

March 1, 1938.

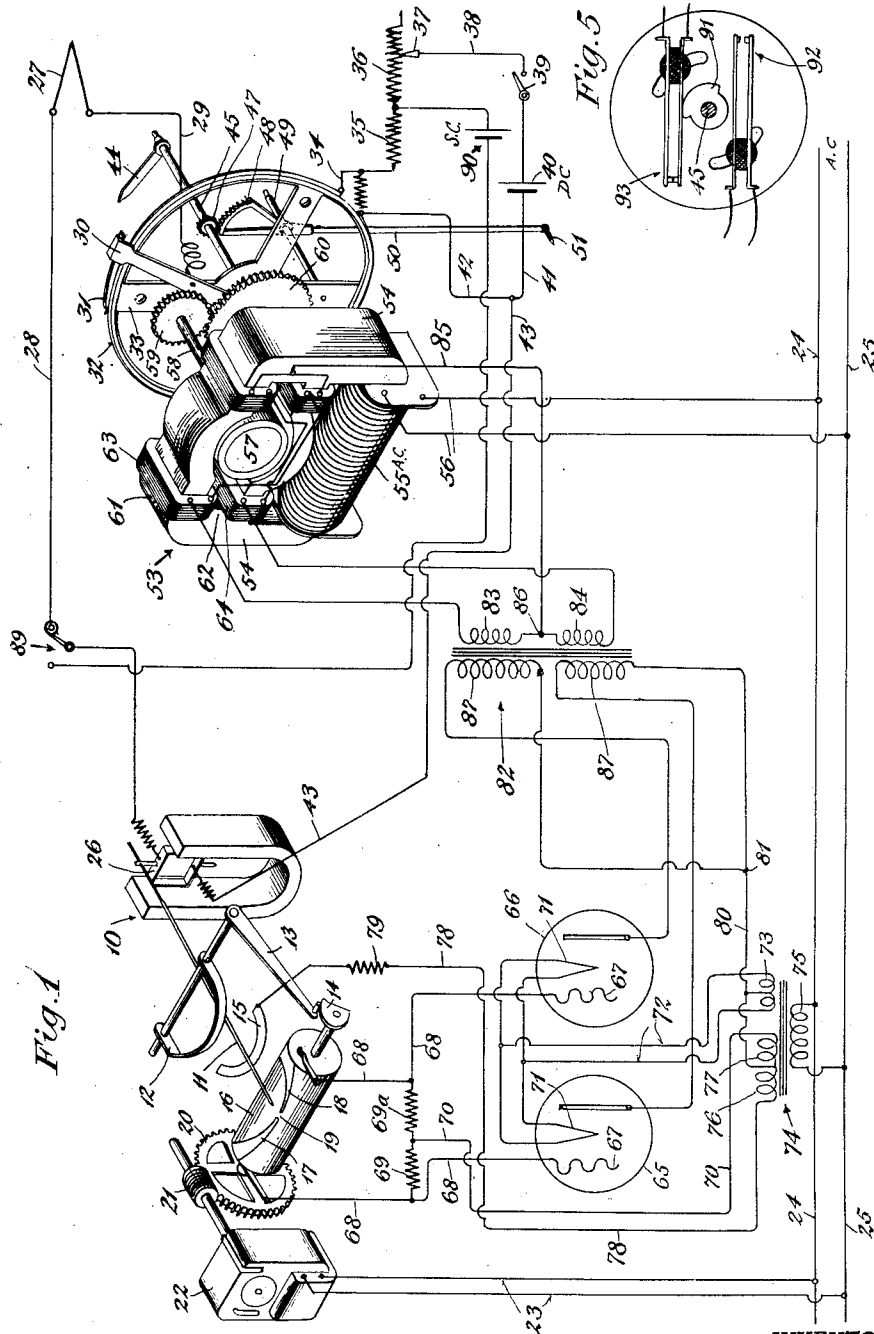
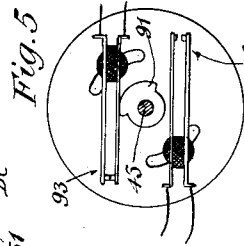
M. J. JOHNSON

