Sept. 12, 1961 M. E. BOURNS ET AL 2,999,995

MECHANICALLY VARIABLE RESISTOR

Filed May 20, 1957

FIG. 1.

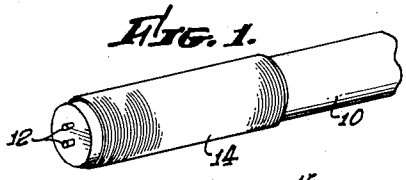


FIG. 2.

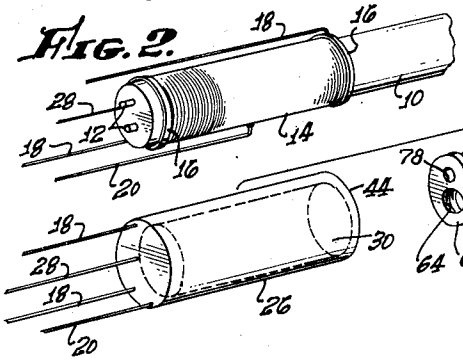


FIG. 3.

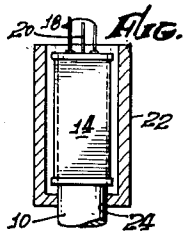


FIG. 4.

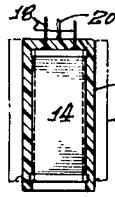


FIG. 6.

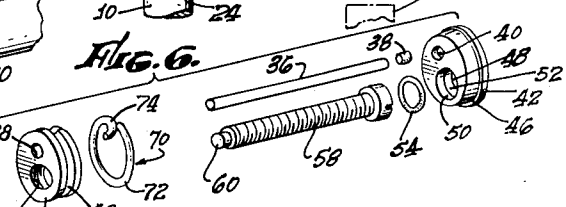


FIG. 5.

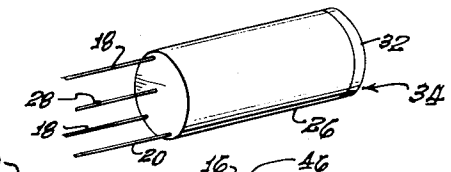


FIG. 7.

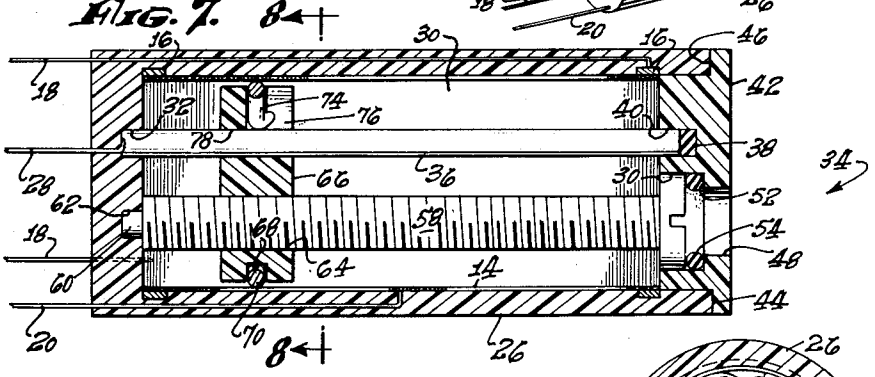


FIG. 8.

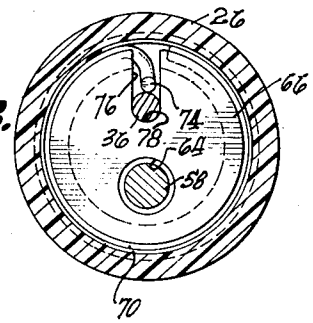


FIG. 9.

