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Description

The present invention is directed to connectors for electrical conductors, for example power distribution cables, and methods for use of the connectors.

As used herein, the term "connectors" refers to connectors that are used both for terminating and for splicing conductors, such as power cables.

A variety of techniques have been developed for terminating or splicing high voltage cables in the field. High voltage cables are used for distributing power, and can vary in size from 4 gauge (16 mm²) up to over 3,000 MCM (1500 mm²).

One technique commonly used is a compression crimp with a metallic sleeve. However, there are problems with compression crimps. For example, heavy hydraulic crimping tools are required, which can weigh 50 to 100 pounds (22.5 to 45 kgs). These heavy tools are awkward to use in the field. In addition, a large number of dies are required because a die is needed for each cable size. If the die size is off by even a small fraction, which easily occurs due to die wear, the tool does not perform satisfactorily and crimp failure can result.

Another problem with compression crimps is lack of reliability, especially with aluminum conductors. If an unsatisfactory crimp is formed, the termination or splice can overheat which can result in a fire, system failure, and a blackout.

When a compression crimp is used, often the crimp is filled with a conductive grease to insure better electrical contact and to prevent oxidation. In the field, this conductive grease is very messy. At high temperature the grease can flow resulting in poor electrical contact.

Another problem noted with compression crimps, particularly for aluminum conductors, is that cold flow occurs due to thermal cycling. This can result in a thermal runaway which can cause a fire.

Another technique for forming terminations and splices that has been used is sweating, where hot molten solder is poured into the termination or splice. This also is a very difficult technique to use in the field. A hot tub of solder is required, which creates safety hazards and there are significant losses of expensive solder. Further, temperature control is essential to a good splice or termination, and is difficult to achieve in the field. If the temperature is too low, a satisfactory connection does not result due to a poor metallurgical bond. If the temperature is too high, flux in the solder degrades, resulting in a brittle connection which can fail. Hence, there is considerable worker skill required.

Another technique that has been considered is a chemical heating system, known under the tradename Cadweld, for welding conductors together using an exothermic reaction and molten aluminum. This technique has achieved only limited use because it can be dangerous, it

involves a gas which needs venting which is difficult in the field, and it is expensive because the molds used wear out after only fifty uses.

One further technique that has been considered is metal inert gas (MIG) welding, that is welding the aluminum conductors under inert gas to prevent oxidation of the aluminum. This technique requires expensive equipment which is generally unsuitable for field use in that it weighs several hundred pounds or more and is not easily portable.

US—A—2838592 and US—A—3601783 disclose electrical connector arrangements employing solder-filled connectors wherein an electrical conductor is pushed into the molten solder to effect the connection, and US—A—3 396 460 discloses sleeves which contract to grip the conductors and the solder within the sleeve.

In accordance with one aspect of the present invention, there is provided an electrical connector comprising: at least one tubular sleeve having a closed end and an open end for receiving an electrical conductor within the sleeve, the peripheral inner wall of the sleeve being pretinned, the sleeve being arranged to receive a slug of solder therein proximate to the closed end; and means disposed within the sleeve for exerting pressure on the slug of solder so as to urge the solder towards the open end of the sleeve at the temperature at which the slug of solder melts.

As used herein the term "pretinned" means that a surface has been coated with solder or solder-like material such as zinc or bronze. Although the invention will be discussed below principally with regard to pretinning with solder, it is to be understood that coating other than solder can be used.

A single sleeve is used for termination connections and two sleeves in electrically conductive connection are used for splice connections.

The peripheral inner wall of the sleeve may be pretinned with a solid coating of solder or zinc for example.

The connector can be provided with the slug of solder in position, preferably proximate to the closed end of the sleeve, or the user of the connector can add the slug of solder in the field.

In accordance with another aspect of the present invention, there is provided a method of connecting a connector to an electrical conductor, wherein the connector comprises: at least one tubular sleeve having a closed end and an open end for receiving the electrical conductor within the sleeve, the peripheral inner wall of the sleeve being pretinned, a slug of solder in the sleeve proximate to the closed end of the sleeve, and means disposed within the sleeve for exerting pressure on the slug of solder so as to urge the solder towards the open end of the sleeve at the temperature at which the slug of solder melts; the method comprising placing the electrical conductor into the sleeve of the connector, and heating the solder to at least its melting temperature while simultaneously main-

taining the conductor in the sleeve against the force of the pressure-exerting means.

In accordance with a still further aspect of the present invention, there is provided a method of splicing first and second electrical conductors together by means of an electrically conductive connector that comprises first and second metallic sleeves in electrically conductive connection with each other, each sleeve having a closed end, and an open end for receiving a conductor within the sleeve, the peripheral inner wall of each sleeve being pretinned; a slug of solder in each sleeve proximate to the closed end of the sleeve; and at least in the second sleeve, means disposed within the sleeve for exerting pressure on the slug of solder to urge the solder towards the open end of the sleeve at the temperature at which the slug of solder in the second sleeve melts; the method comprising the steps of connecting the first conductor to the connector by placing the first conductor in the first sleeve and heating the first sleeve to a temperature sufficiently high to melt the slug of solder in the first sleeve; and connecting the second conductor to the connector by placing the second conductor in the second sleeve, heating the slug of solder in the second sleeve to at least the temperature at which the slug of solder melts while simultaneously maintaining the second conductor in the second sleeve against the force of the pressure-exerting means, thereby to force the molten solder towards the open end of the sleeve to fill the space between the second conductor and the second sleeve with solder.

The connector of the invention is used in the method of the present invention by heating the sleeve to melt the solder while simultaneously applying a force to relatively move the connector and the conductor toward each other. Until the slug of solder has at least softened, no relative movement between the connector and the conductor is possible. When the solder has melted, the sleeve and the conductor are moved relatively toward each other. The sleeve is continued to be heated and simultaneously the sleeve and conductor are continued to be moved relatively toward each other to extrude solder toward the open end of the sleeve. This completely fills any interstices in the conductor, such as spaces between strands of stranded conductors, and also completely fills the space between the conductor and the sleeve with solder. Preferably the heating and the moving continue until the conductor can no longer move, i.e., it bottoms out in the connector. Preferably the size of the slug of solder is chosen so that as the conductor bottoms out, a small portion of the solder is extruded out of the sleeve, which indicates to an operator that connection has been made.

In some circumstances, it is not possible to move the sleeve and the conductor toward each other. For instance, when splicing two electrical conductors together, after the first conductor is connected to the connector, the connector can no longer be moved, and often the other conductor is relatively immobile.

In accordance with one aspect of the invention as set out in Claim 14, the conductor and connector are held immobile, while the pressure-exerting means extrudes the solder around the conductor and into the interstices of the conductor.

Preferably the pressure-exerting means produces a force at T_m of at least 10 psi (0.07 MPa), and more preferably at least 30 psi (0.21 MPa), to achieve adequate filling of space between strands. Preferably the pressure-exerting means produces a force at T_m no greater than 200 psi (1.4 MPa) to prevent the conductor from being forced out of the sleeve.

Exemplary of suitable pressure-exerting means are (1) a spring; (2) a heat expandable metal which can be in the form of a spring; (3) a swellable polymer; (4) a gas; (5) a container containing pressurized gas that is released at a temperature greater than 100°C and up to T_m ; (6) reactants that evolve a gas, the reactants being separated by a barrier that allows the reactants to react at a temperature greater than 100°C and up to T_m ; and (7) reactants that evolve gas when they react, the reactants being reactive only at a temperature between 100°C and T_m ; and (8) a material that is a fluid at the temperature at which the slug of solder melts, and wherein the connector comprises a sealing member for preventing leakage of the fluid past the barrier.

