

Nov. 3, 1959

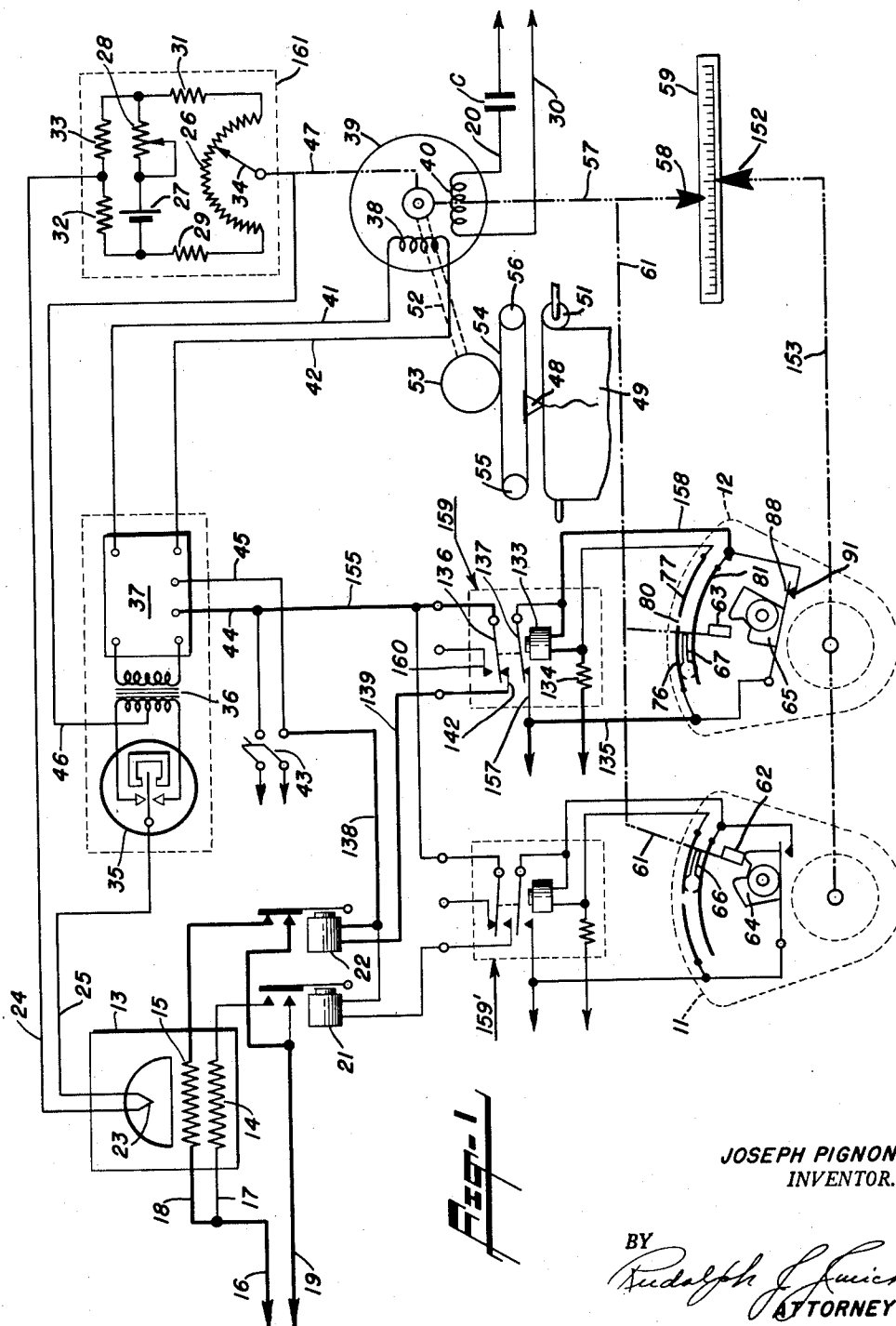
J. PIGNONE

2,911,577

SERVOCIRCUIT AND CONTROL SWITCH

Filed Feb. 12, 1957

4 Sheets-Sheet 1



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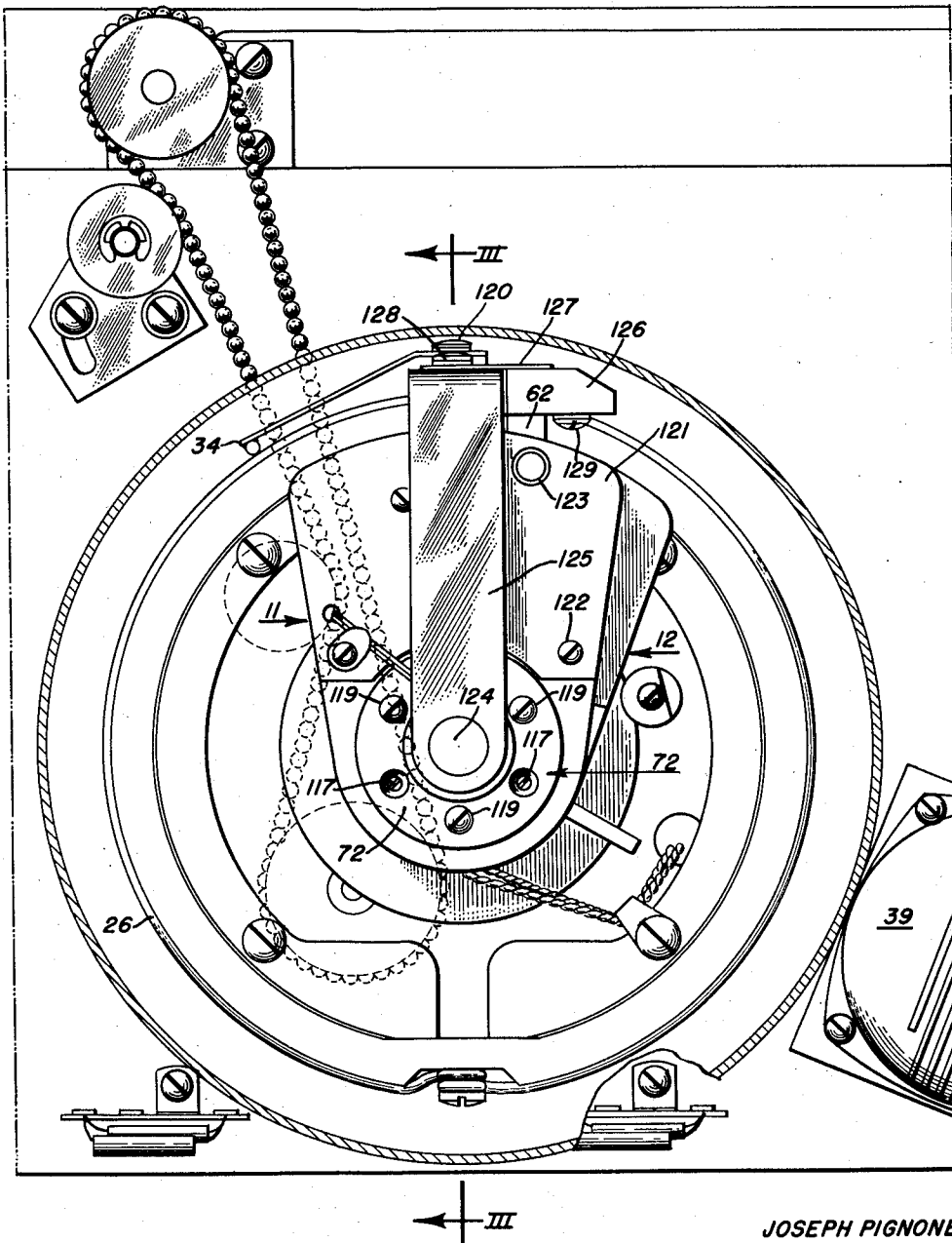
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SERVOCIRCUIT AND CONTROL SWITCH