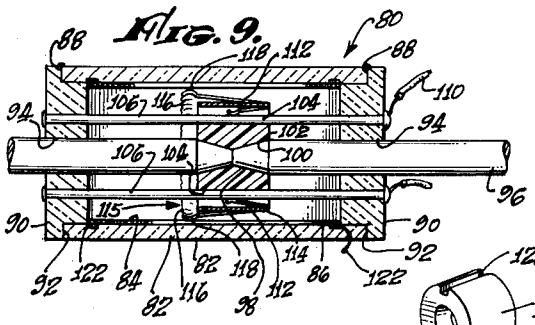
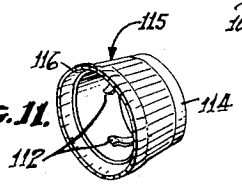


FIG. 10.

FIG. 11.



Edward D. O'Brien

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2,999,995

MECHANICALLY VARIABLE RESISTOR

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Filed May 20, 1957, Ser. No. 660,246
2 Claims. (Cl. 338—180)

This invention relates to a new and improved method for manufacturing resistance elements, resistance elements produced by this method, and to adjustable electrical instruments designed primarily to utilize these resistance elements.

Although a wide variety of different metal film, resin composition and other related resistance elements have been developed in the past, the common resistance elements used in potentiometers and adjustable resistors are manufactured by winding a resistance wire upon a non-conductive mandrel or card. Such wire wound resistance elements are commonly used because of the electrical characteristics of the wires employed, and because of the fact that these wires can be manufactured very accurately.

Wire wound elements of this category are normally employed in instruments in which they are separately enclosed within a housing. These elements are employed with other parts such as an electrical return, a shaft, a movable post attached to the shaft, and a contact member carried by the post so as to engage the electrical return and the resistance element employed. In such electrical instruments normally no major parts serve a dual function. As a result conventional potentiometers and variable resistors tend to be unnecessarily complicated in construction, and because of the number of parts involved tend to be unnecessarily large. Further, the housings used in such conventional instruments have a comparatively large number of edges which must be sealed in providing electrical instruments of a sealed category.

An object of the present invention is to provide new and improved complete resistance elements each of which includes a resistance material and an attached support. A related object of this invention is to provide new and improved complete adjustable electrical instruments such as potentiometers and variable resistors utilizing complete resistance elements as indicated in the preceding sentence in such a manner that the supports employed with these resistance elements serve essentially a dual function, in that these supports serve as a housing which protects and encases an entire instrument, and in addition serves to support the resistance material in an instrument.

A further object of the present invention is to provide new processes for manufacturing complete resistance elements, which processes may be easily and conveniently carried out which are characterized by their simplicity and which are especially adapted to provide complete resistance elements in which a resistance material is attached to and encased within a supporting material capable of being used as a housing.

Because of the nature of this invention, it is not considered necessary to set forth in this specification a further long, detailed list of other objects and advantages of the invention itself. Such other objects and advantages of the invention will be fully apparent to those skilled in the art to which the invention pertains from a detailed consideration of the remainder of this specification, the appended claims, the accompanying drawing in which:

FIGS. 1 and 2 are perspective views showing steps in forming resistance elements as herein described;

FIGS. 3 and 4 are diagrammatic cross-sectional views showing further steps in forming such elements;

FIG. 5 is a perspective view of a potentiometer formed in accordance with the teachings of this invention;

FIG. 6 is an expanded perspective view showing various parts employed in this potentiometer;

FIG. 7 is a cross-sectional view taken longitudinally through the instrument shown in FIG. 5;

FIG. 8 is a cross-sectional view taken at line 8—8 of FIG. 7;

FIG. 9 is a cross-sectional view similar to FIG. 7 of a modified potentiometer formed in accordance with this invention; and

FIGS. 10 and 11 are perspective views of parts employed in the modified potentiometer illustrated in FIG. 9.

In all figures of the drawing like numerals are used to designate like parts wherever convenient for purposes of illustration and explanation. It is to be understood that the accompanying drawing is not to be taken as limiting the invention in any respect. Those familiar with the art to which this invention pertains will realize from a consideration of this drawing and the remainder of this description that the diagrammatic views illustrating the steps employed carrying out this invention can be carried out in other manners than are specifically illustrated. They will further realize that resistance elements created by the methods of this invention can be employed in a wide variety of other adjustable electrical instruments than are specifically illustrated, and that electrical instruments as shown in certain of the figures of the drawing can be employed utilizing parts which are equivalents for certain of the parts shown and described.

