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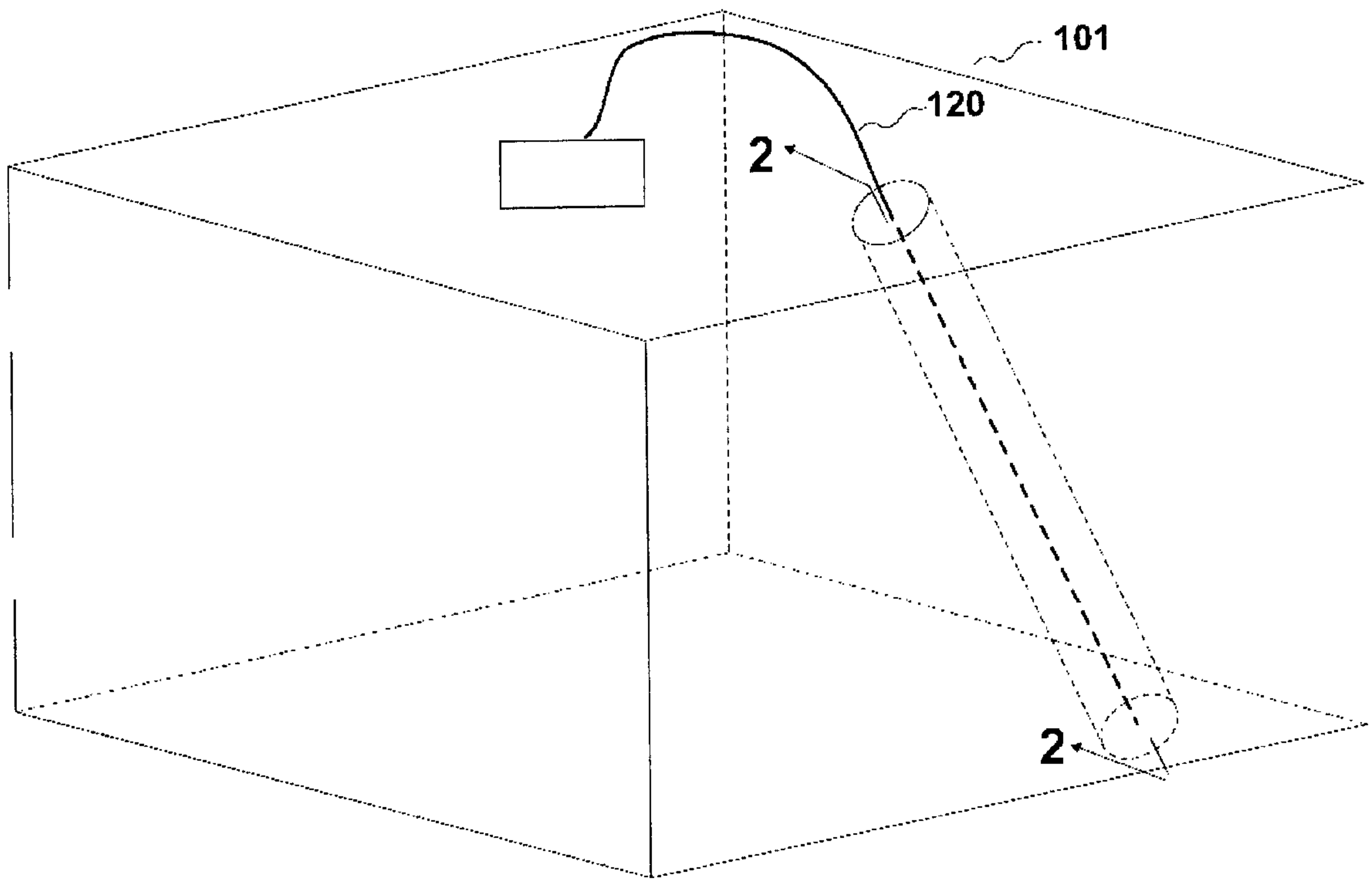
(54) Title: PRESSURE SENSITIVE CABLE DEVICE FOR MONITORING ROCK AND SOIL DISPLACEMENT



(57) Abrégé/Abstract:
The present invention is a substance displacement device. The device includes a sensing unit which is positioned in a drill hole or otherwise within the substance, such as soil or rock. A measurement device is connected to the sensing unit to measure changes in resistance caused by deformation of the sensing device. A control device connected to the measuring device determines whether the change in resistance exceeds a threshold, and thus activates an alarm. The sensing device preferably includes a fixed resistance device across its terminations to enable the establishing of a baseline resistance. The sensing device may include an electrical element or an optical element. The alarm can be any suitable type of alarm.

