ELECTRIC TERMINATOR COMPRISING ONE-PIECE BIMETALLIC CONNECTOR AND METHOD FOR MAKING SUCH CONNECTOR

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ABSTRACT

An elbow-type loadbreak/deadbreak terminator or bushing for electrically connecting an insulated aluminum conductor wire to a copper terminal of an electrical device comprises an L-shaped insulated housing having intersecting passages, one of which accommodates a one-piece bimetallic (aluminum-copper) connector and the other of which accommodates a cylindrical copper probe threaded at its inner end. The connector comprises an aluminum portion and a copper portion welded together across their entire interface by an inertia welding process. An opening extends inwardly axially from the end of the aluminum portion of the connector for receiving the bare end of the aluminum wire which is cramped therein. A threaded opening extends inwardly transversely from a side of the copper portion of the connector for receiving the threaded inner end of the copper probe which screws thereinto. A method for making a one-piece bimetallic connector broadly comprises the steps of providing a cylindrical copper blank and a cylindrical aluminum blank, heat treating the aluminum blank, cleaning those faces of the blanks which are to be welded, welding the two blanks together by an inertia welding process and machining the joined blanks into a connector of desired shape.

19 Claims, 8 Drawing Figures
FIG. 8

1. Heat treat and anneal the aluminum blank in an oven.
2. Clean the face of the blank.
3. Form the flats using a machine face.
4. Prepare to weld both faces and weld using the inertia welding process.
5. Weld the blank and remove any flash.
6. Drill the wire receiving opening.
7. Drill the probe receiving opening.
8. Tap the probe receiving opening.
1. Field of Use

This invention relates generally to electric terminators such as loadbreak or deadbreak terminators and in particular to electrical connectors used therein.

2. Description of the Prior Art

Terminators of the aforesaid character are used, for example, in underground electrical distribution systems to connect flexible insulated electrical conductor wires or cables to the terminals of electrical devices or apparatus, such as transformers, mounted in vaults located below ground level. Typically, such terminators are of the elbow-type (i.e., generally L-shaped) and comprises an L-shaped insulated housing having a passage in each leg, which passages intersect with each other within the housing. One passage accommodates an electrically conductive male probe which is threaded at its inner end and adapted at its outer end for plug-in connection with a female receptacle or terminal on the apparatus. The other passage in the terminator accommodates an electrically conductive cylindrical connector which is adapted, as by a hole extending axially into one end, to be crimped or otherwise connected to a bare end of the cable which extends into the latter passage. The probe, which is threaded at its inner end, screws into a threaded hole extending transversely through the connector near the other end thereof. In practice, the terminator is usually furnished for field installation with the probe and connector screwed together within the housing or in kit form for field assembly. During installation, the connector is securely attached, as by crimping, to the bare end of the cable. Then, the end of the cable with the connector attached is inserted into the appropriate passage in the housing and the threaded end of the probe disposed in the other passage is screwed into the threaded hole in the connector thereby readying the terminator for plug-in connection to the terminal on the apparatus.

If the conductor wire, apparatus terminal, probe and connector are all made of a similar metal, such as copper, electrical resistance and heating problems at the point where each such member connects to the other can be minimized. However, if any two adjoining members are of dissimilar metals (such as copper and aluminum), the difference in their coefficients of thermal expansion can result in resistance and heating problems at their connection point as the two members expand and contract unevenly in response to cyclical heating and cooling resulting from increasing or decreasing electric current flow therethrough or climatic variations. Such cycling, if prolonged or exaggerated or both, facilitates the formation of oxides and other high-resistance films at the contact points between the members, thereby increasing contact point resistance and heating until the problem becomes so aggravated that a burn-out, explosion or other electrical failure can occur. In addition, the poor creep, strength, or dimensional stability, of aluminum, when copper is threaded therein, results in a loose fitting, high resistance connection within a relatively short period of time. In many instances the apparatus terminals are copper, whereas the cables to be connected thereto are aluminum. If the terminator employs an all-copper connector and a copper probe, failure sometimes occurs at the connection between the wire and the connector. Attempts to solve the problem by substitution of an all-aluminum connector for an all-copper connector in the terminator have proven unsatisfactory for several reasons. More specifically, although the aluminum connector is well-adapted to make a good electrical and mechanical connection to the aluminum cable, attempts to screw the threaded end of the copper probe into the threaded hole in the all-aluminum connector often result in cross-threading (especially in cases where the connector is cocked or off-center with respect to the probe) as the harder copper threads cut into or deform the softer aluminum threads. Such cross-threading can itself result in a very poor high-resistance connection because the probe is not in full threaded engagement with the connector and subsequent reattachment of the probe may be impossible because of damage to the connector. Furthermore, all-aluminum connectors are mechanically weak and can be bent or deformed as the terminator is connected and disconnected during use, rendering them unfit for subsequent detachment and reattachment of the cables.

