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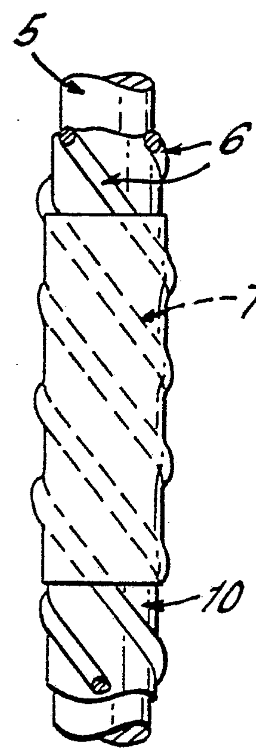
(54) Title: IMPRESSED CURRENT SYSTEMS FOR CATHODIC PROTECTION

(57) Abstract

Submergeable structure provided with cathodic protection means comprising a flexible impressed current anode assembly including an elongate electrode (6) wound around a support (5) to provide an anodic region and rope extensions (5) extending from the anodic region in at least two different directions, said extensions being secured to the structure so as to space the anodic region from metal of the structure to be protected. In addition, the invention includes an impressed current anode assembly suitable for use as the above defined cathodic protection means and having an anodic region comprising an elongate electrode (6) wound around an insulating rope (5) which passes through the anodic region and extends therefrom in at least two different directions.



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IMPRESSED CURRENT SYSTEMS FOR CATHODIC PROTECTION

This invention relates to submergeable structures provided with cathodic protection means comprising an impressed current rope anode assembly and to impressed current rope anode assemblies which are suitable for cathodic protection of marine, and other submergeable, structures. The invention also provides a new reference electrode.

Cathodic protection is the chief line of defence for corrosion control of steel structures in a marine environment. Whilst sacrificial anodes may be used for this purpose, the design lives of 25 to 30 years which have been specified as the theoretical maxima for such anodes are open to doubt. Sacrificial anodes do, of course, have the advantage that they provide immediate protection of the structure when submerged. Impressed current systems for cathodic protection require a DC power supply, and there may be considerable delay due to other constraints in providing this effectively in an offshore structure. Furthermore, existing impressed current systems are based on long life anodes with heavy coatings of platinum on, for example, a substrate of niobium. Such anodes are extremely expensive.

It will be apparent that in many circumstances, the provision of a relatively short to medium life system would have considerable advantages (say from 3 to 10 years in expected lifetime). Such an impressed current anode system should be relatively cheap and easy to install. All impressed current anodes have the great advantage that their output and effectiveness can be monitored and they are extremely easy to control.

According to the present invention there is provided a submergeable structure provided with a cathodic protection means comprising a flexible impressed current anode assembly including an elongate electrode wound around a support to provide an anodic region and rope extensions extending from the anodic region in at least two different directions, said extensions being secured to the structure so as to space the anodic region from metal of the structure to be protected.

Preferably a plurality of said electrodes are employed per anode assembly, more preferably three of said electrodes.

The electrode(s) may comprise titanium as a substrate having an anodically active coating.

The said electrodes may be in the form of wires, e.g. platinised titanium or niobium wire (desirably copper-cored) such as the type supplied commercially by IMI Marston Limited.

The skilled reader will appreciate that platinum is the most suitable material for the protection of submerged structures as a result of its extreme resistance to corrosion. (Other possible materials include all corrosion-resistant anodically active materials, in particular, the platinum group metals, alloys and oxides thereof.) However, the use of solid platinum anodes being generally too expensive, it is preferred to employ anodes which comprise a platinum coating on a substrate. Niobium and titanium are desirable substrates which can be used with platinum and which possess the characteristic of developing an oxide film on the surface thereof which protects the metal from further corrosion. These metals have highly desirable electrolytic characteristics. (The other film-forming metals, hafnium zirconium and tantalum can also be used.)

By the term "rope" as used herein we mean a material which is elongate and which is resistant to corrosion, rot proof and has load-bearing capability.

The present invention, in fact, also provides an impressed current anode assembly suitable for use as the cathodic protection means defined above and having an anodic region comprising an elongate electrode wound around an insulating rope which passes through the anodic region and extends therefrom in at least two different directions. By the term "insulating" as used above we mean substantially non-conductive of electricity.

Polypropylene or polyester ropes are highly suitable materials for use in ropes in the present invention and a typical polypropylene rope for use in the present invention has a diameter of 20 millimeters. Such ropes, being insulating ropes, are, of course, particularly suitable for use in the above-defined anode assembly. Metal ropes can be used in those embodiments where the rope need not be insulating, although such ropes must, of course, be insulated from the metal structure being protected. Indeed, the present invention envisages that in many circumstances the nature of the rope is not of great significance. The invention includes structures provided with anode assemblies (and, indeed, the assemblies themselves) wherein the rope is totally insulating, totally electrically conductive, or part of the rope is insulating and part is electrically conductive. By way of example, some form of insulated current feeder can be used as one of the rope extensions - the extension then having the dual functions of supporting and assisting in positioning the anodic region and of supplying current thereto. In the above-defined anode assembly which incorporates an insulating rope passing through the anodic region, the elongate electrode must be selected from a material which is sufficiently electrically conductive to allow for adequate current for satisfactory cathodic protection with a modest voltage. In addition to the nature of the material for the electrode, the shape of the elongate electrode (e.g. strip or wire from) is significant in this context. In particular, a wire-like shape is more suitable to provide the desired electrical characteristics than a stouter and less elongate form of electrode. It will be appreciated that (as will be indi cated in more detail later in connection with a specific embodiment of the invention to be described with reference to the accompanying drawings) the above-defined anode assembly involving a relatively lightweight rope and a long lightweight electrode wound therearound has several considerable practical advantages.

