United States Patent

Cleaver et al.

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[54] METHOD OF JOINTING AND TERMINATING ELECTRIC CABLES

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Nov. 11, 1968	Great Britain	53,372/68

[52] **U.S. Cl.** ..... **29/628,** 29/630 A, 29/401, 29/474.6, 134/21, 156/49, 164/108, 164/107, 174/20 R, 174/22 R, 29/488, 29/494

[51] **Int. Cl.** **H01r 43/00**

[58] **Field of Search** ..... 174/19, 20, 21, 22, 23; 29/624, 630 A, 628, 401, 474.6, 494, 488; 164/108, 100; 18/36; 156/49; 134/21; 228/44

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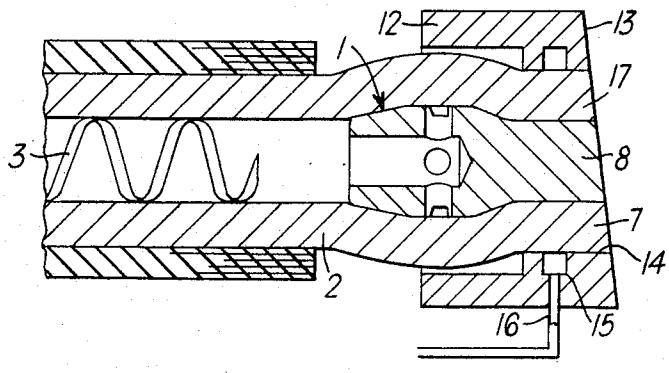
[57] **ABSTRACT**

In a method of jointing or terminating an electric cable having at least one conductor in the form of a hollow strand through the bore and the interstices of which liquid impregnant for the cable dielectric can pass the stranded conductor is bonded to a terminal or to another conductor by application in the molten state of an adherent body of metal to substantially the whole of the cut end face of the stranded conductor or between the cut end face of the stranded conductor and the end of the terminal or of the other conductor. During the process a mandrel is inserted in the end of the bore of the conductor and passage of impregnant from the bore to an end portion of the strand is inhibited, by said mandrel or otherwise, a heat sink is formed so as to surround the end of the stranded conductor and liquid impregnant is removed from the interstices between the wires of the stranded conductor in the end portion thereof by applying vacuum thereto. The bonding process is preferably an MIG (metal/inert gas) or other welding process. Preferably oil flows through radial passages formed in the wall of the strand. In the case of a joint, these radial passages are preferably interconnected by longitudinal passages formed in a ferrule.

21 Claims, 11 Drawing Figures



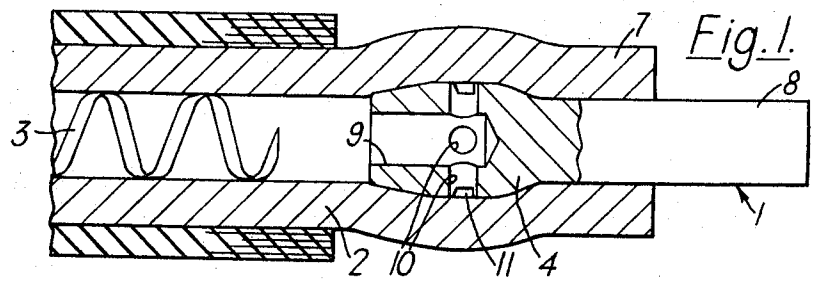


Fig. 1.

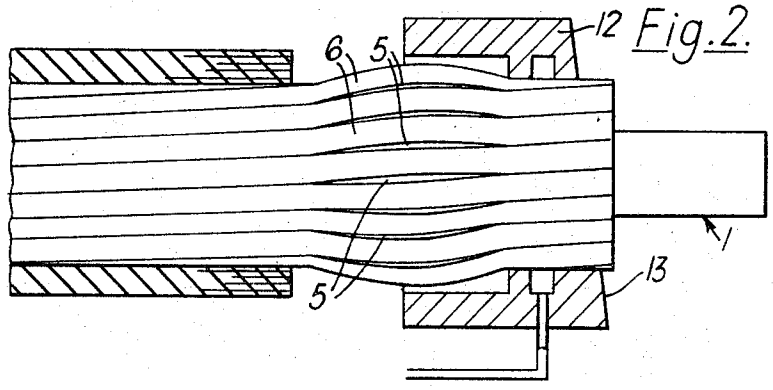


Fig. 2.

