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(54) ELECTRICAL CONNECTION

(57) An electrical connection 1 for electrically connecting a flat connector 2 and an electrical cable 3, the electrical connection 1 comprising a flat connector 2 with an insulated portion 21 and an exposed electrically conductive portion 20e, an electrical cable 3, a first seal 6a, a second seal 6b and an enclosure 4, wherein the flat connector 2 and the electrical cable 3 are secured together in order to provide electrical contact between one another at the exposed electrically conductive portion 20e of the flat connector 2, the first seal 6a being outboard of the exposed electrically conductive portion 20e of the flat connector 2 and adjacent a distal edge of the exposed electrically conductive element 20 of the flat connector 2, whereby the enclosure 4 encases the first seal 6a and the electrical contact.

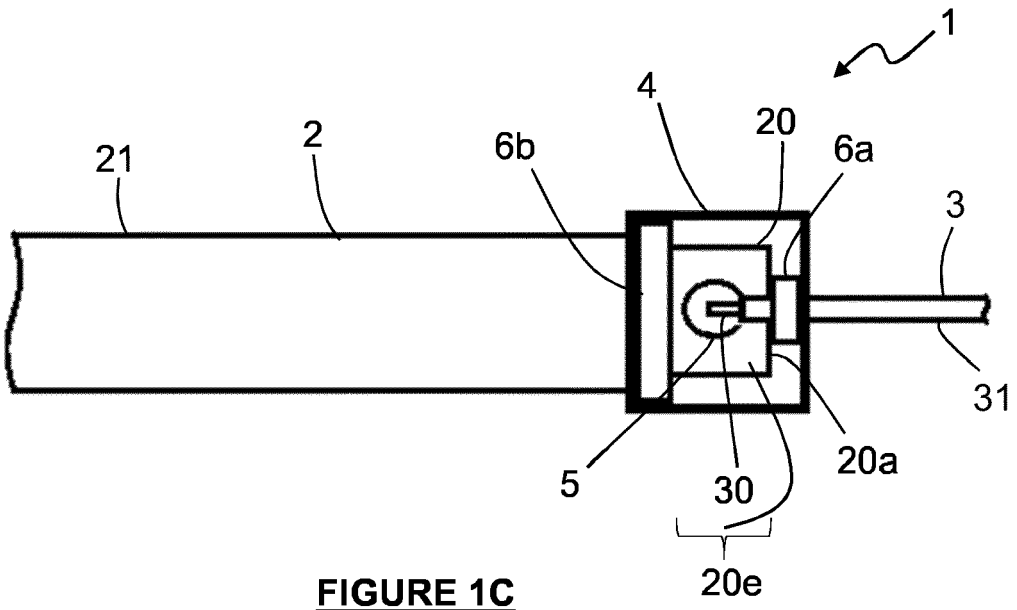

FIGURE 1C

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Description

[0001] This invention relates to an electrical connection. More specifically, although not exclusively, this invention relates to an electrical connection for joining a flat connector to an electrical cable.

[0002] Electrical connections as described herein are used in various ways. One of those uses is for electrically connecting flat connectors and electrical cables as used in heated windscreen assemblies, in which heating elements are disposed within the glass laminates of the windscreen. Electricity supplied to the heating elements causes resistive heating which heats the glass and hence melts snow or ice and/or evaporates fog or mist which inhibits driver visibility. Accordingly, it is necessary to supply the metal wires with electricity. The flat connectors provide electrical connection to the heating elements within the glass laminate of the windscreen while the electrical cables provide electrical connection between the flat connectors and a source of electrical energy, e.g. an automobile battery.

[0003] Because of the location of the electrical connection it is essential that the electrical connection is able to withstand environmental conditions such as water, thermal cycling, humidity and chemical use (for example, salt from road traffic spray, de-icer compositions and so on) and the physical requirements of installation in a windscreen assembly and use in a motor vehicle environment. It is particularly important that the electrical connection does not corrode through exposure to water and/or other undesirable elements as corrosion may lead to increased resistance and hence reduced efficiency of electrical transfer, and, in extreme cases failure of the electrical connection. One example of a waterproof structure for connecting electrical cables to a flat electrical cable is described in EP1058349A1, another is EP1619759A1.

[0004] Formation of a heated windscreen assembly entails heating of the glass laminate of the windscreen in an autoclave in order to effect bonding thereof together. The electrical connection is commonly formed and affixed to the windscreen laminate at a prior stage and is hence located within the autoclave during bonding. As a result it is essential that the electrical connection is able to withstand the 150°C temperature within the autoclave for the period of heating (which may be around three hours).

[0005] It can also be a problem to accurately locate an electrical cable relative to a flat connector prior to forming an electrical connection betwixt the two members. Furthermore, the electrical connection must be durable enough to withstand potential physical shocks during installation and/or use thereof.

[0006] It is an object of the current invention to provide an electrical connection which has a high degree of physical resilience to temperature and to physical shock. It is an additional or alternative object of the invention to provide an electrical connection which is protected from potentially corrosive elements such as water and/or species entrained (e.g. dissolved) in water.

[0007] Accordingly, a first aspect of the invention provides an electrical connection for electrically connecting a connector, preferably a flat connector, and an electrical cable, the electrical connection comprising a flat connector with an insulated portion and an electrically conductive portion, an electrical cable, a first seal, an optional second seal, and an enclosure, where the connector, e.g. flat connector, and the electrical cable are secured together in order to provide electrical contact between one another at the electrically conductive portion of the connector, e.g. flat connector, the first seal being outboard of the electrically conductive portion of the connector, e.g. flat connector, and adjacent a distal edge of the exposed electrically conductive element of the flat connector, whereby the enclosure encases the first seal and the electrical contact.

[0008] Advantageously the position of the first seal ensures a robust connection with the minimum enclosure size.

[0009] A second aspect of the invention provides an electrical connection for electrically connecting a connector, e.g. flat connector, and an electrical cable, the electrical connection comprising a connector, e.g. flat connector, with an insulated portion and an electrically conductive portion, an electrical cable, a first seal and an enclosure, where the connector, e.g. flat connector, and the electrical cable are secured together in order to provide electrical contact between one another at the electrically conductive portion of the connector, e.g. flat connector, the first seal located around the electrical cable, whereby the electrical contact is free of the first seal and the enclosure encases the first seal and the electrical contact.

[0010] The enclosure may encase the electrically conductive portion of the connector, e.g. flat connector. The electrically conductive portion may comprise or be a terminal portion (e.g. an end portion) of the connector, e.g. flat connector.

[0011] In a preferred embodiment the electrical connection further comprises a second seal. The second seal is preferably distinct from the first seal. The second seal may contact the insulated portion of the flat connector, whereby the electrical contact is free of the second seal. The second seal may contact the insulated portion of the connector, e.g. flat connector and be adjacent to or contact the electrically conductive portion of the flat connector, whereby the electrical contact is free of the second seal. The second seal may be outboard, for example entirely or partially outboard, of the electrically conductive portion of the connector, e.g. flat connector. Where the electrical connection comprises a second seal the enclosure may encase the first seal, the second seal and the electrical contact.

