This invention relates to an insulated high voltage electrical connector for splicing together cable carrying high currents at high voltages. More particularly, the invention includes a current-carrying connector housing which contains a power-driven piston assembly for driving wedge-shaped jaws onto the center conductor of the cable. An internal shield positioned at either end of the housing modulates voltage potential lines to prevent dangerous stress buildup. Between the housing and a molded external shield, a continuous body of insulation is provided. Vent tubes provide escape means for otherwise trapped air and gases which could contaminate the semi-conductive and non-conductive members. The integrity of the molded external shield is maintained by placing ignition wires through the ends of the connector to the power-driven piston assembly.

6 Claims, 4 Drawing Figures
HIGH VOLTAGE ELECTRICAL CONNECTOR

BACKGROUND OF THE INVENTION

In recent years, emphasis has been placed on the developments of underground electrical distribution and transmission systems which will be capable of carrying much higher currents at higher voltages. Various components, such as shielded electrical cable, transformers, electrical connectors and terminals have and are being evolved for use in such high energy systems.

Included in these components are the shielded, electrical connectors which are easily usable in the field to facilitate the construction and installation of underground electrical systems. Among the several types of insulated electrical connectors are those employing propellants to drive segmental jaws onto the ends of the electrical conductors thereby splicing together a continuous cable. Such an electrical connector is disclosed in U.S. Pat. No. 3,761,602, and in U.S. Pat. No. 3,681,512, both of which are incorporated herein by reference.

In the aforementioned development of components for use in underground electrical distribution and transmission systems, it soon became evident that to accommodate higher currents at higher voltages required larger size components with increased emphasis in providing the required voltage stress relief. It was also found that the larger size components were more difficult to install, and the possibility of trapping air along the interfaces of the various components during installation increased.

In the electrical connectors being currently used, the detonation of the propellant is accomplished by using the electrical conductors as part of the firing system. Although such a method is quite satisfactory, it does require going to the opposite open ends of the cable which may be some distance away from the point of the actual splice.

As is known in the art, the cables move laterally during the firing of the jaws onto the conductors. Since the exact movement of the larger-size cables is difficult to predict for each firing, a means for adjustment must be provided to insure that all components are properly positioned after firing to avoid possible electrical failure.

Accordingly, the present invention provides an electrical connection having an outer metallic current-carrying external shield, current-carrying housing which contains a piston chamber-ram assembly and detonating means, metallic rivets associated with each side of the detonating means and centrally located through and insulated from the chamber and ram, a group associated with each piston, slide and radially movable metallic jaws electrically insulated by tape from the current-carrying housing prior to detonation, a first adapter means for engaging the center conductor, a second adapted means for engaging the portion of the cable having its outer semi-conductive jacket removed, a pair of propellant ignitor wires positioned between said second adapted means and exposed cable insulation with one end being positioned between the center conductor and the first adapted means and another end connectable to a power supply whereby a current from the power supply may travel through the wires, center conductors and insulated rivets, and detonate the propellant, a voltage stress relief member positioned on each end of the current-carrying housing, and a vent tube extending from adjacent the jaws to the outside of the connector for removing air and gases otherwise trapped within the current-carrying housing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially sectionalized, perspective view of the high voltage electrical connector constructed in accordance with the present invention;

FIG. 2 is a cross-sectional view of the mid-section of the connector in FIG. 1;

FIG. 3 is a perspective view of the cable conductor adapter assembly seen in FIG. 1; and

FIG. 4 is a cross-sectional view of one end of the connector in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The high voltage electrical connector illustrated in FIG. 1 is a preferred embodiment of the invention and is used for splicing together large capacity cable, an end of which is shown inserted into the open right end 11 of connector 10 and is designated by the reference numeral 12. The open left end 13 of connector 10 receives the end of another cable which is to be spliced to cable 12. As is well known in the art, large capacity cables are normally supplied on reels in lengths of from 1,000 to 2,000 feet. Therefore, splices must be utilized when cable requirements exceed the aforementioned lengths.

Such cable have a stranded center conductor 14 whose size is greater than 500 kcmil and which can be either aluminum or copper. A strand screen (not shown), a semi-conductive material, may be extruded over conductor 14 to provide a smooth surface for a strong, void-free bond with insulation 16. Insulation 16 is relatively thick and may be made from one of a variety of materials such as a low-density, high molecular weight polyethylene, a cross-linked polyethylene, or an ethylene propylene rubber. A metallic shield 18 surrounds insulation 16. Not shown is an outer jacket of polyvinyl chloride which commonly covers the metallic shield.