2,109,776

MEANS FOR INDICATING AND/OR RECORDING UNKNOWN QUANTITIES

Filed Aug. 7, 1935

2 Sheets-Sheet 1



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MEANS FOR INDICATING AND/OR RECORDING UNKNOWN QUANTITIES

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2 Sheets-Sheet 2

Fig. 4

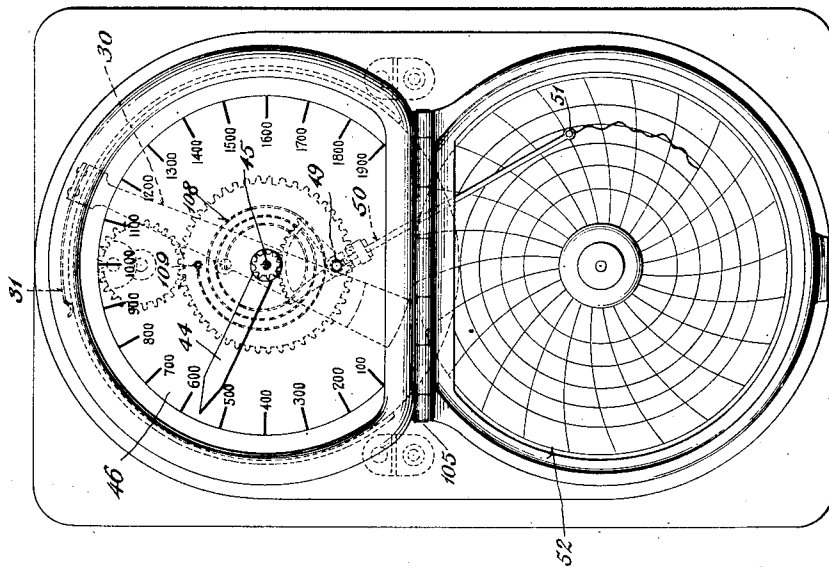


Fig. 3

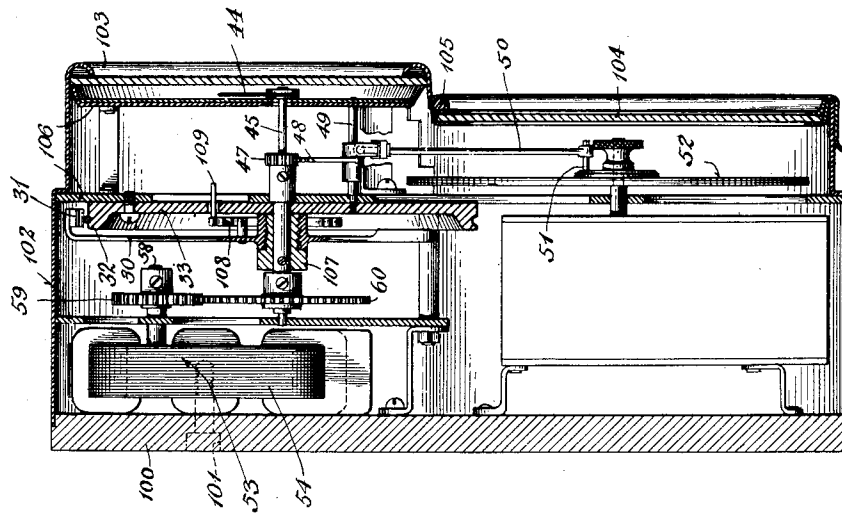
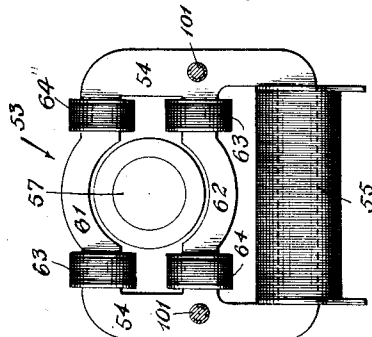


Fig. 2



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UNITED STATES PATENT OFFICE

2,109,776

MEANS FOR INDICATING AND/OR RECORD-
ING UNKNOWN QUANTITIESManfred J. Johnson, Naugatuck, Conn., assignor
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Application August 7, 1935, Serial No. 35,151

18 Claims. (Cl. 172-239)

This invention relates to potentiometer systems, and more particularly to an instrument for indicating and recording unknown quantities such as temperatures and for controlling operation of apparatus so as to maintain predetermined conditions, as in a furnace.

An object of this invention is to provide an improved recording potentiometer, particularly one which can be made very small and economically and yet which is quick-acting and accurate.

Heretofore, as in my prior Patent No. 1,910,340, a slide wire and the indicating or recording pointer are adjusted by operation of a motor in one direction or another according to the direction of off-zero movement of a galvanometer needle having a contact adapted to engage with either of two cooperating contacts periodically brought into position to engage the galvanometer needle contact. In this prior proposal, the current was sent to the motor through the galvanometer needle contact and the cooperating contact and this resulted in considerable arcing between the contacts. The motor, being of a normally deenergized type having two separate fields to control direction of rotation, was not in all cases instantaneous in its action as to starting and stopping. These difficulties and disadvantages have been to a large measure obviated by my more recent invention disclosed in Patent No. 1,971,313. In the latter, the directional contact which cooperates with the galvanometer needle contact controlled the grid circuit of thermionic devices or vacuum tubes, and in doing so caused the plate current to operate a reversing clutch in one direction or the other according to which directional contact is engaged.

