United States Patent

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[54] **TWIN CONDUCTOR WITH FILLER**
8 Claims, 2 Drawing Figs.

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[50] **Field of Search** 174/113, 115, 116, 126; 156/167

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ABSTRACT: A conductor assembly of improved physical properties including high tensile strength, crush force resistance and fungi resistance is prepared with at least two individually insulated conductors such as round wires and a cordage product comprising a continuous coherent fibrous article of substantially cylindrical configuration produced from an oriented film composed essentially of a polymeric material, said article being a longitudinally fibrillated fibrous web, the fibroid segments forming said web being in random coherent association. An outer jacket of weatherproofing material surrounds the pair of conductors and the cordage product.

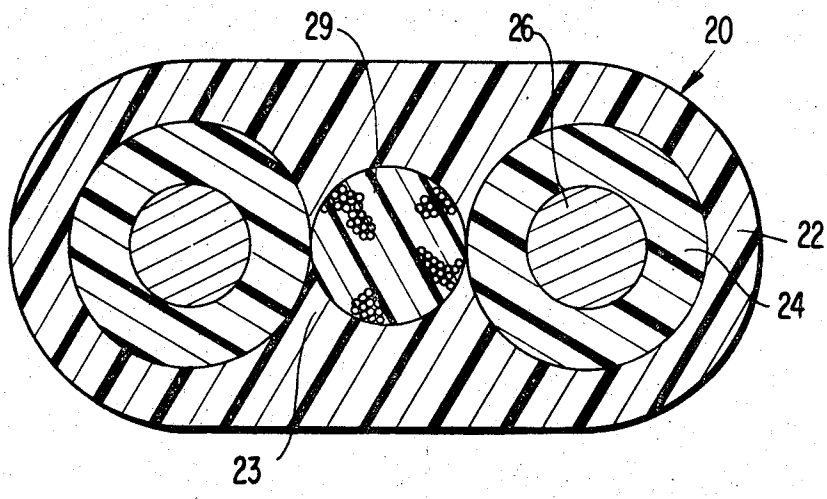


FIG. 1

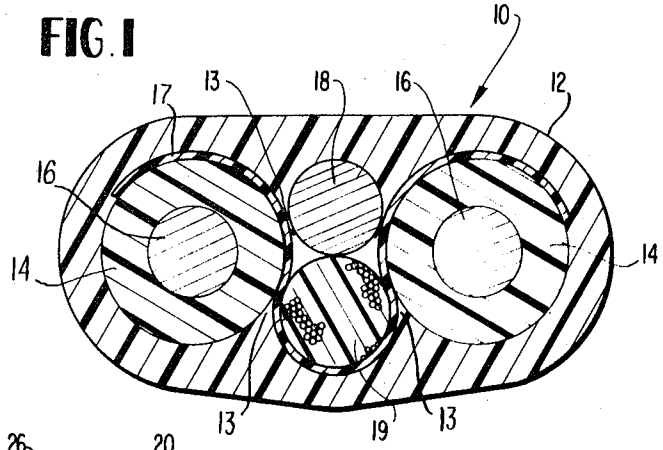
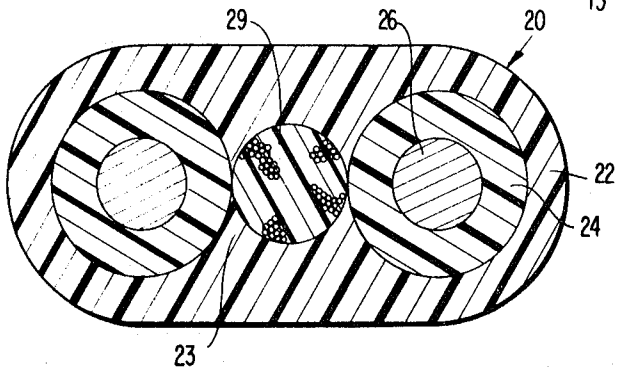


FIG. 2



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TWIN CONDUCTOR WITH FILLER

This invention concerns a conductor assembly having improved physical properties, and more particularly relates to an assembly containing at least two individually insulated conductors and a cordage product which not only promotes proper and uniform spacing between the two conductors, but also contributes significantly to the tensile strength and crush force resistance of the assembly while additionally providing fungi resistance for the assembly.