3. SUMMARY OF THE INVENTION

In accordance with the present invention there is provided an electrical terminator for connecting a wire to a terminal on an electrical device where, for example, the wire and terminal are made of dissimilar metals, such as aluminum and copper, respectively. The terminator comprises an insulating housing having a pair of transverse intersecting passages therein. A one-piece bimetallic electrically conductive connector is removable mounted in one of the passages and comprises two portions of dissimilar metals welded together across their entire interface, as by inertia welding. An electrically conductive probe, preferably threaded at its inner end, is disposed in the other passage and is connectable to the connector. Wire connection means are provided on one portion of said connector which is made of the same metal as said wire. Probe connection means are provided on the other portion of said connector which is made of the same metal as the probe. The connection means comprise a wire receiving opening extending inwardly into the said one portion from an end of said connector to receive a wire and define crimpable wall means on the connector. The probe connection means comprise an opening, preferably threaded, extending laterally inwardly from a side of the said other portion of the connector. In a preferred embodiment, the said one portion of the connector is aluminum and the said other portion of the connector is copper.

A method for making the one-piece cylindrical connector in accordance with the invention broadly comprises the steps of providing a cylindrical copper blank and a cylindrical aluminum blank, annealing or heating the aluminum blank to a specified degree of hardness, cleaning the end faces of the blanks which are to be joined, inserting the blanks in an inertia welding or friction welding machine and performing the welding process to effect weld bonding of the aluminum and copper blanks entirely across their interface, and subsequently removing the flash from the finished weld and providing the specified holes. The foregoing method steps may be carried out discretely on or by means of separate machines or may be carried out on
automated machinery comprising appropriate tools for performing the various method steps. Furthermore, certain of the steps may be performed in sequences differing from the above described sequence.

Inertia welding is a solid state welding process which requires that temperature of the metals to be joined be in the forging range to permit plastic flow, and requires forging of the face or faces to obtain intimate contact and produce a weld across the entire interface of the materials being joined. More specifically, the inertia welding process, which is described in detail in U.S. Pat. No. 3,273,233, issued Sept. 20, 1966 to Oberle et al. for "Method of Bonding Metal Workpieces" is a method of bonding metal workpieces by using a flywheel to control the process and comprising storing in a rotating flywheel coupled with and driving a first workpiece all of the energy required to bond the workpieces; applying pressure to force a surface of said first workpiece into rotational rubbing contact with a surface of a second workpiece, continuing said rotational rubbing contact to heat said surfaces to a plastic condition and a bondable temperature at the pressure applied until said surfaces bond and the stored energy of the flywheel is expended; and predetermining the duration of such rotational rubbing contact between said surfaces by the amount of energy stored in the flywheel. Continued rotation after the beginning of bonding serves to refine the structure of the weld and to force out any entrapped voids, oxides and other defects from the weld. The inertia weld results in an interface wherein no intermetallic compounds are present to increase electrical resistance or physically weaken the mechanical bond between the joined metals. Other advantages of inertia welding are disclosed in a publication entitled "Caterpillar's Inertia Welding Process" by T. L. Oberle et al. and identified as bulletin ME-20890-1 of Caterpillar Tractor Co., Peoria, Ill.

