Oct. 28, 1969 I. E. BENTOV 3,474,791

MULTIPLE CONDUCTOR ELECTRODE

Filed March 24, 1966

Fig. 1.

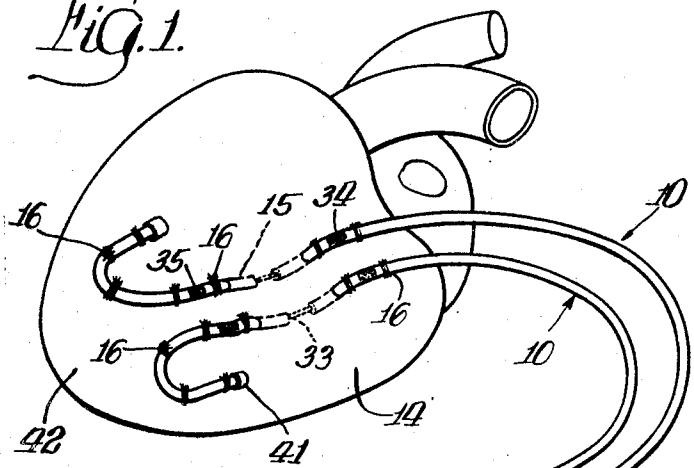
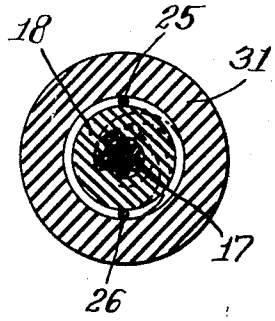


Fig. 5.



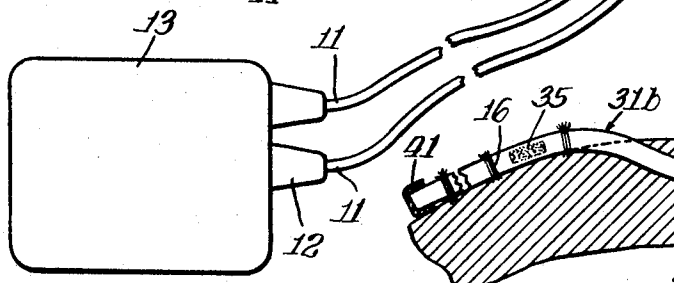


Fig. 2.

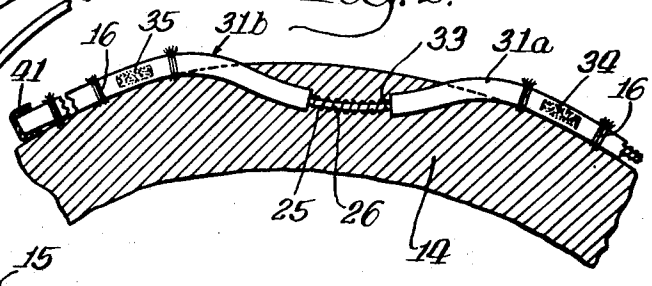
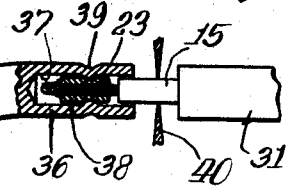


Fig. 6.



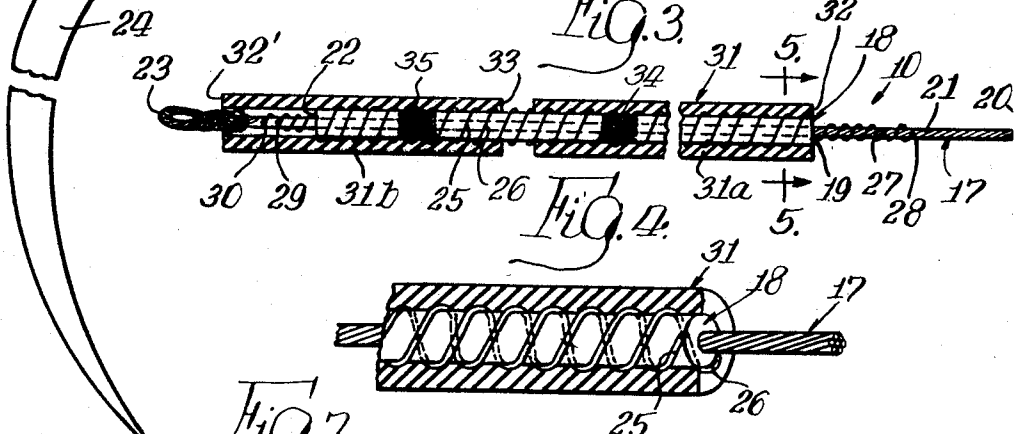
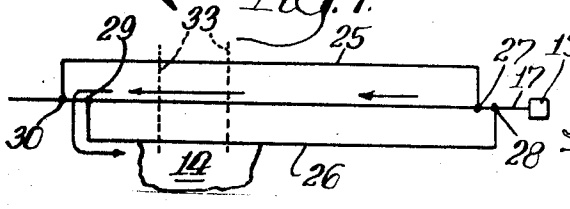


Fig. 3.

