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DE WITT T. VAN ALLEN ET AL

2,665,355

POTENTIOMETER

Filed Feb. 7, 1952

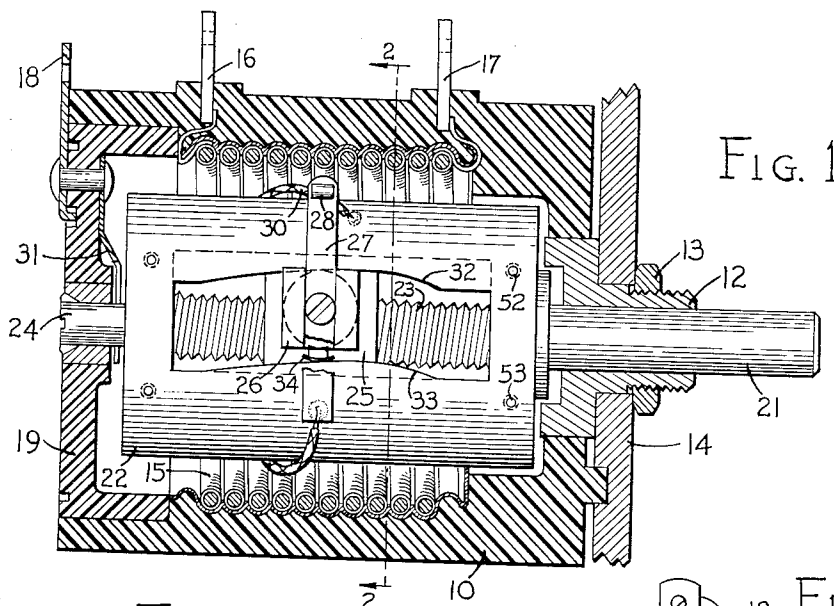


FIG. 1

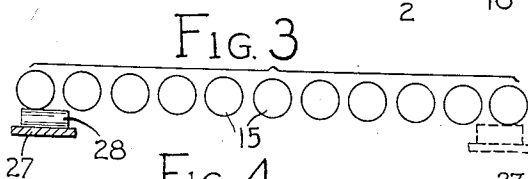


FIG. 3

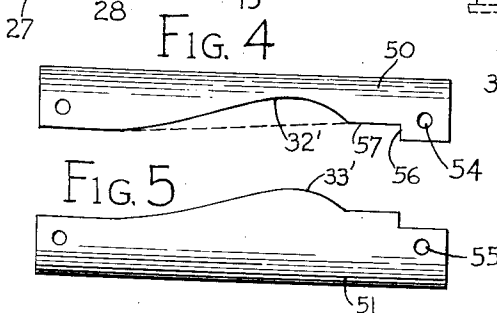


FIG. 4

FIG. 5

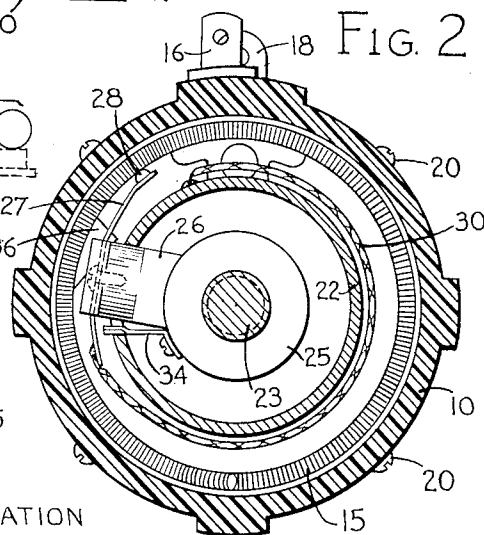


FIG. 2

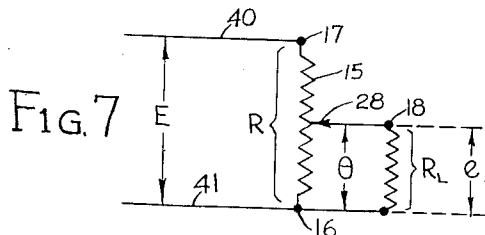
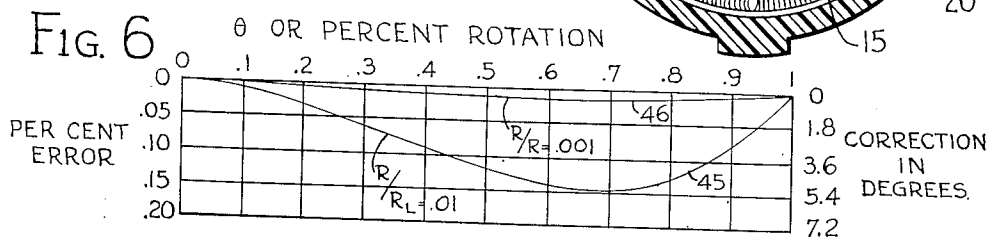


FIG. 7

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POTENTIOMETER

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Application February 7, 1952, Serial No. 270,364

12 Claims. (Cl. 201—56)

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The present invention relates in general to multi-turn potentiometers, or variable resistors, in which the resistance element has the form of a compound helix, and the object of the invention is a new and improved potentiometer of this character.

The invention may be considered as an improvement on the potentiometer disclosed in the U. S. patent to Gibbs et al., No. 2,495,321, granted January 24, 1950.

The Gibbs et al. potentiometer comprises a resistance element having preferably ten turns in the major helix, a lead screw concentric therewith and having the same pitch, a nut or support threaded on the lead screw, said support carrying a slider contact engaging the resistance element, and means comprising a coaxial shaft and a slotted cylinder mounted thereon for rotating the support, the lead screw being effective during such rotation to advance the support and contact axially to enable the contact to follow the turns of the major helix.

According to one feature of the invention the guiding edge of the cylinder slot is given a formation which advances or retards the rotation of the slider contact relative to the rotation of the operating shaft according to a predetermined curve. The non-linear relation between contact rotation and shaft rotation is employed to produce a potentiometer in which the relation between the output voltage and shaft rotation is linear although there is a load in the output circuit. It may also be used to correct manufacturing errors and for other purposes, as will be explained.

