Oct. 17, 1967 J. HUS ETAL 3,347,977

HOMOGENEOUS SODIUM CONDUCTOR CONNECTIONS

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FIG. 1

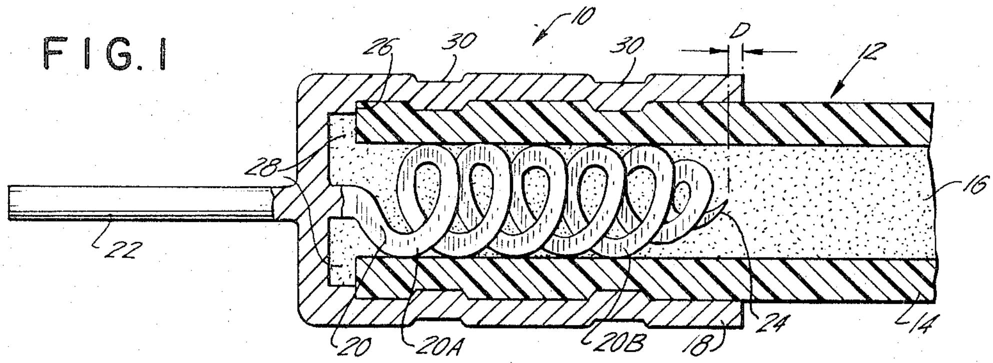


FIG. 2

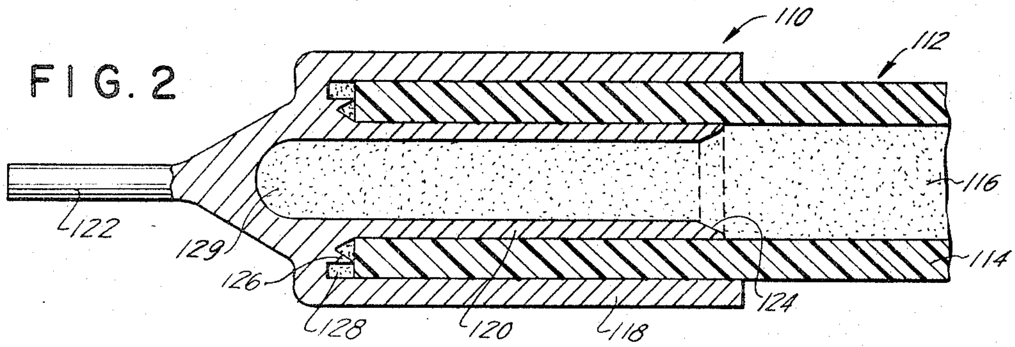


FIG. 3

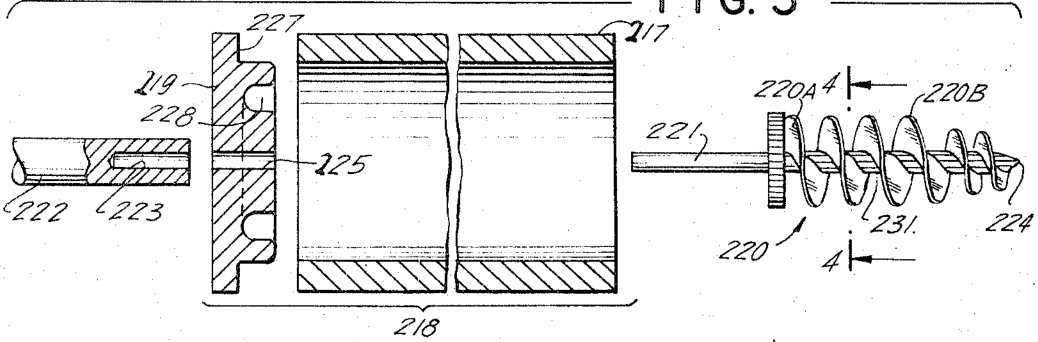
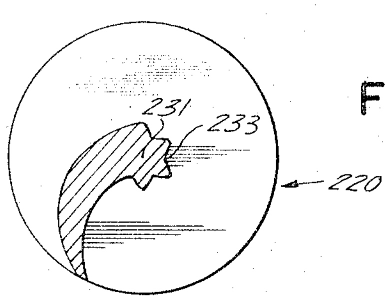


FIG. 4



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HOMOGENEOUS SODIUM CONDUCTOR CONNECTIONS

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This invention relates to electrical connections and connectors, and has the general object of providing a simple, sturdy and effective means for establishing reliable electrical connections to electrical cables of unusual type.