Fig. 4.

Fig. 7.



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MULTIPLE CONDUCTOR ELECTRODE

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U.S. Cl. 128—418 11 Claims

ABSTRACT OF THE DISCLOSURE

An electrode having high break-resistance and flexibility and particularly suitable for implantation in a human body for conducting heart stimulating electrical currents from a suitable current supply to the heart muscle. The electrode structure comprises a plurality of flexible electrical conductors wrapped longitudinally and coaxially around a break-resistant, flexible, electrically conductive core, with the opposite ends of the conductors electrically connected to the core. The conductors and core are enclosed by an outer coaxial flexible insulating sheath arranged to expose the conductors at a point intermediate their ends.

This invention relates to electrical conductors and in particular to an electrode for use such as a cardiac pacer.

A number of devices have been developed heretofore for external electrical stimulation of a heart which has stopped beating or which is beating improperly as one which is fibrillating. An early example of such a device is that shown in Hyman et al. Patent No. 1,913,595. The present invention comprehends an improved electrode structure for conducting heart stimulating electrical currents from a suitable current supply to the heart muscle in such pacer apparatus.

Thus, a principal feature of the present invention is the provision of a new and improved electrode structure.

Another feature of the invention is the provision of such an electrode structure comprising an improved heart pacer electrode.

A further feature of the invention is the provision of such an electrode structure having new and improved construction providing long life at relatively low cost.

Still another feature of the invention is the provision of such an electrode structure providing improved circuit redundancy for improved maintained conductive functioning of the electrode.

A yet further feature of the invention is the provision of such an electrode structure having new and improved means for facilitating connection thereof to the heart muscle by the implanting surgeon.

Another feature of the invention is the provision of such an electrode structure having new and improved means for preventing deterioration thereof by body fluids and the like.

Another feature of the invention is the provision of such an electrode structure having a new and improved axial core construction providing improved functioning thereof.

A further feature of the invention is the provision of such an electrode structure wherein the core construction is formed of a plurality of extremely fine metal filaments.

Other features and advantages of the invention will be apparent from the following description taken in connection with the accompanying drawing wherein:

FIGURE 1 is a fragmentary elevation of an electrode structure embodying the invention electrically connected between a suitable electrical current supply and a heart muscle;

FIGURE 2 is a fragmentary enlarged view of a portion of the electrode implanted in the heart muscle;

FIGURE 3 is a broken diametric section of the electrode prior to the installation of the stitching needle to one end thereof;

FIGURE 4 is a fragmentary, enlarged isometric view of a mid-portion of the electrode;

FIGURE 5 is a transverse section taken substantially along the line 5—5 of FIGURE 3;

FIGURE 6 is a fragmentary side elevation of the stitching needle attached to the end of the electrode with portions thereof shown in diametric section; and with a severing means shown fragmentarily for removing the stitching needle from the electrode upon completion of the implantation of the electrode in the heart muscle; and

FIGURE 7 is a schematic electrical wiring diagram of the circuit arrangement of the electrode.

In the exemplary embodiment of the invention as disclosed in the drawing, an electrode generally designated **10** is shown to comprise an elongated flexible structure having one end **11** connected by a suitable connector **12** to an electrical power supply **13** for providing suitable electrical current through the electrode **10** to a heart muscle, such as muscle **14**. As shown in FIGURE 1, the opposite end **15** of the electrode is secured to the heart muscle **14** as by stitching **16**. In the illustrated embodiment, a pair of electrodes **10** is provided for conducting the electrical current both to the heart muscle and back to the power supply **13**; each of the electrodes is substantially identical and thus the following specific description thereof will be limited to a single electrode.