According to another feature, the slider contact is enlarged in the direction parallel to the axis of the resistance element, being given a semi-cylindrical shape, for example, and the lead screw is made with a pitch which is slightly different from the pitch of the major helix of the resistance element. When the contact is rotated along the resistance element the small area of the contact which is in engagement with the resistance element progressively changes or shifts along the contact surface, thereby greatly increasing the useful area of the contact and increasing the life thereof.

The foregoing and other features of the invention will be described more in detail hereinafter, reference being made to the accompanying drawing, in which—

Fig. 1 is a partial vertical section through a potentiometer embodying the invention;

Fig. 2 is a transverse section on the line 2—2, Fig. 1;

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Fig. 3 is a diagrammatic view showing the relation between the slider contact and the helix turns at opposite ends of the resistance element;

Figs. 4 and 5 show removable strips which are mounted on the cylinder such as shown in Fig. 1 in a modified form of the invention;

Fig. 6 is a graph showing curves produced by plotting loading error against shaft rotation, the curves also showing the correction in degrees for any per cent of shaft rotation; and

Fig. 7 is a circuit drawing which will be used in the explanation of the invention.

Except for the improvements introduced by the present invention the potentiometer is substantially the same as the one disclosed in the Gibbs et al. patent previously referred to and consequently it will not be necessary to go into great detail regarding its construction and process of manufacture.

Referring to Figs. 1 and 2, the reference character 10 indicates a casing of generally cylindrical form which is molded of some material such as Bakelite. The casing is closed at one end by the flanged bearing member 12, which is molded into the casing when it is made. The bearing member has an externally threaded portion carrying the nut 13 by means of which the potentiometer may be mounted on a panel such as 14.

The resistance element is indicated at 15 and with its terminals 16 and 17 is also molded into the casing when it is made. The resistance element has an insulated core of soft copper wire and a helical winding of bare resistance wire, wound on the core in spaced turns. The core is formed into a major helix and is long enough to make somewhat more than ten complete turns. The turns of the helix and the turns of the resistance wire wound thereon are held in fixed position by the molded casing.

