April 12, 1960 M. E. BOURNS ET AL 2,932,808

ADJUSTABLE ELECTRICAL INSTRUMENTS

Filed May 20, 1957

2 Sheets-Sheet 1

FIG. 1.

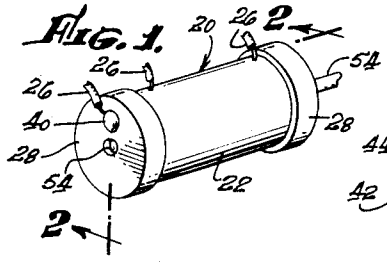
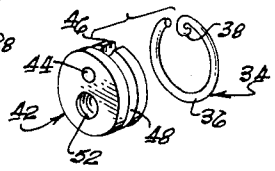


FIG. 4.



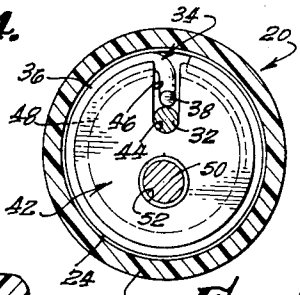


FIG. 3.

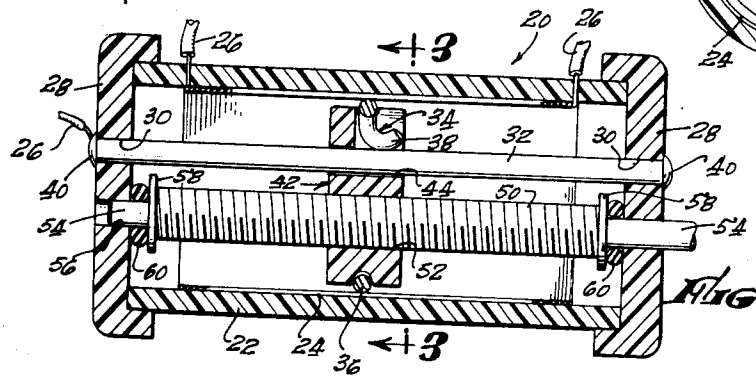


FIG. 2.

FIG. 5.

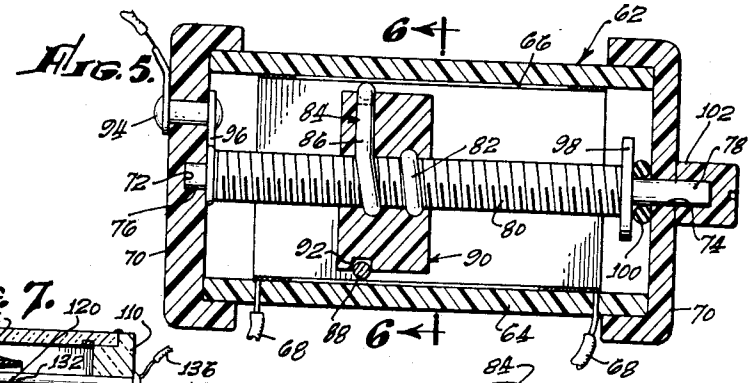


FIG. 7.

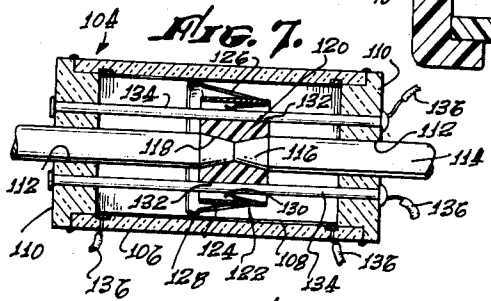


FIG. 6.

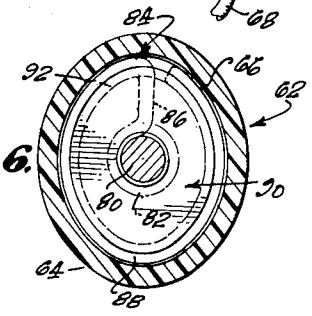


FIG. 8.

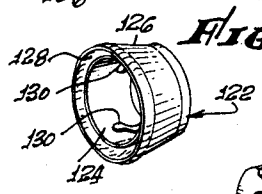
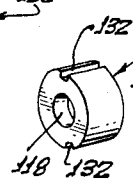


FIG. 9.



INVENTOR.

BY

Attorney.