[0012] The first seal may be outboard of the electrically conductive portion of the connector, e.g. flat connector and located around the electrical cable, whereby the electrical contact is free of the first seal. The first seal

may be adjacent the electrically conductive portion of the connector, e.g. flat connector. Additionally or alternatively, the first seal may be configured to provide a seal, e.g. a continuous fluid tight seal, against or around the electrical cable. Most preferably the first seal encircles the electrical cable, e.g. encompasses the entire circumference thereof.

[0013] Additionally or alternatively, the first seal may be configured to provide a seal, e.g. a continuous fluid tight seal, against the enclosure. The first seal may be configured to resiliently contact the enclosure and/or may comprise a resilient material.

[0014] Preferably the first and/or second seal comprises a resilient material. Additionally or alternatively, the first and/or second seal may comprise adhesive material, e.g. such that the first and/or second seal may be secured to the electrical cable and/or the flat connector respectively and/or so as to lie between the enclosure and a facing portion of the connector. For example, the first seal (and/or second seal) may comprise an adhesive material which is located between the enclosure and facing portion of the cable (and/or the facing portion of connector which may be one or both of the insulated portion or the electrically conductive portion).

[0015] Where provided, the adhesive material may be a pressure and/or heat sensitive adhesive. The or some of the adhesive material may be covered by a release liner prior to use. This, advantageously, means that the or some or one of the components or part-formed components can be provided with adhesive prior to use to fabricate the connector.

[0016] The first and/or second seal may comprise a carrier substrate with a pair of major surfaces, e.g. an inner surface and an outer surface, each one of which may carry adhesive material. Preferably the adhesive material has two faces, each carrying adhesive or having adhesive properties. The carrier substrate may be formed from a resilient material. Adhesive material on the inner and/or outer surface may be covered by a release liner, e.g. a siliconized release liner such as siliconized paper, which is removably retained on the adhesive material. Alternatively, the first and/or second seal may comprise an adhesive, e.g. a single layer of adhesive material applied to the required part, and which may be covered by a release liner. Surprisingly, we have found the presence of adhesive to be beneficial in fabricating a robust seal.

[0017] Where provided, the second seal may be configured to provide a seal, e.g. a continuous fluid tight seal, against or around the flat connector. The second seal may be further configured to provide a seal, e.g. a continuous fluid tight seal, against the enclosure. The second seal may be configured to provide a seal, e.g. a continuous fluid tight seal, against or around the flat connector. Most preferably the second seal encircles the flat connector, e.g. encompasses the entire circumference or periphery thereof.

[0018] The connector, e.g. flat connector, and the electrical cable are preferably secured together by solder material, e.g. a solder material comprising one or more of lead, bismuth, tin, silver, or any other suitable material, most preferably a lead-free solder material.

[0019] The electrically conductive portion of the flat connector may be located at or adjacent an end thereof. Most preferably the electrically conductive portion of the flat connector is located at an end thereof. Alternatively, the electrically conductive portion of the flat connector may be located away from an end thereof.

[0020] The flat connector may comprise a flat strip of electrically conductive material, e.g. copper, for example provided with a thin cover layer (e.g. tin), encased in a thin layer of non-conductive material.

[0021] The flat strip of electrically conductive material preferably has a cross sectional area of less than 3 mm^2, preferably less than 2.75, less than 2.5, less than 2.25, less than 2, for example less than 1.95, less than 1.9, less than 1.85 or less than 1.8 mm^2. The flat strip of electrically conductive material preferably has a cross sectional area of between 1.0 or 1.5 and 4mm^2, say from 1.5 to 3 mm^2, say from 1.5 to 2.5mm^2.

[0022] In one embodiment the flat strip of electrically conductive material has a thickness of from 80 to 120 x 10^{-6}m (*i.e.* from 80 to 120 μm), say from 85 to 118, 90 to 115, 95 to 113 μm.

[0023] The flat strip of electrically conductive material preferably has a width of from 10 to 30 mm, say from 12 to 28 mm, for example from 14 to 25 mm.

[0024] The electrical cable may comprise an electrically conductive core encased in a thin layer of non-conductive material.

[0025] The thin layer of non-conductive material may have a thickness of from 20 to 60 x 10^{-6}m (*i.e.* from 20 to 60 μm), say from 25 to 55, 30 to 52, 35 to 51 or 40 to 50 μm. The thickness of the non-conductive material may include the thickness of a cured, partially cured or uncured adhesive layer located between the conductive material and the non-conductive material.

[0026] The connector, *e.g.* flat connector and/or the electrical cable may be dimensionally invariant, except in locations where the non-conductive material has been removed.

[0027] In this specification, the term dimensionally invariant means a component which has a constant cross-section in a longitudinal direction, and constant in this context means that the cross-sectional area varies by less than 15%, preferably equal to or less than 10%, preferably equal to or less than 9, 8, 7, 6 or 5% along a 1 mm longitudinal portion, for example along a 2, 3, 4, 5, 6, 7, 8, 9, 10mm portion.

[0028] The electrical cable may comprise a free end, *e.g.* connected or connectable to electrical components and/or a source of electrical power. The flat connector may comprise a free or second end, e.g. connected or connectable to electrical components, for example to one or more busbars or other electrical components. The free or second end of the flat connector may be located or

locatable within a windscreen, *e.g.* electrically connected to electrical components disposed therein.

[0029] The enclosure may comprise a unitary body, for example where the unitary body is overmoulded around the point of contact, the first seal and (if provided) the second seal. In this way the first seal is encased by the enclosure, that is the enclosure may entirely cover and/or encapsulate the first seal.

[0030] The enclosure may comprise an enclosure material which is a rigid material, *e.g.* a material suitable to protect the electrical join from physical shocks. Additionally or alternatively the enclosure may comprise an enclosure material which is flexible, *e.g.* a material able to withstand the stresses generated upon flexure of the electrical cable and/or of the flat connector. Preferably the enclosure material is a thermoplastic, *e.g.* a polyamide, for example polyamide 6 (PA6), polyamide 6/6 (PA66), polybutylene terephthalate (PBT), polypropylene, Macromelt (RTM) and the like. Indeed, one or more of the polymers may comprise glass fibres, particles, microbeads or microspheres (which we call glass-filled polymer (GFP) or glass-reinforced polymer (GRP)), for example glass-reinforced polyamide or glass-reinforced polypropylene. We prefer glass-reinforced polymers because we believe it increases the softening point of the polymer, which is beneficial from a processing, aesthetic and finished product point of view and, surprisingly, it may yield a product better able to withstand environmental factors in use.

[0031] Preferably the enclosure comprises a continuous outer surface which is interrupted only by a first aperture through which the electrical cable extends and a second aperture through which the flat connector extends. Thus the enclosure may encase the second seal, that is the enclosure may entirely cover and/or encapsulate the second seal.

[0032] A third aspect of the invention provides an electrical connection for electrically connecting a flat connector and an electrical cable, the electrical connection comprising a flat connector with an insulated portion and an electrically conductive portion, an electrical cable and an enclosure, where the flat connector and the electrical cable are secured together in order to provide electrical contact between one another at the electrically conductive portion of the flat connector, the enclosure encases the electrical contact and is formed from a polymer comprising glass particles (GRP or GFP), preferably a polymer having over 20 w/w % of glass particles and most preferably having over 25 w/w% of glass particles. In one embodiment the polymer may comprise from 10 to 40 w/w% glass particles (which may be termed 10 to 50% GFP or 10 to 40% GRP), say from 15 to 50 or 40% GRP or GFP, say 20 to 50% GRP, and in some cases is 20 to 40% GRP.

