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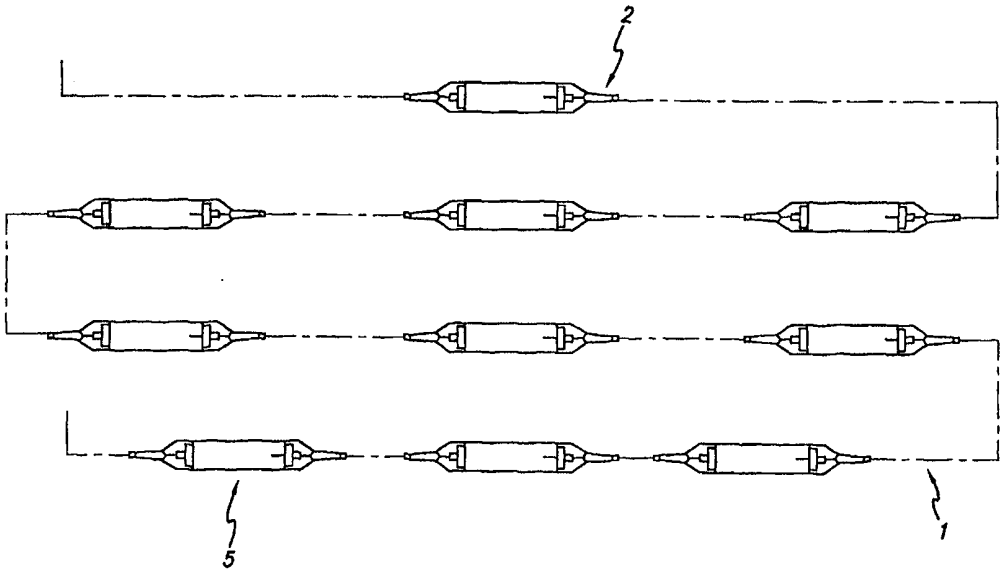

(57) Abstract

A sensor array cable (1) and method of construction thereof utilizing a sensor/interlink assembly (3, 6) to facilitate the relatively easy and inexpensive installation of a sensor device (3) in a cable that includes a strength member (4) to provide tensile strength to the cable, optical fibers or wires for carrying electrical or optical energy to and from the sensor device, and a protective outer jacket (8). A portion of the protective outer jacket is removed allowing access to the inner strength (4) and optical fibers (7). A segment of the strength member (4) is removed and an interlink/sensor assembly (3, 6) is installed in its place. The interlink serves to maintain the tensile strength of the cable. Optical fibers (7) and/or electrical wires are connected to the sensor device for operation. The interlink/sensor assembly (3, 6) and associated optical fibers and electrical wires are then enclosed in an overmold (9) which is sealed to the outer protective jacket.

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SENSOR ARRAY CABLE AND FABRICATION METHOD

TECHNICAL FIELD

The field to which the invention relates is that of cables including acoustic sensors of the kind most commonly used in marine seismic surveying.

BACKGROUND ART

This invention relates to a sensor array cable and a method of making such cable.

DISCLOSURE OF THE INVENTION

This invention provides a sensor array cable that incorporates a strength member, wires and/or optical fibers located around the strength member, a protective outer jacket, and one or more interlink/sensor assemblies. Such assemblies permit the easy and low cost installation of sensor devices in the cable. The methods of this invention include the steps of stripping off a portion of the protective outer jacket of such a cable, removing a portion of a strength member and inserting an interlink/sensor assembly in place of the removed portion. The cable is then overmolded with a plastic material. This method maintains the tensile strength, structural integrity and environmental ruggedness of the cable.

BRIEF DESCRIPTION OF DRAWINGS

Fig.1 is a top elevation view in cross section of a typical embodiment of a sensor array cable.

Fig.2 is a perspective view in partial cross section of an interlink/sensor assembly.

Fig 3. is a perspective view of components of an embodiment of an interlink/sensor assembly.

Fig 4. is a side view in cross section of a portion of the cable of Fig. 1 between nodes

Fig 5. is a side view of a node on the cable of Fig. 1 showing the overmold.

Fig 6. is a side view of an interior portion of the protective jacket segment being removed from between nodes of the cable of Fig. 1.

Fig. 7. is a side view of a portion of the strength member segment being removed from between nodes of the cable of Fig. 1.

Fig. 8. is a side view of the free ends of the strength member segment with termini between nodes of the cable of Fig. 1.

Fig. 9. is a side elevation view in partial cross section of the strength member termination of the cable of Fig. 1 with a wedge termination.

Fig 10. is a side elevation view in partial cross section of the strength member termination of the cable of Fig. 1with a cast termination.

Fig 11. is a side elevation view in partial cross section of the strength member termination of the cable of Fig. 1with a braided splice termination.

Fig 12. is a side elevation view in partial cross section of the strength member termination of the cable of Fig. 1with a knot termination.

Fig 13. is a side elevation view in partial cross section of the strength member termination of the cable of Fig. 1with a capstan termination.

Fig 14. is a perspective view of the interlink being attached to the strength member segments of the cable of Fig. 1.

Fig 15. is a side view in cross section of a clip being installed onto an interlink to capture a terminated strength member.

Fig 16. is a top elevation view of installed clips next to an interlink/sensor assembly.

Fig. 17. is a top view in cross section of an installed interlink/sensor assembly encapsulated within an overmold.

Fig. 18. is a perspective view of an installed interlink/sensor assembly and overmold in the cable of Fig. 1.

Fig. 19. is a perspective view of an installed interlink/sensor assembly where the interlink is internal to the sensor device.

Fig. 20. is a side view of in cross section of a portion of the cable of Fig. 1 between nodes.

BEST MODE FOR CARRYING OUT THE INVENTION

Figure 1 shows a sensor array cable **1** that includes interlink/sensor assemblies **5** at various locations along its length, denoted nodes **2**.

Figure 2 illustrates components of an embodiment of interlink/sensor assembly **5** in partial cross section which comprises interlink **6** and sensor device **3** which when combined form interlink/sensor assembly **5**.

Interlink **6** allows sensor device **3** to be quickly and inexpensively installed into cable **1** while still maintaining the tensile strength of cable **1**. Interlink **6** is a structure preferably of appropriate shape and composition to evenly and continuously transmit mechanical stresses. Interlink **6** may be made of a plastic material such as engineering thermoplastic, or of a composite material such as glass reinforced epoxy, although this is not required and other suitable materials such as aluminum may be used as well, or a combination of materials may be used. In a preferred embodiment interlink **6** is internal to sensor device **3** as is illustrated in Figure 19. Figures 2 and 3 shows an alternative embodiment where interlink **6** is an external structure that contains sensor device **3**.

Sensor device **3** may include, as an example, any device that responds to a physical stimulus (for example heat, light, sound, pressure, magnetism or a particular motion) and transmits a resulting impulse (as for measurement or control). In one embodiment, for example, sensor device **3** is a hydrophone of the type commonly used in marine seismic surveying. Such hydrophones include but are not limited to those which operate using fiber optics or piezoelectric phenomena. Sensor device **3** may also include, as an example, any device for telemetry, signal conduction, signal processing, signal amplification, or the like.

As such, sensor device **3** may contain, for example, optics and/or electronics for amplifying and/or transmitting output from a sensing device like a hydrophone. Sensor device **3**, when used to amplify optical signals, may contain a plurality of one or more optical fiber couplers, optical fiber delay coils, optical fiber splices, wavelength division multiplexer couplers and optical fiber doped with such atoms as erbium or ytterbium. Electronics for amplifying and multiplexing electrical signals may also be included in sensor device **3**. The precise function and configuration of sensor device **3** will vary with the application and does not affect the practice of the present invention.

Figure 19 shows a preferred embodiment of interlink/sensor assembly **5** (as shown in Figure 1) where interlink **6** is internal to sensor device **3**. In such an embodiment interlink **6** may be a machined or cast solid object, such as a rod, containing slots **14** for receiving termini of strength member segments **4**. Interlink **6** is then inserted into a cavity within sensor device **3** and bonded to sensor device **3**. Strength member segments **4** are subsequently attached, through termini, to interlink **6** at slots **14** by way of bonding with rigid adhesive such as glass filled epoxy or by set screws.

Figure 3 shows the components of another embodiment of interlink/sensor assembly **5** (as shown in Figure 1) where sensor device **3** is contained within interlink **6**. As illustrated, interlink **6** is a hollow body comprised of lower half **11** and upper half **12**. Upper half **12** is shown as, for example, a frame with a window **50**. Window **50** is an opening in upper half **12**. Either, or both, lower half **11** or upper half **12** may, or may not, contain window **50** to facilitate visual inspection/handling access during assembly of interlink/sensor assembly **5** and flooding with encapsulant when used. Lower half **11**, as shown, contains open cavity **13**, and slots **14** for receiving termini **17** for attachment to cable strength member segments **4**. Sensor device **3** is contained within hinged sleeve mount

15. The combined hinged sleeve mount **15** and sensor device **3** is placed into open cavity **13** of lower half **11**. Hinged sleeve mount **15** protects enclosed sensor device **3** during handling. Upper half **12** may then be placed over and attached to lower half **11**, resulting in the combination of interlink **6** with sensor device **3** by encapsulating sensor device **3** within interlink **6** to form interlink/sensor assembly **5** (as shown in Figure 1).