In any cathodic protection system, the protection is provided by the current supplied and it is, of course, necessary to provide a voltage to "drive" the current. As indicated earlier, titanium and niobium (and the other film-forming metals) in use develop oxide films which cover the surface of the metal. When a piece of, for example, titanium, is first connected as an anode in an electrolytic cell, the plot of current against voltage will show an initial increase in current with an increase in voltage followed by a rapid fall in current to a small leakage value. This reflects the formation and existence of the protective oxide film on the surface of the metal. However, as the voltage continues to increase the oxide film breaks down and thereafter the plot of current against increasing voltage is linear, an increase in voltage resulting in an increase in current flowing. In physical terms, the subjection of a piece of, for example, titanium to a voltage in excess of the breakdown voltage will result in destruction of the protective oxide layer and rapid dissolution of the metal. This is, of course, disastrous from the point of view of a stable electrode system. With titanium the breakdown voltage appears to be of the order of 8 to 10 volts whereas with niobium the breakdown voltage is of the order of 100 volts. Since in practice a platinised titanium (for example) anode may comprise a piece of titanium which is only partially covered by a layer of platinum, it is important to restrict the voltage appearing between such bare titanium and the adjacent electrolyte to a value below the breakdown voltage, otherwise the titanium will corrode. Obviously, the higher the operating voltage which can be applied the greater the current flow and the more effective the cathodic protection. One method of avoiding corrosion induced by voltage breakdown is to employ niobium for the substrate although it has a much greater cost.

Where a platinised, e.g. titanium, anode is located close to e.g., a steel structure which it is desired to protect, the resulting electrical field when the anode is in operation has a voltage gradient which is such that operating voltages which are close to the breakdown voltage are dangerous; there being great risk of breakdown of the protective oxide film on those portions of the, e.g. titanium, which are not coated with platinum and subsequent destruction of the anode structure. In contrast, it has been found that the same anode located an appreciable distance from the structue which it is desired to protect may be operated at a system voltage in excess of the breakdown voltage sine the voltage gradient around the anode when the anode is in use is much less severe. Furthermore, a better current distribution is obtained with such a structure and consequently better and more uniform overall protection of the structure being protected. With a concentrated field of the type which results with an anode located very close to the structure to be protected, very high local protection currents will be produced adjacent to the anode, resulting in the possibility of problems such as hydrogen embrittlement and excessive cathode deposits, together with difficulty in obtaining adequate current at some distance from the anode. Thus, if the anode employed in a cathodic protection system can be located an appreciable distance from the structure being protected, it will survive a higher operating voltage and can provide higher current output with more satisfactory protection. In such circumstances, the life of the platinised anode is then related to the thickness of the platinum that has been applied. In practice, the minimum practical thickness of platinum to be applied to titanium or niobium surfaces is 2.5 microns. Longer lives can be obtained by employing thicker platinum coatings. A suitable thickness would be 5 to 20 microns.

In the present invention, the incorporation of rope into the anode assembly extending in at least two different directions from the anodic region enables the anodes to be suspended inside the framework of, for example, a marine structure with the anodic regions thereof relatively distant from any steel work. This can allow a titanium-based anode to be used at a system voltage in excess of its breakdown voltage. In the case of a titanium-based electrode, the ratio of the spacing between the anodic region and the structure being protected to the anodic length is usually from about 0.4 to about 4, preferably from 0.5 to 2.

The present invention is extremely flexible in that a "tailor-made" cathodic protection system can be designed for any particular structure to be protected and the system can be used as a "retrofit" installation to provide protection for a structure which is already suffering corrosion attack. Thus, for example, a number of rope anode assemblies in accordance with the present invention can be strung at each level in an offshore oil rig to provide, at each level, a cone-shaped overall anodic system to which a suitable current can be applied.

A number of the anode ssemblies of the present invention together with any associated cables (if desired) and/or with suspensions can be made up and coiled onto a drum to ease transport and handling on site at sea or elsewhere.

The preferred structure for the anode assembly of the present invention is a polyester or polypropylene rope having wound around it three copper-cored platinised titanium wires of, for example, 4 millimeter diameter, spirally wound round the rope to conform to the pitch of the rope itself. The rope may be protected from degradation products produced electrolytically at the anode surface by covering the rope with a protective layer, e.g. heat shrink sleeving such as the material sold under the trade name "Kynar". The same material may also be used to attach the electrodes to the rope at periodic intervals by providing a series of spaced external Kynar sleeves around the electrode windings along the overall rope structure.

With the structure as described above, power connections may be effected by means of flexible insulated conductors similar to welding cable. Electrical cable connection may be made at one end of the anode in such a manner that sea water dissolution products do not contaminate the connection. Furthermore, the anchoring arrangements (which obviously depend upon the structure which it is desired to protect) at each end of the rope may be fabricated from non-metallic material except where bolts are required.

It is important to appreciate that in the present invention the length of the rope and the suspension arrangements for the entire structure are unrelated to the length of the electrodes and may be designed to suit the particular application. A harness system may be designed for a number of such structures to provide protection for a sizeable structure.

Using the preferred titanium-based rope anode assembly described above it has been calculated that the maximum economical output is 250 amps per anode. With this structure, if the anodic region on the rope is longer than 10 meters a reduced output per unit length is obtained and a large voltage drop occurs making such longer anodic regions undesirable. It is also not desirable (for the reason described above) to have the anodic region closer to the steel structure being protected than 10 meters or so. The pitch of the anode windings is preferably dependent upon the pitch of the lay of the rope. In practical terms it is believed that from 12 to 18 meters length of the platinised titanium wire is desirable to provide (in wound form) the 10 meter anodic region length, more preferably from 12 to 14 meters of platinised titanium wire. In practice, from 5 to 15 volts are applied to the anodes.

Reference has been made above to the use of "Kynar" as the material for heat shrink sleeving to protect the rope and to hold the electrode windings to the rope. This material is highly desirable because of its extreme chemical inertness. However, it should be noted that each of the anode wires where they emerge at the ends of the, for example, 10 meter, anodic region length may be protected by heat shrink sleeving (e.g. Atum shrink fit sleeve manufactured by Raychem Limited) or the ends of the anode wires may be sealed with titanium.

Suspension of an anode assembly in accordance with the present invention may be achieved by using eyes at each end of the rope and utilising standard rope and webbing slings at anchor points. A preload may be applied to the assembly during installation to restrain excessive movement during storms (particularly important with offshore structures).

