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Method for electrically connecting non-corrodible anodes to the corrodible core of a power supply cable insulated with a standard insulating material.

An improved method of connecting one or more non-corrodible valve metal anodes, the surfaces of which have been activated by a deposit of a non-passivable material, to the corrodible core of an insulated power supply in order to produce a flexible anode assembly to be used for the cathodic protection of metallic structures.

In the inventive method, a plurality of ductile metal bushings (7, 8, 9) are disposed over a tubular valve metal anode (6) provided with a corrosion resistant outer surface. The power supply cable (2) is passed through at least one piece of an elastomeric tubing (5a, 5b) having an inner diameter slightly larger than the cable insulation and an outer diameter slightly smaller than the inner diameter of the anode. The cable and tubing is passed through the anode until a segment of the cable, previously stripped of its insulating sheath, and supplied with a highly conductive split collar (4a, 4b) having a thickness substantially similar to the combined thickness of the cable insulation and elastomeric tubing, is underneath one of the bushings, and at least one piece of the tubing is located on at least one side of the stripped cable segment and underneath at least

one of the bushings. After the anode is in place, the circumference thereof is reduced at positions corresponding to the bushings by cold-heading. The inventive method can be used to form a seal between the anode and cables insulated with low cost and chemically resistant non-elastomeric insulating materials.

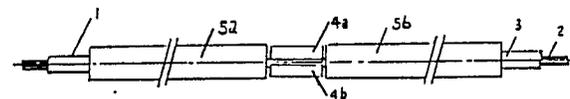


FIG. 1

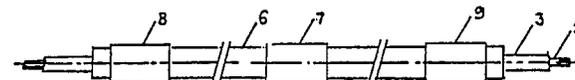


FIG. 2

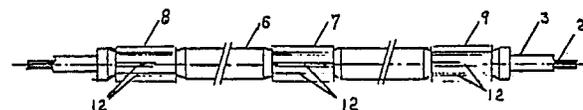


FIG. 4

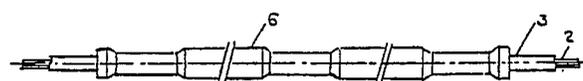


FIG. 5

EP 0 401 483 A1

METHOD FOR ELECTRICALLY CONNECTING NON-CORRODIBLE ANODES TO THE CORRODIBLE CORE OF A POWER SUPPLY CABLE INSULATED WITH A STANDARD INSULATING MATERIAL

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method for providing a sealed electrical connection between a non-corrodible anode and the corrodible core of a power supply cable. More specifically, the invention relates to a method for providing a sealed electrical connection between an anode and the core of a power supply cable which is insulated with a standard, low cost, chemical resistant insulating material.

Description of the Prior Art

The use of cathodic protection as a means for controlling the corrosion of metal structures operating in natural environments such as sea water, fresh water or soil, is well known and broadly utilized. Such systems operate by electrochemically reducing the oxygen located near the surface of the structure being protected. Corrosion of the metal is prevented as the oxygen near the structure surface is eliminated.

Cathodic protection can be applied using sacrificial anodes or, alternatively, the impressed current method. In the impressed current method to which the present invention is directed, the structure to be protected is cathodically polarized by connecting the structure to the negative pole of an electric current source. The anode is connected to the positive pole of the same current source. The resulting current circulation causes oxygen reduction to occur at the cathode while causing the oxidation of anions at the anode.

The anodes used for the cathodic protection of buried or immersed metal structures by the impressed current method often need to be placed at great distances from the surface of the structure to be protected in order to insure a uniform distribution of current over the entire structure. Therefore, the electric current must be supplied to the anodes using power supply cables exhibiting a low ohmic drop. Such cables are usually formed of insulated copper or aluminum. These highly conductive metals, however, readily undergo anodic dissolution if they come into contact with the medium, either

water or soil, in which the anodes operate.

The introduction of permanent anodes, anodes made of materials resistant to anodic corrosion and dissolution, represented a major technological improvement as these anodes offer a practically unlimited performance life or, at least, a much longer service life than conventional impressed current anodes such as graphite, cast iron-silicon-chromium, magnetite, etc. Permanent anodes are usually produced with a valve metal base such as titanium, tantalum, niobium, hafnium, tungsten, zirconium, or alloys thereof. The anodes' surface is, at least partially, coated with a layer of a material resistant to corrosion and anodically non-passivable, such as a noble metal belonging to the platinum group, including platinum, iridium, rhodium, ruthenium, palladium, osmium or, more preferably, an oxide thereof in single form or admixed with other materials, or constituting mixed crystals with oxides of valve metals or of other metals, preferably other transition metals.