ABSTRACT

[Para 62] The present invention is a substance displacement device. The device includes a sensing unit which is positioned in a drill hole or otherwise within the substance, such as soil or rock. A measurement device is connected to the sensing unit to measure changes in resistance caused by deformation of the sensing device. A control device connected to the measuring device determines whether the change in resistance exceeds a threshold, and thus activates an alarm. The sensing device preferably includes a fixed resistance device across its terminations to enable the establishing of a baseline resistance. The sensing device may include an electrical element or an optical element. The alarm can be any suitable type of alarm.

PRESSURE SENSITIVE CABLE DEVICE FOR MONITORING ROCK AND SOIL DISPLACEMENT

Heading

BACKGROUND - FIELD OF THE INVENTION

[Para 1] This invention relates to the improvement of event detection capabilities for cable monitoring devices installed in geotechnical materials, utilizing both time domain reflectometry (TDR) and electrical resistance principles.

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BACKGROUND - DESCRIPTION OF PRIOR ART

[Para 2] Time Domain Reflectometry, or TDR, is a remote sensing electrical measurement technique that has been used for many years to determine the spatial location and nature of various objects. An early form of TDR, dating from the 1930s, that most people are familiar with is radar. The type of TDR most commonly referred to by the acronym in the industry is coaxial TDR. Coaxial TDR is essentially a "closed circuit radar". It involves sending an electrical pulse along a coaxial cable and using an oscilloscope to observe the echoes returning back to the input. This technique was reported in the literature in the 1930's and 40's for testing telephone coaxial cables. Numerous TDR articles and books have been written on the subject since.

[Para 3] TDR has been actively investigated by both government and private enterprise for uses in monitoring mining induced displacements in the geologic mass surrounding the mine. US Bureau of Mine research was started in the 1960's, when TDR was primarily used to locate breaks in electrical power cables. Since then, use of the method has expanded, but has still not reached its full potential in the field.

[Para 4] If a geologic material is subject to excess stress, whether generated by natural events (excess rainfall, earthquakes, etc), or by human events (excavation) it displaces to equilibrate this excess stress. This will result in discrete displacement (failure along a plane) or distributed displacement within the geologic mass. TDR cable monitoring is generally conducted by placing a TDR capable cable in a drill hole in the geologic mass. Prior to installation, the cable may be crimped to provide reference reflections in the cable at known physical locations in the rock mass. After crimping, the cable is attached to an anchor, lowered down a borehole, and bonded to the surrounding rock with a cement grout. At locations where progressive geologic movement is sufficient to fracture the grout, cable deformation occurs that can be monitored with a TDR cable tester.

[Para 5] This technique has been tested at Syncrude Canada, amongst others. Syncrude operates an oil sand mine in northern Alberta, Canada. The oil sand is mined by large draglines, which operate adjacent to the edge of a highwall that varies in height from 40 to 60 m. Coaxial cables were installed in vertical holes at three highwall locations in the immediate vicinity (less than 10 m) of slope inclinometers so that a comparison could be made between the two types of instrumentation. The objective of these installations was to assess the ease or difficulty of installation, suitability to field conditions, ease or difficulty of data acquisition, comparison with existing monitoring procedures, and sensitivity of TDR to slope movements.

[Para 6] In addition to the field study, an extensive laboratory test program was implemented to correlate TDR reflection magnitude with shear deformation of grouted cables.

[Para 7] It was concluded that TDR represented a promising technology for slope monitoring, but modifications would be required to increase its sensitivity in oil sands and stiff clay soils. Applications in hard rock mining, such as block caving, indicate that block displacement is sufficiently discrete to shear the cable at distinct points, giving a better response than would be expected in stiff clays. In addition, proper selection of the type of cable to be encapsulated, as well as the encapsulation material (stiffer grout, etc.), can be utilized to increase the system sensitivity to displacement.

[Para 8] Electrical resistance within a cable has been used anecdotally in a somewhat similar fashion as to TDR cable. For the electrical resistance cable monitoring device, loops of varying length of conducting wire are placed in the ground in a borehole, as discussed previously. Being of various lengths, these conductive loops will all extend to differing depths within the borehole. The conductive end of each loop is left extending from the top of the borehole such that an electrical signal can be transmitted through the cable.

[Para 9] As for the TDR cable, deformation of the earth results in deformation of the cable. After sufficient deformation has been attained, the cable loops extending below the line of ground deformation are sheared, resulting in a dead open circuit with no signal transmission. Those loops that are intact above the line of ground deformation within the borehole still conduct a signal. By measuring the electrical resistance readings, once can ascertain approximately at what depth the ground is experiencing deformation, as those loops extending below the level of ground displacement will show either a high, or an infinite, resistance.