As an aid to understanding the invention it may be stated that it concerns complete resistance elements which are formed so as to have a resistance material attached to a supporting material. If desired, this supporting material may be used in electrical instruments of the type indicated so as to serve a dual function in supporting the resistance material and as a housing. Complete resistance elements of this type may be easily created by placing resistance material upon a mandrel and then forming a non-conductive support upon the resistance material and the mandrel, and then removing the mandrel from the resistance material and the support. The method used in removing the mandrel is of course, dependent upon the nature of the mandrel employed, the nature of the resistance material used and the nature of the support employed. Mandrels used with the processes of this invention may be removed by melting, by chemical attack, by dissolving or by a collapsing type of action. The dual purpose resistance elements and housings of this category may be then used in electrical instruments in which an electrical return passes through the cavity created, a shaft passes through this cavity, and a member carrying a contact member are operatively associated with the shaft so as to be capable of movement within the cavity in order to bring the contact member into engagement with various portions of the resistance element and the electrical return.

The exact nature of the invention is best more fully explained by referring directly to the accompanying drawing. The initial step employed in creating a dual purposed resistance element of the invention capable of being used as a housing for an electrical instrument is to provide an appropriately formed cylindrical mandrel **10** as illustrated in FIG. 1 of the drawing. Preferably such a mandrel should be formed out of a comparatively low melting material. A number of low-melting alloys of a known variety may be used for this purpose. Further, if desired, the mandrel can be created from a suitable wax composition. Wax compositions based upon carnauba wax are particularly suitable. This mandrel **10** should have approximately the same internal shape as the cavity desired within the final resistance element. If de-

sired, it may be formed with various small projections 12 of a cylindrical nature which will produce small holes in the final resistance element.

The mandrel 10 after being appropriately formed is covered with a wound resistance element 14 in accordance with known techniques. Virtually any common resistance wire may be used in forming this element 14. Thus, for example, various Nichrome wires or the like may be used in forming it. If desired, the ends of the wire may be temporarily secured by any convenient method such as by using an adhesive.

Following the above operations appropriate terminals 16 of a band-like configuration may be attached to the ends of this resistance element 14 as by soldering or other equivalent techniques. Next various terminal wires 18 may be attached to the terminals 16 so as to extend from the resistance element 14 substantially as indicated in FIG. 2 of the drawing. If desired, the wires 18 may be welded or otherwise directly secured to the ends of the resistance element 14. Also one or more other wires 20 may be attached to the resistance element 14 in an equivalent manner so as to serve as center taps for this resistance element.

Following these operations the complete mandrel and the various parts attached to it are located within a mold 22 as indicated in FIG. 3 of the drawing. It is noted that all of the various parts specified are spaced from the walls of this mold except, of course, for the mandrel which extends through an opening 24 in the bottom of it. If desired, the mandrel may, of course, be formed of a shorter dimension so that it need not project through such an opening. Within the form of mold shown, the wires 18 and 20 extend out through the top of this mold substantially as indicated.

After this assembly is located within a mold, the mold itself is preferably filled with a suitable non-conductive resinous composition or the equivalent which serves to bond directly to the resistance element 14 and the various wires 18 and 20 so as to form a housing. The resinous compositions used may be various conventional casting resins, such as for example, epoxy resins or the equivalent. Also, if desired, the mandrel 10 and the various other parts positioned upon it may be inserted within a mold in an injection molding machine or a compression molding machine and various resins such as for example, phenolic compositions or various thermoplastic resins such as styrene or the like may be injected molded so as to form a complete housing 26 which is attached to the resistance element 14 and parts of the wires 18 and 20. It is to be noted that these wires 18 and 20 project from the housing 26 so as to be capable of being used in connecting the resistance element into an electric circuit.

Specific note is made of the fact that a wire 28 may be attached to one of the projections 12 so as to extend therefrom and that this wire 28 is partially secured to the housing 26 so as to completely extend through this housing when it is formed.