With the advent of the new permanent anodes, which afford extremely long periods of operation, it has become of paramount importance to insure that all parts constituting the anode structure display a reliability and durability matching that of the anode itself. In particular, the main requirement to be met is to provide a suitable electric connection to the power supply cable which is long lasting and absolutely protected from contact with the medium wherein the anodic structure operates.

Various solutions have been heretofore proposed. Among these, U.S. Patent No. 3,134,731 illustrates a connecting method which utilizes stuffing boxes and sealing putty. U.S. Patent No. 2,841,413 describes a connecting method utilizing a sleeve welded onto one end of the anode, the conducting strands of the power supply cable being inserted into said sleeve which is then squeezed onto the strands. The electrical connection is protected by a means of an impermeable adhesive tape. By utilizing auxiliary sealing material, however, perfect sealing reproducibility and reliability is not always achieved. Moreover, the materials used to seal the connection tend to lose their properties and efficacy with time and the performance of the anodic structure often depends on the effective life of these auxiliary means.

In order to obviate the need for stuffing boxes, sealing tapes and other auxiliary means, U.S. Patent No. 4,526,666 suggests the use of a continuous cable insulated with an elastomeric material such as ethylpropylene rubber (EPR) or chlorinated polysulphonated polyethylene (HYPALON pro-

duced by DuPont de Nemours) which is passed through tubular anodes. The anodes are positioned over portions of the cable which have previously been stripped of their insulation and the ends of the anodes are crimped onto the insulation forming a seal between the anode and the insulating sheath. A split collar of conductive material positioned on the stripped portion of the cable insures an adequate electrical connection between the anode and cable.

While the above-described method eliminates the need for additional sealing means by using the elastomeric sheathing material to form the necessary seal, this method is not without disadvantages. Because of the high cost of cables insulated with elastomeric insulating materials, it is not feasible to design anode systems having only one anode per cable and therefore, as a cost reduction means, a plurality of anodes must be strung along a single cable. The placement of multiple anodes on a single cable is considered disadvantageous as, when several anodes are installed on the same cable, the failure of one anode on the cable will automatically break the electrical circuits of all anodes on the cable located below (downstream of) the failed anode. Further, these elastomeric insulating materials are not highly resistant to chemicals and, when for instance the cables are buried, the environment will quickly deteriorate the insulation, at which time the underlying cable will begin to corrode. Elastomeric insulating materials are especially notorious for their low resistance to wet chlorine which is often encountered when the anodes are used in seawater applications. These materials degrade very quickly in the presence of chlorine, exposing the copper conductor of the power supply cable to the aggressive environment.

OBJECTS OF THE INVENTION

The present invention directly addresses the above-mentioned problems and provides a method for connecting an anode onto a power supply cable insulated with a standard low cost, chemical resistant insulating sheath, in a leak-proof and long lasting manner, without relying on stuffing boxes, sealing tapes or other auxiliary sealing means.

SUMMARY OF THE INVENTION

The method of the present invention is particularly well suited for the connection of one or more anodes placed and fixed at intervals, along the insulated power supply cable passed coaxially

through the anode or anodes and which act as both a supporting element and a means for conducting current from one anode to another.

The inventive method for making a sealed electrical connection between anodically insoluble tubular valve metal anodes and a corrodible core of an insulated power supply cable, comprises:

(a) disposing a plurality of ductile metal bushings over the tubular valve metal anode provided with a corrosion resistant outer surface;

(b) passing the power supply cable through at least one piece of an elastomeric tubing having an inner diameter slightly larger than the diameter of the cable insulation and an outer diameter slightly smaller than the inner diameter of the anode;

(c) passing the cable and tubing through the tubular anode until a segment of the cable, previously stripped of its insulating sheath and provided with a split collar of highly conductive metal around the conductive core of the cable, said collar having a thickness substantially similar to the combined thickness of the cable insulation and elastomer tubing, is underneath one of the bushings and at least one piece of the tubing is located on at least one side of the stripped cable segment and underneath at least one of the bushings and;

(d) plastically reducing the circumference of the anode in correspondence to the externally exposed bushings by cold-heading the valve metal anode around the split collar disposed on the conductive core in correspondence to one of the bushings and directly around the tubing in correspondence to the bushings located on at least one side of the bushing in correspondence to the split collar.

