

March 8, 1960

K. W. JARVIS
VARIABLE RESISTOR

2,927,367

Filed Aug. 27, 1956

2 Sheets-Sheet 1

FIG. 1

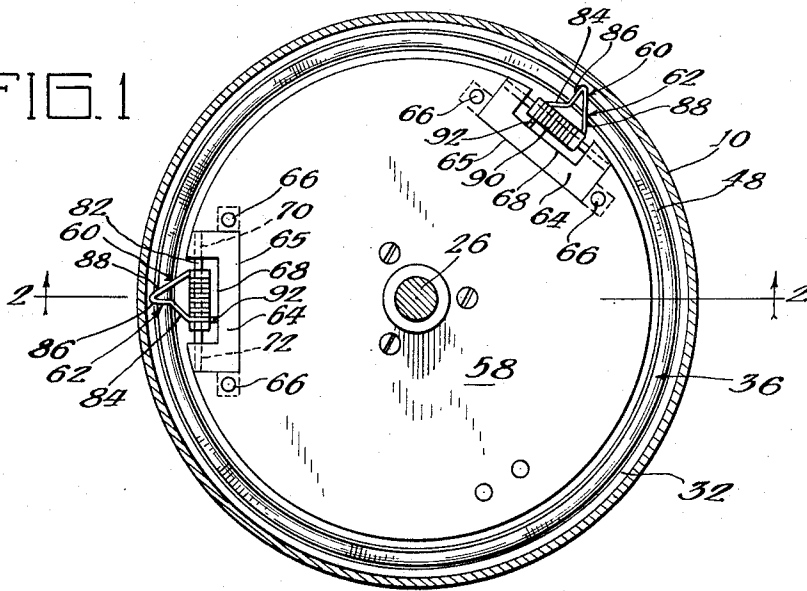


FIG. 2

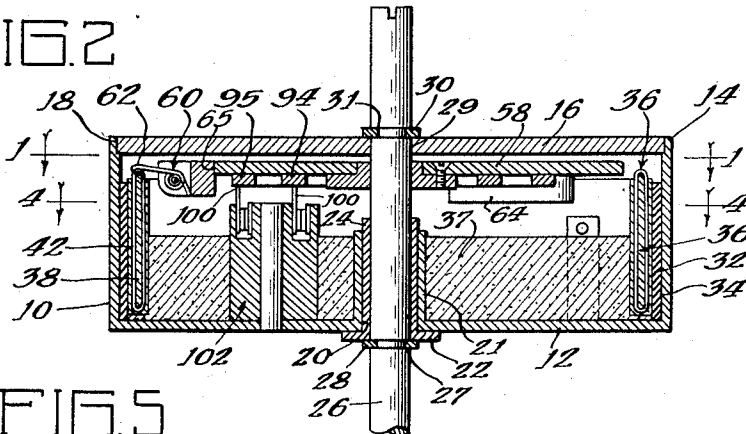
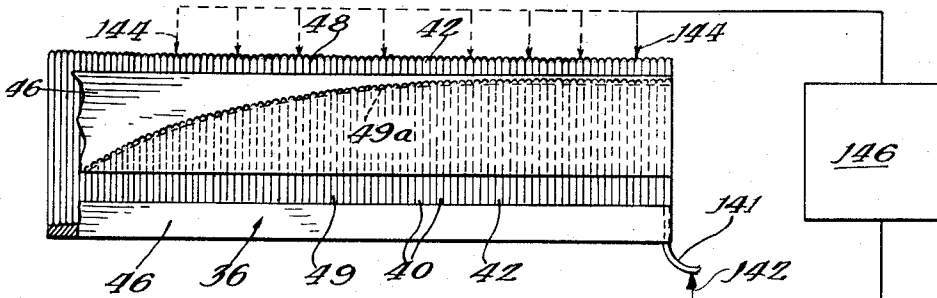