[0033] A further aspect of the invention provides a method of forming an electrical connection between a connector, *e.g.* flat connector, and an electric cable, the method comprising the steps of:

a) providing a connector, *e.g.* flat connector, with an insulated portion and an electrically conductive portion, an electrical cable and a first seal;

b) securing the connector, *e.g.* flat connector, and the electrical cable together in order to provide electrical contact between each other at the electrically conductive portion of the connector, *e.g.* flat connector;

c) fitting a first seal outboard of the electrically conductive portion of the connector, e.g. flat connector and/or around the electrical cable such that the electrical contact is free of the first seal;

d) preferably providing a second seal; and

e) encasing the first seal and electrical contact with an enclosure.

[0034] In a preferred embodiment of the invention step c) may occur prior to step b).

[0035] Where step c) occurs prior to step b), step b) may further comprise positioning, *e.g.* accurately positioning, the electrical cable relative to the flat connector. Step b) may further comprise use of the first seal as a guide for positioning of the electrical cable relative to the flat connector. Additionally or alternatively, securing the flat connector to the electrical cable may entail soldering the flat connector, *e.g.* the electrically conductive portion of the flat connector, to the electrical cable.

[0036] The method may further comprise a step e) entailing fitting a second seal, *e.g.* distinct from the first seal. Step e) may comprise fitting a second seal in contact with the insulated portion of the flat connector and adjacent to or in contact with the electrically conductive portion of the flat connector, whereby the electrical contact is free of the second seal. Step e) may further comprise fitting the second seal outboard, for example entirely or partially outboard, of the electrically conductive portion of the flat connector.

[0037] Where the method includes step e) this step may occur prior to step d) such that step d) entails encasing both the first and second seals and the electrical contact.

[0038] Encasing preferably comprises overmoulding, *e.g.* with a thermoplastic material. Overmoulding may comprise: positioning a mould around the electrical join; introducing (e.g. injecting or pouring) an enclosure material into the mould; and setting (*e.g.* cooling or allowing to cool) the enclosure material into the form of the enclosure.

[0039] A further aspect of the invention provides a windscreen assembly comprising an electrical connection as described above, *e.g.* and further comprising glass laminates and heating elements.

[0040] For the avoidance of doubt, any of the features described herein apply equally to any aspect of the invention. Furthermore, any electrical connection according to the invention may include plural flat connectors and/or plural electrical cables.

[0041] Within the scope of this application it is express-

ly envisaged that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. Features described in connection with one aspect or embodiment of the invention are applicable to all aspects or embodiments, unless such features are incompatible.

[0042] Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1A is a diagrammatic plan view of an electrical connection according to a first embodiment of the invention;

Figure 1B is a diagrammatic side view of the electrical connection of Figure 1A;

Figure 1C is a diagrammatic cut-away plan view of the connection of Figure 1A;

Figure 1D is a sectional view along line i-i of Figure 1A together with a magnified view of the same;

Figures 2A to 2D are diagrammatic plan views of the stages of a method of manufacturing the electrical connection of Figure 1A;

Figure 3 is a diagrammatic plan view of an additional stage in an alternative method of manufacturing the electrical connection of Figure 1A;

Figure 4A is a diagrammatic plan view of an electrical connection according to a second embodiment of the invention;

Figure 4B is a diagrammatic cut-away plan view of the electrical connection of Figure 4A;

Figure 5A is a diagrammatic plan view of an electrical connection according to a third embodiment of the invention; and

Figure 5B is a side elevation of the connection of Figure 5A.

[0043] Referring firstly to Figures 1A and 1B, there is shown an electrical connection 1 according to one embodiment of the invention for electrically and mechanically joining a flat connector 2 to an electrical cable 3 at a first end 2a of the connector 2. The electrical connection 1 in the region of the first end 2a of the connector 2 is protected by an enclosure 4. The flat connector 2 has a second end (not shown), connected or connectable to electrical components, for example to one or more busbars or other electrical components.

[0044] Referring now to Figure 1C, there is shown a cut-away view of the electrical connection 1 of Figures 1A and 1B, where the flat connector 2 comprises of a flat electrically conductive element 20 encased by a thin layer of electrically insulating material 21 to leave a free end portion 20e. The electrical cable 3 comprises an electrically conductive wire 30 of generally cylindrical cross-section surrounded by a thin layer of insulating material 31. Other shapes of cable 3 and connector 2 are possible, with the provision that, at least in most cases, the connector 2 is flat or substantially flat and/or provides a flat conductive surface to which the cable 3 is to be attached. In this specification, by 'flat' we mean that the cross sectional width (W) of the connector is greater than the cross sectional depth or thickness (D), preferably where W>10D, say W>50D.

[0045] In a preferred embodiment the electrically conductive element 20 is flat and is from 5 to 40mm, *e.g.* 10 to 30mm, say 15 to 20mm, *e.g.* 17 mm, wide and about 10 to 1000 microns (1 micron is 10^{-6}m), say 50 to 500 microns, for example 100 microns thick, and is preferably formed from copper, which may or may not be coated. If the electrically conductive element 20 is coated, it may be coated with a protective substance, for example a substance capable of imparting at least a degree of environmental protection. One such coating material is tin or an alloy thereof. The insulating material 21 is preferably marginally wider than the electrically conductive element 20, for example to leave a marginal border outboard of the electrically conductive element 20 along the edges of the electrically conductive element 20. In an embodiment where the electrically conductive element 20 is 17 mm wide, the insulating material may be from 18 to 30mm wide, *e.g.* 21 to 25 mm wide (for example 22 or 23mm wide), and from 20 to 80, say 40 to 50 microns, *e.g.* 45 microns, thick at each major surface of the electrically conductive element 20. The insulating material 21 is preferably formed from a temperature-stable plastics material. One such plastics material is polyimide. The insulating material 21 may conveniently be formed from Kapton (RTM) film supplied by E.I. Dupont of Delaware, USA. The flat connector 2 may also include an adhesive patch (not shown) for attaching the flat connector to a site of use. The adhesive patch, where provided, may be located about 3mm from an end of the insulating material 21 towards the second end of the connector 2. The adhesive patch, where provided, may be covered by a release liner (not shown), which helps to ensure accurate location of the flat connector 20 at a site of use.

[0046] The flat connector 2 has an exposed portion or exposed end 20e of electrically conductive element 20 at its first end 2a. The exposed end 20e of the conductive material 2 may be from 2 to 20 mm long, *e.g.* from 5 to 18 mm long and in one embodiment is about 9 or 10 mm long.