The cable is flexible and made of plaited or stranded wires with a conducting metal such as copper, tinned copper, aluminum and/or steel. The cable can be insulated with any generally acceptable insulating material. Several cable insulating materials have recently been developed specifically for use in the cathodic protection industry. These materials include dual layer insulations wherein the outer layer is high molecular weight polyethylene (HMWPE) and the inner layer is KYNAR (polyvinylidene difluoride produced by Pennwalt Corp.) or HALAR (fluoropolymer produced by Allied Chemical Corp.). These materials display a superior resistivity to the acidic and sometimes chlorine saturated environments in which anodes often operate, and the use thereof is preferable. Other well suited insulating materials include HMWPE, KYNAR, HALAR, TEFLON (polytetrafluoroethylene produced by E.I. DuPont de Nemours & Co.), combinations of HMWPE and KYNAR, HMWPE and HALAR, and HMWPE and TEFLON.

The assembly described in this application can be used in all types of cathodic protection installations including deep ground beds, horizontal

ground beds, shallow vertical ground beds, offshore installations, water tanks, and others. The use of these assemblies is particularly attractive in applications where it is very difficult to replace the anodes such as in deep ground beds, and in ground beds or sea water applications wherein wet chlorine is likely to come into contact with the cable insulation. Placement of all anodes on one cable is not recommended where anode installation is difficult and expensive as the failure of one anode will break the electrical circuit to all downstream anodes. The ability of the inventive assembly to operate with relatively inexpensive power supply cables makes the use of multiple cables economically feasible.

In the inventive method, a plurality of ductile metal bushings are disposed over a tubular valve metal anode sleeve provided with a corrosion resistant outer surface. The anode can be formed of any valve metal base including titanium, tantalum, niobium, hafnium, tungsten, zirconium, or alloys thereof, with or without a conductive coating. Preferably, the anode is formed of titanium with a conductive mixed metal oxide catalytic coating. Preferably, the metal oxide catalytic coating will be formed of a non-passivable material, such as a noble metal belonging to the platinum group, including platinum, iridium, rhodium, ruthenium, palladium, osmium or mixtures thereof, more preferably, an oxide of one of these materials or a mixture thereof or other transition metals are used.

The power supply cable is passed through at least one piece of elastomeric tubing, this tubing having an inner diameter slightly larger than the cable insulation, and an outer diameter slightly smaller than the inner diameter of the anode. preferably, this tubing is formed of elastomeric EPDM (diene modified ethylene propylene copolymer rubber) tubing. Other suitable tubing materials include EPR (ethylene-propylene copolymer), neoprene, and natural rubber. The cable and tubing are passed through the anode until a segment of the cable previously stripped of its insulating sheath and supplied with a highly conductive split collar having a thickness substantially equal to the combined thickness of the cable insulation and elastomeric tubing is underneath one of the bushings and at least one piece of the tubing is located on at least one side of the stripped cable segment and underneath at least one of the bushings.

The split collar is preferably formed of silver plated copper but can also be formed of unplated copper, tinned copper, aluminum, a nickel alloy a valve metal or other conductive materials. Bushings are preferably copper but can be also made of iron or other materials. The bushing may have a wall thickness of between 0.1 and 10 mm and a length substantially equal to or greater than that of the

split collar fixed to the conducting core of the power supply cable.

After the necessary positioning, fixing is carried out by inserting the thus-prepared anode assembly into a segmented circular die of a swaging press, and closing the die onto the external bushing, swaging (cold-heading) the valve metal tube onto the split collar and conductive core of the power supply cable, thus providing a solid electrical connection between the anode and the cable. The external ductile bushings undergo unavoidable superficial wrinkling due to the impressing of the circular swaging die and allow for a more uniform reduction, without any substantial wrinkling of the underlying valve metal.

Sealing occurs by placing the additional bushings near the two ends of the anode at positions overlying the elastomeric tubing, and cold-heading the additional bushings as described above. Thus, the valve metal tube is plastically squeezed onto the elastomeric tubing which, in turn, is squeezed onto the insulating sheath of the power supply cable insuring a perfect hydraulic seal.

The inventive method is further advantageous as the uniform plastic circumferential reduction of the anode over the elastomeric tubing is achieved without giving rise to any perceptible wrinkling of the valve metal tube itself, which could cause microcracking or expose the valve metal to possible localized stress corrosion. Moreover, the exceptionally uniform circumferential reduction of the anode underneath the ductile bushings prevent the pinching of the elastomeric tubing which, otherwise, could give rise to defects in the hydraulic seal.

