United States Patent

Cleaver et al.

[15] **3,667,119**

[45] **June 6, 1972**

[54] METHOD OF JOINTING AND TERMINATING ELECTRIC CABLES

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June 10, 1968	Great Britain	27,500/68
Nov. 11, 1968	Great Britain	53,371/68
Nov. 11, 1968	Great Britain	53,372/68

[52] **U.S. Cl.** ..... **29/628 R**, 29/474.6 R, 29/488 R, 29/494 R, 29/401 R, 134/21 R, 156/49 R, 164/100 R, 164/108 R, 174/19 R, 174/20 R, 228/44

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

[58] **Field of Search** ..... 164/108, 100; 18/36; 29/624–630, 488, 494, 401, 474.6; 174/19, 22, 23 R, 20; 156/49; 34/15; 134/21; 228/44

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Primary Examiner—John F. Campbell
Assistant Examiner—Robert W. Church
Attorney—Webb, Burden, Robinson & Webb

[57] **ABSTRACT**

Electric cables having at least one conductor in the form of a strand through the interstices of which liquid impregnant for the cable dielectric can pass are jointed or terminated by forming a heat sink surrounding the end of the stranded conductor and bonding the stranded conductor to a terminal or to another conductor by 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. During bonding, liquid impregnant is removed from the interstices between the wires of the stranded conductor in the region of a cut end thereof by applying vacuum to the stranded conductor. The bonding process is preferably a welding process, suitably MIG welding, comprising a first stage in which the end of the stranded conductor is sealed by a layer of weld metal and a second stage in which the connection is completed.

20 Claims, 10 Drawing Figures

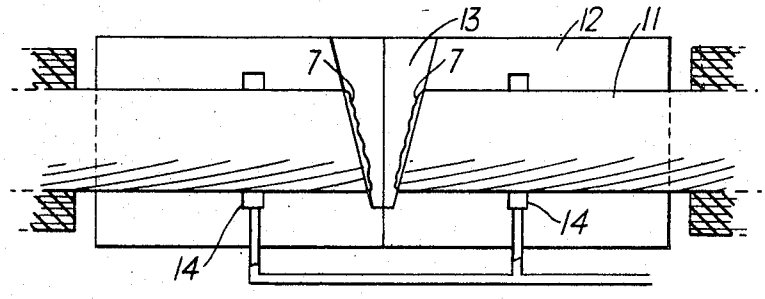


Fig.1.

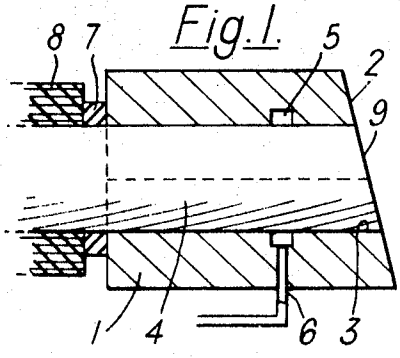


Fig.2.

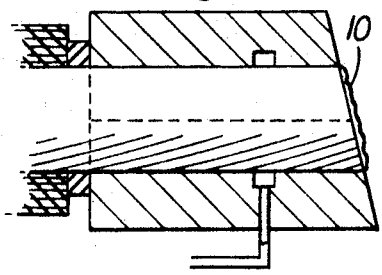


Fig.3.

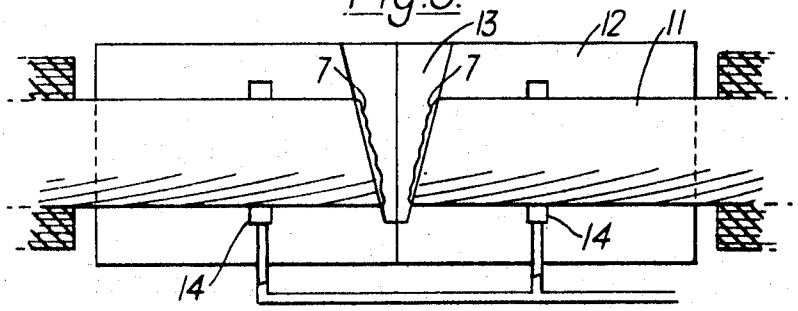


Fig.4.