Connector 10 consists of two major groups; the connection group 20 and the insulation group 22.

The connection group 20 includes a current-carrying connection housing 24 which is seen in cross-section in FIG. 2. Housing 24, which is made from a conductive material such as aluminum, contains a mid-section 26 and tapered left and right end portions 28, 30 extending away from either side of mid-section 26. Within the mid-section area an ignition subassembly 32 is positioned.

Subassembly 32 includes a firing barrel 34 held in place within mid-section 26 by two O-rings 36. A longitudinal extending passageway 38 houses metallic piston chamber 40 which in turn contains concentric bores 42-44, the latter being of the smallest diameter. An annular shoulder 46 is formed at the juncture of the two bores. The entrance leading into bore 44 from bore 42 is tapered to receive the tapered head of a metallic contact rivet 48, this rivet extending through bore 44.

The end of the rivet opposite the head hollow for a short distance to allow the end to be peened back to form an outwardly extending flange 50. Prior to such peening a jaw-retainer 52 and washer 54 is slid onto the
rivet and positioned between the flange 50 and barrel 32-piston chamber 40. Rivet 48 is insulated as seen at 55.

Bore 42 receives therein and positioned against shoulder 46 a igniter subassembly 56 which consists of a plastic collar 58 and metallic end plates 60-62. A charge of propellant 64 fills the chamber defined by the collar and plates and a nichrome wire 66, extending through the propellant, electrically connects the two plates together. Attachment of the wire may be accomplished by simply trapping the ends thereof between a plate and an end of the collar.

Plate 60 abuts contact rivet 48 while plate 62 abuts metallic contact rivet 68 which, like rivet 48, has a tapered head and a flange 70 at its opposite end. Rivet 68 is positioned in bore 72 in metallic piston ram 74 one end of which also abuts plate 62. The other end of piston ram 74 is an outwardly extending annular cap 76 which has the same diameter as piston chamfer 40 against which it bears. A jaw-retainer 78 and washer 80 is positioned between flange 70 and cap 76 in the same manner as their counterparts, retainer 52, washer 54 located on the other end of the subassembly 32.

Further included in connection group 20 are two sets of tapered jaws 82 located in tapered end portions 28-30. The outer surfaces of the jaws are serrated as seen at 83. Each set consists of four jaws 82 held in an annular configuration by the combined efforts of the aforementioned jaw-retainers 52-78 and spacer rings 84-86 the former being found within the jaws in left-end portion 28, the latter within the jaws in right-end portion 30. As seen in FIG. 2, the jaw retainers have on the end facing away from firing barrel 34, a beveled recess in which mating projections 88 on each jaw is received. The spacer rings 84-86, each positioned in aligned grooves 90 in each jaw 82, maintain the correct inner diameter of each set of jaws.

A cone-shaped metallic coil spring 92, 94, its small end secured to flanges 50, 70 respectively, extend away from ignition subassembly 32 toward the open ends 13, 11 respectively of connector 10 (see FIG. 1).

Another member of the connection group 20 is conductor adapters 96 which is shown in FIG. 3. Adapter 96, tubular in shape and made from a conductive material such as aluminum, consists of an inner perforated sleeve 98 and outer segments 100 positioned in annular spaced relation on sleeve 98 and attached thereto. Adapter 96 is placed around the center conductor 14 which is inserted inbetween the sets of jaws 82.

The final members of connection group 20 are two ignition wires 102, one of which can be seen extending from between center conductor 14 — conductor adapter 96 to outside connector 10 via right end 11 in FIG. 1. The outer ignition wire (not shown) would extend from another center conductor 14 — conductor adapter 96 combination positioned on the left-hand side of connection group 20 to outside connector 10 via left-end 13.

The insulation group 22 includes a molded external shield 106 which is best seen in FIG. 1. Shield 106 is made from peroxide-cured, semi-conductive diene-modified ethylene propylene synthetic rubber, known in and referred to by the art as “EPDM.” Shield 106 has a long, cylindrical mid-section 108 and tapered end portions 110 on the left side and 112 on the right sides respectively. The end portions terminate in left-end opening 114 and right-end opening 116. As FIG. 1 shows, connection group 20 is entirely within mid-section 108 of the shield being centralized and held in position therein by a body of insulation 118. The body of insulation 118 is made from a non-conductive, peroxide-cured EPDM and as will be explained below, is injected into external shield 106.

