June 19, 1956 M. A. COLER ET AL 2,751,473

ELECTRIC RESISTOR

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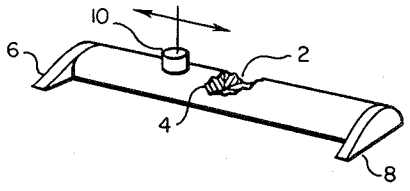


Fig 1

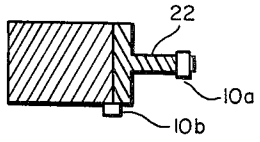


Fig 5

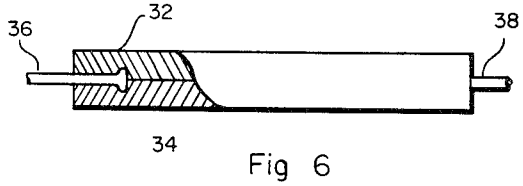


Fig 6

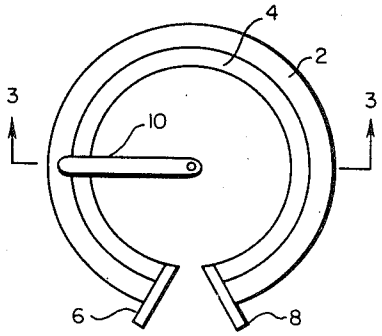


Fig 2

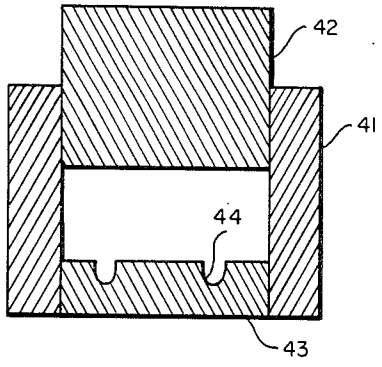


Fig 7

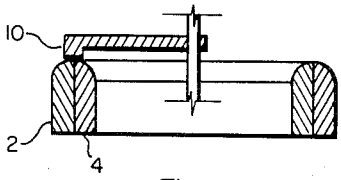


Fig 3

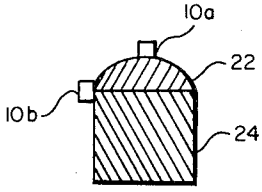


Fig 4

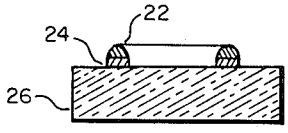


Fig 8

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ELECTRIC RESISTOR

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5 Claims. (Cl. 201—55)

This invention relates to improved electrical resistance devices. In particular this invention relates to potentiometers and rheostats having desirable temperature coefficients of electrical resistivity.

A common problem in the design of electrical equipment is the change in ohmic resistance of a circuit element with change in temperature. Most commonly, such temperature changes are caused by power dissipation resulting from passage of current through the element or by exposure to an external heat source such as the heat from a nearby vacuum tube. Even more serious disturbances can occur within a circuit element when nonuniform heating occurs, as, for instance, when the element is used as a rheostat or when one side of a potentiometer is selectively heated. Prior art attempts to compensate a circuit for such changes have, to the best of our knowledge, been directed to the use of a compensating circuit placed either in series or in parallel with the resistance element.

A variable resistance device such as a rheostat or a variable voltage device such as a potentiometer in conjunction with a compensating element would be properly compensated by a series compensator only at one position of the slider unless a variable compensating element is provided. This latter is a costly and complex solution. A compensating element connected in parallel with the end terminals of a potentiometer may provide constant voltage output with temperature change provided that the temperature is uniform throughout the potentiometer and its compensating resistor at all times.

In particular it should be noted that the foregoing attempts are particularly unsuitable for elements subject to differential heating. The use of separate compensating resistors serves only to correct the unit as a whole. If parts of the potentiometer are heated differently or if the potentiometer and compensator are heated differently, the accuracy of the compensation is destroyed.

This invention provides a resistance unit having two or more resistance elements of different temperature coefficients of electrical resistivity combined in such a manner that each differential length of the unit is corrected to the desired temperature coefficient of electrical resistivity. This contribution to the art is significant because the manufacture of such items as temperature stable potentiometers is now possible; adherence to function is maintained at all points along the path between the fixed terminals of the unit.

It is an object of this invention to provide an improved resistance device.

It is a particular object of this invention to provide a resistance device having a zero temperature coefficient of electrical resistivity.

It is still another object of this invention to provide a potentiometer exhibiting the same temperature coefficient of electrical resistivity at all positions of the variable contact.

Other objects and advantages will in part be obvious

and in part pointed out in the following description and accompanying drawings in which:

Fig. 1 presents isometrically a rectilinear potentiometer element of this invention.

Fig. 2 discloses a plan view of a rotary potentiometer element of this invention.