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4 Sheets-Sheet 2



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Fig-2

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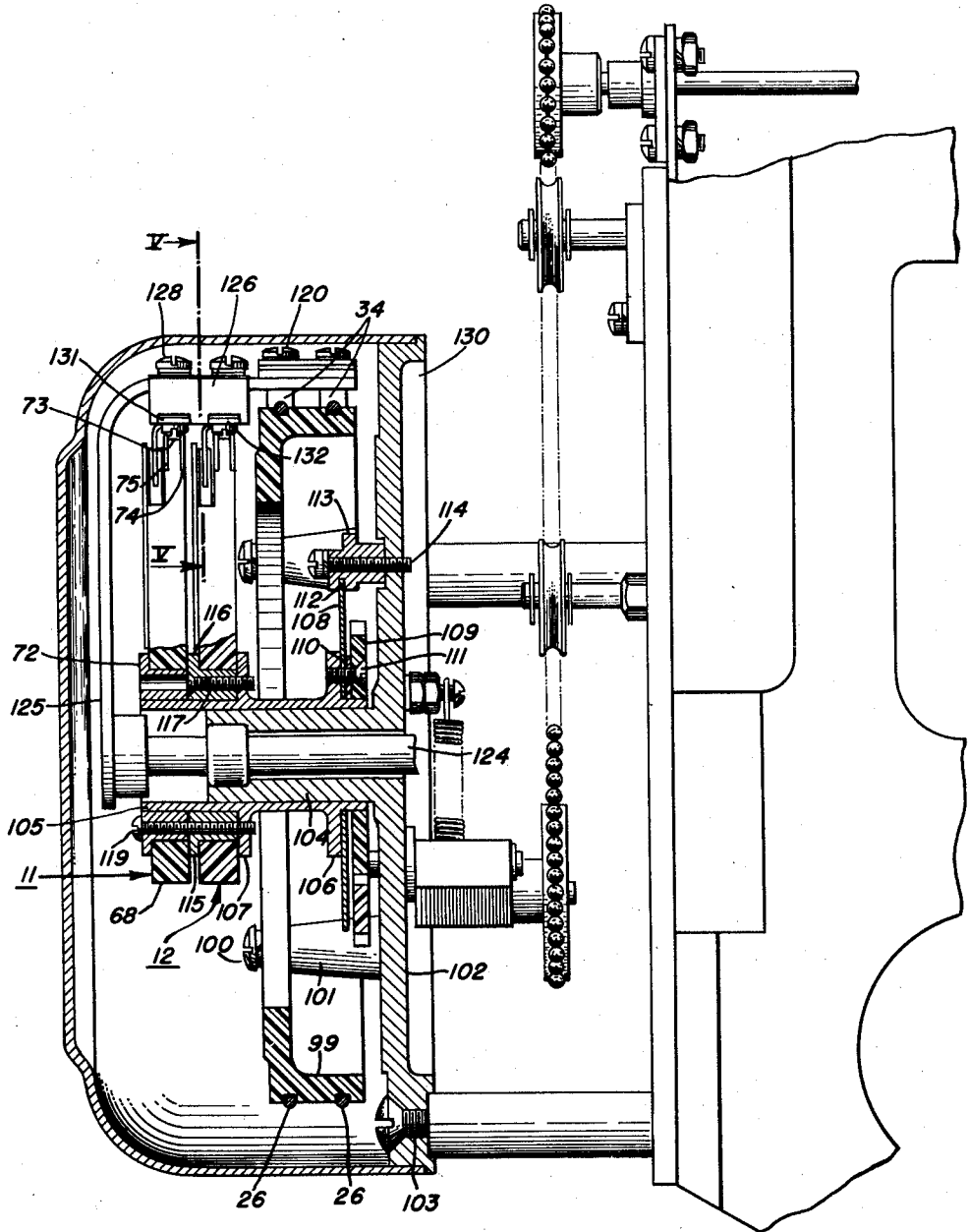
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SERVOCIRCUIT AND CONTROL SWITCH

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4 Sheets-Sheet 3



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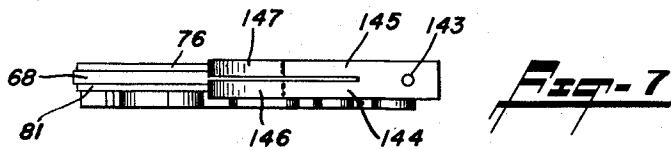
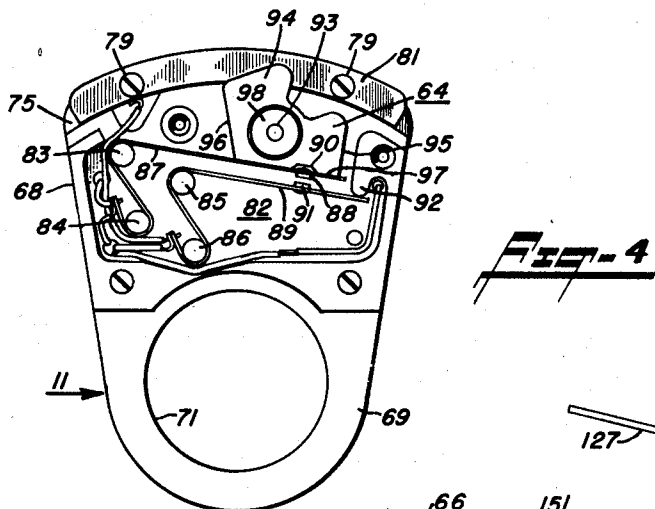
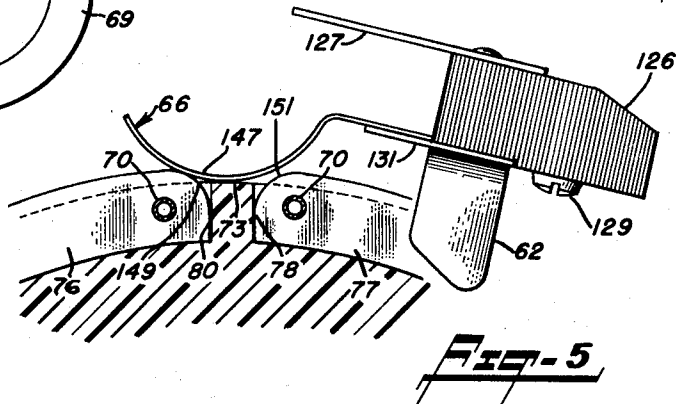
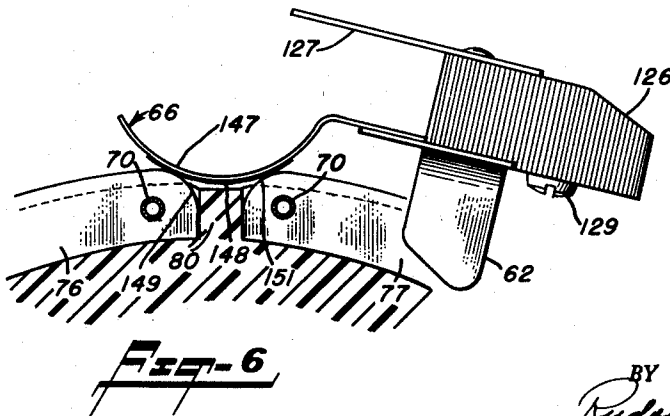
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2,911,577

SERVOCIRCUIT AND CONTROL SWITCH

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4 Sheets-Sheet 4



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SERVOCIRCUIT AND CONTROL SWITCH

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Application February 12, 1957, Serial No. 639,822

22 Claims. (Cl. 318—29)

This invention relates to a system of adjustable point switching to control altitude, function or process, or to throttle or modulate predetermined portions thereof, and more particularly to an adjustable control switch and circuitry for use in a self-balancing potentiometric recorder or the like.