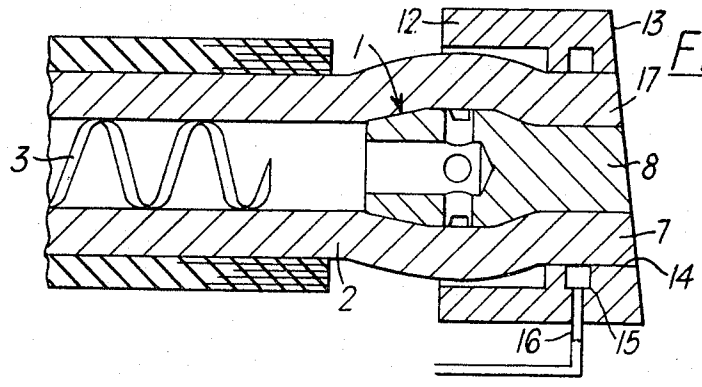


Fig. 3.

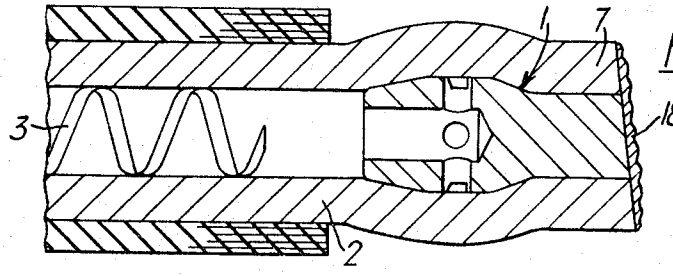


Fig. 4.

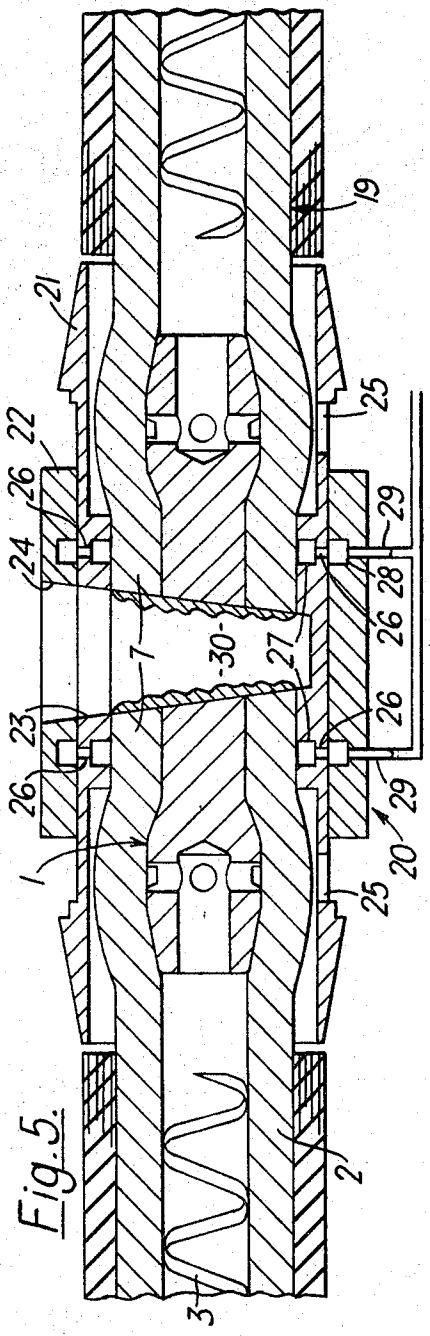


Fig.5.

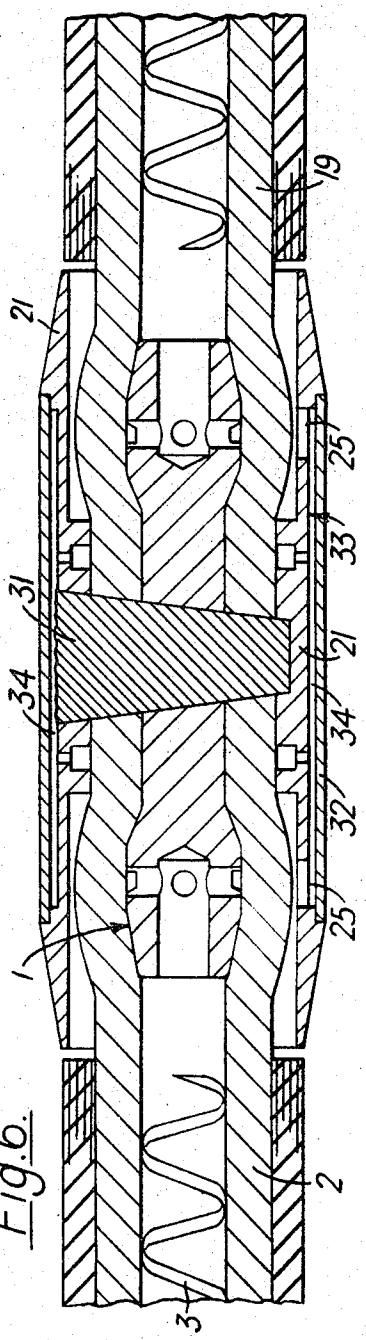


Fig.6.

Fig. 7.

