

June 14, 1949.

A. O. BECKMAN

2,473,048

VARIABLE RESISTANCE UNIT

Filed Oct. 22, 1945

2 Sheets-Sheet 1

Fig. 1

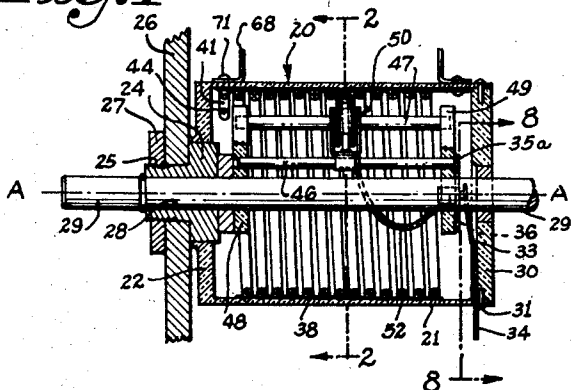


Fig. 4

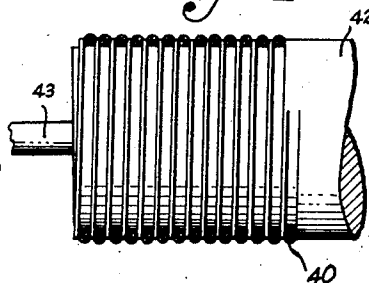


Fig. 2

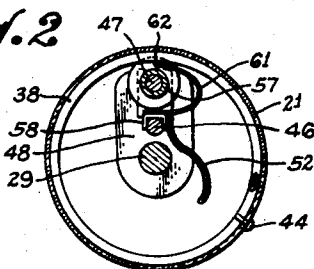


Fig. 3

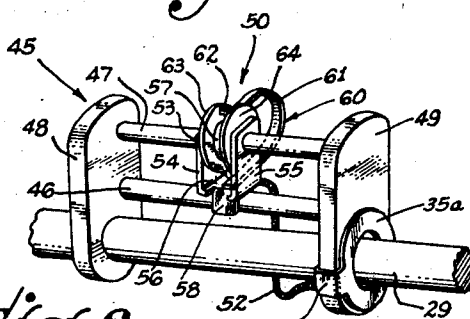


Fig. 5

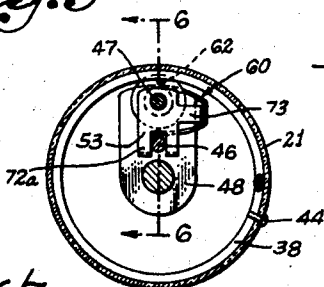


Fig. 6

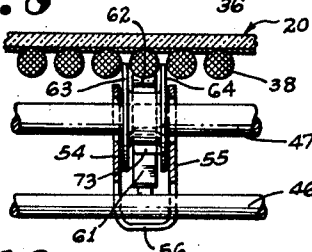


Fig. 7

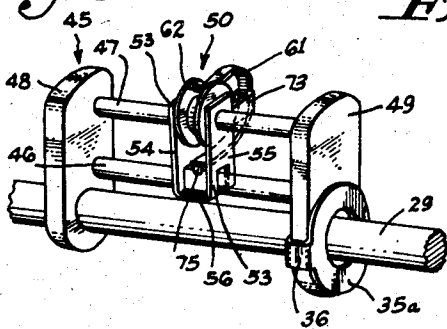
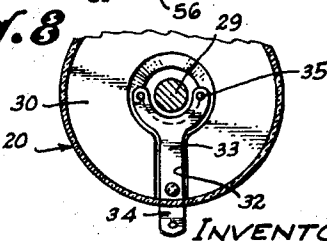