A connector containing pressure-exerting means, referred to as a "self-activated connector" herein, can include a metallic barrier between the slug of solder and the pressure-exerting means, the barrier, which may be pretinned, acting as a piston and being dimensionally stable at T_m and axially slidable within the sleeve. The barrier may be arranged to melt at a temperature greater than T_m . Preferably the connector includes sealing means for preventing leakage of the pressure-exerting means past the barrier, particularly when the pressure-exerting means comprises a material that is a fluid at T_m .

The connector can be provided with a tubular insert for use with conductors that are non-circular in transverse cross-section. The tubular insert is metallic, rotatably positioned in the sleeve, and the peripheral inside wall of the insert is pretinned. The inside wall of the insert is non-circular in transverse cross-section, having a cross-section that corresponds to the cross-section of the conductor.

The connector can have a view hole through the wall of the sleeve proximate to the open end of the sleeve for determining when the slug of molten solder has been extruded to a position proximate to the open end of the sleeve.

So that a single sleeve can accommodate more than one conductor size, inserts of varying wall thickness can be provided, where the peripheral inner wall of each insert is pretinned. Alternatively, a flexible metallic sheet coated with solder can be provided. The sheet is wrapped around the conductor until the outer diameter of the wrapped conductor is sufficiently large for the internal diameter of the conductor.

The connector of the invention may be provided with a mounting hole through the wall of the sleeve for attaching fastening means to the connector for holding an electrical conductor in place as the pressure-exerting means urges molten solder towards the open end of the sleeve.

The connector of the invention may be provided with a star-shaped washer positioned proximate the open end of the sleeve with the points of the star extending inwardly such that they grip an electrical conductor inserted in the sleeve.

This method for making splices or connections is safe, reliable, and easy to use in the field. The only significant piece of equipment required is a torch. The resulting terminations and splices are electrically reliable and physically secure. This method can be used for both aluminum and copper conductors, and also can be used for splicing an aluminum conductor to a copper conductor.

Preferably the or each tubular sleeve and/or insert used in the invention is metallic.

In arranging for the sleeve to receive the slug of solder, it will be appreciated that the relative size of these components is to be taken into account.

The connector and method of the present invention may be used with a stranded or solid conductor, and the conductor may form part of a cable insulated with polymeric material or oil saturated paper. The cable may be a multi-conductor sector cable having conductors that are non-circular in cross-section.

The connector of the invention will in general be of generally cylindrical configuration, but may, alternatively, be of irregular cross-section.

Preferably the area of a transverse cross-section of the wall of the connector is at least equal to the area of a transverse cross-section through the conductor so that the connector and the conductor have the same capability to conduct electricity. This avoids hot spots in the termination or splice.

Several embodiments of electrical connectors, and connecting and splicing methods, each in accordance with the present invention, will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1A shows in transverse cross-section a connector being used to terminate a power cable;

Fig. 1B shows the termination of Fig. 1A;

Fig. 2 shows in transverse cross-section a splice connector.

Each of Figs. 3—6 shows a self-activated termination connector provided with means for pressurising molten solder toward the open end of the connector;

Fig. 7A is a front elevation view of a power cable where the conductor is wrapped in a pretinned flexible sheet of metal;

Fig. 7B is a transverse cross-section view of the cable of Fig. 7A taken on line B—B in Fig. 7A;

Fig. 8 shows in transverse cross-section a splice connector having an insert therein; and

Fig. 9 is a view of the splice connector of Fig. 8 taken along line 10—10 in Fig. 8.

With reference to Fig. 1, an electrically conduc-

tive connector 10 is used for terminating a power cable 12 that comprises insulation 14 that has been cut back to expose a stranded conductor 16.

As shown in Fig. 1, the connector 10 comprises a metallic cylindrical tubular sleeve 18 having a closed end 20 and an open end 22.

The connector 10 is pretinned with a thin, solid coating of solder 24 on the inner peripheral wall 26 of the sleeve 18. There is also a slug of solder 28 in the sleeve proximate to the closed end 20.

Preferably the sleeve 18 is formed from the same material used for the conductor, which in the case of the aluminum conductors can be 1100 series aluminum alloys.

The same solder, which can be a fluxless solder, can be used both for the coating 24 and the slug 28. A preferred solder for a copper conductor contains tin, cadmium and zinc, and is available under the tradename Neptune-SS from Rock Mount Research and Alloys, Inc. of Denver, Colorado. A preferred fluxless solder for an aluminum conductor contains zinc, aluminum, copper, iron, and magnesium, and is available under the tradename Neptune-S from Rock Mount. Solder used in conjunction with a flux can also be used. In such event, it is preferred to use a multi-cored solder such as for example a solder comprising lead, tin and optionally silver. Multi-cored solder typically is an extruded rod of solder containing two or more areas of flux extending longitudinally within the solder rod. A multi-cored solder of this type is commercially available from Multi-Cored Solders, Ltd. of Great Britain and under the trademark HMP Solder.

The thickness of the coating of solder can be in the order of a few tenths of a millimetre (ten thousandths of an inch), and generally is in the order of a few hundredths of a millimetre (thousandths of an inch). The pretinning can be achieved by heating the sleeve 10 and melting solder onto the inner peripheral wall 26 or by electroplating.

The internal diameter of the sleeve 18 must be larger than the outer diameter of the conductor 16, and preferably is at least 12.5×10^{-2} mm (5 mils) greater.

The solder 28 can be pre-placed in the sleeve 18, or the user of the connector can place the solder. When the solder is pre-placed, it can be melted for placement in the sleeve, and when it solidifies it attaches to the walls of the sleeve and securely stays in place.

To use the connector 10, the conductor 16 is inserted into the sleeve, bottoming out on the slug 28 of solder. Then the sleeve is heated such as by a torch 30 while simultaneously forcing the connector and the conductor towards each other with a force of at least about 0.07 MPa (10 pounds), preferably at least about 0.21 MPa (30 pounds). When the solder melts, the force results in the sleeve and the conductor moving relatively toward each other. This results in the solder being extruded toward the open end of the sleeve under pressure. The pressurized solder fills any interstices in the conductor, including spaces between

strands, completely fills the space between the conductor and the sleeve, and fills the closed end of the sleeve as shown by reference number 31 in Fig. 1B.

Filling the closed end of the sleeve with solder is important in that it provides good electrical contact between the end of a conductor and the connector. Such contact is absent in a crimp connection.

The relative movement between the conductor and the solder in a closed environment tends to encourage a metallurgical bond and a high-quality connection.

Preferably, any oxide on the conductor is mechanically removed such as with a stainless steel brush before the conductor is inserted into the connector. Preferably any oxide film on the inner peripheral wall of the sleeve is removed by mechanical abrasion or an ultrasonic technique before pretinning the sleeve to aid in formation of a metallurgical bond between the conductor and the connector.

The conductor and connector are moved relatively toward each other until the conductor bottoms out in the sleeve and cannot be forced any further. Generally, a small portion of the solder is extruded out of the sleeve as shown by reference numeral 32 in Fig. 1B when bottoming out occurs this helps let the operator know that the connection is complete. The heat is then removed, and the conductor and connector are allowed to cool. This process results in a strong and electrically conductive metallurgical bond between the conductor and the connector.

The slug of solder has sufficient mass to completely fill any interstices in the conductor, to fill the space between the conductor and the sleeve, and to allow a small portion to be extruded out of the sleeve.

The sleeve 18 can be formed from a tube that is crimped down to form a closed end 20. With this configuration, there can be an opening toward the closed end. An advantage of the present invention is that molten solder is extruded into any openings to close them off. The mass 31 of solidified solder stops ingress by water and other contaminants.

