May 7, 1963 M. E. BOURNS ETAL 3,089,110

VARIABLE RESISTORS

Filed Feb. 18, 1960

FIG. 1.

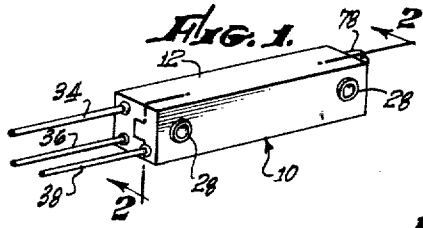


FIG. 4.

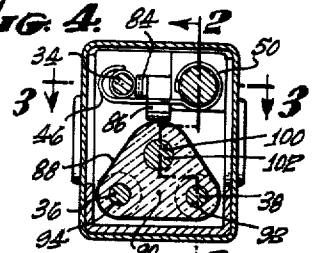
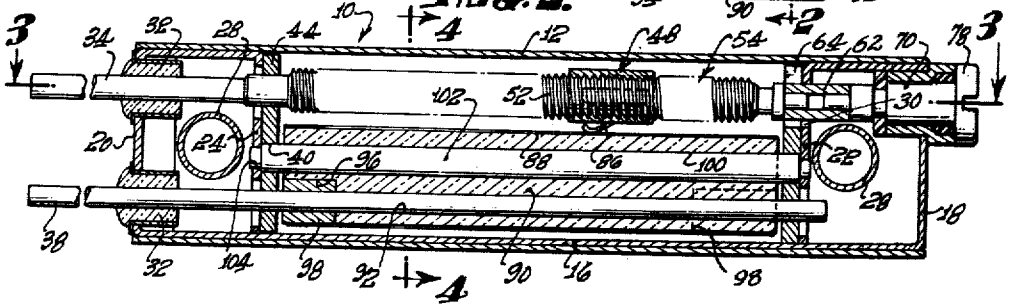


FIG. 2.



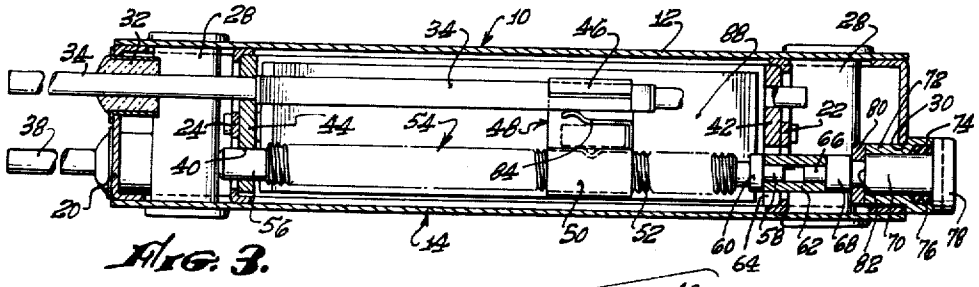
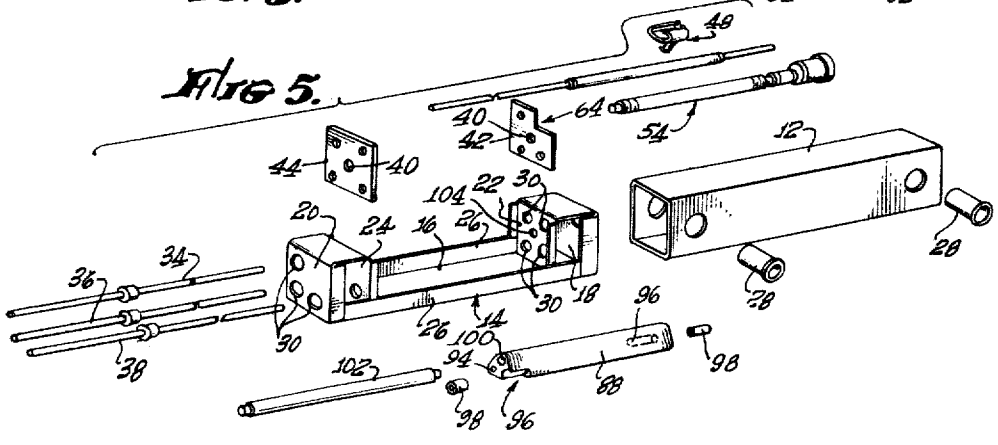


FIG. 3.

FIG. 5.



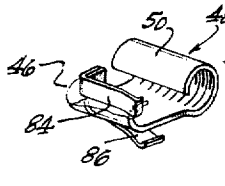


FIG. 6.