Fig. 8



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2 Sheets-Sheet 2

Fig. 9

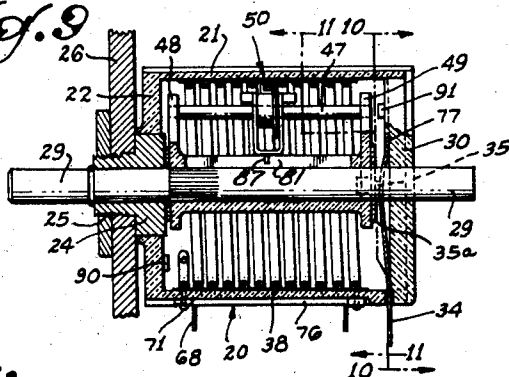


Fig. 10

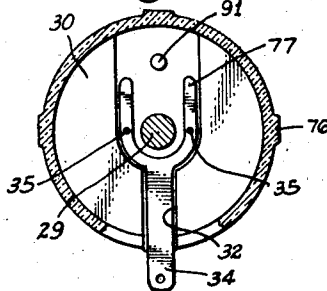


Fig. 11

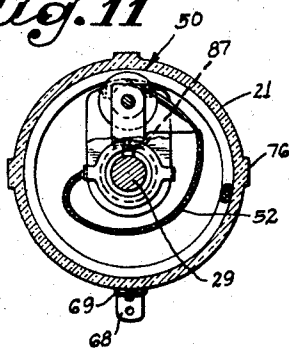


Fig. 12

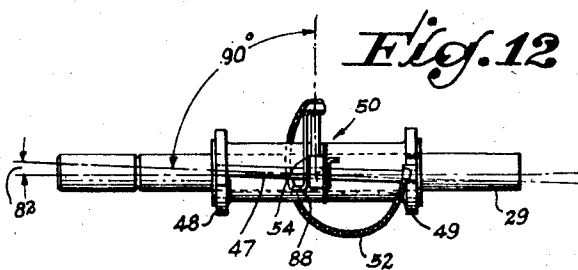


Fig. 13

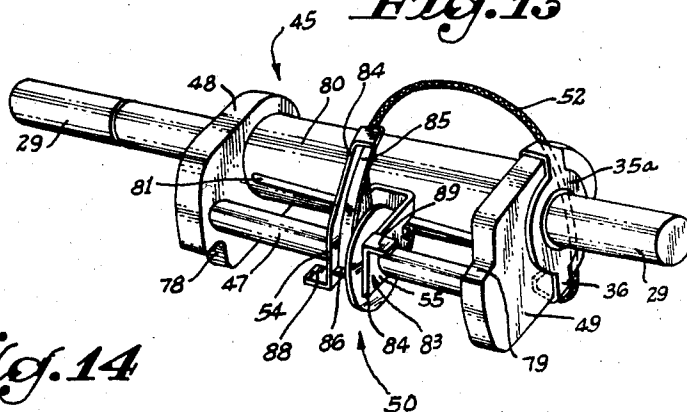
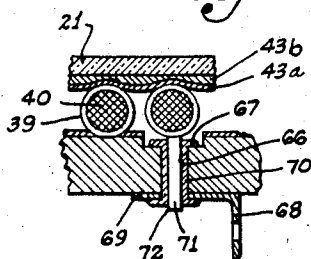


Fig. 14



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VARIABLE RESISTANCE UNIT

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Application October 22, 1945, Serial No. 623,643

17 Claims. (Cl. 201—56)

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My invention is directed generally to resistances for electric circuits and, more particularly, to a low-torque device for controlling the resistance of a circuit. The device of the invention is illustrated, for purpose of description, in use as a variable resistor or potentiometer.

The invention is particularly applicable to variable resistors having a spirally wound resistance element, and is an improvement over the device of the patent to Henry H. Cary et al., No. 2,361,010. In the present application, as in the referenced patent, the term "spiral," as applied to the winding of the conductor or resistance element, is employed in the ordinary sense as including a configuration having a plurality of turns either strictly helical or spiral in a geometric sense, or a configuration in which progressive turns form some other geometric pattern.

Variable resistors of the type herein disclosed may include an operating shaft which is turned through a plurality of revolutions to effect maximum adjustment. In use it is often desirable that the turning torque of this shaft be low and that the resulting change in resistance per degree of operating shaft rotation, and per unit length of conductor winding, be substantially linear throughout the range of resistances measured.

It is an object of the present invention to provide a device which operates at low torque and provides substantially linear, or uniform, resistance variations per unit length of conductor winding and per degree of operating shaft rotation.

It is a further object of the invention to provide a novel contact which moves along a resistance element, and a novel guide element therefor, the contact cooperating with the resistance element and being guided therealong by the guide element.

Further objects of my invention relate to the cooperation of the movable contact with the spiral resistance element. Among these objects are: to effect soft engagement of the contact with the resistance element by the use of a resilient conductive strip therefor; to arrange that the contact ride over the turns of the resistance element within a limited contact area; and to maintain sufficiently rigid disposition of the contact with the resistance element to effect consistently accurate resistance measurements.

