Oct. 8, 1968 A. J. WRIGHT 3,405,382

TERMINAL AND TAP CONNECTIONS FOR RESISTANCE ELEMENT

Filed Sept. 13, 1965 2 Sheets-Sheet 1

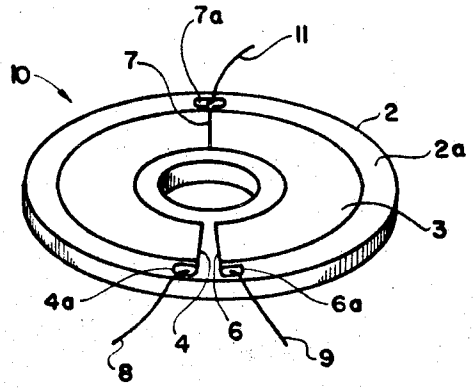


FIG. 1

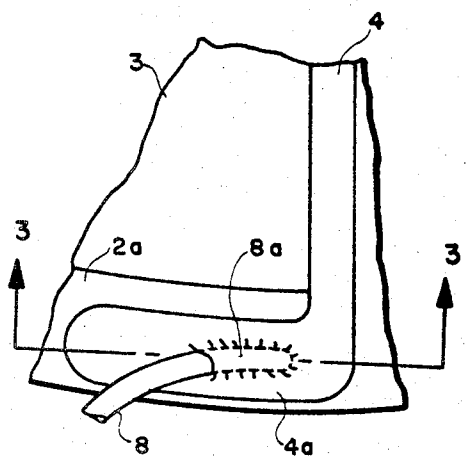


FIG. 2

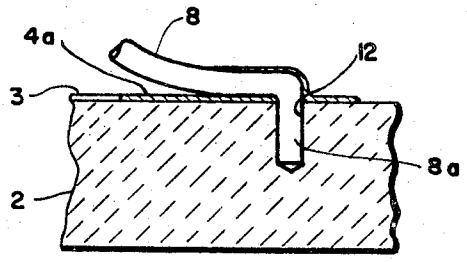


FIG. 3

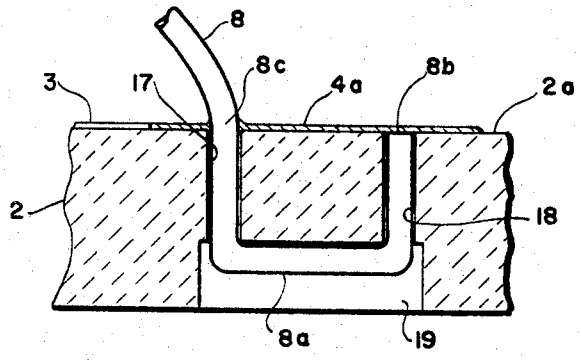


FIG. 8

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TERMINAL AND TAP CONNECTIONS FOR RESISTANCE ELEMENT

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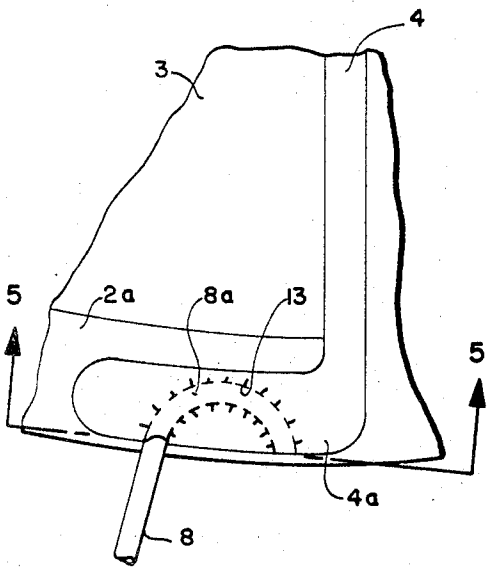