FIG. 5



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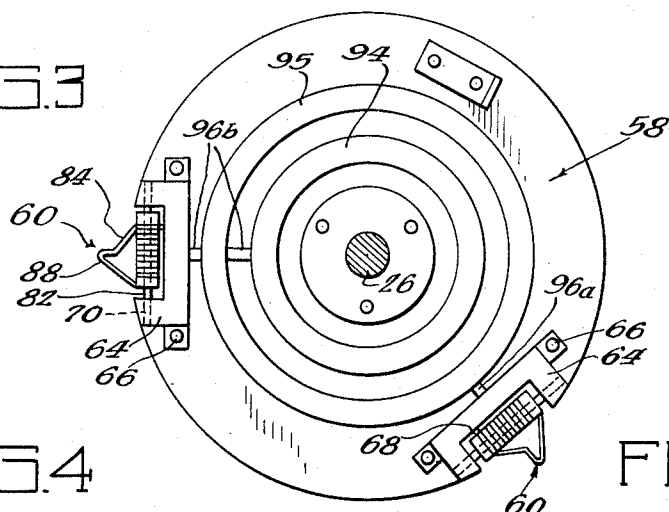
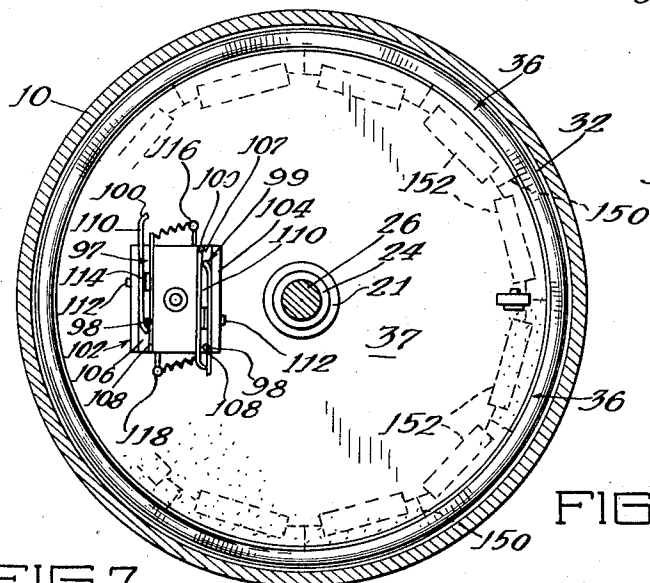
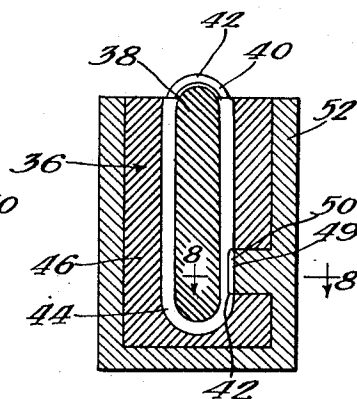
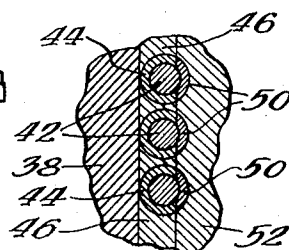
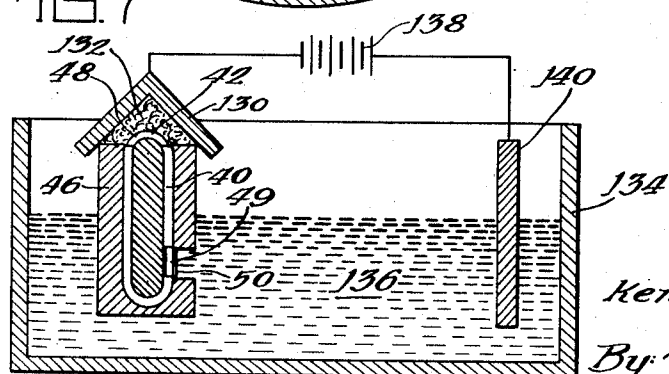
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VARIABLE RESISTOR

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Application August 27, 1956, Serial No. 606,408

3 Claims. (Cl. 29—155.68)

The present invention relates generally to variable resistors, and more specifically to variable resistors in which a given displacement of the movable contact on the resistance element produces a precise change in resistance. The invention also relates to methods of manufacturing variable resistors.

