

[54] **TERMINAL CONSTRUCTION FOR ELECTRICAL CONDUCTORS**

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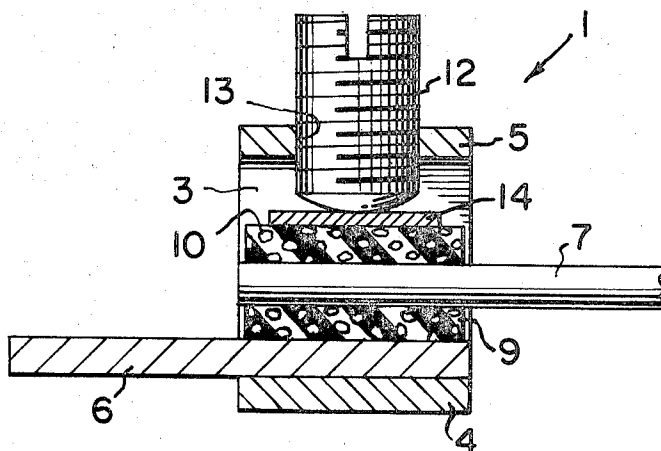
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[57] **ABSTRACT**

A terminal for coupling electrical conductors formed of different materials and arranged in confronting, overlapping relation comprises a body formed of elastomeric, non-conductive material encircling at least one of the conductors and bearing against another of the conductors, the body containing a plurality of discrete, electrically conductive particles responsive to compression of the body to establish an electrically conductive path between the conductors. Force applying means acts on the body via a force distributing member which overlies a substantial portion of the length of the body so as to apply sufficient compressive force to the body to render the latter conductive.

14 Claims, 7 Drawing Figures



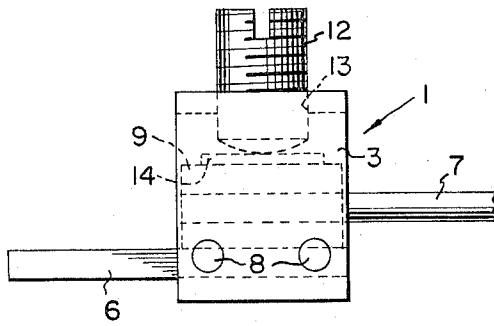


FIG. 1

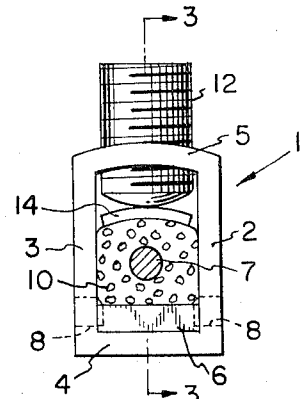


FIG. 2

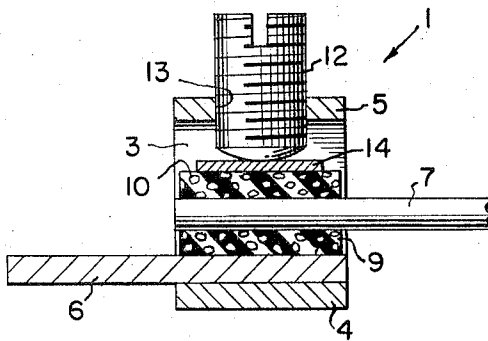


FIG. 3

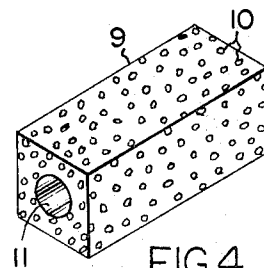


FIG. 4

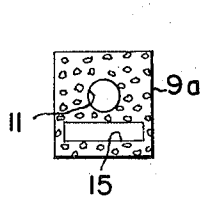


FIG. 5

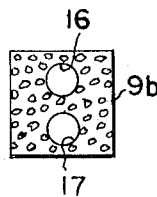


FIG. 6

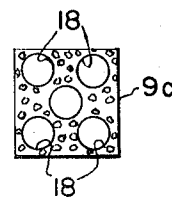


FIG. 7

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TERMINAL CONSTRUCTION FOR ELECTRICAL CONDUCTORS

The invention disclosed herein relates to apparatus for coupling electrical conductors and more particularly to a connector especially adapted for the electrical coupling of conductors formed of different materials.