Fig. 2 shows a splice connector 32 according to the present invention that comprises two axially aligned metallic tubular sleeves 44 in electrically conductive connection with each other. This connector 32 can be formed from a single metal tube that has a barrier 46 therein. The barrier 46 can be held in place by soldering, welding an interference fit, or a press fit. Each sleeve 44 is pretinned on its inner peripheral wall with a solid coating 24 of solder and has a slug 28 of solder at its closed end.

One of the sleeves is shown as having a view hole 46 through its wall so that operator can observe molten solder as it is extruded toward the open end, and stop heating the solder before it extrudes out of the sleeve. Although only one of the sleeves is shown as having a view hole 46 in Fig. 2, clearly both sleeves can be provided with a view hole.

The splice connector 42 is used in the same

manner as the termination connector 10. That is, each of two conductors is connected to one of the sleeves in the same manner as described above with regard to termination connector 10. The two conductors can be attached to the connector simultaneously, or connection can be done sequentially.

Splice connectors comprising more than two sleeves can be used. For example, splice connectors having three sleeves in the form of a "Y" or "T" can be used, and splice connectors having four sleeves in the form of an "H" can be used.

Figs. 3—6 show self-activated connectors having means provided for pressurising the solder to the open end of the sleeve when the solder melts. Although the pressurising means is only shown with regard to termination connectors, the pressuring means can be used with one or both sleeves of a splice connector such as the splice connector 32 shown in Fig. 2. As noted above, it is with splice connectors that the pressurising means are most useful. With splice connectors, often once one conductor is connected, it is impossible to have relative movement between the connector and the second conductor. With a self-activated connector, relative movement is not required.

In Figs. 2—6, the same reference numerals are used as in Fig. 1 to show elements that are substantially the same.

In Fig. 3, the pressuring means comprises a solid cylinder 52 of a heat swellable or foamable polymer. Between the cylinder 52 and the slug of solder 28 is a barrier or piston 54. The piston 54 is axially slidable within the sleeve 18 and is made of a material that is thermally stable and does not melt at the temperature, T_m , at which the slug of solder 28 melts. The piston 54 can be made of the same alloy used for the sleeve. Preferably the piston 54 is pretinned with a coating 55.

When heat is applied to the connector 50, the polymer increases in size. Once the slug of solder 28 melts, the polymer forces the piston 54 and the solder 28 toward the open end 22 of the sleeve 18. To prevent the conductor 16 from being forced out of the sleeve, it is held in place by a fastener such as a screw 56 extending through a fastening hole 58 in the wall of the sleeve 18 proximate to the open end 22 of the sleeve. An alternate approach to prevent conductor "pull out" is the provision of a star-shaped washer about 7.5×10^{-2} mm to 12.5×10^{-2} mm (3 to 5 mils) thick proximate the open end of the sleeve. Such a star-shaped washer has a smooth outer circumference and an inner circumference having a plurality of points. When positioned in the sleeve the smooth outer surface fits against the inner peripheral wall of the sleeve and the points of the star extend inwardly. The points of the star contact and grip the conductor when it is inserted in the sleeve. As the conductor is forced into the connector the sharp inner circumference of the washer scrapes the conductor removing any oxide layer that might be present. In addition, the washer firmly holds the conductor in place and acts as a dam to retain the solder, when molten, within the sleeve.

To prevent the polymer from leaking out around the piston 54, a high temperature polymeric sealing sleeve member 60 is provided on the inner peripheral wall of the sleeve 18 adjoining the cylinder 52. As the polymer swells, it forces the sealing member 60 against the inner peripheral wall of the sleeve. The piston 54 has a skirt 62 extending toward the closed end 20 of the sleeve 18 and the sealing member 60 is pressured against the inner wall of the skirt 62, thus preventing leakage of the swellable polymer 52 beyond the piston. The polymeric sealing member 60 is particularly useful when the pressuring means is a fluid as shown in Figs. 4, 5 and 7. The sealing member 60 can be made from a flexible heat-resistant material such as thin aluminum or a polymeric material, preferably a sheet of a polyimide available under the tradename Kapton from DuPont. A suitable sleeve can be made from 3 to 4 wraps of 2.5×10^{-2} mm (1 mil) thick Kapton.

Preferably the pressurising means produces a force on the piston at T_m , which is generally about 150 to 400°C for solders for aluminum and copper conductors, of at least 0.07 MPa (10 psi), and more preferably at least 0.21 MPa (30 psi) on the piston, to achieve adequate filling of the space between strands and extrude solder all the way toward the open end. Preferably the pressurising means produces a force at T_m less than 1.4 MPa (200 psi) on the piston to prevent the conductor and the piston from being entirely forced out of the sleeve.

A preferred material for the polymer contains:

	(Parts by weight)
Low density polyethylene	80 pbw
Ethylene ethylacrylate	20 pbw
Hindered phenol antioxidant	0.5 pbw
p-Oxy bis(benzene sulfonyl hydrazide) (foaming agent)	2 pbw

The foaming agent is available under the tradename Celagen from Uniroyal. Other sulfonyl hydrazide foaming agents can be used.

Other suitable polymers can include polyethylene, ethylene vinyl acetate and polypropylene that have been crosslinked by radiation to prevent them from oozing out by the piston 54. Also polymers such as silicone polymers having a foaming agent therein can be used.

With reference to Fig. 4, a connector 71 is provided with pressurising means comprising a cylinder 72 containing compressed non-reactive gas 74. The cylinder is closed with a solder plug 76. As the connector 70 is heated, the plug of solder 76 melts, thereby releasing the compressed gas 74, which drives the piston 54 and the slug of solder 28, once it is melted, toward the open end of the sleeve.

With reference to Fig. 5, a connector 80 has a spring 82 as the pressurising means. The spring is made of a material that does not lose its temper at the temperature, T_m , at which the solder melts,

i.e., at 360 to 400°C. Suitable materials for the spring 82 include 302 stainless steel, SAE 52100 alloy carbon steel, T1 High speed tool steel, steel alloy 8286 and Inconel 718. The spring 82 can be made from a heat-recoverable metal that expands upon heating such as nitinol, a nickel-titanium based alloy available under the trademark Tinel.

To hold the piston 28 in place in the version of the invention shown in Fig. 5, a solder pin 84 is provided. The pin 84 extends through two aligned openings 86 in diametrically opposite portions of the sleeve. The pin preferably is made of the same solder used for the slug 28 so that when the pin 84 melts, the slug of solder 28 is molten as it is forced by the spring 82 toward the open end of the sleeve.

As shown in Fig. 6, a connector 87 can have as pressurising means two reactants 88 and 90 separated by a barrier 92 that melts at a temperature greater than 100°C up to T_m . The barrier 92 can be made of solder. The reactants can be materials that evolve gas when they react such as sodium bicarbonate and acetic acid. Once the connector 87 is heated and the barrier 92 melts, the reactants 88 and 90 react to evolve a gas which pressures the piston 54 and the slug of solder 28 toward the open end of the sleeve once the slug of solder has melted.

The barrier 92 can be eliminated if the reactants do not react or do not exert excessive pressure until reaching an elevated temperature of at least greater than 100°C.

Also a powder can be used that releases a gas at an elevated temperature.

Pressuring means are particularly useful in one or both sleeves of a splice connector having first and second sleeves in electrically conductive connection. With such a connector, a first conductor is connected in the first sleeve. Then, a second conductor is connected to the connector by placing the second conductor in the second sleeve, heating the slug of solder in the second sleeve to at least T_m while simultaneously maintaining the second conductor in the second sleeve against the force of the pressuring means. The pressuring means forces the molten solder toward the open end of the sleeve to completely fill the space between the second conductor and the second sleeve with solder. Thus, it is not necessary to move the second conductor and the connector toward each other after the first conductor is connected.