Referring now more specifically to FIGURES 2 through 5, the electrode **10** includes an axial elongated core **17** formed of a flexible, break-resistant material. In the illustrated embodiment, core **17** comprises a 300 end yarn formed of an electrically conductive material, such as 304 stainless steel filaments each having a cross-section of approximately 12 microns with the filaments having approximately 5 to 7 turns per inch twist therein. The filaments are impregnated with an elastomer, such as silicone rubber, which may be suitably cured as by heating in an oven at approximately 400° F. The core may be of suitable length, and in the illustrated embodiment, is approximately 28 inches long.

A silicone rubber sheath **18** is then provided over the core. As shown in FIGURE 3, a first end **19** of the sheath is spaced from one end **20** of the core to provide an exposed outer end **21** of the core, and the opposite end **22** of the sheath **18** is spaced from the opposite end **23** of the core. The end **23** may be twisted back upon itself to define an enlarged end suitable for connection thereto of a stitching needle, such as needle **24** shown in FIGURE 6. The silicone rubber sheath **18** may be provided on the yarn in any suitable conventional manner such as by extrusion thereonto, or by providing the sheath in a form of a tube which may be suitably cemented to the core after being drawn thereover. The sheath preferably is fixedly retained against axial slippage on the core.

A plurality of electrically conductive cables are wound helically about the sheath, herein a pair of cables **25** and **26** are provided 180 degrees apart. Cable **25** has a first end **27** secured in electrical contact with the core **17**, and cable **26** has a first end **28** secured in electrical contact with the core adjacent first cable end **27**. Cable **25** has a second end **29** secured in electrical contact with the core end **23**, and cable **26** has a second end **30** secured in electrical contact with the core end **23** adjacent cable end **29**. Herein, cables **25** and **26** are formed of platinum and comprise seven strand cables wherein each strand has a diameter of approximately .001 inch.

The electrode further includes an outer sheath **31** having an outer end **32** coplanar with end **19** of sheath **18** and an inner end **32'** spaced inwardly of the inner end **22** of

the sheath **18** with the connections **29** and **30** of the platinum cables being disposed within the outer sheath **31** inwardly of the inner sheath end **22** and with the end **23** of the core extending outwardly therefrom. As best seen in FIGURES 2 and 3, the outer sheath **31** is provided with a gap **33** at a point outwardly of the inner sheath end **22**. In the illustrated embodiment, the gap **33** may be approximately four inches outwardly of sheath end **32'** and approximately two and one-half inches outwardly of inner sheath end **22**. The gap may be approximately a half inch wide to provide a substantial exposed portion of the platinum cables for improved contact with the heart muscle as shown in FIGURE 2.

As discussed above, the outer sheath **31** may be formed of a resilient material such as silicone rubber. In constructing the electrode **10**, the sheath **31** may actually be formed of two portions such as first portion **31***a* extending to the right from gap **33** and portion **31***b* extending to the left therefrom. The sheath portions may be suitably provided as by extrusion thereof onto the subassembly of the core **17**, sheath **18**, and conductors **25** and **26**, or by drawing of preformed tubular sheath structures onto the subassembly for positive retention thereon as by cementing. As shown in FIGURES 1 through 3, means are provided for indicating the location of the gap **33**, herein in the form of a pair of black marks **34** and **35** adjacent gap **33** on sheath **18** to be viewable through portions **31***a* and **31***b* respectively of sheath **31**.

As indicated above, the electrode **10** may be provided with a stitching needle **24** secured to the end **23** of core **17** thereof for use by the surgeon in implanting the electrode suitably in the heart muscle **14**. As best seen in FIGURE 6, the needle may comprise an arcuate needle having an attaching end **36** provided with an axial outwardly opening recess **37**. An electrically conductive ferrule **38** is secured to the end **23** of the electrode core as by soldering and the core end **23** with the ferrule **38** secured thereto is retained in the recess **37** as by crimping of the needle end **36** illustratively shown at **39**.

The electrode **10** may be utilized as follows. The surgeon may firstly install the power supply **13** under the patient's skin in the abdomen or upper left chest cavity with the ends **11** of the electrode suitably secured to the connectors **12**. The electrodes are drawn through the space between the internal organs of the patient and the rib cage to adjacent the heart. As shown in FIGURE 1, the distal ends of the electrodes are then stitched into the heart muscle **14** by means of the needle **24** to dispose the exposed cables **25** and **26** at gap **33** within the heart muscle thereby making electrical contact therewith. As shown in FIGURE 1, the ends of the electrodes are brought out from the heart muscle whereby the black marks **34** and **35** indicate to the surgeon the accurate centering of the gap **33** in the heart muscle. The exposed portions of the electrode adjacent the heart muscle may be suitably stitched thereto by surgical sutures **16**. The needle **24** is removed from the end of the electrode as by cutting the end **15** by suitable means such as scissor blades **40** as shown in FIGURE 6. The cut end of the electrode may be suitably capped if desired as by insulating cap **41**. A loop is retained in the electrodes adjacent the heart to preclude tugging of the electrodes by the heart movements. In the illustrated embodiment, the heart muscle **14** is the left ventricle portion of the heart with the ends **15** of the electrodes extending toward the apex **42** thereof.