Another object of the invention is to provide a novel guide member for such a guide element, preferably so disposed as to extend substantially parallel to adjacent turns of the resistance element. A further object is to provide a guide ele-

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ment having a wheel rotatable about the axis of said guide member and extensible into a space provided between adjacent turns of the resistance element.

Further objects of the invention are to provide a novel arrangement of a resistance element near its ends to permit the movable contact in cooperation therewith to move to a position near, at, or beyond the end of the resistance element while simultaneously being guided in a path substantially conforming to the shape of the resistance element.

Still a further object of the invention is to provide a novel terminal means whereby electrical connections can be made to the ends of an electrically conductive element, such as the aforesaid resistance element, or to intermediate portions thereof to form taps therefor. Another object of the invention is to provide such a terminal means which acts as a support for the end or some other portion of an electrically conductive element.

A further object is to provide a novel method and apparatus for mounting a helical resistance element in a housing to be accurately concentric with an axis about which the control shaft turns. Any lack of such concentricity interferes with the linearity of the device. The present invention includes among its objects the use of a housing having a substantially cylindrical side wall, this housing being typically formed of phenol formaldehyde or other molded plastic, and a novel method of mounting a helical resistance element therein so that any deviation of the wall of the housing from cylindrical shape is not imparted to the resistance element.

Further objects lie in the provision of a variable resistance unit which is relatively simple and inexpensive to manufacture and which is structurally durable during operating conditions.

Further objects and advantages of the invention will be evident hereinafter from the description of two exemplary embodiments.

In the drawings, which are to be considered as illustrative only:

Fig. 1 is a longitudinal section through one embodiment of my invention;

Fig. 2 is a sectional view, taken as indicated by the line 2—2 of Fig. 1;

Fig. 3 is a perspective view of the inner mechanism of the device;

Fig. 4 is a fragmentary longitudinal section of a mandrel having a neck and shows the resistance element of the invention wound thereon, prepara-

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tory to mounting the resistance element in the housing;

Fig. 5 is a sectional view as in Fig. 2, showing an alternative embodiment of the contact assembly of the invention;

Fig. 6 is a fragmentary, enlarged view of the contact assembly of the form of Fig. 5, taken as indicated by the line 6-6 of Fig. 5;

Fig. 7 is a perspective view of the inner mechanism of the device, having modifications as in Fig. 5;

Fig. 8 is a sectional view, taken on the line 8-8 of Fig. 1;

Fig. 9 is a longitudinal section through a second embodiment of my invention;

Fig. 10 is a sectional view, taken on the line 10-10 of Fig. 9;

Fig. 11 is a sectional view, taken on the line 11-11 of Fig. 9;

Fig. 12 is a plan view of the inner mechanism of the device;

Fig. 13 is a perspective view of the inner mechanism of the device as in Figs. 9 to 12, inclusive; and

Fig. 14 is a fragmentary enlarged view of a portion of the conductor winding as engaged by the terminal contact.

Referring to Figs. 1-7, inclusive, and Figs. 9 and 13, one embodiment of the invention includes a housing 20, shown as having a cylindrical portion 21 closed by an end wall 22. These portions of the housing 20 are formed of insulating material, for example, of phenol formaldehyde or other plastic. During the molding operation, the radial flange of a tubular member 24 is molded integral with the end wall 22, this member providing an externally-threaded neck 25 which may traverse an opening in a panel 26 to receive a nut 27, thereby positioning the device of the invention. The tubular member 24 provides an opening 28 journaled an operating shaft 29 which rotates about an axis A-A at or near the center of the cylindrical portion 21 of the housing 20.

The housing 20 is closed by a removable cover 30 formed likewise of phenol formaldehyde. The cover 30 is secured in place by any suitable means, such as pins 31, and the inner face thereof is provided with a transverse groove 32, best shown in Fig. 8. Within the groove 32 is a bifurcated conductive strip 33, an exposed portion 34 of which extends beyond the cover 30 and forms an outside terminal connection. Electrical contacts 35 are provided on the strip 33 and resiliently engage an annular member 35a secured by tabs 36 to the structure rotating with the shaft 29, best shown in Figs. 1 and 3. The cover 30 is also provided with a centrally located circular opening, preferably bushed as shown, to journal an extended portion of the shaft 29 to facilitate "ganging" of the resistors of the invention.