I have found since, however, that a single reversible electric motor may be used to adjust the slide wire, pointer, ruling pen, or other device while at the same time employing electron discharge devices in a circuit with their attendant advantage of being able to reduce to a minimum the current passing between the galvanometer needle and its cooperating directional contact.

I have found that an induction motor of the kind usually known as a shaded pole type will, when properly organized and arranged with other apparatus connecting it with the galvanometer, give excellent results both as to rapid response and speed of operation, certainty of movement, and accuracy of the indications or the controlling operations which may be initiated by movement of the motor.

I have discovered that the proposed wire wound

shading coils on the pole pieces of a continuously energized motor may have their respective circuits opened and closed, in effect, by means of electron discharge devices controlled by the directional contacts of the galvanometer proper. When this is done, the motor being constantly energized, immediately moves to one direction or the other depending upon which shading coil is operative and that immediately upon the rendering of the shading coil inoperative, the motor stops and remains motionless without any tendency whatever to overthrow.

In carrying out my invention, I connect the proposed wire wound shading coils of the constantly energized field poles of a motor to the primary windings of a transformer, the secondaries of which are connected respectively to the plates or anodes of the electron discharge devices. Thus, when the field of the motor is energized, voltages are induced in the shading coils and these, which may be in the nature of 12 volts, are built up in the coupling transformer to satisfactory plate voltages which may be in the nature of 280 volts. This potential is impressed upon the plates or anodes of the electron discharge devices.

In the form of the invention herein disclosed, the filaments of the vacuum tubes are energized by another transformer having a primary connected to a suitable source of current, for instance 110 volts, 60 cycles. This transformer has one secondary connected to the filaments. It has two other secondaries similar to each other connected together in the middle, and this connected to the middle of the coupling transformer while one outside lead of the secondaries connects to the galvanometer needle contacts and the other side leads to its cooperating directional contacts, in each case, through suitable high resistances or leaks.

Further, in carrying out my invention, the transformers are arranged and connected to their respective circuits in such a way that at the instant that a positive potential is applied to both plates, a negative potential will be impressed on the grids of the tubes. When, however, the galvanometer needle contact is brought into engagement with one of the directional contacts, the grid of the vacuum tube associated with that contact is made less negative, and may even be made slightly positive. For such a condition, and of course this happens when, due to an unbalanced condition, the galvanometer needle deflects from its zero position, current flows through the plate circuit of the associated vac-

uum tube and thereby in effect loads one of the shading coils and causes the motor to operate. As soon as a balanced condition is established by the motor adjusting the slide wire, the galvanometer needle moves to its zero position and the grid again becomes more negative and sufficient current ceases to flow in the plate circuit with the result that the circuit of the shading coil is in effect open or unloaded and the motor ceases to operate.

In the broader aspects of my invention, the described method of opening and closing the circuits of the shading coils may be simplified and the shading coils may be controlled directly by the directional contacts and the galvanometer needle. However, in such cases, danger of arcing between the needle and the directional contacts is eminent; nevertheless if economy of manufacture is of paramount consideration, such modifications may be made.

Also, whereas in the particular apparatus described herein, thermionic electron tubes have been used, any other kind of suitable electron discharge devices in proper circuits may be employed to serve instead.

Other features and advantages will hereinafter appear.

In the accompanying drawings, which illustrate one form of this invention—

Figure 1 is a diagrammatic view showing the system of this invention and the apparatus embodied therein.

Fig. 2 shows the field structure and rotor and the windings in the form of the motor employed by this invention to adjust the slide wire and indicator, recorder or controlling switches, as the case may be.

Fig. 3 is a sectional view of the instrument of this invention embodying the slide wire, the indicator, the recorder, the motor for adjusting the same, and the motor or clockwork for rotating the recording dial.

Fig. 4 is a front view of the instrument shown in Fig. 3.

Fig. 5 shows a modification of the control means.

Referring now to the system diagrammatically illustrated in Fig. 1, the galvanometer 10 may be of any suitable kind of deflection instrument having a pointer or needle 11 movable in opposite directions from a zero position, in which it is shown in Fig. 1.

As in my Patent No. 1,971,313 the needle 11 is flexible and is depressed periodically by a bail 12 having an arm 13 controlled by a cam 14 and is brought into contact with an anvil 15, and at the same time its end engages a drum 16. The latter is made of insulating material and has contacts 17 and 18 tapering toward the middle of the drum and having a space 19 between them. When the needle 11 is in zero position, and is depressed by the bail 12, it contacts with the insulating material in the space 19, but if it had deflected to one side or the other it would engage the contacts 17 or 18, according to the direction of deflection.