[0047] The electrical cable 3 has an exposed portion of electrically conductive wire 30 at one of its ends. The exposed electrically conductive wire 30 at the end of the electrical cable 3 is soldered to the exposed electrically conductive element 20 at the end of the flat connector 2 by solder 5 which may be of any suitable type, for example a solder 5 consisting of 60% tin and 40% lead, or alternatively and preferably a lead-free solder, for example SAC305 or 97Sn3Ag. Alternatively or additionally the connector 2 and wire 30 may be otherwise secured together so as to allow electrical conduction from the connector 2 to the wire 30, and/or *vice versa.*

[0048] A first seal 6a is provided, which seal 6a comprises a strip of adhesive tape, for example acrylic adhesive tape, e.g. comprising an acrylic foam layer and acrylic adhesive on one or both major surfaces thereof. In this embodiment the first seal 6a comprises a strip of VHB (RTM) tape, produced by 3M of St. Paul, Minnesota, USA. The VHB tape circumferentially extends about (and completely around) the cable 3 so as to form a continuous fluid seal. The VHB tape may comprise a release liner (not shown) provided on its outer surface which covers an adhesive layer, which may be removed prior to encasement. The first seal 6a is located outboard of the free end portion 20e of the electrically conductive element 20 and adjacent a distal edge 20a of the electrically conductive element 20 of the flat connector 2.

[0049] There is further provided a second seal 6b, which second seal 6b comprises a strip of adhesive tape, for example acrylic adhesive tape, *e.g.* comprising an acrylic foam layer and acrylic adhesive on one or both major surfaces thereof. In this embodiment the second seal 6b comprises a strip of VHB tape which extends about (and completely around) the flat connector 2. The VHB tape may comprise a release liner (not shown) provided on its outer surface which covers an adhesive layer, which may be removed prior to encasement. The second seal 6b is located at the exposed end of the flat connector 2 where the insulating material 21 ends and the electrically conductive element 20 is exposed, such that the second seal 6b covers the end of the insulating material 21 and extends over a portion of the exposed end 20e and over a portion of the insulating material 21. Alternatively, the second seal 6b extends about and over the insulating material 21 adjacent the exposed end 20e of the electrically conductive element 20 so as not to lie over any portion of the exposed end 20e and not to be in facing relations therewith.

[0050] Referring to the expanded sectional view of Figure 1D, there is shown the second seal 6b located about the electrically insulating material 21 which is located about the electrically conductive element 20, the whole being encased within the enclosure 4. As shown, the seal 6b comprises an innermost layer of adhesive 61, a supporting layer 62 and an outermost layer of adhesive 63. The innermost layer of adhesive 61 secures the seal 6b to the electrically insulating material 21 (and to the conductive material 20 if the seal 6b is placed over and in facing relations with the conductive element 20). The outermost adhesive layer 63 is adjacent the enclosure 4. As will be appreciated, the first seal 6a could be similarly formed.

[0051] The enclosure 4, which is preferably moulded from a thermoplastic such as a polyamide, for example polyamide 6 (otherwise known as Nylon(RTM) 6 or PA6) or polyamide 6/6 (otherwise known as PA66) or polybutylene terephthalate (PBT) or polypropylene (and preferably glass reinforced PA6 or glass-reinforced PA66 or glass-reinforced PBT or glass-reinforced polypropylene) or Macromelt, is suitably sized and configured such that it encases the point of contact between the electrically conductive element 20 and the exposed end 30 of the wire 3 and extends from the flat connector 2 to the electrical cable 3 and over both of the first and second seals 6a, 6b. Inner surfaces (not shown) of the enclosure 4 seal against both the first and second seals 6a, 6b so that the enclosure 4 is therefore continuously fluidly sealed thereagainst. The enclosure 4 may be formed from a transparent or effectively transparent thermoplastic material so that the integrity of the electrical connection can be checked via visual inspection.

[0052] The manufacture of a heated windscreen entails providing a windscreen laminate comprising separate glass blanks between which are disposed a plurality of heating elements electrically connected to flat connectors of the type described herein. The flat connectors are electrically connected at their free ends to cables which are intended for future connection to a source of electrical power. The windscreen laminate, including the flat connectors and cables joined by an electrical connection, is then heated under vacuum in an autoclave at temperatures of up to 150°C and for durations of around three hours in order to bind together the layers of the laminate (and also, in some cases, to solder electrical connections). It is imperative that the electrical connection is not damaged during this process and further that the electrical connection remains sealed against undesirable elements (particularly water and salt) which might otherwise corrode and hence degrade the connection.

[0053] The applicant has found that an electrical connection between a flat connector and an electrical cable and including an enclosure, but not first and second seal, does not reliably prevent subsequent ingress of undesirable elements. Without wishing to be bound by any theory it is believed that movement and flexing of the cable and/or of the flat connector during the course of manufacture of the windscreen and automobile (and also during subsequent use of the automobile) may result in cyclical wear of the join between the cable and enclosure and/or of the join between the flat connector and the enclosure. This wear may produce gaps between the enclosure and the cable and/or flat connector through which undesirable elements may ingress. It is further believed that without the presence of the seals 6a, 6b, upon moulding the thermoplastic insufficiently wets and/or seals against the electrically insulating material 20 and/or insulating material 31, thereby allowing potential routes for ingress of undesirable elements.

[0054] The use of first and second seals 6a, 6b located respectively around the electrical cable 3 and the flat connector 2 mitigates against wear of the join between the enclosure 4 and the electrical cable 3 and/or flat connector 2 and/or provides a seal which reduces (and preferably prevents or eliminates) water ingress as well as ingress of other undesirable elements into the enclosure 4 and thence onto the electrical contact. The applicant has found that an enclosure 4 formed from polyamide 6 is particularly resistant to shocks and protects the elec-

trical contact thereagainst.

[0055] Referring now to Figures 2A to 2D, there is shown a method of forming the electrical connection 1 shown in Figures 1A to 1C. The method involves a first step (Figure 2A) entailing removing insulating material 21, 31 from ends of the flat connector 2 and electrical cable 3 so that portions of the electrically conductive element 20 and electrically conductive wire 30, respectively, are exposed . Alternatively, the insulating material 21 and/or the cable 3 may be formed without material covering their respective ends.

[0056] In a second step (as shown in Figure 2B) the thus exposed portion of electrically conductive wire 30 of the electrical cable 3 is positioned adjacent the exposed end portion 20e of electrically conductive element 20 of the flat connector 2 and electrically joined thereto with a solder 5, according to a commonly known method, preferably using a lead-free solder.

[0057] In a third step shown in Figure 2C, a first strip of VHB tape is wrapped tightly around the electrical cable 3 adjacent a distal edge 20a of the exposed electrically conductive element 20 of the flat connector 2 in order to form a first seal 6a. A second strip of VHB tape is tightly wrapped all the way around the flat connector 2, at the region where the insulating material 21 ends and the electrically conductive element 20 has been exposed, thereby forming a second seal 6b. A first portion of the width of the second seal 6b contacts the insulating material 21 and a second portion of the width of the second seal 6b contacts the electrically conductive element 20 (although the second strip of VHB tape may be located entirely upon the electrically insulating material 21). The release liners, if included, are then removed from the VHB tape of the first and second seals 6a, 6b to expose the outermost adhesive layer 63 of the seal 6b (and seal 6a).