Referring also to FIG. 4 as well as to FIG. 1, another member of the insulation group, internal shield 120, can be seen. Actually, there are two such internal shields, one being positioned on either end of current-carrying connector housing 24 as seen partially in FIG. 2. These internal shields are molded collars or rings and are made from semi-conductive EPDM. The outwardly extending ends 122 of the shields are rounded as shown to prevent bunching of equipotential and voltage stress lines in the vicinity of the ends of the shields. The rounding thereof provides wide distribution of the equipotential and stress lines and consequently eases the voltage concentration.

The last four members of the insulation group are two cable insulation adapter sleeves 124 and two cable shield adapter collars 126. As is apparent from the drawings, one sleeve and one collar are positioned in each end of connector 10. The sleeves, molded from non-conductive EPDM, are sized to fit around the portion of cable 12 where insulation 16 is exposed and extends from an end of current-carrying connection housing 24 to an end of the tapered end portion of the external shield 106. The outside end of the sleeves, designated at 128 are beveled at the same angle, relative to the longitudinal axis of the connector, as the tapered end portion of the external shield 106.

Cable shield adapter collars 126, molded from the same semi-conductive EPDM as used in external shield 106, are sized to fit around the portion of cable 12 where the metallic shield 18 is exposed. The inside end 130 of the collars are beveled inwardly to make with the beveled end 128 of sleeve 124 and to extend the tapered end portion of the external shield 106 to metallic shield 18 without corners or other abrupt changes.

Two other elements remain to be described. The first are the bands of insulating tape 132 two of which are wrapped around each set of jaws 82 before assembly (FIGS. 1 and 2). The tape electrically isolates the jaws, adapater 96, rivets 48-68 and insulation sleeve 56 from the rest of connector 10 before firing.

The second element is two vent tubes 134, one of which is seen in FIGS. 1 and 4. The tubes extend from either end of current-carrying connection housing 24 to the outside of connector 10 via ends 11-13. As FIG. 4 shows, the tube is placed along the outside of sleeve 124.

ASSEMBLY AND UTILITY OF THE INVENTION

An assembled igniter subassembly 32 is placed within current-carrying connection housing 24 and secured therein by crimping, such crimping creating the aforementioned O-crimps 36. Included with the subassembly are the jaws 82, jaw-retainers and so forth. Internal shields 120 are then placed on either end of housing 24 and the combination positioned within the molded external shield 106 on mandrels (not shown). Non-conductive EPDM synthetic rubber is injected into the external shield via a port (not shown) to form the body of insulation 108. The EPDM remaining in the port is smoothed off and painted over with a conductive paint to insure electrical continuity of the external shield.
After the EPDM has set, the mandrels are withdrawn, leaving passages extending from housings 24 to ends 11-13.

The user prepares the ends of the two cables 12 in the manner shown in FIG. 4 and selects the properly sized center conductor adapters 96. A bare end of ignition wire 102 is laid along each of the two center conductors 14 and adapters 96 are slid thereonto, trapping the wire between the conductors and adapters. Each wire is notched at a point where it emerges from the adapter, such point being indicated by reference numeral 138 in FIG. 4.

Properly sized sleeves 124 and collars 126, previously bonded together along beveled ends 128-130, are now slid down each of the two cables 12 and positioned therein so that sleeve 124 covers the portion of cable 12 where insulation 16 is exposed and collar 126 covers the portion of exposed metallic shield 18. In sliding on the sleeves-collars, the ignition wires are positioned alongside cables 12 as shown in FIG. 4. This acts as a vent tube for that particular interface. Note that ignition wire 102 is insulated from near notch 138 to preferably the current source (not shown).

The adapter-sleeve-fitted cable ends are now inserted into open ends 11-13 of connector 10 accompanied by vent tube 134 along the out side of the sleeve-collar as seen in FIG. 4. As the outside diameters of the sleeve-collars are the same as the inside diameters of passageways 136, silicone grease, spread thereon, facilitates assembly. The cable ends are inserted into connector 10 until the ends of center conductors 14 firmly abut springs 94. Verification of correct positioning is accomplished by a simple continuity check through the ignition wires, center conductors and subassembly 32 via rivets 48-68 and ignition subassembly 56.

After the continuity check, current source is applied to Nichrome wire 66 via ignition wires 102. Propellant 64 ignites, driving piston chamber 40 and piston ram 74 in opposite directions. Jaws 82 are in turn driven forwardly (toward ends 11-13) and radially inwardly to grip center conductors 14. As the jaws move forward, tape 132 is rubbed off, establishing electrical continuity between the center conductors 14 and current-carrying connection housing 24 through the jaws.

Sleeves 124 - collars 126 are readjusted by hand to compensate for cable movement which might have occurred during firing.