For economic and other reasons it is desirable in many instances to use conductors formed of aluminum rather than copper and to couple the aluminum conductors to copper terminals. The coupling of electrical conductors having different metallurgical properties, however, presents certain problems. For example, an aluminum conductor, when exposed to atmosphere, undergoes an oxidation process which forms a high resistance oxide on the surface of the conductor. The presence of such an oxide film at the interface between an aluminum conductor and a copper conductor results in a voltage drop at the interface with consequent electrical losses. To prevent the formation of such oxide films, it has been the practice heretofore to coat an aluminum conductor with an anti-corrosive grease or other substance, but such coatings have limited longevity.

A voltage drop at the interface between conductors generates heat. If there is a high resistance oxide film at the interface, the voltage drop, and consequently, the heat generated are greater. The coefficient of thermal expansion of aluminum is greater than that of copper as a consequence of which the generation of heat at the interface will cause the expansion of the aluminum conductor to be greater than that of the copper conductor. If the aluminum and copper conductors are assembled in a clamping device, the greater expansion of aluminum may cause one or both of the conductors to be deformed and weakened by the reaction with the clamping device. Repetitive expansion cycles thus may weaken the conductors to the point at which they fail structurally.

The generation of heat at the interface between conductors has other disadvantages. For example, the thermal expansion of the conductors not only subjects the conductors themselves to deformation, but also may subject the clamping or connecting device to distortion. When the flow of current through the conductors ceases, they will cool and contract. If the expansion of the conductors causes distortion of the clamping or connecting device, the contraction of the conductors may result in looseness between the conductors and between the conductors and the connecting device. Such looseness between the conductors causes an even greater voltage drop therebetween with the consequent generation of greater heat and an even greater expansion of the conductors.

Whenever two metallic conductors are placed in face-to-face engagement it is virtually impossible to provide more than a few points of actual contact between the conductors due to irregularities which inevitably exist in the confronting surfaces of the conductors. When current flows from one conductor to the other, it flows through the points of engagement, thereby resulting in high current density at such points of engagement. Since the voltage drop between two conductors, and consequently the heat generated thereby, is directly proportional to the value to the current, the high current concentration at the points of actual engagement of the two conductors causes the heat

generated between the two conductors to be concentrated at the points of engagement, thereby subjecting the conductors to uneven rates of thermal expansion which magnify the problems referred to above.

An object of this invention is to provide apparatus for coupling electrical conductors and which overcomes or greatly minimizes the disadvantages hereinbefore described.

Another object of the invention is to provide apparatus for coupling electrical conductors formed of the same or different materials and which minimizes greatly the voltage drop and the generation of heat between the conductors.

A further object of the invention is to provide apparatus for coupling electrical conductors and which possesses inherent resilience so as to avoid distortion and deformation of the conductors or the coupling apparatus due to thermal expansion of the conductors.

Another object of the invention is to provide a resilient coupling for electrical conductors which permits thermal expansion of the conductors and which is capable of maintaining the conductors in intimate electrical engagement notwithstanding changes in size of the conductors due to thermal expansion and subsequent contraction.

A further object of the invention is to provide apparatus of the character referred to and which provides a large number of current paths between confronting conductors regardless of irregularities in the confronting surfaces of the conductors.

Other objects and advantages of the invention will be pointed out specifically or will become apparent from the following description when it is considered in conjunction with the appended claims and the accompanying drawings in which:

FIG. 1 is a side elevational view of an electrical terminal constructed in accordance with one embodiment of the invention;

FIG. 2 is an end elevational view of the apparatus shown in FIG. 1;

FIG. 3 is a sectional view taken on the line 3—3 of FIG. 2;

FIG. 4 is an isometric view of an elastomeric sleeve forming part of the invention; and

FIGS. 5, 6, and 7 are end elevational views of other embodiments of the invention.

Apparatus constructed in accordance with the invention is adapted for use in electrically coupling a plurality of electrical conductors having either the same or different metallurgical properties. The apparatus illustrated in FIGS. 1 - 4 comprises a hollow, rectangular connector 1 formed preferably of copper and having a pair of generally parallel side walls 2 and 3, a base 4, and a top wall 5. The ends of the connector are open so as to permit a pair of electrical conductors 6 and 7 to be introduced to the connector from either end thereof.

The conductor 6 preferably is quadrangular in configuration and is of such size as snugly to fit between the side walls 2 and 3 of the connector and lie flush against the base 4. The conductor 6 may be fixed in the connector 1 in any suitable manner, such as by staking 8. The conductor 6 preferably is formed of copper.

The conductor 7 may be a wire having a cylindrical or any other configuration in cross-section and may be formed of copper, aluminum, or any other electrically

conductive metal. The conductor 7 is of such size as loosely to be accommodated within the connector 1.