[0058] Finally, in a fourth step as shown in Figure 2D, the intermediate electrical connection of Figure 2C is over-moulded by a thermoplastic material, for example polyamide 6, thereby encasing the exposed ends of the cable and flat connector and the contact therebetween to form the enclosure 4. A mould (not shown), configured to encase the exposed portion of electrically conductive element 20e, the first seal 6a and the second seal 6b, is positioned around the electrical connection 1. Heated, liquid thermoplastic material is introduced into the mould and is then cooled so as to form the enclosure 4. The first and second seals 6a, 6b are tightly pressed against an inner surface (not shown) of the enclosure 4 by this process, such that a continuous fluid tight seal is formed between the enclosure and both the first and second seals 6a, 6b. The outermost layer of adhesive 63 helps ensure an effective seal.

[0059] Referring now to Figure 3, there is shown an alternative step in a further method of forming an electrical connection 1 according to the invention. This step is intended to commence after the first step and prior to second step of the method of forming an electrical connection 1 shown in Figures 2A and 2B respectively.

[0060] The additional step entails tightly wrapping a first strip of VHB tape around the electrical cable 3 at a location adjacent to or spaced from the exposed portion of electrically conductive wire 30 at the end thereof, in order to create the first seal 6a. Subsequent steps then occur as described above in relation to Figures 2A to 2D, although the third step entails installation only of the second seal 6b and not of the first seal 6a.

[0061] The applicant has surprisingly found that it is particularly advantageous to install the first seal 6a on the electrical cable 3 prior to soldering of the exposed portion of electrically conductive wire 30 of the electrical cable 3 to the exposed portion of electrically conductive element 20 of the flat connector 2. The first seal 6a has been found to be useful as a location guide of the electrical cable 3 relative to the distal edge 20a of the flat connector 2. It will be appreciated by one skilled in the art that manufacture of a laminate heated windscreen is a complex process wherein time of manufacture is a key differentiating factor between similarly engaged enterprises. By using the first seal 6a as a location guide for the electrical cable 3 relative to the flat connector 2 the process of locating the exposed portion of electrically conductive wire 30 against the exposed portion of electrically conductive element 20 is achieved more accurately and more swiftly. Therefore, the time for processing the windscreen is reduced with a concurrent beneficial reduction in expense of overall manufacture. Furthermore, by more accurately locating the electrical cable 3 relative to the flat connector 2 the integrity of the thus formed electrical connection 1 is enhanced such that fewer failures of said electrical connections 1 subsequently occur.

[0062] Referring now to Figures 4A and 4B, there is shown an alternative embodiment of an electrical connection 1' according to the invention, wherein like references are designated with a prime (') and refer to like components which will not be described further. The electrical connection 1' of Figure 4A differs from the electrical connection 1 of Figure 1A in that the exposed portion of electrically conductive element 20' of the flat connector 2' has edges 22' which taper towards the distal edge 20a'. The enclosure 4' also includes edges 40' which taper in plan.

[0063] Beneficially, the tapering of the edges 22' of the exposed portion of electrically conductive element 20' only removes electrically conductive material from portions of the electrically conductive element 20' which are not required for forming a solder connection to the electrically conductive wire 30'. Furthermore, by tapering the exposed portion of the electrically conductive element 20' it is possible to also taper the enclosure 4' and hence reduce the volume thereof. It will be appreciated by one skilled in the art that the dimensions within and adjacent the edges of an automobile windscreen are particularly small and that therefore any reduction in the volume of the enclosure 4' is of benefit.

[0064] Manufacture of the electrical connection of Fig-

ures 4A and 4B is achieved according to the steps as described above and as shown in Figures 2A to 2D and, possibly but preferably, the step A' shown in Figure 3, along with a further step, which occurs prior, subsequent or at the same time as the third step. The further step entails removing corner portions of the exposed portion of electrically conductive element 20 in order to form tapered edges 22 thereon. This removal is achieved by cutting, for example using a mechanical blade or a laser.

[0065] Referring to Figures 5A and 5B there is shown a further embodiment which is equivalent to that shown in Figures 1 to 3, with the proviso that the exposed end portion 20e" is only exposed on one of its major surfaces, the other major surface being covered with electrically insulating material 21". The electrically insulating material 21 " which covers the other major surface of the exposed end portion 20e" may protrude beyond the exposed end portion 20e", may cover it exactly or may only cover a portion thereof, preferably a major portion thereof. It is considered that this construction provides an even better seal than the above embodiments because a smaller amount of the exposed end 20e is exposed.

Test results

[0066] Electrical connections 1 according to the invention were tested according to the following tests:

Test 1 - Insulation resistance following mechanical cycling

[0067] Electrical connections 1 according to the invention were prepared with 6mm wide first and second seals 6a, 6b, formed from VHB tape with adhesive on both major surfaces. Multiple electrical connections 1 were prepared with enclosures 4 formed from: polypropylene having 30 w/w% glass fibres; from PBT having 30 w/w% glass fibres; and from PA66 having 30 w/w% glass fibres.

[0068] Each electrical connection 1 was subjected to cyclic bending by fixing the enclosure 4 and bending the flat connector 2 around the enclosure 4 by an arc of 180°, five times. Each electrical connection 1 was also subjected to cyclic bending by fixing the enclosure 4 and bending the cable 3 around the enclosure 4 by an arc of 180°, five times. The purpose of this bending is to mechanically stress the joins between the enclosure 4 and the flat connector 2 and/or cable 3 and to therefore test the efficacy of the seal provided by the enclosure 4 and first and second seals 6a, 6b.

[0069] A 5% salt water solution at approximately 20°C was prepared. Each electrical connection 1 was then tested in turn by partially submerged it in the solution such that the enclosure 4 was submerged in the solution but not the second end of the flat connector 2. The insulation resistance of each electrical connection 1 was tested by passing electricity, with a voltage greater than 12V, therealong and by measuring the resistance between the free second end of the flat connector 2 and the solution (using an ohmmeter). A resistance greater than 10MΩ shows that an electrical connection 1 passes the test.

***Result*:** All of the electrical connections with enclosures manufactured from: polypropylene having 30 w/w% glass fibres; PBT having 30 w/w% glass fibres; and PA66 having 30 w/w% glass fibres successfully passed this test.

Test 2 - Insulation resistance following thermal cycling

[0070] Multiple electrical connections 1 with enclosures 4 formed from PBT having 30 w/w% glass fibres, and multiple electrical connections 1 with enclosures 4 formed from PA66 having 30 w/w% glass fibres, were prepared as described in relation to Test 1.

[0071] Two 5% salt water solutions were prepared, one at a temperature of 65°C (+5°C), the other at 0°C (±3°C).

[0072] Each electrical connection 1 was submerged in the first solution for a period of 30 minutes before being transferred to the second solution for another period of 30 minutes. The time taken to transfer the electrical connections 1 between first and second solutions was less than 10 seconds. This procedure was repeated five times in total for each of the electrical connections 1. The purpose of this thermal cycling is to test the efficacy of the seal provided by the enclosure 4 and first and second seals 6a, 6b.

[0073] The insulation resistance of the thus thermally cycled electrical connections 1 was then measured as described above in Test 1. Again, a resistance greater than 10MΩ shows that an electrical connection 1 passes the test.

[0074] ***Result***. Both the electrical connections with enclosures formed from PBT having 30 w/w% glass fibres and the electrical connections with enclosures formed from PA66 having 30 w/w% glass fibres successfully passed this test.