The insulated electrical cable contemplated for use with this invention comprises a core of highly ductile conductive materials such as sodium encased within a tubular insulating jacket of strong flexible material such as commercially available polyethylene.

Sodium conductor cables are of significant interest to the electrical power industry because the metal offers electrical characteristics favorably comparable to the more commonly used copper and aluminum conductors at substantially less cost. It is known, however, that certain other physical characteristics of sodium and similar conductive materials differ substantially from those of the standard cable conductors.

Sodium, for example, is characterized by a high rate of chemical reactivity with air and water. The high ductility of the metal causes it to behave in a pseudo fluid manner in response to unbalanced forces. Its very low tensile strength makes it a generally poor structural material.

It has been found that the previously known connection and construction techniques for electrical contacts do not operate effectively with a conductor which cannot be welded, soldered or physically clamped in any practical manner. Connections to cables of the sodium conductor type are further complicated by the necessity for protecting the conductor from exposure to air, water and other reactive elements.

Accordingly, the objects of this invention are directed toward providing reliable, inexpensive, and easily applied connectors and connection techniques for establishing secure electrical and mechanical contact with an electrical cable having a conductor formed of highly reactive and/or highly ductile material.

Features of this invention include the use of a connector which is applied axially to the end of a cable in which a longitudinally extending inner contact member serves the dual functions of contacting the conductor and of supporting the cable shape so that it may be circumferentially gripped by an outer cap member.

A further feature includes the provision, in such a connector, of an exclosed space for safely capturing the cable conductor material which is extruded from the cable jacket by insertion of the contact element.

Yet another feature is the use of an axially insertable contact element which has a low actual physical volume in relation to the theoretical total volume enclosed within the envelope defined by the outer periphery of the contact shape. One such contact element has a spiral ramp configuration which may be rotated into a ductile core material.

These and other objects, features and advantages of this invention will be distinctly and specifically pointed out in the accompanying claims, and will be more fully disclosed and explained in the following specification and drawings, in which:

FIGURE 1 is a longitudinal cross section view of a connection formed in accordance with one embodiment of this invention;

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FIGURE 2 is a similar view in accordance with another embodiment of this invention;

FIGURE 3 is an exploded cross sectional view of a connector which may be constructed in accordance with yet another embodiment of this invention; and

FIGURE 4 is a partial transverse cross section view taken along the line 4—4 of FIGURE 3.

Referring now more particularly to the drawings, FIGURE 1 may be seen to illustrate an electrical connector **10** secured to the end of an electrical cable **12**. The cable comprises a strong, flexible outer insulating jacket **14** and a soft, ductile core conductor **16**. The connector comprises an outer cap **18**, an inner contact element **20** in the form of a helical ramp having coils represented by **20A** and **20B**, and an external contact element **22**.

The cable jacket **14** is telescopically disposed within the cap **18**, and the contact element **20** is seen to be embedded in conductor **16**. Penetration of the contact **20** into conductor **16** is accomplished by rotating the entire connector about its own axis thereby advancing the spiral ramp shape of the contact into the conductor material in the manner of a corkscrew. The pointed end **24** on the contact facilitates rotation and axial advance, while the centerless corkscrew shape of the contact advantageously minimizes displacement of the core material **16** during insertion.

Since the core material in cables of the type under discussion are characteristically highly ductile, a certain amount of the material is unavoidably displaced by the finite physical volume of the inserted contact. Due to the highly reactive nature of ductile conductors such as sodium, it has been found desirable to capture the extruded conductor material in a sealed enclosure. In the connector embodiment illustrated in FIGURE 1 an enclosure **28** has been provided by deliberately positioning the inner end wall of cap **18** at a short axial distance from the end of cable **12**. While this positioning might be allowed for by an installer during installation, it is preferable to provide a positioning stop means, such as transverse shoulder **26**, on the inner surface of the cap to assure proper spacing. By constructing shoulder **26** as a substantially continuous ridge around the inner periphery of the cap, it can be made to serve the purpose of an additional sealing means for securely capturing the material within space **28**.

