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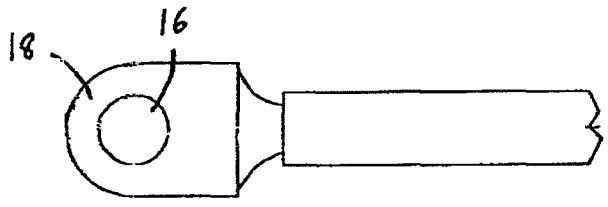
(54) Title: CONNECTION CABLE




(57) Abstract: A connection cable comprising a length of metal cable (4), the metal cable at one end of the length being compressed and fused together to form a fused metal region, the fused metal region including additional metal (10) which provides the fused metal region with an increased thickness compared with that which would be provided by fused metal cable alone, the fused metal region having a hole (16) in it, thereby forming a connector for receiving a battery terminal or other conducting member.

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# CONNECTION CABLE

The present invention relates to a connection cable.

Connection cables are used in many applications, including applications in which they are required to carry substantial amounts of power. An example of such an application is in batteries of electrically powered vehicles. A battery for a forklift truck may comprise 24 cells, the cells being linked together by connection cables. The connection cables are typically formed from copper, and are required to pass current between cells of the battery with a low resistance and voltage drop.

Conventionally connection cables have been formed by stripping insulation from either end of a length of braided copper cable, passing copper piping over each end, and then crimping the piping and cable such that the piping is flattened onto the cable to form connectors. The braided copper cable is also flattened during the crimping, with the result that the connector ends are flat. Holes are punched through the connector ends to allow connection to terminals of battery cells. Insulation is usually provided over the connectors.

Copper is usually used to form the connection cables because it has very good electrical properties. However, copper is expensive, and it is therefore desirable to reduce the cost of the connectors. European patent EP1101255 describes a connection cable which is more economical to produce than the conventional connection cable. The connection cable described in EP1101255 includes connector plates which are welded to ends of a length of braided copper cable, and which extend well beyond ends of the braided copper cable. This allows a given distance between two battery cell terminals to be spanned using a connection cable which has a shorter length of braided copper cable (compared to that which would be used in a conventional connection cable).

It is an object of the invention to provide a connection cable which is novel and inventive over the prior art.

According to a first aspect of the invention there is provided a connection cable comprising a length of metal cable, the metal cable at one end of the length

being compressed and fused together to form a fused metal region, the fused metal region including additional metal which provides the fused metal region with an increased thickness compared with that which would be provided by fused metal cable alone, the fused metal region having a hole in it, thereby forming a connector for receiving a battery terminal or other conducting member.

Preferably, the additional metal surrounds the connector. The additional metal may have a thickness of 1mm or less, preferably 0.7mm or less, and most preferably 0.5mm or less. The metal cable and the additional metal may be both formed from the same metal, such that the fused metal region comprises a fused mass of a single metal. The metal cable and the additional metal may be copper. The connector may be rectangular or round in cross-section. The connector may be formed at both ends of the connection cable. Insulation may be provided around the connector and the metal cable.

According to a second aspect of the invention there is provided a method of making a connection cable, the method comprising encircling an end of a length of metal cable with metal foil, compressing the metal foil and the metal cable and fusing them together to form a fused metal region, then punching a hole through the fused metal region, thereby forming a connector for receiving a battery terminal or other conducting member.

Preferably, the metal foil is fused with the metal cable using a welding machine. The metal foil may have a thickness of 1mm or less, preferably 0.7mm or less, and most preferably 0.5mm or less. An outer edge of the metal foil may be flush with an outward end of the metal cable. The metal foil is preferably copper foil, and the metal cable is preferably copper. The connector is preferably formed at both ends of the connection cable. Insulation is preferably provided around the connector and the metal cable.

According to a third aspect of the invention there is provided a connection cable comprising a length of metal cable, the metal cable at one end of the length being compressed and fused together to form a fused metal region, the fused metal region including a metal foil which encircles the metal cable, the fused metal region having a hole in it, thereby forming a connector for receiving a battery terminal or other conducting member.

