(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 December 2007 (13.12.2007)

PCT

(10) International Publication Number
WO 2007/141548 A2

(51) International Patent Classification:
G01V 3/12 (2006.01)

(21) International Application Number: PCT/GB2007/002138

(22) International Filing Date: 8 June 2007 (08.06.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0611497.9 9 June 2006 (09.06.2006) GB

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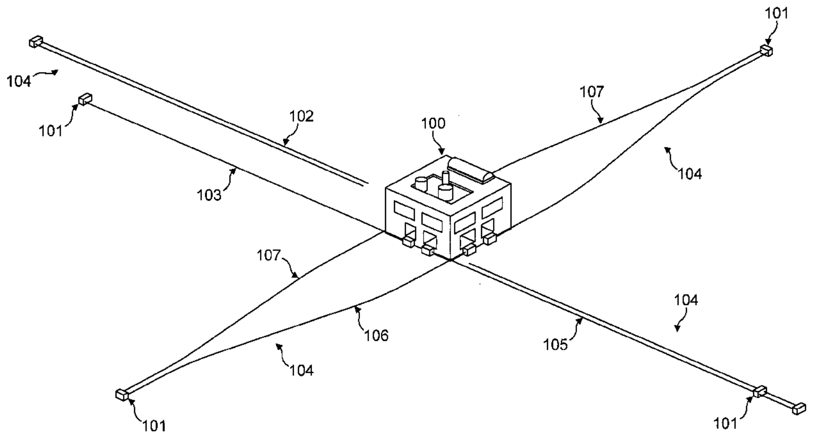
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: INSTRUMENT FOR MEASURING ELECTROMAGNETIC SIGNALS



(57) Abstract: A device for measuring electromagnetic signals is provided, which can be used to take measurements at or near the sea floor. The device comprises a central housing, a data management system located within the housing and at least two arms extending outwards from the housing. Each arm comprises a flexible elongate sheath attached to the housing, a sensor head, a flexible electrical cable attached to the sheath and connecting the sensor head to the data management system and a rod which is removeably locatable within the sheath; the rod is connectable relative to the housing at one end and connectable relative to the sensor head at the end remote from the housing.

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Instrument for measuring Electromagnetic signals

The present invention is directed towards instruments for measuring electromagnetic signals, and particularly, towards instruments for taking measurements at or near the seafloor during electromagnetic surveying, or "Sea Bed Logging".

Sea Bed Logging methods can be used to detect hydrocarbon reservoirs beneath the sea floor. These methods comprise deploying an electromagnetic source near the sea floor and measuring the response using receiver instruments located at intervals spaced across the sea floor. The receiver instruments may be in the form of long rigid arms carrying electrical sensors, extending from a central body, which facilitates the detection of low level electrical signals in sea water.

The method of deploying existing instruments is as follows: the positively buoyant instrument and an attached concrete anchor are dropped from a survey vessel at a chosen location; the instrument sinks freely to the sea floor; the position of the instrument while sinking is monitored by acoustic methods; the instrument is positioned on the sea floor in a desired location when steady and the instrument is then used to measure and store data while located on the sea floor. After the measurements are complete, acoustic commands from the sea surface cause the instrument to be released from the anchor; the instrument then floats up to the sea surface for retrieval by a survey vessel and the data are extracted from the instrument.

The speed and efficiency of deployment and storage of the receiver instruments affects the overall efficiency of the survey. The mechanical performance of the instruments also affects the survey results. While instruments are known which may be partially disassembled for storage, these require sensor wires to be disconnected from sensors and data loggers when removing the arms for storage. This leads to the requirement for a system to track all the individual arms, sensors and data-loggers, and manage the reconnection back to the correct channel input. Further, a risk of failure or degradation is introduced each time a marine electrical connector is opened and reconnected.

Higher degrees of accuracy in sensor positioning are required for new acquisition techniques, for example, 3D acquisition, as well as being desirable for improving the accuracy of results obtained from other processing techniques. Therefore, there is a need to improve the performance of receiver instruments, in order to improve the accuracy and efficiency with which surveys may be carried out.