FIG. 4

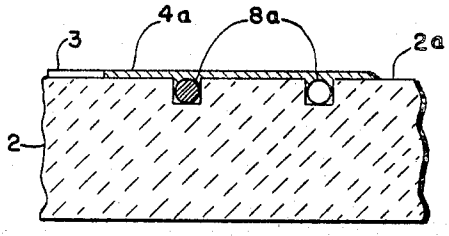


FIG. 5

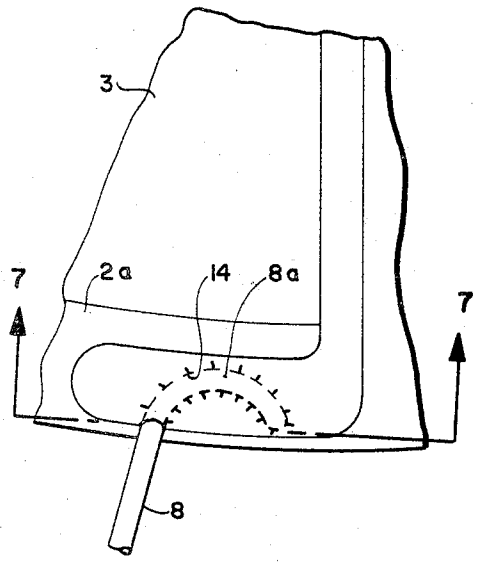


FIG. 6

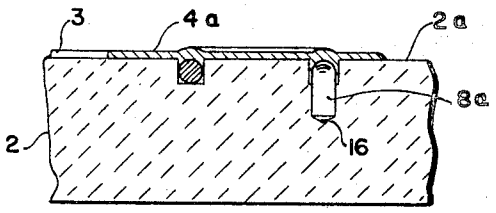


FIG. 7

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3,405,382

TERMINAL AND TAP CONNECTIONS FOR RESISTANCE ELEMENT

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Filed Sept. 13, 1965, Ser. No. 486,607
2 Claims. (Cl. 338—323)

ABSTRACT OF THE DISCLOSURE

A terminal lead wire connection for a resistance element in the form of a deposited layer of resistance material on a non-conductive base member. The base includes a terminal lead passage having at least two sections formed at an angle with respect to each other and adapted to snugly receive an end portion of a terminal lead wire over which is deposited a conductive material for conducting a current between the resistance layer and the terminal lead wire.

The present invention relates to electrical resistance elements employing deposited layer resistance materials and is more particularly directed to lead wire connections to tap and end terminations of such resistance elements.

The invention is primarily directed to resistance elements and devices using a resistance material which is applied as a layer or track on a non-conductive support or base. One such layer of resistance material, suitable for such devices, is formed of a mixture of glass and metal particles and commonly called "cermet" resistance material. Another such resistance material is the well-known conductive plastic material, which is formed of a mixture of a powdered plastic and conductive metal particles of carbon. The resistance element may also be formed of a thin film of deposited metal.

Cermet type resistance elements are formed from composite mixtures of finely divided glass particles and finely divided metal particles which are applied to a non-conductive base member and fired to a temperature below the melting point of the metal but sufficient to melt the glass particles and to fuse the mixture into a conglomerate mass. In these cermet mixtures, it has been found desirable to use noble metals which tend to resist oxidation at the temperatures required to melt the glass and to fuse the mixture.

The fused cermet mixture produces a smooth continuous track or film having a surface that is resistant to high humidity and fungus. The hard smooth surface and its durability makes this resistance element especially applicable for use in variable resistance devices, such as potentiometers or rheostats which utilize a movable contact that must traverse over the surface of the resistance layer. A number of typical resistance films and methods of making the same are described in U.S. Patents No. 2,950,995; 2,950,996 and 3,149,002 issued in the name of Thomas M. Place, Sr. et al. and assigned to the same assignee as the present invention.