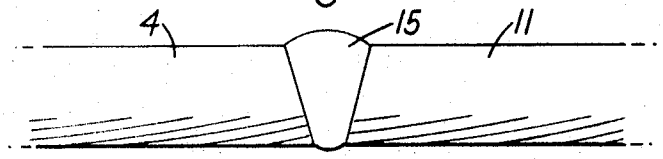


Fig.5.

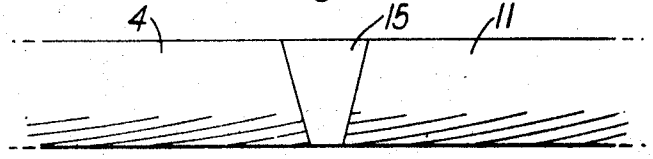


Fig. 6.

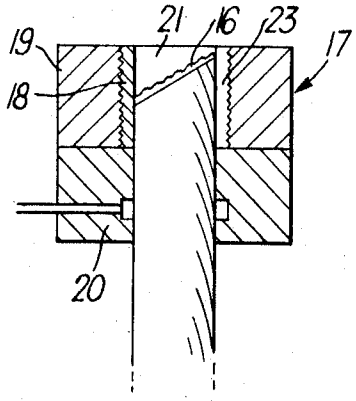


Fig. 7.

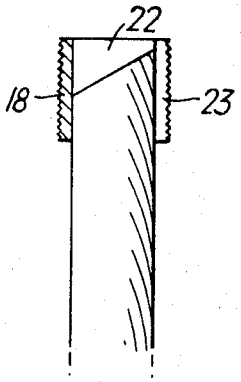


Fig. 8.

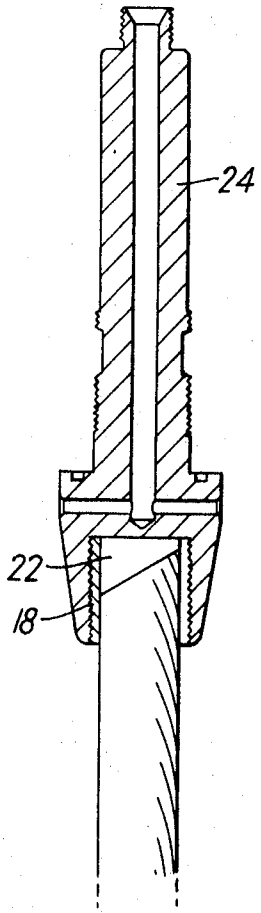


Fig.9.

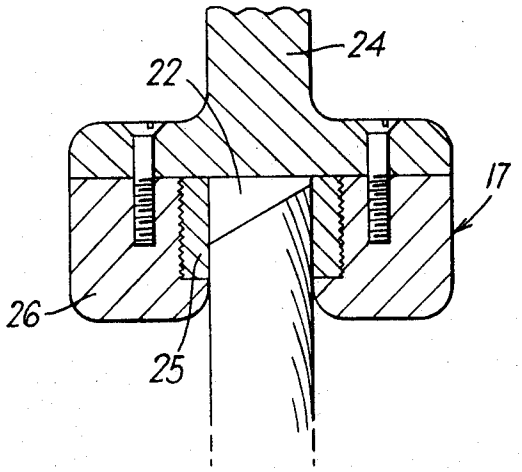
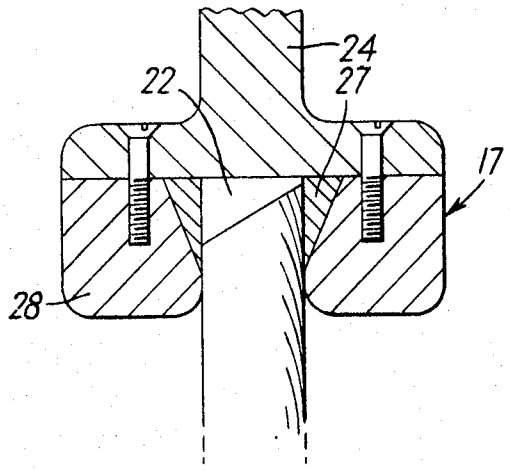


Fig.10.



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 strand 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. An important example of an impregnant which is liquid at the normal working temperature is the free-flowing oil used in oil-filled cables having longitudinal passages to facilitate access of the impregnant to all parts of the dielectric. An example of an impregnant which becomes liquid at a temperature which the strand may reach during the jointing or terminating process is the compound, based on an oil-wax mixture, used in mass-impregnated non-draining (MIND) cables.