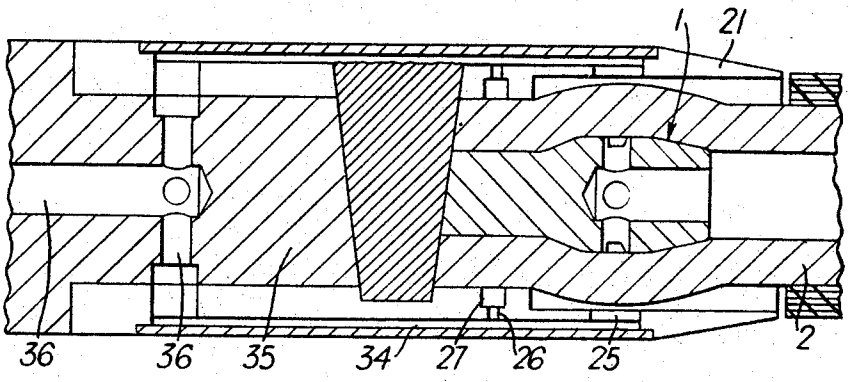


Fig. 8.

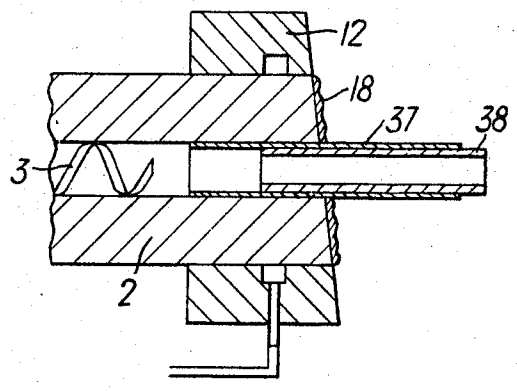


Fig. 9.

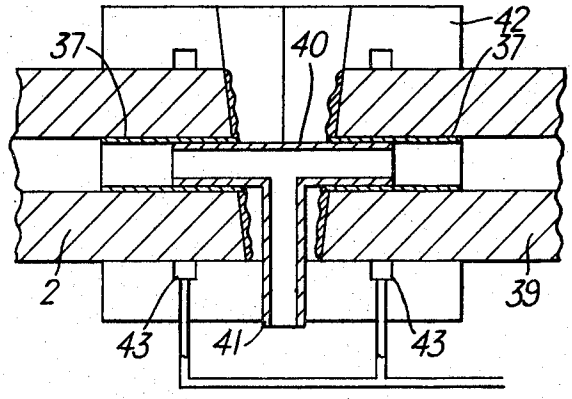


Fig. 10.

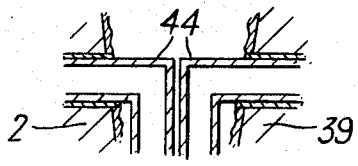
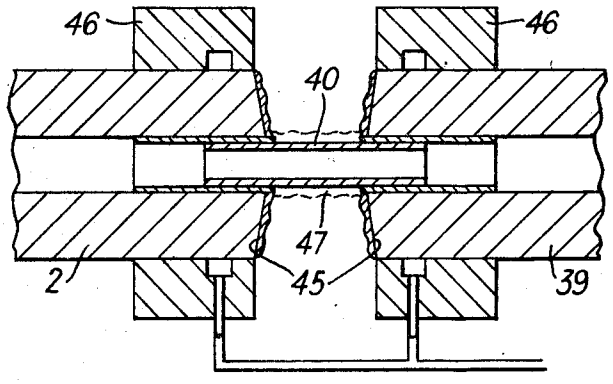


Fig. 11.



METHOD OF JOINTING AND TERMINATING ELECTRIC CABLES

This invention relates to a method of jointing and terminating electric cables having a conductor made up of a plurality of wires constituting a hollow strand through the bore and through the interstices of which a liquid impregnant for the cable dielectric can pass. By the term "a liquid impregnant" is meant an impregnant which is liquid at the normal working temperature of the cable or which becomes liquid at a temperature which the strand may reach during the jointing or terminating process. More especially, but not exclusively, the invention relates to a method of jointing hollow-conductor oil-filled cables in which the bore of the hollow conductor forms a longitudinal passage to facilitate access of a free-flowing impregnant (usually referred to as an oil) to all parts of the dielectric.

The method in accordance with the invention comprises inserting a mandrel in the end of the bore, inhibiting passage of impregnant from the bore to an end portion of the strand by said mandrel or otherwise, forming a heat sink surrounding the end of the stranded conductor and bonding the stranded conductor to a terminal or to another conductor by a process entailing the application in the molten state of an adherent body of metal to substantially the whole of the cut end face of the stranded conductor or between the cut end face of the stranded conductor and the end of the terminal or of the other conductor whilst removing liquid impregnant from the interstices between the wires of the stranded conductor in the region of a cut end thereof by applying vacuum thereto.