The aim of the present invention is to provide a device for detecting electromagnetic signals, which minimises drag when moving through water, and which allows sensors to be positioned with a high degree of accuracy; the device having arms which are thin, strong, stiff horizontally but flexible vertically while measurements are being taken, stiff in use but which can be disassembled without disconnection of wires connecting sensors and data loggers, flexible and unjointed when the instrument is not in use, and which minimise vibrations introduced by underwater currents, among other goals.

According to the present invention, there is provided an electromagnetic signal detecting device, comprising a central housing, a data management system located within the housing, and at least two arms extending outwards from the housing, each arm comprising a flexible elongate sheath attached to the housing, a sensor head, a flexible electrical cable attached to the sheath and connecting the sensor head to the data management system, and a relatively rigid rod which is removably locatable within the sheath, connectable relative to the housing at one end and connectable relative to the sensor head at the end remote from the housing.

During deployment of the device, the rod is located within the sheath, connected relative to the housing and connected relative to the sensor head, whereby the sheath and the flexible electrical cable are held in the same configuration as that of the rod. Preferably, the rod is straight and extends away from the housing, perpendicularly to the point at which it is connected relative to the housing.

Preferably, the rod is connected to a bracket located on the housing. Preferably, each rod is connected to the bracket by a latch connection with a ferrule located at the end of the rod. Preferably, the ferrule is fabricated from metal, more preferably stainless steel.

Preferably, when the device is not in use, for example during storage or transportation, the rod is removed from the sheath and disconnected from the rest of the device. The rod may then be stored separately from the rest of the device. The arm may be stored in a coiled or folded configuration close to the housing, to which the sheath may remain attached. These storage arrangements minimise the storage footprint of the device. The complexity and duration of the preparation of the device for deployment after a period of non-use is also minimised. The preparation simply comprises locating the rod within the sheath and connecting the rod relative to the housing and relative to the sensor head.

Preferably, the housing is cuboid in shape. Preferably, the geometrical centre lines of two arms are parallel and extend outwards from opposite points on the perimeter of the housing. Preferably, the arms are approximately horizontal when the device is deployed. Optionally, the device has four arms, comprising two pairs of two parallel arms, with one pair orthogonal to the other.

Preferably, the rod is fabricated from fibre glass. Preferably, the rod is connected to a second similar rod by a connector, to form a twin rod assembly wherein the rods are parallel when the rods are not connected relative to the housing. When the first rod is located within the sheath and connected to the bracket, the second rod is connected to a second bracket located on the housing. The second bracket is on the same sidewall of the housing and on the same horizontal plane as the first bracket, but spaced as far apart as possible from the first bracket. When connected, the second rod stiffens the arm against horizontal movement and bending, while vertical bending of the arm is not greatly impeded. This allows the horizontal position of the sensor heads to be known with greater accuracy and improves the processing of survey data.

When connected to the brackets, the two rods thus form two sides of an approximate triangle. The ends of the rods are preferably attached into the brackets perpendicularly to the sidewall of the housing from which the arm extends, so the sides of the "triangle" formed by the rods are slightly bent into an "S" shape. This increases the stiffness of the arm and stabilizes the position of the sensor heads. When the instrument is in use on the sea floor, this also minimises horizontal vibrations of the arms caused by water streams near the sea floor. Bending forces prevent certain oscillation modes of the arms which can be introduced in systems having only one rod per arm.

Preferably, the sensor head is attached to the sheath, and is located at the end remote from the housing. Preferably, each sensor head comprises one or more electrical sensors. More preferably, each sensor head comprises two electrical sensors. In the case of failure of one of the electrical sensors in a sensor head, the second sensor can continue to record data.

Preferably, the data management system comprises data loggers and components arranged to control the positioning and release of the device during deployment. Preferably, each electrical sensor is connected to one data logger via the electrical cable connecting the data management system and the sensor head in which the electrical sensor is located.

Optionally, the device also comprises magnetic sensors located in the housing. Optionally, there are two magnetic sensors per electrical sensor.

Optionally, the flexible electrical cable is attached to the sheath by a soft braid. The electrical cable may be attached to the sheath continuously along the length of the arm, or alternatively, it may be attached to the sheath only at certain points spaced along the length of the arm. Alternatively, the electrical cable may be incorporated in the fabric of the sheath.