A reference electrode may be attached to the assembly of the present invention or incorporated in the structure of the present invention by any suitable means in order to enable measurement of the potential of the structure which is to be protected. Thus, a reference electrode may be connected to one or both (or each) of the rope extensions substantially near the end thereof in order that the potential of the structure being protected in the immediate vicinity of the reference electrode(s) may be assessed. A suitable form of reference electrode comprises a substantially cylindrical block of zinc of high purity having a galvanised steel wire core therein, galvanised steel wiring leading from the core for electrical connection purposes. Being cylindrical, such an electrode may be positioned on the rope extensions of the anode assemblies utilised in the present invention by simply sliding it along the desired rope. The electrode may be positioned where desired by the use of heat shrink sleeving such as noted above and cables and electrical connections associated therewith similarly protected by the use of heat shrink sleeving. In this way, the potential at desired points in the structure being protected may be monitored and, if desired, feedback may be arranged of such monitored potential to an automatic rectifier to ensure that the current supplied through the anodic region of the anode assembly or assemblies employed in protecting the structure to be protected is adequate to maintain potential levels in the structure which are appropriate for cathodic protection. In addition to embracing the reference electrode per se, the present invention also includes its combination with any anode assembly referred to herein and the combination of the reference electrode together with the anode assembly with means for automatically adjusting the supply of current to the anodic region of the anode assembly in response to changes in potential monitored by the reference electrode.

As an alternative to positioning the reference electrode of the invention on the rope of an anode assembly of the invention, one or more such reference electrodes may be positioned on a pre-tensioned rope entirely separate from the anode assembly. When a plurality of the reference electrodes are so-used they may be spaced in a predetermined pattern along a rope in order to measure the potential of a submerged structure at desired locations when the resulting reference electrode assembly is hung adjacent to the submerged structure (suitably weighted). This type of assembly may be wound on a drum like the anode assembly of the invention. The present reference electrode assembly may, of course, be used entirely separately from the present anode assembly and can be employed in situations where it is either not possible or necessary to use the anode assembly.

It will be understood that given any particular structure which it is desired to provide cathodic protection for, the skilled man can calculate in advance the necessary current demand for various points on the structure and hence provide what can be termed a "cathodic protection load centre" for the overall structure somewhat analogous to the centre of gravity (to use a mechanical analogy). A cathodic protection system can then be designed using the anode assemblies of the present invention which takes account of this information. It has already been indicated that the anode assemblies of the present invention allow the anodic region thereof to be positioned remote from the structure being protected thus allowing for better current distribution around the structure and enabling the use of system voltages higher than the breakdown voltage.

An anode assembly in accordance with the present invention may be suspended through a tube positioned amongst the members of a structure which it is desired to protect, e.g. an oil rig, a rope extension of the anode assembly being positioned through the tube and secured to the structure at one end of the tube whilst the anodic region of the anode assembly is outside the tube at the other end thereof and a second rope extension being fastened to another portion of the structure. With such a design, cables which are needed may be led to upper levels of the structure being protected through the tube. The tube may be provided, at the end thereof adjacent the anodic region of the anode assembly, with a bell fitting to facilitate positioning of the anode assembly there-through. Suitable tubes which can be used with the anode assemblies of the present invention are sometimes found in cathodically protected structures which employ more conventional fixed anodes rather than the flexible anodes of the present invention.

It will be appreciated that whilst the present invention is highly suitable for cathodic protection of oil rigs and the like, the invention has extremely wide applicability where protection of submerged structures is desired and, indeed, it is the extreme flexibility of the present system in comparison to most prior art systems that provides the major advantage of the present invention.

The present invention also provides an impressed current cathodic protection system which comprises a plurality of anode assemblies in accordance with the invention prefabricated into a harness. A suitable number of anode assemblies in accordance with the invention for incorporation into a harness is from 3 to 10, e.g. 5 or 6.

The invention will now be further described and illustrated by reference to the accompanying drawings, in which:-

Figure 1 shows a diagrammatic overall view of an anode assembly in accordance with the present invention;

Figure 2 shows the detail of the termination of the electrode windings in the anode assembly of Figure 1;

Figure 3 shows detail of an intermediate section of the electrode windings of the anode assembly of Figure 1;

Figures 4a and 4b show the detail of electrical cable connection to the electrode windings of the anode assembly of Figure 1;

Figure 5 shows a cross-section through Figure 4a at line A-A;

Figure 6 shows a side view of an oil rig structure which has cathodic protection provided to one level thereof by the incorporation of anode assemblies in accordance with the present invention;

Figure 7 is a plan view of a section through Figure 6 looking down from line 7-7;

Figure 8 is a section along line 8-8 Figure 7 showing the anode assemblies in the plane of the section only; and

Figure 9 is a sectional view of a reference electrode in accordance with the invention which is positioned on the rope of an anode assembly of the invention.

Turning first to Figure 1 of the drawings, it will be seen that the specific anode assembly shown comprises a rope 5 made of polyester fibre and protected by a Kynar heat shrink sleeve. The rope is suitably of 20 millimeter diameter. Rope 5 has electrode windings 6 (Figures 2 and 3) consisting of 4 millimeter diameter copper-cored platinised titanium wires wound therearound. There are three such platinised titanium wires wound helically around rope 5.

At periodic intervals rope 5 is provided with a shrink fit sleeve 7 of Kynar to secure the electrode windings 6 to rope 5. A further Kynar sleeve is provided to an end 2 of the overall electrode (anodic) region (designated generally by reference numberal 8) which is remote from the electrical cable connection to the electrode region (itself designated generally by reference numeral 4).

Eyes 9 are provided at the ends of rope 5 for securing the anode assembly to the structure which it is desired to protect. It will be noted that an additional eye is fitted to the rope 5 at the end thereof which is remote from electrical cable connection 4 in order to facilitate tensioning and diver installation of the anode assembly. The rope is preferably provided with a preload of between one half and one ton during installation to prevent excessive movement thereof after installation and during storms.

Figure 2 of the drawings, as already indicated, shows the end of the electrode region designated 2 in Figure 1. It will be seen that rope 5 is protected by Kynar sleeving 10 from electrode windings 6. The ends of the electrodes 11 are sealed in Atum heat shrink sleeving 12 (available from Raychem Limited), although titanium sealing may alternatively be used. The ends 11 are covered by further Kynar sleeving 13.