Most variable resistors for use in devices requiring relatively small currents, such as electronic devices, are constructed with resistance cards which have a plurality of turns of resistance wire wound transversely around a strip of electrical insulating material. A slidable electrical contact is in physical contact with a narrow band of exposed turns which extends generally normal to the direction of the turns, so that movement of the electrical contact along this band forms electrical contact with different portions of the resistance card. If the change in resistance is to be linear with displacement of the electrical contact, each of the turns must be separated by an identical distance, and the total resistance around each turn must be identical. Neither of these requirements can be readily accomplished except by expensive precision equipment. To accomplish the first requirement, it is necessary to wind the turns of resistance wire onto the electrically insulating strip with great accuracy and to secure them in place before any change in their position can occur. The second requirement is hampered by the fact that resistance wire has a non-uniform incremental resistance along its length, largely due to manufacturing difficulties.

It is one of the objects of the present invention to provide a variable electrical resistor which exhibits the desired relationship between displacement of the electrical contact and resistance with precision greater than that obtainable by ordinary production methods.

It is also an object of the present invention to provide a method of manufacturing precision variable resistors which corrects the error in the contact displacement resistance relationship of the resistor after the resistance card has been formed.

The difficulty in constructing a variable resistor having a precise resistance to displacement of the electrical contact relationship is magnified if the resistance to displacement relationship is to be other than linear, for example, exponential. At present, variable resistors of this type are wound with different spacings between adjacent turns of a resistance wire on the resistance card, or by having a resistance card wound about an electrically insulating strip of increasing width. Further, the precision of the relationship between resistance and displacement of the electrical contact for such a resistor is limited by the same factors that limit a linear resistor. It is therefore an object of the present invention to provide a variable resistor in which the resistance to displacement relationship is precise and may be either linear or non-linear.

It is a further object of the present invention to provide a method of manufacturing variable resistances with precision relationships between resistance and displacement of the electrical contact in which this relationship may be either linear or non-linear.

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These and other objects of the present invention will be readily apparent to the man skilled in the art from a further reading of the present disclosure, particularly when viewed in the light of the drawings, in which:

5 Figure 1 is a sectional view of a resistor constructed according to the teachings of the present invention, the section being taken along the line 1—1 of Figure 2;

Figure 2 is a sectional view of the resistor taken along the line 2—2 of Figure 1;

10 Figure 3 is an elevational view of the opposite side of the contact disc from that illustrated in Figure 1;

Figure 4 is a sectional view taken along line 4—4 of Figure 2;

15 Figure 5 illustrates one of the steps in the manufacturing process and shows an elevational view of the resistance card;

Figure 6 is a sectional view through the resistance card in another step in the manufacturing process;

20 Figure 7 is a sectional view illustrating still another manufacturing step; and

Figure 8 is an enlarged fragmentary sectional view taken along the line 8—8 of Figure 6.

25 The variable resistor illustrated in the figures has a hollow cylindrical casing 10 with a closed end 12 and an open end 14. A cover 16 is secured to the open end 14 of the casing 10 by press-fitting the cover 16 in a groove 18 about the inner perimeter of the open end 14 of the casing 10. The closed end 12 of the casing 10 is provided with a central aperture 20 and has a sleeve 21 which extends toward the open end 14 of the casing 10. A bushing 22 is secured to the casing 10 and disposed within the aperture 20. The bushing 22 is provided with a sleeve 24 which extends into the sleeve 21 coaxially therewith. A shaft 26 is journaled within the bushing 22 and sleeve 24. The shaft is provided with a groove 27 adjacent to the bushing 22 and a C-washer 28 is disposed in the groove 27. The cover 16 is also provided with an aperture 29, the shaft 26 extending through the aperture, and a second C-washer 30 is disposed in a groove 31 in the shaft adjacent to the cover 16, thereby preventing translation of the shaft 26 within the casing and limiting its motion to rotation.

35 The interior of the casing 10 is lined with an annular strip 32 of electrically insulating material which is secured to the interior surface of the casing 10, for example, by a layer 34 of cement. A resistance card 36, which will be later described in greater detail, is disposed in contact with the strip 32 of electrically insulating material and extends about the periphery of the casing 10 in the interior thereof. A mass of potting compound 37 is also disposed within the casing 10 and extends to a level adjacent to the edge of resistance card 36.