The method in accordance with the invention comprises 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 while removing liquid impregnant from the interstices between the wires of the stranded conductor in the region of a cut end thereof by applying vacuum to the stranded conductor.

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 M.I.G. (metal/inert gas) welding, which entails transfer of metal from an electrode to the work across an arc struck in an inert atmosphere, normally argon, is especially suitable. We prefer to build up the coherent 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 the 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. Alternatively the heat sink or part of it may become bonded to the weld, so forming a permanent part of the joint or termination. For example the heat sink may comprise a metal sleeve (which may be solid, longitudinally cut, or longitudinally divided into two or more parts) contiguous with the stranded conductor, which becomes bonded to the weld, and an outer part which is removable. 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 heat sink (including any sleeve) for the introduction of bonding metal. Normally this aperture should be located at the top of the heat sink. In the case of a termination, the conductor will usually extend vertically, and an annular heat sink then allows access for bonding metal through its open upper end.

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.

Preferably the end of the manifold further from the cut end of the stranded conductor is sealed by resilient means, e.g. a rubber washer, to increase the effectiveness of the suction at the cut end face of the conductor.

It will usually be necessary to remove residues of impregnant from the cut end of the stranded conductor by washing with a suitable solvent while 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. **1–5** show successive stages in a cable jointing method,

FIGS. **6–8** show successive stages in one cable terminating method, and

FIGS. **9** and **10** show modified terminating methods at a stage corresponding to that of FIG. **8**.

The jointing method to be described is especially suitable for jointing corresponding conductors of adjacent lengths of a multicore oil-filled cable of the kind having ducts or passages for the impregnant located in the interstices between the cores. The cable ends are first cut back in the usual way, and if the conductors to be joined are non-circular, they are preferably "circularized" in the region where the joint is to be made, e.g. by squeezing between semi-circular dies.

A heat sink **1** made of a metal of good thermal conductivity is 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 **2** 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. 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°–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 **3** which make close contact with the peripheral surface of the stranded conductor **4**, and the bore is formed with an annular groove **5** in communication with an outlet **6** on the outer surface of the mold, so that heat sink can act also as a vacuum manifold through which oil can be extracted from the interstices between the wires of the strand. Preferably a rubber washer **7** is interposed between the heat sink and the cut-back end of the cable dielectric **8** to seal the adjacent end of the manifold and so to increase the effectiveness of the suction at the cut end face **9** of the conductor. In addition, it acts as a jig to prevent splaying of the wires of the strand.

After the heat sink has been firmly attached to the conductor, the outlet **6** is connected to a vacuum pump by which oil is drawn from the conductor until oil no longer flows from its cut surface. 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 pressure at the cut end face of the stranded conductor. In accordance with normal practice, the opposite end of the cable length is connected to an oil reservoir so that any oil withdrawn from the cable length by the vacuum pump is continuously replaced under hydrostatic pressure.

Large gaps are present in the conductor end, as there usually will be if an initially non-circular strand has been circularized, these are preferably plugged by insertion of short lengths of wire, e.g., from the piece trimmed from the end of the strand.

While the vacuum continues to be applied, the cut surafce 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 face **2** of the heat sink surrounding the cut end **9** of the conductor and/or by applying an inert gas under pressure to the cut end. The cap may simply consist of an 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 **10** (FIG. **2**) of weld metal is applied to the whole of the cut end face of the conductor 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 thermal capacity 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.

The second conductor **11** (FIG. **3**) 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 **12** generally similar to the heat sink **1** but in the form of a mold which surrounds both conductor ends and provides access to the V-shaped gap **13** between them, the lower part of the gap being closed by the bottom of the mold.

A vacuum pump is connected to annular grooves **14** in the bores of the two parts of the heat sink, and the 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 **13** is filled with an adherent body of weld metal **15** (FIG. **4**) by means of an MIG welding gun, and the heat sink is quickly removed to avoid over-heating the conductor ends. This heat sink also may be force-cooled if required.

As a final operation (FIG. **5**) the weld formed between the two conductors is dressed down, e.g. by filing or milling, to the conductor diameter, prior to insulation of the joint in the usual way.