In order to conduct an electrical current to and from the resistance track, end and tap connections or terminations are normally attached to the resistance track. These are usually formed by means of a conductive material bonded to the substrate or base member and also bonded or intimately in contact with portions of the resistance track. The tap and end terminations may be formed of commercially available "fired-on" silver films which are applied as a paste to suitable portions of the base member. After application, the film is fired to drive off the organic carrier materials and to solidly fuse the material to form a conductive strip.

The base member, with the resistance track and its associated end and tap terminations, may be mounted within a housing which is, in turn, supplied with suitable terminal posts or studs for connecting the device into an electrical circuit. It is necessary, therefore, to connect the terminal posts or studs of the housing to the conductive strips, or end and tap terminations, deposited on the base member. This is sometimes accomplished by use of small lead wires which are connected at one end to the end termination on the base member and at the other end to the terminal post or stud of the housing member. It is difficult to achieve a physically strong bond between the termination wire and the end termination strip connected to the resistance track. These wires have been spot welded to the termination strip, but such welding operation is extremely difficult due to the different types of material involved and because of the thinness of the termination strip. In order to further support the connection it has been necessary to apply an epoxy bond over the termination pad and its weld to provide a measure of support. The selection of an appropriate epoxy becomes especially critical under certain environmental conditions due to the difference in expansion between the epoxy and the base member.

Accordingly, it is an object of the present invention to provide an improved arrangement for attaching lead wires to the termination strips of a deposited layer-type resistance device.

It is another object of the present invention to provide for a deposited layer resistance element an improved lead wire connection to the end terminations and taps which connection exhibits relatively great physical strength and excellent electrical characteristics.

Further objects and advantages of the invention will become apparent as the following description proceeds and the features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

Briefly, in accordance with a preferred form of the present invention, there is provided a non-conductive base member having disposed thereon a deposited layer of resistance material which is in turn electrically connected with end termination strips and tap connections formed of a suitable conductive material also deposited on the surface of the base member. In order to connect the termination strips and taps to terminal posts in a housing member, there are provided a plurality of electrically conductive lead wires firmly attached to the base member by means of terminal lead passages formed in the base member, the passages having a cross-sectional dimension adapted to snugly receive an end portion of the terminal lead wire. The end portion of the terminal lead wire is bent so that, when a tension force is applied axially to said terminal wire, the terminal lead passage exerts a frictional force against the surface of the end portion of the terminal wire thereby restraining movement of the terminal wire and retaining the end portion of said end terminal wire in electrical contact with the termination pad.

For a better understanding of this and further aspects of the invention, reference may be had to the accompanying drawings in which:

FIGURE 1 is a perspective view of a resistance element embodying the structure of the present invention;

FIGURE 2 is an enlarged partial top view of a section of the resistance element of FIGURE 1 illustrating in greater detail the terminal wire connection to the end termination;

FIGURE 3 is a partial cross-sectional view taken along line 3—3 of FIGURE 2 illustrating the terminal wire passage and connection;

FIGURE 4 is a partial top view similar to that of

FIGURE 2 illustrating in detail another embodiment of the invention;

FIGURE 5 is a partial cross-sectional view taken along line 5—5 of FIGURE 4;

FIGURE 6 is a partial top view of still another embodiment of the invention;

FIGURE 7 is a partial cross-sectional view taken essentially along line 7—7 of FIGURE 6; and

FIGURE 8 is a cross-sectional view of still another embodiment of the invention.

Referring now to FIGURE 1 of the drawing, there is shown a resistance element of the type adapted for use in a variable resistance device. The resistance element comprises a substrate base member **2** of non-conductive material which may be in the form of a circular wafer or disc. The base member **2** is usually formed of an unglazed homogeneous, non-porous, ceramic material, such as steatite or alumina or other non-conductive material well-known in the art. While the illustrated resistance device is in the form of a circular disc of the type used in rotary single turn potentiometers or rotary variable resistors, it will be understood that the present invention is not limited to resistance devices of this particular shape and that the invention is equally applicable to resistance devices of rectangular shape or any other suitable configuration.