A specific embodiment of the invention will now be described by way of example only with reference to Figures 1 to 5, which illustrate a method of making a connection cable which embodies the invention and the resulting cable.

Figure 1 shows an end of a insulated copper cable 2 which is to be formed into a connection cable that embodies the invention. The insulated copper cable 2 comprises a copper cable 4 surrounded with rubber insulation 6. The rubber insulation 6 may for example be Evoprene, Forprene or Santoprene thermoplastic rubber, available from Santoprene Specialty Products of Ohio, USA.

The copper cable may be for example 26mm in diameter. Other diameters of copper cable may be used, depending upon the electrical requirements of the connector during use. The copper cable may be a solid piece of metal, or comprise a plurality of copper strands or copper wires. The copper cable may, for example, comprise a plurality of intertwined or braided strands or wires.

A length of insulation is cut and stripped away from an end of the cable, to expose the copper cable 4 as shown in Figure 1. The length of the exposed copper 4 may for example be 32mm. A different length of copper cable may be exposed (this depends upon the size of the battery terminal to which the connection cable will be connected).

Referring to Figure 2, a piece of copper foil 8 approximately 25mm by 40mm, and having a thickness of approximately 0.5mm is bent around on itself to form a sleeve 10. The sleeve 10 has a diameter of around 13mm. The length of the copper foil 8 is selected such that it forms a sleeve 10 with a diameter sufficiently large that it can encircle the copper cable 4. Thus, if a thicker copper cable were to be used, a longer piece of copper foil may be used. Similarly, the copper foil may have a different width, if a different length of exposed copper cable is used.

Referring to Figure 3, the sleeve 10 formed from the copper foil 8 is placed over the copper 4 cable, so that it encircles the end of the copper cable 4. It is positioned so that its outer edge is flush with an outward end 12 of the copper cable 4. The copper foil 8 and copper cable 4 are then compressed to a thickness of around 2mm using a power press. At the same time a welding machine is used to apply a

current through the copper foil 8 and copper cable 4. Resistance to the current causes the copper cable 4 and copper foil 8 to be heated. The copper foil 8 begins to melt, and fuses onto the copper cable 4 such that a solid piece of homogenous copper is formed. The power press and welding machine may be a single combined machine (which may simultaneously apply pressure and provide current).

The end of the copper cable 4 is removed from the welding machine. The copper cable 4 and the copper foil 8 have been compressed into a flat area 14 which is rectangular in cross-section, is approximately 25mm by 20mm and has a thickness of 2mm. The copper foil 8, which has fused with the copper cable 4, retains the copper cable (which may comprise strands, wires, etc) in place during the compression. In other words, the copper cable 4 (e.g. strands thereof) is prevented from splaying during compression by the copper foil 8. The copper cable 4 and the copper foil 8 fuse together to form a fused metal region (i.e. a solid homogenous piece of copper). The copper foil 8 therefore provides additional metal which provides the flat area 14 with an increased thickness compared with that which would be provided by fused copper cable alone.

Referring to Figure 4, a punch is used to punch a hole 16 with a diameter of approximately 10mm through the flat area 14. The hole 16 is dimensioned such that it may receive a terminal of a battery cell (for example a battery cell of a forklift truck). The combination of the flat area 14 and the hole 16 form a connector 18 at the end of the copper cable 4.

Corners of the connector 18 are shaved off to provide a curved shape, as shown in Figure 4a.

Referring to Figure 5, a thermoplastic rubber insulator 20, which may for example be formed from Santoprene, is provided over the connector 18. The insulator 20 is provided with a hole 22 which is aligned with the hole 16 in the connector 18. The diameter of the insulator hole 22 is greater than the diameter of the connector hole 16, with the result that an annular region of the connector 18 is exposed. This allows electrical contact to be conveniently made between the connector 18 and a battery cell terminal.

The method illustrated in the figures is repeated at an opposite end of the insulated copper cable 2, so that a connector is provided at each end of the copper cable 4. This completes manufacture of the connection cable.

The connection cable may be any desired length, for example from 50mm to 500mm or longer.

Dimensions of different parts of the connection cable (which may sometimes be called a take off lead) are given above as examples only. It will be appreciated that the parts may have other suitable dimensions.