Fig. 3 shows the potentiometer element of Fig. 2 in section.

Fig. 4 is a cross-sectional view of an alternate arrangement of this invention.

Fig. 5 is a cross-sectional view of another embodiment of this invention.

Fig. 6 presents in elevation, and partially sectioned, a fixed resistance element made in accordance with this invention.

Fig. 7 is a cross-sectional view of a mold adapted to the manufacture of potentiometer elements of this invention.

Fig. 8 shows in cross-section a potentiometer element of this invention.

There is shown in Figures 1, 2 and 3 simple embodiments of this invention in a device having a zero temperature coefficient of electrical resistivity. This device is formed of two resistive portions in intimate electrical contact at all points along their length.

For purposes of illustration, assume the simple case of Fig. 1 wherein the resistive portions **2** and **4** are composed of material having like specific resistivities and having like cross-section areas. They will carry like currents for any potential applied to terminals **6** and **8**. If, in addition, the materials have equal but opposite temperature coefficients of electrical resistivity, then, to a first approximation, the composite element will exhibit a zero temperature coefficient of resistivity. Contact **10** is located so as to contact both resistive portions **2** and **4**.

In actual practice it is unlikely that suitable materials of like resistivity and exactly equal and opposite temperature coefficients of resistivity exist. However, if a zero temperature coefficient of electrical resistivity is desired, the resistance of two unlike resistance paths having temperature coefficients of opposite sign need only be in the direct ratio of their individual temperature coefficients. In terms of cross-sectional area of the resistance paths, the following formula may be used:

$$A_1/A_2 = -k_2P_1L_1/k_1P_2L_2$$

where A_1 and A_2 are the respective cross-sectional areas of the resistance paths, P_1 and P_2, are the respective specific resistivities of the paths, k_1 and k_2 are the respective temperature coefficients of resistivity of the materials of each path and L_1 and L_2 are the respective lengths of the resistive paths. L_1 and L_2 may be slightly different when the variable resistor is of the rotational type of Figure 2 rather than the rectilinear type of Figure 1 but even in the former case the difference may often be ignored for practical purposes so that the simpler equation,

$$A_1/A_2 = -k_2P_1/k_1P_2$$

applies.

In order that the above equation may hold throughout the length of the variable resistor it is preferred that terminals **6** and **8** make contact with the resistive paths having both temperature coefficients of resistance. Otherwise there will be a small part of the element near the terminal where the lines of current flow will not have distributed themselves through the entire cross-section of the element and the calculated conditions will not prevail. Still preferable is the arrangement shown in Figure 1 where terminal **8** intersects the entire active cross-section of the element.

If a particular specific temperature coefficient of resistivity k_s is desired, the following equation applies:

$$k_s(R_1+R_2)=R_2k_1+R_1k_2$$

where R_1 is the ohmic resistance of one portion, R_2 is the ohmic resistance of the second portion, k_s is the resultant equivalent temperature coefficient of electrical resistivity of one portion and k_2 is the temperature coefficient of electrical resistivity of the second portion.

From this equation, the proper resistance of the second component of a pair can be determined once the resistance of the first member has been chosen if the individual properties of the materials are known.

It should be appreciated that three or more elements of selected temperature coefficients may be employed in the same fashion.

It is apparent that once the basic principles disclosed herein are understood, a person skilled in the art can vary accordingly cross-sectional areas and substitute materials of various specific resistivities and temperature coefficients in order to obtain the desired result without departing from the spirit of my invention. Whereas for purposes of compensating variable resistors it may be desired that contact be simultaneously made to the different materials, it is often found simpler to manufacture the element in a form wherein the contact is made to only one material.

It is appreciated that the equations given earlier are exact for variable resistors only in the case where contact is made simultaneously to all the resistive elements; however, the deviation resulting from contacting only one element is often sufficiently small to be negligible or may be readily corrected for in an empirical manner. This effect will be negligible for a potentiometer being fed into a circuit of high impedance.

In general, other cases where the effect is negligible are those wherein the contacted element is thin; where the structural geometry requires a thick element the effect may be considerable. This latter case is often a preferred design as it makes possible the utilization of a small amount of material of say a low positive temperature coefficient to control a larger amount of negative temperature coefficient material.

Such a situation is illustrated by Figures 4 and 5 wherein portion **22** exerts a greater effect in proportion to its cross-section than portion **24** because of the location of probe **10***a*. If probe **10***b*, located at the juncture of the materials of **22** and **24**, were utilized a correspondingly greater amount of the material of layer **22** would be required.

The embodiment of this invention in a fixed resistor is disclosed in Figure 6 wherein portion **32** may be a resistive material of a positive temperature coefficient of resistivity comolded to portion **34** which may be material of a negative temperature coefficient of resistivity. Pigtails **36** and **38** may be integrally molded.