The welding to provide a connector in accordance with the invention was performed on a Caterpillar Model No. 150 machine being sold and serviced by Production Technology Inc., a subsidary of the Caterpillar Tractor Co. located in Peoria, Ill.

A bimetallic connector in accordance with the invention has superior electrical conductivity properties as compared to prior art connectors due to the fact that the inertia weld joins the dissimilar metals across their entire interface and eliminates voids and high resistance brittle intermetallic compounds. Furthermore, such a greatly improved transverse bending strength properties and can be bent up to and beyond 60° from its axis without failure of the weld. Furthermore, a bimetallic connector in accordance with the invention makes excellent electrical and mechanical contact with the metals of the probe and wire with which it is associated. The method disclosed herein for making a bimetallic connector enables low cost mass production of connectors having uniform electrical and mechanical properties. Connectors in accordance with the invention are mechanically and electrically superior to bimetallic connectors formed by crimping together dissimilar metals or by flash butt welding of dissimilar metals which results in the formation of intermetallic compounds along the interface which increase electrical resistance and produce a mechanically weak, easily broken connector. Other objects and advantages of the invention will hereinafter appear.

**DRAWINGS**

FIG. 1 is a side view in cross section of a terminator employing a connector in accordance with the present invention;

FIG. 2 is an end elevation view taken of the terminator of FIG. 1;

FIG. 3 is an enlarged front elevational view of the connector shown in FIG. 1;

FIG. 4 is a side elevational view of the connector shown in FIG. 3;

FIG. 5 is an end view of the top of the connector shown in FIG. 4;

FIG. 6 is an end view of the bottom of the connector shown in FIG. 4;

FIG. 7 is a cross sectional view taken on line 7—7 of FIG. 4, and

FIG. 8 is a flow chart or schematic showing of one preferred series of method or process steps for making a connector in accordance with the invention.

**DESCRIPTION OF A PREFERRED EMBODIMENT**

Referring to FIGS. 1 and 2, the numeral 10 designates an elbow-type terminator in accordance with the invention which is used to connect a flexible high voltage cable 12 to a receptacle 13 which, for example, may be mounted on a high voltage device or apparatus, such as an underground distribution transformer, circuit breaker or the like, or even on the end of another cable. Cable 12 comprises an aluminum conductor 14, cable insulation 16, an electrically conductive cable sheath 18, and a concentric connector wire 20. Receptacle 13 comprises an insulating cone 22 in which a hollow electrically conductive copper terminal member 24 is mounted.

Terminator 10 is representative of a variety of commercially available elbow-type terminators which may differ in size and in details as regards various features and options available. Terminator 10 comprises a generally L-shaped insulating body, member or housing 26 having a cable passage 34 extending inwardly of one leg and a probe passage 36 extending inwardly of the other leg. The passages 34 and 36, which are of circular cross-section, are transverse (i.e., at right angles) to each other and intersect with each other within housing 26. Housing 26 is provided electrically conductive shielding on its exterior, as at 28, and on a portion of its interior, as at 30. Such shielding may take the form of a neoprene compound molded or bonded to housing 26. Terminator 10 is provided with a metal pulling ring or eye 32 secured to the shielding 28 on its exterior and with an attachment hole 29 for connector wire 20.

Terminator 10 is provided with a one-piece electrically conductive bimetallic cylindrically shaped connector 40, hereinafter described in detail, which is disposed in passage 34 and with a one-piece electrically conductive cylindrically shaped copper probe 38 having an externally threaded inner end portion 39 which is disposed in passage 36. Probe 38 is engageable in and with terminal 24 of receptacle 13. Connector 40 comprises an aluminum portion 40A for permanent crimp connection to the bare end of aluminum conductor 14 and a copper portion 40C for releasably threaded engagement with or connection to the inner end of probe 38. The portions 40A and 40C of connector 40 are welded together across their entire interface 50, as by
the process of inertia welding, and in accordance with a method hereinafter described. Aluminum portion 40A of connector 40 is provided with a cylindrical wire receiving opening 42 which extends axially inwardly of the connector from one end face 43 of the connector. After wire receiving opening 42 is formed, it is surrounded by an adjacent relatively thin cylindrical wall 45 of aluminum which is adapted to be cramped or swedged into tight engagement with the wire 14 inserted in opening 42.

