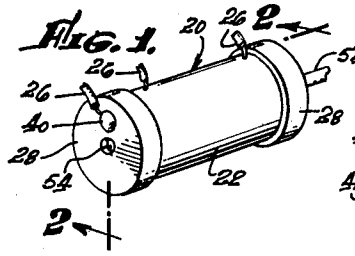
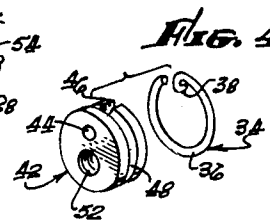
Dec. 18, 1962 M. E. BOURNS ETAL 3,069,648

ADJUSTABLE ELECTRICAL INSTRUMENTS

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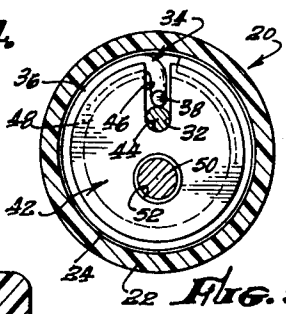


FIG. 3.

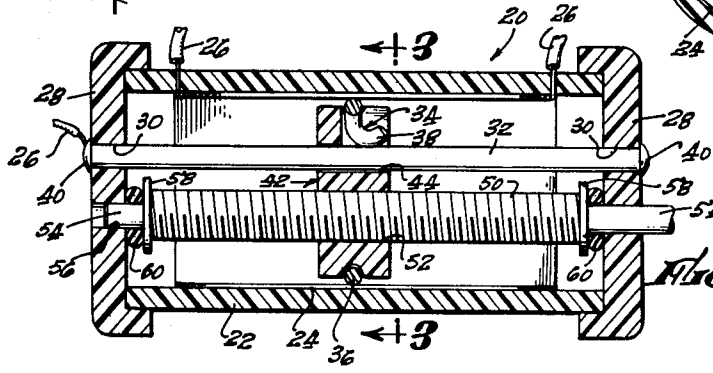
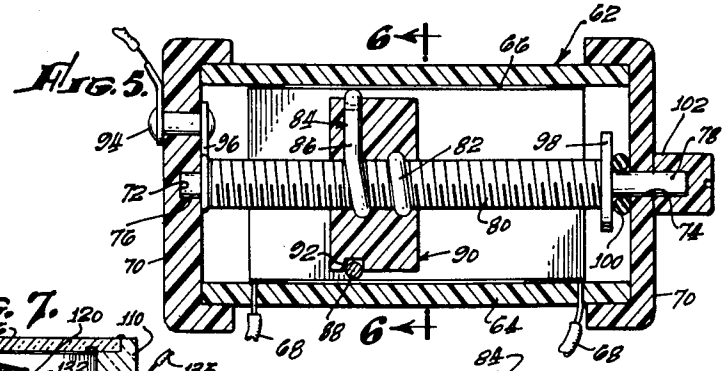
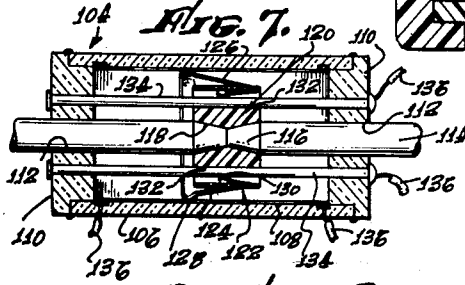
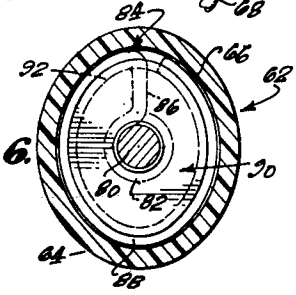
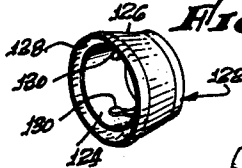


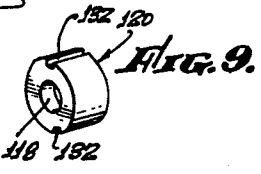
FIG. 2.











INVENTOR.
MARLAN E. BOURNS
BY CARL N. BOODE
EDWARD D. O'BRIAN
Herbert E. Kidder
AGENT

Dec. 18, 1962 M. E. BOURNS ETAL 3,069,648

ADJUSTABLE ELECTRICAL INSTRUMENTS

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FIG. 10.

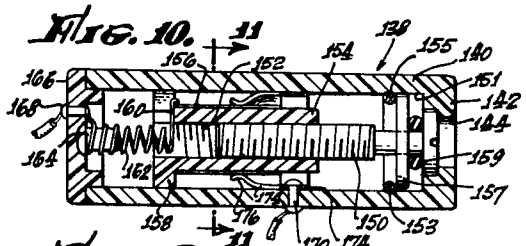


FIG. 11.

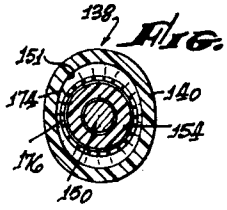


FIG. 12.

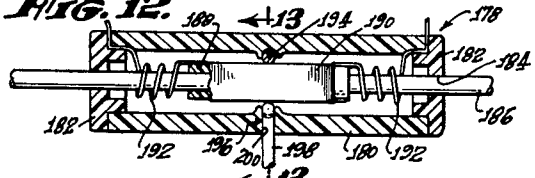


FIG. 13.

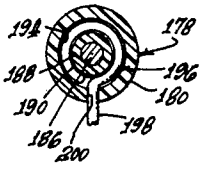


FIG. 14.

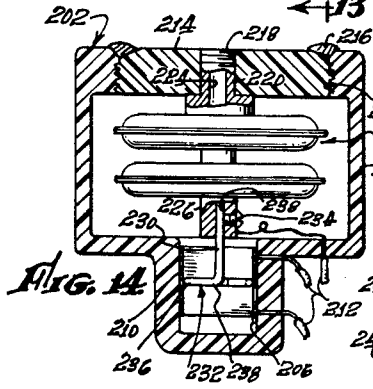


FIG. 15.