In the housing 20 is mounted an electrically conductive element exemplified as a resistance element and generally designated 38. This resistance element is preferably of the wound type. In the preferred construction, best shown in Fig. 14, a resistance wire 39 is wound helically around a wire core 40 of larger diameter in small-diameter turns hereinafter referred to as minor turns. Thereafter, the core 40 is likewise bent spirally, here illustrated as helically, in turns hereinafter referred to as major turns. In the preferred construction, the major turns are sufficiently spaced to provide a spiral space therebetween. Similarly, in the preferred construction, the minor turns of the wire 39 are space-wound on the core

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40. This wire 39 is preferably a bare or uncoated wire and, if the core 40 is of non-conductive material, can be wound directly thereon. In the preferred construction, however, the core 40 is of a conductive material providing a thin coating of insulating material which separates the minor turns of the wire 39 from the core 40.

It should be further understood that the invention is not limited to space-winding of the major and minor turns of the resistance element, but may comprehend the type of winding employed in the Cary et al. referenced patent, i. e., an insulation-coated wire wound on a core.

In the preferred construction, the minor turns extend along the core 40 and stop to leave an exposed portion 41 of the core 40 at each end thereof, one of the core portions 41 being shown in Fig. 1.

For the change in electrical resistance to be a linear function of the rotation of the operating shaft, the helical resistance element 38 must be so disposed as to orient the major turns thereof concentrically with the axis A-A about which the operating shaft 29 rotates. Some difficulty has been experienced through inherent warping of the molded housing 20. Such warpage may cause the cylindrical portion 21 to become elliptical, or may displace the cylindrical portion 21 from a truly concentric relationship with the axis A-A and, in either case, the device of the invention will then measure resistances not strictly linear within the required tolerances.

While the resistance element 38 may be mounted in the housing 20 in any suitable manner, one method of assembly contemplates winding the core 40, enclosed in the turns of the wire 39, upon a truly cylindrical and externally-threaded mandrel 42 having a neck 43, as shown in Fig. 4. A plastic-impregnated tape 43a (Fig. 14) is then bound around the mandrel 42, the whole is covered with a rubber bag, then evacuated and cured in hot water. This adheres the tape to the minor turns, the plastic entering the spaces between the minor turns, and rigidifies the winding in desired shape. The rubber bag is then removed and the mandrel 42 inserted into the housing 20, the neck 43 fitting snugly into the neck 25. This placement disposes the turns in truly concentric relationship with the axis A-A. An insulating and shape-retaining compound 43b is introduced to fill the intervening space between the tape 43a and the housing 20, and is hardened therein to secure the winding within the housing. The mandrel is then unscrewed and removed, leaving the windings in concentric relationship with the axis A-A.

The assembly procedure recited above may contemplate various modifications in practice, such as, for example, the omission of the step of the process involving binding of the mandrel 42 with plastic-impregnated tape, covering with a rubber bag, and evacuating and curing in hot water. In this modified method, the mandrel, after being wound with the resistance winding, is directly inserted into the housing 20 and the space-retaining compound 43b applied therebetween. It is to be understood that my invention comprehends the above-mentioned and other methods of assembly in practice, embodying the instrumentalities and the principles involved.

In all preferred assembly procedures, the last step involves fastening the resistance element 38 in place within the housing 20. This may be done in any suitable manner, as by passing a pin or

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rivet 44 through the exposed portions 41 thereof and through the housing 20.

Disposed in the housing 20 to turn with the operating shaft 29 is a rotor, generally designated 45. This rotor includes a lower guide member or rod 46 and an upper guide member or rod 47 which extend between radially-extending members or side panels 48 and 49 and on which rides a contact assembly, generally designated 50. The side panels 48 and 49 are made of an insulating material, for example, a laminated phenolic resin, and are drilled to receive the operating shaft 29 as a press fit. As shown in Figs. 1, 2, and 3, the rods 46 and 47 extend only partially through the panels and may be of any suitable metal as they are insulated from the shaft by the side panels. The rods are oriented at an angle to the operating shaft 29, being skewed relative to the axis A—A at an angle equal to the helix angle of the resistance element 38, such orientation being achieved in assembly by displacing the panel 49 relative to the panel 48. Such orientation assists tracking of the guide element, to be later described, with the turns of the resistance element 38.

The annular member 35a is affixed to the side panel 49 by tabs 36 to encircle the operating shaft 29. This annular member 35a may be of any suitable conductive material and, in the preferred construction, is of copper. In the embodiment of Fig. 3, electrical connection with the contact assembly 50 is made by means of a pigtail lead 52 soldered thereto and partially encircling the rotor 45. The other end is electrically connected to the annular member 35a.

