Oct. 9, 1951 W. F. MULLER 2,570,968

POTENTIOMETER

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Fig. 2.

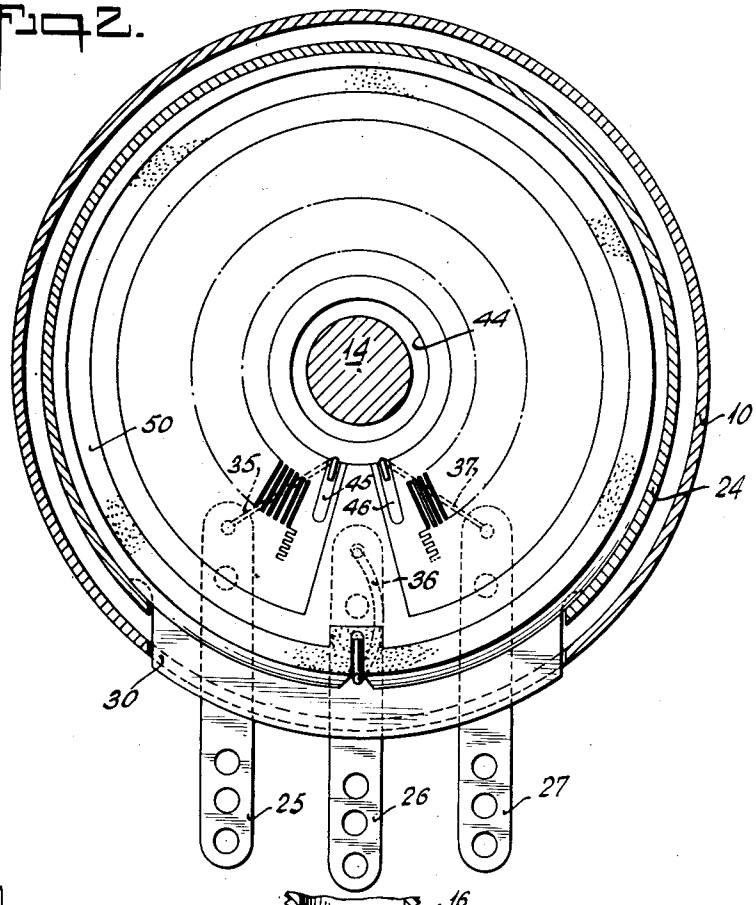
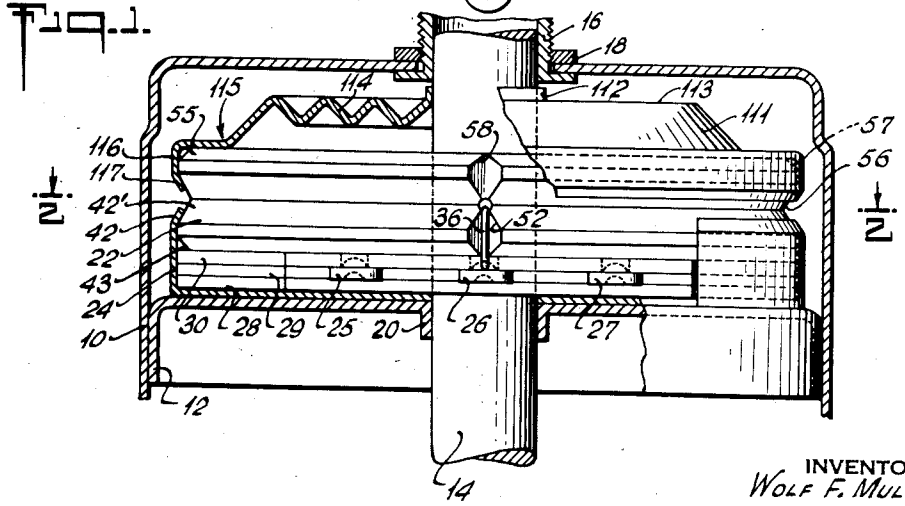


Fig. 1.



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POTENTIOMETER

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Fig. 3.