The drum 16 is rotated by worm-wheel 20 and a worm 21 and a motor 22 fed by wires 23 tapped off from the main current supply wires 24 and 25. The motor 22 is preferably a synchronous motor, and the supply wires 24 and 25 are preferably 60-cycle alternating current, and hence the drum 16 and the cam 14 are time-controlled.

The galvanometer winding 26 is connected to a thermocouple 27, or other source of voltage

varied according to a change of conditions to be indicated and/or recorded by the instrument. One side of the thermocouple is connected by a wire 28 to the coil 26 of the galvanometer, while the other side is connected by a wire 29 to a movable arm 30 having a contact 31, adapted to engage a slide wire 32, which in the form of the invention shown, is mounted on the periphery of a stationary disk 33. One end of the slide wire 32 is connected by a wire 34 to a resistance 35 and a calibrating resistance 36, the latter having a movable contact 37 connected by a wire 38, and a switch 39 to a battery or source of current 40, which in turn has a wire 41 joined to a wire 42 leading to the other end of the slide wire, and a wire 43 leading to the other side of the galvanometer winding.

When a change in the E. M. F. generated by the thermocouple 27, or other source of voltage occurs, current flows through the galvanometer coil 26 and causes deflection of the needle 11 and this increase or decrease in potential is counter-balanced by adjustment of the slide wire 32, as in my patent No. 1,971,313.

In the form of the invention herein disclosed, the pointer 44 is carried by a shaft 45, which also carries the slide wire contact arm 30; the pointer in cooperation with a dial 46 of the instrument (see Fig. 4), indicates the value of the unknown quantity acting on the thermocouple. Also carried by the shaft 45 is a gear 47 meshing with a segment 48 carried by a shaft 49 which also carries a recording arm 50, the end of which has a marking device 51 in position to engage a chart 52 carried by the instrument and rotated by clockwork which may be mechanical or electrical, as desired.

The present invention is primarily concerned with the method and means for adjusting the slide wire in response to the off-zero movements of the galvanometer and aims to perform these operations in a quick and positive manner, and with comparatively inexpensive apparatus.

For this purpose, the present invention provides a unique form of motor and control therefor for actuating the slide wire arm 30 in accordance with the direction and extent of off-zero movement of the galvanometer. This motor 53 is of the squirrel-cage type and has field pieces 54 constantly energized by windings 55 connected by wires 56 to the 60-cycle alternating current supply wires 24 and 25. The rotor 57 of the motor may, if desired, be directly connected to the shaft 45 of the slide wire contact arm 30 and pointer 44, but preferably, there is reduction gearing between the shaft 58 of the rotor and the shaft 45. This reduction gearing comprising, in the form of the invention herein shown, a small gear 59 on the shaft 58 and a large gear 60 on the shaft 45. Connections between the rotor 57 and the slide wire arm 30 are, according to the present invention, preferably permanent, and no clutch or other interruptible connection need be provided unless for some other purpose than the controlling and operation of the slide wire by the motor.

In order to control the operation of the motor 53 as to starting and stopping and as to the direction of rotation of the rotor, the pole pieces 61 and 62 are provided with wire wound shading coils 63 and 64 respectively, and the circuits of the shading coils are selectively controlled, in a manner hereinafter explained, by the off-zero movements of the galvanometer needle 11 and

through the medium of the directional contacts 17 and 18 of the controller drum 16.

It will be understood by those skilled in the art that when the windings of the shading coils 63 alone are short-circuited, the rotor will turn in one direction, and when the windings of the shading coils 64 alone are short-circuited, the rotor will turn in the opposite direction, and that the turning will continue only so long as one pair of shading coils are actually, or in effect, short-circuited or loaded. Immediately upon opening of the one pair of short-circuited shading coils, the rotor will be brought to an abrupt stop, due to the mutual opposition of the pole pieces 61 and 62.

I have taken advantage of these characteristics of this type of motor to produce the desired directional adjustments of the slide wire control arm 30 and indicator 44 and recorder 50, and I have found that, by having the field pieces of the motor constantly energized, the response of the rotor is almost instantaneous and quickly accelerates, and yet stops quickly and suddenly upon opening the short-circuited shading coils, due to the mutual opposition of the pole pieces 61 and 62. Hence, I am able to quickly adjust the slide wire and indicator and the recorder and bring it to a balanced condition without danger of over-throw which would result in "hunting" of the galvanometer needle. This permits me to reduce substantially the time allowed for balancing the system and permits me to use a large number of thermocouples or other devices responsive to unknown quantity with the same indicating and/or recording instrument. If, as is preferable, the directional contacts 17 and 18 have more or less prolonged engagement with the galvanometer needle, depending upon the extent of the off-zero movement, the ability of the instrument to quickly and accurately indicate the unknown quantity will be further enhanced.