Passage of impregnant from the bore to the end portion of the strand may be inhibited by plugging the bore at a place spaced from the cut end of the conductor. It has been found however that a more efficient clearance of oil is obtained if the boundary between the bore of the conductor and the inner surface of the hollow strand along a length of the bore of the conductor extending longitudinally from the cut face of the conductor at least up to and preferably beyond the manifold is sealed in such a way as substantially to inhibit or entirely to prevent flow of oil from the duct into the interstices between the wires of the strand. Such sealing can be obtained by using a mandrel which is a close fit in the end portion of the bore.

Usually it will be necessary to provide for the passage of impregnant between the bore of the stranded conductor and an adjacent cable length or a reservoir or other apparatus. If a tubular mandrel is used, the impregnant may pass through the bore of the mandrel. Preferably, however, one or more radial passages are provided through the wall of the hollow strand at a point adjacent to the end thereof.

In a preferred method in accordance with the invention, the mandrel has a head of a maximum cross-sectional area greater than that of the bore and a neck which may be solid or tubular and is of a cross-sectional area less than that of the head. The cross-sectional shape and size of the neck is preferably substantially the same as the original size and shape of the bore of the conductor. Such a mandrel is forced head first into the bore of the conductor to cause the head to expand it at a point adjacent to its end, and the conductor is then contracted onto the neck, for example by means of a compression tool. The head of the mandrel has a bore which is open, at least at the end of the head opposite to that which is secured to or integral with the neck of the mandrel, and at least one passage extending through the wall of the head to the external surface of the head.

It is to be understood that reference to the bore of the conductor and its shape and cross-sectional area is to the bore after any ancillary internal supporting structure such as a steel spiral has been removed.

Clearance of oil may be assisted by temporarily closing the open end of the head (opposite to the end of the head adjoining the neck) by means of a valve which may subsequently be opened by means of an operating rod passing through the neck of the mandrel or which may be a drop-out valve which can subsequently be operated, to open the passage, by applying reverse oil or gas pressure.

Where, as will normally be the case, the head is provided with a number of uniformly spaced radial passages these are preferably interconnected by a circumferential groove formed in the outer surface of the head.

We have found that joints of greater tensile strength are obtained by so shaping the head as to leave a right cylindrical center part tapering down, both towards the neck of the mandrel and towards the opposite end of the head, to a cross-section approximately equal to the original cross-section of the bore of the conductor.

When a tubular mandrel is used and is not closed during the bonding process, it should project sufficiently from the cut end face of the conductor to stop oil escaping from it impinging on that end face, at least during the first part of the bonding process.

The bonding process may be a soldering or brazing process but for maximum mechanical strength and reliability a welding process is preferred. The arc welding technique known as MIG (metal/inert gas) welding, which entails transfer of metal from an electrode to the work across an arc struck in an atmosphere of argon, is especially suitable. We prefer to build up the adherent body of metal by a two stage welding process comprising a first stage in which a thin layer of metal is applied to the cut end of the stranded conductor to seal it, while vacuum is maintained on the conductor end, followed by a second stage in which the stranded conductor end is again subjected to vacuum and a larger quantity of metal is applied to connect the conductor to another conductor or to a terminal. Although in the second stage the metal is applied by a welding process, this stage will usually resemble a casting operation since it will entail filling a cavity bounded on at least one side by the cut end of a stranded conductor with molten metal.

The heat sink may take the form of a jig which prevents separation of the individual wires of the conductor during welding, and is afterwards removed, or at least part of the heat sink may become bonded to the weld, so forming a permanent part of the joint or termination. Preferably the heat sink used in the second stage comprises a metal sleeve contiguous with the stranded conductor, which becomes bonded to the weld, and an outer part which is removable. Such a sleeve, which may be solid, longitudinally cut, or longitudinally divided into two or more parts, will hereinafter be referred to as a "ferrule."

In the case of a joint, the conductors will usually extend substantially horizontally, and an aperture will be provided through the surrounding wall of the ferrule (and of the outer part of the heat sink) for the introduction of bonding metal. Normally this aperture should be located at the top of the ferrule. Where passage of impregnant between the bore of the hollow stranded conductor and a bore of another conductor jointed to it is required and one or more radial passages are provided through the wall of the hollow strand as above described, a ferrule extending along the conductor beyond the position of the radial passage or passages is preferably used. One or more apertures are provided through the wall of the ferrule for the application of vacuum during jointing and for the eventual passage of the impregnant, and the external surface of the ferrule is preferably shaped to provide a longitudinal passage or passages for impregnant in the completed joint.

In the case of a termination, the conductor will usually extend vertically, and access for bonding metal can be obtained through the open upper end of the ferrule.

The heat sink serves to prevent undue temperature rise at the cut-back end of the cable dielectric, minimizes annealing of the conductor ends, and (in the case of an arc welding process) prevents burn-back of individual wire ends which would result in inadequate welding.