Instead of forming vacuum manifolds by providing annular grooves in either of the heat sinks **1** and **12**, 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.

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 mold.

The termination method illustrated in FIGS. **6–8** is similar to the jointing method already described up to the stage shown in FIG. **2**.

The prepared conductor end **16** is inserted in a composite heat sink **17** comprising an inner part **18** in the form of a sleeve of the same metal as the conductor, which is to become a permanent part of the termination, and an outer, removable part **19** in screw-threaded engagement with it.

A vacuum manifold **20** preferably also acts as an auxiliary heat sink. Cleaning of the conductor end is completed after assembly of the heat sink and with the vacuum applied, and after clearance of solvent the space **21** is filled with an adherent body of weld metal **22** (FIG. **7**) using an MIG welding gun, so forming a permanent connection between the conductor end and the sleeve **18**. This sleeve is preferably longitudinally cut, the cut **23** preferably being located in the position where the depth of the weld metal **22** is smallest. This cut enables the sleeve **18** to contract with the weld metal as it cools, so facilitating removal of the outer part **19** of the heat sink.

Finally a terminal stem **24** (FIG. **8**) is screwed onto the sleeve **18**, the mating threads preferably being electrotinned and sweated to ensure a sound connection, and the termination insulated in any conventional way. The terminal stem **24** may be of a metal dissimilar to the metal of the stranded conductor, e.g. of copper if the stranded conductor is of aluminum this avoids the problem of bimetallic corrosion where, as is usual, the termination is provided with an insulator having an exposed end-fitting of a copper-base alloy, and enables a connection relying upon mechanical pressure to be used at the other end of the terminal stem.

FIGS. **9** and **10** show modified terminations which also permit use of copper terminal stems on aluminum conductors; in both cases the whole of the heat sink **17** becomes a permanent part of the termination, and the terminal stem **24** is bolted to it. In the construction of FIGS. **9**, the heat sink comprises an inner sleeve **25** of aluminum secured in an outer body **26** of copper by a preformed, permanent, electrotinned and sweated screwed connection. In the construction of FIG. **10**, aluminum sleeve **27** is secured in copper body **28** by a pressure welding process, e.g. friction welding or flash butt welding, as a preliminary step, preferably carried out in the factory.

In the case of a cable having an impregnant which is not free-flowing at ambient temperature, the cleaning techniques so far described will usually be inadequate, and appropriate modifications will be needed. Thus for a mass-impregnated non-draining compound, the wires of the strand may be slightly separated and the bulk of the impregnant between them melted out by gentle heat from a propane torch. Residue is then removed by washing several times with a suitable hot solvent (for example a free-flowing insulating oil), preferably aided by brushing. After washing with a volatile solvent (e.g.naphtha) to remove the cleaning solvent the heat sink (**1**) may be applied, and jointing or termination then proceeds as already described.

The method in accordance with the present invention may be used in jointing and terminating cables having a hollow stranded conductor, as is more fully described and claimed in our U.S. application No. 813,523 filed on the same day as this Application.

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

We claim:

1. A method of connecting an electric cable comprising (a) an outer sheath, (b) a liquid-impregnated dielectric and (c) at least one conductor in the form of a strand through the interstices of which liquid impregnant for the cable dielectric can pass, comprising the steps of

1. applying to the cut end of the impregnant-containing stranded conductor and another conductive member a mould that acts as a heat sink and forms a manifold surrounding said stranded conductor in a region removed from said end and
2. introducing metal in the molten state into said mold to form therein a body of metal that adheres to substantially the whole of the cut end face of the stranded conductor and to the other conductive member while contemporaneously removing said liquid impregnant from the interstices between the wires of the stranded conductor at said region to leave said cut end substantially free of said impregnant by applying vacuum to said manifold.

2. A method as claimed in claim **1** in which the bonding process is a metal/inert gas welding process.

3. A method as claimed in claim **1** in which the heat sink is made of a metal of good thermal conductivity.

4. A method as claimed in claim **1** comprising the preliminary step of cutting the end of the stranded conductor so that its end face is inclined at an angle of from **15°–30°** with respect to a plane perpendicular to the conductor axis.

5. A method as claimed in claim **1** in which said manifold is formed by an annular groove in the bore of said mold.

6. A method as claimed in claim **5** comprising sealing the end of the manifold further from the cut end of the stranded conductor by resilient means to increase the effectiveness of the suction at the cut end face of the conductor.