40 The resistance card 36 is provided with a strip 38 of electrically insulating material which is disposed in an annular form within the casing 10. The strip 38 supports a plurality of turns 40 of resistance wire 42. The resistance wire 42 is provided with a coating 44 of electrically insulating material, such as enamel for example. A layer 46 of electrically insulating cement is disposed about the strip 38 and windings 40 thereabout, except for two bands 48 and 49 which extend longitudinally along the resistance card. The first band 48 is disposed on the edge of the resistance card confronting the cover 16 of the variable resistor, and the turns 40 along this band 48 are also free of the electrically insulating coating 44. The second band 49 is disposed centrally of the side of the resistance card confronting the shaft 26 and extends longitudinally about the resistance card. This band 49 also is a band in which the insulating coating 44 on the turns 40 is removed, so that electrical contact may be made directly with the wire 42.

A coating 50 of electrically conducting material is disposed on the portion of each turn 40 of resistance wire disposed in the second band 49 remote to the insulating strip 38, this coating 50 extending only along the resistance wire 42 and not bridging between adjacent turns 40 of resistance wire or being disposed upon the electrically insulating strip 38. The purpose of the coating 50 of electrically conducting material upon the exposed portions of the turns 40 in the second strip 49 is to short out this portion of each turn, and the thickness of the coating should be sufficient for this purpose but as thin as practical otherwise, since too great a thickness of coating tends to bridge between adjacent turns. A layer 52 of electrically insulating material is disposed over the second band 49 and over the coated portion of the turns in the second band 49.

A disc 58 of electrically insulating material is secured to the shaft 26 at its center adjacent to the end of the sleeve 24, and a pair of electrically conducting contacts 60 are mounted to the disc 58 adjacent to its periphery. Each of the contacts 60 has a wire shaped contact member 62 which is disposed in slidable contact with the exposed portion of the turns 40 on the edge 48 of the resistance card 36. Each of the contacts 60 has a supporting bar 64 which is secured to the electrically insulating disc 58 in an indentation 65 generally parallel to and adjacent to the periphery of the disc 58, for example by a pair of screws 66 disposed at the end of the support bars 64. The support bar 64 of each contact 60 is provided with an indentation 68 confronting the resistance card 36, and a pair of aligned screws 70 and 72 generally parallel to the axis of the support bar 64 are threadably engaged within support bar 64 and extend through the support bar 64 into the indentation 68 to confront each other. A pin 82 extends between the confronting ends of the screws 72 and 70 within the recess.

The contact member 62 of each contact 60 is in the form of a ridged electrically conducting wire which is secured to the ends of the pin 82, as by soldering for example, and makes electrical contact with the pin 82. Each contact member 62 has three adjacent portions 84, 86 and 88. The central portion 86 is disposed normal to the pin 82 between the end portions 84 and 86 of the contact member 62 on the side remote from the electrically insulating disc 58. A helical spring 90 is also disposed about each pin 82 between the ends thereof, and one end 92 of the spring 90 extends outwardly from the helix and abuts the support bar 64 to place a spring bias upon the contact member 64 in the direction of the resistance card 36. In this manner the central portion 86 of each contact member 62 is maintained in abutment with the exposed portion of the turns 40 on edge 48 of the resistance card 36.

The electrical insulating disc 58 also supports a pair of concentric electrically conducting rings 94 and 95 which are coaxially disposed about the shaft 26 on the side of the disc 58 confronting the closed end 12 of the casing 10. The ring 94 is electrically connected to one of the contact members 60 and the ring 95 is connected to the other contact member 60 by wires 96a and 96b, respectively.