[0075] In all of the embodiments it is particularly advantageous that the first seal (e.g. seal 6a) lies adjacent a distal edge of the electrically conductive element 20 and/or that the second seal (e.g. seal 6b) overlies the end of the insulating material 21 as this ensures that a minimum of enclosure material need be used. This is beneficial due to cycling times, cost and performance not least because the flexibility of the connector is greater than one of equivalent length in which the enclosure is larger, thereby reducing strain, in use.

[0076] It will be appreciated by those skilled in the art that several variations to the aforementioned embodiments are envisaged without departing from the scope of the invention. For example, the solder 5 may be lead free and/or may include any suitable combination of solder materials. Although the first and second seals 6a, 6b have been described as consisting of VHB tape they need not do so and one or both may additionally or alternatively include one or more o-ring seals or rubber grommets or

any other suitable sealing means, for example an amount of an adhesive, for example a contact adhesive, may be provided as the first seal 6a and/or second seal 6b. The use of a tape is convenient because it allows for (at least semi) mechanical processing. The use of adhesives may be similarly convenient.

[0077] It will also be appreciated by those skilled in the art that any number of combinations of the aforementioned features and/or those shown in the appended drawings provide clear advantages over the prior art and are therefore within the scope of the invention described herein.

Claims

1. An electrical connection (1; 1') for electrically connecting a flat connector (2; 2'; 2") and an electrical cable (3; 3'; 3"), the electrical connection (1; 1') comprising a flat connector (2; 2'; 2") with an insulated portion (21; 21") and an exposed electrically conductive portion (20e; 20e"), an electrical cable (3; 3'; 3"), a first seal (6a; 6a"), a second seal (6b) and an enclosure (4), where the flat connector (2; 2'; 2") and the electrical cable (3; 3'; 3") are secured together in order to provide electrical contact between one another at the exposed electrically conductive portion (20; 20'; 20") of the flat connector (2; 2'; 2"), the first seal (6a; 6a") being outboard of the exposed electrically conductive portion (20; 20'; 20") of the flat connector (2; 2'; 2") and adjacent a distal edge (20a) of the exposed electrically conductive element (20; 20'; 20") of the flat connector (2; 2'; 2"), whereby the enclosure (4) encases the first seal (6a; 6a") and the electrical contact.

2. A connection (1; 1') according to Claim 1, wherein the first seal (6a; 6a") is located around the electrical cable (3; 3'; 3").

3. A connection (1; 1') according to Claim 1 or 2, wherein the enclosure (4) encases the electrically conductive portion (20e; 20e") of the flat connector (2; 2'; 2").

4. A connection (1; 1') according to any preceding Claim, wherein the second seal (6b) contacts the insulated portion (21; 21") of the flat connector (2; 2'; 2"), whereby the electrical contact is free of the second seal.

5. A connection (1; 1') according to of Claims 1 to 3, wherein the second seal (6b) is adjacent to and/or contacts the electrically conductive portion (20e; 20e") of the flat connector (2; 2'; 2").

6. A connection (1; 1') according to any preceding Claim, wherein the enclosure (4) encases the second seal (6b).

7. A connection (1; 1') according to any preceding Claim, wherein the first seal (6a) and/or the second seal (6b) comprises an adhesive material (61, 63).

8. A connection (1; 1') according to Claim 7, wherein the adhesive material (63) provides an interface between the first seal (6a) and/or the second seal (6b) and the enclosure (4).

9. A connection (1; 1') according to any preceding Claim, wherein the flat connector (2; 2'; 2") comprises a flat strip of electrically conductive material (20; 20'; 20") encased in a thin layer of non-conductive material.

10. A connection (1; 1') according to Claim 9, wherein the flat strip of electrically conductive material (20; 20'; 20") has a cross sectional area of less than 3 mm^2, preferably less than 2.75, less than 2.5, less than 2.25, less than 2, for example less than 1.95, less than 1.9, less than 1.85 or less than 1.8 mm^2, and/or wherein the flat strip of electrically conductive material (20; 20'; 20") has a thickness of from 80 to 120 x 10^{-6}m (*i.e.* from 80 to 120 μm), say from 85 to 118, 90 to 115, 95 to 113 μm and/or wherein the flat strip of electrically conductive material (20; 20'; 20") has a width of from 10 to 30 mm, say from 12 to 28 mm, for example from 14 to 25 mm.

11. A connection (1; 1') according to any preceding Claim, wherein the exposed electrically conductive portion (20e") has two major surfaces, and one of the surfaces is covered with an electrically insulating material.

12. A connection (1; 1') according to any preceding claim, wherein the enclosure (4) comprises a glass reinforced polymer.

13. A method of forming an electrical connection between a flat connector and an electric cable, the method comprising the steps of:

    a) providing a flat connector with an insulated portion and an electrically conductive portion, an electrical cable and a first seal;
    b) securing the flat connector and the electrical cable together in order to provide electrical contact between each other at the electrically conductive portion of the flat connector;
    c) fitting a first seal outboard of the electrically conductive portion of the flat connector and/or around the electrical cable such that the electrical contact is free of the first seal;
    d) providing a second seal; and
    e) encasing the first seal and electrical contact with an enclosure.

14. Method according to Claim 16, wherein step c) occurs prior to step b)and wherein step b) further comprises use of the first seal as a guide for positioning of the electrical cable relative to the flat connector.

15. A windscreen assembly comprising an electrical connection according to any of Claims 1 to 12 and/or formed by a method according to any of Claims 13 or 14.