The contact assembly 50 is slidably mounted on the guide members or rods 46 and 47 of the rotor 45, and includes a frame or U-shaped member 53 having spaced arms 54 and 55 and a bottom wall 56. The frame 53 is slidably journaled on the guide member 47 and supports between the arms 54 and 55 thereof a guide element, shown as a wheel 57, which is rotatable about the axis of the guide member 47. Bent portions or tabs 58 of the bottom wall 56 serve as a means for preventing pivoting of the contact assembly 50 about the axis of the guide member 47.

Partially encircling the wheel 57 is the movable contact of the invention, shown as comprising a resilient contact element, generally designated 60, and formed of a strip of spring bronze or the like bent into the configuration shown in Figs. 2 and 3. One portion of this strip is bent to form a loop 61 of substantial length with its free end terminating in a contact or tip 62 formed of a hard, durable material having good electrical conductivity, for example, Stellite. The tip progressively advances in engagement with the minor turns of the resistance element 38 as the rotor 45 is turned, good electrical contact between the tip 62 and the resistance element 38 being maintained through aid of the resiliency in the loop 61.

While various means may be employed for conducting current to and from the resilient contact element 60 from a stationary position outside the housing 20, the arrangement by means of the pigtail lead 52 is in many respects desirable since the pigtail lead 52 permits freedom of movement of the entire contact assembly 50. Another means is discussed hereinafter and is best shown in Figs. 5 and 7.

As hereinabove mentioned in connection with the orientation of the guide elements or rods 46 and 47, it is desirable that the resistance element 38 serve as a track to guide the movement of the

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contact assembly 50 in such a way that the contact 62 follows the turns of the major spiral of the resistance element 38 while sliding from one minor turn to the next during this advancement.

A means to accomplish such a result, which requires the application of a very low torque to the operating shaft 29 yet which guides the contact 62 in a positive manner, is provided by the wheel 57. Flanges 63 and 64 thereof, best shown in Fig. 3, extend loosely into the spiral space formed by adjacent major turns in a manner to permit limited movement of the contact assembly 50 along the guide member 47. These flanges preferably terminate short of the midsection of the major turns and do not wedge into the spiral space, thus decreasing the operating torque.

The preferred embodiment of the invention also contemplates that the flanges 63 and 64 shall parallel the major turns of the resistance element 38. In the helical form shown, it is desirable that the guide elements 46 and 47 be disaligned with respect to the axis of the shaft 29 by an angle equal to the helix angle of the major spiral in order that the flanges 63 and 64 shall be parallel to the major turns, thus further reducing the operating torque. This angle is typically around 4-5 degrees.

A novel terminal means, best shown in Figs. 1 and 14, is provided for electrically connecting a fixed portion of the resistance element 38 to an external circuit. This terminal means may also be employed to tap the resistance element 38 at any position along its length or to make electrical connection to other types of electrically conductive elements, irrespective of configuration.

As shown in Fig. 14, an opening 66 is drilled or otherwise formed in the cylindrical portion 21 of the housing 20. The opening 66 is internally counterbored, as indicated at 67. A terminal 68 is preferably employed, having a base section 69 providing an opening of substantially the same diameter as the opening 66. Through these openings is extended a tubular member formed of electrically conductive material and exemplified as a hollow rivet 70, this being done before the resistance element 38 is in place. One end of the rivet 70 flares outward in the counterbore 67 and the other end flares outward beyond the terminal 68 to hold this terminal in position. Actual electrical contact between the hollow rivet 70 or the terminal 68 and the resistance element 38 is made by inserting a pin 71, preferably formed of copper and tinned on all surfaces. The inner surface of the hollow rivet may be tinned or uncoated and in the former instance, the periphery of the pin need not be tinned. The pin 71 provides an end 72 which may be contacted by a heated soldering iron or other heating element which applies sufficient heat to solder the pin 71 in the rivet 70 and to solder the inner end of the pin 71 to the immediately adjacent turns of the resistance wire 39 of the resistance element 38, thus insuring good electrical contact between the wire 39 and the terminal 68. The soldered connection also retains the end turn of the resistance element 38 in a fixed position and prevents any unwinding or loosening of the minor turns of the wire 39 from the core 40.