In conventional practice, the substrate or base member **2** is molded, fired and then ground or lapped to provide a smooth relatively flat surface **2***a* for supporting a resistance film or layer **3** thereon. The resistance layer **3** forms a conductive path when an electrical current is applied to the resistance layer through end terminations such as members **4** and **6** and tap member **7**. As hereinafter used in the specification and claims, the term conductor terminals or lead wire connections are meant to include both end terminal connections or center tap connections as are commonly employed in the resistor or variable resistor field.

The resistance element or layer **3** may be formed of a suitable resistance material, such as conductive plastic material having a carbonaceous metal dispersed throughout the fused plastic, or of a cermet resistance material, comprising a non-conductive glass binder material having minute particles of noble metal or metal alloy dispersed throughout the element. Or the layer **3** may comprise a thin metal film conductor of the type well-known in the art. Particular examples of cermet materials and their methods of manufacture are fully explained in the aforementioned Place et al. Patents Nos. 3,149,002; 2,950,996; and 2,950,995 which are assigned to the assignee of the present invention.

When the resistance track is formed of cermet materials, a mixture of glass and metal particles, forming the layer **3**, are deposited on the substrate or base member **2** by any suitable operation well-known in the art, such as brushing, spraying, stenciling or silk screening. After the cermet film or layer has been deposited upon the surface **2***a* of the base member **2**, the base and layer are preferably permitted to dry in circulating warm air for a short period and then fired in a furnace or conventional ceramic kiln. The purpose of the firing operation is to fuse the glass particles of the material into a continuous glassy phase with the metal particles being uniformly dispersed throughout the material, and without melting the metal particles or producing bubbles or blisters on the surface of the layer **3**. A mixture of glass and metal particles, after fusion at a temperature below that of the metal constituents, forms a continuous element having a hard smooth glassy surface.

End terminations **4** and **6** or tap member **7** may be applied to the base member **2** either before or after the application of the resistance layer **3**. The end terminations are preferably formed of a material such as fired-on silver paste and deposited in the requisite configuration on the surface of the base member and fired thereon at a sufficiently high temperature to convert the metallic paste into conductive strips of metal thermally attached to the base. These strips are formed in position to be in electrical contact with the resistance track (if the resistance track is applied after the strips). One metallic paste used to form these strip portions is formed of a combination of metal powders comprising about 50% by weight, gold (Au) and about 40% by weight, platinum (Pt), together with about 10% by weight of a glass binder.

Preferably the conductive end terminations extend at least the entire width of the resistance track **3** and provide outwardly extending pads **4***a*, **6***a* and **7***a* arranged proximate the resistance track but out of the path of any movable electrical contact or wiper to be positioned thereover. The pads **4***a*, **6***a*, and **7***a* provide a space for the connection of terminal lead wires through which current is applied to the resistance element from the terminals of the housing (not shown).

As will be hereinafter described, the present invention is directed to an improved design construction for attaching the terminal lead wires to the end terminations. As will be seen in FIGURE 1, lead wires **8** and **9** are attached to the termination pads **4***a* and **6***a* and a lead wire **11** is attached to the tap termination pad **7***a*. In order to produce a relative strong attachment, the substrate is first prepared by forming an end termination passage therein which is adapted to receive one end portion of one of the respective lead wires. In the embodiment illustrated in FIGURE 3, the passage comprises a hole **12** drilled or otherwise formed in the substrate **2** which receives the end **8***a* of the lead wire **8** therein. The end portion or tip **8***a* is then placed through the unfired terminal pad **4***a* and the lead wire bent so that it extends outward generally in the same plane as the surface **2***a* of the base member **2**. Any tension force on the lead wire causes the sides of the lead wire to engage the inner surface of the terminal lead passage **12** and produces a frictional force restraining movement of the end portion **8***a* of the lead wire.