Electric service cable of the type used for service entrance cable to dwellings, for appliance cords, and for underground service cables and the like, conventionally contain two individually insulated conductors and optionally a third grounding wire maintained out of electrical contact with the two conductors, paper or other such product as a cushioning insert, and an exterior coat of weatherproofing material surrounding all the elements of the cable. It has been found that the two insulated conductors, with no additional elements, lack sufficient crush force resistance for many applications. The paper insert, while adding some crush force resistance, does not contribute significantly to the overall tensile strength of the cable, and, in fact, does promote rotting within the cable because of the susceptibility of the paper to attack by various fungi. In addition, past electric service cables, when constructed from aluminum alloy wire, employed a wire such as EC which possesses less than desirable properties of elongation, tensile strength and fatigue resistance.

Thus, a need has arisen within the industry for a conductor assembly of improved physical properties and it is, therefore, an object of the present invention to provide a conductor assembly having increased crush force resistance, improved tensile strength, improved ultimate elongation and fatigue resistance, and substantial inertness to fungi attack.

These and other objects, features and advantages of the present invention will become apparent from a review of the following detailed description and the accompanying drawings wherein:

FIG. 1 represents one embodiment of the invention and

FIG. 2 represents a second embodiment of the invention, both in transverse cross section.

Referring now in more detail to the drawings, in which like numerals indicate like parts throughout the several views, FIG. 1 disclosed the preferred embodiment of the present invention. In this embodiment, the conductor assembly **10** includes an exterior sheath of thermoplastic weatherproofing material **12** such as polyvinyl chloride, polyethylene, polypropylene, neoprene, and the like. Preferably, the sheath is prepared from polyvinyl chloride. The sheath surrounds two round wire conductors **16** which are, in turn, individually insulated by a coat of thermoplastic material **14**, such as polyvinyl chloride, polyethylene, polypropylene, neoprene, and the like. Preferably, the coat is polyvinyl chloride and is applied in a thickness of one sixty-fourth to seven sixty-fourths of an inch.

Positioned between the two conductors and serving to space them apart in appropriate distance are an uninsulated ground wire **18** and a cordage product **19**. The cordage product **19** comprises a continuous, coherent fibrous article of generally cylindrical configuration which is produced by fibrillating an oriented film composed essentially of a polymeric material. The cylindrical article is composed of a longitudinally fibrillated fibrous web, the fibroid segments forming said web being in random coherent association. It is contemplated that fibrillated films of polymeric material may also be used; such fibrillated films including those wherein the individual fibroid segments are not in random coherent association. However, preferably the cordage product employed in the present invention is a fibrous article consisting of a longitudinally fibrillated coherent sheet of fibroid segments physically connected to each other at random intervals by short links which are an integral part of each of those fibroid segments. Such a fibrillated or fractured film is disclosed in U. S. Pat. Nos. 3,214,899; 3,293,844; 3,294,300; and 3,336,174.

The uninsulated ground wire **18** has, preferably, the same diameter as the two conductors so that all three wires are generally the same American Wire Guage (AWG). However, when employing a No. 8 guage conductor or larger, the ground wire may be reduced in size with respect to the conductor. When employing a No. 10 gauge conductor, the ground wire may be No. 10 or No. 8 gauge.

As shown in FIG. 1, ground wire **18** is positioned adjacent cordage product **19** and both are positioned between the insulated conductors **16**. As the exterior sheath of thermoplastic material is extruded around the assembly of conductors, ground wire and cordage product, portions of the sheath pass into the areas between the ground wire and cordage product and conductors to form retaining ridges **13**. These ridges assist in reducing internal movement of the elements of the assembly.

An additional element which aids in reducing movement within the assembly while also providing an insulating shield is continuous film **17**. The film is a polymeric material such as polyethylene terephthalate, polyethylene or polypropylene. Preferably, the film is polyethylene terephthalate and has a thickness of 0.5 to about 10 mils. The film is continuous throughout its length and is positioned within the assembly so that the central portion of the film surrounds a portion of the exterior surface of cordage product **19**. The lateral edge portions of the film **17** surround a portion of the exterior surfaces of the insulating material **14** which surround conductors **16**. The lateral portions of the film overlie that portion of the exterior surfaces of insulating material **14** which is substantially opposite from the surrounded surface of cordage product **19**. Cordage product **19** lies between ground wire **18** and that section of film **17** which is looped around the exterior surface of the cordage product. Cordage product **19** is retained in its position adjacent ground wire **18** and between conductors **16** by the film **17** which, in turn, is retained in its position by the retaining force created between the outer jacket **12** and insulating material **14**. The film, therefore, serves as a support to assist in retaining cordage product **19** in its position between conductors **16**. In addition, film **17** lies between ground wire **18** and the insulating material **14** surrounding conductors **16** so that there is no direct contact between the ground wire and this insulating material.