According to the present invention in its broader sense, there is provided an instrument for detecting electromagnetic signals, having arms comprising two removable rods and a flexible conduit, whereby, while the instrument is in use, the arms are stiff in the horizontal direction and flexible in the vertical direction, and while the instrument is not in use the arm can be disassembled.

Before the instrument is deployed, the arms are made rigid and straight by feeding a rod into the sheath. The rods are then fixed to brackets on the main body of the instrument with individual quick-lock type connections. This assembly process can easily be conducted as a single person operation. When the instrument is not in use, the arms can be disassembled, the rigid rods stored separately and the flexible conduit stored, or coiled, next to the instrument.

The invention may be put into practice in a number of ways and one embodiment is shown here by way of example with reference to the following figures, in which;

Figure 1 is a schematic perspective view of a device according to the invention;
Figure 2 as an enlarged view of a sheath and sensor head, according to the invention;
Figure 3 is an enlarged view of a twin rod assembly according to the invention.
Figure 4 is a perspective view to an enlarged scale of the connection of a rod to a bracket according to the invention.

According to the embodiment shown in Figure 1, the instrument comprises an approximately cuboid logger frame 100 and four arms 104 with integrated sensor heads 101. The approximate dimensions of the logger frame 100 are 0.7 m x 0.7m x 0.7m. Each arm is approximately 3.9m in length and extends out from one of the four sidewalls of the logger frame 100. The sensor heads 101 are located at the end of each arm 104 furthest from the point where the arm connects to the logger frame 100. There is therefore a distance of approximately 8m between opposite pairs of sensors heads 101. There is one pair of sensor heads 101 in each of two directions, the two directions being approximately orthogonal and horizontal when the instrument is in use during an electromagnetic survey. Each sensor head comprises two single electrical sensors. Each single electrical sensor is connected by signal wires to a central data logger located inside the logger frame 100.

The instrument also comprises a number of magnetic sensors mounted within the logger frame. The arms allow the position of each electrical sensor relative to a pair of magnetic field sensors to be chosen and accurately maintained.

The arms 104 are rigid when the instrument is in use. Each arm comprises a pair of connected flexible glass fibre rods 102, and when the instrument is in use, one end of each rod is attached into two spaced brackets on the logger frame 100. The space between the two brackets depends on the dimensions of the logger frame and here the two brackets for each arm are positioned at opposite bottom corners of the side of the logger frame to maximise their separation. The other ends of each of the two rods 102 are connected at the sensor head end of the arm.

In each arm, one of the two rods 107 is not located within the sheath, and its main function is to allow the entire arm to be stabilized in the horizontal direction while maintaining flexibility in the vertical direction, when the instrument is in use. The other rod is located in a sheath 103 constructed from a flexible plastics material. The signal wires (not shown) for each arm extend between the electrical sensors and the logger frame, and are fastened along the outside of the sheath, secured by a protective soft braid. The total outer dimension of each arm is thus minimised. In Figure 1, arm 105 is in a partly assembled state and arm 106 is in a fully assembled state.

The vertical flexibility of the arms is important as it allows arms to bend safely when the instrument is sinking towards or rising up from the sea floor. This also minimises drag forces which increases the speed of the sinking or rising stage and reduces overall operation time.

The rod located in the sheath 103 can be removed from the sheath when the instrument is not in use. The sheath can then be coiled and stored beside the logger frame without disconnecting the signal wires and sensors. This minimises the storage space required for the instrument, wear on the electrical equipment and the time required to assemble the instrument before use.

The pairs of glass fibre rods 102 are all of the same dimensions and thus interchangeable. They can be stored separately from the logger frame, also minimising the storage space required.

Figure 2 shows details of an arm according to the invention, in which a rod is located within sheath 205 and connected to bracket 200 by the pin 206. Retainers 204 attach the sheath 205 to the bracket 200 and the sensor head 203. Electrical sensors 201 and 202 are located on the sensor head 203.

Figure 3 shows details of a pair of flexible glass fibre rods which are to be attached to the frame according to the invention. A connector 301, with a latch 300 for attaching the connector to the sensor head of an arm, connects the ends of two flexible glass fibre rods 302, which are terminated at the other ends with ferrules 303. The ferrules 303 are made of, for example, stainless steel.