In the broader aspects of this invention, the shading coils may be short-circuited or open circuited in any suitable manner by the off-zero movement of the galvanometer, or by the contacting of the needle 11 thereof with a controlling drum 16, or its equivalent. However, to reduce to a minimum the arcing and the quantity of current which would necessarily pass through the contacts if the shading coils were so controlled, the present invention provides means including electron discharge devices for effectively opening and closing the shading coil windings. For this purpose, and in the particular apparatus to be described, there is provided a pair of thermionic devices 65 and 66, the grids 67 of which are respectively connected by wires 68 to the directional contacts 17 and 18, the wires 68 being connected by high resistances 69 and 69a between which there is a lead 70. The filaments 71 of the thermionic devices 65 and 66 are connected in parallel and to wires 72 leading to windings 73 of a transformer 74, the primary 75 of which is connected to the supply wires 24 and 25. The transformer 74 has two other secondary windings 76 and 77 similar to each other, and having a common terminal effecting a series plus to minus connection and connecting to the center tap of the filament winding 73, and through wire 80, to the intermediate point 81 of transformer 82, which couples the shading coils with the thermionic devices. The remaining end of secondary coil 77 is connected to the wire 70 leading to the grid resistors 69 and 69a; the remaining end of secondary coil 76 goes to resistor 79,

which is in turn connected to anvil 15 which is engaged by the galvanometer needle 11.

Transformer 82 has primary windings 83 and 84, one end of each being connected respectively to the shading coils 63 and 64. The shading coils have a common return wire 85 leading to the common terminal 86 of the primary windings of the transformer 82. The secondaries 87 of the transformer 82 have a common connection 81 such that the two remaining ends are either positive, zero, or negative in polarity at any instant, and these remaining ends are connected individually and respectively to the plates of the thermionic devices 65 and 66.

Voltage is induced in the shading coils 63 and 64, due to the constant A. C. energization of the field coil 55 of the motor 53; this voltage energizes the transformer 82 and induces in the secondaries relatively high A. C. voltages to be impressed on the plates of the thermionic devices 65 and 66. Thus, each plate is alternately positive and negative, and connections of the secondary coil are such that when one plate is positive the other is also positive. In thermionic tubes, there is a plate current flow only when a sufficient positive charge is impressed on the plate. The energization of transformers 74 and 82 from the 60-cycle supply line and the shading coils respectively will always have a constant phase relationship, due to the one ultimate source of supply, wires 24 and 25. This relationship is such that when the plates of devices 65 and 66 are both positively energized, the grids of these devices are negative due to their connection to wire 70 and the negative side of the secondary coil 77 of transformer 74, all providing no contact is made through the galvanometer needle 11 to the drum contacts 17 and 18. The magnitude of the negative charge on the grids is such that for this condition of negative grids and positive plates in the thermionic devices 65 and 66, no plate current will flow. If, however, at this point, contact is made from anvil 15 through the pointer to contact 18 on the drum, this action will tend to cause the grid connected to that contact to become zero in polarity. The manner of this action is as follows: Resistors 69, 69a, and 79 are of like value. When anvil 15 is connected, for instance, to drum contact 18 through the pointer 11, resistors 69a and 79 are placed in series across the terminals of the secondary coils 76 and 77. The potential of the grid with respect to the filament is the potential from the common terminal of coils 76 and 77 to the central common connection of the resistors. Considering absolute potential, and starting at the common terminal of coils 76 and 77, traversing coil 76 gives rise to an E. M. F.; traversing the resistance 79 results in a voltage drop which is equal in magnitude and opposite to the E. M. F. of coil 76. Therefore, a potential of zero is arrived at on anvil 15, pointer 11, and grid 67 of the thermionic device 66; the potential of the common terminal of coils 76 and 77 being zero also, there exists therefore no potential difference between said grid and this latter common terminal which connects with the center tap of the filament coil.

Thus the grid has become less negative in polarity, and a current will flow in the associated plate circuit of thermionic device 66, which, by means of transformer 82, places a load on shading coils 63 and causes rotation of the motor. Due to the tapered construction of the drum contacts, a greater magnitude of deflection of the galvanometer needle 11 expedites the action de-

scribed above and prevents hunting of the galvanometer needle.

In a like manner, if the galvanometer needle swings to the left, contacting anvil 15 to drum contact 17, a similar grid and plate action would take place in thermionic device 65, loading shading coils 64 and causing opposite rotation of the motor and attached pointer. The intervals during which the plates of the thermionic devices are negative and the grids positive are characterized by no current flow in the plate circuit, and no motor rotation.

Although the above method of controlling grid polarity has been found to be exceedingly satisfactory, in the broader aspects of this invention, any other means, by which right and left deflection of the galvanometer needle 11 will cause a change in the charges impressed on the grids 67 of thermionic devices 66 and 65 respectively for controlling the flow of current through the shading coils may be used.