The external ductile bushings may be removed after the assembly procedure is terminated with, for example, the aid of a burr mill, or they may be left in place. The bushings may also be formed of a valve metal, resistant to anodic dissolution or, more preferably, they can be formed with anodically dissolvable materials, such as copper, aluminum, iron (ARMCO iron), or cuprous-nickel alloys. In the latter case, the bushings are left in place and become an integral part of the anode, being anodically dissolved during the initial period of operation.

Moreover, the use of dissolvable bushings made of copper or cuprous-nickel alloy provide, through their dissolution, an efficacious source of inhibitory agents, essentially represented by cuprous ions, against the bio-fouling of the surface of the structure to be protected during the initial conditioning of said surface.

The tooling system which is utilized for the swaging process comprises a tool body into which is fitted a segmented bored die, in which bore diameter may be varied by suitably substituting the segments constituting the die. The tool body is

assembled on the press platen and on the ram of a press. The press is preferably of the hydraulic type having a capacity of about 100 to 200 tons. The hydraulic system of the press may advantageously be designed to give a fast approach speed at low pressure, followed by a slower high pressure closing rate as the assembly is swaged. The swaging operation is completed at one stroke by closing the die around the bushing on the outside of the tubular valve metal anode.

The method of the present invention may be better illustrated making reference to the series of drawings schematically represented by the attached figures and the detailed description of the preferred embodiment of the invention which follows.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 is a view of a portion of the power supply cable prepared for the connection to an anode.

Fig. 2 is a view of a tubular anode inserted onto the cable of Fig. 1.

Fig. 3 is a schematic illustration of the swaging die used to reduce the diameter of the anode of Fig. 2.

Fig. 4 illustrates the tubular anode of Fig. 2 after the swaging operation.

Fig. 5 shows the anode of Fig. 4 after the removal of the bushings used for pressing or, after the anodic dissolution of the same has terminated.

Fig. 6 shows a terminal anode wherein one end of the anode is sealed with a titanium end cap.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

According to the present invention, the location or locations of anodes on a cable 1 are marked. For example, the user may wish to have two tubular anodes 6 with outer diameters of 2.5 cm and inner diameters of 2.3 cm and lengths of 100 cm, mounted on No. 10 AWG (American Wire Gage) HMWPE insulated cable 1 with a total length of 70 m with the anodes having a center to center spacing of 6 m. The cable 1 is marked so that each anode 6 can be placed in the correct position on the cable 1. One mark is placed 1 m from the end of the cable 1 for the terminal anode as shown in Fig. 6, and marks are placed 6 and 7 m from the end of the cable for the intermediate anode as shown in Fig. 5. Additional marks are placed 0.47 m, 0.53 m, 6.47 m, and 6.53 m from the end of the cable.

The cable insulation 3 is then removed from the power supply cable 1 between the 0.47 m and the 0.53 m marks and between the 6.47 m and the 6.53 m marks.

The elastomeric tubing 5a, 5b is then placed onto the cable. The tubes would have an inner diameter of approximately 3/8 of an inch and an outer diameter of approximately 7/8 of an inch. Four tubes with lengths of 0.47 m would be required. One tube would be slid down the cable so that it extended from the 6.53 m to the 7 m points from the end of the cable. The next tube would extend from the 6.0 to the 6.47 m points from the end of the cable. The third tube would extend from the 0.53 to the 1.0 m points and the fourth from the 0.00 to the 0.47 m points. Metal collars 4a, 4b are placed around the bared cable wire 2. Two silver plated collars approximately 0.04 m long would be placed around each 0.6 m long section of previously bared cable wire.

Figure 1 illustrates the assembly for the intermediate anode at this point in the process. The cable insulation 3 has been removed for a short distance so that the metal collars 4a and 4b can be placed around the bare cable wire 2. Two pieces of elastomeric EPDM tubing, 5a and 5b, have been slid onto the cable 1 with one piece being located on each side of the bared portion of the cable. The tubular anode 6 is then slid onto the cable. The anode 6 would be slid so that the intermediate anode extended from the 6 to 7 m mark from the end of the cable and the terminal anode from the 0 to 1 m mark from the end of the cable. The intermediate anode is a hollow tube open on each end. The terminal anode is open at one end at the 1 m mark but is capped on one end at the 0 m mark of the cable by an end cap 13. The terminal end of the terminal anode may also be sealed by locating the terminal anode and the terminal piece of elastomeric tubing so that they extend past the end of the cable and forcing a non-elastomeric plastic rod with a diameter substantially equal to the inside diameter of the elastomeric tubing, into the elastomeric tubing and crimping the rod in place.