Figure 4 shows the way in which the rods of Figure 3 are attached to the frame or main body of an instrument via a bracket. The rod 402 and its ferrule 403 are releasably retained in a bracket by the pin 401.

The mechanical properties of the arms do not affect the measurement system itself. However, the arms allow fixed distances and angles between sensors to be maintained during measurements, thus improving the quality of survey results. The arms also fulfil the function of guiding the signal wires from the sensors to the data logging units in the logger frame.

1. An electromagnetic signal detecting device which comprises electromagnetic signal detecting instruments borne by arms, wherein each arm comprises a removable rod and a flexible conduit arranged to receive the rod.

2. An electromagnetic signal detecting device according to claim 1 which comprises;

    a central housing;

    a data management system located within the housing;

    at least two arms, the arms extending outwards from the housing;

wherein each arm comprises;

    a sensor head, the sensor head constituting at least part of the electromagnetic signal detecting instruments;

    a flexible elongate sheath attached to the housing, the flexible elongate sheath constituting at least part of the flexible conduit;

    a flexible electrical cable attached to the sheath and connecting the sensor head to the data management system; and

    a rod which is removeably locatable within the sheath;

wherein the rod is more rigid than the sheath and one end of the rod is connectable relative to the housing and one end of the rod remote from the housing is connectable relative to the sensor head.

3. An electromagnetic signal detecting device according to any preceding claim, suitable for use under water.

4. An electromagnetic signal detecting device according to any preceding claim, wherein the rod is straight and extends away from the point of

attachment relative to the housing, substantially perpendicularly to the housing.

5. An electromagnetic signal detecting device according to any preceding claim, wherein the rod is connected to a bracket located on the housing.

6. An electromagnetic signal detecting device according to any preceding claim, wherein the rod is fabricated from fibre glass.

7. An electromagnetic signal detecting device according to any preceding claim, wherein each rod is connected to a second similar rod at a point along the first rod which is remote from the housing, one end of the second rod being independently connectable relative to the housing.

8. An electromagnetic signal detecting device according to any preceding claim, wherein the number of arms is four, comprising two pairs of arms which are substantially parallel to each other, one pair of arms being substantially orthogonal to the other.

9. An electromagnetic signal detecting device according to any preceding claim, wherein the sensor head is attached to the sheath at the end of the sheath remote from the housing.

10. An electromagnetic signal detecting device according to any preceding claim, wherein each sensor head comprises one or more electrical sensors

11. An electromagnetic signal detecting device according to any preceding claim, wherein each sensor head comprises two electrical sensors.

12. An electromagnetic signal detecting device according to any preceding claim, wherein one or more magnetic sensors are located in the central housing.

13. An electromagnetic signal detecting device wherein the flexible electrical cable is attached to the sheath with one or more connectors.

14. An electromagnetic signal detecting device according to any preceding claim, wherein the flexible electrical cable is incorporated in the fabric of the sheath.

15. A method of deploying an electromagnetic signal detecting device which comprises;

storing the device;

locating the rods within the flexible elongate sheaths, connecting the rods relative to the housing at one end and connecting the rods relative to the sensor head at the end of the arm remote from the housing; and

using the device to detect electromagnetic signals.

16. A method according to claim 15, additionally comprising the step of positioning the device on or near the seafloor before using the device to detect electromagnetic signals.

17. A method of deploying an electromagnetic signal detecting device according to claim 15 or 16, wherein a controlled electromagnetic source near the sea floor is the origin of the electromagnetic signals.