A switch 89 is provided in the apparatus which, when thrown to the left, inserts the standard cell 90 in the circuit so that the current through and potential drop across the slide wire 32 and resistance 35 may be checked against the standard cell.

Although in Fig. 1 the reversible A. C. motor is shown as operating a pointer 44 on a dial, and an indicating pen 51 on a chart, it can be arranged for the shaft 45 to operate switches and/or contacts which, in turn, may be connected for controlling other devices, relays, etc. In Fig. 5, which shows one means of effecting such an arrangement, cam 91 attached to shaft 45 operates the contacts of jack switch 92 or 93, depending upon the direction of oscillation. Any multiple cam and switching arrangement, or other type mechanism to operate mercury or other switches, may be used, however.

The present invention also includes the slide wire and recording or indicating instrument per se shown in Figs. 3 and 4, which is simple in construction, economical to manufacture, and convenient to use.

As shown in these figures, the instrument comprises a back plate 100 on which the motor 53 is secured by screws 101. There is an enclosing casing 102, the front end of which has a beveled opening 103 preferably covered by glass and another opening preferably covered by a glass door 104 hinged at 105. Behind the door 104 is the clockwork mechanism which may be either electrical or mechanical, and this rotates the dial 52 over which the marking device 51 on the pen arm 50 of the instrument rides. The pen arm shaft 49 is mounted in plates 106 carried by the casing.

The slide wire 32 is preferably mounted on the disk 33 of insulating material. The slide wire adjusting arm 30 is mounted on an insulating hub 107 and the inner end of the arm is connected by a spiral or pigtail 108 to a terminal 109 to which the wire 29 leading to the thermocouple is connected.

The pointer 44 is substantial, and is so made that it can be viewed from quite a distance from the instrument.

Variations and modifications may be made within the scope of this invention and portions of the improvements may be used without others.

Having thus described the invention, what is claimed as new and for which it is desired to obtain Letters-Patent, is:—

1. In a potentiometer system, an alternating

current motor having a continuously energized A. C. field, a rotor, and wire wound shading coils on the pole pieces; a slide wire and indicating means adjusted by said rotor; a galvanometer connected in circuit with the slide wire; a pair of thermionic devices; circuits controlled by the off-zero movements of the galvanometer connected to the respective grids of the thermionic devices; means coupling the wire wound shading coils of the motor to the respective plates of the thermionic devices, said means including a step-up transformer whereby voltages induced in the shading coils are increased and impressed on said plates; and means connected to the galvanometer to cause one or the other of the grids to assume a less-negative potential causing current to flow in the associated plate circuit and making operative the associated shading coil which causes the rotor to operate, all depending upon the direction of off-zero movement of the galvanometer.

2. In a potentiometer system, an alternating current motor having a continuously energized A. C. field, a rotor, and wire-wound shading coils on the pole pieces; a slide wire and indicating means adjusted by said rotor; a galvanometer connected in circuit with the slide wire; a pair of thermionic devices; circuits controlled by the off-zero movements of the galvanometer connected to the respective grids of the thermionic devices; means coupling the wire wound shading coils of the motor to the respective plates of the thermionic devices, said means including a step-up transformer whereby voltages induced in the shading coils are increased and impressed on said plates; and means connected to the galvanometer to cause one or the other of the grids to assume a less-negative potential causing current to flow in the associated plate circuit and making operative the associated shading coil which causes the rotor to operate, all depending upon the direction of off-zero movement of the galvanometer and quantitatively in accordance with the extent of such off-zero movement.

3. In a potentiometer system, an alternating current motor having a continuously energized A. C. field and wire-wound pole-shading means; a slide wire and indicating means operated by the motor; a galvanometer connected in circuit with the slide wire; means controlled by the latter and including electron discharge devices for controlling the shading of the motor and causing rotation thereof in one direction or the other in accordance with the direction of the off-zero movement of the galvanometer; and means whereby the plates of the electron discharge devices are energized from the pole-shading means.

4. In a potentiometer system, an alternating current motor having a continuously energized A. C. field and wire-wound shading coils; a slide wire and indicating means operated by the motor; a galvanometer connected in circuit with the slide wire; and means controlled by the latter and including a pair of thermionic devices having their plates coupled to and energized by shading coils on said motor and their grids under the control of the galvanometer for controlling the shading of the motor and causing rotation thereof in one direction or the other in accordance with the off-zero movement of the galvanometer.