Vent tubes 134 are pulled out as are ignition wires 102, the latter breaking at notches 138. As the tubes and wires are extracted, sleeves 124-collars 126, having been squeezed by the presence of the tubes and wires, expand into complete annular engagement with cables 12 and external shield 106. The connection is completely sealed and may be buried underground without additional environmental protection required.

The present invention provides a high voltage electrical connection in which the current-carrying connection housing is directly bonded to the body of insulation surrounding it. There are no air, oil or other barriers to restrict heat dissipation therefrom.

Another novel advantage of the present invention is that only a small current is required to ignite the propellant. Two 1 ½ - volt flashlight batteries or the equivalent suffices. Connection of the ignition wires 102 and time of propellant ignition is a matter of seconds.

Yet another advantage of the present invention is that a wide range of conductor sizes can be accommodated by the use of the conductor adapters 96, and sleeves 124-collars 126. Thus, only one size of jaws 82 are needed.

Still another advantage is the use of the perforated sleeve 98 in connector adapter 96. The perforated sleeve, as it is pressed onto center conductor 14 by jaws 82, breaks up any oxides and the like on the strands and thus provides a superior electrical interface.

An advantage which is provided by coil springs 92-94 is that electrical contact between center conductors 14 and rivets 48-68 is insured.

Vent tubes 134 and ignition wire 102 provide a means for releasing gases developed on firing the propellant and air which would otherwise be trapped within current-carrying connection housing 24.

Yet another advantage in the present invention is the semi-conductive internal shields which prevents the bunching of equipotential and voltage stress lines.

Still another advantage is the unique, thick (about ¼ inch) external shield which maintains the outer surface of the body of insulation (reference numeral 118) effectively a ground potential, and which provides a reproducible path for fault current in the event of a puncture failure. Relative to the latter advantage, the resistance of the external shield is about 500 ohms and, in the event of puncture failure, the shield will repeatedly initiate an arc from the puncture to a neighboring metallic ground, thereby firmly establishing the existence of a fault in the system. In other words, as happens with painted-on semi-conductive shields, there will not be sufficient material burnt away during the initial circuit interruption such that a restrike may not be possible.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, some modifications will be obvious to those skilled in the art.

What is claimed is:

1. A high voltage electrical connection comprising:
   a. a semi-conductive tubular external shield;
   b. a current-carrying housing positioned within said shield;
   c. a body of insulation positioned between the housing and the inside of the shield and bonded to the surfaces thereof, said body of insulation defining cable receiving passageways extending from either end of the shield to the housing;
   d. two cables of the type having a center conductor and a metallic shield with insulation in between, each positioned in one of the passageways and in the housing, the portion of the cables in the housing having the metallic shield and insulation removed therefrom;
   e. two metallic conductor adapters, each having an inner perforated sleeve and a plurality of segments fixed on the sleeve in spaced annular relation, each of said conductor adapters being in crimped engagement with the center conductor of the cable extending into the housing; and
   f. two sets of tapered jaws, each set being driven onto one of the conductor adapters thereby crimping the adapters into crimped engagement with the center conductors.

2. The connection of claim 1 further including two molded insulated sleeves, each positioned between one of the cables and the body of insulation.
3. The connection of claim 1 further including two molded semi-conductive collars, each positioned between the metallic shield on one of the cables and the external shield whereby electrical continuity between the metallic shield of the cables and the external shield is provided.

4. A high voltage electrical device useful for splicing two cables together, the cable being of the type having a center conductor, a metallic shield and insulation therebetween; said device comprising:
   a. a semi-conductive, generally tubular external shield;
   b. a current-carrying housing positioned within the external shield and having within a propellant charge and two slidably mounted pistons extending outwardly from either side of the propellant charge;
   c. insulation positioned between the housing and shield and bonded to each, the insulation defining cable-receiving passageways extending from either end of the shield to the housing;
   d. a pair of gripping means each adapted for being moved into gripping engagement with an end of a cable which may be inserted into the housing;
   e. retaining means for attaching and retaining each of the gripping means to an end of the pistons;
   f. means for detonating the propellant charge whereby the pistons drive the gripping means into gripping engagement with the ends of cables which may be inserted into the housing; and
   g. vent tubes extending from the housing to without the external shield whereby gases developed upon detonating the propellant charge may be released.

5. The high voltage electrical device of claim 4 wherein each of said gripping means includes a plurality of tapered jaws.

6. The high voltage electrical device of claim 4 further including a pair of cone-shaped metallic coil springs, each being fixed to an outwardly facing end of the pistons.

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