In order to produce an extremely good electrically conductive bond between the lead wire **8** and the terminal pad **4***a*, it is preferable to coat the end portion **8***a* of the lead wire with the same metal-glass mixture or silver paste as that used for the conductive terminal strip **4**. When the unit is then fired to a sufficiently high temperature to convert the metal-glass mixture or silver paste into a layer of metal, this coating forms a bond retaining the lead wire firmly in the passage **12** and in good electrical contact with the end pad **4***a* of the terminal strip or end termination **4**. The lead wires **8**, **9** and **11** are not only bonded directly to the end pad portion of the terminal strips but also are physically restrained by the end termination passage and bonded therein by the coating material. As may be seen in FIGURES 2 and 3, in this embodiment of the invention the terminal lead passage **12** is arranged at substantially a right angle to the surface **2***a* of the base member **2** and the lead wire **8** is bent at substantially a right angle as it exits from the lead wire passage. After the unit is fired, the lead wire **8**, termination pad **4***a*, and covering material **13** are integrally bonded to the base **2** and the strip **4** is arranged in contact with the resistance element **3** which may have been fired previously or may be fired thereafter.

Referring now to FIGURES 4 and 5, there is provided another embodiment of the invention in which the termination lead passage is in the form of a semicircular groove **13** formed in the surface of the substrate base member **2**. The groove is substantially the same diameter as the lead wire **8** and provides a curved seat for the end portion **8***a* of the lead wire. This lead wire connection is constructed, as in the previously described embodiment, by first coating the end portion **8***a* of the lead wire **8** with a conductive material such as the aforementioned metal-glass mixture, and bending the lead wire **8***a* to the configuration of the semicircular lead wire passage **13**. The end **8***a* of the lead wire is then inserted into the passage and the end termination pad **4***a* is then deposited there-

over. The unit is then fired to a temperature sufficient to form a continuous metal conductor. As in the previously described embodiment, the resistance element **3** may be deposited on the substrate base prior to or after the connection of the lead wire to the end termination.

In this embodiment of the invention, it is unnecessary to bend the lead wire **8** at right angles to make it emerge along a line substantially parallel to the surface **2***a* of the base member. Because of the curvature of the passage **13**, the lead wire engages the sides of the passage and the coated portions of the lead wire are firmly attached or bonded thereto as well as being in good electrical contact with the end pad **4***a*.

Referring now to FIGURES 6 and 7, there is illustrated a combination of the lead wire connection concepts of FIGURES 2, 3, 4 and 5. In this embodiment of the invention, the lead wire passage is in the form of a semicircular groove **14** which terminates in a hole **16** formed at an angle to the surface of the base member **2**. While, the hole **16**, in the illustrated embodiment, is at right angles with respect to the remaining portions of the passage **14**, it could be disposed at any desired angle in order to facilitate the assembly of the lead wire.

In this embodiment the tip of the end portion **8***a* of the lead wire is formed over to fit into the hole **16**, or angularly disposed portion of the passage, and the remaining portion of the end portion **8***a* is bent to conform to the semicircular groove **14**. As in the previous embodiments of the invention, it is preferable to coat the end portion **8***a* of the lead wire with a conductive bonding material. Prior to firing, the pad **4***a* is deposited over the surface **2***a* of the base member and over the passage containing the end portion **8***a* of the lead wire. The unit is subsequently fired to a temperature sufficient to drive off the organics in the conductive material and to fuse the conductive material and terminal wire into an electrically conductive connection. The conductive resistance track **3** may be deposited on the surface of the base member **2** either prior to or after the formation of the end termination pad and the attachment of the lead wire.