The apparatus also includes a body 9 formed of a resiliently deformable, non-conductive, elastomeric, air and water impervious material such as silicone rubber throughout which a plurality of electrically conductive particles 10 are dispersed. The body 9 comprises a sleeve and has an axial bore 11 therethrough having a configuration corresponding substantially to the configuration of the conductor 7. It is preferred that the cross-sectional area of the bore 11 be slightly smaller than that of the conductor 7 so that the body may have a frictional, air-tight fit on the conductor so as to prevent oxidation of the en-circled portion thereof due to its exposure to atmosphere. The width and length of the body 9 preferably are such as to enable it to fit snugly within the connector 1.

The connector 1 includes a force applying set screw 12 threaded into a correspondingly threaded opening 13 formed in the top wall 5 so as to be adjustable toward and away from the base 4. A force distributing plate 14 also is included and may be formed of either insulating or conductive material. The plate preferably is arcuate from side to side and has a length so related to the length of the body 9 as to be able to overlie a substantial portion of the body.

To condition the apparatus thus far disclosed for operation, one end of the conductor 6 will be introduced to the connector 1 and staked in place against the base 4. The body 9 will be fitted onto one end of the conductor 7 and then introduced to the connector so that the adjacent ends of the conductors 6 and 7 are in overlapping, confronting relation with the wall of the body 9 interposed therebetween. The plate 14 then may be mounted atop the sleeve and the screw 12 advanced toward the base 4 so as to subject the body 9 to compression. The force imposed on the body 9 will be distributed over substantially the entire length of the latter by the plate 14.

The compressive force to which the body 9 is subjected is transmitted to the conductor 7 through the upper wall of the body 9 so as to cause that portion of the body 9 between the conductors 6 and 7 also to be subjected to compressive force of such magnitude as to cause a plurality of the conductive particles 10 to move into engagement with one another and establish a plurality of electrically conductive paths between the conductors 6 and 7, thereby providing an electrically conductive coupling between the conductors. The resilient deformability of the elastomeric body 9 will enable it to conform to any irregularities in the confronting surfaces of the conductors 6 and 7, and the magnitude of the force exerted on the sleeve wall between the conductors 6 and 7 is sufficient to establish electrical conductivity over virtually the entire length of the body 9.

The elastomeric material from which the body 9 is made should be resilient at both low and high temperatures, readily moldable, stable at high temperatures, and have high dielectric strength. Several kinds of silicone rubber possess all of these properties. Silicone rubbers are prepared by milling together a silicone polymer, a filler, and a vulcanizer or catalyst. Any one of a number of commercially available silicone rubbers having the aforementioned properties may be used. In the preparation of the body 9, a silicone resin and catalyst are mixed with metallic particles, the latter being present in such quantity to be dispersed substantially

uniformly throughout the mixture. The mixture then may be poured into a mold and cured in the manner prescribed for the particular resin, the particles remaining in suspension.

The conductive particles 10 preferably are formed from a metal which has excellent conductive properties and also should be one which, if it oxidizes, has an electrically conductive oxide. Particles made from noble metals, such as silver and gold, have the desired inherent conductivity and normally form conductive oxides, but particles composed entirely of noble metal are quite expensive. There are available, however, discrete spherical metal particles composed of base metals, such as copper, iron, and the like, and coated with silver or tin. Such coated particles act very much like solid silver or tin particles, but are much less expensive.

The size of the conductive particles 10 will depend on several factors such as the magnitude of the current to be conducted and the magnitude of the force to which the body 9 is to be subjected. Satisfactory results have been obtained using particles ranging in size from about 1 to 100 mils. In general, the magnitude of current which can be accommodated by the body 9 is directly proportional to the size of the metallic particles 10.

The compressive force required to render the body 9 conductive will be directly proportional to the wall thickness and the density of the elastomer. Satisfactory results have been obtained using a silicone rubber having a durometer hardness of about 70.

The electrical sensitivity of the body also is related to the quantity and size of the conductive particles, the force required to render the body conductive varying inversely according to the quantity of particles contained within the body and varying directly according to the size of such particles. Satisfactory results may be obtained by incorporating between about 75 percent and about 90 percent, by weight, of particles in a silicone rubber body.