Turning to Figure 3, it can be seen that electrode windings 6 are covered by further Kynar sleeving 7 and thereby held in place on Kynar sleeving 10 which covers rope 5.

Turning to Figures 4a, 4b and 5 of the drawings, electrode windings 6 at the electrical cable connection 4 end of the anode assembly are provided with coverings of Atum heat shrink sleeving 14. Coverings 14 extend just below a Kynar sleeve 15 which holds the electrode windings 6 in place on Kynar sleeve 10 which protects rope 5. The electrode windings 6 pass into a cable/electrode joint assembly which is generally designated by reference numeral 19 and which is secured to rope 5 by further heat shrink sleeving 16. Assembly 19 comprises a polythene tube 17 having an epoxy filling 18 with windings 6 (each being a platinised titanium wire as described above in a heat shrink sleeve) embedded therein. A single core cable 20 leads from a cable gland 21 to a crimp type cable connector 22 to thereby provide electrical connection with the windings 6. Connector 22 is provided with a heat shrink sleeve 23. The single core cable 20 is conveniently of 50 square millimeters cross-section and a convenient size for the polythene tube 17 is 50 millimeters inside diamter and 300 millimeters length.

The region of the assembly from the Kynar sleeve 15 to just below the top of tube 17 is preferably bound in rubber tape to give protection to the assembly during transit.

Referring again to Figure 2 of the drawings, an area from just below Kynar sleeve 13 to somewhat further above the same may be protected by means of one or more (e.g. three) layers of half lapped "Scotch 23" electrical tape, covered overall by a suitably sized heat shrink sleeve. The sleeve 13 is of somewhat greater length than the various sleeves 7 and sleeve 15, preferably about double the length of sleeves 7 and 15. Sleeve 13 may, for example, be 150 millimeters or so in length and sleeves 7 and 15 may, for example, be 75 millimeters in length.

It should be noted that protective Kynar sleeve 10 extends from just above the top of tube 17 (Figure 4b) to some way past sleeve 13 at the other end of the electrode region 8. Electrode region 8 is conveniently about 10 meters in length and the Kynar sleeving 10 may be, for example, approximately 11½ meters in length to thereby totally cover the electrode region 8.

Referring to Figure 4b of the drawings, cable 20 is usually fairly flexible and may be unarmoured and insulated with EPR and sheathed with CSP. It should also be appreciated that an electrical cable connection of the type shown in Figure 4b may be replaced by a simple cable-electrode joint in which a protective jacket (e.g. vulcanised rubber) is positioned over the joint. Thus, by way of example, an outer protective jacket around the electrical cable may be extended over the end of the electrode to cover the joint.

The anode assembly of the present invention described specifically above with reference to the drawings has the following desirable features for cathodic protection of metallic marine structures (although it may, of course, be used to protect other submerged structures):-

(a) the electrode itself is long and thin which not only reduces the necessary "driving" voltage but results in economy of material;

(b) the assembly is flexible and can be coiled and the present invention includes such a coiled structure (or, indeed, a plurality of anode assemblies of the present invention coiled on a drum for use as needed);

(c) provided suitable anchoring arrangements are made, the anode assembly is unlikely to suffer from wear or fatigue in use and is a natural eddy shedder;

(d) the anode assembly typically has a current capacity of up to 250 Amps and may be assembled into a harness to provide an overall system for a particular installation with a capacity of, for example, 1500 Amps (i.e. six anode assemblies);

(e) the minimum theoretical life of a platinum layer is three years and this can be extended as required;

(f) mounting of the anode assembly on a structure which it is desired to protect can be achieved very simply and the direction of hang of the anode assembly may be adapted to suit particular requirements.

It will be appreciated that many of the details of the anode assembly described above may be varied depending upon individual requirements and materials available. Thus, alternative mans of attaching the electrodes to the rope can be employed other than the use of heat shrink sleeve. However, heat shrink sleeve is a simple and effective means of achieving this end.

Looking now at Figures 6, 7 and 8, Figure 6 shows a side view of an oil rig structure with anode assemblies in accordance with the present invention and designated by reference number A fitted into position at a particular level in the rig, each anode assembly A being connected to an interconnecting member M in the centre of the rig.

From Figure 7, it can be seen that there are five anode assemblies arranged in a half conical shape and Figure 8 shows the fastening arrangement for the two assemblies in the plane of the section indicated by the line 8-8 in Figure 7.

In installing anode assemblies in accordance with the present invention in, for example, an oil rig structure components such as washers may be made from, for example, an appropriate grade of "Tufnol" and any bolts may be made from titanium which is unaffected by water or electrolytic action.

In general, when considering the use of the present invention to provide cathodic protection for an oil rig structure, all cables for a group of anode assemblies in accordance with the present invention (for example that illustrated in Figures 6, 7 and 8) may be taken up to cellar deck level inside a non-metallic hose. The hose may be made of PVC with nylon reinforcement and may be strapped to a convenient vertical member in the oil rig structure. Furthermore, if all the members of a group of anode assemblies have the same cable and electrode lengths they can easily be connected in parallel to one rectifier to provide the necessary DC current. Facilities at an appropriate junction box should allow a clip-on ameter to be used to check that all anodes are dissipating approximately the same current.

As will be apparent, the dispostion of a group of anode assemblies in accordance with the present invention inside a particular structural level of, for example, an oil rig will be, to a large extent dictated by the arrangement of the members which form the oil rig structure. Within this limitation, the anode assemblies may be arranged so as to satisfy the requirement for cathodic protection loading and current distribution in order to achieve appropriate corrosion resistance for the structure which it is desired to protect.

Referring now to Figure 9, a reference electrode generally designated 30 may be positioned over rope 5. Such an electrode enables the measurement of the potential of the structure being protected within a small radius thereof, say, from ½ to 1 meter radius. Electrode 30 may be suitably calibrated prior to use using a standard electrode and a feedback system may be designated to relay information from electrode 30 to an automatic rectifier which then adjusts the current supplied through electrode region 8 of the anode assembly of the present invention in response to changes in potential in the structure being protected monitored by the reference electrode 30. Electrode 30 comprises a substantially cylindrical member 26 formed of high purity zinc which has a core 25 running therethrough of galvanised steel wire. Heat shrink sleeve-protected galvanised steel wire 27 leads from electrode 30 to an appropriate crimp connector 28 for electrical cables. Electrode 30 is retained in position on rope 5 by means of heat shrink sleeving 24 and 29. Heat shrink sleeving 29 is of sufficient duration to cover one end of electrode 30 and wire 27 in addition to crimp connector 28.