Vacuum is preferably applied to the strand by a surrounding manifold, preferably in the form of an annular groove in the inner wall of the heat sink.

It will usually be necessary to remove residues of impregnant from the cut end of the stranded conductor by washing with a suitable solvent whilst vacuum is applied to the conductor and before the bonding process begins.

The invention will be further described, by way of example, with reference to the accompanying drawings wherein:

FIGS. 1 – 4 show successive stages in a preferred method of jointing or terminating an oil-filled cable having a hollow stranded conductor,

FIGS. 5 and 6 show two subsequent stages as applied to jointing of the cable to another similar cable,

FIG. 7 shows a stage in a method of making a stop joint, and

FIGS. 8 – 11 show stages in a number of alternative jointing methods.

In the preferred method in accordance with the invention, the cable end is first cut back in the usual way, and a headed mandrel 1 (FIG. 1) is driven into the bore of the hollow stranded conductor 2 after any internal support 3 has been cut back. The head 4 of the mandrel has a diameter greater than that of the bore of the stranded conductor, so that the conductor is expanded to form radial passages 5 (FIG. 2) between the individual wires 6 of the strand. The end portion 7 is contracted onto the neck 8 of the mandrel, which has a diameter substantially equal to the original diameter of the bore of the stranded conductor, using a suitable compression or swaging tool. A bore 9 and passages 10 in the head of the mandrel allow passage of oil between the bore of the stranded conductor and a circumferential groove 11, which in turn communicates with the radial passages 5 (FIG. 2) through the strand.

A heat sink 12 made of a metal of good thermal conductivity is now assembled about the conductor end. Preferably the heat sink is of copper if the conductors to be joined are of aluminum or of mild steel or stainless steel if the conductors are of copper. The end face 13 of the heat sink is inclined with respect to a plane perpendicular to the conductor axis and serves as a cutting jig for trimming the conductor end together with the neck 8 of the mandrel, to the shape shown in FIG. 3. The position of the cut is such that, in the completed joint, the end of the conductors are spaced further apart at their upper than their lower edges. Depending on the conductor size, an angle of from 15° to 30° between the plane of the cut and the plane perpendicular to the conductor axis is suitable.

The heat sink has a cylindrical through bore 14 which makes close contact with the peripheral surface of the end portion 7 of the stranded conductor, and the bore is formed with an annular groove 15 in communication with an outlet 16 on the outer surface of the mould, so that the heat sink can act also as a manifold through which oil can be extracted from the interstices between the wires of the strand. In addition, it acts as a jig to prevent splaying of the wires of the strand.

After the heat sink 12 has been firmly attached to the conductor, the outlet 16 is connected to a vacuum pump by which oil is drawn from the conductor until oil no longer flows from its cut surface 17. It has been found sufficient to reduce the pressure at the vacuum pump to a few millimeters of mercury (absolute) the pressure increasing to substantially atmospheric at the cut end face of the stranded conductor. In accordance with normal practice, the opposite end of the cable length is connected to a reservoir of oil so that any oil withdrawn from the cable length, by the vacuum pump or otherwise, is continuously replaced under hydrostatic pressure.

While the vacuum continues to be applied, the cut surface 17 of the conductor is washed with a suitable volatile solvent for the oil, e.g. a few milliliters of petroleum ether. Clearance of excess solvent may be assisted, if required, by placing a cap over the flat end of the heat sink surrounding the cut end of the conductor and/or by applying an inert gas under pressure to the cut end. The cap may simply consist of and end plate and a peripheral wall in the form of a suitably shaped circular gasket which can be held under pressure against the end face 2 of the heat sink.

When this cleaning process is complete and with the vacuum still applied, a thin adherent layer 18 (FIG. 4) of weld metal is applied to the whole of the cut end face of the conductor and of the mandrel by means of an MIG welding gun. On completion of this operation, the hot heat sink is quickly removed from the end of the conductor. Preferably it has sufficient mass to ensure that it acts alone to prevent an undue rise in the temperature of the conductor during welding, but it can if necessary be force cooled, for example by water circulation.

When a joint is to be made between two hollow stranded conductors, the second conductor 19 (FIG. 5) is similarly prepared, and the prepared ends of the two conductors are cleaned by wire brushing and washing with solvent. They are then brought into alignment with a small gap between them in another heat sink 20 in-

cluding a ferrule **21** which is to become a permanent part of the joint, and a removable outer part **22**. A central aperture **23** is provided in the top of the ferrule, and the outer part of the heat sink is correspondingly apertured at **24**. Between the aperture **23** and each end of the ferrule, two sets of holes **25**, **26** are provided in its pheripheral wall. The holes **25** are preferably grouped around the lower part of the joint, and provide an exit for oil flowing from the conductor ducts through the heads of the mandrels and the expanded part of the strand. The holes **26** connect annular grooves **27**, **28** in the ferrule and in the outer part of the heat sink respectively. Grooves **28** are provided with outlets **29** whereby vacuum may be applied to the grooves **27** to draw out oil from the end portions **7** of the two conductors. In some cases it may be possible to dispense with the holes **26** and to apply suction instead to holes **25**. With vacuum applied to withdraw oil from the ends of the conductors, washing of the prepared end surfaces of the conductors is repeated. Clearance of solvent may be assisted, in a similar way to that described above, by the use of a cap which fits over and seals the top of the cavity in the mould and which may allow for the application of gas pressure to the cavity.