Recorders of the type to which this invention relates are useful in providing a measurement and record of variable conditions such as, for example, temperature. However, they are also designed to measure and record output from such primary elements as thermocouples, tachometer generators, photoelectric cells, resistance thermometer bulbs, and any transducer that provides an electrical output which varies in accordance with changes in a condition to be measured. Such recorders can also be employed to measure flow, pressure and weight by using suitable converters to provide an electrical output.

The indication and recording of the instantaneous state of a variable condition by a self-balancing potentiometric recorder is accomplished by electrical networks which are adapted to be unbalanced by a variation in the condition and to effect an operation of a suitable rebalancing means. Such rebalancing operations include the actuation of suitable power means for simultaneously moving an inking pen or stylus over a power-driven, constantly-movable, calibrated chart.

One or more control switches, made in accordance with this invention, are adapted for attachment to a potentiometric recorder and readily adjustable to provide one or more control functions at any desired point within the operating range of the recorder. Each control switch is of novel construction comprising a pair of coaxial tracks disposed in parallel planes, one of which includes a central gap. A brush contact, carried by the arm which also carries the potentiometer slider, is slidably movable over the tracks to electrically connect the continuous track with one or the other of the portions of the segmented track.

Simultaneously with the movement of the brush contact, a tumbler cam is operated to close a pair of auxiliary contacts when the brush contact advances in one direction, and to open the auxiliary contacts when the brush contact is moved in the opposite direction. The actual control function is initiated when the brush contact bridges the gap in the one track, whereas the auxiliary contacts serve as a safety switch in the event of temporary power failure. The auxiliary contacts also serve to apply a selected control function when the brush contact is moved beyond the range of the tracks.

The control switch provides an "on" and "off" control function as the brush contact is moved in one or the other direction. By making the brush contact of arcuate form and spanning the gap in the segmented track, the "on" and "off" control function will occur at the identical point of brush travel in either direction, thereby resulting in a zero differential between the application of the "on" and "off" control function. Although such operation is highly desirable in certain applications, the

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curvature of the brush contact and the length of the gap can be designed to provide a desired differential between the effective "on" and "off" control points.

5 An object of this invention is the provision of a control switch for a self-balancing, potentiometric recorder or the like, which control switch readily is mountable in the recorder, is adjustable to a desired set or control point, and is of a construction promoting a long, trouble-free operating life.

10 An object of this invention is the provision of an adjustable control switch for use in a self-balancing type controller, which switch will provide an "on" and "off" control function at a common selected set point to maintain a variable condition at a preselected normal level or value.

An object of this invention is the provision of a control switch for a self-balancing, potentiometric type recorder, said control switch comprising an insulating body provided with an aperture to receive a supporting shaft, a pair of tracks carried by said body and disposed end to end with a gap therebetween, a third track carried by the body, said third track being disposed in a plane parallel to the said pair of tracks and coextensive therewith, a movable brush contact adapted for sliding contact with the tracks, a tumbler cam pivotally supported by the body, a pair of auxiliary contacts, spring means supporting the auxiliary contacts on the body, and a tab movable with the said brush contact to actuate the tumbler cam to a first or second position and thereby open and close the auxiliary contacts.

30 An object of this invention is the provision of a control switch for use with a potentiometric recorder including a shaft rotating the potentiometer slider, said switch including means adjustably mounting the switch on the shaft to provide an "on" and "off" control function at a selected set point, and means to restore the control function to that condition which prevailed at a time preceding a disruption in the electrical energy supplied to the recorder.

40 An object of this invention is the provision of a novel mounting arrangement for adjustably securing one or more control switches to the operating shaft of an automatic, potentiometer-type recorder.

45 These and other objects and advantages will become apparent from the following detailed description when taken with the accompanying drawings. It will be understood that the drawings are for purposes of illustration and do not define the scope or limits of the invention, reference being had for the latter purpose to the appended claims.

In the drawings, wherein like reference characters denote like parts in the several views:

55 Figure 1 is a diagrammatic representation of potentiometer and control circuits, including members embodying my invention, for controlling the temperature of a furnace;

60 Figure 2 is a rear elevational view of an automatic indicating and recording instrument, showing a pair of my control switches mounted on the shaft which carries the slider of the potentiometer;

Figure 3 is a side view, with parts in elevation and parts in vertical section on the line III—III of Figure 2, in the direction of the arrows;

65 Figure 4 is a detailed elevational view of the outer control switch of Figure 2, with its protective plate removed to show the enclosed parts;

70 Figure 5 is an enlarged fragmentary sectional view on the line V—V of Figure 3, in the direction of the arrows, showing the arm of the brush contact which cooperates with the short tracks on the control member together with certain support elements, and the tab which operates the tumbler cam switch;

Figure 6 is a view corresponding to Figure 5, but showing a modified form of the same arm of the brush contact arranged for another mode of operation; and

Figure 7 is a plan view showing the top end of the control member with the brush contact added.

Referring first to Figure 1, there is shown a pair of control members or switches 11 and 12, embodying my invention, for regulating a condition; in this case the temperature in a furnace 13. The furnace is shown as supplied with heat from a pair of electrical resistors or heating elements 14 and 15 which receive electrical energy from a suitable source of power. Here, the power is directed through a common lead 16 with branches to individual leads 17 and 18, and a return lead 19 connected to the contacts of contactor relays 21 and 22, respectively. The purpose of showing the furnace receiving heat from a pair of resistors 14 and 15, instead of only one, is so that the power to heat one of these resistors may be cut off in anticipation of reaching the temperature for which the furnace is set, and on a down movement, they may be energized sequentially, to thereby prevent excessive overheating and undercooling of the furnace. In other words, the circuit here disclosed is that for three-position control, that is, (1) a position where the furnace temperature is increasing with both resistors energized, (2) a position in which one of said resistors is deenergized in anticipation of reaching the temperature at which the furnace is set, and (3) a position in which both resistors are deenergized upon the furnace reaching the temperature for which the control is set.

The condition or temperature of the furnace 13 is measured by a device sensitive to the condition, such as a thermocouple 23. Such thermocouple is inserted through an opening in the furnace wall and connected to an automatically balancing potentiometer circuit 161 through leads 24 and 25. As shown diagrammatically, the balancing or measuring circuit comprises a circular resistance wire 26 connected across a source of fixed voltage, such as the battery 27, through an adjustable resistor 28 and fixed resistors 29 and 31. The lead 24 is connected to this circuit through fixed resistors 32 and 33. The voltage of the thermocouple 23 is opposed by the potential drop across the measuring circuit as determined by the position of a rotatable contact member or slider 34 engaging the resistor 26.

Connected between the thermocouple 23 and the potentiometer slider 34 is a vibrator or chopper 35 and the primary winding of a transformer 36. The vibrator 35 is adapted to open and close the thermocouple circuit at a frequency of 60 cycles per second and thereby apply to the transformer primary winding a pulsating voltage having a magnitude depending upon the difference between the voltage generated by the thermocouple and the opposing output voltage of the measuring circuit. Specifically, the pulsating current flowing in the primary winding of the transformer 36 is in a direction and of a magnitude depending upon the extent of circuit unbalance and constitutes what is generally termed an error signal. The secondary winding for transformer 36 is connected directly to the input of an electronic amplifier 37 which is energized, through the leads 44, 45 from a 60-cycle power source upon closure of the switch 43.