It will be appreciated that electrode 30 of Figure 9 may be positioned at any desired point on rope 5 of the anode assembly of the present invention. It is, of course, preferred to site the reference electrode 30 as close as possible to that portion of the structure being protected which it is desired to measure the potential of. The present invention embraces the use of such reference electrodes at one or both of an anode assembly in accordance with the present invention (or where there are more than two rope extensions in the anode assembly, each end). It will be appreciated that the use of such reference electrodes in combination with the anode assembly of the present invention enables an extremely flexible system to be designed for cathodic protection of a structure which is submerged.

Reference has already been made to a reference electrode assembly wherein one or more, preferably a plurality, of such reference electrodes is/are positioned on a rope (not being the rope of an anode assembly of the invention). It can be seen that the above-described reference electrode (Figure 9) and its associated electrical cable using heat shrink sleeving for protective, fastening and positioning purposes lends itself readily to fabrication into such an assembly. Such an assembly may, for example, be slung from an oil rig at a point sufficiently far beneath the surface of the sea to avoid bad weather conditions (say, 15-30 meters, e.g. 20 meters below the surface) and can be as long as is desired (e.g. 100 to 200 meters, say 150 meters). The assembly can have approximately the same lifetime as the anode assembly of the invention (e.g. 5 years) and can thus provide useful short to medium term guidance on the potential of a structure being given cathodic protection until some form of "permanent" reference can be installed.

CLAIMS:

1. A submergeable structure provided with cathodic protection means comprising a flexible impressed current anode assembly including an elongate electrode wound around a support to provide an anodic region and rope extensions extending from the anodic region in at least two different directions, said extensions being secured to the structure so as to space the anodic region from metal of the structure to be protected.

2. A structure as claimed in claim 1, wherein the electrode comprises a titanium substrate having an anodically active coating, the assembly being secured to the structure so that the anodic region is remote from metal of the structure to be protected.

3. A structure as claimed in claim 1, or claim 2, wherein the electrode is in the form of wire.

4. A structure as claimed in claim 3, wherein the wire is platinised titanium copper-cored wire.

5. A structure as claimed in any one of claims 1 to 4, wherein the support is conductive of electricity.

6. A structure as claimed in any one of claims 1 to 4, wherein the support is non-conductive of electricity.

7. A structure as claimed in claim 6, wherein the support and rope extensions are made of the same material.

8. A structure as claimed in any one of claims 1 to 7, wherein the rope extensions are made of polypropylene or polyester.

9. A structure as claimed in any one of claims 1 to 8, wherein there are two rope extensions extending in substantially opposite directions.

10. A structure as claimed in any one of claims 1 to 9 which is an oil rig or a portion thereof.

11. A structure as claimed in claim 1 and substantially as hereinbefore described.

12. An impressed current anode assembly suitable for use as the cathodic protection means defined in claim 1 and having an anodic region comprising an elongate electrode wound around an insulating rope which passes through the anodic region and extends therefrom in at least two different directions.

13. An assembly as claimed in claim 11, wherein the pitch of the electrode winding conforms to the pitch of the rope.

14. An assembly as claimed in claim 12 and substantially as hereinbefore described.

15. An impressed current anode system for cathodic protection of a submerged structure and comprising a plurality of anode assemblies as claimed in any one of claims 12 to 14 prefabricated into a harness system.

16. A submergeable structure provided with cathodic protection means comprising an impressed current anode system as claimed in claim 15.

FIG. 1.

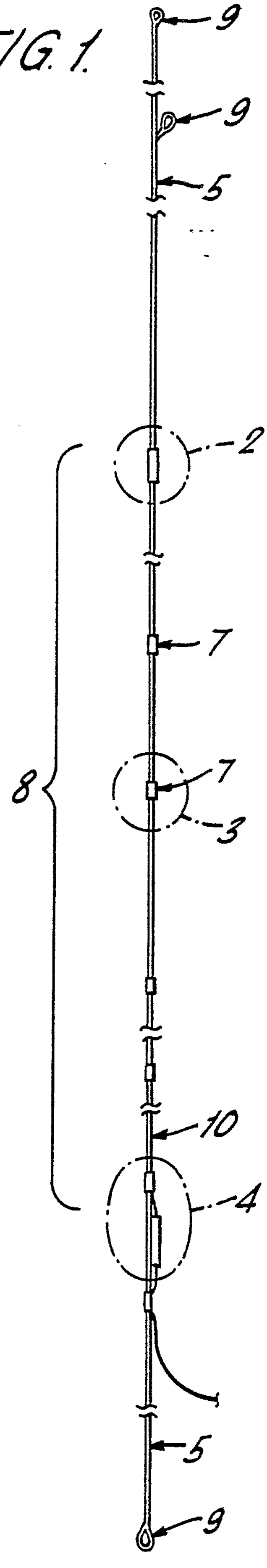


FIG. 2.

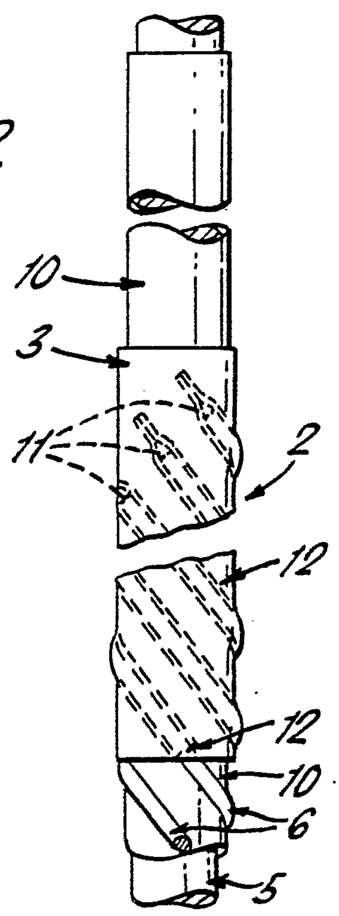


FIG. 3.