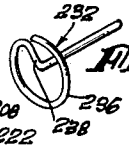


FIG. 16.

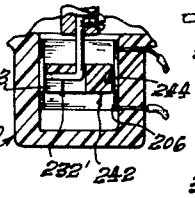


FIG. 17.

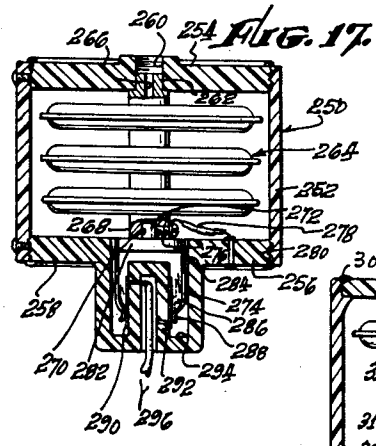


FIG. 18.

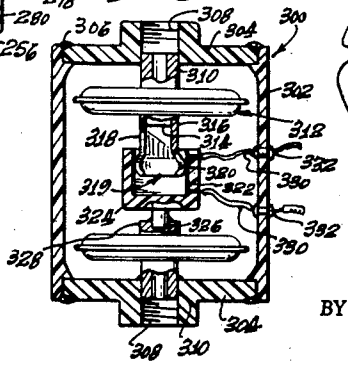


FIG. 19.

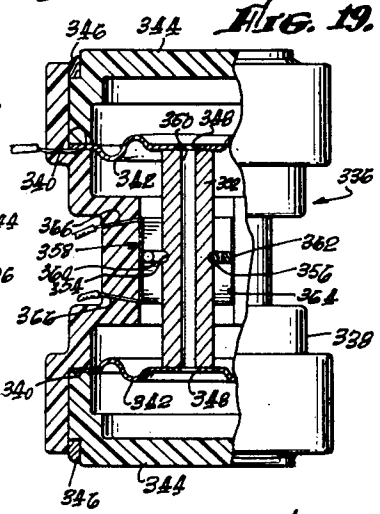
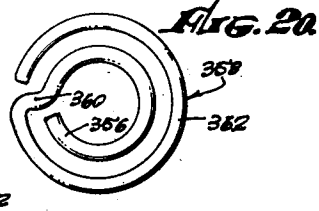


FIG. 20.



INVENTOR.
MARLAN E. BOURNS
CARL N. BOODE
EDWARD D. O'BRIAN
BY Herbert E. Fidder
AGENT

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3,069,648

ADJUSTABLE ELECTRICAL INSTRUMENTS

Marlan E. Bourns and Carl N. Boode, Riverside, and Edward D. O'Brian, Anaheim, Calif.; said Boode and O'Brian assignors to Bourns, Inc., a corporation of California

Continuation of application Ser. No. 660,247, May 20, 1957. This application Apr. 4, 1960, Ser. No. 23,119
14 Claims. (Cl. 338—180)

This invention relates to new and improved adjustable electrical instruments and more particularly to electrical instruments each of which utilizes a wound resistance element and contact means engaging this element. This application is a continuation of our pending application, Serial No. 660,247, filed May 20, 1957, now Patent No. 2,932,808, dated April 2, 1960.

A number of different types of electrical instruments are known which are capable of being actuated manually or in response to variables such as acceleration, pressure, etc., in order to vary an electrical value. At the present time a large number of such instruments utilize a resistance element and contact means resiliently engaging the resistance element so as to permit adjustment of the relative positions of these two parts. In most cases instruments using both a resistance element and contact means are formed in order to obtain a potential dividing action; hence, they may be termed "potentiometers" even if they are manufactured so as to be capable of other than manual adjustment. Frequently, however, such instruments are used in order to vary a resistance value; instruments of this category may be termed "variable resistors."

Although a large number of attempts have been made to develop and manufacture satisfactory composition and other resistance elements for use in potentiometers and variable resistors, experience has proved the value of instruments of this category in which a wound resistance element is created by winding an appropriate Nichrome wire or the equivalent upon a non-conductive carrier or mandrel. With this type of construction the wire in effect extends along a helical path and resembles a common coil spring in configuration. With conventional wire wound variable resistors and potentiometers the contact means employed are mounted so that during adjustment the resistance element and/or the contact means employed are moved so that the contact means in effect "jumps" from one turn of the resistance wire to the next turn.

With this type of construction when the change in resistance between the contact member and one end of the resistance element is plotted on a graph against the adjustment of the instrument itself a curve is obtained which tends to have a stair-step appearance. For many applications it is desired that this curve be of a smooth, continuous category in order to provide uniform readings. The term "resolution" is used in the industry so as to indicate the degree to which a curve of this type tends toward smoothness. Thus, the operation of a potentiometer or a variable resistor having a high degree of resolution may be graphically illustrated in this manner, and the curve obtained while of a "jumping" or zig-zag category nevertheless tends to be of a smoother nature than an equivalent curve for a potentiometer or variable resistor having comparatively low resolution.

In order to provide electrical instruments such as potentiometers and variable resistors having a high degree of resolution a number of different expedients have been proposed. Usually the resolution of potentiometers is increased by forming elongated resistance elements out of comparatively fine wire. This type of solution to the problem is disadvantageous inasmuch as fine wire tends to be relatively expensive and somewhat difficult to handle satisfactorily in many manufacturing operations. Also

the lengths of such elements often are disadvantageous. Also, relatively fine resistance wire may be of a non-uniform character. Attempts have also been made to improve the resolution of potentiometers and variable resistors by providing various types of resilient contact constructions. Although these and related expedients have proved relatively effective for the purpose intended, they have not resulted in instruments having extremely great or, in effect, infinite resolution.

A broad object of the present invention is to provide potentiometers and variable resistors having extremely great or substantially infinite resolution. A related object of the present invention is to provide instruments of this category which may be manually actuated, or which may be actuated in accordance with the variables such as acceleration, pressure or the like. Another object of the present invention is to provide new and improved potentiometers and variable resistors which may be easily and inexpensively manufactured and which are extremely reliable in use.