The output of the amplifier 37 is connected to one of the field windings 38 of a two-phase motor 39 through leads 41 and 42. The other field winding 40 of the motor 39 is connected to a 60 cycle, power line through leads 20 and 30 and the capacitor C. As is well known in this art, the system normally is in a balanced condition. A change in the furnace temperature results in a corresponding change in the thermocouple voltage thereby unbalancing the system in a direction and to an extent corresponding to the deviation in the furnace temperature. Upon such system unbalance, the amplifier energizes the motor for rotation in one or the other direction and the slider 34 is rotated, through the mechanical link-

age 47, to reestablish a balance of the system at a new point. Such new balance point corresponds to the new temperature of the furnace.

The motor 39, in addition to driving the potentiometer slider 34, also serves to move a pen or stylus 48 across a chart 49, as by means of a shaft 52, cable pulley 53, and drive cable 54 passing around idler pulleys 55 and 56. The chart 49 may be driven in a conventional manner as by a power-driven roller 51. The motor also, through the mechanical linkage or connection 57, moves the indicating pointer 58 of the instrument along a calibrated temperature scale 59. As indicated diagrammatically at 61, the motor armature is also mechanically coupled to a pair of tabs 62 and 63, one for actuation of the tumbler cam 64 of control switch 11 and the other for the tumbler cam 65 of control switch 12. The linkage 61 also actuates brush contacts 66 for the control switch 11 and brush contacts 67 for control switch 12.

The construction of the control switches 11 and 12, which are identical, is shown in detail in Figures 4-7 and the mounting of the switches on a controller is shown in Figures 2 and 3. It will be seen that in the present embodiment each of these switches comprises an insulating body portion 68, desirably molded from a suitable plastic, flaring from a hub or circular portion 69. The hub portion is apertured, as indicated at 71, to receive a clamping ring or mounting member 72 (or 115), see Figure 3. The part remote from the hub portion 69 is arcuate about the center of said hub portion, as indicated at 73, and inset on each face as indicated at 74 and 75 in Figure 3.

Mounted in the inset 74 are a pair of arcuate, conductive tracks 76 and 77, desirably formed of durable sheet metal, projecting slightly beyond the upper arcuate surface of the insulating portion. The adjacent end portions of these tracks are separated by a gap generally defined by a boss 80 formed integral with the insulating body portion 68. These tracks are secured to the body portion in any suitable manner as by means of hollow rivets or eyelets 70. Likewise, in the inset 75, in the other face of the insulating body portion, is attached in a similar manner, or as by means of screws 79, an arcuate conductive track 81, desirably formed of durable sheet metal, which is spaced from and parallel to the tracks 76 and 77. The track 81 has an arcuate length approximately equal to the sum of the lengths of the tracks 76 and 77 plus the gap therebetween.

The insulating portion 68 also is provided with a recessed portion or pocket 82 in the outer face (see Figure 4) in which upstanding spring-contact-holding bosses 83, 84, 85 and 86 are formed. The bosses 83 and 84 support a normally-upper spring member 87 which has secured thereto a contact button 88 made of a material having good electrical conductivity such as silver, platinum alloy, etc. The portion of the spring 87 that is remote from the contact button is wound around the bosses 83 and 84, whereby such spring is retained in proper position on the supporting insulating member 68. A cooperating spring member 89 has a contact button 91 secured thereto at one end and the other end is wound around the upstanding bosses 85 and 86. The free end of the spring member 89, that is, the end remote from the lugs 85 and 86, normally engages a shoulder portion 92 desirably molded on the insulating member 68, whereby the spring member normally is disposed in the position shown. The spring members constitute a safety switch adapted to close and open in response to rotary movement of a tumbler cam as will now be described.

Also disposed in the pocket 82 is a tumbler cam 64, which is pivotally mounted on the outer end portion of a stud 93 extending from the insulating portion 68. This cam has a pair of arms 94 and 95 defined by generally straight sides 96 and 97, making an obtuse angle about its hub portion 98. The side 96 is disposed at a distance from the axis of the stud 93 so that when in the position

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illustrated for the cam 65 in Figure 1, it pushes the spring contact member 87 down to cause engagement between the contact buttons 88 and 91. In the position illustrated in Figure 4, these buttons are allowed to disengage because the side 97 is sufficiently close to the axis of the stud 93 for that purpose. The generally straight side 97 is desirably inset or notched, as indicated at 90, to accommodate the adjacent end portion of the contact button 88.

Referring now particularly to Figures 2 and 3, the circular resistance wire 26 is shown mounted on a plastic ring 99 which is, in turn, supported as by means of screws 100 on posts 101 extending from a generally circular casting 102 having a peripheral flange 130. This casting is, in turn, secured to suitable posts extending from the frame of the recording and controlling instrument, as by means of screws 103. Outstanding from a central portion of the casting 102 is a hollow cylindrical portion or hub 104 carrying a bushing 105. This bushing is provided with a flange 106, near but not at its inner end, and an intermediate flange 107. The flange 106 carries a guide plate 108 and a gear wheel 109, both of which may be fitted over the bushing extension beyond the flange 106, separated by a washer 110, and secured thereto by suitable means such as screws 111. The guide plate 108 serves to keep the bushing 105 from coming off the hub 104, as by being held in a groove 112 in a keeper 113 secured to the casting 102 as by means of a screw 114. It may, if desired, be clamped in position after adjustment, as by means of a device similar to the keeper 113, except that the portion which defines the groove and which engages the face of the plate 108 remote from the casting 102, is separate from and tightened toward the body of the device by the holding screw.

The other flange 107, of the bushing 105, serves for the adjustable mounting of the switches 11 and 12, or one of them. This is accomplished by a clamping ring or mounting member 115, the body portion of which fits the aperture 71 in the hub 69 of one of the switch members, such as that designated 12. The ring 115 is provided with a flange 116 which, when in place, clamps over the outer face of said hub portion of the switch 12 to hold the switch in adjusted position, the body portion of the member 115, inwardly of the flange 116, being sufficiently short axially for that purpose. Screws 117 pass through clearance holes in the clamping ring 115 and are threaded into suitable holes in the flange 107, whereby the switch 12 is firmly clamped in any set position.

A similar clamping ring or mounting member 72 serves for adjustably securing the other switch member, such as that designated 11, over the first switch member. This ring is likewise secured in place by screws 119 which pass through the clamping ring 115, between the screws 117, and on to threadably engage the flange 107. It will be apparent, then, that one or both of the switches 11 and 12 may be set in any angular position on the bushing 105 by merely loosening the fastening screws 119 or 117, respectively, to release the clamping force between the flange 107 and the flanges of the members 115 and 72, respectively.

As a protection for the elements including the tumbler cam of each of the switches 11 and 12, there is desirably provided a protective plate 121 which overlies the pocket 82 and is secured to the insulating body portion 68 as by means of screws 122. This plate also is desirably formed of plastic and conforms in shape to the insulating body portion. Such plate is provided with an observation aperture 123 (see Figure 2) so positioned that the tumbler cam, which is desirably formed of white material such as molded nylon, is visible therethrough when in one switch-setting position but removed from view in the other. This is to show at a glance the position of the tumbler cam, and the corresponding switch setting, without removal of the protective plate. In the embodiment illustrated, the tumbler cam 64 is visible when in the

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position in which the switch contacts 88 and 91 are engaged, that is, in the position illustrated for the cam 65 in Figure 1, but not visible when in the position illustrated for the cam 64 in the same figure.