Figs. 5, 6, and 7 show an alternative construction of the inner mechanism of the embodiment described above, whereby a pigtail lead, such as that designated 52 hereinabove, may be omitted. The guide element or rod 46 is in this construction necessarily of conductive material and extends through the side panel 49, being soldered to the

inner surface of the annular member 35a. The frame or U-shaped member 53 is formed to slide along the guide members 46 and 47, and is kept from turning about the latter by bifurcated arms 72a straddling the guide member 46. The frame 53 also provides a sidewardly-extending arm 73 to which the loop 61 of the resilient conductive strip 60 is secured. A contact 75 is affixed to the inner portion of the strip 60 and presses against and slides along the guide member 46 to make electrical contact therewith, the inner portion of the strip being disposed between the arms 54, 55 of the U-shaped member 53.

The embodiment of the invention shown in Figs. 9 to 13, inclusive, is essentially similar to those shown in Figs. 1 to 7, inclusive. Only variations from the previous structure are described below.

The housing 20 in the embodiment of Figs. 9 to 13 is provided with longitudinal reinforcing ribs 76 which may be straddled by the base section 69 of the terminal 68. As before, a cover 30 is provided but the transverse groove 32 therein holds a bifurcated strip having arms 77 extending beyond the contacts 35 so that the contacts 35 are on the crests of the bowed arms 77 and, as before, engage the annular member 35a.

As best shown in Fig. 13, the rotor 45 of the present embodiment includes side panels 48 and 49 having notches 78 and 79, respectively, therein. The portion of the shaft 29 lying between the side panels 48 and 49 is surrounded by an insulating sheath 80 having a groove 81 therein parallel to the guide member 47 and skewed relative to the axis of the shaft 29. This arrangement is clearly shown in Fig. 12, where the angle of disalignment of the guide member 47 from the shaft 29 is designated 82 and is equal to the helix angle of the major spiral.

A frame 83, which rides on the guide member 47, corresponds to the frame or U-shaped member 53 in the previous embodiment. As before, the frame 83 provides arms 54, 55 but the former is extended to provide a supporting arm 84 to which is affixed a resilient contact element 85 formed of spring bronze or the like and having a contact or tip 86 formed of silver graphite or other hard, durable material of good electrical conductivity. The previously described pigtail lead 52 is soldered at one end to the arm 84 and at the other end to one of the tabs 36 of the annular member 35a. The contact 86 is spaced outwardly from the periphery of the hub of a single-flanged wheel 84 which rotates on the guide member 47 between the arms 54, 55. The single flange of this wheel extends into the spiral space between the major turns of the resistance element 38 and is sufficiently thin to permit a slight amount of play longitudinally of the guide member 47 to prevent wedging of the flange in the spiral space. It is within the contemplation of the present invention to use the single-flanged wheel of this embodiment in the structures of the previously described embodiments as further reduction in operating torque is made possible by use of a single flange.

The inner portion of the frame 83 provides a tongue or prong 87 which slides in the groove 81, as suggested in Fig. 11, to prevent the contact assembly 80 from turning on the guide member 47. Thus, the groove 81 in the sheath 80 performs a function similar to the guide member 46 of the previous embodiments.

In addition, the arms 54 and 55 of the frame 83 respectively provide extensions 88 and 89 which

enter and extend beyond the notches 78, 79 when the contact assembly is adjacent the side panels 48 and 49, respectively. The extension 88, when in such extreme position, is adapted to move into engagement with a stop member 90 extending inward from the end wall of the housing 20 to limit the rotation of the shaft 29. Similarly, the extension 89, when in its extreme position, extends beyond the side panel 49 to engage a stop member 91 extending inward from the cover 30. The stop members 90 and 91 are usually positioned to stop the rotation of the shaft when the contact 86 is at or near an extreme end of the resistance element 38.

In practice, variable resistors of the type herein disclosed have been made which deviate from strict linearity only very little, and torque requirements for operation are extremely low owing to the relatively rigid rotor construction, the rotor 45 maintaining the wheels 57 and 84 at a fixed radial distance from the axis of the shaft so that the flange or flanges of such wheels do not wedge between the major turns of the resistance element 38. While the contact assembly 50 is guided to move spirally to correspond to the configuration of the resistance element 38 so that the wheels 57 and 84 cannot slip over any of the major turns, the contact pressure between the contacts 62 or 86 and the resistance element 38, is maintained sufficient to insure good electrical contact.

It is understood that the embodiments shown are illustrative only and may suggest to those skilled in the art various modifications therefor within the spirit of the invention and the scope of the appended claims.