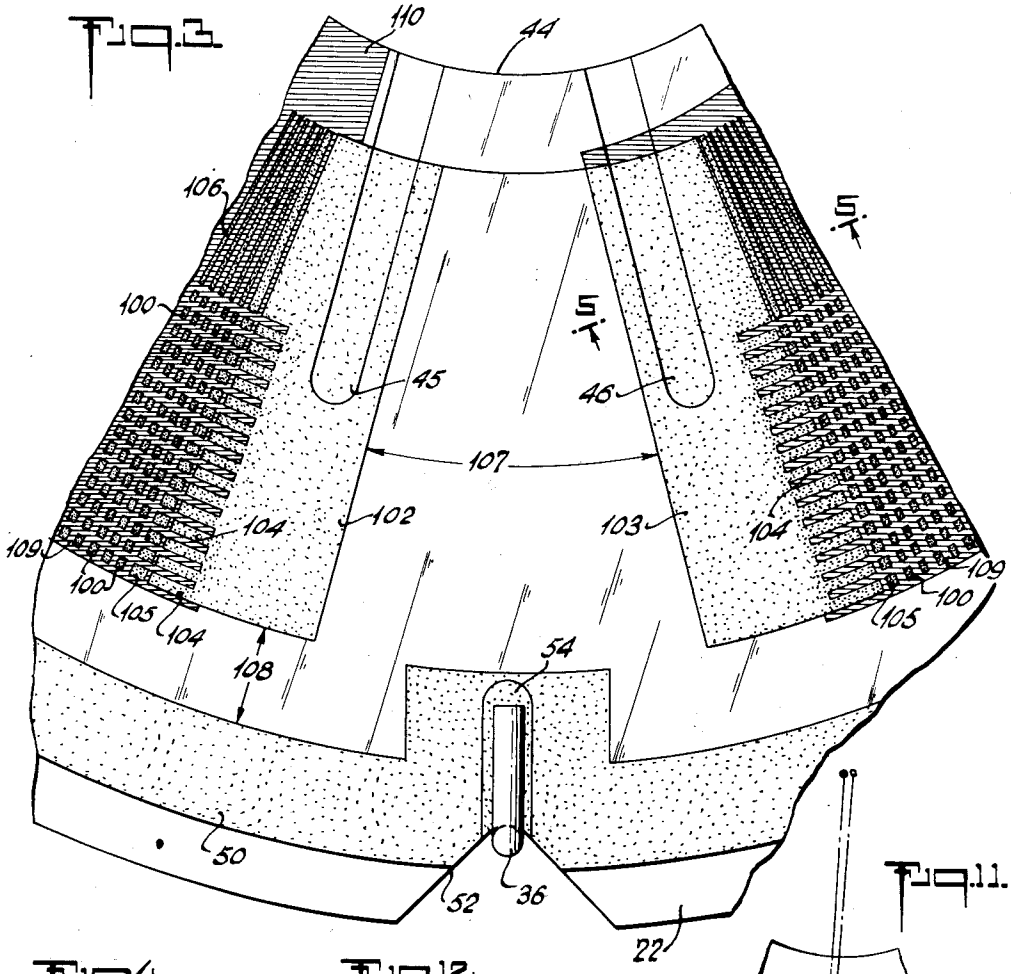


Fig. 11.

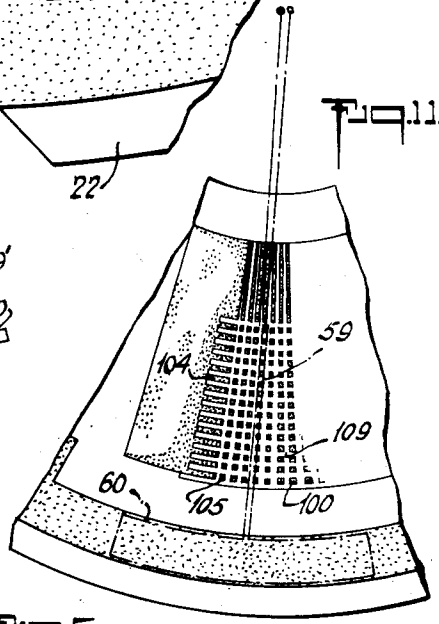


Fig. 4.

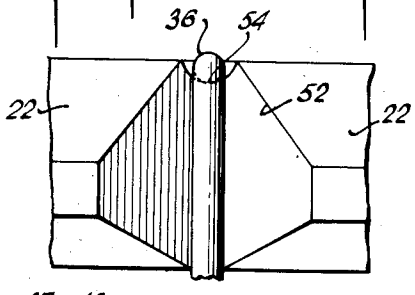
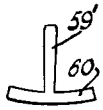


Fig. 12.



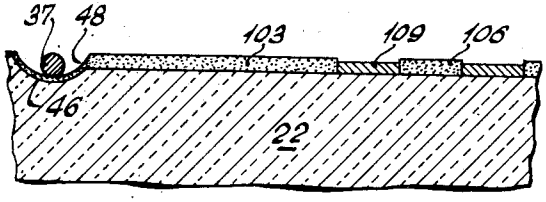


Fig. 5.

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POTENTIOMETER

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Fig. 6.