The embodiments shown in figures 19 and 3 are not intended to be exclusive. Other embodiments may be appropriate depending upon the particular application, including but not limited to, embodiments where the interlink is an integral part of a sensor device, such as being internal to the sensor device or an external appendage.

Figure 4 shows an embodiment of sensor array cable **1** of Fig. 1, between nodes **2**, that facilitates the quick and inexpensive installation of interlink/sensor assembly **5**. Between nodes **2** cable **1** is comprised of a strength member segment **4** that bears mechanical stresses placed upon cable **1**, at least one transmission medium segment **7**, and a protective jacket segment **8** which protects the interior components of the cable.

Strength member segments **4** may be cord or braid made of metal or a synthetic material such as Aramid fibers or Vectran. As is common in the art strength member segments may also have an outer coating jacket. Strength member segments **4** are joined together at the nodes **2** by attachment to interlink/sensor assemblies **5**.

Transmission medium segments **7** may be electrical wires, optical fibers, or any other suitable energy wave guide or carrier which carries power and signals to and from sensor devices **3**. Segments **7** lie in close proximity to strength member segments **4** and in a preferred embodiment are wound helically around strength member segment **4** as shown, for example, in figure 20.

Transmission medium segments **7** are connected to sensor device **3** of interlink/sensor assembly **5** as necessary for its operation (receiving power, transmitting signals, etc.), or may pass through one or more nodes **2** without connection to a sensor device **3**. In such a situation, transmission medium segment **7** may be dressed onto interlink/sensor assembly **5**.

Protective jacket segments **8** may be made of any suitable material, but plastic material of sufficient elasticity, durability, strength and sealing ability such as polyethylene, polyurethane or nylon is preferred.

Figure 5 illustrates how protective jacket segments **8** are connected together at nodes **2** through an overmold **9** which surrounds and contains interlink/sensor assembly **5**.

Overmold **9** is made of a material such as plastic, rubber or other suitable elastomer which seals and protects interlink/sensor assembly **5** and segments **7** from the environment and forms a seal with segments **8** on either side of node **2**.

Thus, the exterior of cable **1** includes protective jacket segments **8** joined together through overmolds **9**, to form a continuous sealed protection from an exterior environment, such as water.

Interlink/sensor assemblies **5** are easy to add to cable **1**. Figure 6 shows the first step of installing an interlink/sensor assembly **5** into cable **1**. A middle portion **16** of protective jacket segment **8** between nodes **2** is removed, through stripping or otherwise, to expose the interior of cable **1** (including strength member segment **4** and transmission medium segments **7**). This leaves a first protective jacket segment **18** and a second protective jacket segment **19** alongside the newly exposed cable interior.

Figure 7 shows the second step of installing an additional sensor device. Exposed transmission medium segments **7** are manipulated to provide easy access to a predetermined length of exposed strength member segment **4**. If

strength member segment **4** has an outer coating jacket then a portion of this outer coating jacket is removed by stripping or other means. An interior portion **22** of the strength member segment **4** is removed, which should be longer than interlink/sensor assembly **5** to be installed, leaving two exposed free ends **20** & **21**, one on either end of the gap formed by removing interior portion **22**.

Figure 8 shows the third step of installing an additional sensor device. Each exposed free end **20** & **21** is given a terminus **17**. The termini **17** prevent ends **20** & **21** from fraying, and allow for their attachment to interlink/sensor assembly **5** to transfer tensile loads from the strength member to interlink/sensor assembly **5**. Different configurations of terminus **17** are feasible and will vary with the type of strength member segment **4** used and connection mode to interlink/sensor assembly **5**. Figure 8 shows an example of terminus **17** as ball swage (or right circular cylinder swage) where strength member segment **4** is steel cord or the like.

Figure 9 shows wedge termination **23** which is another embodiment of terminus **17**. Strands **24** making up non-metallic strength member segment **4** are inserted and spread throughout conical volume **25** within termination block **26**. Metal wedges or cylinders **27** are driven into conical volume **25** between strands **24**.

Figure 10 shows a cast rope termination **28** which is another embodiment of terminus **17**. Strands **24** of strength member segment **4**, which may be either metallic or synthetic cord or braid, are inserted and spread throughout conical volume **25** within termination block **26**. A hard casting material **29**, such as a glass-filled epoxy, is placed within conical volume **25** and effectively bonds strength member segment **4** to termination block **26**.

Figure 11 shows a braided splice termination **30** which is another embodiment of terminus **17** when a braided synthetic cord, such as aramid, is

used. A braided eye splice **31** is shown, the method and description of which is described in handbooks for sailing etc. such as *Chapman Piloting: Seamanship & Small Boat Handling* (62nd Ed.) Elbert S. Maloney, Charles Frederic Chapman (September 1996) Hearst Books Publishing ISBN 0688 148921.

Figure 12 shows a knot termination **32** which is another embodiment of terminus **17** when a synthetic cord is used. Any suitable knot **33** may be used in forming the termination, the method and description of which is described in handbooks for sailing etc. such as *Chapman Piloting: Seamanship & Small Boat Handling* (62nd Ed.) Elbert S. Maloney, Charles Frederic Chapman (September 1996) Hearst Books Publishing ISBN 0688 148921.

Figure 13 shows a friction creating capstan termination **34** which is another embodiment of terminus **17**. The free end of strength segment **8** is looped around capstan **35** preferably at least three times. Secure end **36** is then terminated by bonding end **36** to capstan **35,** or interlink to which capstan **35** is attached, or other means to prevent unraveling of the loop around capstan **35**. Other means of termination are also feasible and may be used as appropriate.

Figure 14 shows the fourth step. Lower half **11** of interlink **6** with, as an example, slots **14** receives ends **20** & **21** which are terminated with, for example, a ball swage **17**. Each end **20** & **21** is inserted into a slot **14**. Termination link clamps **37** are then placed over slots **14** and attached to lower half **11** to hold terminated ends **20** & **21** in place. Other means of attachment are also feasible and suitable depending upon the type of terminus employed, if any, e.g. swaged fitting, bonded connection, threaded crimp fitting, compression fitting, etc.

Figures 15 and 16 illustrates an embodiment where a clip **40** is installed onto interlink/sensor assembly **5** to capture terminus **17** in order to further assure a solid connection.

After attaching strength segment members **4** to interlink/sensor assembly **5**, the fifth step is to cut (if not already done) and connect the necessary transmission medium segments **7** (e.g. wires or optical cables) to sensor device **3**. For sensor devices **3** using optical components or fibers (such as a fiber optic hydrophone) optical fiber connectors such as FC/APC may be used , although the preferred method of optical fiber connection for such a sensor is fusion splicing. Other connection means will be appropriate depending upon the particular application. Any transmission medium segments **7** which are not connected to interlink/sensor assembly **5** may be dressed onto interlink/sensor assembly **5**.

Figure 17 shows overmold **9**, the result of the sixth and final step of installing a sensor into cable **1**. After installing interlink/sensor assembly **5** as described above, the exposed cable interior with the interlink/sensor assembly **5** is then overmolded with a protective material such as plastic, rubber or another suitable elastomer, so that overmold **9** is formed and a watertight seal is made with protective jacket segments **8** on either side of the exposed cable interior. Overmold **9** may be formed by injection molding, casting or otherwise. It is also feasible, before forming the overmold to surround and contain said interlink/sensor assembly within a rigid tube . This provides the advantages of more flexibility in implementing molding/curing processes. Furthermore, if a rigid tube is employed which extends over the protective jacket segments it may simply be filled with an encapsulant and thus itself serve as an overmold.

Figure 18 shows a perspective view in cross section of a completed node **2** on cable **1** containing an interlink/sensor assembly **5** and overmold **9.**

This method for installing a sensor device into a cable may be used to make an entire sensor array cable **1**, starting with a cable containing a strength member **4**, one or more transmission mediums **7**, and a protective jacket **8**, then adding the desired number of interlink/sensor assemblies **5**. This method

permits including any number of interlink/sensor assemblies to form sensor array cable **1**.

What follows is a glossary of terms to aid in the understanding of the disclosure and claims.

Node -	A location on a sensor array cable where a sensor device or an interlink/sensor assembly is located.
Cord -	A long slender flexible material which may consist of several strands woven or twisted together.
Fiber -	A slender and elongated natural or synthetic filament, which may be constructed of a material, such as glass or metal, which can convey (carry) electrical or light energy.
Braid -	A cord having at least two component strands forming a regular diagonal pattern down its length.
Strength member segment -	A cord made of a material, such as metal or Aramid fibers, that lies between nodes and provides tensile strength to a sensor array cable.