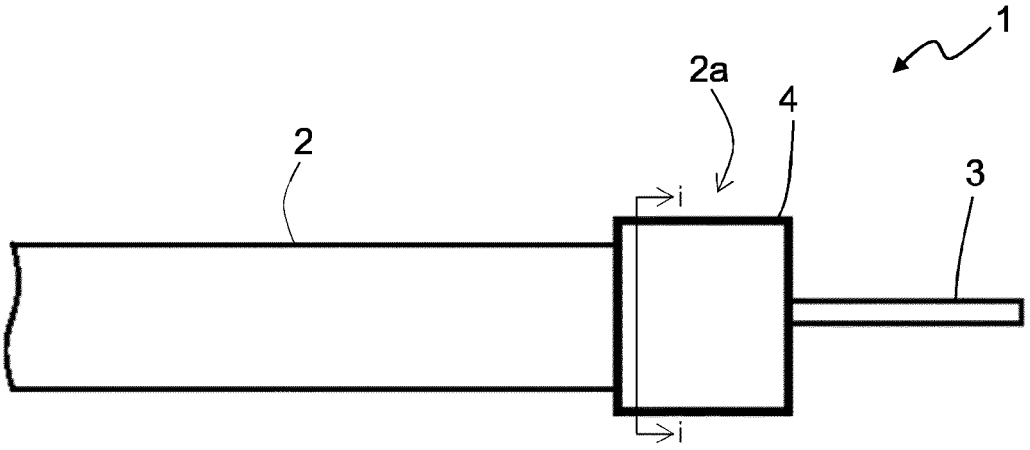

FIGURE 1A

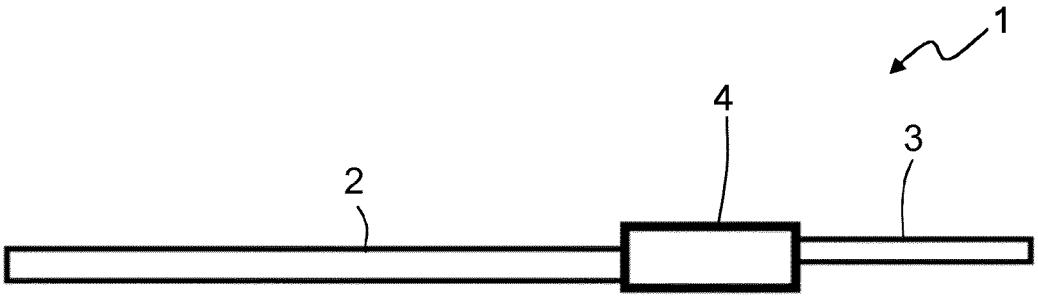

FIGURE 1B

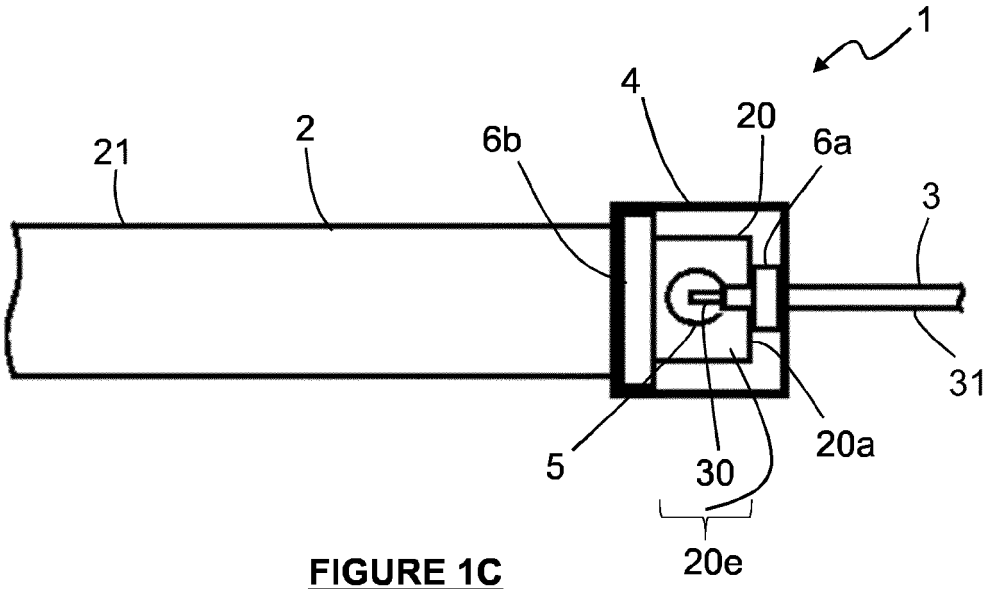

FIGURE 1C

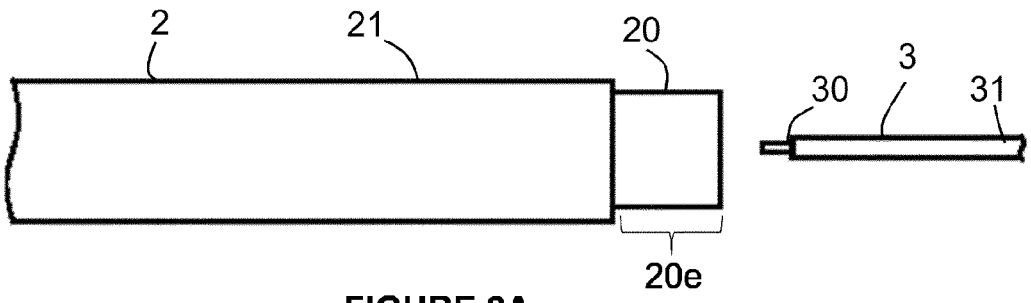

FIGURE 2A

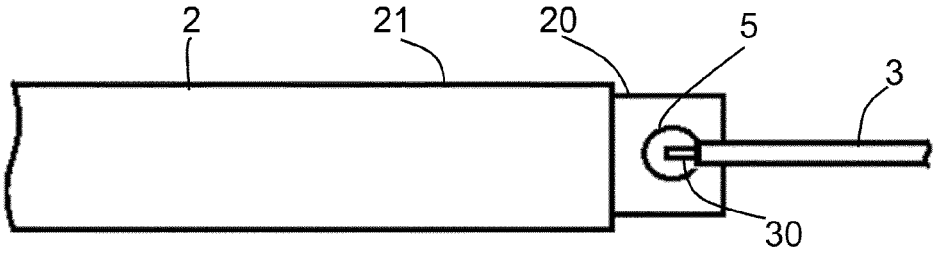

FIGURE 2B

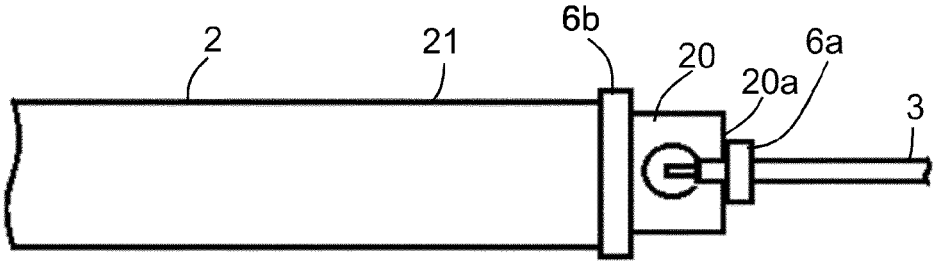

FIGURE 2C

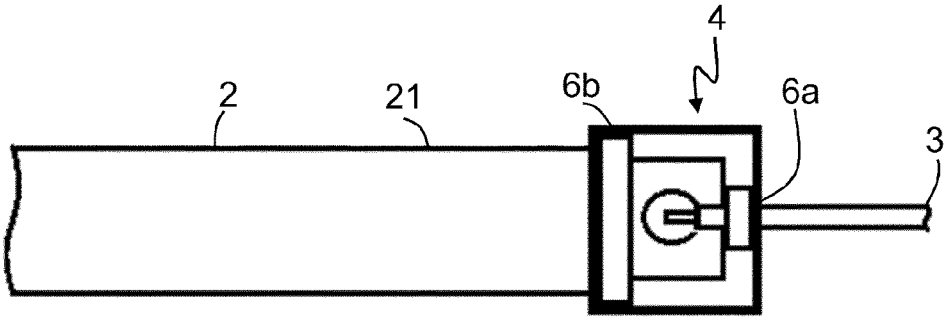

FIGURE 2D

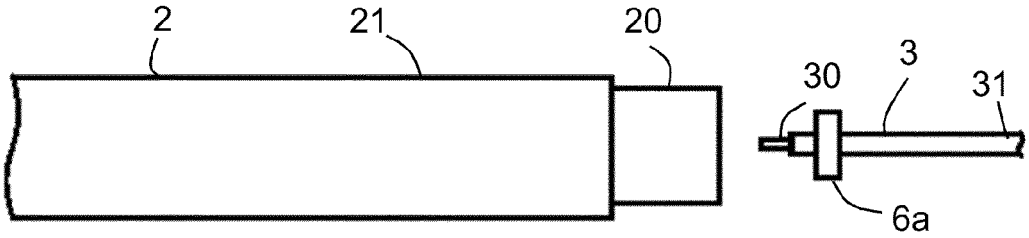

FIGURE 3

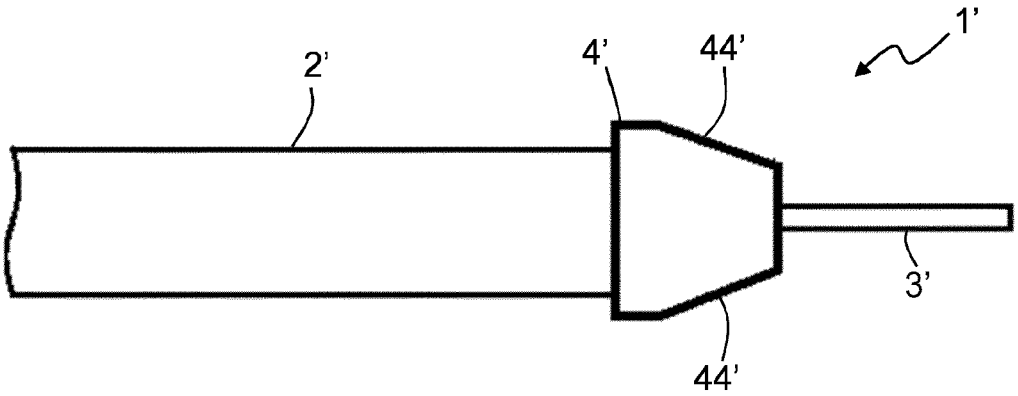

FIGURE 4A