FIGURE 8 illustrates another embodiment of the invention in which the lead wire passage is formed by two holes **17** and **18** drilled or formed through the base member **2** and connected by a groove or passage **19** formed in the surface of the base member opposite from that upon which the resistance material **3** is deposited or is to be deposited. In this embodiment of the invention, the paste material for the terminal pad **4***a* is preferably deposited on the surface **2***a* of the base member **2** prior to the insertion of the end portion **8***a* of the lead wire **8**. The end **8***a* of the lead wire is coated with a suitable conductive material and inserted through the hole **17** of the passage. The end portion of the lead wire is then reversely bent with the tip portion **8***b* of the lead wire extending upwardly through the hole **18** of the passage. As shown in the drawing, it is preferable to have the end or tip **8***b* of the lead wire in contact with the end pad **4***a*, however, this is not absolutely essential inasmuch as the lead wire does contact the end pad **4***a* at its point of emergence **8***c*. The unit is then fired to a temperature sufficient to drive off the organics in the conductive material and to form a metallic bond between the conductive material and the lead wire **8**. The coating on the end portion **8***a* of the lead wire forms a bond between the lead wire and the sides of the passage thereby firmly holding the lead wire in place against any tension forces applied to the lead wire.

These "fired-on" lead wires have much more strength than a similar lead which is spot welded or soldered onto the terminal pad. The lead wire connection also provides a much better electrically conductive path because of the greater length of engagement between the wire and the termination pad. Because of the strength of the bond the connection does not have to be covered by an epoxy material in order to support the bond and retain the wire in place.

Because the lead wire does not have to be spot heated at the point where it fuses with the end termination pad, its size can be greatly increased because the heat flow away from the bond point is no longer a critical factor. A larger diameter wire greatly facilitates the connection and increases the strength of the unit. The larger diameter wire also greatly facilitates the connection of the lead wire at its opposite ends thereof to the electrical terminal studs (not shown) of the housing member in which the unit is mounted.

While in accordance with the patent statutes there has been provided what at present are considered to be the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is, therefore, the aim of the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A lead wire connection for a deposited film type resistance element or the like comprising:

a non-conductive base member having disposed thereon a resistance element formed of a deposited layer of resistance material;

a terminal lead passage formed in said base member proximate said resistance element, said terminal lead passage including a first section in the form of a curved groove having one end thereof communicating with the edge of said base member and a second section in the form of a hole in said base member arranged at an angle with respect to said groove, an electrically conductive terminal lead wire having an end portion thereof disposed in said sections of said terminal lead passage and bent to conform to the configuration thereof so that when a tension force is applied axially to said terminal wire said passage exerts a frictional force against the surface of said end portion of said terminal wire restraining movement of said terminal wire; and

a layer of conductive material deposited on said base member over said terminal lead passage and said terminal wire disposed therein, said layer of conductive material bonding said terminal lead wire into said passage and being in electrical contact with said resistance element for conducting current between said resistance element and said terminal lead wire.

2. A lead wire connection for a deposited film type resistance element or the like comprising:

a non-conductive base member having disposed thereon a resistance element formed of a deposited layer of resistance material;

a terminal lead passage formed in said base member proximate said resistance element, said terminal lead passage comprising a groove having a shape substantially in the form of a semi-circle formed in said surface of said base member, one end of said groove communicating with the edge of said base member;

an electrically conductive terminal lead wire disposed in said groove, said groove having a cross-sectional dimension adapted to snugly receive an end portion of said lead wire with the remainder of said lead wire projecting from said groove along a line substantially parallel with the surface of said base member, said terminal lead wire being bent to conform to the semi-circular shape of said groove so that when a tension force is applied axially to said terminal lead wire said passage exerts a frictional force against the surface of said end portion of said terminal wire restraining movement of said terminal wire; and

a layer of conductive material deposited on said base member over said terminal lead passage and said terminal wire disposed therein, said layer of conductive material bonding said terminal wire into said pas-

sage and forming an electrical contact with said resistance element and said terminal lead wire for conducting current between said resistance element and said terminal lead wire.

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