Referring again to Figure 3, the hub portion 104 pivotally carries a shaft 124, on the outer end of which is mounted a lever or arm 125. This shaft 124 is part of the mechanical linkage, designated 47 in Figure 1, for rotating the potentiometer slider by the armature of the control motor 39. In other words, the motor 39 is connected to the shaft 124 (by means not here shown) so as to turn the arm 125 and thereby move the potentiometer sliders 34, connected thereto by suitable means such as the screws 120, along the slide wire 26 to effect the desired balancing action previously described. It may here be pointed out that in the diagrammatic illustration of Figure 1, the potentiometer wire 26 is shown as a single wire. In actual practice, however, two such wires are used side by side and the slider 34 electrically bridges across the two wires. Consequently, in Figure 3 there are shown two resistance wires 26 and two sliders 34. The arm 125 also carries an insulating block 126 (see Figures 2, 3 and 5) which is secured to a plate 127 which is, in turn, mounted on the end of the arm 125 as by means of screws 128. The block 126 carries the brush contacts 66 and 67 (see Figure 1) secured thereto as by means of screws 129 which pass through overlying plates 131 and 132 (see Figure 3) which latter carry the cam-actuating tabs 62 and 63, respectively (see Figure 1).

Figures 5, 6 and 7 illustrate in detail how the brush contact members 66 and 67 may each be constructed and employed. Each contact member is formed from an elongated sheet or plate of resilient, durable, preferably cuprous metal. One end portion, which is that to the right as viewed in these figures, has an aperture 143 for receiving the screw 129, which connects the plate 131 and said brush contact to the insulator block 126. The other end portion of the member 66 is bifurcated to provide prongs 144 and 145, the free end portions of which are arcuately curved, as indicated at 146 and 147, with the convex or lower portions adapted, respectively, to make contact with the tracks 76 and 77 and the track 81.

Each arcuate or cylindrical portion of the brush contact desirably has on its convex or lower surface a silver insert 148, adapted for bridging the distance between the points of tangency with the curved end portions 149 and 151 of the longitudinally-spaced tracks 76 and 77, respectively, and desirably extending slightly therebeyond. This construction is shown most clearly in Figure 6, which illustrates this embodiment as contrasted with an alternative construction shown in Figure 5, in which the brush contact is formed homogeneously of resilient material with no insert. It will, therefore, be seen that by virtue of the curved portion 147, a condition is provided in which the two points of tangency occur at the same time as in Figure 6, that is, at some point in its travel the brush contact will simultaneously contact the two curved track end portions 149 and 151.

On the other hand, by bending the curved end portion 147 to a slightly smaller radius, as in Figure 5, these points of tangency do not occur simultaneously. There is then a time delay between the point at which the brush contact breaks contact with track 76, for example, and the point at which the brush contact engages track 77, the delay corresponding to the space between the curved end portion 151 and the curved portion 147 of the brush contact 66.

As shown in Figure 7, the long track 81 is parallel to and laterally spaced from the aligned tracks 76 and 77, all such tracks being secured in position on the insulating body portion 68 of the device and the major portions of their outer peripheral edges being coaxial. These tracks are electrically insulated from each other, and their outer peripheries extend slightly above the portion 68 as shown

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by the track 81 in Figure 4 and the tracks 76 and 77 in Figure 5. The bifurcated, curved ends of the brush contact 66 are adapted to electrically connect one or both of the tracks 76, 77 to the long track 81 as said brush is rotated in one direction or the other by the arm 125, see Figure 3.

As shown in Figure 4, the tumbler cam 64 is set so that the contact buttons 88 and 91 are in the open circuit position. Upon counterclockwise rotation of the brush contact 66 (from the position shown in Figure 5), the tab 62 will engage the arm 94 of the tumbler cam 64 and rotate such cam counterclockwise about its pivot axis 93, causing the pointed, lower corner of the cam to depress the spring member 87, thereby bringing the contact button 88 into physical and electrical contact with the cooperating contact button 91. Further rotation of the cam causes a flexure of both of the spring members 87 and 89 until the lower corner of the cam passes beyond, to the right of, the pivot axis 93, whereupon the combined tension of the spring members 87, 89 will cause the cam to flip over to a position where the spring member 87 is in surface contact with the flat cam side 96. As described hereinabove, the distance between the flat cam side 96 and the pivot axis 93 is greater than that between the flat cam side 97 and such pivot axis.

The cam dimensions are so proportioned that when the cam is in the position illustrated in Figure 4, the contact buttons 88 and 91 are separated. When the cam is flipped to its other position (upon counterclockwise rotation of the tab 62) the contact buttons are engaged and remain so engaged regardless of the further advance of the tab in the counterclockwise rotation. However, upon a subsequent clockwise rotation of the tab the tumbler cam is flipped back to its original position. In practice, the tumbler cam is flipped to one or the other position when the brush contact 66 is positioned in about the center of the track 76. Circuitwise, the contact buttons 88, 91 serve as a safety means to restore the apparatus to the control function prevailing at the time of a temporary power failure and as a means to start heating the furnace from a cold or starting condition, as will be described hereinbelow.

Reference is now made specifically to Figure 2. Visible in this view is one of the potentiometer sliders 34 rotatable by the arm 125 along the circular resistance wire 26, said wire and slider constituting a portion of the measuring circuit 161 shown in Figure 1. Also shown are the two control switches 11 and 12 mounted coaxially on the shaft 124. Upon loosening the fastening screws 119, the outer control switch 11 can be rotated about the shank of the mounting member 72 to angularly position the control switch at any desired point relative to the position of the slider, that is, to set the control point at a selected temperature value.

The position of the slider 34 corresponds precisely to the temperature of the furnace (in terms of thermocouple voltage) as indicated by the position of the indicating pointer 58, see Figure 1, relative to the scale 59 of temperature values, and the position of the effective operating point of the control switch is indicated by the pointer or index 152, which is mechanically coupled to the control switch by suitable means, not shown in the drawings. Once the control switch 11 is set at the desired operating point it is secured in such position by merely tightening the fastening screws 119. It may here be pointed out that the other control switch 12 similarly is settlable to a desired control point after first loosening the fastening screws 117, and then tightening them to maintain said switch in set position.

From the above description it will be clear that one or more control switches, of the illustrated construction, can readily be mounted on the shaft of a self-balancing, potentiometric recorder and each such switch is positionable to a desired control point anywhere within the op-

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erating range of the recorder. When once so positioned, the actual operation from "on" to "off" position, or vice versa, is effectuated by the movement of the brush contact which is rotated, by the arm 125, simultaneously with the potentiometer slider.

Operation

Figure 1 shows an arrangement for three-position control. However, by using only the single switch 12, a two-position control may be effected and this operation will be first described. In general, in a two-position controller, the means which supplies the media determining the condition (or in this case the means which supplies the power to the heating element 15 in the furnace) is full on when the measured variable falls below the control set point, and when the measured variable rises above the control set point, the media determining the condition, valve or heating element 15, is turned full off. If power is applied in two successive steps instead of one, the action is called "three-position control" and is as here fully illustrated although diagrammatically.

By connecting the controller in the circuit of a solenoid valve, for example, the flow of fuel to a furnace could be turned on and off and thus the temperature would be controlled at a desired set point. As shown in Figure 1, however, the controller energizes and deenergizes the electromagnet 22, or 21 and 22, of a contactor relay for controlling an electric furnace.

In the two-position control action, now being described, the second control switch 11 may be ignored, it being understood that in this only the single control switch 12 is mounted in the recorder-controller instrument. When the furnace temperature is below the control set point, as indicated by the positions of the indicating pointer 58 and the control index 152 relative to the scale 59, the brush contact 67 (of the control switch 12) engages the long track 81 and the short track 76, as shown. The moment the brush contact bridges these two tracks an electrical circuit is completed to the operating coil 133 of the power relay 159, the circuit being traced as follows: lead 135 from one side of a suitable power source, track 76, brush contact 67, track 81, lead 156, relay coil 133, and the current-limiting resistor 134 which is connected to the other side of the power source.