Preferably, the size and quantity of conductive particles dispersed throughout the body 9 are such that, when the latter is in its normal or non-compressed condition, the body is non-conductive. That is, when the body is in its non-compressed condition, the metallic particles 10 are not in particle-to-particle engagement. When the body is subjected to compressive force, however, as is indicated in FIG. 2, the metallic particles are forced to move relatively to one another and to the body 9 in such manner that a sufficient number of the particles move into engagement with one another to establish a plurality of conductive trains or paths along the length of the body. The resistance of the body, when the latter is conductive, corresponds substantially to the resistance of the metal particles. Since the electrical resistance of materials such as silver, tin, and the like is quite low, the resistance of the body also is quite low and, therefore, permits the body to accommodate a high current value without high heat generation.

The low resistance of the body, when it is conductive, coupled with the multiple current paths formed by the engaged particles 10, provides for an excellent electrical interface between the conductors 6 and 7, thereby minimizing greatly the voltage drop between the conductors and, consequently, minimizing greatly the generation of heat. If there should be sufficient generation of heat to cause thermal expansion of the conductors 6 and 7, the deformability of the body 9 enables it to

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absorb the enlargement of the conductors without subjecting the connector 1 to deformation. When the current flow terminates, and the conductors cool, the resilience of the body will enable it to compensate for contraction of the conductors so as to prevent any looseness from developing among the several parts.

Although the conductor 7 is disclosed as constituting a single wire, it should be understood that the conductor could be one formed by a plurality of wire strands.

In the embodiment disclosed in FIGS. 1 - 4, only the conductor 7 is encircled by the body 9. It is possible, however, to construct a body 9a (FIG. 5) having a rectangular bore 15 in addition to the bore 11 so as to enable both of the conductors 6 and 7 to be encircled by the body.

It is not necessary that one conductor be circular and the other rectangular. Instead, both conductors may have the same configuration. FIG. 6 discloses a body 9b having two cylindrical bores 16 and 17 adapted to encircle two correspondingly shaped conductors. The bores 16 and 17 may be of any other configuration, however, to correspond to the configuration of the conductors.

FIG. 7 discloses a body 9c having a plurality of spaced apart bores 18 each of which is adapted to accommodate a correspondingly shaped conductor. A body of this kind can couple a large number of conductors together.

The body members disclosed in FIGS. 5 - 7 may be used with the connector 1 or with any other suitable connector or clamp which is operable to render the bodies conductive.

The disclosed embodiments are representative of presently preferred forms of the invention, but are intended to be illustrative rather than definitive of the invention. The invention is defined in the claims.

We claim:

1. A terminal construction for coupling a plurality of electrical conductors, said construction comprising a first conductor; at least one other conductor spaced from said first conductor; a body of elastomeric, deformable, non-conductive material encircling and engaging a portion of at least one of said conductors and having a portion thereof interposed between said conductors and in engagement with said first and said other conductors, said body having a plurality of discrete, electrically conductive particles contained therein, said particles being responsive to compressive deformation of said portion of said body to establish an electrically conductive path between said conductors; and force

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applying means acting on at least one of said conductors and urging the latter toward the other of said conductors under a force sufficient to compress said portion of said body and establish said conductive path between said conductors.

2. The construction set forth in claim 1 wherein said conductors are composed of different materials.

3. The construction set forth in claim 2 wherein one of said conductors includes copper.

4. The construction set forth in claim 2 wherein one of said conductors includes aluminum.

5. The construction set forth in claim 1 wherein said body comprises a sleeve.

6. The construction set forth in claim 1 wherein said body has a plurality of openings therein for the accommodation of said plurality of conductors.

7. The construction set forth in claim 1 wherein the number and size of said particles contained in said body are such that said body is non-conductive in the absence of externally applied compressive force.

8. The construction set forth in claim 1 wherein said force applying means acts on said one of said conductors through said body.

9. The construction set forth in claim 8 including force distributing means interposed between said force applying means and said body.

10. The construction set forth in claim 1 wherein one of said conductors is substantially circular in cross-section and the other of said conductors is quadrangular in cross-section and confronts one side of said one of said conductors.

11. The construction set forth in claim 1 wherein said force applying means bears against that side of said one of said conductors opposite the side thereof which confronts said other conductor.

12. The construction set forth in claim 11 including force distributing means interposed between said force applying means and said one of said conductors and overlying a substantial portion of said body.

13. The construction set forth in claim 1 wherein said body is formed of a non-porous, air and moisture impervious material to prevent exposure of the encircled portion of said one of said conductors to atmosphere.

14. The construction set forth in claim 1 wherein said body has a plurality of spaced apart bores therein corresponding in number and shape to the number and shape of said conductors, each of said bores accommodating one of said conductors.

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