Interlink -	An object of a particular shape and composition adapted to transmit and bear mechanical stresses.
Sensor device-	A device that responds to a physical stimulus (for example heat, light, sound, pressure, magnetism or a particular motion) and transmits a resulting impulse (as for measurement or control), or a device for telemetry, signal conduction, signal processing, signal amplification, or the like.
Interlink/sensor assembly-	A combination of a sensor device and an interlink.
Transmission medium segment	An object of a fixed length made of a material which can carry power and energy signals to and from a sensor device, and which may include, for example, electrical wires or optical fibers.
Protective jacket segment	An object made of a material, such as plastic, rubber or other elastomer which protects a strength member segment, a transmission medium segment, or both, from the surrounding environment, such as water.

Overmold - An object made of a material, such as plastic, rubber, or other elastomer which surrounds and contains an interlink/sensor assembly and transmission medium segments at a node, and forms a watertight seal with the protective jacket segments on either side of the node.

Terminus (plural: Termini) - An end of a cord, fiber, or wire which has been shaped or treated mechanically, chemically, or otherwise to prevent fraying and which allows attachment to a interlink and transmission of tensile loads.

Electrical wiring - A conductor of electricity.

Optical fiber - A fiber that conveys (carries) light energy.

Plastic - An elastomer, rubber, or any of numerous organic synthetic or processed materials that are mostly thermoplastic or thermosetting polymers of high molecular weight and that can be molded, cast, extruded, drawn, or laminated into objects, films, or filaments.

Injection molding - A method of creating plastic objects, films, or filaments.

Attachment point - A location on an interlink/sensor assembly where a strength segment may be attached, such as a groove for accepting a terminus.

Dressed - The placement of a transmission medium segment in and/or over and/or around an interlink/sensor assembly.

Connector - A device that joins or links a transmission medium segment and a sensor device so that electrical or light energy can pass between them.

Telemetry module - Any device used to receive an electrical or optical signal and to transmit the signal with, or without, amplification or modification.

Combine - To bring two or more objects into close relationship, such as physical contact, without necessarily permanently or removably attaching the objects.

Occupy - To fill, at least partially, a volume of space within a cavity.

Cavity - An unfilled space within an object.

Open Cavity - An unfilled space within an object that is contiguous with the space surrounding the object.

Closed Cavity - An unfilled space within an object that is not in contact with the space surrounding the object.

Encapsulant - A material used to encapsulate an object, such as an interlink/sensor assembly, which serves to protect the object encapsulated from mechanical stresses or loads or environmental conditions (such as water or air), and in some circumstances is used to facilitate or enhance performance of a device by , for example, matching the acoustic impedance of the surrounding environment. An encapsulant may be any suitable material including, but not limited to, polyurethane, polyethylene or other elastomer.

Encapsulate - To completely enclose in.

Outer Coating Jacket - An object made of a material, such as plastic, rubber or other elastomer which coats and protects a strength member segment.

What is claimed is:

1. A sensor array cable comprising;
at least two strength member segments connected together through an interlink/sensor assembly;
said interlink/sensor assembly comprising an interlink and a sensor device;
at least one transmission medium segment connected to said sensor device.

2. The sensor array cable of claim 1 wherein said interlink/sensor assembly is connected to said strength member segment through a terminus.

3. The sensor array cable of claim 1 further comprising a clip on either side of said interlink/sensor assembly.

4. The sensor array cable of claim 1 further comprising a protective jacket segment surrounding said strength member segments and transmission medium segments on either side of said interlink/sensor assembly.

5. The sensor array cable of claim 4 further comprising an overmold surrounding said interlink/sensor assembly and sealed to said protective jacket segments on either side of said interlink/sensor assembly.

6. A method for installing a sensor device in a cable with a protective jacket segment surrounding at least one strength member segment and at least one transmission medium segment, comprising the steps of;

a. removing a portion of said protective jacket segment to expose a length of said strength member segment and a length of said at least one transmission medium segment, leaving a first protective jacket segment and a second protective jacket segment on either side of the removed portion;

b. removing an interior segment of said exposed strength member length resulting in two exposed strength member ends on either side of where said interior segment was;

c. attaching said exposed strength member ends to an interlink/sensor assembly;

d. connecting said sensor device to at least one of said exposed transmission medium segments.

7. The method for installing a sensor device in a cable of claim 6 further comprising the step of terminating each of said exposed strength member ends with a terminus.

8. The method for installing a sensor device in a cable of claim 6 further comprising the steps of

a. attaching said exposed strength member ends to an interlink; and

b. combining a sensor device with said interlink to form said interlink/sensor assembly.

9. The method for installing a sensor device in a cable of claim 6 further comprising the step of surrounding and containing said interlink/sensor assembly within an overmold.

10. The method for installing a sensor device in a cable of claim 9 further comprising the step of sealing said overmold to said first and second protective jacket segments.