Fig. 7 shows a conductor 16 wrapped in a flexible sheet of wrapping 96 so that the conductor 16 can fit into a connector having a sleeve with an internal diameter too large for the unwrapped conductor. The wrapping 96 can comprise a flexible metallic sheet having a solid coating of solder on one or both surfaces. The wrap can be made of aluminum of about 12.5×10^{-2} mm to about 50×10^{-2} mm (about 5 to about 20 mils) thick with a coating of solder, the same type used for the plug of about 2.5×10^{-2} mm to 5×10^{-2} mm (about 1 to 2 mils) thick. The wrap can have markings thereon to identify the length required

for conductors of different diameter. Thus, a kit can be provided comprising a connector and pre-marked wrapping so that a single kit can accommodate a large number of sizes of conductors.

A connector can be provided with a metallic insert that is pretinned on its inner peripheral surface. With reference to Fig. 8, the splice connector 100 comprises two sleeves 102, one of which is provided with a metallic insert 104 having a solid coating 106 of solder on its inner peripheral surface. The insert 104 is rotatably mounted in the sleeve 102. As shown in Fig. 9, the inner wall of the insert is non-circular in transverse cross-section. This allows the connector 100 to be used for conductors that are non-circular in transverse cross-section, and particularly the conductors of sectorial high power cables.

An important feature is that the insert 104 is rotatable. This allows the insert to be aligned with the conductor so the conductor can be inserted into the insert. Without such a rotatable insert, alignment can be impossible once the splice connector 100 has been connected to a first conductor. After this first connection, it is impossible to rotate the connector to achieve alignment, and often the second conductor cannot be rotated.

Different features of the present invention described above can be used alone or in combination. For example, inserts 104, pressuring means, wrapping 90, and view ports 46 can be used alone or in combination, and can be used with both splice connectors and termination connectors.

The components needed to make a connection according to the present invention can be provided as a kit. For example, a kit can contain a pretinned sleeve having a slug of solder therein, or the slug of solder can be provided separately in the kit. Further, the kit can have a variety of sizes of slugs of solder to accommodate different sizes of cables. Further, the kit can include wrapping, inserts, and fasteners 56.

It should be realized that the barrier at the "closed" end of a sleeve can be (1) the wall of the sleeve itself as in Fig. 1A; (2) an installed barrier such as barrier 46 in Fig. 2; or (3) can in effect be the piston 28. An example of this third version is a self-activated two sleeve splice connector where there is no barrier 46 and a single spring is used to power two pistons, one piston in each sleeve.

These and other features of the present invention will be better understood with reference to the following examples.

Example 1

A termination connector 10 having the form shown in Fig. 1A was formed from a tube made of 6061 aluminum alloy that was 112.5 mm (4½ inches) long. One end of the tube was crimped closed to produce a sleeve about 50 mm (2 inches) long. The sleeve had an internal diameter of 13.67 mm (35/64 inch) and an outer diameter of 18.75 mm (¾ inch). The inner peripheral wall of the sleeve was pretinned with Neptune-S in a thick-

ness of about 1.25×10^{-1} mm (5 mils). Sixteen grams of Neptune-S was placed at the closed end of the sleeve.

The sleeve was used to make a connection with 4 gauge size stranded aluminum conductor by simultaneously pushing the conductor toward the closed end of the sleeve and melting the solder.

A conventional crimped termination was made at the other end of the conductor. A tensile force was then applied to the assembly. The crimped connection failed while the connection made with the connector 10 held fast.

Example 2

A splice connector 42 having the configuration shown in Fig. 2, except without a view hole 46, was made from a 112.5 mm (4½ inches) long tube made of aluminum 6061 alloy. The tube had an internal diameter of 13.67 mm (35/64 inch) and an outer diameter of 18.75 mm (¾ inch). A cylindrical block of 12.5 mm (½ inch) thickness was press fitted into the center of the tube, thereby forming two sleeves, each of which was pretinned with Neptune-S solder. A slug of Neptune-S solder weighing 16 grams was placed at the closed portion of each sleeve. A first 4 gauge stranded aluminum conductor was connected to one of the sleeves by simultaneously pushing the conductor toward the closed end of the sleeve while melting the solder therein. Thereafter, a second stranded 4 gauge aluminum conductor was connected to the connector by pushing the conductor toward the closed portion of the second sleeve while simultaneously melting the solder therein.

Example 3

A termination connection and a splice connection were made as described in Examples 1 and 2 except the conductors were 1,000 MCM stranded aluminum conductor and the termination connector and splice connector were correspondingly larger. Heat cycle tests are currently under way using a heat cycle period of 4 hours on, 2 hours off, a current of 1100 amps and a maximum temperature during each cycle of 130°C. The tests have been under way for three weeks and so far the connections have passed the tests in that the temperature rise of the connections has been substantially the same as the temperature rise of the conductors themselves.

From the above description, it is apparent that significant advantages compared to prior art techniques are obtained from use of the connectors and the method of the present invention. For example, the method is safe, and requires no bulky equipment, only using a simple torch. The connectors are easy to use and connections formed are not craft sensitive. Moreover, connections can be made even with cables having insulation formed from oil saturated paper.

The resultant connection can handle thermal cycling without failure, remains intact even under high tensile forces, and can be used with cables over 1,000 MCM in size, where crimps often can not be used.

Although the present invention has been described in considerable detail with reference to certain preferred versions thereof, other versions are possible. For example, the barrier 46 can be eliminated from a splice connector, and a single means for pressuring solder such as a spring can be used for simultaneously pressuring both slugs of solder toward both open ends of the connector. Further, small diameter cables can be connected to large diameter conductors without using wrapping 96. Also, although the sleeve has been referred to throughout as being "tubular", the sleeve may be made in the form of two (or more) longitudinally split partial sleeves ("clam-shells"), which may be assembled about the conductor(s) to form the tubular sleeve for use.

Claims

1. An electrical connector comprising: at least one tubular sleeve having a closed end and an open end for receiving an electrical conductor within the sleeve, the peripheral inner wall of the sleeve being pretinned, the sleeve being arranged to receive a slug of solder therein proximate to the closed end; the connector being characterised in that means is disposed within the sleeve for exerting pressure on the slug of solder so as to urge the solder towards the open end of the sleeve at the temperature at which the slug of solder melts.

2. A connector according to claim 1, characterised in that a slug of solder is located in the sleeve proximate to the closed end thereof, and is arranged on melting to fill the space between the conductor and the sleeve.

3. A connector according to claim 2, characterised in that the pressure-exerting means comprises a spring positioned between the slug of solder and the closed end of the sleeve.

4. A connector according to any preceding claim characterised in that the pressure-exerting means comprises a swellable polymer that swells at a temperature no greater than the temperature at which the slug of solder melts.

5. A connector according to any of claims 1 to 3, characterised in that the pressure-exerting means comprises a gas.

6. A connector according to any of claims 1 to 3, characterised in that the pressure-exerting means comprises reactants that react together to evolve a gas, the reactants being separated by a barrier that allows the reactants to react at a temperature greater than 100°C and up to the temperature at which the slug of solder melts.

7. A connector according to any of claims 1 to 3 characterised in that the pressure-exerting means comprises reactants that evolve gas when they react, the reactants being reactive only at a temperature greater than 100°C and up to the temperature at which the slug of solder melts.