Copper portion 40C of connector 40 is provided with a cylindrical internally threaded probe receiving opening 44 which extends laterally inwardly of the connector from a side of the connector. Preferably, copper portion 40C is provided with two flat surfaces or flats 47 on opposite sides thereof adjacent or near the end thereof between which the opening 44 extends. The flats 47 are useful during the manufacture of connectors 40, as hereinafter explained, and also aid in aligning and directing the threaded portion 39 of probe 38 into threaded opening 44 during field assembly and installation. It is to be understood, however, that opening 44 need not extend entirely through connector 40.

If terminator 10 is furnished for field installation with probe 38 and connector 40 secured together therein, then prior to installation it is necessary to unscrew probe 38 from connector 40 and to slide the connector out of passage 34. A portion of the insulating 16 is stripped from an end of cable 12 to expose an end of conductor 14 and a portion of conductive cable sheath 18 is stripped from the cable to expose a portion of the insulating 16. The exposed end of conductor 14 of the cable is inserted into opening 42 in connector 40 and the wall 45 of the latter is cramped in place on the wire by means of a suitable conventional crimping tool. The cable 12 with connector 40 attached is then inserted into passage 34 and manipulated so that one end of threaded opening 44 is aligned with passage 36 and probe 38 is inserted into passage 36 and rotated to screw its threaded portion 39 into threaded opening 44 in connector 40. Subsequently, conductor 20 of cable 12 is attached to opening 29 on terminator 10 and the terminator is ready to be attached to or plugged into receptacle 13, as shown in FIG. 1.

In preparation for welding, the copper blank surface 50C which is to be welded is machine cleaned or finished, as by a cutting or facing tool 64 of a lathe, to square it and to remove dirt, oxides and other foreign materials. Surface 50C of copper blank 40c is finished to approximately 90 RMS. Finished surface 50C must be kept absolutely clean after finishing and prior to welding and make to physical contact with other materials or surfaces, including human hands. The time interval between cleaning surface 50C and welding should not exceed approximately 5 minutes so that undesirable films do not form or redeposit on finished surface 50C.

In preparation for welding, the aluminum blank surface 50A which is to be welded is subjected to a cleaning treatment or finishing, as by abrasive means such as a disc sander wheel 65, to remove dirt, oxides and other foreign materials, but need not be machined as on a lathe. Like surface 50C, surface 50A must be kept absolutely clean after the cleaning treatment or finishing and prior to welding and, again, the time interval between cleaning and welding should not exceed approximately five minutes so as to avoid reformation and redeposition of undesirable films or coatings which would
inhibit the welding process or result in the possible formation of gas-formed voids or intermetallic compounds.

As FIG. 8 schematically shows, welding of the blanks 40a and 40c is typically carried out on an inertia welding machine 66 of a type and in accordance with a method described in U.S. Patent No. 3,273,233 hereinafter referred to. Generally considered, inertia welding machine 66 comprises a linearly movable rotatable chuck, spindle or fixture 67 driven by an electric motor 68 by means of a belt drive 69. A flywheel 75 is attached to and drives chuck 67, as hereinabove explained. Welding machine 66 further comprises a rotatable linearly movable chuck or fixture 70 movable by means of a drive means or element 71, such as a pneumatic roto-chamber, through a lever arm 72 pivotally mounted at point 73 on machine 66 and connected between fixture 70 and drive element 71.