The open end of the casing 10 is closed by the end cap 19 which may also be molded of material such as Bakelite. The end cap carries a terminal 18 for the slider contact, and is removably secured in the casing by means of screws such as 20, Fig. 2.

The operating shaft of the potentiometer is indicated at 21, and is rotatably supported in the bearing member 12. The cylinder 22 inside the casing is fixed on the flanged end of shaft 21 by means of a disc of insulating material which electrically insulates the cylinder from the shaft.

The reference character 23 indicates the lead screw. At one end the lead screw has a cylindrical portion 24 by means of which it is fixed to the end cap 19. At the other end the lead screw

3 has a similar cylindrical portion of reduced diameter which has a bearing in the shaft 21. The cylinder 22 which is fixed to shaft 21 as previously mentioned is supported at the other end by means of a disc of insulating material which has a bearing on the part 24 of the lead screw.

The nut 25 is threaded on the lead screw 23 and includes a slider contact support 26 which projects through a slot in the cylinder 22. The nut and support are made of insulating material. The support 26 may be square in cross-section, except for a rounded portion where it passes through the slot in the cylinder, and is recessed at the end for reception of the spring 27. This spring is secured to the support 26 by a screw and carries the slider contact 28 which it presses against the resistance element 15.

The contact spring 27 is electrically connected to the cylinder 22 by means of the conductor 30 which has one end soldered to the contact spring and the other end soldered to the cylinder, the conductor being loosely wrapped around the cylinder to permit axial movement of the nut 25 and contact spring 27. The cylinder has an annular contact at the left hand end which is engaged by the bifurcated contact spring 31, whereby the cylinder is electrically connected to the terminal 18.

The heretofore mentioned slot in cylinder 22 has a guiding edge 32 against which the rounded portion of the support 26 is pressed by the spring 34. This spring is fixed to the nut 25 as shown in Fig. 2 and rides along the other edge 33 of the slot. The guiding edge 32 of the slot has an accurately predetermined curved contour as will be subsequently explained. The edge 33 could in most cases be straight but in order to allow a minimum tension in spring 34 it is preferably given a contour which conforms generally to the contour of edge 32.

The end cap 19, lead screw 23, nut 25, cylinder 22, and shaft 21 constitute an assembly which is removable from the casing as a unit.

The potentiometer may be operated by means of a suitable dial mounted on the shaft 21. Rotation of the shaft rotates the cylinder 22, which rotates the nut 25 and moves the slider contact 28 along the major helix turns of the resistance element, the stationary lead screw causing the necessary axial movement of the nut to enable the contact 28 to follow the turns. Rotation of the shaft 21 in a counterclockwise direction as seen from the right in Fig. 1 moves the nut 25 to the left, or toward the terminal 16, until the support 26 engages the stop 36, Fig. 2, which arrests the movement. The stop is part of the end cap 19 which is so oriented in the casing that when the shaft and dial have been rotated as far as they will go in this direction, the support 26 having engaged the stop 36, the slider contact 28 will be in engagement with the minor helix coil of the resistance element which is connected to the terminal 16. In this position of the slider contact the resistance of the connection between terminals 18 and 16 is zero, or substantially zero.

If a calibrated dial is used for rotating the shaft 21 the dial should read zero when the slider contact is at the terminal 16. A turn counting dial which is suitable for the purpose is disclosed in the application of Van Alen et al., Serial No. 152,596, filed March 29, 1950. This dial counts turns from 1 to 10 and also shows decimal fractions of a turn.

Rotation of the shaft 21 in a clockwise direction moves the nut 25 and slider contact 28 to the

right or toward the terminal 17. Upon rotating slightly more than 3600 degrees in this direction the slider contact 28 passes the minor helix coil which is connected to terminal 17 and after a few more degrees of rotation the support 26 engages a stop (not shown) which is part of the casing 10 and similar to the stop 36 in the end cap, although facing in the opposite direction. It will be noted from the foregoing that the terminals 16 and 17 are slightly more than 3600 degrees apart. This is to insure that the resistance element will have a minimum of ten effective turns, or an angular length of 3600 degrees as measured by the dial.