8. A connector according to claim 2, comprising a metallic barrier between the slug of solder and the pressure-exerting means, the barrier being arranged to melt at a temperature greater than

the temperature at which the slug of solder melts, the barrier being axially slidable within the sleeve.

9. A connector according to claim 8 characterised in that the pressure-exerting means comprises a material that is a fluid at the temperature at which the slug of solder melts, and wherein the connector comprises a sealing member for preventing leakage of the fluid past the barrier.

10. A connector according to claim 2, characterised in that the slug of solder is of a size such that when a stranded conductor is inserted into the sleeve and the solder is melted, the solder completely fills interstices in the conductor, fills the space between the conductor and the inner wall of the sleeve, and extrudes out of the open end of the sleeve.

11. A connector according to any preceding claim, characterised in that it includes a star-shaped washer positioned proximate the open end of the sleeve with the points of the star extending inwardly such that they grip an electrical conductor inserted in the sleeve.

12. A connector according to any preceding claim, comprising two of said tubular sleeves in electrically conductive connection with each other.

13. A connector according to claim 12, characterised in that both sleeves have pressure-exerting means therein.

14. A method of connecting a connector to an electrical conductor, wherein the connector comprises: at least one tubular sleeve having a closed end and an open end for receiving the electrical conductor within the sleeve, the peripheral inner wall of the sleeve being pretinned, a slug of solder in the sleeve proximate to the closed end of the sleeve, and means disposed within the sleeve for exerting pressure on the slug of solder so as to urge the solder towards the open end of the sleeve at the temperature at which the slug of solder melts, wherein the method comprises placing the electrical conductor into the sleeve of the connector, the method being characterised by heating the solder to at least its melting temperature while simultaneously maintaining the conductor in the sleeve against the force of the pressure-exerting means.

15. A method according to claim 14, characterised by the step of relatively moving the conductor and the connector towards each other when the solder is molten.

16. A method according to claim 14 or 15, characterised by the step of moving the sleeve and the conductor relatively towards each other to extrude solder toward the open end of the sleeve so as substantially completely to fill any interstices in the conductor with solder and so as substantially completely to fill the space between the conductor and the sleeve with solder.

17. A method of splicing first and second electrical conductors together by means of an electrically conductive connector that comprises first and second metallic sleeves in electrically conductive connection with each other, each sleeve having a closed end, and an open end for

receiving a conductor within the sleeve, the peripheral inner wall of each sleeve being pretinned; a slug of solder in each sleeve proximate to the closed end of the sleeve; and at least in the second sleeve, means disposed within the sleeve for exerting pressure on the slug of solder to urge the solder towards the open end of the sleeve at the temperature at which the slug of solder in the second sleeve melts; wherein the method comprises the steps of connecting the first conductor to the connector by placing the first conductor in the first sleeve and heating the first sleeve to a temperature sufficiently high to melt the slug of solder in the first sleeve; and connecting the second conductor to the connector by placing the second conductor in the second sleeve the method being characterised by heating the slug of solder in the second sleeve to at least the temperature at which the slug of solder melts while simultaneously maintaining the second conductor in the second sleeve against the force of the pressure-exerting means, thereby to force the molten solder towards the open end of the sleeve to fill the space between the second conductor and the second sleeve with solder.

Patentansprüche

1. Elektrischer Verbinder, der wenigstens eine rohrförmige Hülse aufweist, die ein geschlossenes Ende und ein offenes Ende zur Aufnahme eines elektrischen Leiters in der Hülse hat, wobei die innere Umfangswand der Hülse vorverzinnt ist und die Hülse derart angeordnet ist, daß sie eine Lotmasse darin dem geschlossenen Ende benachbart aufnimmt, und wobei der Verbinder dadurch gekennzeichnet ist, daß eine Einrichtung in der Hülse angeordnet ist, die auf die Lotmasse einen Druck derart ausübt, daß das Lot in Richtung des offenen Endes der Hülse bei der Temperatur gedrückt wird, bei der die Lotmasse schmilzt.

2. Verbinder nach Anspruch 1, dadurch gekennzeichnet, daß sich eine Lotmasse in der Hülse in der Nähe des geschlossenen Endes derselben befindet und diese derart angeordnet ist, daß beim Schmelzen der Raum zwischen dem Leiter und der Hülse ausgefüllt wird.

3. Verbinder nach Anspruch 2, dadurch gekennzeichnet, daß die Druckausübungseinrichtung eine Feder aufweist, die zwischen der Lotmasse und dem geschlossenen Ende der Hülse angeordnet ist.

4. Verbinder nach einem der vorangehenden Ansprüche, dadurch gekennzeichnet, daß die Druckausübungseinrichtung ein quellbares Polymer aufweist, das bei einer Temperatur schwillt, die nicht größer als die Temperatur ist, bei der die Lotmasse schmilzt.

5. Verbinder nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß die Druckausübungseinrichtung ein Gas aufweist.

6. Verbinder nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß die Druckausübungseinrichtung ein Reaktionsmittel aufweist,

das zur Entwicklung eines Gases mitreagiert, wobei das Reaktionsmittel durch eine Sperre abgetrennt ist, die gestattet, daß das Reaktionsmittel bei einer Temperatur reagiert, die größer als 100°C ist und sich bis auf die Temperatur beläuft, bei der die Lotmasse schmilzt.

7. Verbinder nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß die Druckausübungseinrichtung ein Reaktionsmittel aufweist, das bei der Reaktion Gas entwickelt, und daß das Reaktionsmittel nur bei einer Temperatur reaktionsfähig ist, die größer als 100°C ist und sich bis auf die Temperatur beläuft, bei der die Lotmasse schmilzt.

8. Verbinder nach Anspruch 2, der eine metallische Sperre zwischen der Lotmasse und der Druckausübungseinrichtung aufweist, wobei die Sperre derart beschaffen ist, daß sie bei einer Temperatur schmilzt, die größer als die Temperatur ist, bei der die Lotmasse schmilzt und wobei die Sperre in der Hülse axial verschieblich ist.

9. Verbinder nach Anspruch 8, dadurch gekennzeichnet, daß die Druckausübungseinrichtung ein Material aufweist, das bei der Temperatur ein Fluid ist, bei der die Lotmasse schmilzt und bei dem der Verbinder ein Dichtungselement aufweist, um ein Austreten des Fluids an der Sperre vorbei zu verhindern.

10. Verbinder nach Anspruch 2, dadurch gekennzeichnet, daß die Lotmasse solche Abmessungen hat, daß, wenn ein geflochtener Leiter in die Hülse eingeführt ist und das Lot schmilzt, das Lot vollständig die Zwischenräume im Leiter und den Raum zwischen dem Leiter und der inneren Wand der Hülse ausfüllt und aus dem offenen Ende der Hülse herausgepreßt wird.

11. Verbinder nach einem der vorangehenden Ansprüche, dadurch gekennzeichnet, daß er eine sternförmige Zwischenlagescheibe enthält, die in der Nähe des offenen Endes der Hülse angeordnet ist, wobei die Spitzen des Sterns derart nach innen verlaufen, daß sie einen in die Hülse eingeführten elektrischen Leiter erfassen.

12. Verbinder nach einem der vorangehenden Ansprüche, der zwei rohrförmige Hülsen in elektrisch leitender Verbindung miteinander aufweist.

13. Verbinder nach Anspruch 12, dadurch gekennzeichnet, daß beide Hülsen darin befindliche Druckausübungseinrichtung haben.