Illustratively, the power supply **13** may provide a current pulse of approximately 14 milliamperes at 6 to 7 volts and of approximately 2 millisecond duration. Referring to FIGURE 7, the current pulse is delivered to the exposed conductors **25** and **26** at gap **33** by three separate paths, thereby providing an improved long life characteristic of the electrode as a result of the circuit redundancy. More specifically, the current pulse may flow to the exposed portion of the wire **25** at gap **33** from the power supply **13** through the core portion **17** to the contact **27** and thence through the conductor **25**. Similarly, the current pulse may be delivered to the exposed portion of the conductor **26** at gap **33** by delivery of the current from power supply **13** through core **17** to the contact **28** and thence through the conductor **26**. As the opposite ends of the conductors **25** and **26** are also electrically connected to the core **17** at points **29** and **30**, a plurality of additional current flow paths to the exposed portions of the wires **25** and **26** is provided. More specifically, should a break in the wire **25** occur between the gap **33** and the point **27** the pulse could still be delivered to the portion of the conductor **25** at gap **33** through the core **17** to contact **30** and thence back to the exposed portion of the conductor at gap **33**, as well as from the conductor **26** through contact **29** to contact **30**. A similar supply of the current pulse to the exposed portion of conductor **26** at gap **33** would be provided in the event of a break in the conductor **26** between gap **33** and contact **28**. Still further, should a pair of breaks occur, one each in conductors **25** and **26** between gap **33** and contact points **27** and **28**, the current pulse could still nevertheless be delivered to the exposed portions of the conductors **25** and **26** at gap **33** by delivery thereof through the core **17** and thence through contact points **29** and **30** to the exposed portions of the conductors. Still further, by virtue of the improved redundancy circuitry of the electrode, a break in one of the conductors **25** and **26** between the gap **33** and the contact point **29** or **30** thereof, in addition to breaks in each of the conductors between the gap **33** and the contacts **27** and **28** would still permit current flow to the other of the conductors in gap **33** through the core **17** and thence through the unbroken portion of the conductor extending backwardly to the gap **33**.

Thus, electrode **10** provides an improved low cost, high reliability electrode adapted for use in such critical applications as heart pacer conductors.

While I have shown and described one embodiment of my invention, it is to be understood that it is capable of many modifications. Changes, therefore, in the constructions and arrangement may be made without departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. An electrode comprising: an elongated core of flexible, break-resistant, electrically conductive material; a plurality of flexible electrical conductors extending longitudinally of and coaxially about said core and electrically connected to said core at opposite end portions of said conductors; and an outer sheath of flexible insulating material coaxially about said core and electrical conductors and arranged to expose said electrical conductors at a point intermediate said opposite end portions of said conductors.

2. The electrode of claim **1** wherein said core is formed of a plurality of filaments having a diameter of under approximately one-half mil.

3. The electrode of claim **1** wherein said core comprises a yarn of metal filaments impregnated with an elastomer.

4. The electrode of claim **1** wherein said electrical conductors comprise a plurality of stranded cables.

5. The electrode of claim **1** wherein an intermediate sheath of flexible insulating material is disposed coaxially about said core, said electrical conductors being wrapped about said intermediate sheath.

6. The electrode of claim **1** wherein said conductors extend helically and are spaced from each other intermediate said end portions thereof.

7. The electrode of claim **1** wherein said electrical conductors comprise a pair of conductive elements extending helically 180 degrees apart.

8. The electrode of claim **1** further including means adjacent said point at which said electrical conductors are

exposed for indicating the location of the exposed portion of said electrical conductors.

9. The electrode of claim **1** further including a connector electrically and mechanically connected to one end thereof.

10. The electrode of claim **1** wherein said outer sheath is formed of two spaced portions defining between them said point at which said electrical conductors are exposed.

11. The electrode of claim **10** wherein an intermediate sheath of flexible insulating material is disposed coaxially about said core, said electrical conductors being wrapped about said intermediate sheath.

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U.S. Cl. X.R.

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