5. In a potentiometer system, a wire wound shaded-pole alternating current motor having a continuously energized A. C. field; a slide wire and indicating means operated by the motor; a

galvanometer connected in circuit with the slide wire; and means controlled by the latter and including electron discharge devices for controlling the shading of the motor and causing rotation thereof in one direction or the other in accordance with the direction of the off-zero movement of the galvanometer, said motor having oppositely disposed wire wound shading coils and said electron discharge devices having their plates coupled respectively with said shading coils to be supplied with current therefrom.

6. In a potentiometer system, a slide wire and indicator; a galvanometer connected in circuit with the slide wire; and means including an alternating current motor having a continuously energized A. C. field and two wire-wound shading coils, and including thermionic devices having their plate circuits energized by said shading coils and controlled by said galvanometer for adjusting the slide wire and indicator in accordance with the direction of off-zero movement of the galvanometer.

7. In a potentiometer system, a slide wire and indicator; a galvanometer connected in circuit with the slide wire; and means including an alternating current motor having a continuously energized A. C. field and two sets of wire-wound shading coils, and including thermionic devices having their plate circuits energized by said shading coils and controlled by said galvanometer for adjusting the slide wire and indicator directionally in accordance with the off-zero movement of the galvanometer, and quantitatively in accordance with the extent of such off-zero movement.

8. The invention as defined in claim 3, in which the means controlled by the galvanometer also includes a contact member on the galvanometer needle and a pair of contacts movable relatively to the contact member to periodically be in position to engage the said contact member, said contacts extending in opposite directions from the zero position of the needle to be engaged respectively by the latter when in off-zero position and said contacts being connected respectively to the grids of said thermionic devices.

9. The invention as defined in claim 3, in which the means controlled by the galvanometer also includes a contact member on the galvanometer needle and a pair of contacts movable relatively to the contact member to periodically be in position to engage the contact member, said contacts extending in opposite directions from the zero position of the needle to be engaged respectively by the latter when in off-zero position and said contacts being connected respectively to the grids of said thermionic devices, and resistance in the circuit of said contact member to render the potential of one of said grids less negative when the contact member engages the associated one of said contacts.

10. In a potentiometer system, a slide wire, means for adjusting the slide wire including a reversible motor having shading means for controlling the direction of rotation; a galvanometer connected in circuit with the slide wire; means for controlling the operations of the motor including a pair of thermionic devices; a source of alternating current supply for the plates and grids of said thermionic devices including means for supplying positive voltage to the plates from the induced voltages of the shading means of the motor during the time negative voltage is impressed on the grid and vice

versa; and means responsive to movement of the galvanometer for making one or the other of said grids less negative, the particular grid chosen being in accordance with the direction of off-zero movement of the galvanometer and controlling the direction of rotation of said motor.

11. In a potentiometer system, an adjustable slide wire and work producing means associated therewith; means for adjusting the slide wire including a reversible shaded pole A. C. motor having a continuously energized field and two sets of wire wound shading coils, each set capable of acting oppositely on the rotor of the motor; an electron discharge device system to load through suitable coupling means either set of shading coils to cause rotation of the motor, said system receiving plate energization from the shading coils; a galvanometer connected in circuit with the slide wire; and means responsive to movements of the galvanometer for causing to function the electron discharge devices of said system, resulting in loading of one or the other set of shading coils according to the direction of off-zero movement of the galvanometer, effecting by this action adjustment of the slide wire through the response of the motor.

12. In a potentiometer system, an adjustable slide wire and work producing means associated therewith; means for adjusting the slide wire including a reversible shaded pole A. C. motor having a continuously energized field and two sets of wire wound shading coils, each set capable of acting oppositely on the rotor of the motor; an electron discharge device system to load through suitable coupling means either set of shading coils to cause rotation of the motor, said means also supplying properly timed charges to the electron discharge devices from the induced voltages of the shading coils; a galvanometer connected in circuit with the slide wire; and means responsive to movements of the galvanometer for causing to function the electron discharge devices of the system, resulting in loading of one or the other set of shading coils according to the direction of off-zero movement of the galvanometer, effecting by this action adjustment of the slide wire through the response of the motor.

13. In a potentiometer system, an alternating current motor having a continuously energized A. C. field, a rotor, and wire wound shading coils on the pole pieces; a slide wire and indicating means adjusted by said rotor; a galvanometer connected in circuit with the slide wire; a pair of thermionic devices; circuits controlled by the off-zero movements of the galvanometer connected to the respective grids of the thermionic devices; means coupling the wire wound shading coils of the motor to the respective plates of the thermionic devices, said means including a step-up transformer whereby voltages induced in the shading coils are increased and impressed on said plates, these voltages being in phase; means including a transformer for impressing in-phase alternating voltages on the grids of the thermionic devices, such that a constant phase relationship exists between grid and plate voltages, and such that plate voltages are positive when grid voltages are negative; and means connected to the galvanometer to cause one or the other of the grids during its intervals of negative polarity to assume a less-negative potential causing current to flow in the associated plate circuit and making operative the associated shading coil

which causes the rotor to operate, all depending upon the direction of off-zero movement of the galvanometer and quantitatively in accordance with the extent of such off-zero movement.