On completion of the cleaning process and while vacuum is still applied, the space **30** between the conductor ends is filled with an adherent body of weld metal **31** (FIG. **6**) by means of an MIG welding gun inserted through the apertures **23**, **24**, and the outer part **22** of the heat sink is quickly removed to avoid overheating the conductor ends. The outer part of this heat sink, like heat sink **12**, may be force-cooled if required.

A longitudinally divided sleeve **32** is assembled around the ferrule **21** to enclose an annular recess **33** in its external surface, so forming an annular passage **34** which allows oil to flow between the holes **25**, so completing an oil path between the bores of the two stranded conductors **2**,**19**. The ferrule **21** and divided sleeve **32** are shaped to form the necessary smooth surface about which the joint insulation is finally applied in the usual way.

An alternative method of obtaining longitudinal flow of oil from the conductor duct through an aperture or apertures in the head of the mandrel into the ferrule is to contract the conductor in a non-uniform manner on to a mandrel having a neck of greater cross-sectional area than that of the conductor duct, so as to leave a gap or gaps between elements of the conductor. This particularly applies to conductors built up from solid segments and to Milliken type conductors, which can be arranged onto the neck in such a way as to leave, for example, a single space between two of the segments, preferably at the lower part of the joint.

FIG. **7** shows a modification of the method just described for the formation of a stop-joint. The second stranded conductor is replaced by a solid metal joint member **35** having appropriate oil passages **36** machined in it to provide for oil flow between the annular oil passage **34** and auxiliary apparatus. A similar connection is made between the joint member **35** and a second hollow stranded conductor. The method of making the welded joint shown in FIG. **7** is exactly as described with reference to FIGS. **1 – 6** except that no preliminary treatment (except cleaning) of the solid member **35** is required and that no application of vacuum to member **35** is needed.

FIG. **7** also shows another modification, which may be used also in ordinary joints, in that the ferrule **21** is longitudinally divided, e.g. in a vertical plane, into two parts. This avoids the need to form a hump in the cable in order to inset the conductor end through the end of the ferrule.

Instead of forming vacuum manifolds by providing annular grooves in either of the heat sinks **12** and **20**, a separate manifold may be applied between that heat sink and the cut-back end of the cable dielectric. This manifold may for example be in the form of a thin-walled sleeve which surrounds and is sealed at each end by binding to the conductor and which has intermediate its ends an enlargement which provides an annular passage between the sleeve and the conductor. The enlargement is provided with an outlet for connection to a vacuum pump.

A further possibility is to provide an additional manifold between the vacuum manifold and the end of the stranded conductor. The additional manifold may be connected to a source of inert gas under pressure, before or during application of vacuum to the vacuum manifold, to facilitate oil clearance.

In the alternative methods shown in FIGS. **8 – 11**, an oil passage is maintained though the end portion of the bore of the stranded conductor. The conductor end is first inserted in the heat sink **12** and its end trimmed to the required angle. The boundary between the bore of the conductor is sealed, after cutting back any internal support **3**, by insertion of a close-fitting tubular mandrel **37**, which preferably extends at least 5 cm. beyond the place where vacuum is to be applied. Clearing of the cut end face of the stranded conductor and coating with weld metal **18** is then carried out as in the method described above. Mandrel **37** is preferably thin-walled (e.g. less than 3 mm.) and if it is of the same metal as the conductor, and additional mandrel **38**, which may be tubular or solid, is temporarily inserted in it to prevent burning through of the permanent mandrel **37** during welding. The tubular mandrel **37** is then cut off approximately level with the surface of the weld metal deposit.

The conductor end so prepared may then be connected to another conductor end **39** (FIG. **9**) similarly prepared by first connecting their bores by means of a further tube **40** which is a close fit, possibly a screw fit, in the tubular mandrels **37** and is preferably provided with a branch tube **41** for escape of oil during jointing. A heat sink **42** generally similar to the heat sink **12** but in the form of a mould which surrounds the conductor ends and provides access to the gap between the conductor ends is applied. A vacuum manifold **43** is provided round each conductor end, and whilst vacuum is applied the cut end faces of the conductors and the exposed parts of the tubes **40**, **41** are washed with solvent, and after clearance of the solvent the space between them is filled with weld metal using an MIG welding gun.