7. 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.

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

9. A method of connecting an electric cable comprising (a) an outer sheath, (b) a liquid-impregnated dielectric, and (c) at least one conductor in the form of a strand through the interstices of which liquid impregnant for the cable dielectric can pass, comprising the steps of

1. surrounding the cut end of the impregnant-containing stranded conductor with a heat sink comprising a metal sleeve contiguous with the stranded conductor and
2. bonding the stranded conductor at least to the sleeve 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 and to the sleeve while contemporaneously removing said liquid impregnant from the interstices between the wires of the stranded conductor by applying vacuum to the stranded conductor in a region removed from the said cut end to leave said cut end substantially free of said impregnant.

10. A method as claimed in claim 9 in which the heat sink comprises a removable outer part.

11. A method as claimed in claim 10 in which the removable outer part is in screw-threaded engagement with the metal sleeve.

12. A method as claimed in claim 10 in which the metal sleeve is of the same metal as the stranded conductor and the removable outer part of the heat sink is of a different metal.

13. A method as claimed in claim 12 in which the metal sleeve is longitudinally cut to allow it to contract with the bonding metal as it cools.

14. A method as claimed in claim 9 in which the metal sleeve is longitudinally divided into at least two parts.

15. A method as claimed in claim 9 in which the metal sleeve constitutes substantially the whole of the heat sink.

16. A method as claimed in claim 9 in which bonding is effected by a metal/inert gas welding process.

17. A method of jointing an electric cable comprising (a) an outer sheath, (b) a liquid-impregnated dielectric and (c) at least one conductor in the form of a strand through the interstices of which liquid impregnant for the cable dielectric can pass, comprising the steps of

1. forming a first heat sink surrounding the cut end of the impregnant-containing stranded conductor,
2. sealing said cut end of the stranded conductor by a welding process entailing the application in the molten state of an adherent layer of metal to substantially the whole of said cut end face of the stranded conductor while contemporaneously removing said liquid impregnant from the interstices between the wires of the stranded conductor by applying vacuum to the stranded conductor, in a region removed from said end, to leave said cut end substantially free of said impregnant removing said first heat sink and
3. forming a second heat sink surrounding the sealed end of the stranded conductor and an end of another conductor, and
4. bonding the stranded conductor to the other conductor by a process entailing the application in the molten state of an adherent body of metal between the sealed end of the stranded conductor and the end of the other conductor while contemporaneously removing said liquid impregnant from the interstices between the wires of the stranded conductor by applying vacuum to the stranded conductor in a region removed from said end to leave said sealed end substantially free of said impregnant.

18. A method as claimed in claim 17 in which vacuum is applied to the stranded conductor by means of a surrounding manifold formed by an annular groove in the bore of the heat sink.

19. A method of terminating an electric cable comprising (a) an outer sheath, (b) a liquid-impregnated dielectric and (c) at least one conductor in the form of a strand through the interstices of which liquid impregnant for the cable dielectric can pass, comprising the steps of

1. forming a first heat sink surrounding the cut end of the impregnant-containing stranded conductor,
2. sealing said cut end of the stranded conductor by a welding process entailing the application in the molten state of an adherent layer of metal to substantially the whole of said cut end face while contemporaneously removing said liquid impregnant from the interstices between the wires of the stranded conductor by applying vacuum to the stranded conductor in a region removed from said end to leave said cut end substantially free of said impregnant
3. removing said first heat sink and replacing it with a second heat sink comprising a sleeve contiguous with and made of the same metal as the stranded conductor and
4. bonding the stranded conductor to the said sleeve by a welding process entailing the application in the molten state of an adherent body of metal to the sealed end of the stranded conductor and to the sleeve while again contemporaneously removing liquid impregnant from the interstices between the wires of the stranded conductor by applying vacuum to the stranded conductor in a region removed from said end to leave said sealed end substantially free of said impregnant.

20. A method as claimed in claim 19 in which vacuum is applied to the stranded conductor by means of a surrounding manifold formed by an annular groove in the bore of the heat sink.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,667,119 Dated June 6, 1972

Inventor(s) John Stephen Cleaver et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 61, "Large gaps" should read -- If large gaps --.

Signed and sealed this 12th day of September 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

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* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.

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