With a conductor assembly as previously described, it has been found that ultimate tensile strength of the assembly has been improved due to the tensile strength of the cordage product and the film, in addition, crush resistance has been improved, especially so with respect to lateral force. When lateral force is applied, a particularly revealing test for insulated conductors, film **16** and ridges **13** retain cordage product **19** in its position between the conductors so that the cordage product and the two thicknesses of film absorb a great deal of the shock of the applied force. Thus, the amount of force required to rupture the assembly is increased to a figure above the minimum required for the type assembly involved. The cordage product and film also provide additional areas of insulation over assemblies possessing only insulated conductors. Moreover, since the cordage product and film are substantially inert with respect to fungi and other deteriorating organisms, the assembly is fungi resistant and, therefore, suitable for underground use.

FIG. 2 represents an alternative embodiment of the present invention. The figure discloses a two-conductor assembly **20** wherein the two conductors **26** are individually insulated with a thermoplastic material **24** such as used in the embodiment of FIG. 1. Positioned between the insulated conductors is cordage product **29**, similar in design and composition to cordage product **19**. An exterior sheath of thermoplastic material **22** surrounds the insulated conductors and cordage product, and portions of the sheath are extruded into the areas between the cordage product and the insulated conductors to form ridges **23**. These ridges serve to support product **29** in its position between the conductors so that applied lateral force may be absorbed by the cordage product. Preferably, the cordage

product is positioned on the center line between the conductors so that applied lateral force will not tend to dislocate the product, but collapse it. As with the embodiment of FIG. 1, it has been found that the embodiment of FIG. 2 has improved physical properties of ultimate tensile strength, resistance to fungi attack and crush force resistance.

The individual conductors and ground wires of all the embodiments of the present invention are prepared from an aluminum alloy comprising less than about 99.70 weight percent aluminum, more than about 0.30 weight percent iron, and no more than 0.15 weight percent silicon. Preferably, the aluminum content of the present alloy comprises from about 98.95 weight percent to less than about 99.45 weight percent with particularly superior properties being achieved when from about 99.15 to about 99.40 weight percent aluminum is employed. Preferably, the iron content of the present alloy comprises about 0.45 weight percent to about 0.95 weight percent with particularly superior results being achieved when from about 0.50 weight percent to about 0.80 weight percent iron is employed. Preferably, no more than 0.07 weight percent silicon is employed in the alloy of the present conductor. The ratio between the percentage iron and percentage silicon must be 1.99:1 or greater. Preferably, the ratio between percentage iron and percentage silicon is 8:1 or greater. Thus, if the present aluminum alloy conductor contains an amount of iron within the low area of the present range for iron content, the percentage of aluminum must be increased rather than increasing the percentage of silicon outside the ratio limitation previously specified. It has been found that a properly processed individual conductor having aluminum alloy constituents which fall within the above-specified ranges possesses an acceptable conductivity of at least 61 percent IACS and improved tensile strength and percent ultimate elongation when compared to conductors prepared from conventional electrically conductive alloys.

The present individual aluminum alloy conductors are prepared by initially melting and alloying aluminum with the necessary amounts of iron or other constituents to provide the requisite alloy for processing. Normally, the content of silicon is maintained as low as possible without adding additional amounts to the melt. Typical impurities or trace elements are also present within the melt but only in trace quantities such as less than 0.05 weight percent each with a total content of trace impurities generally not exceeding 0.15 weight percent. Of course, when adjusting the amounts of trace elements, due consideration must be given to the conductivity of the final alloy since some trace elements effect conductivity more severely than others. The typical trace elements include vanadium, copper, manganese, magnesium, zinc, boron and titanium. If the content of titanium is relatively high (but still quite low when compared to the aluminum, iron and silicon content), small amounts of boron may be added to tieup the excess titanium and keep it from reducing the conductivity of the wire. Iron is the major constituent added to the melt to produce the alloy of the present invention. Normally, about 0.50 weight percent iron is added to the typical aluminum component used to prepare the present alloy. Of course, the scope of the present invention includes the addition of more or less iron together with the adjustment of the content of all alloying constituents.

After alloying, the melted aluminum composition is continuously cast into a continuous bar. The continuous bar is then hot rolled to form continuous rod.