Because of the nature of this invention and because of the fact that a great many different constructions fall within the general scope of the invention itself, and because of the fact that many of these constructions are in and of themselves considered to be of an inventive nature, it is not considered necessary to set forth in the initial part of this specification a detailed list of various objects and advantages of each of the various constructions falling within the scope of this invention. In the remainder of this specification various other objects and advantages of the invention, and in particular of many of the specific constructions falling within the scope of it, are indicated. Further, various other objects and advantages of the invention will be fully apparent to those skilled in the art to which this invention pertains from an examination of the appended claims and the accompanying drawings in which:

FIG. 1 is a perspective view of a potentiometer of this invention;

FIG. 2 is a cross-sectional view taken at line **2—2** of FIG. 1;

FIG. 3 is a cross-sectional view taken at line **3—3** of FIG. 2;

FIG. 4 is a perspective view showing an assembly of parts employed in the instrument illustrated in the preceding figures;

FIG. 5 is a cross-sectional view similar to FIG. 2 of a modified potentiometer of this invention;

FIG. 6 is a cross-sectional view taken at line **6—6** of FIG. 5;

FIG. 7 is a cross-sectional view similar to FIG. 2 of a further modified potentiometer of this invention;

FIGS. 8 and 9 are perspective views showing parts employed in the potentiometer illustrated in FIG. 7;

FIG. 10 is a cross-sectional view similar to FIG. 2 of a variable resistor of this invention;

FIG. 11 is a cross-sectional view taken at line **11—11** of FIG. 10;

FIG. 12 is a cross-sectional view of another modified potentiometer of the invention;

FIG. 13 is a cross-sectional view taken at line **13—13** of FIG. 12;

FIG. 14 is a cross-sectional view similar to FIG. 2 of a pressure responsive potentiometer of the present invention;

FIG. 15 is a perspective view showing the shape or configuration of a part of the potentiometer shown in FIG. 14;

FIG. 16 is a partial cross-sectional view showing the use of an additional part in the potentiometer illustrated in FIG. 14;

FIG. 17 is a cross-sectional view similar to FIG. 2 of a still further modified potentiometer of this invention;

FIG. 18 is a cross-sectional view similar to FIG. 2 of another pressure responsive potentiometer of the present invention;

FIG. 19 is a partial cross-sectional view similar to FIG. 2 of an acceleration responsive potentiometer or accelerometer of the present invention; and

FIG. 20 is a detailed view of a contact member employed in the instrument shown in FIG. 19.

The accompanying drawing is not to be considered as limiting the present invention in any respect. Obviously a wide variety of differently appearing instruments may be manufactured which utilize the essential features and principles of operation set forth in this specification and illustrated in the drawings. Whenever convenient for purposes of illustration and explanation like numerals have been used to designate like parts in various figures of the drawing.

As an aid to understanding the basic features of this present invention it may be stated in essentially summary form that it involves adjustable electrical instruments such as potentiometers or variable resistors, each of which includes: an elongated, wound resistance element having an axis extending along its length; contact means resiliently engaged substantially all points of this resistance element in a plane perpendicular to the axis of the element; means for varying the relative positions of the resistance element and the contact means so that the contact means at all times engages substantially all points of this resistance in a plane perpendicular to the axis of the resistance element itself. Within the broad scope of this invention instruments are nivolved in which the resistance element itself may be located on either the outside of an appropriate mandrel or be located within an internal cavity and in which the resistance element tiself or the contact means employed or both are capable of being moved so as to vary their relative positions.

The nature of the contact means employed with the present invention is considered to be important. Such contact means may comprise or include a resilient wire ring or a plurality of resilient fingers. Such fingers may advantageously be manufactured so as to have different resonant frequencies by either varying their lengths or their weights. When the various resilient fingers employed in a contact member or a contact means of the present invention differ from one another in this manner, the contact means employed do not vibrate at the same frequency and, hence, various errors caused by vibration are substantially eliminated.

The use of contact means of the type broadly indicated in the preceding in conjunction with wound resistance elements has a number of practical ramifications. Frequently prior potentiometers and variable resistors have been manufactured with comparatively long resistance elements so as to obtain satisfactory resolution. Because of the high degree of resolution possible with electrical instruments constructed in accordance with the teachings of this invention, instruments having very satisfactory resolution for virtually any purpose can be manufactured having relatively short resistance elements. These elements can be satisfactorily formed of comparatively high resistance wire so as to lessen the size required for an instrument of this invention below that of comparable conventional instruments. The fact that such resistance elements can be manufactured so as to be relatively short has the effect that instruments falling within the scope of this invention may be directly connected to bellows, Bourdon tubes, etc., used in adjusting or varying the relative positions of the contact means and the resistance elements in units of this invention. Such elimination of conventional mechanical linkages such as conventional multiplying linkages has the result that the instruments of the present invention tend to be relatively simple to construct. Such elimination of parts is also very advantageous in overcoming friction and vibration errors such as are often encountered with accelerometers of various types of pressure responsive instruments.

The actual nature of this invention is best more fully explained with reference to the accompanying drawings and to the various instruments illustrated therein. In FIG. 1 of the drawing there is shown a potentiometer 20 of the present invention which includes a tubular, cylindrical housing 22 formed out of appropriate non-conductive material such as, for example, an epoxy resin or the like. Within the cylindrical interior of this housing 22 there extends along the length of it a wound wire resistance element 24. This resistance element 24 is preferably manufactured so as to be secured bonded to the housing 22 as indicated in a copending application, Serial No. 660,246, filed May 20, 1957, now Patent No. 2,999,995. Appropriate wire leads 26 are attached to the ends of the element 24 so as to extend therefrom through the housing 22. The ends of the housing itself are sealed by means of identically formed end caps 28 which are attached to the housing 22 by means of an adhesive or other equivalent means of a type known to the art.