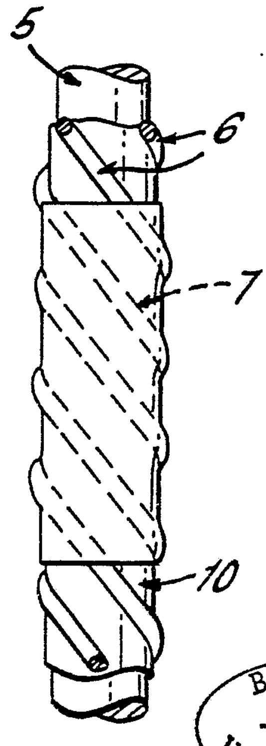


FIG. 4A

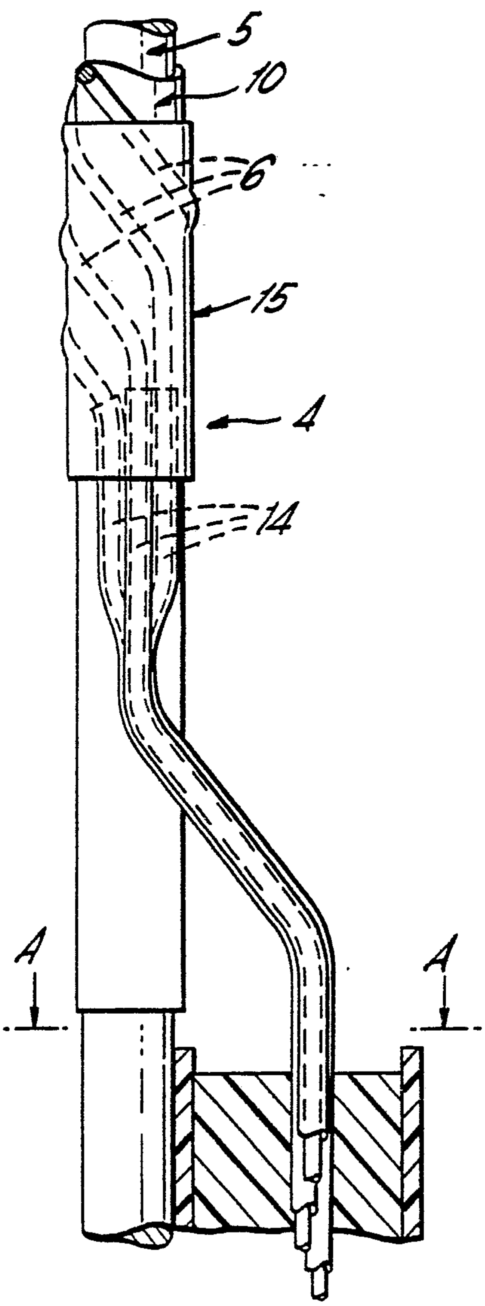


FIG. 4B.

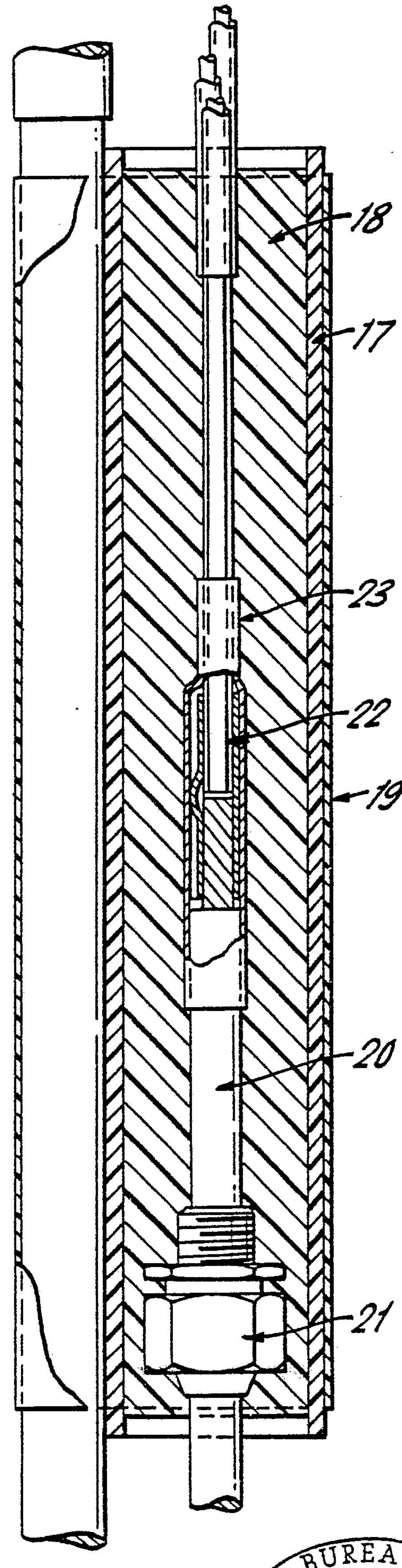


FIG. 5.

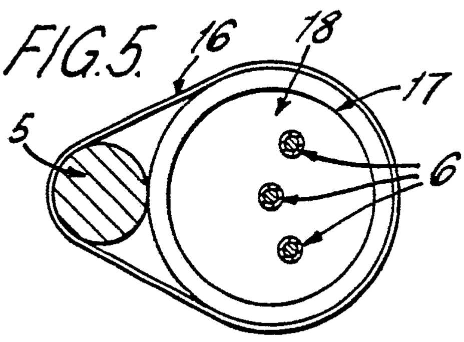


FIG. 6.