April 12, 1960 M. E. BOURNS ET AL 2,932,808

ADJUSTABLE ELECTRICAL INSTRUMENTS

Filed May 20, 1957

2 Sheets-Sheet 2

FIG. 10.

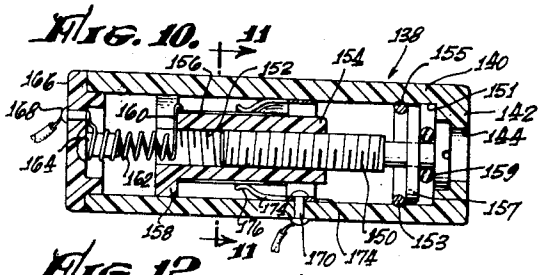


FIG. 11.

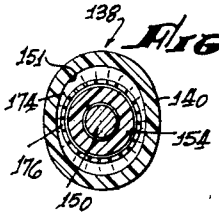


FIG. 12.

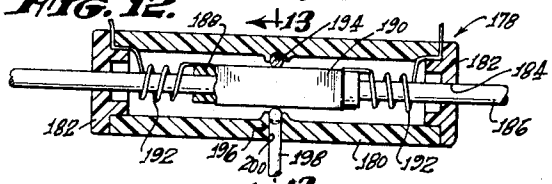
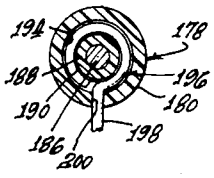


FIG. 13.



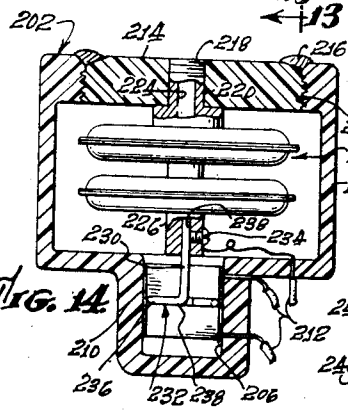


FIG. 14.

FIG. 15.

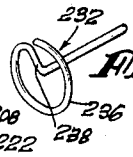


FIG. 16.

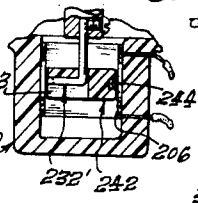


FIG. 19.

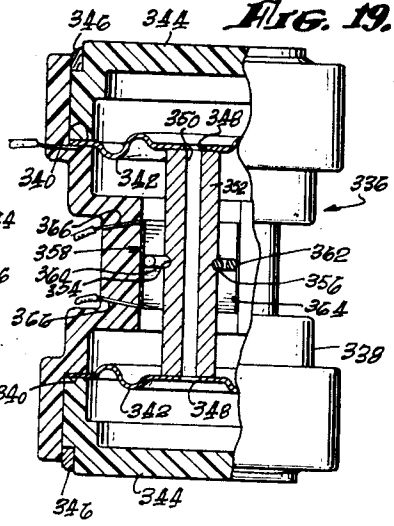


FIG. 17.

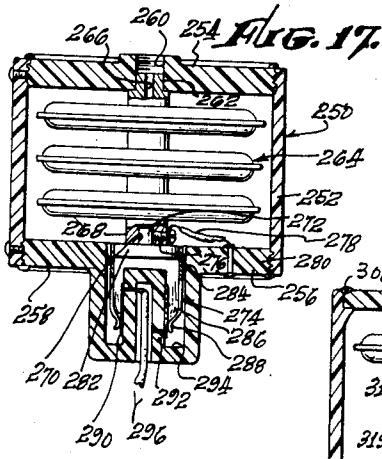


FIG. 18.

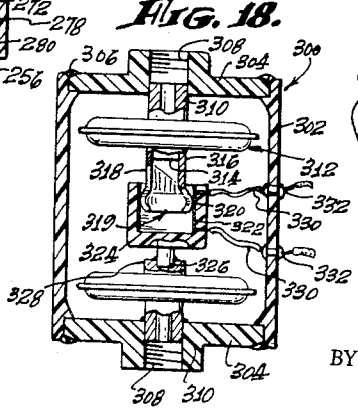
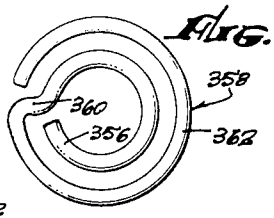


FIG. 20.