14. Verfahren zum Verbinden eines Verbinders mit einem elektrischen Leiter, bei dem der Verbinder aufweist: wenigstens eine rohrförmige Hülse, die ein geschlossenes Ende und ein offenes Ende zur Aufnahme des elektrischen Leiters in der Hülse hat, wobei die innere Umfangswand der Hülse vorverzinnt ist, eine Lotmasse in der Hülse in der Nähe des geschlossenen Endes der Hülse und eine Einrichtung, die in der Hülse angeordnet ist, um auf die Lotmasse einen Druck auszuüben, so daß das Lot in Richtung des offenen Endes der Hülse bei einer Temperatur gedrückt wird, bei der die Lotmasse schmilzt, bei dem das Verfahren aufweist, daß der elektrische Leiter in die Hülse des Verbinders eingebracht wird und wobei sich das Verfahren dadurch auszeichnet, daß das Lot

wenigstens auf seine Schmelztemperatur erwärmt wird, während zu gleich der Leiter in der Hülse der Kraft der Druckausübungseinrichtung entgegenwirkend festgehalten wird.

15. Verfahren nach Anspruch 14, dadurch gekennzeichnet, daß der Schritt vorgesehen ist, gemäß dem der Leiter und der Verbinder in Richtung aufeinander zu relativ bewegt werden, wenn das Lot schmilzt.

16. Verfahren nach Anspruch 14 oder 15, dadurch gekennzeichnet, daß der Schritt vorgesehen ist, gemäß dem die Hülse und der Leiter relativ aufeinander zu bewegt werden, um das Lot in Richtung des offenen Endes der Hülse derart zu pressen, daß es im wesentlichen vollständig alle Zwischenräume im Leiter mit Lot und im wesentlichen vollständig den Raum zwischen dem Leiter und der Hülse mit Lot ausfüllt.

17. Verfahren zum Verspleißen eines ersten und zweiten elektrischen Leiters miteinander mit Hilfe eines elektrisch leitenden Verbinders, der erste und zweite metallische Hülsen in elektrisch leitender Verbindung miteinander aufweist, wobei jede Hülse ein geschlossenes Ende und ein offenes Ende zur Aufnahme eines Leiters in der Hülse aufweist, die innere Umfangswand jeder Hülse vorverzinnt ist, eine Lotmasse in jeder Hülse in der Nähe des geschlossenen Endes der Hülse angeordnet ist und wenigstens in der zweiten Hülse eine Einrichtung in der Hülse angeordnet ist, um einen Druck auf die Lotmasse auszuüben, so daß das Lot in Richtung des offenen Endes der Hülse bei einer Temperatur gedrückt wird, bei der die Lotmasse in der zweiten Hülse schmilzt, bei dem das Verfahren die Schritte aufweist, gemäß denen der erste Leiter mit dem Verbinder dadurch verbunden wird, daß der erste Leiter in die erste Hülse eingebracht wird und die erste Hülse auf eine so ausreichend hohe Temperatur erwärmt wird, daß die Lotmasse in der ersten Hülse schmilzt und der zweite Leiter mit dem Verbinder dadurch verbunden wird, daß der zweite Leiter in die zweite Hülse eingeführt wird, wobei sich das Verfahren dadurch auszeichnet, daß die Lotmasse in der zweiten Hülse wenigstens auf die Temperatur erwärmt wird, bei der die Lotmasse schmilzt, während zugleich der zweite Leiter in der zweiten Hülse entgegen der Kraft der Druckausübungseinrichtung festgehalten wird, wodurch das geschmolzene Lot in Richtung des offenen Endes der Hülse gedrückt wird, um den Raum zwischen dem zweiten Leiter und der zweiten Hülse mit Lot auszufüllen.

Revendications

1. Connecteur électrique comprenant: au moins un manchon tubulaire ayant une extrémité fermée et une extrémité ouverte destinée à recevoir un conducteur électrique à l'intérieur du manchon, la paroi périphérique intérieure du manchon étant pré-étamée, le manchon étant agencé pour recevoir un bloc de soudure à proximité de l'extrémité fermée; le connecteur étant caractérisé en ce que des moyens sont disposés à

l'intérieur du manchon pour exercer une pression sur le bloc de soudure afin de solliciter la soudure en direction de l'extrémité ouverte du manchon à la température à laquelle le bloc de soudure fond.

2. Connecteur selon la revendication 1, caractérisé en ce qu'un bloc de soudure est placé dans le manchon à proximité de son extrémité fermée, et est agencé, en fondant, de façon à remplir l'espace compris entre le conducteur et le manchon.

3. Connecteur selon la revendication 2, caractérisé en ce que les moyens exerçant une pression comprennent un ressort placé entre le bloc de soudure et l'extrémité fermée du manchon.

4. Connecteur selon l'une quelconque des revendications précédentes, caractérisé en ce que les moyens exerçant une pression comprennent un polymère pouvant gonfler, qui gonfle à une température qui n'est pas supérieure à la température à laquelle le bloc de soudure fond.

5. Connecteur selon l'une quelconque des revendications 1 à 3, caractérisé en ce que les moyens exerçant une pression comprennent un gaz.

6. Connecteur selon l'une quelconque des revendications 1 à 3, caractérisé en ce que les moyens exerçant une pression comprennent des corps réactionnels qui réagissent entre eux pour dégager un gaz, les corps réactionnels étant séparés par une cloison qui permet aux corps réactionnels de réagir à une température supérieure à 100°C et s'élevant à la température à laquelle le bloc de soudure fond.

7. Connecteur selon l'une quelconque des revendications 1 à 3, caractérisé en ce que les moyens exerçant une pression comprennent des corps réactionnels qui dégagent un gaz lorsqu'ils réagissent, les corps réactionnels ne réagissant qu'à une température supérieure à 100°C et s'élevant à la température à laquelle le bloc de soudure fond.

8. Connecteur selon la revendication 2, comprenant une cloison métallique entre le bloc de soudure et les moyens exerçant une pression, la cloison étant agencée pour fondre à une température supérieure à la température à laquelle le bloc de soudure fond, la cloison pouvant coulisser axialement dans le manchon.

9. Connecteur selon la revendication 8, caractérisé en ce que les moyens exerçant une pression comprennent une matière qui est fluide à la température à laquelle le bloc de soudure fond, et en ce que le connecteur comprend un élément d'étanchéité destiné à empêcher le fluide de fuir au-delà de la cloison.

10. Connecteur selon la revendication 2, caractérisé en ce que le bloc de soudure est d'une dimension telle que, lorsqu'un conducteur torsadé est inséré dans le manchon et que la soudure est fondue, la soudure remplit complètement des interstices présents dans le conducteur, remplit l'espace compris entre le conducteur et la paroi intérieure du manchon et est extrudé hors de l'extrémité ouverte du manchon.

11. Connecteur selon l'une quelconque des revendications précédentes, caractérisé en ce

qu'il comprend une rondelle en forme d'étoile positionnée à proximité de l'extrémité ouverte du manchon, les pointes de l'étoile s'étendant vers l'intérieur de manière qu'elles agrippent un conducteur électrique inséré dans le manchon.

12. Connecteur selon l'une quelconque des revendications précédentes, comprenant deux desdits manchons tubulaires en connexion électriquement conductrice l'un avec l'autre.

13. Connecteur selon la revendication 12, caractérisé en ce que les deux manchons renferment des moyens exerçant une pression.

14. Procédé pour connecter un connecteur à un conducteur électrique, dans lequel le connecteur comprend: au moins un manchon tubulaire ayant une extrémité fermée et une extrémité ouverte destinée à recevoir le conducteur électrique à l'intérieur du manchon, la paroi périphérique intérieure du manchon étant pré-étamée, un bloc de soudure dans le manchon à proximité de l'extrémité fermée du manchon, et des moyens disposés à l'intérieur du manchon pour exercer une pression sur le bloc de soudure afin de solliciter la soudure en direction de l'extrémité ouverte du manchon à la température à laquelle le bloc de soudure fond, dans lequel le procédé consiste à placer le conducteur électrique dans le manchon du connecteur, le procédé étant caractérisé par un chauffage de la soudure à au moins sa température de fusion, en même temps que le conducteur est maintenu dans le manchon contre la force des moyens exerçant une pression.