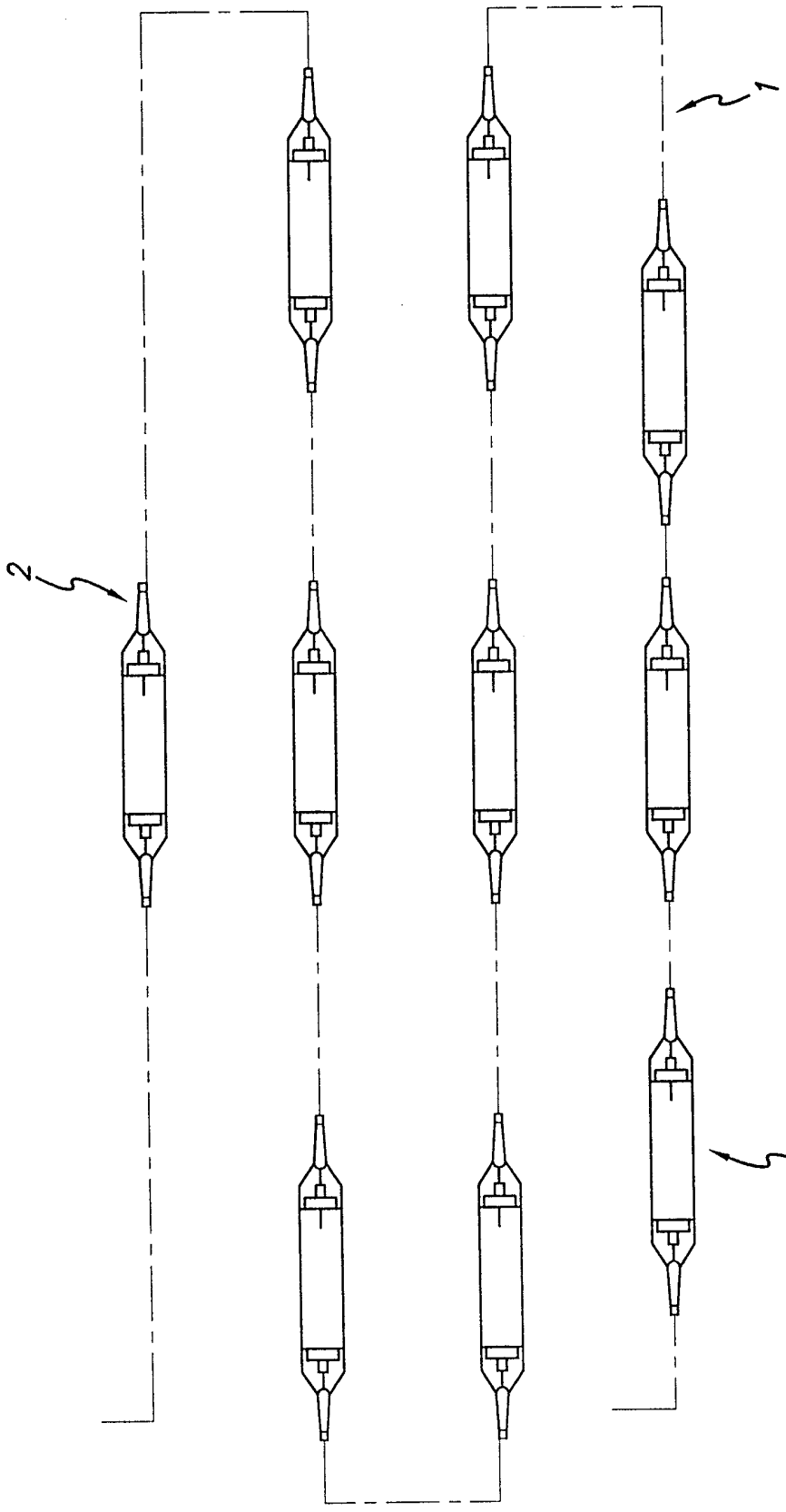


FIG. 1

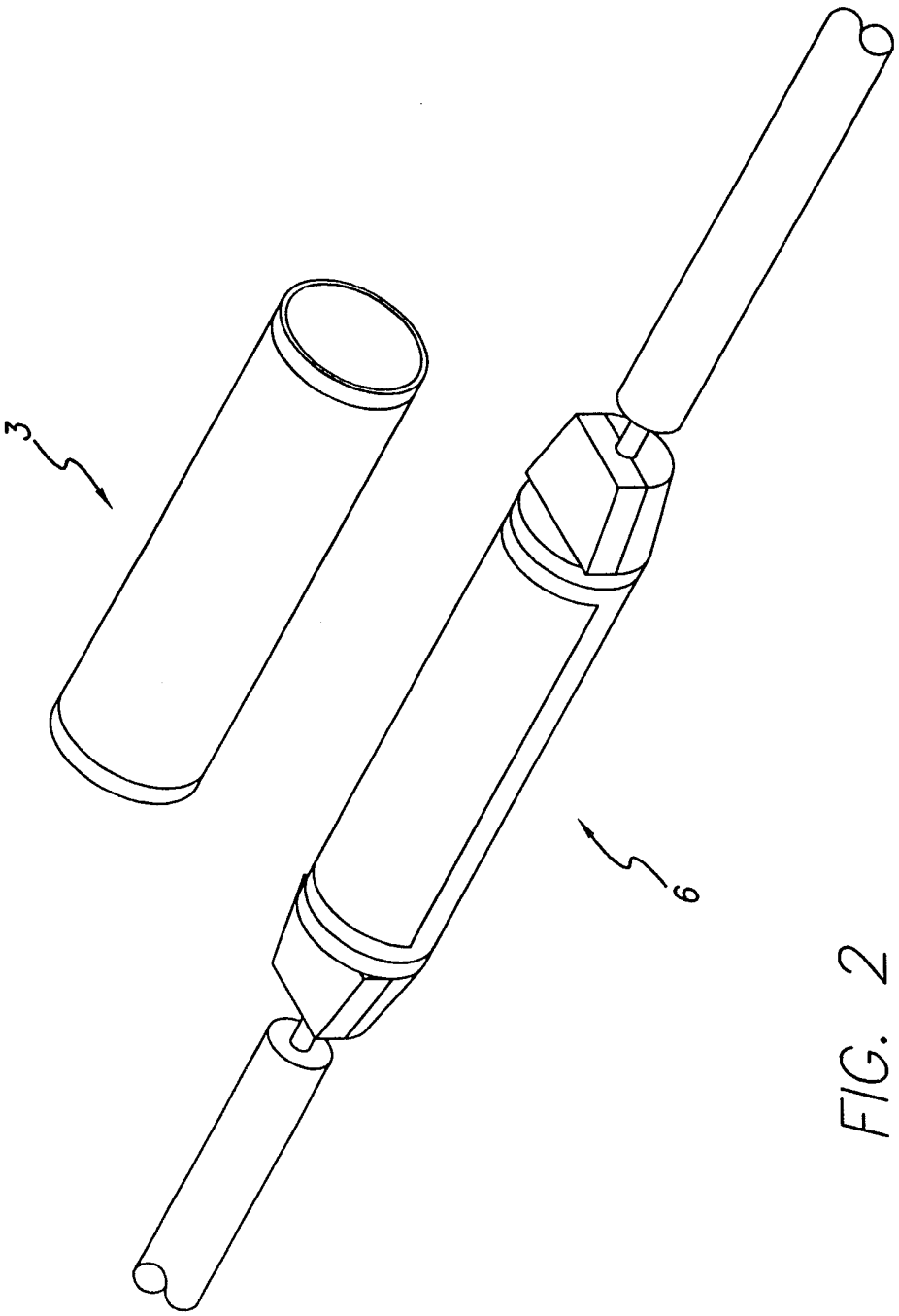
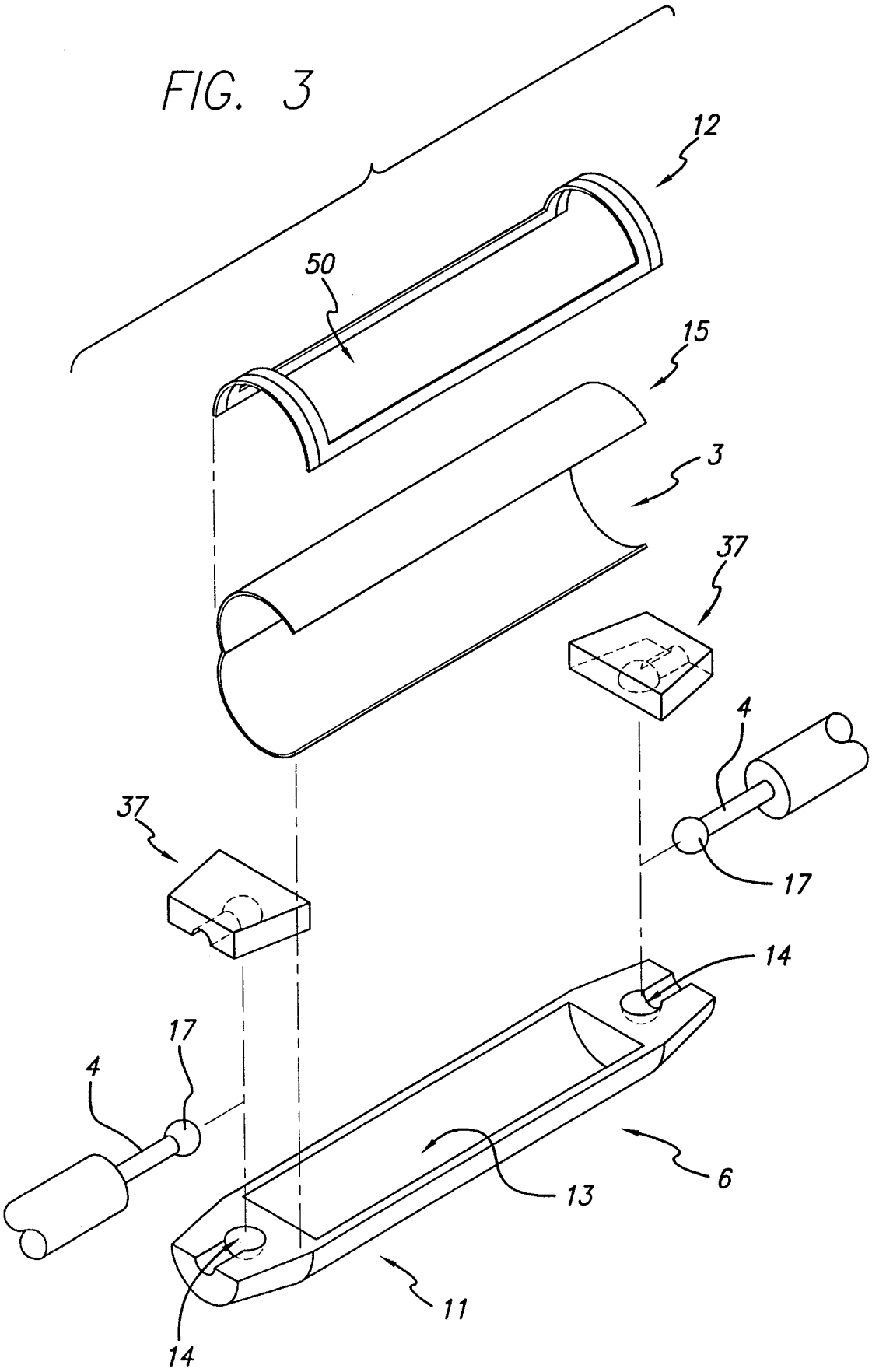