Energization of the relay coil 133 causes a closure of two sets of relay contacts, as shown. One set of contacts, namely, contacts 137 and 157, constitute holding contacts connected across the tracks 76, 81. Consequently, when the relay is energized it locks-in and remains so even though the brush contact 67 advances further in a counterclockwise direction beyond the limits of the tracks 76, 81.

The other set of relay contacts, namely, contacts 136 and 142, control the energization of the electromagnet 22, of the contactor relay, by a voltage source connected to the line switch 43. This circuit can be traced as follows: lead 138, coil 22, lead 139, closed relay contacts 136 and 142, and the lead 155. When energized, the coil 22 causes a closure of the associated contacts which connect the heating element 15 across a power source connected to the leads 16 and 19.

Obviously, if the power requirements are not large, the contacts 136, 142, of the power relay 159 can be utilized to conduct power directly to the heating element. If the furnace were oil- or gas-fired, this conduction of power would be in a circuit, not here shown, to move toward fully open position a valve for supplying fuel or other condition-determining media to the furnace or other device being controlled. As stated hereinabove, when the brush contact moves in a counterclockwise direction to approximately the midpoint of the short track 76, the tab 63 causes the tumbler cam 65 to flip in a counterclockwise direction about its pivot axis, thereby closing the contact buttons 88, 91, as shown. Since the power relay 159 has already been energized and locked-in, the

contact buttons close under a no-current-carrying condition. It is apparent that should there occur a momentary power failure at a time when the brush contact is in a position connecting the two tracks 81 and 76, such connection will immediately close the power relay 159 upon restoration of the power and thereby apply power to heat the furnace.

Assume now, that the furnace is started up from a cold condition. In such case, the brush contact may be positioned to the left and beyond the tracks 81, 76. Since it is these tracks which control the closure of the power relay 159, heat would not be applied to the furnace. However, the contact buttons 88 and 91 are closed for all positions of the brush contact to the left (downscale) of approximately the center of the track 76, and since the contact buttons are connected in parallel across the tracks 76, 81, the energizing circuit to the relay coil 133 is closed through these contact buttons. Hence, the closed contact buttons 88, 91 serve to apply heat to the furnace from a cold start upon the closure of a suitable line switch inserted in the power line.

As the furnace temperature increases, the motor 39 rotates the potentiometer slider 34 in a direction to maintain circuit balance with the increasing voltage generated by the thermocouple. Such movement of the slider is accompanied by a corresponding clockwise rotation of the brush contact 67 and the tab 63. As the brush contact passes to the right a short distance beyond the center of the track 76, the tab 63 flips the tumbler cam 65 to its other position wherein the contact buttons 88, 91 are separated, as shown by the corresponding parts in the control switch 11.

However, since the brush contact still engages the tracks 76 and 81, the relay 159 remains locked-in. A further clockwise movement of the brush contact eventually causes the brush contact to electrically connect the other short track 77 to the long track 81. Inasmuch as the tracks 81, 77 are connected by leads to opposite sides of the relay coil 133, the relay coil is short-circuited the moment the brush contact connects together the tracks 81 and 77, whereupon the relay drops out and the application of heat to the furnace is stopped. If, on the other hand, an oil- or gas-fired furnace were being controlled, the release of the coil 133 would effect a reengagement of the relay contact 136 of the power relay 159 with the upper contact 160 and energize a reversing circuit, not here shown, for closing the fuel valve or cutting off the condition-determining media.

The subsequent cooling of the furnace again produces a counterclockwise rotation of the brush contact and cam-operating tab to the point where the contact brush again bridges the tracks 76 and 81 whereby the power relay 159 is again energized. After one or more cycles of operation the temperature of the furnace does not vary materially from the control set point and the brush contact slowly oscillates to connect one or the other of the short tracks 76, 77 to the long track 81. Obviously, the extent of brush contact movement below or above the control set point is a factor related to the lag between the actual furnace temperature at the heating element 15 and the thermocouple 23.

The brush contact 67 is adapted to contact simultaneously both of the longitudinally-spaced short tracks 76, 77 in each direction of travel, whereby the relay 159 will open and close at the identical temperature point, that is, there is no differential between the "on" and the "off" operating points of the controller. This is a highly desirable feature in certain control operations. However, the control switch is not limited to such zero differential operation. As shown in Figure 6, the upper edge of the spacing member 80, which forms the gap between the longitudinally-spaced short tracks 76, 77 lies somewhat below the upper surface of the tracks on which the brush contact 66 rides. If the radius of curvature of the curved brush portion 147 is relatively large,

it is apparent that the brush contact will simultaneously engage both tracks as the brush contact rotates in either a clockwise or counterclockwise direction.

Specifically, if it be assumed the brush contact 66 is riding on the track 77, a counterclockwise rotation of the brush will result in an electrical contact between both tracks 76 and 77 before the brush contact leaves the track 77. Upon clockwise rotation, the brush contact will result in an electrical connection between the two tracks before the brush contact leaves the track 76. This results in the identical point for "on" and "off" operation of the power relay, mentioned above.

In order to provide a differential between the "on" and "off" operating points, the radius of curvature of the brush contact is made somewhat smaller, as shown in Figure 5. Here, it will be apparent that upon clockwise rotation, the brush contact 66 will leave the track 76 prior to its contact with the track 77. Thus, a desired differential between the "on" and "off" set points of the controller can be effected, either by forming the brush contact curvature on a smaller radius or increasing the height of the spacing portion 80, or both. Although not shown in the drawings, the spacing member 80 can be formed as a separate piece of insulating material and adjustably secured to the body portion of the control switch. This affords a convenient means for adjusting, to a desired degree, the differential between the effective "on" and "off" operating points of the control system.

The use of a second control switch, that is, the use of two control switches 11 and 12 rather than only one, is necessary to give three-position control, and said switches are also disposed in angular relationship to one another as in Figures 1 and 2. The two brush contacts 66 and 67, as well as the brush tabs 62 and 63, are moved as a unit, however, in serially operating the control switches 11 and 12 after they have been clamped in the desired position with respect to one another. Contacts 76 and 81, of the control switch 12, actuate the power relay 159 to bring about the energization of the primary heating element 15. The similar contacts of the control switch 11 actuate the power relay 159', whose upper contacts energize the solenoid 21, the latter closing the associated contacts to connect the auxiliary heating element 14 to the power source. In such arrangement, when the furnace temperature once reaches the control set point, the movement of the two brush contacts is relatively small. Barring a sudden, substantial cooling of the furnace, the brush contact 67 of the primary control switch will remain in contact with the tracks 76, 81, and the brush contact 66 of the auxiliary control switch will oscillate across the gap between the aligned, short tracks to bring about periodic energization of the auxiliary heating element 14 to compensate for the heat loss of the furnace. The setting of one or both of the control switches may be indicated with respect to the scale 59 by one or two indicators, such as the index 152, through appropriate linkage arrangements.

It will be seen, therefore, that the arrangement shown in Figure 1 provides for energizing both heating elements when the furnace is started up from cold. As the temperature rises, one heating element is cut out in anticipation of reaching the temperature for which the controls are set and, finally, both heating elements are cut out. As the furnace temperature decreases, a reverse operation takes place, all of which results in a closer control of the furnace temperature.

It is pointed out that the energizing and short-circuiting of the power relays is accomplished by the brush contacts of the control switches sliding along the upper edges of the associated tracks. These parts preferably are made of relatively heavy materials to promote long, trouble-free operation. On the other hand, the contact buttons never open a current-carrying circuit and never close an active electrical circuit and, therefore, there is no electrical arcing as the buttons engage and

disengage. Consequently, these parts also have a long, trouble-free operating life.