One example of a continuous casting and rolling operation capable of producing continuous rod as specified in this application is as follows:

A continuous casting machine serves as a means for solidifying the molten aluminum alloy metal to provide a cast bar that is conveyed in substantially the condition in which it solidified from the continuous casting machine to the rolling mill which serves as a means for hot forming the cast bar into rod or another hot formed product in a manner which imparts substantial movement to the cast bar along a plurality of angularly disposed axes.

The continuous casting machine is of conventional casting wheel type having a casting wheel with a casting groove partially closed by an endless belt supported by the casting wheel and an idler pulley. The casting wheel and the endless belt cooperate to provide a mold into one end of which molten metal is poured to solidify and from the other end of which the cast bar is emitted in substantially that condition in which it solidified.

The rolling mill is of conventional type having a plurality of roll stands arranged to hot form the cast bar by a series of deformations. The continuous cast machine and the rolling mill are positioned relative to each other so that the cast bar enters the rolling mill substantially immediately after solidification and in substantially that condition in which it solidified. In this condition, the cast bar is at a hot-forming temperature within the range of temperatures for hot forming the cast bar at the initiation of hot forming without heating between the casting machine and the rolling mill. In the event that it is desired to closely control the hot-forming temperature of the cast bar within the conventional range of hot-forming temperatures, means for adjusting the temperature of the cast bar may be placed between the continuous casting machine and the rolling mill without departing from the inventive concept disclosed herein.

The roll stands each include a plurality of rolls which engage the cast bar. The rolls of each roll stand may be two or more in number and arranged diametrically opposite from one another or arranged at equally spaced positions about the axis of movement of the cast bar through the rolling mill. The rolls of each roll stand of the rolling mill are rotated at a predetermined speed by a power means such as one or more electric motors and the casting wheel is rotated at a speed generally determined by its operating characteristics. The rolling mill serves to hot form the cast bar into a rod of a cross-sectional area substantially less than that of the cast bar as it enters the rolling mill.

The peripheral surfaces of the rolls of adjacent roll stands in the rolling mill change in configuration; that is, the cast bar is engaged by the rolls of successive roll stands with surfaces of varying configuration, and from different directions. This varying surface engagement of the cast bar in the roll stands functions to knead or shape the metal in the cast bar in such a manner that it is worked at each roll stand and also to simultaneously reduce and change the cross sectional area of the cast bar into that of the rod.

As each roll stand engages the cast bar, it is desirable that the cast bar be received with sufficient volume per unit of time at the roll stand for the cast bar to generally fill the space defined by the rolls of the roll stand so that the rolls will be effective to work the metal in the cast bar. However, it is also desirable that the space defined by the rolls of each roll stand not be overfilled so that the cast bar will not be forced into the gaps between the rolls. Thus, it is desirable that the rod be fed toward each roll stand at a volume per unit of time which is sufficient to fill, but not overfill, the space defined by the rolls of the roll stand.

As the cast bar is received from the continuous casting machine, it usually has one large flat surface corresponding to the surface of the endless band and inwardly tapered side surfaces corresponding to the shape of the groove in the casting wheel. As the cast bar is compressed by the rolls of the roll stands, the cast bar is deformed so that it generally takes the cross-sectional shape defined by the adjacent peripheries of the rolls of each roll stand.

Thus, it will be understood that with this apparatus, cast aluminum alloy rod of an infinite number of different lengths is prepared by simultaneous casting of the molten aluminum alloy and hot forming or rolling the cast aluminum bar.

The continuous rod produced by the casting and rolling operation is then processed in a reduction operation designed to produce continuous conductors of various gauges. The reduction operation consists of a process whereby unannealed rod (i.e., as rolled to *f* temper) is cold-drawn through a series of progressively constricted dies without intermediate anneals

to form a continuous conductor of the desired configuration. At the conclusion of this drawing operation, the alloy wire will have an excessively high tensile strength and an unacceptably low ultimate elongation, plus a conductivity below that which is industry accepted as the minumum for use in an electrical conductor, i.e., 61 percent of IACS. The wire is then annealed or partially annealed to obtain a desired tensile strength and cooled. At the conclusion of the annealing operation, it is found that the annealed alloy wire has the properties of acceptable conductivity and improved tensile strength and percent ultimate elongation. The annealing operation may be continuous as in resistance annealing, induction annealing, convection annealing by continuous furnaces, or radiation annealing by continuous furnaces; or may be batch annealed in a batch furnace. In addition, the present aluminum alloy wire may be partially annealed by resistance or induction annealing and then additionally annealed by batch annealing. When continuously annealing, temperatures of about 450° F. to about 1200° F. may be employed with annealing times of about 5 minutes to about 1/10,000 of a minute. Generally, however, continuous annealing temperatures and times may be adjusted to meet the requirements of the particular overall processing operation so long as the desired tensile strength is achieved. In a batch annealing operation, a temperature of approximately 450° F. to about 750° F. is employed with residence times of about 24 hours to about 30 minutes. As mentioned with respect to continuous annealing, in batch annealing the times and temperatures may be varied to suit the overall process so long as the desired tensile strength is obtained.