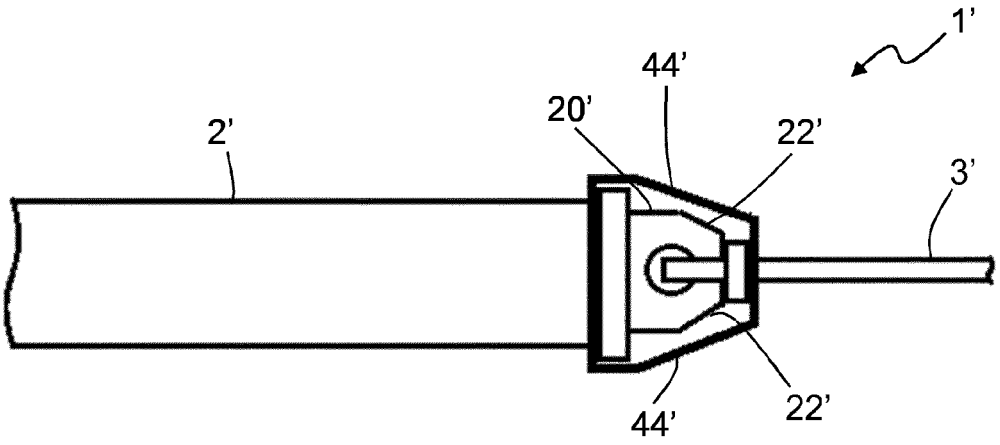

FIGURE 4B

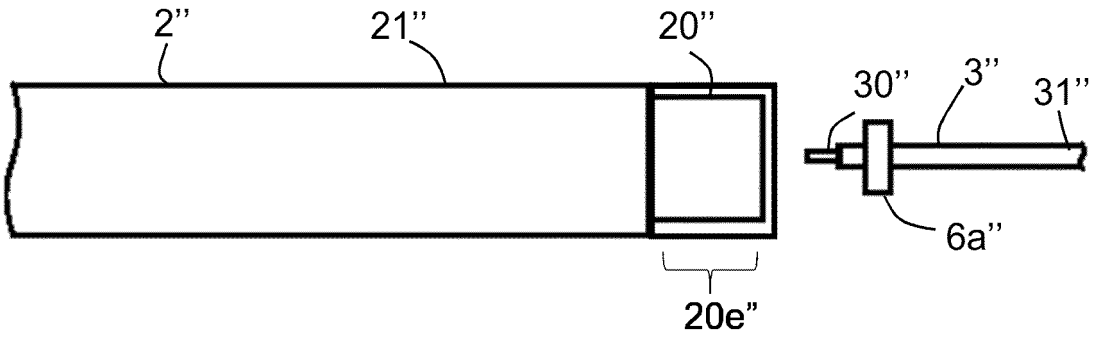

FIGURE 5A

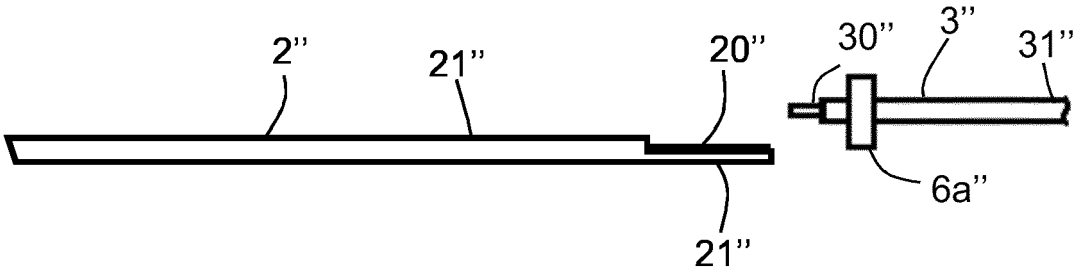

FIGURE 5B

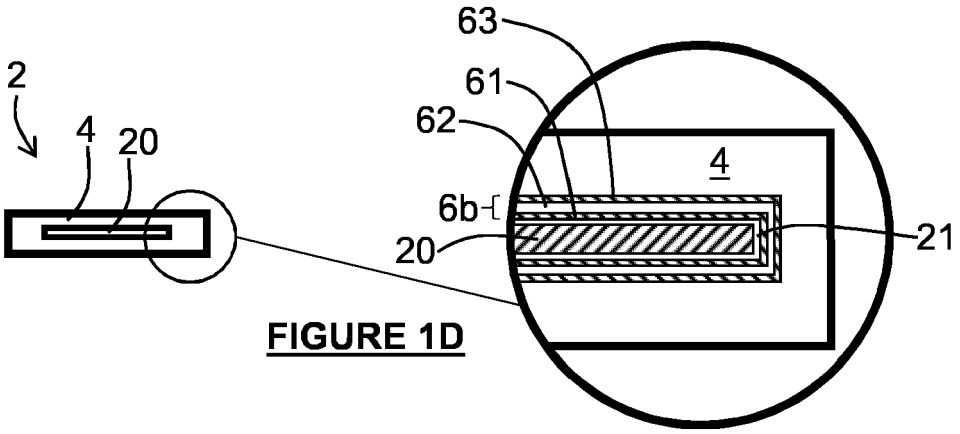

FIGURE 1D

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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 8836

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	28 March 2017	Kandyla, Maria

CATEGORY OF CITED DOCUMENTS

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