After removal of the heat sink, the weld will be dressed down to the conductor diameter, and normally the branch tube **41** will be plugged, before the joint insulation is applied.

Where the direct connection between the bores of the two conductors is not required, the tube **40** may be replaced, as shown in the scrap view in FIG. **10**, by angled tubes **44**, so permitting separate control of oil flow in the two cable lengths.

In some cases, as shown in FIG. 11, it may be possible to omit the branch tube 41. In this case it is preferable to cut the conductor end face to a frustoconical, rather than an inclined planar, shape. By using two separate heat sinks in the second welding step, it then becomes possible to build up weld metal, as indicated at 47, by means of an MIG welding gun which is rotated about the conductor axis.

In making a termination, the preferred method commences with the steps described above with reference to FIGS. 1 – 4; the termination may then be completed by any one of the methods described in our application Ser. No. 813,621 filed on the same day as this Application. The modifications necessary when using the alternative method described with reference to FIG. 8 will be evident.

Although it is preferable always to coat the cut surface of the conductor with welding metal, as described above, it may in some circumstances be possible to obtain a sufficient temporary sealing of the cut end of the conductor in the first stage by mechanically deforming the end of the strand, as by hammering while the strand is supported in a suitable jig or mould.

In the following claims the term "connecting" is used to embrace both jointing and terminating.

What we claim as our invention is:

1. A method of making a connection between an electric cable comprising an outer sheath, a liquid-impregnated dielectric and at least one conductor in the form of a hollow strand through the bore and the interstices of which liquid impregnant for cable dielectric can pass and at least one other conductive member, comprising

i. forming at least one passage for impregnant through the wall of the bore at a place adjacent to the end thereof,

ii. closing the bore of an end portion of the conductor by inserting a mandrel therein,

iii. placing the end of the stranded conductor in adjacent relation to the said other conductive member and forming a heat sink surrounding the cut end of the impregnant - containing stranded conductor and

iv. bonding the stranded conductor to said other conductive member by applying in the molten state an adherent body of metal to the whole of the cut end face of the stranded conductor and to said other conductive member whilst contemporaneously applying vacuum to the stranded conductor in a region removed from the said cut end face to remove liquid impregnant from the interstices of the conductor and leave said cut end face substantially free of said impregnant.

2. A method as claimed in claim 1 in which the said bonding process is a welding process is a welding process.

3. A method as claimed in claim 2 in which at least part of the heat sink becomes bonded to the weld.

4. A method as claimed in claim 1 in which the bonding process is a welding process in which the adherent body of metal is built up by a two-stage process comprising a first stage in which a thin layer of metal is applied to the cut end of the stranded conductor to seal it, while the conductor end is surrounded by a first heat sink and vacuum is applied to it, followed by a second stage in which a larger quantity of metal is applied to the stranded conductor end while it is surrounded by a second heat sink and vacuum is again applied to it to complete the connection.

5. A method as claimed in claim 1 in which vacuum is applied to the stranded conductor end by a surrounding manifold in the form of an annular groove in the inner wall of the or each heat sink.

6. A method as claimed in claim 1 comprising washing the end of the stranded conductor with a solvent for the liquid impregnant prior to bonding.

7. A method as claimed in claim 6 in which the washing is carried out whilst vacuum is applied to the conductor end.

8. A method of making a connection between an electric cable comprising an outer sheath, a liquid-impregnated dielectric and at least one conductor in the form of a hollow strand through the bore and the interstices of which liquid impregnant for the cable dielectric can pass and at least one other conductive member, comprising

i. forming at least one passage for impregnant through the wall of the bore at a place adjacent to the end thereof,

ii. closing the bore of an end portion of the conductor by inserting a mandrel therein,

iii. placing the end of the stranded conductor in adjacent relation to said other conductive member and surrounding the end of the impregnant - containing stranded conductor and the other conductive member with a heat sink comprising a metal sleeve contiguous with the stranded conductor and extending along the conductor beyond the position of the said radial passage and having a wall which is apertured for the application of vacuum during jointing and for the eventual passage of impregnant, and

iv. bonding the stranded conductor to the sleeve and to said other conductive member contiguous therewith by applying in the molten state an adherent body of metal between the cut end face of the stranded conductor, the end of the said other conductor and the wall of the sleeve whilst contemporaneously applying vacuum to the said conductor in a region removed from the said cut end to remove liquid impregnant from the interstices of the conductor and leave said cut end face substantially free of said impregnant.

9. A method as claimed in claim 8 in which the external surface of the sleeve is shaped to provide at least one longitudinal passage for impregnant which communicates with the two jointed conductors by way of apertures through the wall of the sleeve.