FIG. 2

FIG. 3



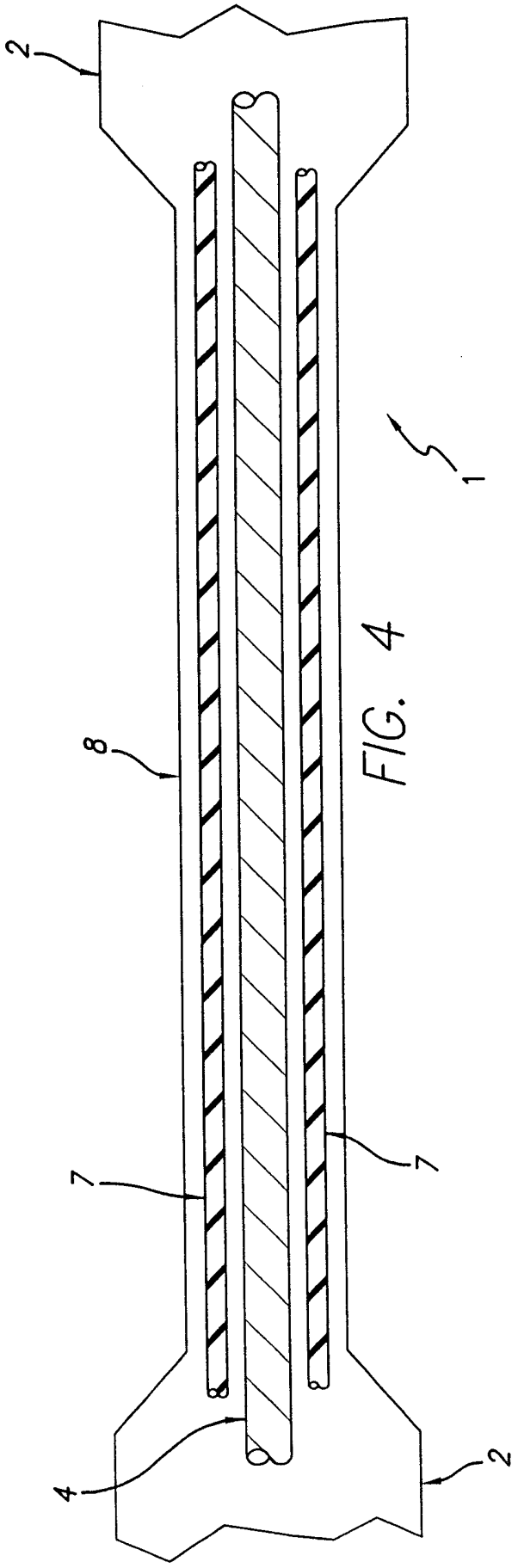


FIG. 4

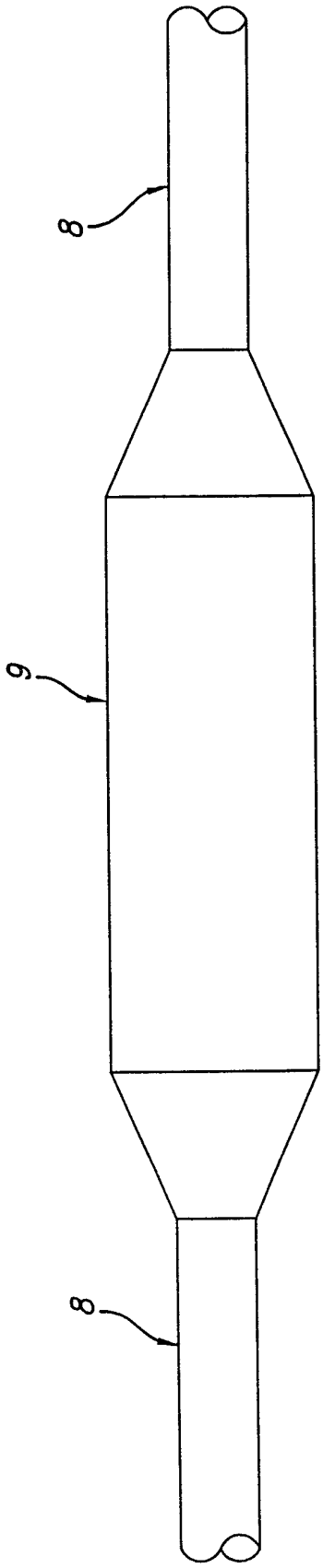


FIG. 5

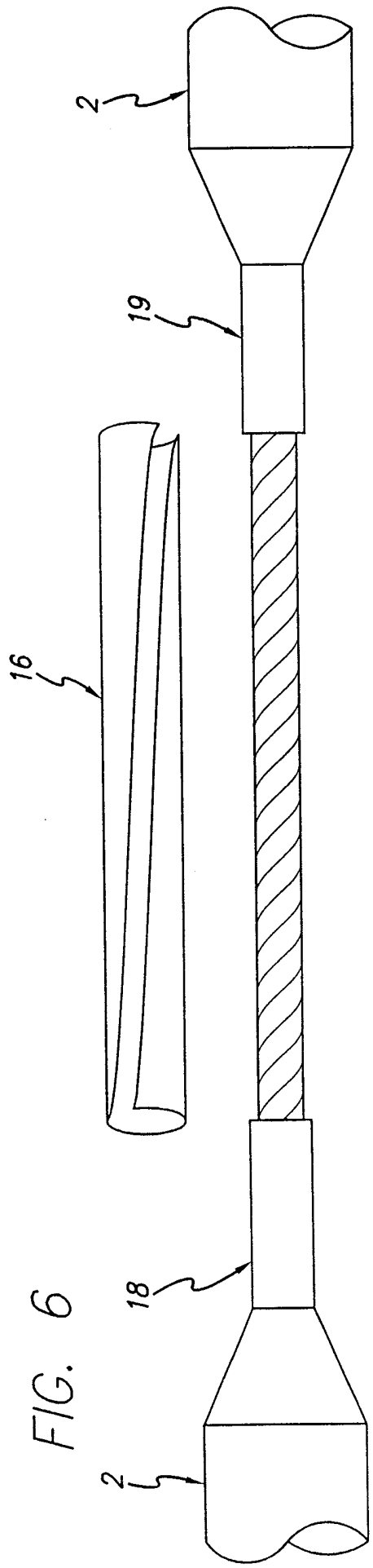


FIG. 6

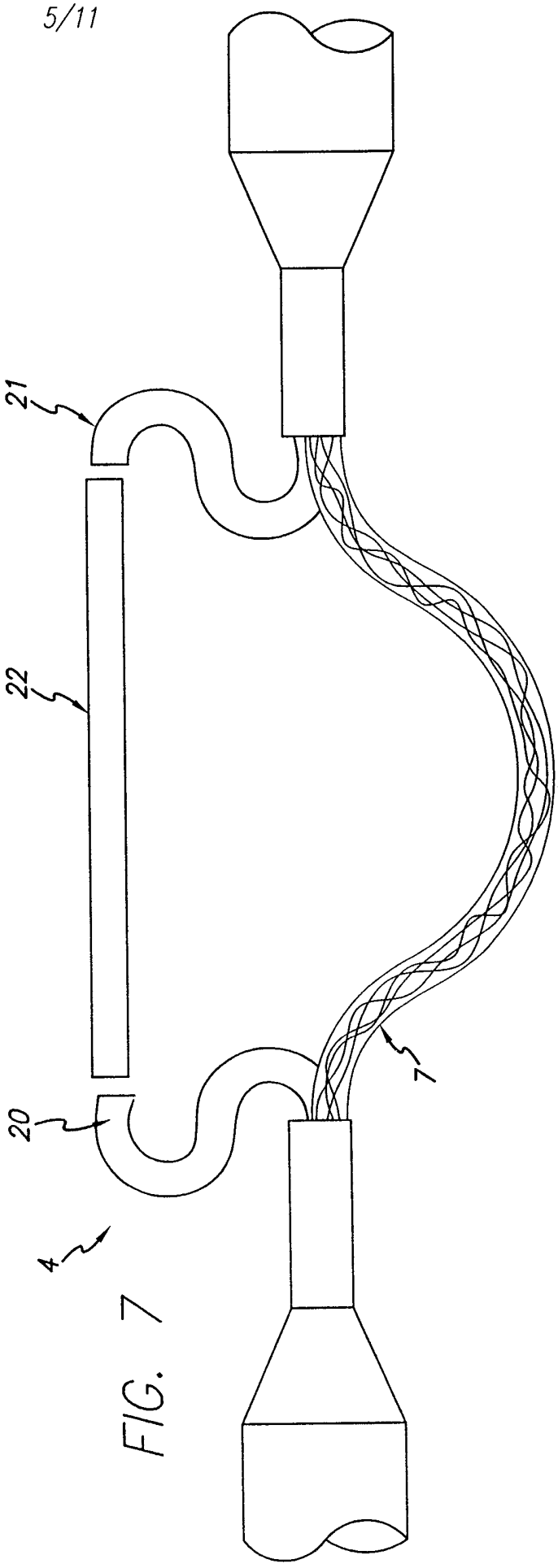


FIG. 7

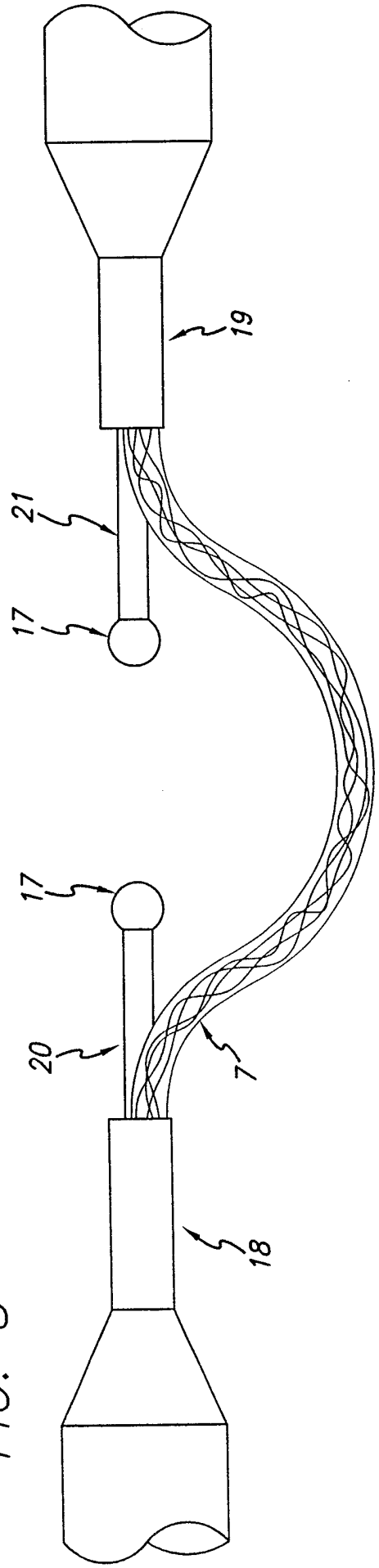