After these operations have been finished, the complete housing 26 with the attached mandrel 10 and other parts is preferably positioned so that the mandrel faces downwardly as indicated in FIG. 4 of the drawing. Moderate heat, capable of melting this mandrel, is then applied to the entire assembly, and as a result the mandrel 10 flows, leaving a housing 26 having an internal cylindrical cavity 30 formed therein. With the preferred construction of the invention the resistance element 14 is thus left so as to be exposed completely around the interior of this cavity 30. Also, the wire 28 is exposed within an appropriate opening 32 in the housing 26. By this procedure greater than one half of the cross-sectional area of the wire composing the element 14 is engaged by a housing 26.

The above procedure for forming the housing 26 and the attached resistance element 14 may be varied in a number of ways. Specific mention is made of the fact that instead of the housing being formed of a resinous material as herein described, this housing 26 may be formed of an appropriate ceramic composition by various techniques such as are commonly employed in providing ceramic coatings for wire wound resistors of a conventional variety. With such techniques a resistance element upon a mandrel essentially as described is, after various wires, such as the wires 18 and 20 are attached to this resistance element, covered with one or more layers of a ceramic composition, such as is commonly termed "frit," and such a ceramic composition is fired at a moderate temperature incapable of melting the mandrel in order to completely form a ceramic housing 26. After such a housing is formed, the mandrel 10 may, of course, be melted away as herein described. Appropriate ceramic compositions for this use are considered to be well known in the art. A wide variety of different materials having a comparatively high melting point capable of withstanding the temperatures employed in firing ceramic compositions of this category may be used for a mandrel such as a mandrel 10.

The housing 26 previously described may be used in a potentiometer 34 such as is indicated in FIGS. 5 through 8 of the drawings. In order to complete this potentiometer a wire-like shaft 36 is positioned within the cavity 30 so as to extend into an opening 32 created by one of the projections 12 so as to bear against the wire 28 in order to establish electrical contact with it. If desired, the shaft 36 may be secured to the wire 28 as by welding or like equivalent means. Preferably, however, this shaft 36 is held in contact with the wire 28 by means of a small resilient rubber or other equivalent member 38 located within another opening 40 in a non-conductive cap 42 designed to seal an end 44 to the housing 26. It is to be noted that the shaft 36 projects into the opening 40 so as to bear against the rubber member 38. The cap 42 is formed so as to fit closely within the end 44 of the cavity 30 as indicated; it preferably includes an exterior flange 46 designed to bear against this end 44. The cap 42 may be sealed in this position by means of any one of a wide variety of different appropriate adhesive or other equivalent means.

Within this cap 42 there is formed a comparatively small opening 48 leading into an enlarged opening 50 which is aligned with the opening 48 so as to have a flange-like shoulder 52 connecting the walls of these two openings 48 and 50. Against this shoulder 52 a small conventional elastomeric O-ring 54 or the like is disposed in such a manner as to resiliently bear against a slotted head positioned upon an end of a shaft 58. It is noted that the shaft 58 is threaded, and projects through the housing 26 in such a manner that its axis is aligned with the axis of the housing 26 proper. The shaft 58 includes a small non-threaded section 60 which fits within an opening 62 in the housing 26.

The shaft 58 fits through a threaded opening 64 in a non-conductive member 66 formed out of nylon, a phenolic composition or the like. The threads upon the shaft 58 mate with the threads of this opening 64; a peripheral groove 68 is provided around the outside of the member 66 as indicated in FIGS. 7 and 8 of the drawing. This groove 68 is adapted to contain a contact member 70 formed out of a conductive circular wire or other equivalent resilient material. The contact member includes a band-like or ring-like peripheral section 72 which is of such dimension as to normally resiliently spring outwardly from the member 66 so as to engage the resistance element 14 establishing electrical communication therewith. A small, bent end 74 upon the contact member 70 projects through a slot 76 in the post 66 so as to resiliently bear against the shaft 36. From an examination of FIGS. 8 and 7 of the drawing, it will be realized that the member 66 includes an opening 78 through which the shaft 36 projects. Preferably the shaft

36 fits closely within this opening 78 so as to serve to prevent rotation of the member 66 as the shaft 58 is rotated.