INVENTOR.

BY

ATTORNEY.

United States Patent Office 2,932,808
Patented Apr. 12, 1960

2,932,808

ADJUSTABLE ELECTRICAL INSTRUMENTS

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

Application May 20, 1957, Serial No. 660,247

5 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.

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;

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 engaging 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 of 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 involved 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 itself 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 or various types of pressure responsive instruments.

The actual nature of this invention is best more fully explained with reference to the accompanying drawing and to the various instruments illustrated in it. In Figt. 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 the co-pending application, Serial No. 660,246, filed May 20, 1957. Appropriate wire leads **26** are attached to the ends of the elements **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. This 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 servometer 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 servometer, 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 nonconductive 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 in the aforenoted co-pending application Serial No. 660,246, filed May 20, 1957, so as to carry an internal 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 for 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 aforenoted application, Serial No. 660,246, filed May 20, 1957. 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 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 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 as 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 it 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 walls of the housing 140 so as to be connected as by welding or the like to a metal band 174 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 and of the resistance element 156 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 the rotation of the mandrel 154. If desired other terminating means can be attached to the 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 is 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 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 within 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 wire resilient 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 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 shown in the earlier noted co-pending application Serial No. 660,246, filed May 20, 1957. 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 box 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 bandlike 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, hence, weights and hence 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 resonant 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 be 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** as 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 resilient 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. A pressure responsive electrical instrument which comprises: a housing; first and second pressure responsive means mounted within said housing, said pressure responsive means having adjacent movable ends located within said housing; a wound resistance element having a uniform cross-sectional configuration along its length mounted on one of said movable ends within said housing; and contact means mounted on the other of said movable ends within said housing, said contact means engaging substantially all points of said resistance element within a plane perpendicular to the axis of said resistance element, said contact means and said resistance element being capable of being moved with respect to one another so that said contact means always engages substantially all points of said resistance element within a plane perpendicular to the axis of said resistance element.

2. An adjustable electrical instrument of the class described comprising an elongated resistance element having a longitudinal axis, contact means including a plurality of resilient fingers engaging said resistance element at a plurality of angularly spaced points around the exposed surface thereof in a plane perpendicular to said longitudinal axis, said fingers differing from one another in dimension, and means for varying the relative positions of said resistance element and said contact means with respect to one another.

3. An adjustable electrical instrument of the class described comprising an elongated resistance element having a longitudinal axis, contact means including a plurality of resilient fingers engaging said resistance element at a plurality of angularly spaced points around the exposed surface thereof in a plane perpendicular to said longitudinal axis, said fingers differing from one another in length, and means for varying the relative positions of said resistance element and said contact means with respect to one another.

4. An adjustable electrical instrument of the class described comprising an elongated resistance element having a longitudinal axis, contact means including a plurality of resilient fingers engaging said resistance element at a plurality of angularly spaced points around the exposed surface thereof in a plane perpendicular to said longitudinal axis, said fingers differing from one another in cross-sectional configuration, and means for varying the relative positions of said resistance element and said contact means with respect to one another.

5. A pressure responsive electrical instrument comprising a housing, a pair of pressure sensitive bellows mounted at opposite ends of said housing, each of said bellows being connected to a source of fluid pressure, the adjacent ends of said bellows being movable responsive to fluid pressure introduced into the bellows, a resistance element of uniform cross-sectional configuration along its length mounted on the movable end of one of said bellows, and contact means mounted on the movable end of the other of said bellows, said contact means including a plurality of spring fingers engaging said resistance element at a plurality of spaced points around the exposed surface thereof within a plane perpendicular to the longitudinal axis of said resistance element, said contact means and said resistance element being moved with respect to one another along substantially parallel paths so that said spring fingers always engage said resistance element within a plane perpendicular to the longitudinal axis of the resistance element.

References Cited in the file of this patent

UNITED STATES PATENTS

686,245	Bachmann et al.	Nov. 12, 1901
1,371,287	Wirt	Mar. 15, 1921
1,491,345	Gargan	Apr. 22, 1924
2,178,241	Rubinstein	Oct. 31, 1939
2,248,047	Addy et al.	July 8, 1941
2,714,147	Reid	July 26, 1955
2,714,184	Peck	July 26, 1955
2,777,925	Stolz	Jan. 15, 1957
2,807,695	Delmonte	Sept. 24, 1957