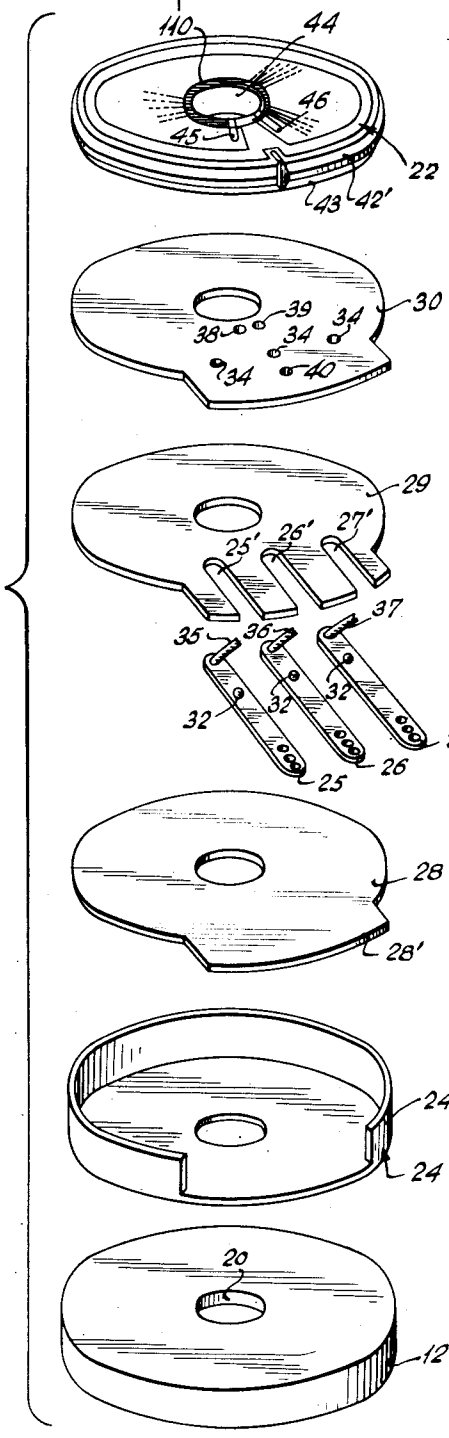


Fig. 7.

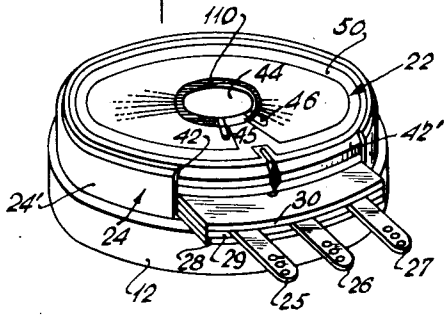


Fig. 8.

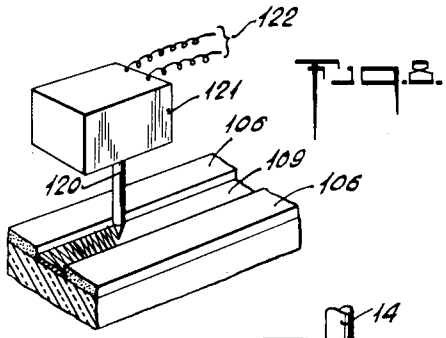


Fig. 9.

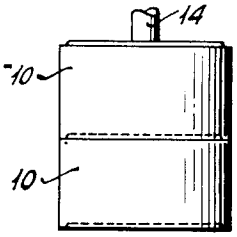
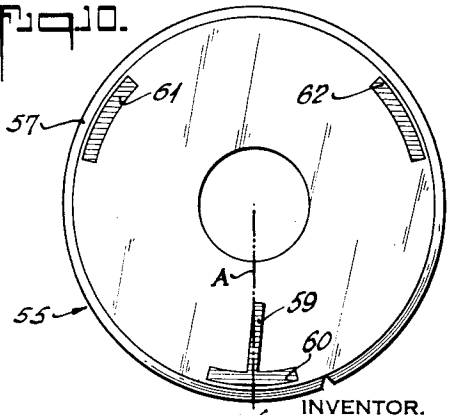


Fig. 10.



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Patented Oct. 9, 1951

2,570,968

UNITED STATES PATENT OFFICE

2,570,968

POTENTIOMETER

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Application August 23, 1950, Serial No. 181,031

16 Claims. (Cl. 201—55)

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This invention relates to variable resistors and more particularly to a new and improved potentiometer structure and method of making the resistance element to reduce contact noise and at the same time obtain very small but positive resistance changes with movement of the contact arm so that for all practical purposes the change in resistance can be considered a linear function rather than a stepped function inherent in wire wound resistors.

Potentiometers known today generally fall in one of three classes, namely, wire wound, carbon and stepped, the latter being of the type wherein the moving arm contacts a series of positive contactors in succession and which contactors are connected one to the other by suitable resistance means.

Wire wound resistors inherently have a stepped function because the contactor rides on one side of a toroidal like winding and thus changes resistance by contacting successive turns. Although these resistors can be made to be extremely stable, in certain critical circuits the stepped function is objectionable. Furthermore, wire wound resistors capable of being incorporated in a case not over one or two inches in diameter are usually limited to resistances less than 10,000 ohms although with great difficulty they can be made with overall resistance values of the order of 50,000 to 100,000 ohms.

Carbon resistors have an advantage over the wire wound potentiometer in that there is practically no upper limit of resistance although they are limited somewhat at the lower end. Carbon resistors are usually not made below 1,000 to 5,000 ohms. Although these resistors are useful for volume control in radio receivers and the like they are not at all reliable for critical control circuits since the resistance changes with humidity as well as with the current flowing through the carbon. Furthermore, they are inherently noisy and this noise increases materially with use. This carbon resistor has the advantage of the wire wound resistor in that it does not have the stepped function but may be perfectly linear.

The stepped potentiometer is one wherein a series of positive contacts are provided usually in circular arrangement so that the contact arm may contact each of these contactors successively during its rotation from one end position to the other end position. In this type of control resistance material which may either be carbon or metallic is connected between successive contactors. This control has the obvious disadvantage in that it completely departs from the desired linear function but it has the advantage of low contact noise.