The operation of the potentiometer 34 is essentially very simple. During use of this instrument the shaft 58 is rotated as through the use of a screwdriver or the like. During such rotation of this shaft 58, the member 66 is moved within the complete potentiometer 34 so as to bring the band-like section 72 of the contact member 70 into engagement with various parts of the resistance element 14. At all times the contact member 70 is in electrical communication with this resistance element 14; also at all times, the contact member 70 is in electrical communication with the shaft 36. This shaft 36 acts as an electrical return with the potentiometer 34.

It is to be specifically noted that the contact member 70 has a circular cross-sectional configuration. Within the preferred construction of the present invention this contact member and the member 66 supporting it are manufactured so that the extreme periphery of the band-like section 72 lies within a single plane which is perpendicular to the axis of the housing 26. In effect the potentiometer 34 has substantially infinite resolution inasmuch as the contact member 70 engages points of the resistance element 14 within the same plane as the periphery of the contact member 70. Obviously other types of contact members than the contact member 70 can be employed with the potentiometer 34. If desired, the band-like section 72 need not extend more than a short distance around the interior of this potentiometer in order to obtain a conventional type of contact action.

In FIG. 9 of the drawing there is shown another potentiometer 80 in which the same type of contact operation described above is achieved. This potentiometer 80 includes a cylindrical housing 82 having an internal cavity 84 formed therein. The housing itself is formed by the process of the invention of a non-conductive ceramic material such as described earlier in this specification. The housing 82 is integrally bonded to an internally wound resistance element 86. It will be realized that the resistance element 86 and the housing 82 may be both manufactured by techniques described in the preceding discussion. At each of the ends 88 of the housing 82 there are provided end caps 90, each of which includes an overhanging shoulder 92 which overlies the end 88 of the housing 82. The caps 90 may be conveniently attached to the housing 82 by any convenient means, such as appropriate adhesive or the like. If desired, these caps may be formed of a ceramic material and may be fused directly to the housing 82.

Within the caps 90 there are provided centrally located aligned cylindrical openings 94 which are designed in such a manner as to support an elongated shaft 96. The portion of this shaft within the housing 82 is provided with a restricted neck 98 which is adapted to fit within a correspondingly shaped opening 100 in a non-conductive member 102 formed out of nylon or other equivalent materials. The entire structure of the member 102 may be conveniently assembled upon the shaft 96 when this member is formed out of an appropriate material having essentially elastomeric properties. Various synthetic rubbers, such as neoprene or the like can conveniently be used for this purpose.

The member 102 is also provided with side openings 104 which are designed to receive shafts 106, the ends of which are secured as by heading over the ends of these shafts or equivalent means within aligned openings 108 in the caps 90. These shafts 106 are conveniently formed out of comparatively strong conductive metal, and may be connected by means of wires 110 into an electrical circuit. The shafts 106 are adapted to serve as an electrical return within the potentiometer 80. Each of these shafts is engaged by small resilient fingers 112 formed so as to project from a metal band-like section 114 of a contact member 115. The band-like section 114 is adapted to be secured to the member 102 by various conventional means such as an adhesive. If desired, it may be secured to this member merely by means of friction. From the band-like section 114 there project an extremely large number of resilient fingers 116 which may be either formed out of sheet metal, wire, or the equivalent. Each of these fingers includes a bent terminal 118; all of the terminals 118 are designed so as to engage the resistance element 86 in a substantially continuous manner in a single plane which is perpendicular to the axis of the housing 82 substantially as described in conjunction with potentiometer 34.

The operation of the potentiometer 80 is considered to be essentially simple. During the use of this instrument the potentiometer is adjusted by means of linear movement of the shaft 96. As this occurs the fingers 116 attached to the bandlike section 114 are moved along the length of the resistance element 86. If desired, the band-like section 114, the fingers 116 and the finger 112 may be considered to constitute a complete contact member or contact means. It is noted that the fingers 112 at all times engage the shaft 106 by projecting through small slots 120 in the member 102. Other wires 122 are attached to the ends of the resistance element 86 as by welding or the like, or through the use of terminals (not shown) such as the terminal 16. These wires 122 project through the housing 82 and are used in attaching the ends of the resistance element 86 into an appropriate electrical circuit.