[Para 10] There does not appear to be any relevant patented, or non-patented, references noted for the system proposed herein. The references relate either to TDR devices or resistance devices as stand alone systems.

Heading

SUMMARY

[Para 11] In view of the insufficiencies discussed above, it is an object of the present

[Para 12] invention to provide a pacifier assembly having a cover movably mounted to the shield. It is a further object of the invention to provide a pacifier assembly which can protect the nipple of the pacifier and which decreases the inconveniences derived from the pacifier falling on the floor.

[Para 13] The present invention is a substance displacement device. The device includes a sensing unit which is positioned in a drill hole or otherwise within the substance, such as soil or rock. A measurement device is connected to the sensing unit to measure changes in resistance caused by deformation of the sensing device. A control device connected to the measuring device determines whether the change in resistance exceeds a threshold, and thus activates an alarm.

[Para 14] The sensing device preferably includes a fixed resistance device across its terminations to enable the establishing of a baseline resistance. The sensing device may include an electrical element or an optical element. The alarm can be any suitable type of alarm.

[Para 15] Other features and advantages of the invention will be apparent from the following detailed description taken in conjunction with the following drawings.

Heading

DRAWING FIGURES

[Para 16] In the drawings, closely related figures may have the same number but different alphabetical suffixes.

[Para 17] Fig. 1 shows the general configuration of the cable monitoring system installed in a geologic material.

[Para 18] Fig. 2 shows a detailed cross section axially along the borehole as depicted in Fig 1 with a single sensor cable.

[Para 19] Fig. 3 shows the general configuration of the cable monitoring system installed in a geologic material with a multiple strand sensor.

[Para 20] Fig. 4 shows a detailed cross section axially along the borehole as depicted in Fig 3 showing a multiple sensor cable.

[Para 21] Fig. 5 shows the general configuration of the cable monitoring system installed in a geologic material for a convoluted conduit/external TDR cable.

[Para 22] Fig. 6 shows a detailed cross section axially along the borehole as depicted in Fig 5 showing the convoluted conduit shrouded cable and external TDR monitoring cable.

[Para 23] Fig. 7 shows a detailed diametric cross section of the borehole with the convoluted conduit shrouded cable and external TDR monitoring cable.

[Para 24] Fig. 8 shows, in axial section, the convoluted cable enshrouding the sensor cable prior to deformation of the shroud.

[Para 25] Fig. 9 shows, in axial section, the convoluted cable enshrouding the sensor cable post deformation of the shroud.

[Para 26] Fig.10 depicts a cut and fill mining system with the backfilled mining room between two rock pillars. Monitoring system installed to detect shear between fill and pillars.

[Para 27] Fig. 11 depicts a sectional view of a surface mount of the monitoring cable system on a rock face.

[Para 28] Fig. 12 depicts an alternative configuration of the pressure sensitive resistant device that may be used as a portion cable monitoring system.

Heading

REFERENCE NUMERALS IN DRAWINGS

[Para 29] The following reference numerals are found in the drawings and have the indicated designations:

101	geologic material (rock or soil)
102	locus of ground dislocation
103	pressure sensitive cable (resistance varying)
104	resistor
105	resistance measurement apparatus
106	resistance measurement and alarm controller
107	alarm circuit
108	coaxial cable
109	----
110	a controller/ID/resistance-measuring device
111	electrical lead
112	electrical lead
113	----
114	multiple device controller
115	backfilled stopes (mining rooms)
116	underground openings above mining areas
117	underground openings below or adjacent to mining areas

118 surface anchor (mechanical or adhesive)

119 electrical bus

120 global representation of pressure sensitive ground motion system

121 ----

122 ----

123 ----

124 ----

128 ----

129 ----

130 convoluted conduit

131 grout

132 open annulus between outer conduit and inner cable

133 impingement of conduit on sensor 103

134 anchor device

135 borehole in geologic material

136 standard coaxial cable

137 shroud or protective covering

139 water and/or gas resistant membrane

140 water sealing end cap

141 ----

142 deformation of outer conduit upon ground displacement

143 ----

144 conductor

145 dielectric

Heading

DETAILED DESCRIPTION

[Para 30] While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will herein be described in detail preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiments illustrated.

[Para 31] A sensor with electrical resistance properties that vary as a function of pressure is placed within, or upon, a rock, soil, or man made material. The sensing portion of the device may be located within the material, such as being cast in place, placed within a drillhole, or placed in a trench. The sensing portion of the device may also be placed on the surface of the material to be monitored.