15. Procédé selon la revendication 14, caractérisé par l'étape qui consiste à déplacer relativement le conducteur et le connecteur l'un vers l'autre lorsque la soudure est fondue.

16. Procédé selon la revendication 14 ou 15, caractérisé par l'étape qui consiste à déplacer le manchon et le conducteur relativement l'un vers l'autre pour extruder la soudure en direction de l'extrémité ouverte du manchon afin de remplir

de soudure à peu près totalement tous interstices présents dans le conducteur et afin de remplir de soudure à peu près totalement l'espace compris entre le conducteur et le manchon.

17. Procédé pour joindre entre eux des premier et second conducteurs électriques au moyen d'un connecteur électriquement conducteur qui comprend des premier et second manchons métalliques en connexion électriquement conductrice l'un avec l'autre, chaque manchon ayant une extrémité fermée et une extrémité ouverte destinée à recevoir un conducteur à l'intérieur du manchon, la paroi périphérique intérieure de chaque manchon étant pré-étamée; un bloc de soudure dans chaque manchon à proximité de l'extrémité fermée du manchon; et au moins dans le second manchon, des moyens disposés à l'intérieur du manchon pour exercer une pression sur le bloc de soudure afin de solliciter la soudure en direction de l'extrémité ouverte du manchon à la température à laquelle le bloc de soudure dans le second manchon fond; lequel procédé comprend les étapes qui consistent à connecter le premier conducteur au connecteur en plaçant le premier conducteur dans le premier manchon et en chauffant le premier manchon à une température suffisamment élevée pour faire fondre le bloc de soudure dans le premier manchon; et à connecter le second conducteur au connecteur en plaçant le second conducteur dans le second manchon, le procédé étant caractérisé par un chauffage du bloc de soudure dans le second manchon à au moins la température à laquelle le bloc de soudure fond en même temps que le second conducteur est maintenu dans le second manchon contre la force des moyens exerçant une pression, afin de forcer ainsi la soudure fondue en direction de l'extrémité ouverte du manchon pour remplir de soudure l'espace compris entre le second conducteur et le second manchon.

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Fig. 1A.

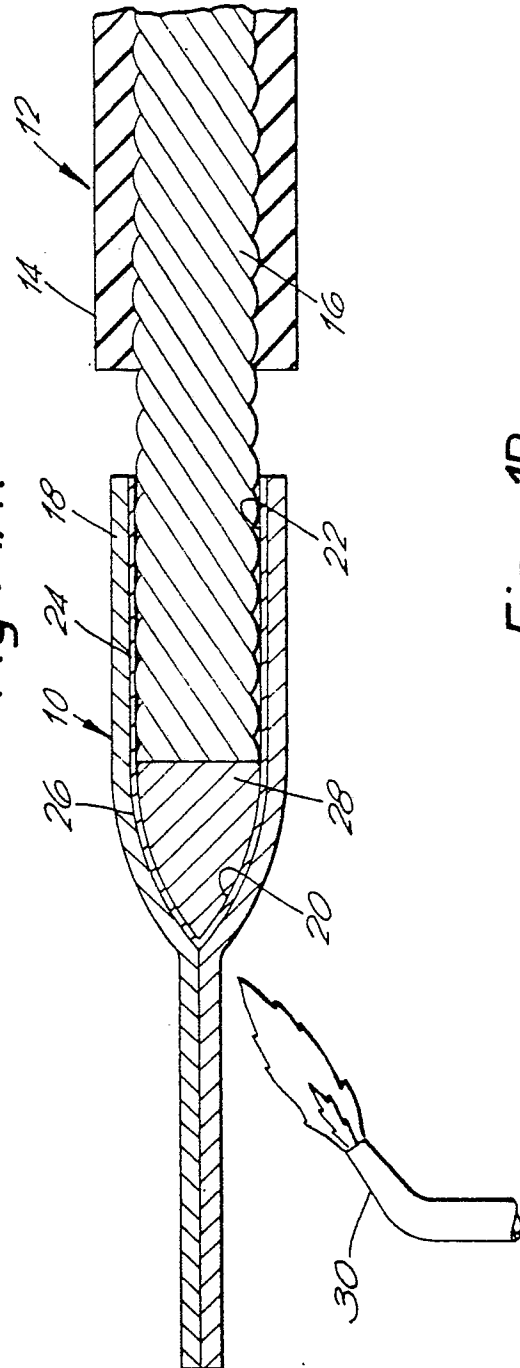


Fig. 1B.

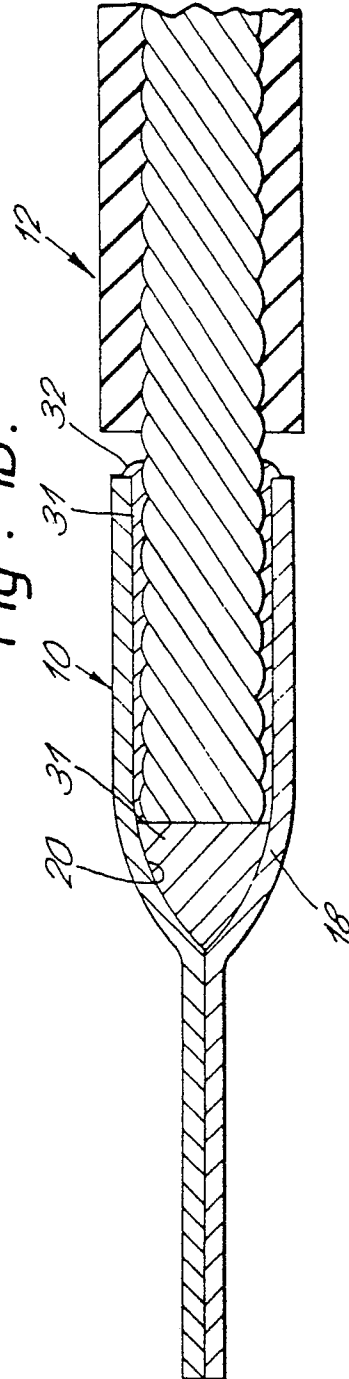


Fig. 2.

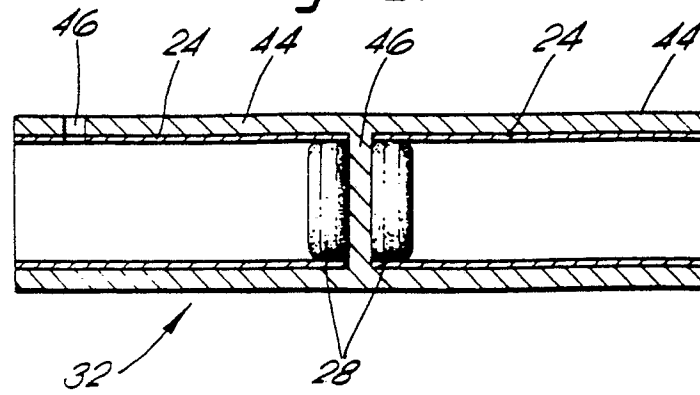


Fig. 3.