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The potentiometer in accordance with this invention is more nearly similar to the stepped control in that it is so constructed as to provide predetermined resistance steps throughout the rotation of the contact arm. In this way low contact noise is obtained which is an important characteristic of the stepped type of potentiometer. With this invention, however, a material improvement in the stepped control is obtained since the contacts have been so constructed and arranged as to provide individual resistance steps that are so minute in character as to produce a virtually linear resistance change that is substantially equivalent to the degree of linearity of the carbon control. Because of the particular structure and arrangement of the contacts and their relationship to the contact arm stable materials may be employed to provide the desired resistance between successive contactors which will enable the production of potentiometers wherein the resistance range obtainable will be substantially equivalent to the combined resistance ranges obtainable by wire wound and carbon resistors.

In addition to the above enumerated advantages of this invention it provides means for accurately calibrating the resistor to obtain substantially any desired resistance taper (change in resistance vs. angle of rotation) and provides a simple and inexpensive structure for the attainment of these ends.

The above and other objects of this invention will become more apparent in the following description and drawings forming part of this application.

In the drawings

Fig. 1 is a cross-sectional view of a potentiometer in accordance with the invention.

Fig. 2 is a cross-sectional view of Fig. 1 taken along the line 2—2 thereof to show a plan view of the resistance element.

Fig. 3 is a greatly enlarged view of the resistance element shown in Fig. 2 to illustrate more clearly the construction thereof.

Fig. 4 is a side view of part of the resistance element shown in Fig. 3.

Fig. 5 is a cross-sectional view on an enlarged scale of the resistance element shown in Fig. 3 and taken along the line 5—5 thereof.

Fig. 6 is an exploded view of a portion of the potentiometer shown in Fig. 1.

Fig. 7 is a perspective view of the assembly of the elements shown in Fig. 6.

Fig. 8 is a diagrammatic illustration of one method of calibrating the potentiometer.

Fig. 9 illustrates the arrangement of two or more potentiometers of the character shown in Fig. 1 in a tandem unit for simultaneous and synchronized operation thereof.

Fig. 10 is a plan view of the contactor for use with the resistance element shown in Fig. 3.

Fig. 11 illustrates diagrammatically the relationship between the contactor of Fig. 10 with the individual contacts forming part of the resistance element shown in Fig. 3; and

Fig. 12 illustrates another form of movable contactor.

The structure of the volume control is shown in Figs. 1, 6 and 7. It comprises an outer housing 10, an internal base member 12 and a central rotatable shaft 14, rotation of which produces a change of resistance between the contact arm and the end terminals of the resistor element. The shaft 14 is supported centrally of the housing 10 and base 12 in any suitable manner. For example a bushing 16 may be securely fastened to the housing 10 by a nut 18 and in the base 12 a central bushing 20 may be formed integrally therewith or secured thereto in the manner shown in connection with the bushing or bearing 16.

The element 22 is firmly mounted on the base 12 by a cylindrical cup 24 that has a short section of the side wall 24' removed for accommodation of the terminal means 25, 26 and 27 and the associated insulating wafers 28, 29 and 30.

In the assembly of element 22 on the base 12 the cup shape member 24 is welded or otherwise fastened to the upper surface of the base 12 and the insulator 28 is placed within the cup shape member 24 with the outstanding edge part 28' of the wafer 28 passing outwardly through the opening formed by the removal of a section of the wall 24'. On the top of wafer 28 is placed the wafer 29 having elongated slots 25', 26' and 27' into which are fitted the terminals 25, 26 and 27. A third wafer 30 is placed over the wafer 29 to insulate the top side of the terminals and cooperate with the terminals to hold them in place. For this purpose small studs or protrusions 32 are formed on each of the terminals 25 to 27 which cooperate with openings 34 in the wafer 30 to lock the terminals in position in their respective slots. The terminal lead wires 35 to 37 of the terminals 25 to 27 are preferably soldered to the inner ends of the terminals. The lead wires 35 and 37 are brought up through the wafer 30 by means of the openings 38 and 39 while the lead wire 36 which is ultimately connected to the movable contactor is brought upwardly through the opening 40 in the wafer 30.

The element 22 is then placed on top of the wafer 30 within the cup 24 with the side of the element to be contacted by the movable contactor in the upward or outer position. The upper edge of the wall 24' is then swedged inwardly as shown at 43 to retain the wafers and terminals in the cup shape member 24 as an electrical subassembly of the control. The central opening 44 of the element 22, together with the corresponding openings in the insulating elements 28, 29 and 30 are made slightly larger in diameter than the central shaft 14 in order to prevent any friction between the shaft and those openings. The opening 44 in the element 22 must also accommodate the lead wires 35 and 37 which pass upwardly through the openings 38 and 39 in the insulating member 30 so that they may be bent forwardly and lie wholly within recesses 45 and 46 in the upper side of the element 22 to form the terminal connections for the element. It might be pointed out at this time that the end strips 102 and 103 along the ends of the element (see Fig. 3) which include the recesses 45 and 46 are coated with a conductive material so that the wires 35 and 37 can be fastened thereto by soldering or other similar process. The recess 46 is perhaps more clearly shown in Fig. 5 and the wire 37 is shown as being soldered to a layer of conducting material 48 such as silver or the like.