[Para 32] The device consists of a measurement unit, a sensing unit, and a control device. The sensing unit is any device such that when subjected to pressure/deformation results in a change in measurable resistance, either optical or electrical. As such this device must at some point form a complete circuit. For the electrical case, this can be prior to the sensing unit being subjected to pressure, where two conductors are connected via a diode, resistor, encoded electrical identifier or other component. This connection may also be created by the application of pressure resulting in a connection between conductors, either by direct contact or through a material which changes conductance with a change in pressure. For the optical case, physical impingement upon the transmitting media results in dissipation and absorption of light such that a received light pulse in a perturbed sensor will be less than a light pulse received in a sensor which has not been disturbed, which is in effect a resistance. In either case, this sensing device is connected to a resistance measurement unit. The resistance measurement unit is connected to a control device. The control device monitors the resistance of the sensor device. When the control device detects a resistance that exceeds the alarm level thresholds the connected alarm device is triggered.

[Para 33] The apparatus may be configured such that it incorporates a single sensing unit, or multiple sensing units connected via a conducting cable (coaxial, twisted pair, etc). A multiple device apparatus may consist of shorter segments of sensors attached to a conducting cable that is connected to a resistance measuring apparatus and alarm controller. Said controller/measurement unit monitors each shorter segment as an individual sensor. In this manner, sections of the geologic material can be monitored for movement instead of using a single device of greater length. This allows greater sensitivity and broadened usage.

[Para 34] In either case, displacement of the geologic material in which a sensor is encapsulated, or is attached to, triggers a resistance change in said sensor at the point of ground dislocation, placing the sensor in shear, tension, or compression. A measurement circuit in the controller detects a resistance change within a sensor. If said resistance change is above a predetermined limit, an alarm device may be triggered. Said alarm device may consist of radio transmission to a base station, flashing lights, stench gas, or whatever alarm is required to provide adequate alert of ground motion.

[Para 35] The device may be utilized in a stand-alone mode such that ground dislocation can be noted at surface. Alternatively, a sensor may be placed in parallel with a TDR (coaxial, twisted pair, etc) or OTDR (fiber optic, single mode, multimode, etc.) capable cable, or the sensor itself may be interrogated with TDR, OTDR, or resistance techniques. This allows detection of the actual location of ground movement along the length of the sensing unit downhole.

[Para 36] Note that an important aspect of the sensor unit is the inclusion of a fixed resistance device across the termination of any individual pair of monitoring strains. By providing such a constant, measurable resistance downhole, a baseline resistance can be determined for the senor. Any shear or short of the monitoring strands within the circuit will change the resistance of the sensor unit circuit. By this means, even standard coaxial cable can become a sensor unit, simply by installing a resistor of known capacity across the terminus of the cable between the inner and outer conductors.

[Para 37] Turning now to the drawings where **FIG.13** is a block diagram representation of electronic components **1000** comprising the present invention, a central processing unit (CPU) **1002** communicates with random access memory (RAM) **1004**, electrically erasable and programmable read only memory (EEPROM) **1006**, analog to digital converter (ADC) **1008**, and input output register (IO) **1010**. A real time clock oscillator **1022** may be used to form a real time clock-calendar by means of a program running upon said CPU. A communication interface **1020** may communicate with device **1000** for purpose of allowing commands and parameters to be input to the device to allow performance of the device to be altered by an operator. The device monitors a sensor **1018** to determine if predetermined conditions are met for an alarm. A method of allowing an operator to attach an alarm is provided by alarm relays **1012** and state of predetermined alarm conditions may be indicated to an operator by alarm indicators **1014**. A separate switchable relay power supply **1016** may be included to power relays. Said the CPU may disable relay power supply **1016** to save power when relays are not being actuated.

[Para 38] Turning now to **FIG.14**, which is a flowchart representation of a program that may run upon CPU **1002**, program starts at **1024** and continues on to **1026** where variables and input output ports are initialized. Program continues to **1028** where a decision is made as to whether a command has been received by means of communication through **1020** and if communication has been received, processes commands received in said communications at **1029** and then returns to **1028** to wait for further commands. If no command is received, program continues to **1030** where a low power mode is entered and processing is suspended but program is not exited. An interrupt routine **1042** triggered by means of **1022** causes processing to resume and at **1044** a decision is made as to whether processing was caused to resume by a clock tick. If a clock tick caused resumption of processing, program continues to **1046** where clock registers are updated and then on to **1048** where processing is suspended. If a clock tick did not cause suspension of processing, a predetermined time period has elapsed and program continues to **1032** where sensors are read by means of ADC **1008** and a determination is made at **1034** as to whether sensor values are within predetermined bounds. If sensor values are within predetermined bounds, program proceeds to **1036** where relays **1012** are set to states to so indicate; program continues to **1038** where indicators are set to inform an operator that predetermined alarm conditions have occurred; program then continues to **1028**. If at **1034** sensor values are outside of predetermined bounds, program continues on to **1040** where relays **1012** are set to states to indicate that no alarming condition has occurred after which program continues to **1041** where indicators are set to indicate that no alarm has occurred after which program continues to **1028**.