After annealing, the alloy wire is passed through an extrusion head where thermoplastic insulating material is extruded around the wire. The insulating material is polyvinyl chloride, polyethylene, polypropylene or neoprene with polyvinyl chloride being preferred.

During the continuous casting of this alloy, a substantial portion of the iron present in the alloy precipitates out of solution as iron aluminate intermetallic compound ($FeAl_3$). Thus, after casting, the bar contains a dispersion of $FeAl_3$ in a supersaturated solid solution matrix. The supersaturated matrix may contain as much as 0.17 weight percent iron. As the bar is rolled in a hot-working operation immediately after casting, the $FeAl_3$ particles are broken up and dispersed throughout the matrix inhibiting large cell formation. When the rod is then drawn to its final gauge size without intermediate anneals and then aged in a final annealing operation, the tensile strength, elongation and bendability are increased due to the small cell size and additional pinning of dislocations by preferential precipitation of $FeAl_3$ on the dislocation sites. Therefore, new dislocation sources must be activated under the applied stress of the drawing operation and this causes both the strength and the elongation to be further improved.

The properties of the present aluminum alloy wire are significantly affected by the size of the $FeAl_3$ particles in the matrix. Coarse precipitates reduce the percent elongation and bendability of the wire by enhancing nucleation and, thus, formation of large cells which, in turn, lowers the recrystallization temperature of the wire. Fine precipitates improve the percent elongation and bendability by reducing nucleation and increasing the recrystallization temperature. Grossly coarse precipitates of $FeAl_3$ cause the wire to become brittle and generally unusable. Coarse precipitates have a particle size of above 2,000 angstrom units and fine precipitates have a particle size of below 2,000 angstrom units.

The cordage products, **19** and **29** are prepared by casting a solution of the polymeric material onto a flat surface and drying the resulting film deposit. Other techniques for preparing a film will be apparent to those skilled in the art. The films so prepared are usually of a thickness of from about 0.001 to 0.01 inches although films of greater or less thickness may be obtained by adjustment of the solids content. Films of the stated thickness range are preferred, however, since they result in fibrous articles of optimum strength, flexibility and other properties. When the films are prepared from crystalline polymers, it is necessary to heat the films to a temperature at which the crystallites will melt followed by supercooling the film, and then stretching the film in one direction to obtain the desired unilateral orientation. Films of noncrystalline polymers may be oriented by stretching them in a heated condition, and the orientation may set in the film by sudden chilling.

The unilaterally oriented film is then randomly fibrillated by brushes, knives or jets of air. Preferably, jets of air are impinged upon the surface of the film to cause random fibrillation thereof. Other appropriate processes are disclosed in the previously mentioned United States patents.

The conductor assembly is prepared by gathering the insulated conductors, ground wire (optional), and cordage product together and feeding them through an extrusion head where the exterior coat of weatherproofing material is applied. In a more specific sense, two or more individually insulated conductors are fed simultaneously through a bath of liquid silicon material or oil such as peanut oil to provide a barrier for the prevention of plastic welding between the insulation material of the conductors and the outer jacket of weatherproofing material. Just prior to entry into the outer jacket extrusion head, a cordage product is positioned alongside the conductors as disclosed in the various embodiments. A bare ground wire is also added at this point, if such is desired. These elements are then guided into their relative positions by a multiple guide assembly. The elements then enter the extrusion head through a guider tube and tip assembly which fix the elements in their final position. At the exit point of the guider tube and tip assembly, the outer jacket of weatherproofing material is extruded around the assembly of elements and shaped to desired size by the extrusion die which places the jacket under sufficient pressure to form around the internal assembly to thereby assist in maintaining the cable configuration. The pressure within the extrusion die, though, is limited to a point below the minimum plastic welding pressure between the insulation of the conductors and the outer jacket. When a continuous film is included in the conductor assembly, as is preferred, the film is fed to the multiple guide assembly and arranged by the assembly in its appropriate position with respect to the conductors, cordage product and ground wire.