The contact rings 94 and 95 are each in slidable contact with a pair of contact assemblies 97 and 99 which have a pair of electrically conducting contacts 98 and 100 of a take-off assembly 102. The take-off assembly 102 has an electrically insulating block 104 which is mounted to the end 12 of the casing 10 confronting the contact rings 94 and 95, as illustrated in Figure 2. A pair of parallel slots 106 and 107 generally parallel to and confronting the contact rings 94 and 95 are disposed in the surface of the block 104. Each of the contacts 98 and 100 are mounted at the ends of arms 108 and 110, respectively, which are constructed of electrically conducting material. Each pair of arms 108 and 110 is pivoted at a point between their ends on a pin 112 which

extends into the block 104 of insulating material normal to the arms 108 and 110 and through one of the slots 106 or 107 in the block 104. A helical spring 114 is disposed about the pin 112 between each pair of arms 108 and 110. One end of each spring 114 is attached to the end of arm 108 opposite to the contact 98, and the other end of each spring 114 is attached to the adjacent arm 110 opposite the contact 100, thereby spring-biasing these ends of the arms 108 and 110 toward the slot 106 or 107, or in other words, spring-biasing the contacts 98 and 100 outwardly from the slot 106 or 107.

The arms 108 and 110 of each contact assembly 97 and 99 are electrically interconnected by the pins 112. Also, one of the arms 108 of contact assembly 97 is connected to a terminal 116, and the arm 110 of contact assembly 99 is connected to a terminal 118. Electrical contact to the other arm of each pair of arms is made through the pins 112. Electrical connections may be made to these terminals 116 and 118 and to one or more points on the resistance card, in the conventional manner.

The inventor has found that a preferred method of manufacturing the precision variable resistor described in Figures 1 through 4 is as follows: The turns 40 of enamel coated resistance wire are wound onto the strip 38 in the conventional manner, generally with the aid of a coil winding machine to assure even spacing between turns. The turns 40 are wound generally parallel to each other and equally spaced from each other. The layer 46 of electrically insulating cement is then applied entirely over the strip 38 and turns 40. The two bands 48 and 49 are then cleared of the layer of insulating cement 46, and enamel coating 44, the one band 48 being along one edge of the resistance card, and the second band 48 being parallel with this edge centrally of one of the sides of the card. This operation may be done with a wire wheel or a scraper.

An electrically conducting strip, such as a right angled trough, designated 130 in Figure 7, is then provided with a pad of electrically conducting wool 132 in its trough, and the edge 48 of the resistance card is secured within this trough. The wool 132 may be steel wool. The resistance card 36 is then lowered into a container 134 of an electrically conducting solution 136. The inventor has found that gold cyanide is a particularly satisfactory solution for gold coating the exposed portions of the turns 40 upon the resistance card 36. An electrical potential is applied from a battery 138 between an electrode 140 in the bath of gold cyanide and the electrically conducting strip 130, thus causing an electrical current to flow through the bath and deposit a gold coating 50 upon the portion of the turns 40 of the resistance wire 42 in the band 49 exposed to the solution. Care is taken that the coating 50 deposited on these turns 40 does not bridge between turns.

The resistance to displacement characteristic of the variable resistor may be adjusted either prior to bending the resistance card 36 or after placing the resistance card 36 in the casing 10. It is preferable, however, to bend the resistance card 36 and secure it in the casing 10 prior to adjusting this characteristic, since the adjustment will then compensate for concentricity errors and other errors which may be introduced in the assembly process.

After the coating 50 has been placed on the wire 42 and the resistance card 36 placed in the casing 10, the resistance is measured between one of the ends of the resistance wire, designated 141, and the exposed portion of each turn 40 of resistance wire 42 in the band 48 by connecting one probe 142 of an ohmmeter 146 to the end 141 of the resistance wire and the other probe 144 to each individual turn in the band 48. The total resistance from the end 141 to each turn is then adjusted to a desired value by scraping enough of the coating 50 of gold from the wire 42 in the band 49 to adjust the resistance of each turn to the desired value. In this way, a constant resistance increment is added by adding additional

turns into a circuit and the resistance to displacement of the movable contact 62 is a linear function.

For some applications, variable resistors need not be completely accurate throughout their range. Variable resistors for such applications can be adjusted to the desired relation between resistance and displacement of the movable contact in steps. The probe 144 may contact only the end turn of each of a plurality of groups of turns, as indicated by the dotted lines in Figure 5, and the coating 50 within each group adjusted, as required, the amount of coating 50 being removed on each turn 40 of each group uniformly. When constructed in this manner, the relation between resistance and contact displacement is accurate only at the end of each group of turns. There may be any number of turns in a group, all groups having the same number of turns, for example 20 to 25 turns.