It is desirable for the inner contact member **20** of this invention to maintain the shape of the outer insulating jacket **14** of the cable to which it is applied. Given this support, the connector securing means discussed later in this disclosure are better able to grip the cable periphery. The desired support is achieved by providing the contact **20** with a portion having a generally uniform outermost diameter which does not differ substantially from the inner diameter of the cable jacket **14**. Thus, in the embodiment shown in FIGURE 1 the contact **20** has been provided with five spiral turns of substantially the same diameter, extending from **20A** to **20B**. This provides internal support for the jacket over a substantial portion of the total length of the contact.

In this embodiment, the cap **18** is shown to have been mechanically secured to jacket **14** by crimping as at **30**. By forming crimps **30** circumferentially about the periphery of cap **18** in accordance with well-know techniques, a secure, sealed joint can be achieved between the flexible jacket material and the malleably deformed cap. Although a crimped joint has been illustrated, it would be possible to achieve a desirable circumferential grip and seal through compression of the cap by means of a mechanical retaining device such as a standard hose clamp.

Where circumferential deformation is relied on to secure the connector **10** to a cable **12** the internal support provided by contact **20** for cable jacket **14** is of particular interest. Under such circumstances the uniform outermost diameter of the contact should preferably be very nearly the same or greater than the inner diameter of the jacket **14** so as to afford optimum support for the crimping or other compressing operation. Further it is preferable for the uniform diameter portion to have substantially the same longitudinal extent as the crimped portion on the cap **18**. Thus, in FIGURE 1, the uniform outer diameter portion of contact **20**, including **20A** and **20B**, may be seen to extend beneath both of the two axially spaced apart crimps **30**, thereby affording substantial internal support to each crimp area.

Added axial retention strength for the connector **10** may be derived from contact **20** by providing relatively sharp edges or areas on the outer perihery of the spiral turns such as **20A** or **20B**. By proper choice of contact diameter these may be adapted to bite into the innner diameter of cable jacket **14** either upon rotation of the connector during insertion, or only in response to the slight reduction in diameter of the jacket caused by external compression.

FIGURE 1 shows cap **18** to be an integral conductive extension of inner contact **20** and external contact **22**. Provided that cap **18** is in conductive contact with contact element **20** it is apparent that the cap and the contact will each exist at the same electrical potential when the core **16** is energized. This identity of electrical potential may be utilized to reduce undesirable corona effects by causing the cap **18** to shield the contact **20**, in effect. To achieve optimum sheilding, contact **20** preferably should not extend beyond the end of cap **18**. This concept is illustrated in FIGURE 1 by showing the end of contact **20** to be a finite distance D short of the plane defined by the end of cap **18**. If the distance D is made sufficiently great to allow cap **18** to receive jacket **14** before contact end **24** engages core **16**, the cap will advantageously serve as a guide to assure proper alignment of the contact with the core.

FIGURE 2 illustrates an embodiment of this invention in which elements having corresponding parts in FIGURE 1 are denoted by the same reference numerals increased by one hundred. Thus, for example, cable **112** corresponds to cable **12**, and connector **110** corresponds to connector **10** in FIGURE 1. In this embodiment, inner contact element **120** is in the form of a thin-walled hollow tube having an outermost diameter adapted to permit insertion into the inner diameter of cable insulation jacket **114**. The forward rim of the tubular contact may be beveled, as at **124**, to ease axial advance during insertion; concurrently the outermost edge of the bevel may in turn be slightly rounded, as shown, to avoid snagging on the inner wall of the jacket **114**.

At the rearward end of contact **120** an enclosed chamber **129** has been provided to capture the displaced volume of material from conductor core **116** in a completely sealed-off space. In addition, a spacing projection **126** may be provided on the outer periphery of the rearward end of contact **120** in order to create an additional enclosed volume **128** beyond the cable end. This external volume serves, as in the embodiment of FIGURE 1, to capture core material which is extruded from the cable between the outer wall of contact **120** and the inner wall of jacket **114**. By forming projection **126** as a continuous circumferential rim with a sharp edge, as shown, highly desirable additional sealing of the end of the cable is obtained.

As in the case of the spiral ramp illustrated in FIGURE 1, the tubular contact element **120** of FIGURE 2 provides a high ratio of theoretical enclosed volume to actual physical volume. It has been found that this ratio assures optimum cable support with minimum core material displacement.