The center terminal 26 is connected to a conductive rim 50 formed on the upper surface of the resistance element 22. This rim is insulated from the resistance element as will be described and connection is made thereto by wire 36 which passes upwardly through the opening 40 in the insulating wafer 30 and a V-shaped opening 52 in the edge of the element 22 and is bent inwardly to lie flat in a recess 54 coated with a conductive material and forming a part of the annular ring 50. The body of the resistance element 22 is preferably formed of an insulating material such as glass, plastic or the like.

The movable contacting arm is illustrated in Figs. 1, 10 and 11 and consists of a circular plate of insulating material 55 that is similar in shape and contour to the body of the resistance element 22 and has beveled edges 56 and 57 similar to the beveled edges 42' and 43 of the element 22. It is also notched on its edge at 58 in a manner similar to the notch 52 in the plate 22. On the underside of the plate 55 (see Fig. 10) is the contact arm 59 formed by deposition of conductive material, such as silver, on the surface of the plate. The contact arm 59 is formed integrally with an arcuate section of conductive material 60 which when the potentiometer is assembled coincides with the circular conductive path 50 formed on the element 22 and electrically connected with the central terminal 26 of the potentiometer. In addition to the arcuate section of conducting material 60 there are two other arcuate sections of conducting material 61 and 62 which are formed on the same radius as the conductive section 60 so as to form a three-point physical contact between the plate 55 and the resistance element 22. The contact arm 59 is disposed at an angle with a radial line A on the circular plate 55. The actual size of this angle is determined by the arrangement of the individual contacts forming part of the resistor element so that very minute steps of resistance change will be obtained. This angular relationship between the contactor 59 and the resistance element 22 will be more clearly described and although contactor 59 has been illustrated as being placed at an angle with respect to a radial line of the circular plate 55 it will become apparent that the relative angle between the contact arm 59 and the successive banks of contacts forming part of the resistance element 22 is in fact the significant angle. This will be taken up in detail in connection with Fig. 11.

The detailed structure of the resistance element 22 is shown most clearly in Fig. 3 which is a fragmentary section of the element as illustrated in Fig. 2. As pointed out above the body of the element 22 is made of an insulating material such as glass, plastic or the like and the resistance element which includes the contact points is formed on the surface thereof by any suitable deposition process.

It will be observed from the fragmentary section in Fig. 3 that the resistance element includes a plurality of radially disposed groups

of silver contacts 100 approximately rectangular in shape with each radial group uniformly spaced from the adjoining groups. This structure is substantially uniform throughout the entire surface of the element and as shown comprehends an angle of about 300°. These contacts are preferably formed of silver and may be formed on the surface of the glass by a photographic printing or template process so that the contacts of each group as well as the successive groups are accurately and precisely positioned in a specific pattern. As illustrated these groups of contacts 100 are of equal angular widths to obtain a linear or substantially linear resistance change. For other resistance characteristics it may be desirable to modify both the angular width of successive groups or the spacings therebetween. These contacts 100 cooperate with the contact 59 in the operation of the potentiometer to effect the desired resistance change. The end terminal portions 102 and 103 of the element are spaced from each other and include the recessed portions 45 and 46 in which the wires 35 and 37 are secured as previously described. These terminal portions are preferably formed of silver or other suitable conducting material and may be formed at the same time the contacts 100 are formed on the surface of the element 22.

One of the great difficulties in potentiometers of this general character is that a sudden resistance change is experienced when the contactor leaves the end terminal and contacts the resistance material. This is especially noticeable in carbon resistors which usually have a silver coating over the ends of the resistor element to form the end contacts for the carbon and also to provide substantially zero resistance between the contact arm and the resistance element when the arm is at one extreme position or the other of the potentiometer. This difficulty although particularly characteristic of carbon controls may be said to be characteristic of any type of high resistance control of the order of one-half megohm or greater. It has however been overcome with this invention by spacing contacts 105 very close to their associated fingers 104. This spacing is usually but a fraction of the radial angle between successive contact groups 100 and effectively minimizes the sudden change in resistance in moving the control arm from one end terminal onto the resistance element. The angle between the group of contacts 105 and the adjoining groups of contacts 100 is preferably made approximately equal to the angle between successive groups of contacts 100.

In addition to the radial groups of contacts 100 and 105 a series of radially disposed contact strips 106 are arranged in alinement with each of the contact groups and extend inwardly from the inner edge of the contact groups to a point spaced from the center opening 44 of the disc 22. As will be pointed out these contact strips 106 provide means for adjusting the taper of the resistance element so that a wide range of tapers may be obtained. The "taper" of a resistance element is used to define the resistance curve of the potentiometer or the change in resistance versus angular rotation of the contact arm.