The bushings are slid to previously marked locations on the tubular anodes. The 28 mm OD x 26 mm ID x 4 cm long copper bushings would be located at the 6.95 to 6.99 m, the 6.48 to 6.52 m, the 6.01 to 6.05 m, 0.95 to 0.99 m, the 0.48 to 0.52 m, and the 0.01 to 0.05 m locations from the end of the cable. Figure 2 illustrates the assembly for the intermediate anode at this point in the process. The cable 1 has been inserted into the coated titanium anode 6. The anode tube is located so that the middle metallic bushing 7 is located over the metal collars 4a and 4b, and the outer metallic bushings 8, 9, are located over the pieces of elastomeric

tubing 5a and 5b.

The assembly is laterally inserted into the tool body schematically illustrated in Figure 3, which comprises a tool body 10 into which is fitted a segmented bored die, consisting of a series of sliding segments 11. The die is schematically illustrated in Figure 3 in its closed position, at the stop limit of the press stroke. Three successive swaging operations are carried out respectively in correspondence to bushings 7, 8, and 9 providing, as previously illustrated, an electrical connection and the sealing of the connection with respect to the external environment. The bushings are crimped so that the OD of the bushing after crimping is 24.5 cm. As illustrated by Figure 4, after crimping, the metal bushings 7, 8, and 9 ductily take up longitudinal wrinkling 12 along their external surfaces. The bushings 7, 8, and 9 are then removed either mechanically or by anodic dissolution during the initial operation period in the operating environment. The anode at this point is represented by Figure 5.

The swaged portions or segments of the titanium or other valve metal anode in correspondence to the central connection and to the sealing of the two ends are substantially cylindrical and free of any wrinkling. The two ends are sealed without necessitating the employment of a power supply cable having an elastomeric insulating material. The method of the invention does not resort to any auxiliary means for the sealing of the electrical connection, which is obtained directly between the valve metal tube and elastomeric tubing and the elastomeric tubing and the cable insulation. This seal produces an exceptionally good and long-lasting connection perfectly protected from corrosion.

Other advantages of the method of the invention are the perfect reproducibility of the quality of the connection, which is quickly completed due to the substantially automated process which reduces the probability of faulty connections or sealing imperfections due to poor workmanship. Furthermore, the two sealing swages on the insulating cable at the two ends of the tubular anode improve the sturdiness of the assembly and effectively prevent any direct stress on the electrical connection during transportation, installation, and the use of the anode assembly.

Other modifications of the present invention will occur to those skilled in the art upon a reading of the present disclosure. These modifications are intended to be included within the scope of this invention.

Claims

1. A method for making a sealed electrical connection between anodically insoluble tubular valve metal anodes and a corrodible core of an insulated power supply cable, said method comprising:

(a) disposing a plurality of ductile metal bushings over the tubular valve metal anode provided with a corrosion resistant outer surface;

(b) passing the power supply cable through at least one piece of an elastomeric tubing having an inner diameter slightly larger than the diameter of the cable insulation and an outer diameter slightly smaller than the inner diameter of the anode;

(c) passing the cable and tubing through the tubular anode until a segment of the cable, previously stripped of its insulating sheath and provided with a split collar of highly conductive metal around the conductive core of the cable, said collar having a thickness substantially similar to the combined thickness of the cable insulation and elastomer tubing, is underneath one of the bushings and at least one piece of the tubing is located on at least one side of the stripped cable segment and underneath at least one of the bushings and;

(d) plastically reducing the circumference of the anode in correspondence to the externally exposed bushings by cold-heading the valve metal anode around the split collar disposed on the conductive core in correspondence to one of the bushings and directly around the tubing in correspondence to the bushings located on at least one side of the bushing in correspondence to the split collar.

2. The method of claim 1 wherein the externally exposed ductile metal bushings are formed of an anodically soluble metal selected from the group comprising copper, aluminum, iron, cuprous-nickel alloys and mixtures thereof.

3. The method of claim 1 wherein three bushings are disposed over the anode, one of which being disposed at a substantially central position with respect to the anode and the remaining being disposed near the two ends of the anode, respectively.

4. The method of claim 1 wherein the power supply cable is insulated with a dual layer insulation comprising an outer layer of high molecular weight polyethylene and an inner layer of polyvinylidene difluoride or fluoropolymer.