In the embodiment shown, copper blank 40c is mounted in rotatable chuck 67 and aluminum blank 40a is mounted in linearly movable chuck 70, with the surfaces 50C and 50A opposite each other. However, if preferred, either blank could be placed in either chuck to carry out the welding. In any event, the aluminum blank 40A must be placed in its chuck or fixture so that not more than approximately one-fourth inch projects from or out of the fixture. Furthermore, no rotational slippage of either blank in its fixture is permitted during any phase of the welding cycle.

Inertia welding machine 66 with the blanks 40a and 40c in place thereon operates as follows to carry out the inertia welding process whereby the blanks are welded together across the entire interface 50 between the surfaces 50A and 50C, respectively. In the inertia welding process, the flywheel 75 is used to control the process. Sufficient inertia energy from motor 68 is stored in rotating flywheel 75 which is coupled with and rotates blank 40c to bond the faces of 50A and 50C of the blanks 40a and 40c, respectively. This inertial energy is on the order of 2,460 foot pounds. The surface 50C rotates at a speed of about 250 feet per minute. Pressure is applied by drive means 71 to move aluminum blank 40a and to force surface 50C of copper blank 40c into rubbing contact with surface 50A of aluminum blank 40a. An axial load pressure on the order of 22,800 psi is required. Rotational rubbing contact between the surfaces 50A and 50C is continued to heat the surfaces to plastic condition and a bondable temperature at the applied pressure until the surface bond and the stored energy of flywheel 75 is expended. The duration of such rotational rubbing contact between the surfaces 50A and 50C is predetermined by the amount of energy stored in flywheel 75. The continued rotation after the beginning of bonding serves to refine the structure of the weld and to force out any entrapped voids, oxides and other defects from the weld. Thus, the inertial weld results in an interface 50 wherein no intermetallic compounds are present to increase the electrical resistance in or through the weld or physically weaken the mechanical bond between the joined pieces. In the course of welding material upset or loss, in the form of flash 80, as shown in FIG. 8, occurs only on aluminum blank 40a and amounts to approximately one-fourth inch of the length of the blank.

As FIG. 8 further shows, the weld results in a one-piece integrally welded bimetallic connector 40 wherein full electrical and mechanical contact exists across and between the portions 40A and 40C at and near their interface 50. An uninterrupted, electrically conductive path is obtained, as compared to prior art connectors wherein two dissimilar members are mechanically connected and have only partially contacting surfaces. A connector 40 in accordance with the invention, if subjected to tensile and bend tests, will exhibit a failure which will occur only in the weaker of the two materials and not in the weld region.

As FIG. 8 also shows, after welding the joined blanks are subject to treatment for removal of the aluminum flash and to provide a connector of finished diameter. These steps may be carried out together or sequentially as by machining on a lathe, forcing through a trim die, impact extrusion or other suitable processes. The flats 47 could also be provided before, during or after the flash removal and diameter finishing stages.

FIG. 8 shows that hole 42 in connector 40 is end-drilled by means of a drill 80, that hole 44A is cross-drilled by means of a drill 82, and that threads in hole 44A are formed by means of a tap 84.

In accordance with other aspects of the invention and assuming proper conditions and machinery, the method steps of flash removal, sizing in a trim die and provision of wire receiving opening 42 could be carried out in a single operation, with drilling and tapping of hole 44 following thereafter.

The foregoing method steps can be carried out discretely on or by means of separate tools or machines in the various orders described or can be carried out on a turret type machine or other types of automated machinery comprising or associated with appropriate tools or devices for performing the various steps.

What is claimed is:

1. In an electrical terminator for connecting a wire to a terminal, said wire and terminal being made of dissimilar metals, a housing having a pair of transverse intersecting passages, a one-piece bimetallic electrically conductive connector in one of said passages and comprising two portions of dissimilar metals, each portion initially having a solid uninterrupted flat end surface and each end surface abutting the other along a common interface, said portions being joined together across their entire interface in a solid state bond, wire connection means on one portion of said connector, said one portion being made of the same metal as said wire, probe connection means on the other portion of said connector, and an electrically conductive probe in said other passage connected to said probe connection means of said connector, that portion of said probe connected to said connector being of the same metal as said terminal and as that portion of said connector to which it is connected.