For the purpose of clarity, the following terminology used in this application is explained as follows:

Rod — A solid product that is long in relation to its cross section. Rod normally has cross section of between 3 inches and 0.375 inches.

Wire or Conductor — A solid wrought product that is long in relation to its cross section, which is square or rectangular with sharp or rounded corners or edges, or is round, a regular hexagon or a regular octagon, and whose diameter or greatest perpendicular distance between parallel faces is between 0.374 inches and 0.0031 inches.

While this invention has been described in detail with particular reference to preferred embodiments thereof, it will be understood that variations and modifications can be effected within the spirit and scope of the invention as described hereinbefore and as defined in the appended claims.

We claim:

1. Conductor assembly prepared from conductors having a minumum electrical conductivity of 61 percent IACS comprising at least two individually insulated conductors; an uninsulated ground wire; a cordage product consisting essentially of a longitudinally fibrillated fibrous web of polymeric material, the fibroid segments forming said web being in random coherent association; an outer jacket of weatherproofing material surrounding said individually insulated conductors, said uninsulated ground wire, and said cordage product; and a continuous film of polymeric material surrounding a portion of the exterior surface of the cordage product and portions of the exterior surfaces of two of the insulated conductors, the lateral edges of the film lying between the exterior surfaces of the two insulated conductors and the outer jacket of weather-

proofing material and the film being constructed and arranged to retain the cordage product in its position within the conductor assembly.

2. Conductor assembly of claim 1 wherein the insulation material surrounding the conductors and the outer jacket of weatherproofing material comprise polyvinyl chloride, the cordage product is prepared from polypropylene, and the film of polymeric material comprises polyethylene terephthalate.

3. Conductor assembly for transmitting electric current including a pair of individually insulated conductor wires; an uninsulated ground wire; a cordage product consisting essentially of a longitudinally fibrillated fibrous web of polymeric material, the fibroid segments forming said web being in random coherent association; a film of polymeric material surrounding a portion of the exterior surface of the cordage product and portions of the exterior surfaces of the insulated conductors opposite from the surrounded surface of the cordage product, said cordage product and ground wire being positioned between the conductors with the film of polymeric material lying between the conductors and the ground wire and cordage product; and an outer jacket of weatherproofing material surrounding the individually insulated conductor wires, the cordage product, the ground wire, and the film of polymeric material.

4. Conductor assembly for transmitting electric current including a pair of individually insulated conductor wires; an uninsulated ground wire; a cordage product for increasing the crush force resistance of the conductor assembly, said ground wire and cordage product lying adjacent one another and being positioned between the conductor wires; a sheet of polymeric material surrounding a portion of the cordage product opposite from the ground wire and lying between the cordage product and the conductor wires and between the ground wire and the conductor wires; and an outer jacket of weatherproofing material surrounding the conductor wires, the cordage product, the ground wire, and the sheet of polymeric material.

5. Conductor assembly for transmitting electric current including a pair of individually insulated conductor wires; an uninsulated ground wire; a cordage product for increasing the crush force resistance of the conductor assembly, said cordage product being positioned between the conductor wires; a sheet of polymeric material surrounding a portion of the exterior surface of the cordage product and a portion of the exterior surface of each of the conductor wires opposite from the surrounded surface of the cordage product; and an outer jacket of weatherproofing material surrounding the conductor wires, the cordage product, the ground wire and the sheet of polymeric material.

6. Conductor assembly of claim 5 wherein the ground wire lies adjacent the cordage product and the sheet of polymeric material provides an effective insulating barrier between the ground wire and the conductor wires while retaining the cordage product in its position adjacent the ground wire and between the conductor wires.

7. Conductor assembly of claim 6 wherein the conductor wires are an aluminum alloy containing substantially evenly distributed iron aluminate inclusions in a concentration produced by the addition of about 0.45 to about 0.95 weight percent iron to an alloy mass consisting essentially of from about 98.95 to about 99.4399 weight percent aluminum, from about 0.01 to about 0.15 weight percent silicon and from about 0.0001 to less than 0.05 **weight percent each of trace elements selected from the group consisting of vanadium, copper, manganese, magnesium, zinc, boron, and titanium, the total content of trace elements being from about** 0.004 to about 0.15 total weight percent, and said iron aluminate inclusions having a particle size of less than 2,000 angstrom units.

8. Conductor assembly of claim 6 wherein the insulation material surrounding the conductor wires and the outer jacket of weatherproofing material comprises polyvinyl chloride, the cordage product comprises a fibrillated sheet of polypropylene, and the film of polymeric material comprises polyethylene terephthalate.