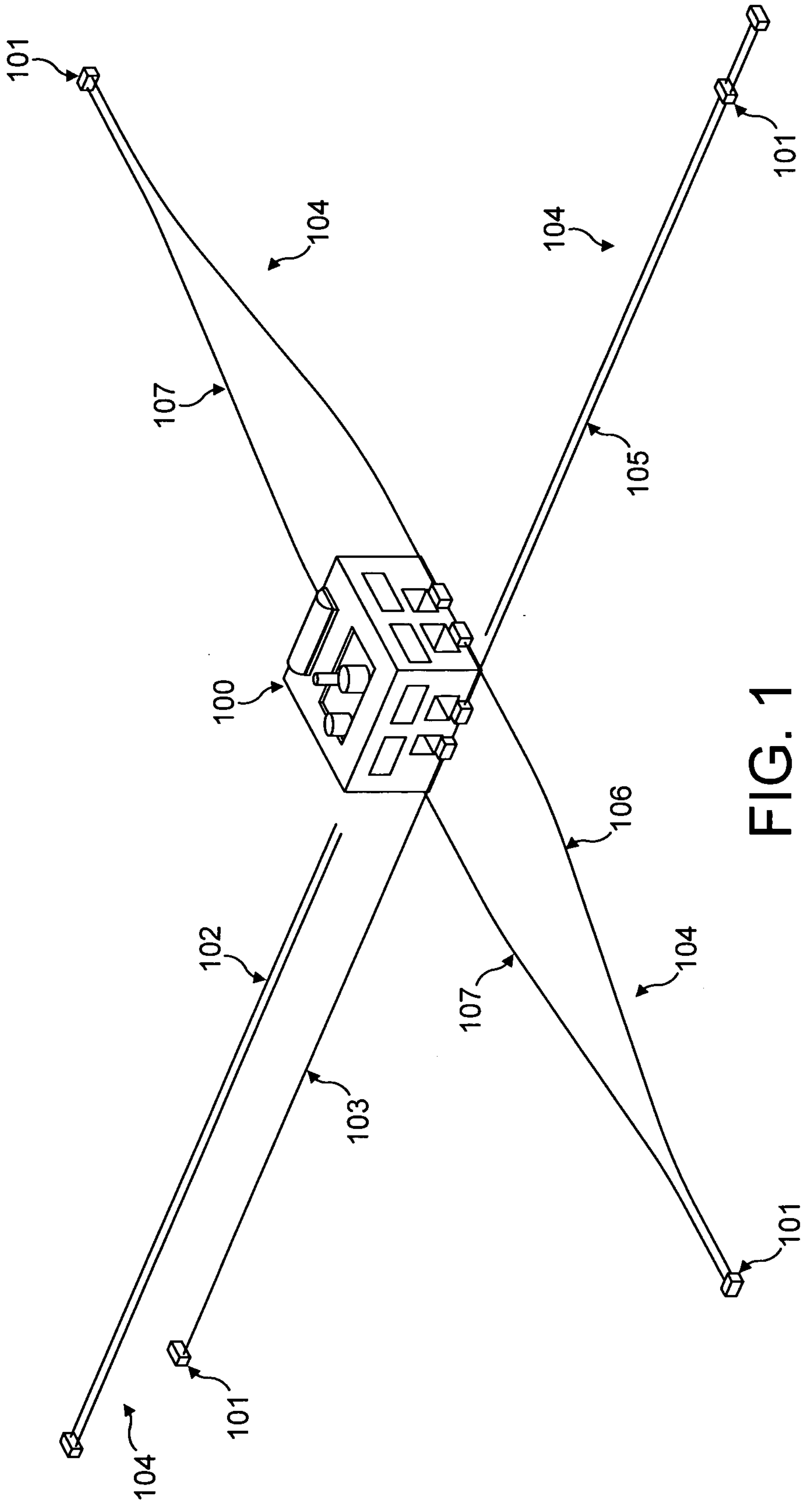

FIG. 1