A potentiometer such as described herein may be used to derive an output potential which is a desired fraction of a given potential which may be referred to as the input potential. Fig. 7 shows a simple circuit arrangement for this purpose. From some source not shown, a voltage E is impressed across the conductors 40 and 41, which are connected to terminals 16 and 17 of the potentiometer. The resistance R is the total resistance of resistance element 15. The output circuit is connected to terminals 16 and 18 of the potentiometer and is represented as including a load resistance R_L . The quantity e represents the voltage across R_L , or the voltage between terminals 16 and 18.

It will be seen that voltage e depends on the position of the slider contact 28 on the resistance element 15, or on the angular distance the slider contact is displaced in a clockwise direction from its zero position at terminal 16. The quantity θ may be used to represent the percentage of full rotation expressed as a decimal fraction. Therefore, in the zero position of the dial the quantity θ is equal to zero, at 50% of full rotation it is equal to .50, and at full rotation (3600 degrees) it is equal to 1.00.

In a potentiometer having a linear output the voltage e corresponding to any position of the slider contact is expressed by the equation

$$(1) \quad e = \theta E$$

in which E represents the input voltage across the terminals of the resistance element and θ is a decimal fraction representing the percentage of slider contact rotation as previously explained.

In the circuit arrangement shown in Fig. 7 the potentiometer output is not linear unless the load resistance R_L is infinite, a condition that may be approximated when terminals 18 and 16 are connected to the grid and cathodes, respectively, of a class A amplifier tube. In other cases when R_L has some finite resistance the voltage e is not a linear function of θ , but is ascertained by the equation

$$(2) \quad e = \frac{\theta E}{1 + R/R_L(\theta - \theta^2)}$$

Examination of Equation 2 shows that when θ is equal to 1.00, e is equal to θE and to E , and that when θ is equal to zero, e is equal to zero. These facts are also evident from inspection of the circuit diagram, Fig. 7.

For other values of θ the value of e depends on the ratio R/R_L and is always less than θE . The difference between e and θE decreases as the load resistance R_L is increased and for very high values of load resistance the output voltage e does not depart very much from linearity.

The relation between e and θE as θ is increased from zero to 1.00 is shown by means of two curves in Fig. 6, each curve corresponding to a

different value of R/R_L . The curve 45 corresponding to a value of .01 for R/R_L is constructed in the following manner: The input voltage E is assumed to be 100 volts and this value and the value .01 for the R/R_L ratio are substituted in Equation 2. The equation is then solved for different values of θ ranging from .10 to .90, giving the value of e in volts for each value of θ . Subtracting the values of e from the corresponding values of θE now gives the error in volts for each value of θ , and the curve 45 is constructed by plotting the respective voltages thus found against the corresponding values of θ .

It will be seen that with the assumed ratio of R/R_L the departure of voltage e from linearity is not great at any point. The error is greatest when θ is approximately 70% and at that point is equal to about .15 volts when the input voltage E is 100 volts. The error expressed as a percentage of the input voltage E is .15 per cent and is independent of the absolute value of E .

The curve 46 corresponding to a value of .001 for the ratio R/R_L is constructed in the same way as described. R_L being larger in proportion to R than in the case of curve 45, the error is smaller and the curve is flattened out considerably, as is to be expected.

It will be appreciated now that since the error is negative, e being smaller than θE at all points on the curve except when θ equals zero or 1.00, it can be corrected by introducing a supplementary clockwise rotation of the slider contact 28 which is cumulative with or additional to the clockwise rotation produced by shaft 21 and measured by the dial. The number of degrees of supplementary rotation which is required to correct any error in volts can be readily calculated and the results of such calculations are shown at the right of the graph, Fig. 6.

Explaining this further, it will be recalled that the angular length of the resistance element is 3600 degrees. When the error is .05 per cent therefore the number of degrees correction required is .05 per cent of 3600 degrees, or 1.8 degrees. An error of .10 per cent requires a correction of .10 per cent of 3600 degrees, or 3.6 degrees. The other values shown are found in the same way.