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United States Patent Office 3,089,110 Patented May 7, 1963

3,089,110

VARIABLE RESISTORS

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Filed Feb. 18, 1960, Ser. No. 9,535
6 Claims. (Cl. 338—183)

This invention relates to variable resistors, and, more particularly, to miniature potentiometers designed for operation under conditions of high temperature and high humidity.

This application is a continuation-in-part of United States patent application by these inventors, Serial No. 678,395, filed August 15, 1957, now Patent No. 2,938,296, for Variable Resistors.

Miniature potentiometers of the type referred to are extensively used in the electronic equipment of supersonic aircraft and guided missiles, wherein the ambient temperatures are frequently quite high due to air friction and to close proximity of extremely hot combustion chambers of rocket or jet engines. At the same time, there is need for operating the said potentiometers at high power levels, which causes the resistance element to heat up due to I^2R losses. These conditions of high ambient temperature and heating up of the element under high power operation, coupled with the fact that the instrument must be humidity sealed for operation in tropical climates, tend to create a high temperature condition that is conducive to rapid failure of the unit.

In the case of wire wound potentiometers, the mandrel, or "card" upon which the resistance wire is wound usually has a higher coefficient of expansion than the wire, and therefore tends to expand at a faster rate than the wire. The result is that the wire is stretched slightly at high temperature, causing a considerable change in the total resistance of the element from the low temperature resistance value. Furthermore, as the wire windings heat up, the temperature coefficient of the wire causes its resistance to increase still further, thereby compounding the difficulty. At the same time, any parts made of organic material, such as instrument bodies of thermosetting plastic or the like, tend to decompose at high temperatures, with deleterious effects on the electrical performance of the instrument.

One of the primary objects of the present invention, therefore, is to provide a humidity sealed variable resistor or potentiometer designed particularly for operation under high temperature conditions. This object has been achieved by providing a variable resistor made almost entirely of inorganic material such as metal and ceramics, wherein provision is made for rapidly conducting heat away from the resistance element to the outer case of the instrument, to be dissipated to the atmosphere. In the preferred form of the invention, a metal rod, sometimes referred to as a "heat sink" rod, is embedded in the mandrel just below the resistance windings, and the ends of the metal rod are held by a metal support member which is in heat-conductive contact with the metal outer case of the instrument. Thus, there is an effective heat-conductive path provided from the resistance windings to the metal outer case, which acts to conduct heat away from the windings as fast as it is generated by the current carried by the resistance element.

Another object of the invention is to provide a variable resistor of the class described which may be hermetically sealed to make a permanently humidity proof instrument. This is achieved by constructing the outer case and inner support member of metal, so that all exposed joints may be soldered closed to make them vapor tight; while the terminal wires are brought through an outer wall of the housing by means of glass feed-

throughs, which are hermetically sealed to the wires and to the housing. The instrument is made entirely, or substantially entirely, of inorganic material so as to withstand the heat of soldering, as well as to conduct heat rapidly from the resistance element to the outer case.

A further object of the invention is to provide a new and improved means for terminating the windings at the end of the resistance element and also provide a length of shorted-out windings at each end of the element, for overtravel of the sliding contact. This is accomplished by providing a pair of round metal plugs which are embedded in the mandrel or card of the resistance element at opposite ends thereof; the outer surface of the plugs being flush with the surface of the mandrel, and the wire windings being wrapped around and subsequently soldered or welded to the plugs. This arrangement has the advantage of providing a simple and inexpensive method of manufacturing resistance elements to close tolerances on total resistance, while the shorted out windings allow for a limited amount of overtravel of the contact without creating an open circuit.

Still another object of the invention is to provide a new and improved contact member for a variable resistor of the type referred to, which has a number of advantages over prior contacts. One advantage of this new contact is that it is formed entirely of sheet metal, and therefore is adapted to conduct heat rapidly from the resistance windings to the leadscrew. Another feature of the contact is that it engages the threads of the leadscrew with a resilient, yielding engagement which permits the contact to slip with respect to the threads if the leadscrew is forced after the contact has reached the end of its travel.

Another object of the invention is to provide a new and improved variable resistor which is simple and inexpensive to manufacture, extremely compact in arrangement, and ruggedly constructed to withstand extreme vibration acceleration, and other external stresses to which such instruments are subjected in aircraft and missiles. A related object is to provide a wire wound resistance element of space saving, non-round configuration, but without extended flat sides that tend to cause loose wires, which permits use of a maximum length of resistance wire within a housing of rectangular cross section.