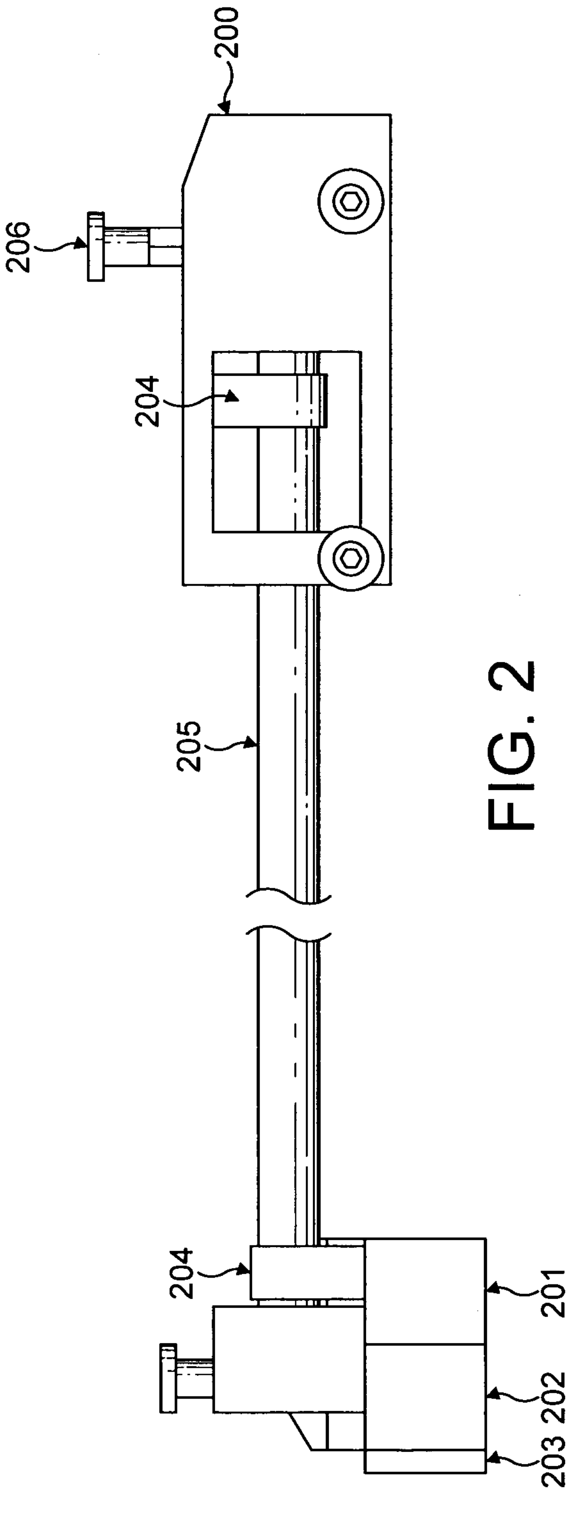

FIG. 2

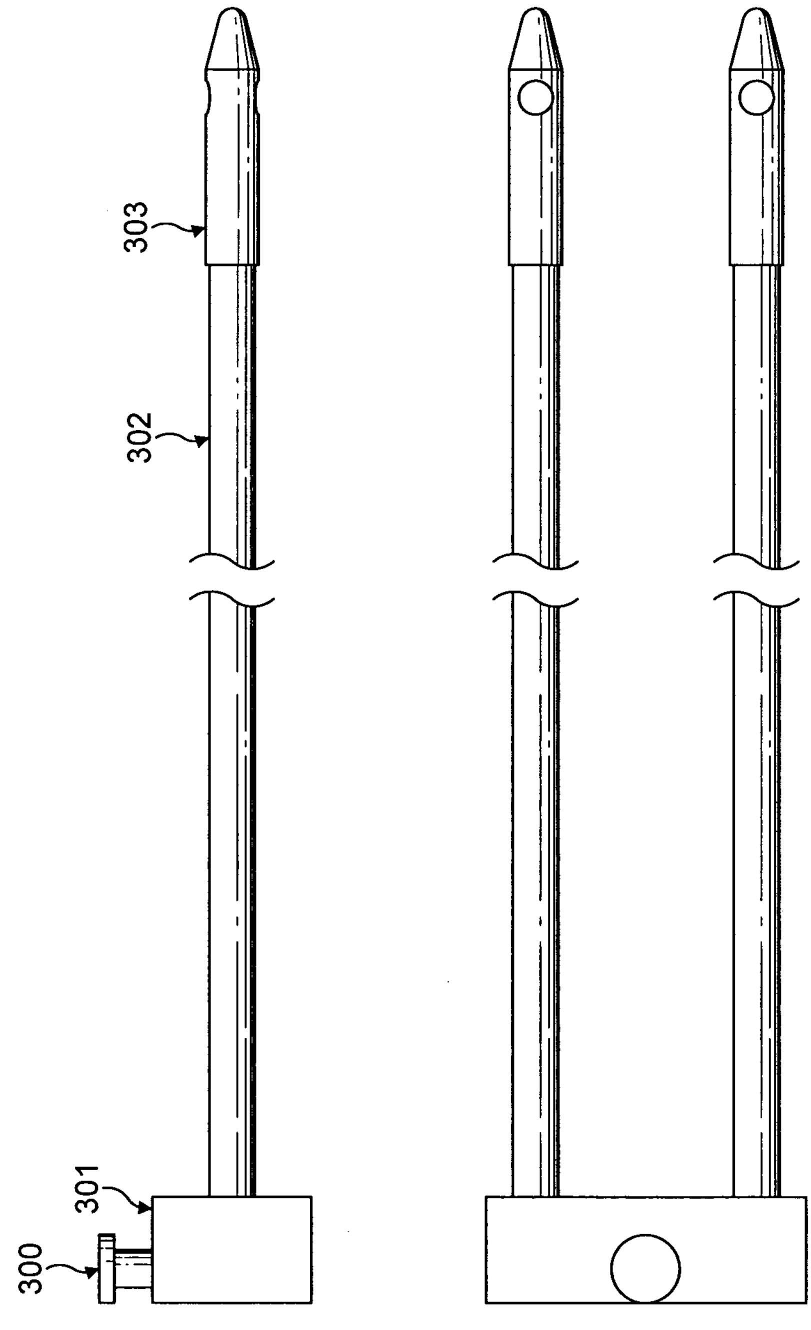