Referring now to Fig. 1, it will be seen that the guiding edge 32 of the slot in cylinder 22 has been given a curved contour corresponding to the curve 45 in Fig. 6 in order to compensate for the error in the value of the output voltage that would otherwise be present, thereby producing a potentiometer having an output voltage e which is a linear function of the per cent rotation θ , notwithstanding that the output circuit is not open but has a finite resistance and draws current. When the shaft 21 is rotated seven full turns, for example, as indicated by the dial, the slider contact 28 is rotated seven full turns, and also, due to the curvature of the guiding edge 32, is rotated approximately 5.4 degrees in addition, thereby correcting for the loading error and making the output voltage e equal to θE .

The guiding edge 32 as shown in Fig. 1 has a contour which corrects the potentiometer when the ratio of R/R_L is equal to .01. The same cylinder can be used for different loadings of the output circuit, however, since the potentiometers are manufactured with resistance elements which vary in resistance over a wide range, and it will usually be possible in any given case to select a potentiometer having a resistance R of such value that the ratio R/R_L is equal to .01. It will be

understood of course that several standard cylinders may be manufactured each having a guiding edge 32 conforming to a different value of the ratio R/R_L .

According to a modification of the invention, the slot in the cylinder 22 is enlarged as indicated by the dotted lines in Fig. 1 and two strips 56 and 51 such as shown in Figs. 4 and 5 are attached to the cylinder by means of screws. The strips have holes such as 54 and 55 at the ends for the screws and the cylinder has corresponding tapped holes such as 52 and 53. When the strips are in position on the cylinder they cooperate to form a slot having the guiding edge 32' and an edge 33' which is engaged by the spring 34.

This modification is more flexible than the first described modification. It can be used in all situations where standard cylinders 22, Fig. 1, can be used, and is also adapted to take care of cases where the potentiometer loading is outside the range of such standard cylinders. That is, in cases where the guiding edge of the cylinder must have a special contour. An advantage of the removable strip slot construction is that it is possible to change the contour of the guiding edge to adapt the potentiometer to a different loading. This is accomplished by taking out the end cap, cylinder and shaft unit and replacing the strips 50 and 51 with a new set having the desired slot contour.

The modified form of the invention may also be used to correct departures from linearity due to manufacturing errors and makes it possible to produce extremely accurate potentiometers.

As applied to an ordinary potentiometer not corrected for loading error, a strip such as 50 is made with a straight guiding edge 32'. The strip 51 if provided should also have a straight edge. The potentiometer is assembled complete, mounted on a test panel and equipped with a dial. The resistance between terminals 18 and 16 is then measured with the dial in a plurality of spaced positions (100 positions, for example) by means of a bridge circuit in order to determine the actual departure from linearity at such positions. The errors thus found are plotted against percentage of rotation and a curve is constructed which shows the manufacturing error at any percentage of rotation. This curve may be substantially a straight line, as when no detectable error is present, but will usually be more or less irregular. If a cyclical error associated with the major helix is present the curve may bear some resemblance to a sine curve, crossing the zero line or Y axis once in each 360 degrees of dial rotation.

In actual practice a testing machine is employed which rotates the potentiometer shaft automatically in steps of 36 degrees each, compares the potentiometer resistance with a standard resistance in each position of the shaft, and records the result of each comparison on a tape in terms of distance above or below a median or zero line. By means of a machine such as described individual error curves for potentiometers can be made very quickly, although the machine is not absolutely essential.

When the error curve of a potentiometer shows that it needs correction, the end cap 19 is removed, bringing with it the lead screw, cylinder and shaft unit. The strip such as 50 is then removed and replaced by a similar strip the guiding edge 32' of which has been ground or otherwise modified to conform to the error curve. The potentiometer is then reassembled and the new strip 50 will modify the slider contact rotation relative

to rotation of the dial and correct the manufacturing error that would otherwise be present.

It will be understood that since correction for loading error and manufacturing error are both accomplished by modifying the relation between slider contact rotation and dial rotation it is possible to make a strip such as 50 having a guiding edge 32' of the proper contour to make both corrections. The two errors should be measured simultaneously, as by testing the potentiometer for manufacturing error with the output circuit of the potentiometer loaded, thereby obtaining the data for constructing a composite curve which is the resultant of manufacturing error and loading error.