Once the control function, either "on" or "off," has been effected by the brush contact, such contact is free to advance in the control-initiating direction to an extent defined by the limits of travel of the rotatable supporting arm 125, see Figure 2. The tumbler cam of the control switch is so formed that its toggle-like rotation from one to the other position clears the path for further movement of the actuating tab.

As is apparent from a study of Figure 2, the control switch, or switches, can be set at any point over an angle of 360°. In practice it is desirable to permit the potentiometer slider 34 to rotate somewhat beyond the point at which the control switch is set and for this reason the effective angular range within which the control switch can be set slightly less than the angular range of rotation of the slider. A control switch for use in a self-balancing, potentiometric-type instrument, having a circular resistance wire, must be setttable to provide a control function at any point within the arcuate length of the resistance wire. At the same time, the control switch, regardless of its specific set position, must not interfere with the potentiometer slider as it moves from one end to the other of the resistance wire.

In the Figure 2 arrangement, which is more or less conventional in this art, the circular resistance wire 26 has an arcuate extent of approximately 340° and, obviously, corresponds to the effective length of the scale 59 shown in Figure 1. If now, the control switch is set to the midscale position, the potentiometer slider must be free to move $340/2=170^\circ$ beyond the control point setting. However, if the control switch is set just slightly above the lower end of the scale, the slider must be free to move approximately the full 340° in the up-scale direction, whereas when the control switch is set just slightly below the upper end of the scale, the slider must be free to move approximately 340° in the downscale direction. It will be seen, therefore, that the control switch must have an effective operational range of about twice the angular extent of the potentiometer, or 680°. Heretofore this requirement has been met by providing a gear reduction arrangement between the slider and the operating member of the control switch and/or by an elaborate construction of the control switch. I have met this requirement by a construction which is of simple character and which permits a quick and convenient means for adjustably mounting the control switch directly on the potentiometer mechanism.

Having now described my invention in detail in accordance with the requirements of the Patent Statutes, those skilled in this art will have no difficulty in making changes and modifications in the individual parts or their relative assembly in order to meet specific requirements or conditions. Such changes and modifications may be made without departing from the scope and spirit of the invention, as set forth in the following claims.

I claim:

1. A control member comprising an insulating body member with an aperture to receive a carrying shaft; a pair of conductive tracks disposed end to end and carried by the body member, said tracks being arcuate at a uniform radius about said aperture and separated by a gap; a third track carried by the body member, said third track being in a plane parallel to the said pair of tracks, coaxial and substantially coextensive therewith; a switch comprising a pair of contact members resiliently biased to a normally open position; and switch-actuating means carried by the body member and movable to a first position to close said contact members and to a second position to allow said contact members to open.

2. A control member comprising an insulating body member with an aperture to receive a carrying shaft; a pair of conductive tracks disposed end to end and mounted on one side of said insulating body member,

said tracks being arcuate at a uniform radius about said aperture and separated by a gap; a third track mounted on the other side of said insulating body member, said third track being in a plane parallel to the said pair of tracks, coaxial and substantially coextensive therewith; a switch comprising a pair of contact members resiliently biased to a normally open position; and a tumbler cam carried by the body member and movable to a first position to close said contact members and to a second position to allow said contact members to open.

3. The invention as recited in claim 2, in which there is a power relay including an operating coil connected to a circuit through a lead from one side of a suitable power source to one of said pair of tracks, a lead from the third track to one terminal of said operating coil, a lead from the other terminal of said operating coil through a current-limiting resistor to the other side of said power source, a lead between said other side of said operating relay and the other of said pair of tracks, a lead between one of said pair of contact members and the first of said pair of tracks, a lead between the other of said pair of contact members and the third track, and relay contacts controlled by said operating coil so that when the coil is energized there is a direct connection between the first side of said power source and said third track and a circuit is closed to a source of condition-determining power, whereas when the operating coil is deenergized the circuit to the source of condition-determining power is opened and the circuit from the first-mentioned side of the power source to the third track is also opened.

4. The invention as recited in claim 2, in which the cam is colored and an opaque protective plate is secured to the insulating member over the spring contact members and cam, said plate having an aperture through which the cam is visible only when in one of its two positions.

5. A control member comprising a generally flat insulating body portion with an aperture to receive a carrying shaft perpendicular thereto, said body flaring in width away from said aperture, the outer edge of said body being generally circular about said aperture and inset at each face, a conductive track carried in the inset on one face of said body and a pair of conductive tracks carried in the other inset on the opposite face of said body, said pair of tracks being separated by a non-inset portion of said insulating body and having their adjacent end portions terminated on curves, that portion of said insulating body at the face carrying the first-mentioned track being pocketed, a pair of resilient contact members mounted in said pocketed portion and formed as springs, one end portion of each of said springs being mounted in said pocketed portion and the other end portion of each spring carrying a contact button, said springs normally disposed with the buttons spaced from one another, and a two-position tumbler cam pivoted in said pocketed portion and formed generally bell-crank shape in elevation, certain edges of its arms being generally straight and diverging from a junction with one another, with one of said edges closer than the other to its pivot, whereby when the cam is in a position, with one of said straight edges engaging the adjacent spring, the contact buttons are separated, and when in the other position with the other straight edge engaging the adjacent spring, said spring is pushed toward the other spring so that the buttons are engaged.

6. A control switch comprising a first member and a second member relatively rotatable about a common axis; means to set the first member at a predetermined fixed position; laterally-spaced tracks of conductive material carried by the first member and lying in parallel planes at a uniform distance from said axis; and a brush contact carried by the second member and adapted to slidably contact the said tracks upon rotation of the second member relative to the first member.

7. The invention as recited in claim 6 including a pair of resilient contact members carried by said first member; and means carried by the second member to close and open the contact members upon a predetermined movement of the second member relative to the first member.

8. A control switch comprising a first member and a second member relatively rotatable about a common axis; means to set the first member at a predetermined fixed position; a pair of laterally-spaced conductive tracks carried by the said first member; resiliently-mounted auxiliary contacts carried by the first member; a cam member rotatably secured to the said first member and adapted to actuate the auxiliary contacts; a brush contact and a cam-actuating member carried by the said second member; the arrangement being such that upon rotation of the second member relative to the first member the brush contact slidably engages the said tracks and the cam-actuating member rotates the cam member to actuate the auxiliary contacts.

9. The invention as recited in claim 8, wherein one of said tracks is segmented with a gap between adjacent track ends.

10. The invention as recited in claim 9, wherein the brush contact includes an arcuate portion having a radius of curvature such that the arcuate portion spans the distance between the adjacent ends of the segmented track.

11. In an instrument for controlling a condition, in combination, a bushing provided with a positioning flange near its inner end and an intermediate flange spaced outwardly therefrom, a control member comprising an insulating body member with a hub apertured to receive said bushing in order to abut said intermediate flange, a clamping ring with a body portion which is receivable in the aperture in said body portion and which is in turn apertured to fit said positioning bushing and receive holding screws, an exterior clamping ring flange to overlie the hub of said insulating body member, and means, for clamping said ring with its flange over said hub to hold it in any set position with respect to said bushing, comprising a plurality of screws passing through screw-receiving apertures in said ring and threadably engaging said intermediate flange.