FIGURE 3 illustrates another modification of this invention and suggests a convenient method of fabricating a connector in accordance with the new concepts here disclosed. In this figure elements having corresponding parts in FIGURE 1 are denoted by the same reference numerals increased by two hundred. Thus, the connector comprises an outer cap **218**, an external contact element **222**, and an inner contact element **220**. For ease of fabrication, cap **218** is formed of two separate elements: tubular side wall **217** and circular end wall **219**. The end wall is provided with a peripheral flange **227** which positions the end wall relative to side wall **217** and provides a convenient surface for securing the two parts together as by soldering, brazing or welding, for example. The end wall **219** may be provided, in addition, with an annluar recess **228** which will communicate with the conductor core of a cable for receiving extruded core material in a space beyond the end of the cable.

The inner contact element in this embodiment may be seen to comprise a form of helical screw having a particular configuration. That is, the turns of the screw gradually decrease in diameter toward the forward end, but at the rearward end, they include several turns of substantially uniform outer diameter, as between **220A** and **220B**. The central spine **231** of the contact includes a rearwardly projecting anchor portion **221**. End wall **219** of cap **218** is provided with a central bore **225** which permits anchor **221** to emerge from the interior to the exterior of the cap. If desired, anchor projection **221** may be sealed in bore **225** and secured directly to end wall **219** by any suitable process. Anchor **221** might thus serve directly as an external contact for the connector. Alternatively, a separate external contact **222** may be used by providing it with a bore **223** adapted to receive anchor **221**. End wall **219** may thus be gripped between contact **222** and the rearward end of contact **220** to secure the latter to cap **218**.

It should be noted that this alternative method of capturing the contact elements to cap **218** suggests that it is not necessary to fabricate cap **218** of metallic material only. Cap **218** may in fact be formed of any suitable metallic or synthetic material and may possibly be formed of the same material as the insulating jacket of the cable to which it is attached. Similarly, the cap may be formed of a conductive material with an insulating coating provided to limit the amount of conductive surface area presented by the connector. In accordance with these concepts, it is considered apparent that the outer caps of connectors constructed in accordance with this invention may be secured to the jacket of an inserted cable by means of various mechanical or chemical bonding techniques which will provide a peripheral seal between the outer jacket of a cable and the outer cap of the connector.

FIGURE 4 represents a transverse cross section through contact element **220** of FIGURE 3. This figure illustrates a feature of this invention which serves to increase the conductive surface area of the inner contact while decreasing its actual physical volume. In accordance with this feature, central spine **231** is seen to be provided with a plurality of longitudinally extending fluted portions **233**.

This invention has thus far been described in terms of terminal connections only. It is apparent that for such terminal connection use the external contact element **22** (also **122** and **222**) may assume any convenient configuration, such as an apertured lug or a flat spade, for cooperation with other contacting and connecting means. And similarly some portion or the entire outer surface of cap **18** may itself serve as the external contact means for connector **10**.

In addition to terminal connections, however, it should be noted that this invention is equally applicable to forms such as splices for joining two cables of the same or even different types. Thus, it is conceivable to simply join two connectors of the form shown in FIGURE 1, in oppositely directed, back-to-back relationship to provide an effective cable splice. Such joined connectors might readily be of identical configurations with the same or different dimensions. In a preferable splice embodiment of the connectors shown in FIGURES 1 and 3, the spiral ramp portion in one half of the connector is formed in a "right-hand" configuration while the opposite spiral ramp has a "left-hand" characteristic. A splice connector thus formed may be simultaneously inserted in two oppositely facing cable ends in response to axial rotation of the joint connector in a given direction.

The invention has thus been described but it is desired to be understood that it is not confined to the particular forms or usages shown and described, the same being merely illustrative, and that the invention may be carried out in other ways without departing from the spirit of the invention; therefore, the right is broadly claimed to employ all equivalent instrumentalities coming within the scope of the appendant claims, and by means of which objects of this invention are attained and new results accomplished, as it is obvious that the particular embodiments herein shown and described are only some of the many that can be employed to obtain these objects and accomplish these results.

We claim:

1. An electrical connector adapted to be electrically coupled to the end of an electrical cable having a homogeneous central core of highly ductile metal enclosed within a substantially tubular insulating jacket, said connector comprising:
- an end cap member capable of telescopically receiving the end of an insulated cable;
- an inner contact member mounted substantially coaxially within said end cap member and having an outermost diameter not substantially less than the inner diameter of the cable jacket;
- an insulation support portion on said inner contact member including a longitudinally extending section having the outermost diameter thereof substantially coincident with a theoretical cylindrical surface of given uniform diameter; and
- external contact means electrically coupled to said inner contact member, including a conductive surface accessible from the exterior of said cap member;
- said inner contact member having a shape which presents a relatively high ratio between the theoretical volume enclosed within said theoretical surface and the actual physical volume of said inner contact member.