The strips 50 and 51 as shown in the drawing are designed to accomplish another object of the invention. As mentioned hereinbefore the terminals 16 and 17 are slightly more than 3600 degrees apart as measured by the dial and as a result the slider contact 28 has not yet reached the terminal 17 when the dial indicates ten full turns. This is generally of no consequence, and is ignored in the manufacture of the cylinder 22 shown in Fig. 1. For some purposes, however, it is desirable to have the slider contact at terminal 17 when the dial indicates 3600 degrees, which requires an additional rotation of the slider contact amounting to perhaps two or three degrees.

Inspection of Fig. 4 shows how the additional rotation above referred to is introduced. The guiding edge 32' has been given a curved contour to correct for loading error, but the base of the curve, indicated by the dotted line, is not parallel to the axis of the cylinder when the strip 50 is assembled thereto. On the contrary, the right hand end of guiding edge 32' is advanced several degrees beyond the left hand end, which gives the slider contact the additional rotation required. The angular length of the line 56 is a measure of the additional rotation thus provided for.

It will be understood that the amount of additional rotation required should be ascertained before the guiding edge 32' is ground to the desired load correcting contour. This is done by setting the dial at 3600 degrees, testing the resistance between terminals 18 and 17, advancing the dial until the measured resistance is equal to zero, and then reading on the dial the number of degrees it has been advanced beyond 3600 degrees. The strip 50 to be used is then cut out along the lines 56-57, after which the guiding edge 32' may be ground to conform to a curve which has its base at the dotted line. In the case of a potentiometer which is not to be corrected for loading, the guiding edge will be made to coincide with the dotted line.

Referring now to Fig. 3, it has been mentioned that the lead screw 23 has a different pitch than the turns of the major helix in order to shift the working contact area along the slider contact 28 as the slider contact is rotated along the turns of the resistance element. The lead screw may have more or less turns to the inch than the major helix but as the parts are shown in Fig. 3 the lead screw is assumed to have the finer pitch of the two. The slider contact 28 is shown in full lines on the first turn of the resistance element 15, where it is located when the dial reads zero; and is shown in dotted lines in the position on the last turn of the resistance element which it reaches when the dial reads 3600 degrees. It will be seen that as the dial is rotated from

zero position the slider contact will move to the right to follow the turns of the resistance element but at a slower rate than the advance of the major helix, due to the finer pitch of the lead screw, with the result that the area of the slider contact which engages the resistance element shifts along the slider contact from left to right. Thus in zero position of the dial the working area of the slider contact is somewhat to the left of the center of the contact, whereas in the farthest advanced position of the dial, when the slider contact is on the tenth turn of the resistance element, the working area is somewhat to the right of the center of the contact. The wear on the contact is thereby distributed over a substantial part of the contact, and the tendency to wear a groove in the contact surface is eliminated.

The invention having been described, that which is believed to be new and for which the protection of Letters Patent is desired will be pointed out in the appended claims.

We claim:

1. A potentiometer comprising a helical resistance element, a slider contact adapted to travel helically along the turns of said element, means including an operating shaft for driving said contact, and means effective during travel of said contact to change its rate of movement relative to the rate of the operating shaft.

2. A potentiometer comprising a resistance element in the form of a multi-turn helix, a slider contact engaging said element, means including an operating shaft for rotating said contact on the axis of said helix, means responsive to such rotation to move said contact axially to enable it to follow the turns of said helix, and means responsive to said axial movement to modify the relation between the number of degrees rotated by said contact and the number of degrees rotated by said shaft.

3. In a potentiometer, a casing, a resistance element having the form of a multi-turn helix supported inside said casing, a slider contact engaging said element a support for said contact rotatable on the axis of said helix, an operating shaft, a device rotated by said shaft and having a guiding edge engaging said support to control rotation of the support and contact, and means responsive to such rotation to move said support axially in sliding engagement with said guiding edge, thereby causing said slider contact to follow the turns of said helix, the said guiding edge having a contour which at different points in the travel of said slider contact causes the number of degrees rotated by the contact to differ from the number of degrees rotated by said shaft.