10. A method as claimed in claim 8 in which the bonding process is a welding process in which the adherent body of metal is built up by a two-stage process comprising a first stage in which a thin layer of metal is applied to the cut end of the stranded conductor to seal it, while the conductor end is surrounded by a first heat sink and vacuum is applied to it followed by a second stage in which a larger quantity of metal is applied to the stranded conductor end while it is surrounded by a second heat sink and vacuum is again applied to it to complete the connection.

11. A method as claimed in claim 8 in which vacuum is applied to the stranded conductor end by a surround-

ing manifold in the form of an annular groove in the inner wall of the heat sink.

12. A method of making a connection between an electric cable comprising an outer sheath, a liquid-impregnated dielectric and at least one conductor in the form of a hollow strand through the bore and the interstices of which liquid impregnant for the cable dielectric can pass and at least one other conductive member, comprising

i. forming at least one passage for impregnant through the wall of the bore at a place adjacent to the end thereof and closing the bore of an end portion of the strand by means of a mandrel which has a head having a maximum cross-sectional area greater than that of the bore of the conductor and a neck having a cross-sectional area less than that of the head, the head of the mandrel having a bore which is open, at least at the end of the head opposite to the neck and at least one passage extending through the wall of the head to the external surface of the head, the mandrel being forced head-first into the bore of the conductor to expand the conductor and the conductor being contracted onto the neck of the mandrel,

ii. placing the end of the stranded conductor in adjacent relation to said other conductive member and forming a heat sink surrounding the end of the impregnant - containing stranded conductor, and

iii. bonding the stranded conductor to said other conductive member by applying in the molten state an adherent body of metal to the whole of the cut end face of the stranded conductor and to the other conductive member whilst contemporaneously applying vacuum to the stranded conductor in a region removed from the said cut end thereof to remove liquid impregnant from the interstices of the conductor and leave said cut end face substantially free of said impregnant.

13. A method as claimed in claim 12 in which the cross-sectional shape and size of the neck of the mandrel is substantially the same as the original size and shape of the bore of the conductor.

14. A method as claimed in claim 12 in which the head of the mandrel is so shaped as to provide a right cylindrical center part tapering down, both towards the neck of the mandrel and towards the opposite end of the head, to a cross-section substantially equal to the original cross-section of the bore of the conductor.

15. A method of jointing an electric cable comprising an outer sheath, a liquid-impregnated dielectric and at least one conductor in the form of a hollow strand through the bore and the interstices of which liquid impregnant for the cable dielectric can pass, comprising

i. forming at least one passage for impregnant through the wall of the bore at a place adjacent to the end thereof and closing the bore of an end portion of the strand by means of a mandrel which has a head having a maximum cross-sectional area greater than that of the bore of the conductor and a neck having a cross-sectional area less that that of the head, the head of the mandrel having a bore which is open, at least at the end of the head opposite to the neck and at least one passage extending through the wall of the head to the external surface of the head, the mandrel being forced head-first into the bore of the conductor to expand the conductor and the conductor being contracted onto the neck of the mandrel,

ii. placing the end of the stranded conductor in contiguous relation with another conductor and surrounding the end of the impregnant - containing stranded conductor with a heat sink comprising a metal sleeve contiguous with the stranded conductor and extending along the conductor beyond the position of the said radial passage and having a wall which is apertured for the application of vacuum during jointing and for the eventual passage of impregnant, and

iii. bonding the stranded conductor to the sleeve and to said other conductor by applying in the molten state an adherent body of metal between the cut end face of the stranded conductor, the end of the other conductor and the wall of the sleeve whilst contemporaneously applying vacuum to the stranded conductor in a region removed from said end to remove liquid impregnant from the interstices of the stranded conductor and to leave said cut end face substantially free of said impregnant.

16. A method as claimed in claim 15 in which the cross-sectional shape and size of the neck of the mandrel is substantially the same as the original size and shape of the bore of the conductor.

17. A method as claimed in claim 15 in which the head of the mandrel is so shaped as to provide a right cylindrical center part tapering down, both towards the neck of the mandrel and towards the opposite end of the head, to a cross-section substantially equal to the original cross-section of the bore of the conductor.

18. A method as claimed in claim 15 in which the external surface of the sleeve is shaped to provide at least one longitudinal passage for impregnant which communicates with the two jointed conductors by way of apertures through the wall of the sleeve.

19. A method as claimed in claim 15 in which the bonding process is a welding process in which the adherent body of metal is built up by a two-stage process comprising a fist stage in which a thin layer of metal is applied to the cut end of the stranded conductor to seal it, while the conductor end, is surrounded by a first heat sink and vacuum is applied to it followed by a second stage in which a larger quantity of metal is applied to the stranded conductor while it is surrounded by a second heat sink and vacuum is again applied to it to complete the connection.

20. A method as claimed in claim 15 in which vacuum is applied to the stranded conductor end by a surrounding manifold in the form of an annular groove in the inner wall of the heat sink.

21. A method as claimed in claim 15 in which the bonding process comprises a metal/inert gas welding process.

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