FIG. 8

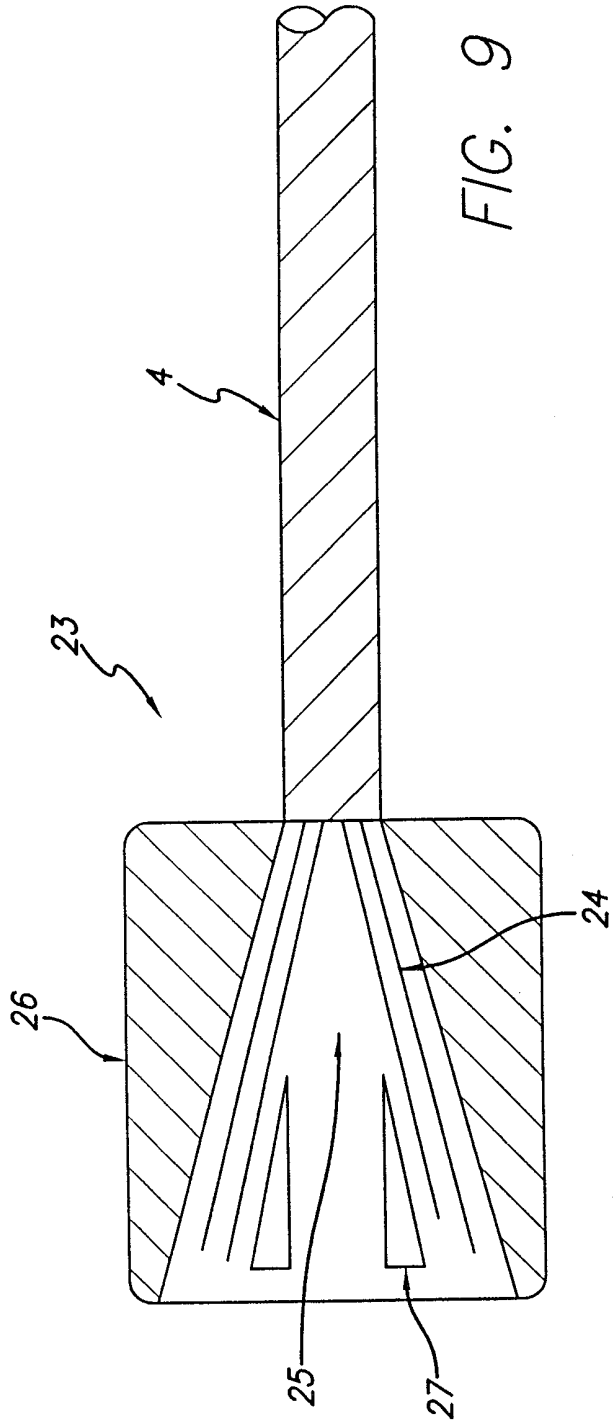


FIG. 9

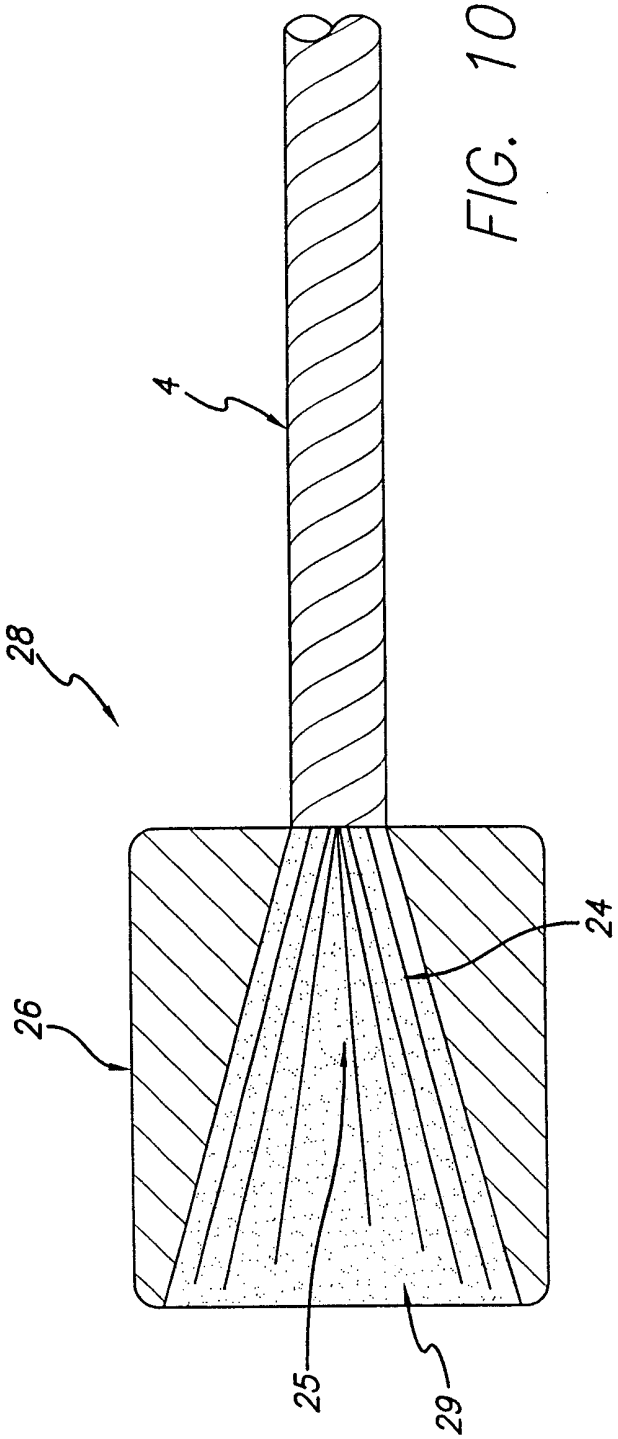


FIG. 10

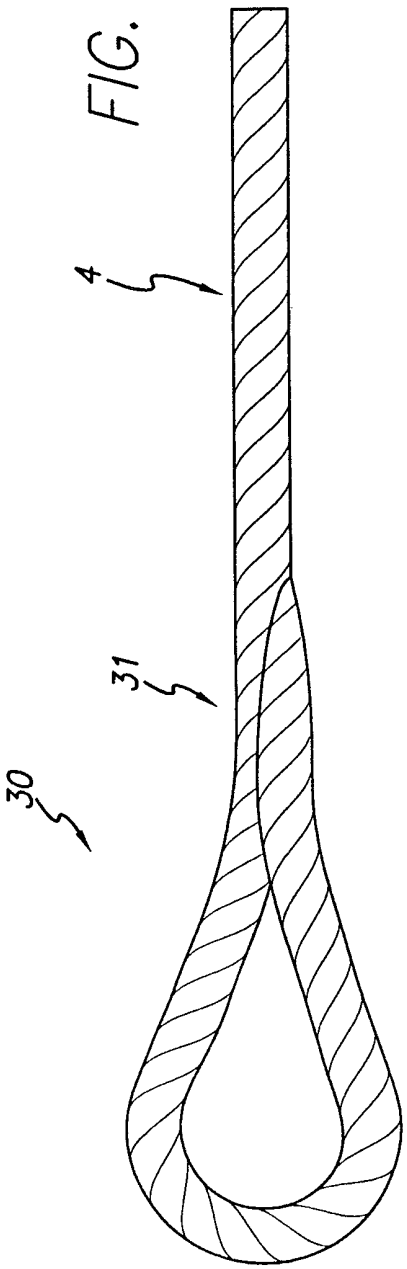


FIG. 11

FIG. 12

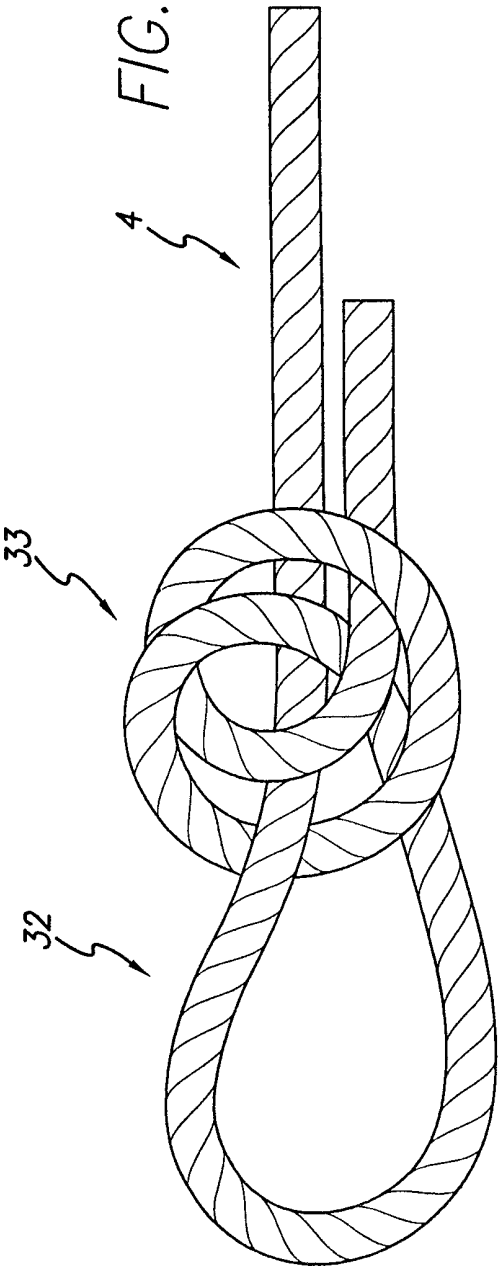
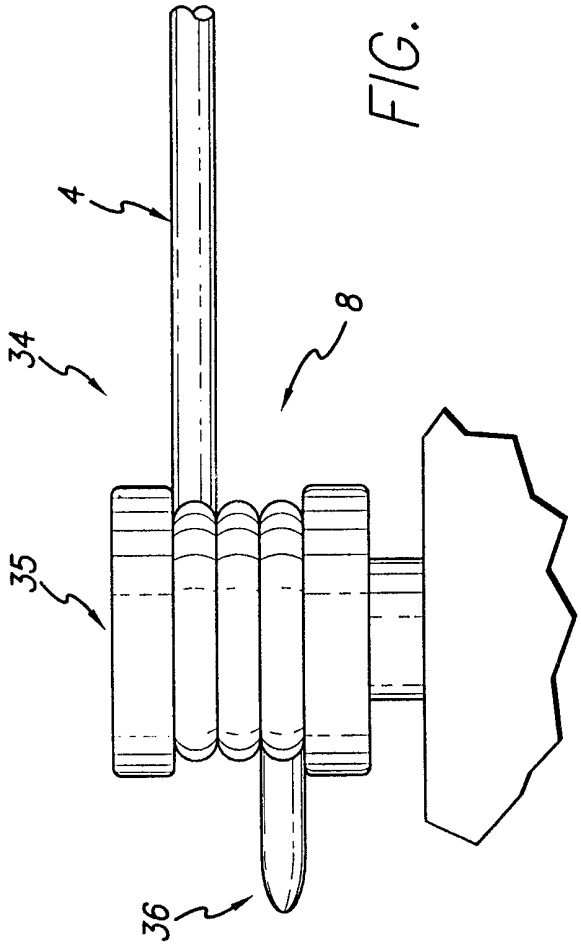