4. In a potentiometer, a casing, a resistance element having the form of a multi-turn helix supported inside said casing, a slider contact engaging said element, a support for said contact rotatable on the axis of said helix, an operating shaft, a device rotated by said shaft and having a guiding edge engaging said support to control rotation of the support and contact, and means responsive to such rotation to move said support axially in sliding engagement with said guiding edge, thereby causing said slider contact to follow the turns of said helix, the said guiding edge having a contour which during the travel of said slider contact causes the number of degrees rotated by the contact to exceed the number of degrees rotated by said shaft by an amount which is sufficient to compensate for the departure from linearity produced by a predetermined load on the output circuit.

5. In a potentiometer comprising a resistance element in the form of a multi-turn helix, a slider contact engaging said element, a support for said contact, means including an operating shaft supported on the axis of said helix for driving said support and contact along the turns of said helix, said means also including a driving element connected to said shaft, said driving element having a guiding edge in continuous engagement with said support and having a contour which uniformly accelerates the rotation of the support and contact relative to rotation of said shaft.

6. In a potentiometer comprising a resistance element in the form of a multi-turn helix, a slider contact engaging said element, a support for said contact, means including an operating shaft supported on the axis of said helix for driving said support and contact along the turns of said helix, said means also including a driving element connected to said shaft, said driving element having a guiding edge in continuous engagement with said support, the portion of said guiding edge which engages said support when said contact is on the last turn of said helix being angularly advanced relative to the portion of said guiding edge which engages said support when said contact is on the first turn of said helix.

7. In a potentiometer as claimed in claim 6, a terminal connected to the resistance element at a point on the last turn thereof which is beyond the point to which the contact would be advanced by a number of rotations of said shaft equal to the number of turns in said helix, the number of degrees by which said contact is advanced in its travel from the first to the last turn of said helix being sufficient to bring said contact to the point on the last turn at which said terminal is connected.

8. In the manufacture of multi-turn potentiometers in which the slider contact is mounted for simultaneous rotary and axial movement and is rotated by means of a shaft and a guide fixed thereto along which the contact support slides during rotation, the method of correcting a potentiometer for loading error which consists in ascertaining the loading error at different points in the rotation of said shaft, and making said guide with a curved working surface which engages said support and advances the support and contact a sufficient amount at said points relative to rotation of the shaft to correct said error.

9. In the manufacture of multi-turn potentiometers in which the slider contact is mounted for simultaneous rotary and axial movement and is rotated by means of a shaft and a guide fixed thereto along which the contact support slides during rotation, the method of correcting a potentiometer for manufacturing error, which

consists in ascertaining the error at different points in the rotation of said shaft, and grinding or otherwise shaping the working surface of said guide to advance or retard the rotation of said support and contact at said points the proper amount relative to rotation of said shaft to correct said error.

10. In a potentiometer, a casing, a resistance element having the form of a multi-turn helix supported inside said casing, a slider contact having a portion of its contact surface engaging said element, a lead screw disposed on the axis of said helix, a support for said contact including a nut threaded on said lead screw, and means for rotating said nut on said lead screw, the pitch of said lead screw being near enough to the pitch of said helix to cause said contact to follow the helix for a plurality of turns but differing therefrom sufficiently to cause successive turns of said element to be engaged by different portions of said contact surface.

11. In a potentiometer, a casing, a resistance element having the form of a multi-turn helix supported inside said casing, a slider contact having a contact surface, extending parallel to the axis of said helix, means supporting said contact with a working area of its contact surface in engagement with said element, means for rotating said supporting means and contact about the axis of said helix, and means responsive to such rotation to simultaneously impart axial movement to said contact to cause the contact to follow the helix turns, said last means comprising a lead screw having a pitch which differs sufficiently from the helix pitch to cause a substantial movement of said working area along said contact surface as the slider contact moves around the turns of said helix.

12. A potentiometer as claimed in claim 11, wherein the lead screw has more threads per inch than the helix, causing the working area to shift along the contact surface in the same direction as the axial movement of the contact as a whole.

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References Cited in the file of this patent

UNITED STATES PATENTS		
Number	Name	Date
2,495,321	Gibbs et al.	Jan. 24, 1950
2,554,811	Bromberg et al.	May 29, 1951
FOREIGN PATENTS		
Number	Country	Date
254,382	Switzerland	Apr. 30, 1948