The connection cable of the embodiment of the invention has the advantage that the copper foil 8 is significantly thinner than copper piping which is conventionally used when forming a connector (typically the piping has a wall thickness of around 2mm). The embodiment of the invention therefore uses significantly less copper than a conventional connection cable. This reduces the cost of the connection cable.

A further advantage of the connection cable of the embodiment of the invention is that, since the copper cable 4 and copper foil 8 are fused such that they form a connector 18 which is a fused metal region, electricity can flow easily through the connector. This is in contrast with conventional connectors, in which crimping copper piping onto a copper cable (e.g. a braided copper cable) may leave air gaps between the copper piping and the copper cable. These air gaps may over time allow oxidation of the copper to occur, thereby reducing the electrical contact between the copper piping and the copper cable. This increases the resistance of the connection cable, and reduces its efficiency. The embodiment of the invention avoids this disadvantage since the connector 18 is a fused metal region.

The term "copper foil" as used above is intended to mean a thin layer of copper. The copper foil may for example have a thickness of 1mm or less, preferably 0.7mm or less, and most preferably 0.5mm or less. This is significantly thinner than the wall thickness of copper piping as used in prior art connection cables. Indeed, it would be difficult if not impossible to form copper piping with a wall thickness of 1mm or less.

The copper foil 8 provides additional metal, which adds thickness to the connector 18. This makes the connector 18 stronger and more durable. For example, its tensile strength is improved, and it is resistant to penetration by the head of a bolt used to connect the flat area to a battery cell.

Although the embodiment of the invention has been described in terms of a copper cable 4 and copper foil 8, it will be understood that the invention may be implemented using other suitable metals. It is not essential that the cable and the foil be formed from the same metal.

Although resistance welding is used in the above described method to fuse the copper foil 8 onto the copper cable 4, it will be appreciated that this fusion may be achieved using other techniques, for example ultrasonic welding.

## CLAIMS

1. A connection cable comprising a length of metal cable, the metal cable at one end of the length being compressed and fused together to form a fused metal region, the fused metal region including additional metal which provides the fused metal region with an increased thickness compared with that which would be provided by fused metal cable alone, the fused metal region having a hole in it, thereby forming a connector for receiving a battery terminal or other conducting member.

2. The connection cable of claim 1, wherein the additional metal surrounds the connector.

3. The connection cable of claim 2, wherein the additional metal has a thickness of 1mm or less.

4. The connection cable of claim 3, wherein the additional metal has a thickness of 0.7mm or less.

5. The connection cable of claim 4, wherein the additional metal has a thickness of 0.5mm or less.

6. The connection cable of any preceding claim, wherein the metal cable and the additional metal are both formed from the same metal, such that the fused metal region comprises a fused mass of a single metal.

7. The connection cable of claim 6, wherein the metal cable and the additional metal are copper.

8. The connection cable of any preceding claim, wherein the connector is rectangular in cross-section.

9. The connection cable of any preceding claim, wherein the connector is formed at both ends of the connection cable.

10. The connection cable of any preceding claim, wherein insulation is provided around the connector and the metal cable.

11. A method of making a connection cable, the method comprising encircling an end of a length of metal cable with metal foil, compressing the metal foil and the metal cable and fusing them together to form a fused metal region, then punching a hole through the fused metal region, thereby forming a connector for receiving a battery terminal or other conducting member.

12. The method of claim 11, wherein the metal foil is compressed and fused onto the metal cable using a welding machine.

13. The method of claim 11 or claim 12, wherein encircling the metal cable with the metal foil comprises forming the metal foil into a tube shape and then locating the end of the length of metal cable within the tube.

14. The method of claim 13, wherein an outer edge of the metal foil is aligned to be flush with an outward end of the metal cable.