Within the end caps 28 there are located aligned openings 30 which serve to carry a wire-like elongated metal rivet 32 which extends through the housing 22 parallel to the axis thereof. This rivet 32 serves as an electrical return for a contact element 34 in the potentiometer 20. This contact element 34 is preferably formed of a resilient metal wire so as to include a cylindrical band or ring-like peripheral section 36 which engages substantially all parts of the resistance element 24 in a plane perpendicular to the axis of the housing 22 during the operation of the potentiometer 20. It also includes a curved end 38 which resiliently bears against the rivet 32 so as to establish electrical contact therewith. It will be realized that the rivet 32 is provided with heads 40 serving to engage the exterior of the end cap 28 and a lead 26 is attached to one of the heads 40 by conventional means. If desired, other types of external terminal constructions may of course be employed.

The contact element 34 is held upon a non-conductive movable member 42 having formed thereon a small opening 44 through which the rivet 32 projects. The opening 44 serves to prevent rotation of the movable member 42 during the operation of the potentiometer 20. The bent end 38 extends through a slot 46 in this movable member so as to engage the rivet 32 at all times. The movable member 42 is also provided with a peripheral groove 48 serving to prevent bending of the section 36 of the contact element 34 during operation of a threaded shaft 50.

The threaded shaft 50 extends through a threaded opening 52 within the movable member 42 and it includes ends 54 of reduced diameter which extend into aligned openings 56 at the end caps 28. One of these ends 54 preferably extends from the potentiometer 20 as shown for use in actuating this instrument by a servo motor or the like. Small flanges 58 are located upon the shaft 50 adjacent to these end caps and serve to hold resilient elastomeric O-ring type washers 60 under compression after the entire potentiometer 20 has been assembled so as to provide an essentially sealed unit.

The operation of the potentiometer 20 is exceedingly simple. One of the ends 54 of the shaft 50 extends from the instrument so that it can be either manually turned or may be turned by a servo motor, or the like. As this occurs the movable member 42 will be moved from one end of the instrument 20 to the other end thereof depending upon the direction of the shaft rotation, and this movable member will at all times cause the contact element 34 to move within the housing 22 so that this contact element is always parallel to any other position in which it may be located. Because of the resilient character of the band-like section 36 the contact element always engages substantially all parts of the resistance element 24 in a plane perpendicular to the axis of this resistance

element so as to affect extremely great or, in effect, infinite resolution to the potentiometer 20.

In FIG. 5 of the drawing there is shown another potentiometer 62 of the present invention which is essentially similar to the potentiometer 20 but which differs from this unit in a number of important respects. This potentiometer 62 includes a non-round housing 64 constructed of a non-conductive material such as indicated in the preceding. This housing 64 may easily be manufactured so as to have an oval or elliptical shape as indicated in FIG. 6 by the technique disclosed in the aforementioned application Serial No. 660,246, so as to carry an internally-wound resistance element 66 extending around the axis of the housing 64. It is noted that the internal configuration of the resistance element 66 is uniform throughout its length. Appropriate leads 68 may be attached to the ends of the resistance element 66 so as to extend from the potentiometer 62 through the housing 64.

The ends of the housing 64 are adapted to be sealed by means of end caps 70 which may be attached to this housing by various conventional means such as an adhesive. These end caps are formed with aligned openings 72 and 74 which serve to carry reduced diameter sections 76 and 78 of a threaded shaft 80. The shaft 80 extends into this housing 64 so as to be aligned with the center of the housing; if desired, it may be considered that the shaft 80 extends along the axis of the housing 64. This shaft 80 serves to carry a coil spring-like end section 82 of a resilient metal wire contact element 84 which also includes a radial section 86 and a connected band-like peripheral section 88 which engages the interior of the resistance element 66 in the same manner in which the section 36 of the contact element 34 engages the resistance element 24. The contact element 84 is generally supported upon and carried by an appropriate non-conductive movable member 90 such as may be formed of nylon or the like. This movable member 90 includes groove-like passages 92 which are adapted to contain and support against bending various portions of the contact element 84 as indicated in the drawing.

Within the potentiometer 62 one of the end caps 70 carries an appropriate rivet-like terminal 94 which supports on the interior of the instrument an attached projecting resilient wire-brush 96 bearing against the section 76 of the shaft 80 at all times so as to establish electrical contact therewith. The other end of the shaft 80 is provided with a flange 98 which serves to retain an elastomeric O-ring 100 under pressure at all times in order to form a seal around the shaft section 78. In order to prevent shorts this shaft section 78 preferably is attached to a non-conductive head or the equivalent 102 by means of an adhesive, a key-way, or the like.

The operation of the modified potentiometer 62 is substantially identical with the operation of the potentiometer 20. Those skilled in the art will realize, however, that this instrument does not include separate means serving to prevent rotation of the contact element 84 during its operation, but instead the movable member 90 and the contact element 84 act with respect to the housing 64 so as to prevent such rotation. It will also be realized that the shaft 80 serves in the potentiometer 62 as an electrical return for this instrument.

In FIG. 7 of the drawing there is shown a still further modified potentiometer 104 of the present invention which includes a cylindrical ceramic housing 106 to the inside of which is attached a correspondingly shaped wound resistance element 108. This housing and the attached element may be conveniently manufactured as indicated in the aforementioned application, Serial No. 660,246. Attached to the ends of the housing 106 by appropriate means such as adhesive, solder or the like are end caps 110, each of which is formed out of a non-conductive material such as a ceramic so as to include centrally located aligned apertures 112. These apertures serve essentially as bearings so as to carry a shaft 114 which is capable of being moved along the axis of the housing 106. It is noted that this shaft 114 is aligned with the axis of this housing.