When the silver contacts have been formed on the surface of the glass element as described above the resistance material is then deposited over the whole surface of the element except for the angular space 107 between the end terminals

102 and 103 and the annular space 108 between the outer edge of the contact groups 100 and the annular conductive strip 50 previously described. The resistance material may be deposited in any suitable manner as by spraying, painting, evaporation or the like, and completely covers the spaces between the individual silver contacting members 100, 104 and 105. The thickness and character of the resistance coating may be varied throughout part or all of the area of the resistance element to produce a desired change of resistance with rotation of the contact arm. Upon deposition of the resistance material denoted by the numeral 109, the entire plate is lapped or ground to expose the surface of the various silver deposits or contacts and to bring them to the same level so that the upper surfaces of all the silver deposits lie in a substantially optically flat plane.

The contact member 55 having silver deposits 59, 60, 61 and 62 is also similarly ground or burnished so that the surfaces of those silver deposits also lie in a susbtantially optically flat plane. In lapping or grinding the surface of the element 22 as well as the silver deposits of the element 55 it is apparent that when the two are brought together as shown in Fig. 1 the silver portions 60, 61 and 62 will ride on the annular silver path 50 of the element 22 and thus form the conductive path for the contact arm 59 through the wire 36 to the center terminal 26 of the potentiometer. The contact arm 59 must be made long enough to contact all contacts of the successive groups of silver contacts 100 and 105, the contact strips 106 and of course the fingers 104.

It was pointed out above that the contact arm 59 is preferably disposed at an angle with respect to the radial line A of the circular plate 55. Positioning of the contact arm 59 in this manner provides the extremely small resistance steps so that the taper will be virtually linear or continuous as distinguished from a stepped operation. It will be apparent that as the contactor arm 59 leaves the end terminal 102 of the element and passes from the fingers 104 to the first row of contacts 105, the arm will first leave the outermost finger 104 and open the gap between that outermost finger and the outermost contact 105. As it is moved still further it will gradually and successively leave each of the remaining fingers until the gap between the radial group of contactors 105 and the group of fingers 104 is entirely uncovered and places some resistance in the circuit. This initial resistance placed in the circuit is made very small by reason of the small gap between the fingers and the contacts 105. Now as the contactor is moved still further it will first uncover the outermost contact 105 and make contact with the next successive outermost contact 100. This will introduce a small amount of additional parallel resistance into the circuit. As movement of the contactor is continued it successively uncovers contacts 105 with additional resistance being placed in the circuit as each contact is uncovered. The effect of this element structure combined with the angular relation of the contact arm 59 with that structure not only results in the series of resistance steps as determined by the resistance between each radial group of contactors 100, but it in effect divides each of these main steps into a plurality of smaller steps determined by the number of radially disposed contacts 105 in each radial group. In the present instance there are 15 such con-

tacts in each group and should there be 100 groups of these contacts on the element then the total number of resistance steps obtained would be 100×15 or 1500. Actually, the number of radial groups of contacts 100 would be far in excess of 100 so that the resistance curve would for all practical purposes be linear or continuous.

In Fig. 3 a spiral strip of resistance material 110 is shown between the inner ends of the contact strips 106 and the center opening 44. The disposition of this strip can probably be more clearly seen in Fig. 6. This resistance film is of course optional and is effective in changing the over-all resistance of the unit as well as affecting to some extent its resistance curve or taper. This strip will be further discussed in connection with the calibration of the element to be described.

Referring again to Fig. 1, to complete the structure of the potentiometer the upper disc 55 is mounted on a central shaft 14 of the control so that a slight misalinement of the shaft will not in any way affect or interfere with the cooperation of the meeting surfaces of the disc 55 and the resistance element 22. This is accomplished by a circular metallic member 111 secured to the shaft by means of a short flange 112 preferably formed integrally with the member 111. This flange may be suitably soldered or welded to the shaft 14 or may be affixed in any other desired manner. The top surface 113 of the member 111 is preferably formed with annular corrugations 114 and then slopes downwardly at the periphery to meet the upper side of the disc 55 at a point 115 a short distance in from the periphery of the disc 55. This member 111 is then curved downwardly at 116 and is crimped inwardly at 117 to cooperate with the beveled edge 56 of the plate 55 and thereby secure it rigidly to the member 111. The corrugations 114 provide a high degree of resiliency and will compensate for any slight misalinement of the shaft 14 relative to the element 22 and the contactor plate 55. Moreover, the corrugated structure of the member 111 provides the desired uniform spring pressure downwardly on the disc or plate 55 to hold it in firm contact with the element 22 and also maintain that force between the plates substantially uniform throughout the life of the unit and throughout wide temperature variations.

Under certain conditions it may be desirable to lubricate the meeting surfaces of the element 22 and contactor plate 55 to prevent any possible condensation of moisture on the element and the accumulation of dust or dirt and to provide positive adhesion between the optically flat surfaces. This added protection can be readily accomplished with this invention because all of the contacting surfaces and resistance materials are contained wholly between the two discs.