5. The method of claim 1 wherein the power supply cable is insulated with high molecular weight polyethylene insulation.

6. The method of claim 1 wherein said elastomer tubing is diene modified ethylene propylene copolymer rubber tubing.

7. The method of claim 1 wherein said collar is formed of silver plated copper.

8. The method of claim 1 wherein said anode is formed of titanium coated with a conductive

mixed metal oxide catalytic coating.

9. The method of claim 2 wherein the bushings are removed by anodic dissolution during initial anodic operation in an operating environment.

10 The method of claim 2 wherein the bushings are removed by mechanical means prior to use. 5

11. An intermediate anode formed by the method of claim 3.

12. A terminal anode formed by the method of claim 1 wherein a first bushing is disposed at a substantially central position with respect to the anode and a second bushing is disposed at one end of the anode, the terminal end of said anode being sealed. 10 15

13. The terminal anode of claim 12 wherein an end cap is welded to the terminal end.

14. The terminal anode of claim 12 wherein said end cap is formed of coated titanium.

15. The terminal anode of claim 11 wherein a non-elastomeric plastic rod with a diameter substantially equal to the inner diameter of the elastomeric tubing is forced into the tubing and the titanium anode is crimped to the position corresponding to the insertion of the rod. 20 25

16. In a method of cathodically protecting metallic structures in electrolytes from corrosion, the improvement comprising using as the anode the electrode produced by the method of claim 1. 30

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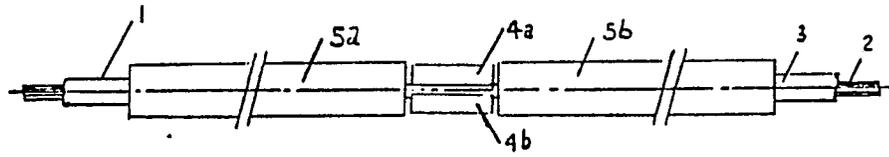


FIG. 1.

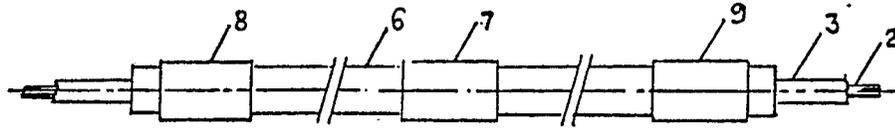


FIG. 2

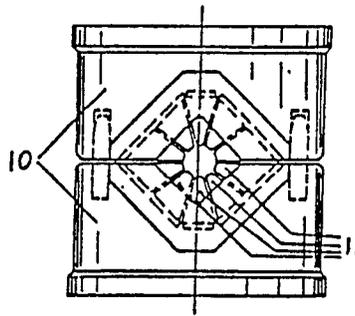


FIG. 3

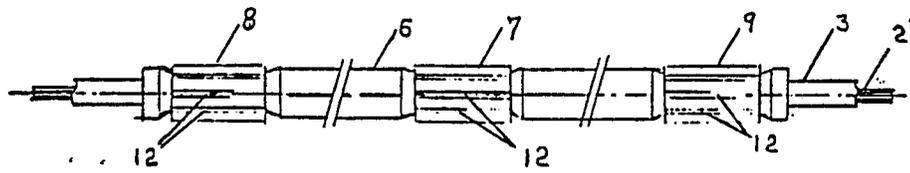


FIG. 4

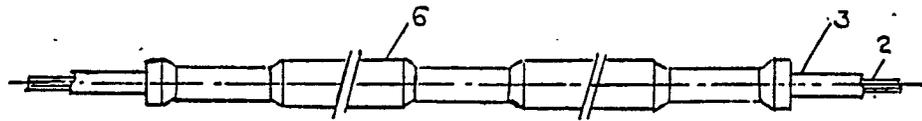


FIG. 5

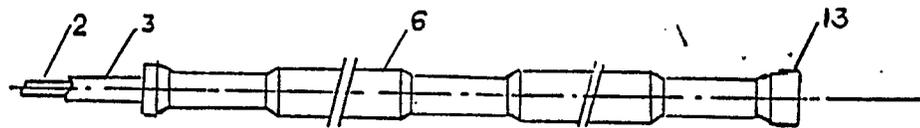


FIG. 6



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X, D	US-A-4 526 666 (BIANCHI) -----	1-11	C 23 F 13/02
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			C 23 F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 13-09-1990	Examiner NGUYEN THE NGHIEP
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			