The portion of the shaft 114 within the housing 106 is provided with a neck 116 of reduced diameter which fits within a correspondingly shaped hole 118 in a movable member 120. This movable member may be conveniently formed out of non-conductive material such as polyethylene or various equivalents so that it may be easily snapped into place over the shaft 114. Its prime function is to carry a resilient metal contact member 122 which includes an interior band-like section 124 fitting tightly against the periphery of the movable member 120. Attached to this band-like section 124, as by welding or the equivalent techniques are a plurality of resilient metal fingers 126, each of which is of an identical construction, and each of which includes a curved end 128 as shown. The curved ends 128 of these fingers 126 all lie within the same plane perpendicular to the axis of the housing 106 and the resistance element 108; further, the fingers 126 are closely spaced with respect to one another so that these ends 128 engage substantially at all parts of the resistance element 108 within this plane.

Attached to the band 124 as by welding or other means are small brushes 130 which extend through the slots 132 in the movable member 120 so as to resiliently engage wire-like shafts 134 which extend through the housing 106 parallel to the axis of this housing. It is noted that the shafts 134 in the construction shown project through appropriate openings (not numbered) in the end caps and are headed on the outside of these caps so as to securely hold the caps with respect to one another. Wires 136 are attached to the heads of these shafts for the purpose of providing an electrical return terminal in connection with the potentiometer 110. Other appropriate wires 136 extending through the housing 106 are attached to the ends of the resistance element 108 for the obvious purpose of connecting this resistance element into an electrical circuit.

The potentiometer 104 is of the linear motion variety and may be operated by merely shifting the shaft 114 along the axis of the housing 106. This in turn adjusts the position of the contact member 122 so that different portions of the resistance element 108 are engaged by it. During such motion the contact member 122 is always held in a plane perpendicular to the axis of the housing 106 and the resistance element 108 and substantially continuous contact between the contact member 122 and this resistance element is made with this plane at all times so as to effect extremely great or infinite resolution.

The same principles may be employed in variable resistors or the potentiometers in which the contact member is located on the outside of a resistance element. This type of construction is illustrated in the variable resistor 138 illustrated in FIGS. 10 and 11 of the drawing. This variable resistor includes a non-conductive, non-round housing 140 which may be formed using various conventional materials such as a phenolic composition or the like so as to include an end 142 having a centrally located opening 144 formed therein. The head of a screw-threaded shaft 150 is normally held against a shoulder 151 within this opening by means of a snap-ring 153 which engages a groove 155 within the interior of the housing 140. As will be seen in FIG. 10 of the drawing the ring 153 bears directly against a washer 157 which is positioned around the neck of the shaft 150 and serves to hold an elastomeric O-ring 159 under compression against the back side of the screw head.

The threaded shaft 150 itself fits within a threaded cylindrical hole 152 in a movable mandrel or support 154 formed out of appropriate non-conductive composition such a phenolic material. This mandrel 154 is provided with a cylindrical external surface spaced from the interior of the housing 140 upon which there is located a wound resistance element 156; it is also provided with a

shoulder 158 which extends so as to slidably engage the interior of the housing 140 in order to prevent rotation of the mandrel as the shaft 150 is actuated. One end of the resistance element 156 is connected by means of a small wire jumper 160 to a coil spring 162 which fits within one end of the hole 152 and which also is attached as by threading or the equivalent to a threaded boss 164 formed upon a cap 166 which is sealed to the end of the housing 140 remote from the opening 144. This cap 166 carries a terminal 168 which is directly attached to the coil spring 162 as by solder or the like and which is used for the obvious purpose of connecting one end of the resistance element 156 into an electrical circuit.

Within the variable resistor 138 another terminal 170 is mounted so as to extend through the wall of the housing 140 so as to be connected as by welding or the like to a metal band 172 which serves to carry a plurality of closely spaced resilient fingers of varying lengths 174 formed integrally with this band 172. These fingers all terminate in curved ends 176 which are located in the same plane transverse to the axis of the housing 140 and of the resistance element 150. It will be noted that with this construction the terminal 170 serves to prevent movement of the band 172 and that the fingers 174 constitute what in effect is a contact member.

This contact member is held in a fixed position in the resistor 138 and by virtue of the construction shown the fingers 174 always engage all points of the wound resistance element 156 within a single plane perpendicular to the axis of the housing 140 as the shaft 150 is turned as by the use of a screwdriver. Such rotation of the shaft 150 causes the mandrel to slide within the interior of this housing 140 and the shape of the housing itself serves to prevent rotation of the mandrel 154. If desired other terminating means can be attached to end of the resistance element 156 remote from wire jumper 160. As will be more fully discussed the different lengths of the fingers 174 are important in preventing vibration errors. Because of the construction of these fingers very great or substantially infinite resolution can be achieved with this construction.

The use of a contact member engaging the outside of the resistance element in a different type of electrical instrument as indicated in FIGS. 12 and 13 of the drawing. Here there is shown a linear motion type of potentiometer 178 which includes a generally cylindrical, elongated housing 180 formed out of phenolic or other similar appropriate material. The ends of this housing 180 are sealed by means of attached end caps 182, each of which is provided with one of aligned apertures 184 which serve as bearings so as to carry an elongated non-conductive shaft 186 which extends through the housing 180 so as to be aligned with the axis. Attached to the shaft 186 with the interior of the housing 180 is a cylindrical non-conductive support 188 upon which there is located a cylindrical wound resistance element 190. The ends of this resistance element 190 are attached to "floppy" or loose wire coils 192, the ends of which pass between the caps 182 and the housing 180 to the outside of the potentiometer 178. When the caps 182 are attached to the housing 180 by an adhesive, these wires or coils 192 may be secured in place by the same means employed to attach the caps. If desired, of course, various other types of terminals can be used.

Within the center portion of the housing 180 there is located an internal groove 194 which serves to hold a ring-like resilient wire contact member 196. This contact member 196 includes an end 198 which extends through an opening 200 in the housing 180 to the outside of the potentiometer 178. If desired, the end 198 may be sealed in place by any of various conventional means. The contact member 196 in this construction resiliently engages the resistance element 190 in a plane perpendicular to the axis of this resistance element and to the axis of the housing 180. This relationship is maintained when the shaft 186 is moved in a linear manner so as to adjust the relative positions of the resistance element 190 and the contact member 196.