The contact means utilized in the potentiometer 80 are also of a substantially infinite resolution variety. A more conventional type of contact action can be achieved in the potentiometer 80 by substituting a single resilient arm for the fingers 116 or by using only closely spaced fingers of this variety. A large number of other similar modifications can, of course, be made in instruments designed to utilize housings formed in accordance with this invention. It is important to note that instruments using these housings can be formed having a high resistance value per unit of volume by virtue of the fact that they contain a comparatively large quantity of resistance wire effectively located within a comparatively small volume or area. It is noted that the head of the shaft 58 in the potentiometer 34 may be formed to project through the opening 48 so that the shaft may be actuated by other means than a screwdriver. Thus, this instrument may be formed so as to be used in place of a more expensive conventional helical potentiometer. Also other means than those shown can be employed for mounting the shafts illustrated.

If desired other processes besides those specifically indicated herein may be employed for creating a complete resistance element such as, for example, the resistance element 14 and the attached housing 26. Thus, the procedure described in connection with FIG. 1–4 of the drawings may be modified so as to utilize a mandrel 10 formed out of a material which may be removed by chemical attack.

This mandrel may be removed from a resistance element and an attached housing by immersing the attached resistance element-housing-mandrel assembly created by a procedure such as indicated in FIG. 3 in a chemical reagent capable of dissolving the mandrel but incapable of attacking the resistance element employed or the housing. Thus, when the mandrel utilized in this procedure is formed of magnesium, it may be easily removed from a complete resistance element having an epoxy resin housing and a Nichrome resistance winding by soaking in dilute acetic acid. For the latter purpose common vinegar may be employed. Obviously an extremely wide variety of other types of mandrels and chemical reagents can be employed in this type of procedure.

It is also possible to form a complete resistance element involving a supporting member and a resistance material or element by utilizing a mandrel which may be placed in solution in a common solvent. Thus, it is possible to utilize various mandrels formed of soluble

resins or the like. As an example of this a suitable mandrel can be formed out of a polyvinyl alcohol or an algin composition. This mandrel may be removed by prolonged agitation in water. Similarly a number of other soluble materials and other solvents can be employed. In the use of processes of this category care must be taken that both the resistance material and the supporting material used are unaffected to any material extent by the particular solvent employed.

Another procedure for creating a complete resistance element involving a resistance material or element and an attached housing involves the use of a collapsible mandrel. A wide variety of different types of collapsible mandrels may be employed within the broad scope of this invention. Thus, it is possible to employ mandrels formed out of rigid material, such as metal, of such a nature that various parts of such mandrels may be withdrawn from a complete assembly in order to achieve a collapsing action. It is also possible to employ mandrels formed out of various expandable materials, such as, for example, certain synthetic rubber compositions. Such expandable materials are employed in the procedure of the present invention in their expanded state and after a complete supporting member or housing has been created are collapsed in order to facilitate removal. Another convenient way of forming a collapsing mandrel for use in this invention is to form a mandrel such as the mandrel **10** out of essentially a gell-like type of alginate or similar composition such as is commonly employed in dental work. A mandrel of this category may be easily removed from a complete resistance element by the sample procedure of carefully digging it out from the resistance element and the housing or support with a spatula or the equivalent.

By any of the processes of the present invention, it is possible to form complete resistance elements in which the housing employed serves a dual function, both holding a resistance element and in serving as housing or casing for an entire instrument. The various types of mandrels indicated above can, in certain cases which will be obvious to those skilled in the art to which this invention pertains, be employed with ceramic housings or supports as well as with resinous materials. Constructions of this category are simpler than similar assemblies used in prior electrical instruments such as potentiometers and variable resistors. In general such assemblies are comparatively light in weight and if prepared as indicated can be used as housing or the like so as to eliminate certain of the parts of conventional units.