15. The method of any of claims 11 to 14, wherein the metal foil has a thickness of 1mm or less.

16. The method of claim 15, wherein the metal foil has a thickness of 0.7mm or less.

17. The method of claim 16, wherein the metal foil has a thickness of 0.5mm or less.

18. The method of any of claims 11 to 17, wherein the metal foil is copper foil.

19. The method of any of claims 11 to 18, wherein the metal cable is a copper cable.

20. The method of any of claims 11 to 19, wherein the method is repeated at an opposite end of the connection cable.

21. A connection cable comprising a length of metal cable, the metal cable at one end of the length being compressed and fused together to form a fused metal region, the fused metal region including a metal foil which encircles the metal cable, the fused metal region having a hole in it, thereby forming a connector for receiving a battery terminal or other conducting member.

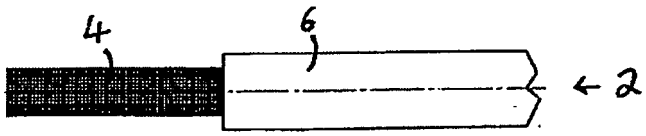


Fig 1

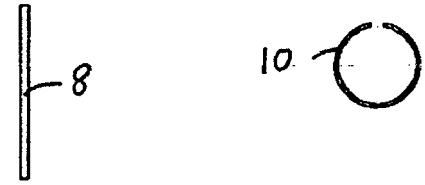


Fig 2

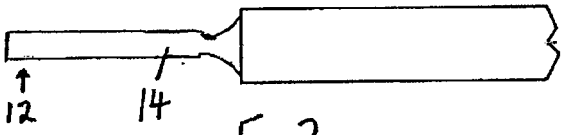


Fig 3

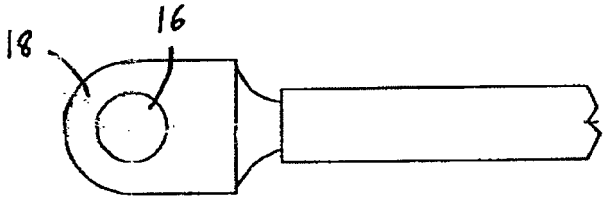


Fig 4a

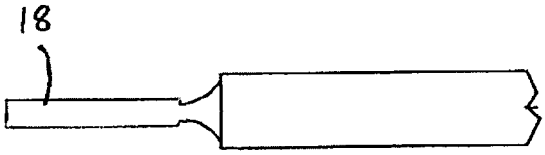


Fig 4b

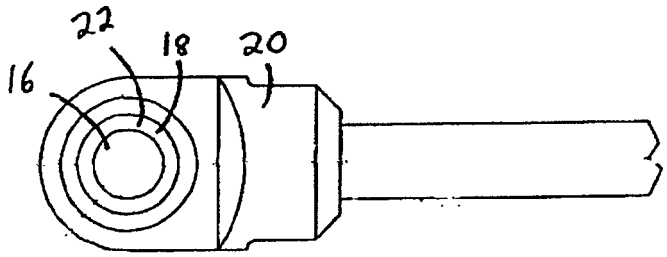


Fig 5a

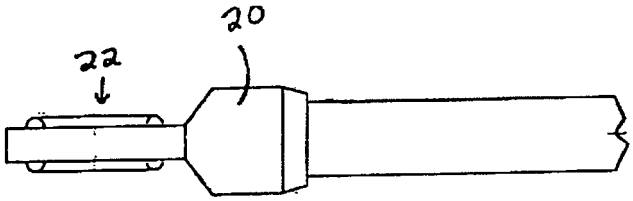


Fig 5b

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2007/005825

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01R4/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>Y | DE 100 07 258 A1 (WELCKER F [DE])<br>30 August 2001 (2001-08-30)<br>column 2; figures | 1-8,<br>11-19,21<br>20 |
| X<br>Y | DE 10 2004 062676 A1 (FROEHLICH BERNHARD [DE]) 22 June 2006 (2006-06-22)<br>paragraph [0030]; figure 2 | 1-10<br>20 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 11 October 2007 | 24/10/2007 |

| Name and mailing address of the ISA/ | Authorized officer |
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2007/005825

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| DE 10007258 A1 | 30-08-2001 | NONE | |
| DE 102004062676 A1 | 22-06-2006 | EP 1831962 A2 | 12-09-2007 |
| | | WO 2006067166 A2 | 29-06-2006 |