A pressure responsive potentiometer constructed in accordance with the teachings of the invention is illustrated in FIG. 14 of the drawings. This potentiometer 202 is provided with a housing 204 having a small cylindrical internal section 206 formed therein and having a threaded opening 208. The entire housing 204 may be conveniently formed out of a wide variety of different non-conductive materials by techniques such as are disclosed in the aforementioned application Serial No. 660,246. When formed in this manner, it is preferred that a wound resistance element 210 be located within the cavity 206 so as to be integrally bonded to the housing 204 and so that terminal leads 212 lead from the ends of this resistance element 210 to the outside of the unit.

The housing 204 is adapted to be sealed by a threaded lid 214 which, if desired, may be sealed in place once the entire instrument has been assembled by means of sealing 216 covering the joint between the housing 204 and the lid 214. This lid is provided with a center threaded opening 218 which, in turn, carries a threaded boss 220 attached to bellows assembly 222 located within the interior of the housing 204. It is noted that a passage 224 extends through the boss 220 from the opening 218. If desired, various means in addition to or in place of threads may be used to hold the boss 220 in position. The side of the bellows 222 remote from the lid 214 is provided with another boss 226 having a centrally located opening 228 formed therein. This opening is adapted to receive the end 230 of a contact element or a contact member 232 such as is indicated in FIG. 15 of the drawing. This end 230 may be conveniently held in place by means of a screw 234 or the equivalent. The contact member 232 is preferably formed of a resilient wire so as to include a band-like section 236 which is attached to the end 230 by means of a radial section 238. It is noted that the radial section 238 extends from the band-like section 236 in the same plane as the section 236, and that this end 230 is located at a right angle to the center of the band-like section 236.

The operation of the instrument 202 is exceedingly simple. As will be obvious to those skilled in the art, various sources of gases or liquids under pressure may be connected to the opening 218 in the obvious manner and as pressure or vacuum is conveyed by such means to the instrument 202 the bellows 222 will either expand or contract moving the contact member 232 within the cylindrical cavity 206. This contact member during such motion at all times engages essentially all points of the resistance element 210 within a single plane perpendicular to the axis of this resistance element. By virtue of this construction exceedingly great or infinite resolution is obtained. In order to complete the instrument another wire 212 is attached as shown as to extend to the outside of the housing 204 and so as to be connected to the contact member 232.

As indicated in FIG. 16 a modified pressure responsive potentiometer 240 may be created which is substantially identical to the potentiometer 202 except for the fact that the contact member 232 surrounds a small plastic member 242 which is formed out of phenolic or other various equivalent materials, so as to include a peripheral groove 244 supporting the band-like section 236 and other grooves 243 serving to allow the passage of the other parts of the contact member 232'. Thus, the member 242 serves essentially as a piston in a dashpot within the cavity 206, and, hence, serves to aid in preventing errors in the operation of this modified instrument 240, such as errors caused through unnecessary vibration or from too rapid response of the entire instrument.

In FIG. 17 of the drawing there is shown another pressure responsive potentiometer 250 of the present invention. This instrument includes a cylindrical, non-

conductive housing 252 having open ends within which there are threaded non-conductive end caps 254 and 256. These caps may be conveniently sealed in place with respect to the housing 252 by means of a conventional sealant 258; preferably the caps 254 and 256 are each formed of non-conductive material. Within the center of the cap 254 there is located a threaded opening 260 within which there is mounted a threaded boss 262 extending from one end of a bellows assembly 264. A passage 266 extends from the opening 260 through the boss 262 into the bellows assembly 264 in a conventional manner.

On the end of this bellows assembly adjacent to the cap 256 there is located another boss 268 having a central opening 270 located therein. A small shaft 272 extending from a contact member 274 is adapted to be secured within this opening by means of a screw 276 or the equivalent. A slack wire 278 is connected to the shaft 272 and the contact member 274 by means of this screw; the slack wire is directly connected to a terminal 280 which extends through the end cap 256. The contact member 274 includes a centrally located cylindrical member 282 formed out of metal so as to resemble a disk; around the periphery of the member 282 there is attached a metal band 284 formed so as to include a plurality of resilient fingers 286 each of which differs from the other of these fingers slightly as to width. The fingers 286 all include curved ends 288 which engage a resistance element 290 in a plane perpendicular to the axis of this resistance element.

As will be apparent from an examination of FIG. 17 the resistance element 290 itself is of a wound wire variety and is mounted upon a hollow boss 292 formed integrally with the lid 256 so as to extend into a cavity 294 located upon this lid. The interior of the cavity fits closely against the exterior of the contact member 274 so that in effect it acts as a wall of a dashpot in controlling movement of the contact member 274 during operation of the potentiometer 250. Appropriate leads 296 extend through a lid 256 from the ends of the resistance element 290 for obvious purpose.

During the operation of the potentiometer 250 as either gas or liquid is conveyed into or out of the bellows assembly 264 the contact member 274 is moved and at all times the curved ends 288 engage the resistance element 290 in a substantially continuous manner in a plane extending completely around this resistance element 290. Errors resulting from various vibrations which would tend to affect the operation of this instrument 250 are prevented by the arrangement specified which acts essentially as a dashpot and by the fact that the fingers 286 are of different widths and therefore of varying weights; consequently they have different resonant frequencies at which they vibrate when the entire instrument is subjected to vibration. Because of this difference in vibration frequencies at least some of these fingers 288 will be in contact with the resistance element 290 at all times.

In FIG. 18 of the drawing there is shown a still further modified pressure responsive potentiometer 300 of the present invention which includes a cylindrical housing 302 formed of a non-conductive material; the ends of this housing are sealed by identically formed non-conductive end caps 304 which may be sealed in place by a conventional sealant 306. Each of the end caps 304 is formed with a centrally located threaded opening 308; within each of these threaded openings there is attached a hollow boss 310 which leads to a bellows assembly 312. If desired, the boss 310 may be secured in place by means of an additional adhesive 306. Attached to one end of the bellows assembly 312 so as to extend therefrom is a small boss 314 to which there is secured as by welding or the like a metal band 316 serving to carry a plurality of attached resilient fingers 318. If desired this band and these fingers may be designated as a contact member 319. It is noted that each of these fingers vary from each of the other fingers as to its length so that each of these fingers has a different reasonant frequency at which it will tend to vibrate. The fingers 318 all include curved ends 320 which resiliently engage the interior of a hollow wound resistance element 322 in the same plane perpendicular to the axis of this resistance element.

