element, the second contact piece and the second electrical means, a third electric circuit which includes a third electrical means, the first switch and the third switch, a fifth switch included in both the first and second circuits, said fifth switch being closed by the third electrical means when energized and opened by the third electrical means when deenergized, an independent circuit which is opened and closed by the second switch, and a second independent circuit which is opened and closed by the fourth switch.

21. In a device of the class described, the combination with a galvanometer having the usual rotatable coil, of a thermo-couple for energizing the coil, a relay, a second relay, a battery, a second battery, a circuit which includes the thermo-couple and the galvanometer coil, a second circuit which includes the first relay, the first battery and the galvanometer coil, a switch operated by the galvanometer coil for closing the second circuit when the galvanometer coil is energized counter-clockwise, a third circuit which includes the second relay, the second battery and the galvanometer coil, a second switch operated by the galvanometer coil for closing the third circuit when the galvanometer coil is energized clockwise, a third switch included in both the second and third circuits, said third switch being closed by a third relay when the third relay is energized and opened by said relay when deenergized, a fourth circuit which includes the third relay, a fourth switch operated by the first relay for opening the fourth circuit when the first relay is energized and closing said circuit when the first relay is deenergized, and a fifth switch operated by the second relay for opening the fourth circuit when the second relay is energized and closing said circuit when the second relay is deenergized.

22. In a device of the class described, the combination with a galvanometer coil which is included in each of three separate circuits, each of said circuits being independent of the other two, of a thermo-couple for energizing the coil and included in the first of said circuits, an electrical means with a battery for energizing the electrical means, both included in the second of said circuits, a second electrical means with a second battery for energizing the second electrical means, both included in the third of said circuits, a movable element actuated by the galvanometer coil and a contact piece with which the element makes electric contact when deflected in one direction, both of which are included in the second circuit, a second contact piece with which the element makes electric contact when deflected in the opposite direction, and which second contact piece with the element is included in the third circuit, a switch included in both the second and third circuits, a third electrical means for closing the switch when energized, and opening the switch when deenergized, a fourth circuit which includes the third electrical means, a second switch operated by the first electrical means for opening the fourth circuit when said electrical means is energized and closing said circuit when said electrical means is deenergized, and a third switch operated by the second electrical means for opening the fourth circuit when said second electrical means is energized and closing said circuit when said second electrical means is deenergized.

23. In a device of the class described, the combination with three separate sources of electrical energy, of a galvanometer coil connected with each source through independent circuits, a potentiometer in the first of said circuits for balancing the electro-motive force of the first source, a switch actuated by the galvanometer coil for closing the second of said circuits when the coil is energized in one direction and which second circuit includes the second source, a second switch actuated by the galvanometer coil for closing the third of said circuits when the coil is energized in the opposite direction and which third circuit includes the third source, a third switch included in both the second and third circuits, a fourth circuit which includes a relay for closing the third switch when energized and opening said switch when deenergized, a fourth switch for opening and closing the fourth circuit, a second relay in the second circuit for opening the fourth switch when energized and closing said switch when deenergized, a fifth switch for opening and closing the fourth circuit, and a third relay in the third circuit for opening the fifth switch when energized and closing said switch when deenergized.

24. In a device of the class described, the combination with three separate sources of electrical energy, of a galvanometer coil, a circuit which includes the coil and the first source, a potentiometer in the circuit for balancing the electro-motive force of the first source, a second circuit which includes the coil and the second source, a switch actuated by the coil to close the second circuit when the coil is energized in one direction, a relay in the second circuit which, when energized, opens a second switch and when deenergized closes said switch, a third circuit which includes the coil and the third source, a third switch actuated by the coil to close the third circuit when the coil is energized in the opposite direction, a second relay in the third circuit which, when energized, opens a fourth switch and when deenergized closes said switch, a fourth circuit which includes the second and fourth switches, and a third relay in the fourth circuit for simultaneously opening the second and third circuits when deenergized and closing said circuits when energized.

25. In a device of the class described, the combination with a galvanometer having the usual pivoted coil and indicating needle, of a battery circuit for energizing the coil to deflect the needle in a clockwise direction, a second battery circuit for energizing the coil to deflect the needle in a counter-clockwise direction, a switch actuated by the clockwise motion of the needle to close the first battery circuit through the galvanometer coil, a second switch actuated by the counter-clockwise motion of the needle to close the second battery circuit through the galvanometer coil, a thermo-couple for energizing the galva-

nometer coil to deflect the needle, a variable potentiometer for balancing the electro-motive force of the couple, a circuit which includes the couple, the galvanometer coil, and the potentiometer, electrical means for actuating the potentiometer in one direction, a second electrical means for actuating the potentiometer in the opposite direction, a third switch included in both battery circuits, a third electrical means which, when energized, closes the third switch and when deenergized opens said switch, an independent circuit for energizing the third electrical means, a relay in the first battery circuit which, when energized, simultaneously closes a circuit through the first electrical means and opens said independent circuit, and when deenergized opens the circuit through the first electrical means and closes said independent circuit, and a second relay in the second battery circuit which, when energized, simultaneously closes a circuit through the second electrical means and opens said independent circuit, and when deenergized opens the circuit through the second electrical means and closes said independent circuit.

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