Such modifications and adaptations are considered to be within the scope of the art to which this invention pertains. Obviously a wide number of differently appearing units besides those specifically illustrated herein may be created using the basic features of this invention, including the method herein shown and described. Also this method can be used in creating other electrical units. For such reasons this invention is to be considered as being limited only by the appended claims, and these claims in turn are to be interpreted in the light of this specification and the patent doctrine of equivalents.

We claim:

1. A variable resistor comprising a tubular housing of dielectric material, said housing being closed at one end by an end wall and having a cap at the other end thereof, said housing, end wall and cap defining a cavity and said end wall having a bearing-hole therein, a resistance element mounted on the inner surface of said housing within said cavity, a rotatable leadscrew having a threaded portion disposed in said cavity parallel to said resistance element, said leadscrew having a smooth unthreaded bearing portion of reduced diameter at one end thereof which bearing portion is journaled within said bearing hole in said end wall, an outwardly facing annular shoulder on said leadscrew adjacent said bearing portion, said shoulder bearing against said end wall around the margins of said bearing hole to limit endwise movement of the leadscrew in that direction, the other end of said leadscrew terminating in a head having a driver-engageable portion, said head being disposed within a cylindrical aperture in said cap, said cap having an inwardly projecting tubular flange encircling the marginal edge of said leadscrew head, the driver-engagement portion of said head being accessible through the aperture defined by said inwardly projecting flange, an elastomeric O-ring seated within said aperture between said inwardly turned flange and said head, said O-ring being compressed slightly so as to seal the clearances between the leadscrew and said housing, and resiliently exerting endwise pressure against the end of said leadscrew so as to hold said annular shoulder against said end wall, a guide rod extending through said cavity parallel to said leadscrew, a slider movable lengthwise of said cavity and having a contact thereon wiping on said resistance element, said slider being operatively engaged by the thread of said leadscrew and movable thereby when the leadscrew is turned, said slider slidably engaging said guide rod so as to be prevented thereby from turning, and terminal means electrically connected to said resistance element and to said contact.

2. A variable resistor comprising, in combination:

first means forming a tubular housing, said housing comprising means forming an elongate tubular structure having a first end closed by an end-wall means to form a cavity, and said end-wall means having at the interior face thereof a recess providing a bearing-hole, said housing further comprising a cap means disposed to substantially close the second end of the said elongate tubular structure, and said cap means having structure forming a longitudinally-extending stepped bore therethrough to provide at the exterior face thereof a smaller aperture formed by a bore of smaller diameter and to provide at the interior face of said cap means a larger aperture formed by a bore of larger diameter merging with the said bore of smaller diameter at a step of said stepped bore;

second means, comprising a leadscrew having a threaded middle portion and first and second end portions the first of which end portions is reduced in diameter and is disposed in said bearing-hole, and the second end portion of which leadscrew forms a head and is of transverse dimension greater than either of said middle portion and said bore of reduced diameter and which head is journaled in said bore of larger diameter;

third means, comprising resilient seal means disposed in said bore of larger diameter between said head and said step of said stepped bore and resiliently pressing said leadscrew against said end-wall;

and fourth means, comprising electrical means including elongate resistive means and terminal means and movable contact means constructed and arranged to be moved along in contact with said resistive means incident to rotation of said leadscrew;

said first, second, third and fourth means being so constructed and arranged that said leadscrew is resiliently pressed against said end-wall means by pressure exerted on the head of said leadscrew by said seal means and being constructed and arranged so said third means seals said cavity against ingress of matter thereinto and with the terminal means accessible from the exterior of said housing and so said leadscrew may be rotated by means inserted into said bore of smaller diameter, and so that as said contact means is moved incident to rotation of said leadscrew the electrical resistance exhibited between terminals of said terminal means is varied.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,999,995 September 12, 1961

Marlan E. Bourns et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 8, for "driver-engagement" read -- driver-engageable --.

Signed and sealed this 3rd day of April 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

UNITED STATES PATENT OFFICE

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