2. An electrical connector in accordance with claim 1, wherein said inner contact member is corkscrew shaped.

3. An electrical connector in accordance with claim 2, wherein the corkscrew shaped inner contact member has relatively sharp outer edges adapted to engage the inner diameter wall of a cable jacket.

4. An electrical connector in accordance with claim 1, wherein said inner contact member has the form of a helical screw, including a threaded portion of substantially uniform diameter corresponding to said insulation support portion, and a pointed end portion.

5. An electrical connector in accordance with claim 4, wherein said helical screw contact member has a central spine portion, and said spine portion includes longitudinal fluting thereon.

6. An electrical connector in accordance with claim 4, wherein said helical screw contact member includes a plurality of threads having relatively sharp outer edges adapted to engage the inner diameter wall of a cable jacket.

7. An electrical connector in accordance with claim 1, wherein said end cap member is formed of deformable material which permits said cap to be deformed into engagement with the outer jacket of an inserted cable.

8. An electrical connector in accordance with claim 7, wherein said deformable material is a malleable metal subject to deformation beyond its elastic limit.

9. An electrical connector in accordance with claim 7, wherein said deformable material is substantially elastic in nature and is subject to deformation by external clamping means.

10. An electrical connector in accordance with claim 9, further including a clamping device for externally compressing said end cap member.

11. An electrical connector in accordance with claim 1 further including means on said end cap capable of engaging and forming a peripheral seal with the end of an inserted cable.

12. An electrical connector in accordance with claim 1 further including means on said end cap adapted for engaging the end of an inserted cable to hold the end of such a cable at a finite axial distance from the inner end of said end cap, thereby providing an inner enclosed space extending beyond the end of such a cable.

13. An electrical connector adapted to be electrically coupled to the end of an electrical cable having a homogeneous central core of highly ductile metal enclosed within a substantially tubular insulating jacket, said connector comprising:
- an end cap member formed of malleable conductive metal capable of telescopically receiving the end of an insulated cable of the type described;
- space means within said end cap providing an enclosed space extending beyond the end of a fully inserted cable to receive extruded core material from such a cable;
- an inner contact member disposed entirely within said end cap in position to axially penetrate a cable inserted into said cap;
- an insulation support portion on said inner contact member including a longitudinally extending section having the outermost dimensions thereof substantially coincident with a theoretical cylindrical surface of uniform diameter which is not substantially less than the core diameter of an inserted cable;
- external contact means electrically coupled to said inner contact member, including a conductive surface portion accessible from the exterior of said cap member;
- said inner contact member being characterized by a shape which presents a relatively high ratio between the theoretical volume enclosed within said theoretical surface and the actual physical volume of said inner contact member;
- wherein said malleable end cap may be circumferentially deformed by cramping to secure said cap to the outer jacket of an inserted cable.

14. An electrical connection comprising:
- an electrical cable having a substantially tubular outer jacket of flexible insulating material and a homogeneous core of highly ductile conductive material disposed within said jacket;
- an inner contact member embedded in said homogeneous core, said inner contact member having an outermost diameter not substantially less than the inner diameter of said tubular outer jacket;
- an end cap member, telescopically disposed about the outer periphery of said tubular insulating jacket, and having a closed end thereon;
- external contact means electrically coupled to said inner contact member, including a conductive surface accessible from the exterior of said cap member; and
- an insulation support portion on said inner contact member having the outermost dimensions thereof substantially coincident with a theoretical cylindrical surface of given uniform diameter, said inner contact member having a shape which presents a relatively high ratio between the theoretical volume enclosed within said theoretical surface and the actual physical volume of said inner contact member.

15. An electrical connection in accordance with claim 14, including a space within said end cap, extending axially beyond the end of said cable, which is occupied by

ductile conductive material extruded from the core of said cable.

16. An electrical connection in accordance with claim **14**, wherein the tubular outer jacket of said cable is gripped between said end cap member and said internal contact member.

17. An electrical connection in accordance with claim **14**, wherein said end cap member is sealed to the periphery of said cable.

18. An electrical connection in accordance with claim **17**, wherein said end cap is sealed to said cable by circumferential crimping of said cap.

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