In Fig. 11 I have illustrated a fragmentary section of the resistance element 22 with the contacting arm 59 outlined thereon to show its relationship to the groups of contacts 100 and 105 on the resistance element. It will be noted in this figure that the contact arm is offset with respect to the radially disposed groups of contacts so that as the contacting arm 59 is moved clockwise it uncovers successive contacts of each group starting with the outer contact first and by the time it uncovers all of the contacts of one group it has moved sufficiently to contact all of the individual contacts of the next successive group. The contacting arm 59 has been shown in a substantially rectangular form and has been disposed at an angle with the radially disposed groups of contacts 100 to obtain this effect. This form of contactor has been shown because it more clearly illustrates an important feature of this potentiometer. The preferred form of contactor 59, however, is shown in Fig. 12 and designated by the numeral 59'. It is also provided with the outer arcuate section 60 for contacting the arcuate contacting ring 50 as shown in Fig. 3. This contactor 59' is wedge-shaped and preferably in the form of an isosceles triangle. The angle between each of the sides of the triangle and the base is chosen in order to obtain the resultant action which was described in connection with Fig. 11. This type of contactor has the advantage over the contactors shown in Fig. 11 in that it operates similarly in both directions of movement since the perpendicular bisector of the base of this contactor would be alined with the radially disposed groups of contacts 100.

Calibration of potentiometers is extremely important especially in critical control applications, and calibration comprehends not only the over-all resistance of the unit such as would be measured between the outside terminals 25 and 27 but also the rate of change resistance with movement of the contacting arm. This latter is of course what is known as the resistance taper and in many instances is probably more important than the over-all resistance of the unit. For this purpose the control has been so arranged as to provide two means for calibration, one being the resistance path 110 and the second being the resistance material disposed between the metallic strips 106.

A rough calibration of the unit can be obtained by forming the resistance path 110 in a spiral as shown in Figs. 3 and 6 to roughly obtain a desired taper. This path in addition to producing or modifying the taper of a control may be used merely to lower the resistance of the resistance element to some degree. Calibration of the control would be carried out by scraping away the portions of the resistance path 110 to obtain the desired resistance for each degree of rotation of the contact arm or fraction thereof depending upon the accuracy desired. If it is found that scratching away the entire conductive path in a particular element does not sufficiently increase the resistance at a given point the scratching may be continued between the radially disposed conducting strips 106 which has a more material effect upon the resistance of the unit at any one point than does the conducting strip 110. The calibration may of course be carried out automatically or manually by any suitable means such as an electronic control device responsive to resistance changes of the control as the contractor is rotated and which electronic device operates means to remove the resistive material from the path 110 and between the contact strips 106 until the desired resistance is achieved before moving the contacting arm to the next successive position.

The device for scratching the resistance material off the plate 22 may be made generally in accordance with the arrangement shown in Fig. 8 of the drawings. This figure illustrates a section of the control element 22 showing a pair of parallel conductive elements 106 with the resistance material 109 disposed therebetween. The scratching is accomplished by a stylus 120 operated by an electromagnetic vibrating head 121 which can be powered by an alternating current applied between the leads 122. The magnetic head 121 with the stylus 120 would be normally carried by a suitable arm and feeding mechanism

so that the device under the control of the electronic calibrating means would be fed outwardly from the center of the control and between adjacent strips 106 until the predetermined resistance is obtained at each step in rotation of the control.

From the above it is apparent that a great variety of resistance tapers are obtainable and that, depending upon a particular resistance material 109 that may be employed, a wide variety of total resistances can be produced. The range of resistance of the control of this character would easily cover the combined ranges of resistances obtainable with the wire wound and carbon type controls and without incurring any of the disadvantages of either.

In critical applications requiring a fine degree of control it is usually desirable that the resistance of the potentiometer be substantially constant with changes in temperature and humidity. It was pointed out above that carbon controls do change their resistance materially with these factors, but that the metallic controls such as the wire wound units are substantially more stable. With a control according to this invention we have found that an extremely high degree of stability under widely varying temperatures can be obtained by the use of tellurium deposited by any suitable process that will provide a sufficiently thin layer. With this metal a wide range of resistances are obtainable that is substantially comparable to the range of resistances obtainable with carbon. By the use of this metal which has a negative coefficient of resistance, it is a relatively simple matter to balance out this negative resistance change by a combination of the potentiometer with a fixed resistor having a positive coefficient. Furthermore, tellurium does not have the disadvantage of carbon which is inherently noisy and also generates additional noise when the slidable contactor is moved over its surface. This is generally caused by the great degree of irregularity in the carbon surface which can not be eliminated when carbon is deposited on a hard base.

With use of tellurium, it is possible to use superimposed layers of tellurium and resistance metals having positive resistance-temperature coefficients to minimize or cancel the temperature effects on the completed resistance unit.

Fig. 9 illustrates the facility with which two or more of the potentiometers described above may be mounted together to form combinations of two or more units for specific applications. By reason of the inherent structure of this unit as described in connection with Fig. 1, a single shaft can be used to operate the controls simultaneously with the parts of each control being assembled successively on the shaft. If desired the controls of course may all be assembled individually and the shafts 14 for each control be coupled together in the assembly of the several controls into a single unit. Moreover, the completely assembled controls, whether single or in stacks, may be dipped or otherwise coated with a suitable coating material such as a plastic to provide further protection for the operating elements.