5 14. The invention as defined in claim 3, in which the means controlled by the galvanometer also includes a contact member on the gal-
 10 vanometer needle and a pair of contacts movable relatively to the contact member to periodically be in position to engage the contact member,
 15 said contacts extending in opposite directions from the zero position of the needle to be en-
 20 gaged respectively by the latter when in off-zero position and said contacts being connected re-
 25 spectively to the grids of said thermionic devices; and means including a transformer and re-
 30 sistances for impressing alternating in-phase voltages on the grids of the electron discharge
 35 devices, and resistance in the circuit of said con-
 40 tact member to render the potential of one of
 45 said grids less negative during its intervals of
 50 negative polarity when the contact member en-
 55 gages the associated one of said contacts.

15. In a potentiometer system, an adjustable
 20 slide wire; means for adjusting the slide wire, in-
 25 cluding a reversible A. C. motor having a con-
 30 tinuously excited field and oppositely disposed
 35 wire wound shading coils; means connected to
 40 the slide wire for performing work by virtue of
 45 this adjusting movement; an electron emission
 50 apparatus coupled to the shading coils of the
 55 motor; means, including a transformer, for cou-
 pling the shading coils to the anodes of the elec-
 tron emission devices in such a manner that the
 induced alternating voltages of the shading coils
 are stepped up and impressed respectively on the
 anodes of the electron emission devices, and are
 in phase; means, including a transformer and re-
 sistances, for impressing alternating in-phase
 voltages on the grids of the electron emission
 devices, and such that these voltages are in con-
 stant phase relationship with and of opposite
 polarity to the plate voltages at any instant; a
 galvanometer connected in circuit with the slide
 wire; and means whereby the off-zero movement
 of the galvanometer makes contact between one
 or the other of the grids, according to the direc-
 tion of the movement, and through a resistance to
 the associated grid transformer secondary to ef-
 fect a less negative potential of the grid, caus-
 ing a flow of current in the plate circuit of the
 associated electron emission device and loading
 the associated shading coil causing the motor to
 operate and adjust the slide wire.

16. In a potentiometer system, an adjustable
 slide wire; means for adjusting the slide wire,
 including a reversible A. C. motor having a con-
 tinuously excited field and oppositely disposed
 wire wound shading coils; means connected to the
 slide wire for performing work by virtue of this

adjusting movement; an electron emission appa-
 ratus coupled to the shading coils of the motor;
 means, including a transformer, for coupling
 the shading coils to the anodes of the electron
 emission devices in such a manner that the in-
 duced alternating voltages of the shading coils
 are stepped up and impressed respectively on the
 anodes of the electron emission devices, and are
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 vices, and such that these voltages are in con-
 stant phase relationship with and of opposite
 polarity to the plate voltages at any instant; a
 galvanometer connected in circuit with the slide
 wire; means whereby the off-zero movement of
 the galvanometer makes intermittent electrical
 contact, time-quantitatively with extent of move-
 ment to either of the grids of the electron emis-
 sion devices according to the direction of move-
 ment; and a resistance in the circuit of the inter-
 mittent galvanometer contact to render the grids
 less negative during their intervals of negative
 polarity, and when contact is made.

17. In a potentiometer system, an adjustable
 slide wire; means for adjusting the slide wire,
 including a reversible A. C. motor having a con-
 tinuously excited field and oppositely disposed
 wire wound shading coils; means connected to
 the slide wire for performing work by virtue of
 this adjusting movement; a galvanometer con-
 nected in circuit with the slide wire; an electron
 valve apparatus to function as two separate re-
 lays; means for coupling the shading coils of the
 motors individually to the electron valve relays;
 said coils supplying charges to the anodes of the
 electron valves; and means for actuating the re-
 lays separately by the off-zero movement of the
 galvanometer, according to direction.

18. In a potentiometer system, an adjustable
 slide wire; means for adjusting the slide wire,
 including a reversible A. C. motor having a con-
 tinuously excited field and oppositely disposed
 wire wound shading coils; means connected to
 the slide wire for performing work by virtue of
 this adjusting movement; a galvanometer con-
 nected in circuit with the slide wire; an electron
 discharge device system; means whereby the off-
 zero movement of the galvanometer causes the
 electron discharge devices to function selectively
 according to the direction of the off-zero move-
 ment, and quantitatively with the magnitude of
 the movement; and means for coupling the plate
 circuit of the electron discharge device system to
 the shading coils of the motor for energization
 therefrom, and so that functioning of said devices
 due to movement of the galvanometer loads the
 shading coils of the motor.

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