The foregoing and other objects and advantages of the invention will become apparent to those skilled in the art upon consideration of the following detailed description of one preferred embodiment thereof, reference being had to the accompanying drawings, wherein:

FIGURE 1 is a perspective view of a potentiometer embodying the principles of the invention;

FIGURE 2 is a cross-sectional view taken at line 2—2 of FIGURE 1;

FIGURE 3 is a cross-sectional view taken at line 3—3 of FIGURE 2;

FIGURE 4 is a cross-sectional view taken at line 4—4 of FIGURE 2;

FIGURE 5 is an exploded view showing the various parts employed in the potentiometer shown in the preceding figures;

FIGURE 6 is an enlarged perspective view of the contact member employed in this potentiometer.

From a consideration of the drawings, it will be realized that FIGURE 2 also corresponds to a sectional view taken in direction of line 2—2 of FIGURE 4 and that FIGURE 3 corresponds to a sectional view taken in the direction of line 3—3 of FIGURE 4. The accompanying drawing is not to be taken as limiting this invention in any respect. Obviously a number of changes of essentially an engineering nature may be made in constructing differently appearing variable resistors or potentiometers in accordance with the basic teachings of this

invention. All such changes or alterations are to be considered as part of the present invention insofar as they are defined by the appended claims.

As an aid to understanding the invention, it may be stated that it concerns variable resistors or potentiometers employing what may be termed "heat sink means" to maintain the temperature of resistance elements utilized in such instruments. Further, with such heat sink means it is considered necessary to employ a housing or casing which is capable of being used in maintaining the temperature within an electrical instrument of the type indicated. Also, it is considered preferable to use specifically formed contact means as hereinafter specified so as to prevent the build up of heat within such instruments. Because of the nature of this invention, it is considered necessary to refer directly to the accompanying drawing in order to explain it more fully.

In the drawing there is shown a complete variable resistor or potentiometer **10** of the present invention which is built to include a tubular type of metal casing or housing **12**. As will be apparent from the drawing this casing **12** is of a generally rectangular cross section and serves to carry a closely fitting internal support **14**. Preferably this support **14** is made out of a single piece of metal and is bent so as to include a bottom **16**, a front end wall **18** and a rear end wall **20**; a front support wall **22** is formed so as to extend from and parallel to front end wall **18** and a rear support wall **24** is similarly formed so as to extend from, and parallel to, the rear end wall **20**. Also, it is normally preferred for structural purposes to provide various flanges **26** upon the support **14**.

This support **14** is normally employed so as to hold all of the principal parts of the potentiometer **10** during the assembly of this instrument. Preferably, in the final instrument it is secured as by soldering or equivalent processes to the casing **12**, although if desired, it may be merely formed so as to fit against this casing **12** in such a manner as to be held in place by means of hollow rivets **28** which fit between the front end wall **18** and the front support wall **22** and which fit between the rear end wall **20** and the rear support wall **24**. Such rivets **28** may be conveniently used in mounting the entire potentiometer **10** for use.

As can best be seen in FIG. 5 of the drawing the rear end wall **20** and the front support wall **22** and the rear support wall **24** all contain a series of aligned openings **30**. The openings in the rear end wall **20** are adapted to carry small insulating bushings **32** formed out of ceramic or the equivalent. Preferably such bushings are secured to the rear end wall **20** as by solder or other equivalent techniques. Preferably these bushings **32** carry respective attached elongate wires **34**, **36** and **38**, which, as indicated in FIGS. 2, 3, and 5 of the drawing, are of such dimension as to extend across the bottom of the support **14** through the openings **30** in the front support wall **22**. The wires **34**, **36** and **38** also all fit closely within small openings **40** in front and rear support plates **42** and **44** formed out of non-conductive material, such as for example, a ceramic. These plates **42** and **44** fit closely against the front and rear support walls **22** and **24**, respectively, and are held in place by certain of the flanges **26** previously mentioned.

The wire **34** in the potentiometer **10** serves as an electrical return for this entire instrument and is resiliently engaged by means of a generally U-shaped end **46** of a metal contact member **48**. As is best seen in FIG. 6 of the drawing this contact member **48** also includes a partially cylindrical end **50** the interior of which may be threaded so as to resiliently engage the threads upon a threaded portion **52** of a shaft **54**. If desired, the end **50** may be considered to have essentially a U-shape. The shaft **54** includes a smooth end **56** which rotatably fits within an opening **40** in the support plate **44**; it also includes another end **58** and a flange **60** which are designed to fit within and engage, respectively, a small

sleeve **62**. As noted in FIG. 2 of the drawing, this sleeve **62** extends through a notch **64** in the front support plate **42** and through an opening **30** in the front support wall **22**. As indicated more clearly in FIG. 3, the sleeve is engaged by an end **66** projecting from a shoulder **68** on an adjusting shaft **70**.