2. A terminator according to claim 1 wherein said wire connection means comprises a wire receiving opening extending inwardly into said one portion from an end of said connector and wherein said probe connection means comprises an opening extending laterally inwardly from a side of the other portion of said connector.

3. A terminator according to claim 2 wherein the opening comprised in said probe connection means is threaded and wherein said portion of said probe connected thereto is threaded.

4. A terminator according to claim 3 wherein said one portion of said connector is aluminum and wherein the other portion of said connector is copper.
5. A terminator according to claim 4 wherein said portions are joined together in a solid state bond.

6. In an electrical terminator for connecting an aluminum wire to a copper terminal: a housing having a pair of transverse intersecting passages; a one-piece electrically conductive connector in one of said passages and comprising an aluminum portion and a copper portion, each portion initially having a solid uninterrupted flat end surface and each end surface abutting the other along a common interface, said portions being joined together across their entire interface in a solid state bond; wire connection means on said aluminum portion of said connector for attachment to said aluminum wire; probe connection means on said copper portion of said connector, and an electrically conductive copper probe in said other passage for connection to said probe connection means on said connector.

7. A terminator according to claim 6 wherein said wire connection means comprises a wire receiving opening extending inwardly into said one portion from an end of said connector and wherein said probe connection means comprises an opening extending laterally inwardly from a side of the other portion of said connector.

8. A terminator according to claim 7 wherein the opening comprised in said probe connection means is threaded and wherein said portion of said probe connector thereto is threaded.

9. A terminator according to claim 8 wherein said portions are joined together in a solid state bond.

10. In an elbow type electrical terminator for connecting an aluminum wire to a copper terminal: an insulating housing having a pair of transverse intersecting passages; a one-piece electrically conductive connector removably mounted in one of said passages and comprising an aluminum portion and a copper portion, each portion initially having a solid uninterrupted flat end surface and each end surface abutting the other along a common interface, said portions being joined together across their entire interface in a solid state bond; wire connection means on said aluminum portion of said connector for attachment to said aluminum wire, said wire connection means comprising a wire receiving opening extending axially inwardly of said aluminum portion from an end of said connector and further comprising a crimpable wall portion adjacent said wire receiving opening; probe connection means on said copper portion of said connector, said probe connection means comprising a probe receiving opening extending laterally inwardly from a side of said copper portion of said connector, and an electrically conductive probe mounted in the other of said passages and having a copper portion for engagement with said probe receiving opening in said connector.

11. A terminator according to claim 10 wherein said crimpable wall portion adjacent said wire receiving opening completely surrounds said wire receiving opening.

12. A terminator according to claim 10 wherein said probe receiving opening is threaded and wherein said copper portion of said probe is threaded.

13. A terminator according to claim 12 wherein said connector is cylindrical.

14. A terminator according to claim 13 wherein said copper portion of said connector is provided with at least one flat surface on a side thereof and wherein said probe receiving opening extends inwardly from said flat surface.

15. A terminator according to claim 14 wherein said copper portion of said connector is provided with flat surfaces on two opposite sides thereof and wherein said probe receiving opening extends between both said flat surfaces.

16. In a connector for an electrical terminator: a one-piece body comprising two portions of electrically conductive dissimilar metals, each portion initially having a solid uninterrupted flat end surface and each end surface abutting the other along a common interface, said portions being joined together across said entire interface in a solid state bond, wire connection means comprising a wire receiving first opening extending axially inwardly of one of said portions from an end face of said body, and probe connection means comprising a second opening extending inwardly of a side of the other of said portions, said second opening being transverse to said first opening.

17. A connector according to claim 16 wherein said second opening is threaded.

18. A connector according to claim 17 wherein said first opening is surrounded by a crimpable wall portion.

19. A connector according to claim 18 wherein said one portion is aluminum and said other portion is copper.