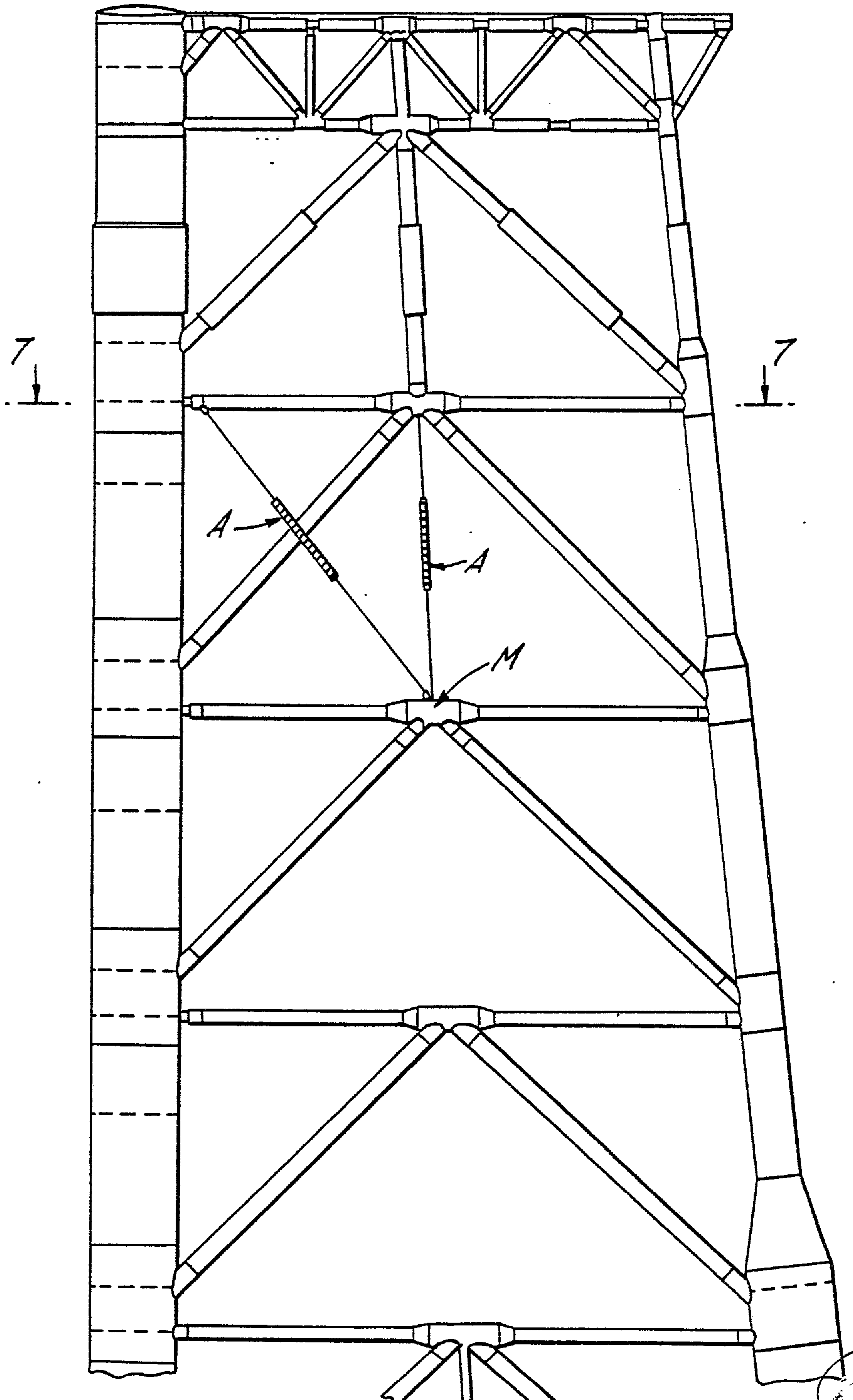


FIG.7. 4/5

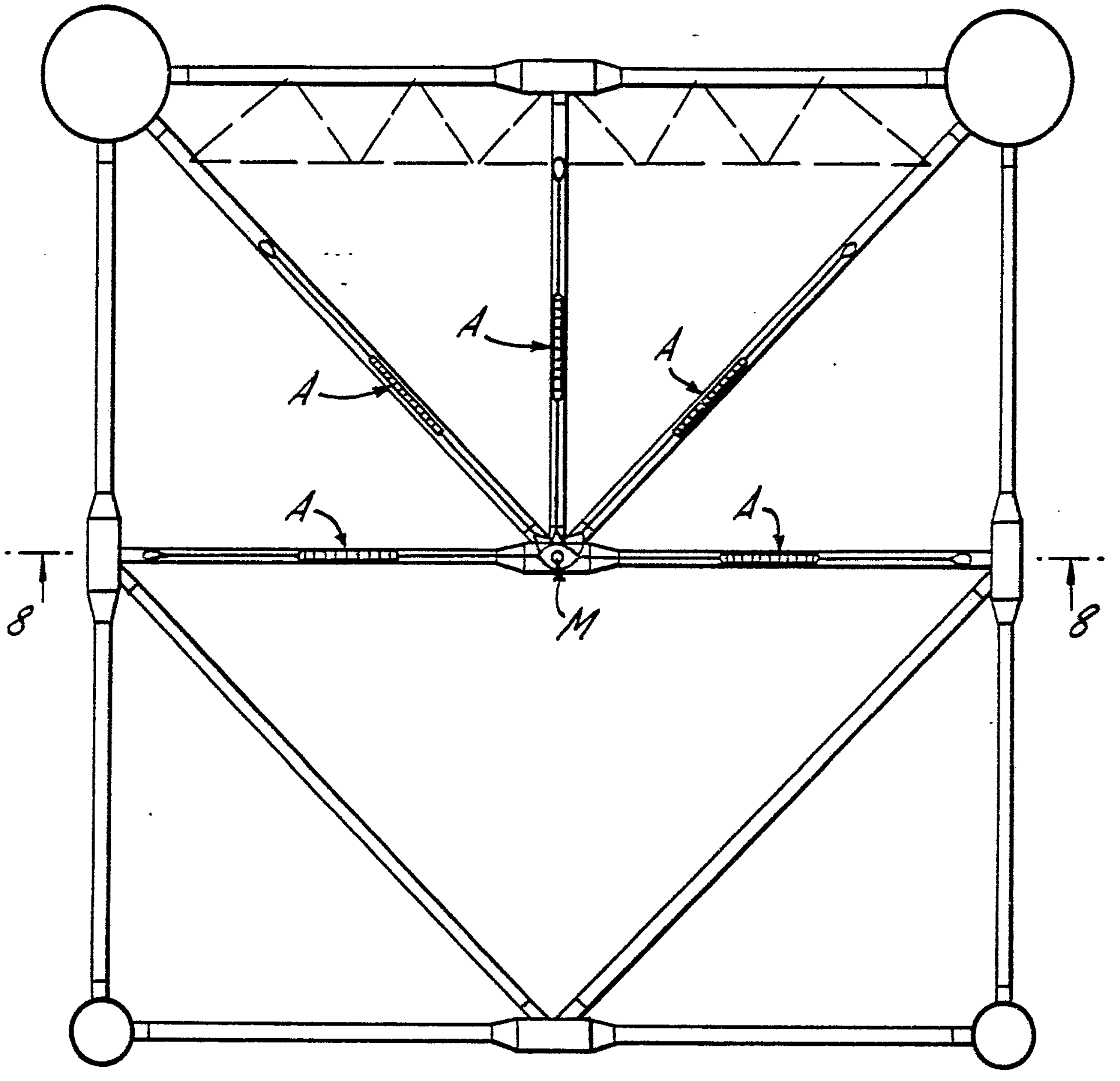


FIG. 8.

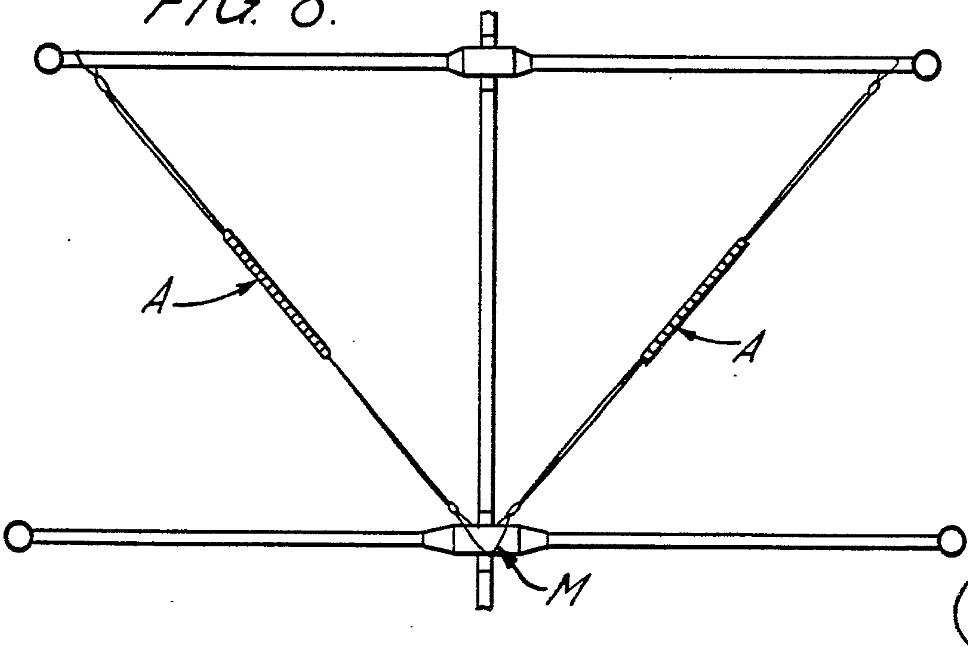
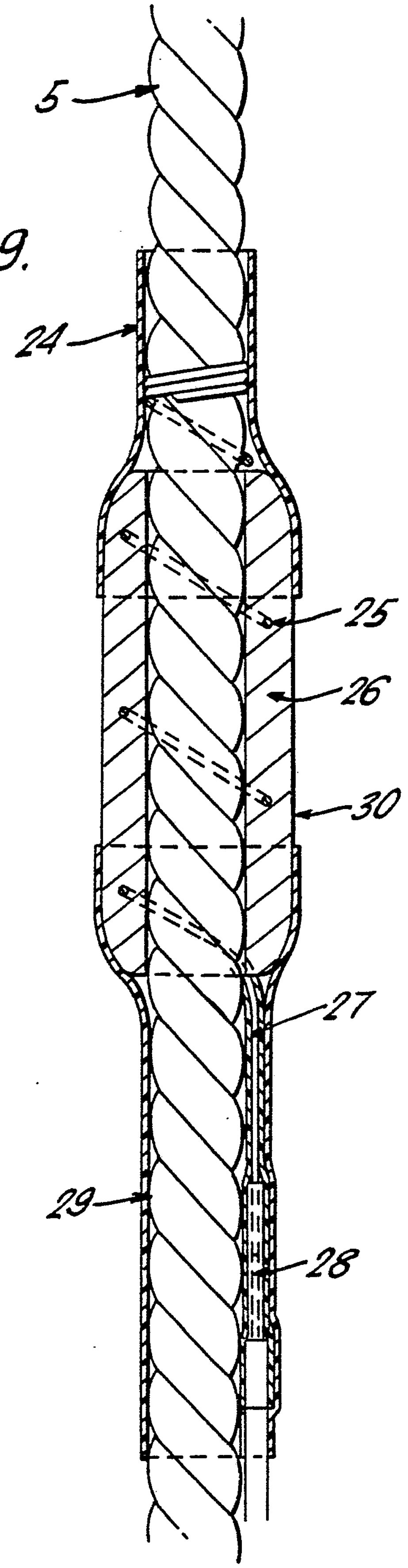


FIG. 9.



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 80/00012

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IntCl.[3] C 23 F 13/00

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
Int.Cl.[3]	C 23 F 13/00; H 01 B 7/00; E 02 D 5/22; E 02 D 31/00 E 02 D 31/06; F 02 B 17/00; F 02 B 17/02

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 3022242, published February 20, 1962 Anderson --	
A	US, A, 2996445, published August 15, 1961 Eisenberg --	
A	DE, B, 1224114, published September 1, 1966 Siemens --	
A	GB, A, 1299989, published December 13, 1972 Engelhard (cited in the application) ------	

* Special categories of cited documents: [15]

"A" document defining the general state of the art

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"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
24th April 1980	9th May 1980
International Searching Authority [1]	**Signature of Authorized Officer** [20]
European Patent Office	G.L.M. Kruydenberg

Form PCT/ISA/210 (second sheet) (October 1977)