I claim as my invention:

1. In a variable resistor, the combination of: a resistance element providing a plurality of turns disposed spirally about an axis, the sides of adjacent turns forming a spiral space; a rotor journaled to turn about said axis; a guide member rigidly secured to said rotor and extending transversely of said turns to move a predetermined distance from said turns, said guide member providing an axis; and a contact assembly slidable along said guide member parallel to the axis thereof and providing a guide element extending into said spiral space, the axis of said guide member being disposed at such an angle relative to the axis of said turns as to dispose said guide element substantially parallel to the sides of adjacent turns, said contact assembly including a contact engaging said resistance element.

2. In a variable resistor, the combination of: a resistance element disposed helically about an axis to provide a plurality of turns, there being a helical space between and bounded by the sides of adjacent turns; a rotor journaled to turn about said axis; a guide member mounted on said rotor to turn therewith, said guide member providing an axis which is skewed relative to the axis of said turns, the angle between planes respectively transverse to said axes being substantially equal to the helix angle of said resistance element; and a contact assembly slidable along said guide member and including a contact engaging said resistance element and a guide element disposed transversely to the axis of said guide member and extending into said helical space to advance said contact assembly along said guide member and maintain said contact in engagement with said resistance element as said rotor is turned.

3. A combination as defined in claim 2, in which

said guide element comprises a roller journaled to turn about the axis of said guide member.

4. A combination as defined in claim 2, including means for preventing pivoting of said contact assembly about said axis of said guide member.

5. A combination as defined in claim 2, including means for preventing pivoting of said contact assembly about said axis of said guide member, said means including a second guide member mounted on said rotor parallel to said first-named guide member, said contact assembly including means slidably engaging said second guide member.

6. A combination as defined in claim 2, including means for preventing pivoting of said contact assembly about said axis of said guide member, said means including walls forming a groove on said rotor substantially parallel to said axis of said guide member and means carried by said contact assembly extending into said groove.

7. In a variable resistor, the combination of: a resistance element providing a plurality of turns extending around an axis, there being a space between the sides of adjacent turns, said space being of the same configuration as said resistance element; a rotor journaled to turn about said axis; a guide member rigidly secured to said rotor and extending transversely of said turns to move a predetermined distance from said turns, said guide member providing an axis; and a contact assembly slidable along said guide member, said contact assembly including a contact carried by said contact assembly and engaging said resistance element and including a wheel providing a flange means extending loosely into said space to advance said contact assembly along said guide member and retain said contact in engagement with said resistance element as said rotor is turned, said flange means providing side surfaces which are closer together than said sides of said adjacent turns to avoid wedging of said flange means in said space, all remaining portions of the periphery of said wheel rotating freely in space and out of contact with said resistance element and all other portions of said variable resistor.

8. A combination as defined in claim 7, in which said wheel includes two spaced flanges with such closely spaced side surfaces and respectively extending into said space at positions on opposite sides of a turn of said resistance element, said contact being disposed between said flanges.

9. A combination as defined in claim 7, in which said contact assembly includes a U-shaped member providing spaced arms slidably journaled on said guide member, said wheel being disposed between said arms, and a resilient member secured to said U-shaped member and providing a free end disposed adjacent said flange means and carrying said contact to retain said contact resiliently in engagement with said resistance element at a position adjacent said flange means.

10. In a variable resistor, the combination of: a resistance element providing a plurality of turns disposed about an axis, there being a space between and bounded by the sides of adjacent turns; a rotor journaled to turn about said axis; a pair of side members each fixed rigidly to said rotor and extending toward said turns at positions adjacent the ends of the resistance element; a guide member extending between and fixed to said side members to extend transversely of substantially all of said turns and move a fixed dis-

tance therefrom; and a contact assembly movable along said guide member in the space between said side members, said contact assembly including a contact in engagement with said resistance element and a guide element extending loosely into said space to provide play between said guide element and the space-forming sides of the adjacent turns of said resistance element, said guide element advancing said contact assembly along said guide member to maintain said contact in engagement with said resistance element.

11. In a variable resistor, the combination of: a cylindrical housing; a resistance element in said housing and disposed helically about the longitudinal axis thereof to provide a plurality of turns, there being a helical space bounded by adjacent turns; a rotor journaled to turn about said axis; a first guide member mounted on said rotor to turn therewith at a predetermined distance from said turns; a contact assembly movable along said first guide member and including a guide element extending into said space to advance said contact assembly along said guide member; a second guide member carried by said rotor and slidably engaged by said contact assembly to prevent rotation of said contact assembly about said first guide member, said second guide member being formed of electrically conducting material; a resilient contact member carried by said contact assembly and providing one portion slidably engaging said resistance element and another portion slidably engaging said second guide member; and terminal means electrically connected to said second guide member.