As is seen in FIGS. 2 and 3 of the drawing this adjusting shaft is carried within a generally cylindrical bearing **72** attached to the front end wall **18** and which bearing includes an external cylindrical flange **74** serving to hold a resilient, elastomeric seal **76** against the back of a slotted head **78** so as to effectively seal the potentiometer **10**. Obviously the head **78** is a part of the adjusting shaft **70** and is used in order to adjust the potentiometer **10**. Movement of the adjusting shaft **70** away from the remainder of the potentiometer is prevented by means of a snap ring **80** fitting within a groove **82** in this adjusting shaft **70** in such a manner that the snap ring bears against an end of the bearing **72**.

As the slotted head is turned as through the use of a screwdriver or the like, the entire shaft **54** is caused to rotate. This, of course, causes the contact member to move within the portion of the potentiometer **10** between the front and rear support walls **22** and **24**. As such motion occurs the ends **46** and **50** upon the contact member **48** resiliently engage both the wire **34** and the threaded portion **52** of the shaft **54**. The ends **46** and **50** of the contact member **48** are capable of springing apart from the wire **34** and the threaded portion **52** of the shaft in the event this contact member **48** is moved into engagement with either of the support plates **42** or **44**. This is considered to be important commercially inasmuch as it prevents damage to the entire potentiometer **10** if this eventuality occurs.

As the contact member **48** is moved as indicated, a small resilient metal arm **84** formed on this contact member resiliently engages the wire **34** so as to effectively establish electrical contact with it. Another similar arm **86** formed on the contact member **48** also engages a resistance winding **88** located upon a non-conductive support **90**. This support may be formed out of a wide variety of materials, such as any of a number of well known ceramic compositions. Preferably within the potentiometer **10** the support **90** has essentially the external shape of a triangular prism, the faces of which are joined by curved edges substantially as shown. A support having a shape of this type makes it possible to obtain effective space utilization within this potentiometer **10** and, further, permits the use of more resistance material in the resistance winding **88** than is possible with many prior types of resistance element support structures.

Within the interior of the support **90** there are formed holes **92** and **94** which extend between the ends of the support. Adjacent to each of the ends of the support **90** there is formed a cavity **96**; these cavities **96** are adjacent to the holes **92**. It is noted that these cavities are of a generally cylindrical configuration and that a part of each of these cavities **96** is contiguous with the exterior configuration or surfaces of the support **90**. As indicated in FIGS. 2 and 4 of the drawing the wires **36** and **38** project through respective ones of the inserts **98** and respective ones of the holes **94** and **92**; each of these wires is attached to one of the inserts **98** as by welding or equivalent techniques. The exposed ends of the wires **36** and **38** are supported within the openings **40** in the support plate **42**.

The electrically conductive inserts **98** are arranged in such a manner that the end portions of resistance winding **88** overlay respective inserts **98** so as to provide effective termination for this winding. Preferably, the resistance winding **88** is attached as by soldering or the like to these inserts although this is not necessary and satisfactory termination can, for many purposes, be made by merely winding a resistance wire around the inserts

98, and the support 90. It is noted that the inserts 98 are located so as to be generally between different faces or sides of this support 90 in such a manner that the wires 36 and 38 can serve to aid in supporting the support 90 and the winding 88. It may be stated that the support 90 and this winding 88 constitute a complete resistance element.

In order to achieve satisfactory heat control within the potentiometer 10 another hole 100 similar to the holes 92 and 94 is provided within the support 90. A metal rod 102 fits closely within this hole and projects through two aligned openings 40 in the support plates 42 and 44 so as to fit closely within and against comparatively small openings 104 in the front and rear support walls 22 and 24. If desired, the ends of this rod 102 may be attached to these support walls as by welding, soldering or other equivalent. In use the rod 102 will convey heat generated within the resistance winding 88 so as to tend to keep the temperature of this resistance winding within a "usable" range so that the total resistance of the winding does not change to any appreciable extent. Thus, if desired, the rod 102 may be termed a "heat sink rod."