12. In an instrument for controlling a condition, in combination, a generally circular casting, means connecting said casting to said instrument, a hollow cylindrical portion extending axially from said casting for receiving a shaft forming part of the instrument control mechanism, a bushing carried on said cylindrical portion, said bushing being provided with a positioning flange near its inner end and an intermediate flange spaced outwardly therefrom, a control member comprising an insulating body member with a hub apertured to receive said bushing in order to abut said intermediate flange, a clamping ring with a body portion which is receivable in the aperture in said body portion and which is in turn apertured to fit said positioning bushing and receive holding screws, an exterior clamping ring flange to overlie the hub of said insulating body member, and means, for clamping said ring with its flange over said hub to hold it in any set position with respect to said bushing, comprising a plurality of screws passing through screw-receiving apertures in said ring and threadably engaging said intermediate flange.

13. In an instrument for controlling a condition, in combination, a generally circular casting, means connecting said casting to said instrument, a hollow cylindrical portion extending axially from said casting for receiving a shaft forming part of the instrument control mechanism, a bushing carried on said cylindrical portion, said bushing being provided with a positioning flange near its inner end and an intermediate flange spaced outwardly therefrom, a first control member comprising an insulating body member with a hub apertured to receive said bushing in order to abut said intermediate flange, a first clamping ring with a body portion which is receivable

in the aperture in said body portion and which is in turn apertured to fit said positioning bushing and receive holding screws, an exterior clamping ring flange to overlie the hub of said insulating body member, means for clamping said ring with its flange over said hub to hold it in any set position with respect to said bushing, comprising a plurality of screws passing through screw-receiving apertures in said first ring and threadably engaging said intermediate flange, a second control member like the first, a second clamping ring like the first, and means, for clamping said second control ring with its flange over the hub of said second control member while on said bushing beyond said first control member, comprising a plurality of screws passing through screw-receiving apertures in said second ring, through such apertures in said first ring between the first-mentioned screws therein, and threadably engaging said intermediate flange.

14. An arrangement for a self-balancing potentiometric instrument for controlling a condition, including a slider movable over an arcuate resistance wire, said arrangement comprising a control member having an insulating portion and mounted to rotate, first and second coplanar arcuate conductive tracks mounted on said insulating portion, disposed end to end and spaced at their adjacent ends by a gap, a third arcuate conductive track in a plane parallel thereto on said insulating portion and substantially coextensive therewith, a tumbler cam and switch controlled thereby mounted on said insulating portion, said control member being manually rotatable to set it for maintaining the condition at a selected point, an arm mounted to rotate coaxially with said control member, means for rotating said arm with said slider, so that it moves in a direction from the first to the second track as the condition increases in intensity and in the opposite direction upon a decrease, an insulating portion carried by said arm, a brush contact mounted on said arm-carried insulating portion for as the arm rotates alternately bridging the distance between the first and third tracks and that between the second and third tracks, a tab also mounted on said arm-carried insulating portion to as the arm rotates actuate said cam to open and close its switch, means for rotating said arm as the condition varies so as to restore the condition to that corresponding with the setting of the control member, and a circuit controlled by movement of said brush contact, including power-relay-controlled contacts for connecting and disconnecting condition determining media in accordance with variations in the condition being controlled.

15. An arrangement for a self-balancing potentiometric instrument for controlling a condition, including a slider movable over an arcuate resistance wire, said arrangement comprising a control member having an insulating portion and mounted to rotate, first and second coplanar arcuate conductive tracks mounted on said insulating portion, disposed end to end and spaced at their adjacent ends by a gap, a third arcuate conductive track in a plane parallel thereto on said insulating portion and substantially coextensive therewith, a tumbler cam and switch controlled thereby mounted on said insulating portion, said control member being manually rotatable to set it for maintaining the condition at a selected point, an arm mounted to rotate coaxially with said control member, means for rotating said arm with said slider, so that it moves in a direction from the first to the second track as the condition increases in intensity and in the opposite direction upon a decrease, an insulating portion carried by said arm, a brush contact mounted on said arm-carried insulating portion for as the arm rotates alternately bridging the distance between the first and third tracks and that between the second and third tracks, a tab also mounted on said arm-carried insulating portion to as the arm rotates actuate said cam to open and close its switch, means for rotating said arm as the condition varies so as to restore the condition to that corresponding with the setting of the control member,

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and a circuit to a power relay including an operating coil, provided by a lead from one side of a suitable power source to said first track, a lead from the third track to one terminal of said operating coil, a lead from the other terminal of said operating coil through a current-limiting resistor to the other side of said power source, a lead between said other side of said operating relay and the second track, a lead between one terminal of the tumbler-cam-controlled switch and the first track, a lead between the other terminal of said tumbler-cam-controlled switch and the third track, and relay contacts controlled by said operating coil so that when the coil is energized there is a direct connection between the first side of said power source and said third track and a circuit is closed to a source of condition-determining power, whereas when the operating coil is deenergized the circuit to the source of condition-determining power is opened and the circuit from the first-mentioned side of the power source to the third track is also opened, whereby as the intensity of the condition increases and the brush contact moves from a position where it does not engage any of said tracks to where it engages the first and third tracks it thereby provides a shunt across the tumbler-cam-controlled switch, whereupon the tab turns the cam and opens its switch, and finally the brush contact bridges the distance between the second and third tracks to thereby provide a short circuit across the operating coil to release its contacts and cut off the condition-determining power.

16. In an instrument for controlling a condition, in combination, a pair of relatively movable members, one of said members comprising an insulating portion, first and second conductive tracks disposed end to end and separated at their adjacent ends by a gap defined by a part of said insulating portion, a third conductive track in a plane parallel thereto and extending a distance generally corresponding to that between the extreme ends of said first and second tracks, the other member also comprising an insulating portion, a brush contact member mounted on said other member insulating portion for alternately bridging the distance between the first and third tracks and that between the second and third tracks, said contact being formed of resilient metal with a stem portion secured to the insulating portion of said other member and a movable end portion bifurcated and curved to generally hollow cylindrical form, one of said bifurcated end portions engaging the third track and the other adjustably curvable so that it selectively engages one of the first and second tracks immediately upon disengagement with the other of said first and second tracks.

17. In an instrument for controlling a condition, in combination, a pair of relatively movable members, one of said members comprising an insulating portion, first and second conductive tracks disposed end to end and separated at their adjacent ends by a gap defined by a

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part of said insulating portion, a third conductive track in a plane parallel thereto and extending a distance generally corresponding to that between the extreme ends of said first and second tracks, the other member also comprising an insulating portion, a brush contact member mounted on said other member insulating portion for alternately bridging the distance between the first and third tracks and that between the second and third tracks, said contact being formed of resilient metal with a stem portion secured to the insulating portion of said other member and a movable end portion bifurcated and curved to generally hollow cylindrical form, one of said bifurcated end portions engaging the third track and the other adjustably curvable so that it selectively engages one of the first and second tracks after a predetermined distance interval.

18. A control member comprising an insulating body, a pair of conductive tracks disposed end to end and carried by said body, said tracks being arcuate at a uniform radius about an axis and separated by a gap, and a third track carried by said body and arcuate about said axis at the same radius, said third track being in a plane parallel to said pair of tracks and substantially coextensive therewith.

19. The invention as recited in claim 18, wherein the insulating body has an aperture to receive a carrying shaft, and the tracks are arcuate about said aperture.

20. A control member comprising an insulating body, a switch carried thereby and comprising a pair of contact members resiliently biased only to a normally open position, and switch actuating means also carried by said body and movable to a first position to close said contact members and to a second position to allow said contact members to open.

21. The invention as recited in claim 20, wherein the switch actuating means comprises a tumbler cam.

22. A control member comprising a generally flat insulating body portion, an edge of said body being generally circular, said body portion being inset at each face adjacent said edge, a conductive track in the inset on one face of said body, and a pair of conductive tracks in the other inset on the opposite face of said body, said pair of tracks being separated by a non-inset portion of said insulating body.

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