12. In a variable resistor, the combination of: a resistance element providing a plurality of turns extending helically about an axis, the exterior of said turns being concentric with said axis; a rotor; a bearing for journalling said rotor to turn about a bearing axis; a contact assembly including a guide element adapted to engage and follow said turns and a contact engaging said resistance element and guided therealong by said guide element; means for mounting said contact assembly to slide longitudinally of said rotor; a housing fixedly carrying said bearing and providing an inner surface which is substantially but not necessarily exactly concentric with said bearing axis, the diameter of said substantially cylindrical inner surface being larger than the external diameter of the helically-wound resistance element to provide an annular space between said inner surface of said housing and the external surface of said helically-wound resistance element, said annular space being of non-uniform width in some of its portions when said axes are not collinear; and an annular insulating member extending transversely of substantially all of said turns and disposed in said annular space, said insulating member being of varying thickness to correspond to said non-uniform-width portions of said annular space to position said helically-wound resistance element relative to said housing with said axes collinear.

13. A variable resistor as defined in claim 12 in which said annular insulating member comprises an insulating compound introduced into and hardened in said annular space while said axes are collinear.

14. A method for mounting a resistance element in a housing providing an inner surface which is substantially but not necessarily exactly cylindrical about an axis of a bearing retained by said housing, which method includes the steps

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of: accurately forming said resistance element into a helical configuration with all of its turns spaced equidistant from a resistance-element axis, the external diameter of the resulting helical winding being less than the diameter of said inner surface of said housing; disposing the thus accurately formed helical winding in said housing to leave an annular space between said inner surface of said housing and the outer surface of said helical winding while bringing said bearing axis and said resistance-element axis into the same straight line; and filling said annular space with and hardening therein an insulating compound during the time that said axes are collinear.

15. A method for mounting a resistance element in a housing by use of a mandrel, said housing including a bearing and providing an inner surface which is substantially but not necessarily exactly cylindrical and disposed about the axis of said bearing, which method includes the steps of: winding said resistance element into helical shape around said mandrel to provide a helical winding with a plurality of turns accurately concentric with the axis of said mandrel; inserting said mandrel into said housing with its axis lying along said bearing axis, said inner surface of said housing being of larger diameter than the exterior of said helical winding to provide an annular space therebetween; and filling and hardening in said annular space an insulating compound.

16. In a variable resistor, the combination of: a resistance element providing a plurality of turns disposed about an axis, there being a space between and bounded by the sides of adjacent turns; a rotor; means for journalling said rotor to turn about said axis and for preventing substantial motion of said rotor in a direction parallel to said axis; a guide rod; means for rigidly securing said guide rod to said rotor at a position spaced a fixed distance from said turns and transversely thereof, said guide rod being of sufficient length to extend transversely of substantially all of said turns at said predetermined distance therefrom; and a contact assembly embracing said guide rod and freely and slidably movable therealong, said contact assembly including a contact in engagement with said resistance element and a guide element extending loosely into said space between and bounded by the sides of said adjacent turns to advance said contact assembly along said guide rod when said rotor is

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turned and to maintain said contact in engagement with said resistance element during movement therealong.

17. In a variable resistor, the combination of: a resistance element providing a plurality of turns disposed around an axis, there being a space between and bounded by the sides of adjacent turns, said space being of the same general configuration as said turns; a rotor journaled to turn about said axis; a guide member rigidly secured to said rotor to extend in a direction transversely of said turns and to be positioned a predetermined and fixed distance from said turns, whereby said guide member turns about said axis with turning of said rotor and at a fixed distance from said turns; and a contact assembly slidable along said guide member and including a contact in engagement with said resistance element and a roller providing a flange means extending loosely into said space between said turns, said contact being adjacent said flange means, said flange means providing side surfaces which are closer together than are those opposed sides of said turns opposite such side surfaces thereby avoiding wedging of said flange means in said space by providing a small amount of play between said side surfaces and such opposed sides of said turns, said play being in a direction parallel to said guide member and transversely of said turns, the loose extension of said flange means into said space between said turns comprising the sole means for moving said contact assembly along said guide member and for maintaining said contact in engagement with said turns during such movement.

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