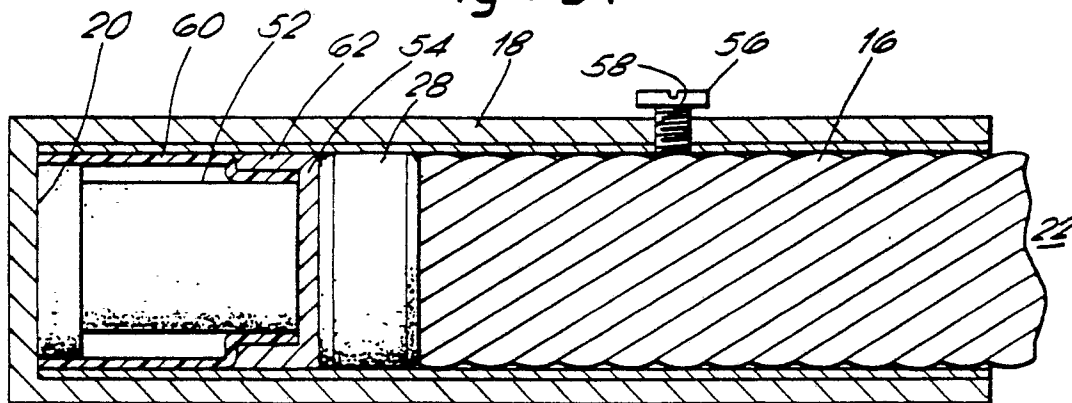


Fig. 4.

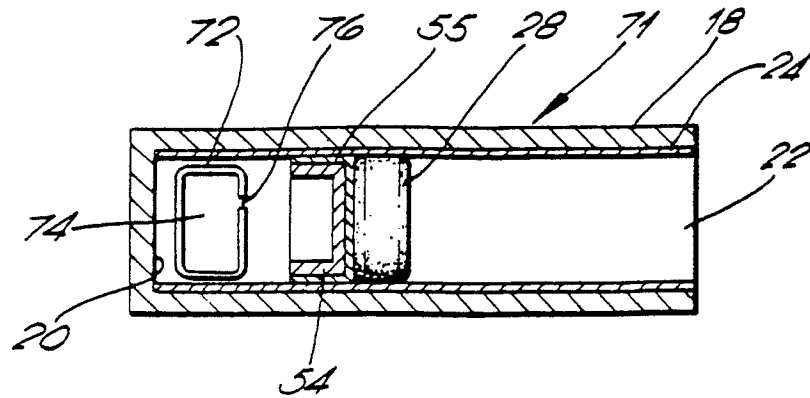


Fig. 5.

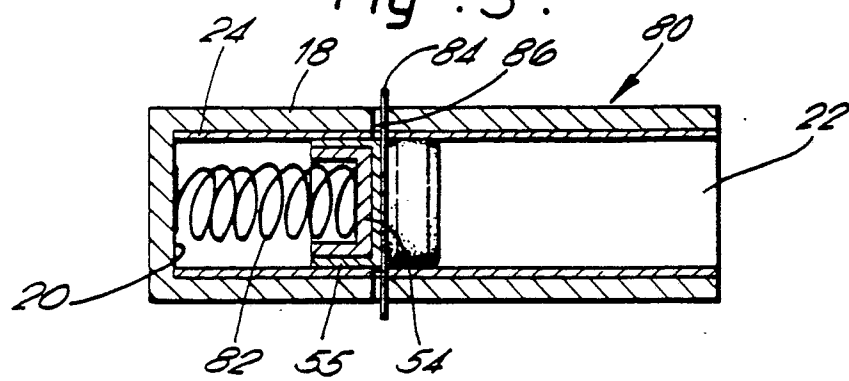


Fig. 6.

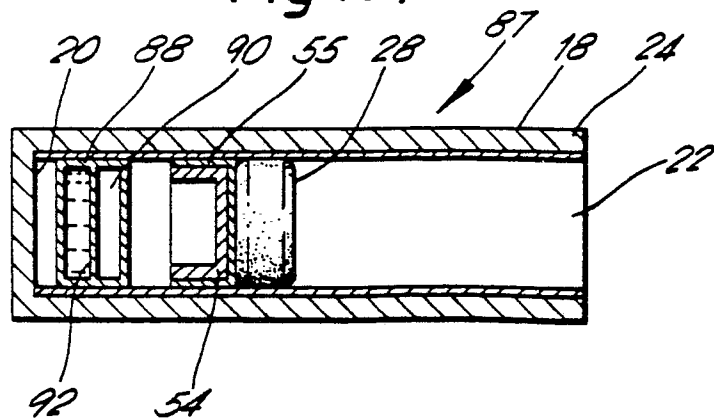


Fig. 7B.

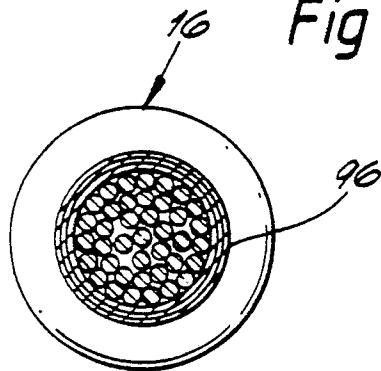


Fig. 7A.

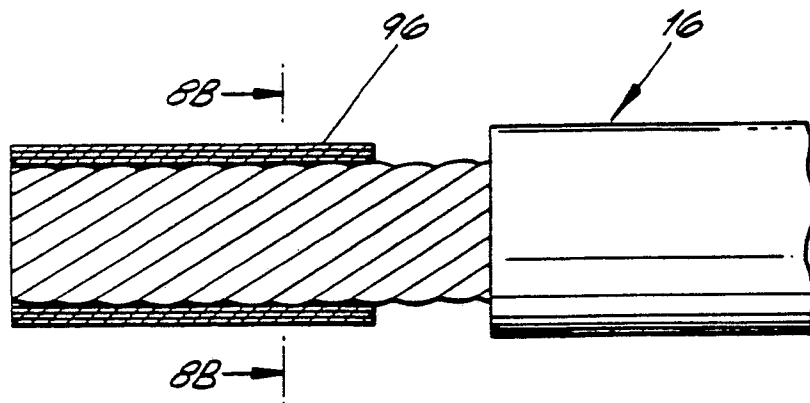


Fig. 8.

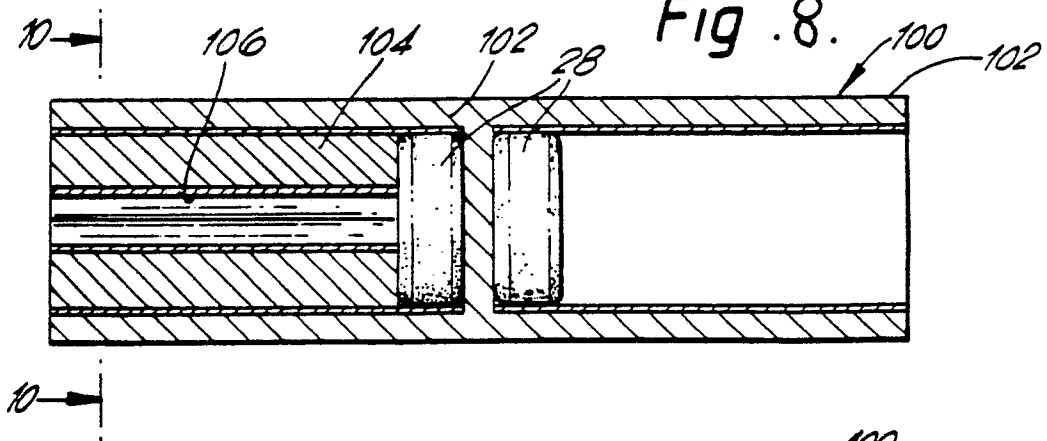


Fig. 9.