It is often convenient that a resistive element such as is shown in cross-section in Figure 8 be integrally comolded to an insulator base piece. This may be accomplished by use of a mold such as is shown in vertical cross-section in Figure 7 where **41** is a simple cylindrical retaining ring and **42** is an upper, close-fitting, movable mold force. Lower force **43** carries a groove **44** adapted to form a resistive element of cross-section such as is shown in Figure 8.

In use, a first preformed conductive composition material ring is loaded into groove **44**. Thereafter a second preformed conductive composition ring is loaded into groove **44** on top of the first preform. Finally, insulating plastic molding compound is charged into the space overlying force **43**. The molding operation is then completed under time, temperature and pressure conditions suitable for the materials in question.

A molding such as would be produced in this fashion is shown in cross-section in Figure 8 where portions **22** and **24** correspond to the resistive portions and portion **26** constitutes an insulating and supporting member whereby the complete element can be readily handled and incorporated in a conventional casing with a moving contact to form an operative potentiometer or rheostat.

Any conductive materials which can be laid down in the desired pattern may be used for the purposes of this invention but it is preferred that composition resistor materials, or, more specifically, electrically conductive plastic materials be used. By such a choice of materials the various component sections of the finished unit can be matched as to temperature coefficient of expansion, hence the assembly will have much greater mechanical stability than would be possible otherwise. By contrast, elements made of dissimilar materials such as pairs of metals or coatings of graphite on metal may tend to distort and even cause one component to break away from the other.

The term potentiometer as used herein is intended to include such articles when used as rheostats and related variable resistance devices.

The invention is further disclosed by the following examples which it should be understood are presented by way of illustration and are not intended to be limiting.

Example 1

A 10 ohm fixed carbon composition type resistor which exhibited a temperature coefficient of —400 parts per million per °C. was coated between terminals with a thin stripe of conductive lacquer (E. I. du Pont silver, formula number 4132). It was found that the temperature coefficient of resistivity of the composite resistor was +10 parts per million per °C. while the resistance was 7 ohms.

Example 2

A mold cavity designed to form a potentiometer resistance element having approximately the shape of cross-section shown in Figure 4 and having a total height of 0.050 inch and a width at its base of 0.040 inch was filled to about 0.015 inch of its depth with a preform of conductive plastic which when molded alone in the same cavity gave an element having a resistance of 2700 ohms and which had a temperature coefficient of resistance of about —400 parts per million per °C. This cavity occupied one face of a lower force such as shown in Figure 6. The remaining space was filled with preformed conductive plastic which when molded alone in the same cavity gave an element having a resistance of 2300 ohms and which had a temperature coefficient of resistance of about +1500 parts per million per °C. The amounts of the first and second plastics used were approximately in the ratio of 3:1 respectively. The lower force was assembled in a retaining ring as shown in Figure 7 and the resulting large cavity filled to a depth of about ½ inch with mineral-filled phenolic molding compound. The whole was molded under usual molding conditions for the phenolic plastic in question.

The temperature coefficient of resistance of the resulting potentiometer element was measured and found to be 30 parts per million per ° C. Its resistance was found to be 2400 ohms. The linearity was found to be ±1.2%.

It is apparent that many varied constructions and combinations within the spirit of the following claims are possible; therefore it is intended that the foregoing material and accompanying drawings be regarded merely as illustrative and not limiting in any sense.

What is claimed is:

1. A potentiometer comprising in combination: a resistance element comolded from two electrically conductive compositions of unlike temperature coefficients of resistivity; a contact member adapted to be variably positioned in contact with said resistance element; two normally fixed spaced terminals electrically connected to said resistance element; wherein said resistance element provides two parallel electrically conductive paths

between said terminals, said paths being in continuous electrical connection.

2. The potentiometer of claim 1 wherein said contact member electrically contacts simultaneously both of said electrically conductive compositions.

3. The potentiometer of claim 1 wherein the relationship of one of said electrically conductive paths to the other of said electrically conductive paths is expressed by the equation:

$$A_1A_2 = -k_2P_1/k_1P_2$$

where A_1 and A_2 are the respective cross-sectional areas of the resistance paths and P_1 and P_2 are the respective specific resistivities of the said paths and k_1 and k_2 are the respective temperature coefficients of resistivity of the composition of each of said paths.

4. A variable resistance device comprising, in combination: a resistance element comolded from two electrically conductive compositions of unlike temperature coefficients of resistivity; a contact member adapted to be variably positioned in contact with said resistance element; at least one fixed means for electrically connecting said resistance element to an external circuit; wherein said

resistance element provides two parallel electrically conductive paths between said fixed means and said contact member, said paths being in continuous electrical connection.

5. A temperature compensated resistor comprising a first resistive portion having a negative temperature coefficient of resistivity, a pair of terminals making electrical contact to said first resistive portion and a second resistive portion having a positive temperature coefficient of resistivity comolded along its entire length to said first portion so as to provide a parallel electrical path between said terminals.

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