What I claim is:

1. A potentiometer comprising a contact arm and a resistance element having a plurality of groups of contacts connected together by resistance material, said contact arm in certain positions shunting all of the contacts of each group and in other positions shunting at least one contact of one group with at least one contact of an adjoining group.

2. A potentiometer comprising a contact arm and a resistance element having a plurality of groups of contacts connected together by a layer of tellurium, said contact arm in certain positions shunting all of the contacts of each group and in other positions shunting at least one contact of one group with at least one contact of an adjoining group.

3. A potentiometer comprising a contact arm and a resistance element having a plurality of groups of radially disposed contacts, said contact arm being positioned to contact all of the contacts of each group as it is rotated about the resistance element and with at least one edge thereof being disposed at an angle relative to the radial groups of contacts to shunt all of the contacts of said groups in certain positions and in other positions to shunt at least one contact of one group with at least one contact of an adjoining group.

4. A resistance element for a potentiometer comprising a plurality of radially disposed groups of contacts, resistance material interconnecting said contacts and resistance means in shunt with said radially disposed groups of contacts to modify the resistance of the element.

5. A resistance element according to claim 3, wherein said resistance material in shunt with said groups of contacts comprises alternate strips of resistance material and conductive elements with each of said conductive elements radially alined with one group of radially disposed contacts.

6. A resistance element for a potentiometer comprising a circular plate of insulating material, a circular resistance path on said plate and a path of conductive material spaced from the resistance material and encircling the outer edge of the plate.

7. In a resistance element for a potentiometer having a movable contact arm comprising a path of resistance material and end terminals therefor formed of a low resistance conductive material, a group of contacts of conductive material for each end terminal and positioned close to said terminals, said contacts cooperating with the contact arm of the potentiometer as it leaves each end terminal to prevent a sudden change in resistance between the contact arm and the resistance element as it is moved from an end terminal onto the resistance element.

8. A resistance element for a potentiometer comprising a circular plate of insulating material, a plurality of radially disposed groups of contacts disposed about at least a portion of said plate and spaced generally midway between the center of said plate and the periphery thereof, a plurality of elongated conductive strips radially disposed on said plate with each strip alined with one of said groups of contacts and extending inwardly thereof to a point spaced from the center of the plate, resistance material connecting said groups of contacts and said strips and a path of resistance material on said plate between the inner ends of said strips and the center of said plate to shunt the resistance material connecting said groups of contacts and their associated strips.

9. A resistance element for a potentiometer comprising a plate of insulating material having an opening in the center thereof, a plurality of groups of contacts radially disposed about at least a portion of said plate, a plurality of radially disposed strips of conductive material with each strip alined with one group of contacts and extending from an inner edge thereof

to a point spaced from the central opening, a section of conductive material at each end of said groups of contacts to form end terminals for said resistance element, a group of radially disposed fingers for each end terminal, said fingers being formed integrally with their adjacent end terminals and extending to a point in close proximity to the first groups of contacts, said spacing being substantially smaller than the spacing between successive groups of contacts, resistance material on said plate interconnecting the groups of contacts, the conductive strips, the fingers and said end terminals, a path of resistance material between the inner end of said contact strips and the central opening in said plate to shunt the first said resistance material and a layer of conductive material about the periphery of said plate and spaced from the outer edge of the resistance element.

10. A variable resistance potentiometer comprising a pair of circular plates of insulating material with one of said plates overlying the other and rotatable relative to said other plate, a path of resistance material on one of said plates and a contact arm cooperating with said resistance material and carried by the other of said plates.

11. A variable resistance potentiometer comprising a circular plate, a path of resistance material on one side of said plate, a second circular plate overlying the first plate and the path of resistance material, a contact arm on said second plate for contacting said resistance material, a central shaft extending through central openings in each of the aforesaid plates and resilient means secured to said shaft and holding one of said plates for rotation thereof with the shaft, said resilient means holding one plate against the other to provide substantially uniform contact pressure at all points of contact between the two plates.

12. A potentiometer according to claim 11,

wherein said resilient means comprises a cup-shaped member having a central opening and a flange surrounding said opening for attachment to said shaft, means about the periphery thereof for securing and holding one of said plates and a plurality of arcuate corrugations concentrically alined with the central opening.

13. Means for calibrating the resistance element of a potentiometer wherein said element is formed of a plate of insulating material having a path of resistance material at one side thereof comprising a stylus means for vibrating the stylus to scratch the resistance material from the plate when the stylus is brought into contact therewith, electrically operated means carrying said stylus and moving it both radially and angularly of said plate, said carrying means being responsive through the resistance of the potentiometer at each point in the rotation of the contact arm to control the radial and angular displacement of the stylus to obtain predetermined resistance taper and over-all resistance of the potentiometer.

14. A resistance element for a potentiometer comprising a base of insulating material, a plurality of contacts on said base and a layer of tellurium on said base connecting each of said contacts with the others.

15. A resistance element for electric circuits comprising at least one layer of tellurium connected in parallel with at least one layer of a resistance material having a positive resistance-temperature coefficient of a magnitude approximately equal to that of tellurium.

16. A resistance element for electric circuits comprising overlying and electrically connected layers of tellurium and another resistance material having a positive resistance-temperature coefficient.

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No references cited.