As will be noted from an examination of this figure the resistance element 322 is carried within a cup-shaped non-conductive member 324 which is attached by means of a shaft 326 to another boss 328 attached to another bellows 312. Appropriate slack wire leads 330 are connected to the band 316 and to the ends of the resistance element 322 so as to lead from these parts to metal terminals 332 extending through the housing 302 for the obvious purpose.

The potentiometer 300 may be operated in a number of different manners; if desired, the threaded openings 308 may be connected by means of appropriate fittings to different sources of pressure or vacuum so that adjustment between the contact member 319 and the resistance element 322 may be made in response to a pressure differential, or, if desired, either of the bellows 312 may be sealed so as to either by evacuated or contain gas under any desired pressure by means of a plug inserted through either of the appropriate openings 308. Also if desired, the two openings 308 may be connected together by appropriate fittings to a single source of gas or liquid under pressure or to a single vacuum source in order that the two bellows 312 will operate in synchronism with one another in order to obtain a differential type of action which compensates for any acceleration error.

The basic principle of this invention can also be applied to advantage with accelerometers. In FIG. 19 of the drawing there is shown an accelerometer 336 having a housing 338 formed of a non-conductive material so as to have internal shoulders 340 located therein. Within this instrument corrugated, spring-like metal diaphragms 342 are held against these shoulders by means of non-conductive end caps 344 which may be held in place by means of an adhesive ring 346. Each of these diaphragms 342 is provided with a centrally located aperture 348 and these apertures 348 are connected together by means of a passage 350 located so as to extend through the center of an elongated cylindrical weight or mass 352. Such a mass 352 may be conveniently formed of metal and may be attached to the diaphragms 342 by means of welding, soldering, or other equivalent techniques. Around the center of weight 352 there is provided an external groove 354 which is adapted to carry an interior snap ring 356 formed as a part of a contact member 358 is indicated in FIG. 20 of the drawing. This contact member can be conveniently formed out of resilient metal so as to include a connecting radial section 360 and a resilient band 362 which resiliently bears against a cylindrical resistance element 364 formed so as to be supported by and attached to the housing 338. Appropriate wire leads 366 are connected to the ends of this resistance element 364 so as to extend to the exterior of the housing 338. Another similar lead 366 is attached to one of the diaphragms 342 so as to also extend through the housing 338.

It will be realized that as the accelerometer 336 is subjected to acceleration that the weight or mass 352 will be moved within the housing 338 and that the passage 350 within this mass connecting what in effect are chambers defined by each of the end caps 344 and each of the diaphragms 342 will act as an air damping passage to prevent unnecessary or overly rapid movement of this weight. Obviously various types of adjustable orifices or the like may be incorporated within the instrument 336 so as to control the damping. During such movement of the mass 352 the contact member 358 will be moved within this instrument so as to engage successive portions of the resistance element 364. At all times the contact member will make electrical connection with portions of this resistance element within a plane perpendicular to

the axis of the resistance element itself so as to obtain extremely great or infinite resolution as indicated in the preceding discussion.

Those skilled in the art to which this invention pertains will realize that many of the specific electrical instruments herein shown and described are of other than conventional design. Obviously it is possible to utilize the various types of contact means shown in the various figures of the drawings with a wide variety of more conventionally constructed electrical instruments without departing from the essential features of this invention. Similarly it is possible to use or substitute within the construction shown the various contact means herein described by an exercise of routine engineering skill.

The various constructions of the present invention are considered to be particularly applicable to units such as accelerometers and pressure responsive potentiometers where it is desired to have a high degree of resolution and where it is normally desired to use as small a resistance element as possible in order to avoid the necessity of mechanical linkages and the like. Instruments of the present invention having a high degree of resolution or infinite resolution are considered to be extremely well adapted for such use. In addition the use of contact means having fingers capable of vibrating at different resonant frequencies is considered to be extremely important in eliminating certain errors which frequently occur in the operation of electrical instruments of the type to which this invention pertains.

Because of the fact that this invention is capable of exceedingly wide modification, it is to be considered as being limited only by the appended claims forming a part of this disclosure.

We claim:

1. An adjustable electrical instrument which includes: an elongate tubular housing of non-circular cross-section; a support reciprocable in said housing and having a portion of non-circular cross-section closely engaging the housing and thereby being restrained against rotation in the housing, said support bearing a wound resistance element having a contact-engaging portion disposed longitudinally of the housing and support; means, including screw-threaded means in said housing in engagement with said support and constructed and arranged to move said support incident to rotation of the screw-threaded means in the direction of its axis; and other means, including contact means mounted within said housing so as to engage substantially all points of said resistance element within a plane perpendicular to the axis of said resistance element.

2. An adjustable electrical instrument which includes: first means, including an elongate tubular housing of generally elliptical internal cross-section; second means, including a threaded shaft means located within said housing; a non-conductive support reciprocable in said housing and having threaded hole means formed therein so that said threaded hole means are engaged by said shaft means, said support having a portion of generally elliptical cross-section closely engaging the housing and thereby being restrained against rotation in the housing, said support bearing a wound resistance element nonconductive support; and other means, including contact means mounted within said housing so as to engage substantially all points of said resistance element within a plane perpendicular to the axis of said resistance element in any position of said resistance element within said housing.

3. An adjustable electrical instrument as defined in claim 2 including means slidably engaging the interior of said housing including conductive means extending through a wall of said housing and constructed and arranged to secure said contact means to said housing and serve as an electrical terminal therefor.