FIG. 3

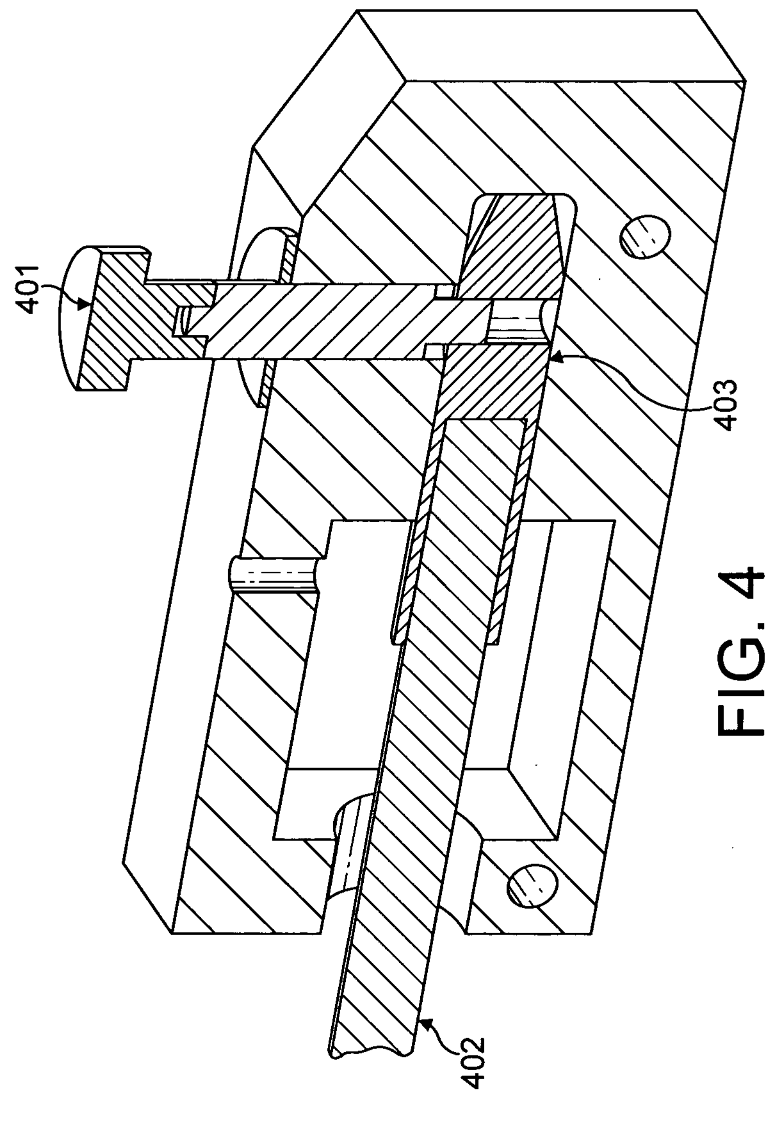

FIG. 4