The electrically conducting coating 50 placed upon each of the turns 40 in the band 49 may be of many different electrically conducting materials, for example copper, silver or aluminum. However, a very fine grain coating is desirable since it is easier to control the thickness of a fine grain coating and prevent bridging between turns. Corrosion resistance of the coating is also important for some applications. For these reasons, the inventor has found it preferable to use gold rather than some other material for this coating 50. In a particular construction, the width of the band 49 was ¼ inch wide, while the width of the electrically insulating strip 38 is approximately ¾ of an inch.

After the resistance to contact displacement characteristic of the resistance card has been adjusted, the coating 52 of electrically insulating material is placed over the band 49 and the layer 46, for example by brushing it on. The variable resistor may then be further assembled in a conventional manner.

An exponential electrical characteristic may be built into a variable resistor of the type here described by constructing the strip 49 in an exponential form, as indicated by the dotted line in Figure 5 and designated 49a. It is clear that each turn 40 of resistance wire 42 has an increasing total resistance considering the turns from right to left. As a result, the sliding contact 62 adds a larger amount of resistance to the total resistance between the left end of the resistance card 36 and the sliding contact 62 for each turn moving in this direction. Also, an exact exponential relation between contact displacement and resistance may be obtained by adjusting the resistance of each individual turn 40 by scraping a portion of the coating 50 from the wire 42, as described above for a linear relationship.

The present invention may also be employed using fixed resistance in combination with a resistance card, as illustrated in dotted lines in Figure 4. The resistance card 36 is provided with a plurality of taps 150, here equally spaced and beneath the surface of the potting compound 37. A fixed resistor 152 is connected between each pair of adjacent taps 150, the resistors 152 having equal resistance for a linear voltage to resistance characteristics and an equal number of turns between taps 150 on the resistance card 36.

The effective resistance, R , between each pair of taps is

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

where R_1 is the resistor 152 between the tap and R_2 is the resistance of the turns on the resistance card 36 between these taps 150.

The voltage-resistance characteristic of the resistor is adjusted by removing a portion of the plating 50 from the band 49, as described above. This construction permits larger currents through the resistor, than with the resistance card alone, and also the use of precision fixed resistors.

It is also clear that virtually any displacement to resistance characteristic may be obtained by shaping the strip 49 to fit the requirements and additionally adjusting the resistance of each turn. Further, the layer 46 may be disposed only on one side of the insulating strip 38, in an extreme case, or omitted entirely, before the coating process places the coating 50 on the wire 42, thus providing a much greater range of adjustment to produce the desired resistance to displacement of the slidable electrical contact.

The man skilled in the art will readily devise many modifications and additional applications for the invention beyond those specifically disclosed herein. It is therefore intended that the scope of the invention be not limited by the foregoing disclosure, but rather only by the appended claims.

I claim as my invention:

1. The method of manufacturing a resistor comprising the steps of winding a plurality of turns of resistance wire around a strip of electrically insulating material, coating the strip and turns with electrical insulating material, removing a band of insulating material from the strip and turns along one edge of the strip, removing a second band of insulating material from the side of said strip and turns, placing an electrically conducting member into contact with the band of turns on the edge of the strip, immersing the second exposed band of turns into a plating bath, applying an electrical potential between the electrically conducting member and an electrode disposed in the plating bath to deposit an electrically conducting coating on the turns, reducing the length of said coating on individual turns to adjust the resistance of said turns, placing a second layer of electrical insulating material on said strip and turns.

2. The method of manufacturing a variable resistor comprising the steps of claim 1, placing the strip and turns in a cylindrical container having an axial shaft, and mounting a contact to the shaft and in slidable abutment with the exposed turns at the edge of the strip.

3. The method of manufacturing a resistor comprising the elements of claim 1 wherein the plating bath contains gold cyanide, and the electrically conducting member placed in contact with the band of turns on the edge of the strip comprises electrically conducting wool.

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