4. A variable resistor comprising first means, comprising a housing having an elongated cavity of non-circular internal cross section provided therein; a member having a portion of complementary non-circular cross-section slidable longitudinally within said cavity in contact with the interior of the housing; a resistance element mounted on said member; rotary screw means for moving said member along the length of said cavity; contact means fixedly secured to said housing within said cavity and wiping on said resistance element; and terminal means electrically connected to said resistance element and to said contact means.

5. A variable resistor as defined in claim 4, wherein said resistance element is wrapped around the outer surface of said member, and said contact means engages said resistance element at substantially all points thereon within a plane perpendicular to the longitudinal axis of said cavity.

6. A variable resistor as defined in claim 4, wherein said rotary screw means for moving said member comprises a leadscrew journaled in said housing and extending longitudinally in said cavity parallel to the longitudinal axis thereof, said leadscrew operatively engaging said member so that the latter is longitudinally moved relative to the contact means when the leadscrew is turned.

7. A variable resistor as defined in claim 4, wherein said resistance element is wrapped around the outer surface of said slidable member, and said contact means comprises a plurality of angularly spaced resilient fingers engaging said resistance element at a plurality of radially spaced points around the surface thereof within a plane perpendicular to the longitudinal axis of said cavity.

8. A variable resistor comprising a housing having an elongated cavity of substantially elliptical and uniform cross section provided therein; a member slidable longitudinally within said cavity, said member including a portion of complementary substantially elliptical cross-section engaging the inner surface of said housing and said member including a generally cylindrical portion extending parallel to the longitudinal axis of said cavity; a resistance element wound around said generally cylindrical portion; an actuating shaft operatively connected to said member to move the latter within said cavity, contact means fixedly secured to said housing and encircling said generally cylindrical portion of said member, said contact means engaging said resistance element at substantially all points thereon within a plane perpendicular to the longitudinal axis of said generally cylindrical portion, and interengagement of said member with said housing preventing rotation of the member in the housing.

9. A variable resistor as defined in claim 8, wherein said contact means comprises a sleeve of conductive sheet metal secured at one end to said housing within said cavity and surrounding said generally cylindrical portion, said sleeve being slit from the other end thereof to form a plurality of spring fingers which engage said resistance element at a plurality of angularly spaced points within a plane perpendicular to the longitudinal axis of said generally cylindrical portion.

10. A variable resistor as defined in claim 8, wherein said member is provided with a threaded hole extending parallel to the longitudinal axis of said generally cylindrical portion, and said actuating shaft is in the form of a rotatable leadscrew which is threaded through said hole so that said member is moved when said leadscrew is turned.

11. A variable resistor comprising a housing having an elongated cavity of uniform non-round cross section provided therein, a member slidable longitudinally within said cavity, said member including a portion of non-round configuration fitting snugly within and slidably engaging the surface of said non-round cavity, said member also including a generally cylindrical portion extending parallel to the longitudinal axis of said cavity, a resistance element wrapped around said generally cylindrical portion, a leadscrew journaled within said housing and extending through said cavity parallel to the longitudinal axis there-

of, said leadscrew being threaded through an aperture in said member whereby the latter is moved longitudinally of said cavity when the leadscrew is turned, contact means fixedly secured to said housing within said cavity and surrounding said generally cylindrical portion of said member, said contact means including a plurality of spring fingers engaging said resistance element at a plurality of angularly spaced points thereon within a plane perpendicular to said generally cylindrical portion, and terminal means electrically connected to said resistance element and to said contact means.

12. An adjustable resistor comprising:

first means, including a tubular housing having an interior wall and ends;

second means, including a screw means having a threaded end-portion and a non-threaded head end-portion, said second means being constructed and arranged to dispose said screw means for rotation about an axis extending longitudinally of the interior of the housing and restraining the screw means against axial movement relative to said housing;

third means, comprising a reciprocable member in said housing, said member having a threaded aperture aligned with and receiving the threaded end-portion of said screw means for longitudinal movement of the member in said housing incident to rotation of the screw means and said member being restrained against rotation in said housing, said third means comprising a resistance element secured to said member for movement therewith;

fourth means, including contact means secured to said housing and disposed inside the housing, said contact means including means providing contact surfaces constructed and arranged to engage said resistance element at a plurality of points in a plane transverse of the axis of said screw means;

and fifth means, including terminal means for providing electrical connections to said contact means and to end portions of said resistance element, from the exterior of said housing.

13. An adjustable resistor comprising:

first means, comprising an elongate tubular housing including means closing one end of the housing and means providing a bore at the other end of the housing;

second means, comprising an elongate translatable support member having a threaded bore and a portion of reduced transverse cross-section and a portion of greater transverse cross-section, slidable longitudinally in said housing, said second means comprising a resistance element on said portion of reduced transverse cross-section, and said second means comprising electrical terminals and connecting means electrically connecting an end portion of said resistance element to a respective one of the electrical terminals, and said portion of greater transverse cross-section being constructed and arranged for sliding contact with the longitudinal inner wall of said tubular housing;

third means, including rotatable screw means accessible at said bore and engaged in said threaded bore of said support member and restrained by said first means against other than rotary motion relative to said first means, for moving said support and element longitudinally in said housing; and

fourth means, comprising contact means electrically connected to a respective one of said terminals and secured to the inner wall of said housing and encircling said support member and having a plurality of resilient fingers of various lengths for providing an electrical contact with said element at any of a plurality of points in a plane generally transverse to said housing.

14. An adjustable resistor as defined by claim 13, said resistor comprising in said connecting means a coil spring expansible and contractible in the direction of movement of said support and connected between and to said resistance element and said respective terminal.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,069,648 December 18, 1962

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 1, line 16, for "April 2" read -- April 12 --; column 3, line 33, for "nivolved" read -- involved --; column 7, line 44, for "as" read -- is --; column 10, line 23, for "by" read -- be --; line 50, for "is" read -- as --; column 11, lines 74 and 75, after "comprising" insert a colon.

Signed and sealed this 30th day of July 1963.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

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