By virtue of the construction shown heat is conveyed by this rod to the front and rear support walls 22 and 24 and to the support 14, thence to the casing or housing 12. Since all of these walls and parts are formed of metal, they conduct heat readily and virtually the entire external surface of the potentiometer 10 is thus available to dissipate heat by either convection or conduction, depending upon where and how this potentiometer 10 is mounted. This is important in that the entire housing for this potentiometer 10 serves to aid in maintaining the temperature of this instrument.

Further, it will be noted that the entire potentiometer 10 is constructed in such a manner that no "massive" parts, such as a comparatively large plastic movable member forming a part of a contact element are employed which would tend to build up or hold heat within the interior of this instrument. The contact member 48 is preferably formed out of comparatively thin resilient metal, and hence the control member 48 does not hold heat to any appreciable extent. Further, this will tend to conduct heat to both the shaft 54 and to the wire 34 serving as an electrical return in such a manner that these parts will tend to conduct heat away from the resistance winding 88.

Although the casing 12 and the support 14 are specifically designed in the potentiometer 10 primarily in order to obtain effective, efficient heat control, these structures may be employed in other instruments. In a potentiometer a variable resistor with a casing such as the casing 12 and a support, such as the support 14, provide a comparatively strong instrument which is resistant to rough handling and the like which can only be bent with comparative difficulty. Further, these advantages can be obtained when these parts are formed out of other materials than are specifically indicated. Further, many of the advantages of the contact member 48 make it advantageous to use this type of contact member in other variable resistors and potentiometers.

Because of the fact that a large number of differently appearing potentiometers may be readily designed which utilize the essential features or principles of this invention, this invention is to be considered as being limited only by the appended claims forming a part of this disclosure.

We claim:

1. An electrical instrument comprising: a generally hollow metallic housing member; support means, comprising a metallic support member, having end wall means and positioned within said housing member in close contact with the housing member over a considerable area of the interior of the housing member to facilitate heat transfer therebetween; other means, including a resistance element and electrical return means, mounted on said wall means; means, including a shaft means, supported by said wall means and extending to the exterior of said housing; means, including a contact member resiliently engaging said resistance element, engaging said shaft means for movement thereby and electricaly connecting said electrical return means with said resistance element and constructed and arranged to be moved to move said contact means along said resistance element in response to movement of said shaft means; means including respective electrical leads connected to said resistance element and said electrical return and extending to the exterior of said housing member; and means sealing the interior of said housing member against ingress of foreign material.

2. An electrical instrument according to claim 1, said resistance element comprising a ceramic mandrel and resistive means supported thereon in intimate contact therewith, and said other means comprising metallic means extending into the interior of said mandrel and disposed in close contact with both said mandrel and said metallic support member for facilitating heat transfer between said mandrel and said metallic support member.

3. An electrical instrument comprising: a generally hollow metal housing member; means, including a metal support member having generally opposed wall-forming portions, disposed within the housing member with close metal-to-metal contact therewith to facilitate heat-transfer therebetween; means, including a resistive means and an electrically non-conductive mandrel supporting the resistive means and having an opening extending into the interior thereof, disposed between said wall-forming portions; other means, including insulated terminal means comprising at least one terminal electrically and mechanically joined to said resistive means, extending from within to respective locations outside said housing member, said other means including means for varying the resistance interposed between said terminal means; metal means extending into said opening and arranged in metal-to-metal contact with said metal support member to form therewith a metallic heat-conducting path from within said mandrel to said metal housing member; and means serving with said support member to seal said housing member against ingress of foreign matter from the ambient exterior thereto.

4. A variable resistor comprising: a resistance element comprising essentially an elongate ceramic mandrel of generally trigonic cross-section with three rounded edges and said mandrel bearing an elongate resistive means along a length thereof with the resistive means exposed along at least one of said rounded edges for cooperation with a movable contact; means, including a movable contact, constructed and arranged for cooperation with said resistive means for variation of resistance exhibited between the contact and one end of the resistive means; and means, including terminal means comprising a metallic member extending longitudinally through said mandrel and serving as a support for said mandrel, said resistive means comprising a resistance element having terminations adjacent respective ends of said mandrel, and said metallic member comprising an exposed bare metallic surface forming a continuation of one of the said rounded edges of said mandrel and underlying said element at one end thereof and mechanically and electrically connected to said element.

5. A variable resistor according to claim 4, said terminal means comprising a second metallic member similar to the first mentioned metallic member and similarly disposed and underlying said resistance element at the opposite end thereof and similarly mechanically and electrically connected to said element.

6. A variable resistor according to claim 4, including metallic housing means enclosing said mandrel means and said element and said contact, and comprising means seal-

ing said housing means and enclosed means against ingress of foreign matter detrimental thereto.

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