FIG. 13



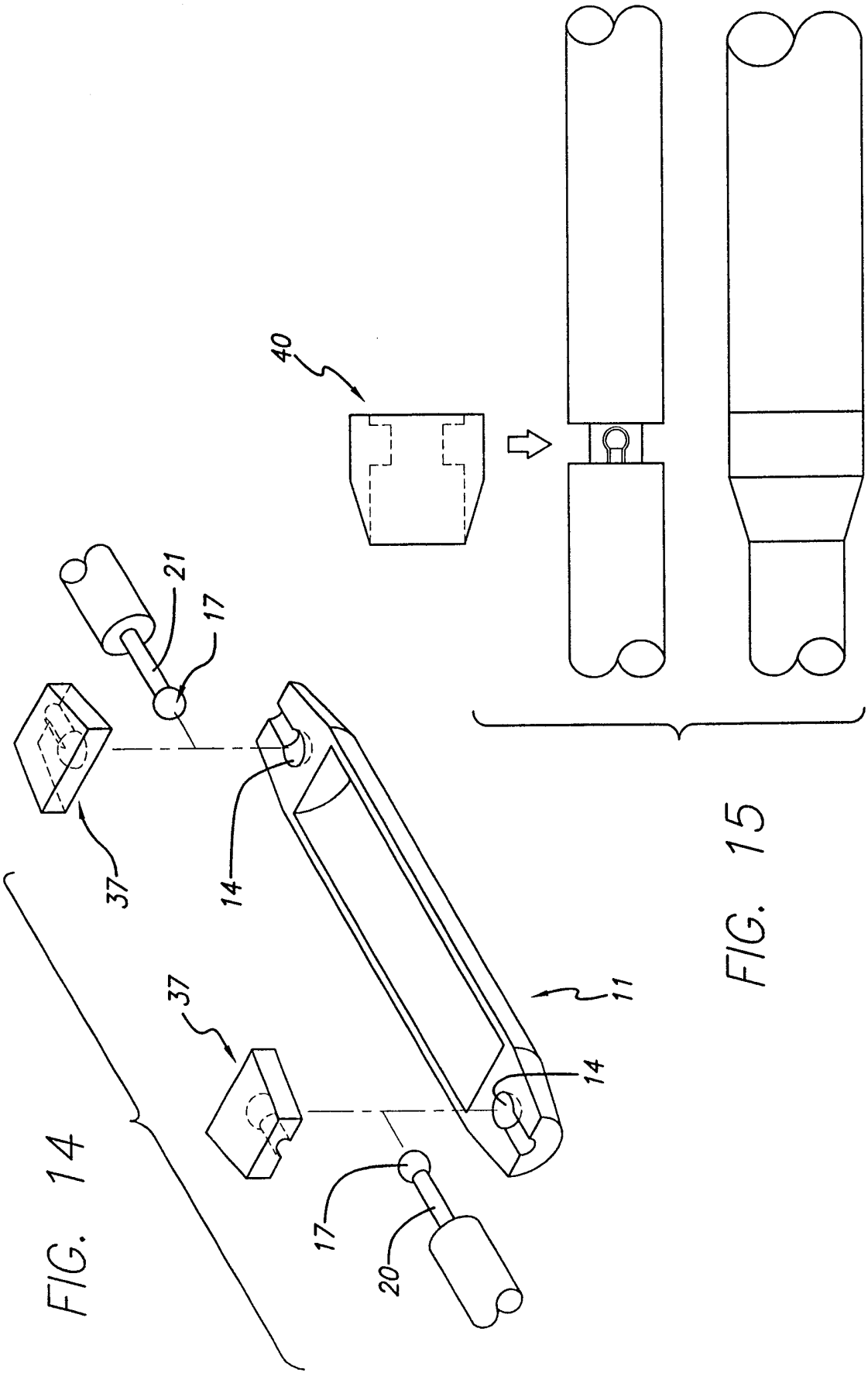


FIG. 14

FIG. 15

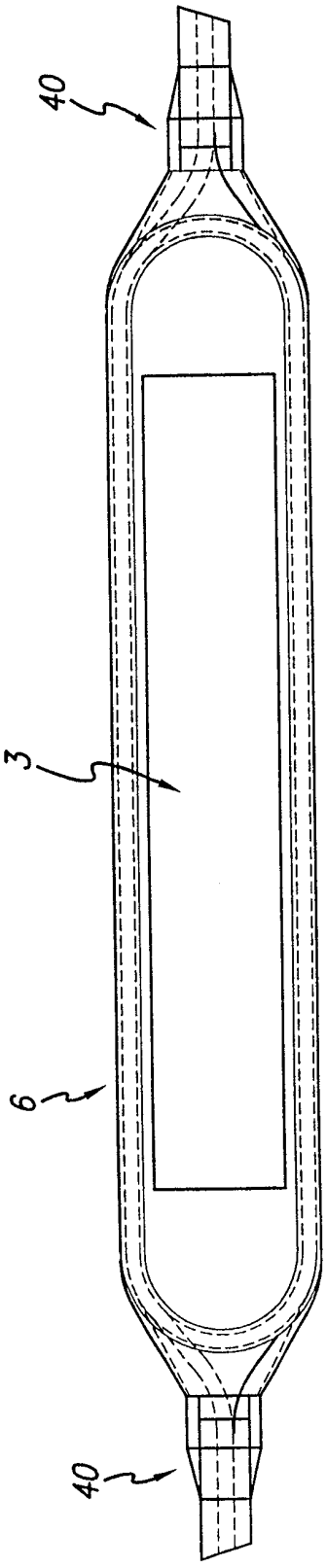


FIG. 16

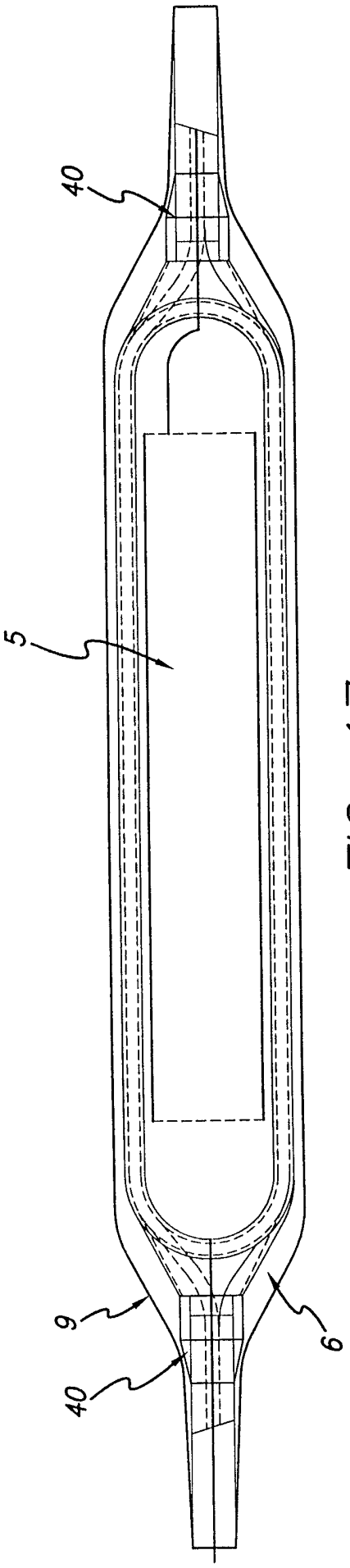


FIG. 17

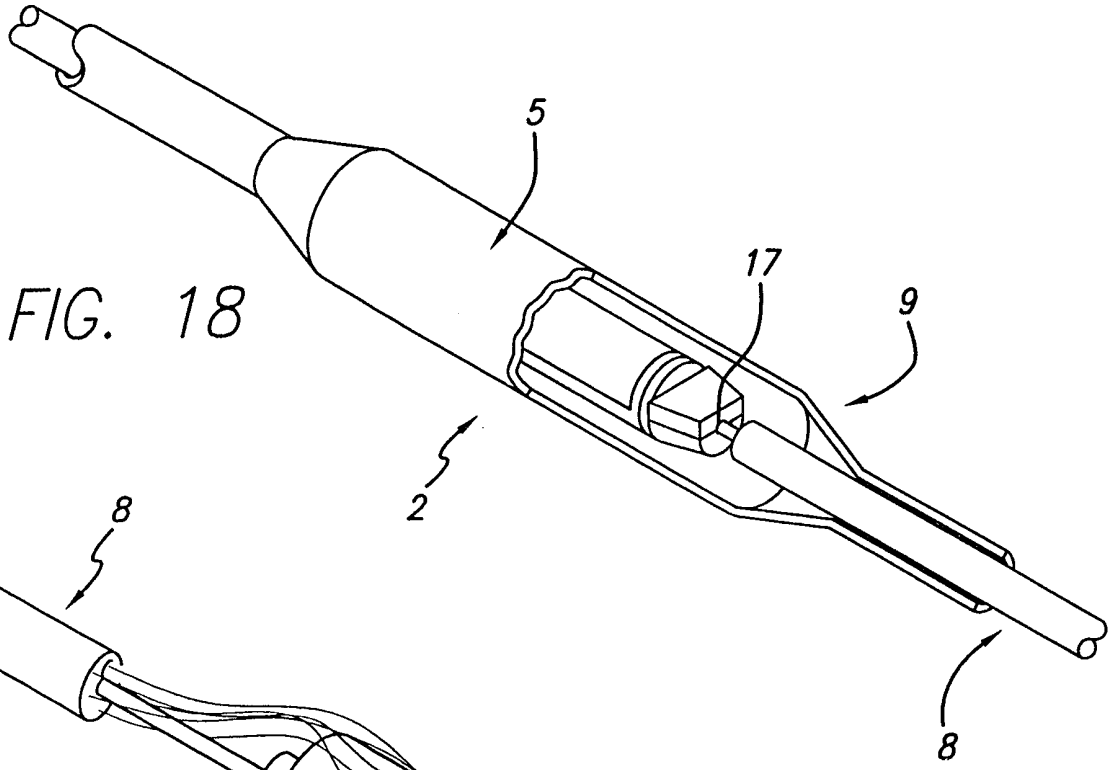


FIG. 18

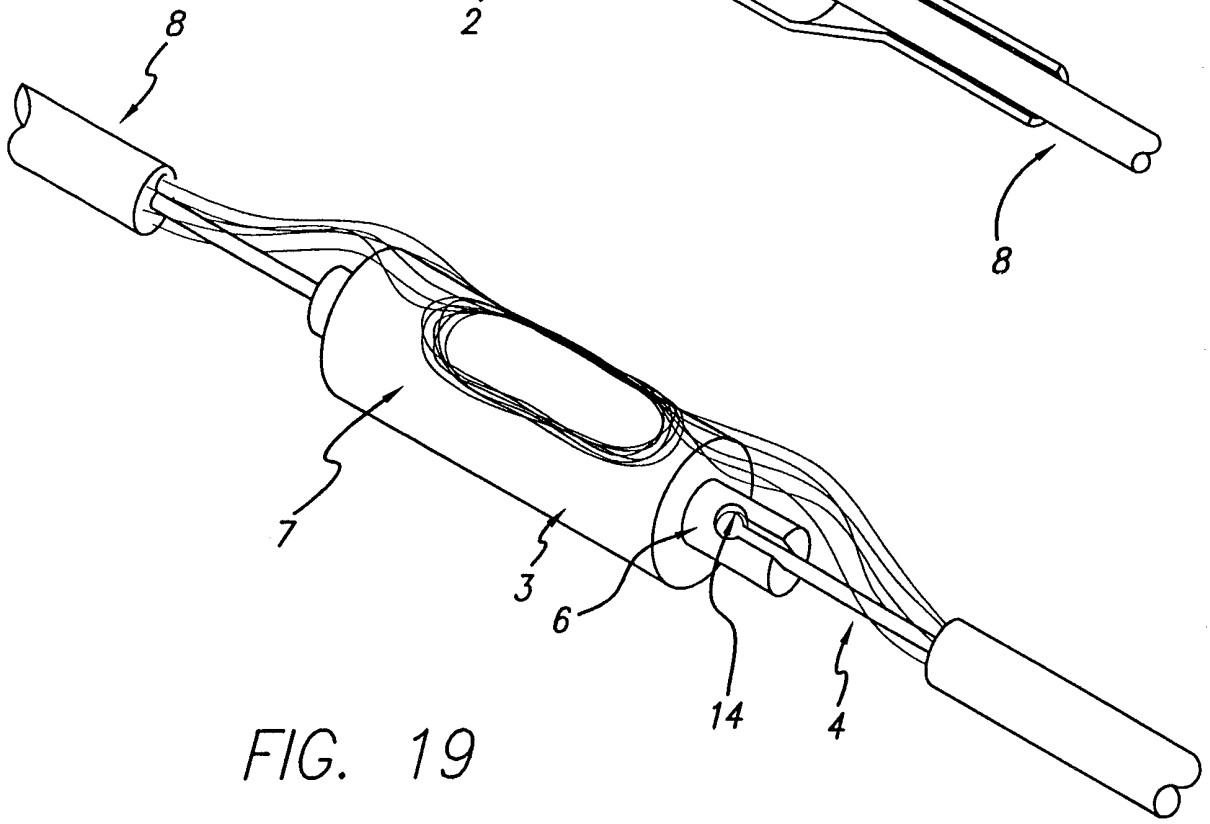


FIG. 19

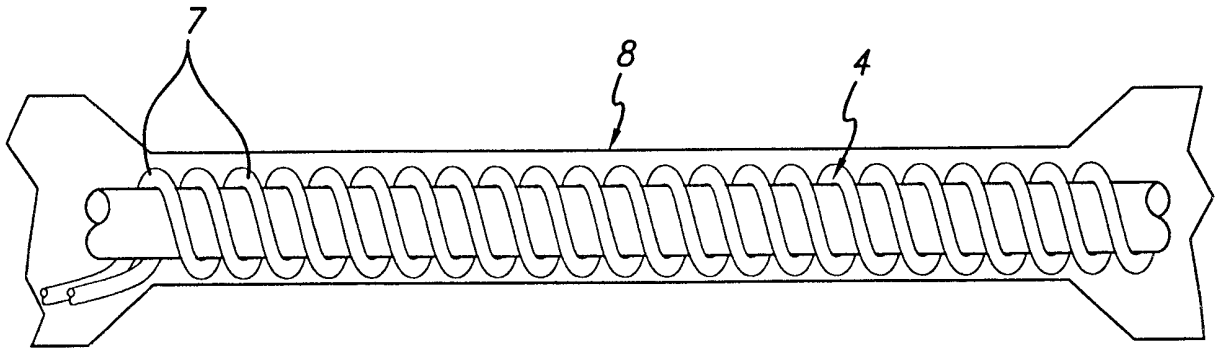


FIG. 20

INTERNATIONAL SEARCH REPORT

In. .ational application No.
PCT/US00/06063

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :G02B 6/00
US CL :385/12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : GO2B 6/00; 385/100, 101, 113, 88, 89, 92

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

SEARCHED EAST, search terms: cable$ adj optic$ and strength$ adj member$ and overmold$ and sensor$ adj interlink$

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,767,168 A (GRANDY) 30 AUGUST 1988 (30/08/88) (NOTE ENTIRE DOCUMENT.)	1-10
A	US 4,273,413 A (BENDIKSEN ET. AL.) 16 JUNE 1981 (16/06/81) (NOTE ENTIRE DOCUMENT)	1-10
A	US 4,761,053 A (COGELIA ET. AL.) 02 AUGUST 1988 (02/08/88)(NOTE ENTIRE DOCUMENT.)	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published 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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 27 JUNE 2000	Date of mailing of the international search report 23 AUG 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer BRIAN HEALY Telephone No. (703) 308-2693

Form PCT/ISA/210 (second sheet) (July 1998)★