Heading

TYPICAL EMBODIMENT A

[Para 39] A typical embodiment of the pressure sensitive device for determining if motion is occurring in a geologic material **101** is shown as Figure 1. The pressure sensitive ground motion detection system, is globally represented as **120** within this Figure.

[Para 40] As shown in section in Figure 2, a cable with electrical resistance properties that vary as a function of pressure (Peratech QTC cable or similar) **103** is placed on or through a rock or soil mass (or man made equivalent) **101.** This may be within a drillhole (encased in grout or open), trench (buried or open), or by attachment to the material surface. The cable (sensor) **103** may be furnished with a resistor **104** at the end of said sensor furthest removed from the measuring device. The purpose of **104** is to provide an electrical connection between the two conductors utilized in cable **103** such that a complete electrical circuit is formed with a known resistance so complete cable shear can be detected. Cable **103** is then connected to a resistance measurement apparatus **105.** Said resistance measurement apparatus measures electrical resistance presented by sensor **103.** A controller **106** determines the interval at which the resistance of the sensor **103** is interrogated. Said controller **106**, is programmable such that a trigger resistance level can be set at which point an alarm circuit **107** is activated. Units **105**, **106**, and **107** are presumed to be battery powered, although they can be powered by any other source of electrical energy. If displacement of the geologic material **101** is sufficient to induce a resistance change in the sensor **103** such that the controller **106** alarm level is exceeded, the alarm circuit **107** is activated. This alarm circuit **107** may consist of electronic transmissions to a base station, triggering of visual or sound alarms (flashing lights, sirens), stench alarms for noisy environments (heavy machine and drilling underground), etc. The sensor **103** may be interrogated by TDR (time domain reflectometry) techniques to determine the point of geologic dislocation (ground motion) **102**. Alternatively, a separate, parallel TDR capable cable (coaxial, twisted pair, etc) or OTDR (optical time domain reflectometry) fiber optic cable **108** may be installed together with **103**. Cable **108** may also be interrogated by TDR/OTDR to locate the physical point of ground displacement **102**. Note also that if the parallel cable **108** is equipped with a terminating resistor **104** downhole, then it may also be described as a sensor **103** and can be monitored in a similar fashion, as may the sensor **103** depending on its configuration.

Heading

TYPICAL EMBODIMENT B

[Para 41] This embodiment is shown in Figure 3 with a sectional representation in Figure 4.

[Para 42] It is similar to the first embodiment described with the exception that multiple pressure sensing cables **103** are connected to an electrical bus **119**. Said electrical bus may consist of any suitable electrical conductors, with twisted pair or coaxial being preferred. Individual, shorter sections of sensor

103 are connected to the electrical bus by means of electrical leads **111** and **112**. Said electrical leads **111** and **112** connect to a controller/ID/resistance-measuring device **110**. Said controller/ID/resistance-measuring device associates a unique serial number (ID) with each segment of sensor **103** to which it is attached. When activated by a multiple device controller **114**, device **110** determines the resistance of each uniquely identified section of sensor **103**. Information obtain is communicated to multiple device controller **114**. Multiple segments of sensor **103** may be placed along a specific monitoring line (downhole, in a trench, along a surface) attached to electrical bus **119**. This enables a user to determine a specific interval along the monitoring line in which ground motion is occurring, as the multiple device controller can identify, by serial number, which sensor **103** segment has experienced ground motion. Alarm systems, reactions, and TDR/OTDR location of the ground motion from this point onward are consistent with the first embodiment.

[Para 43] The obvious hybrids of the first two embodiments are also disclosed and claimed. These are the connection of electrical bus **110** to a single pressure sensitive device **103**, either with, or without, the usage of controller/ID/resistance measuring device **110**.

Heading

TYPICAL EMBODIMENT C

[Para 44] This embodiment is depicted in Figure 5 with sectional representation in Figures 6 thru 9.

[Para 45] As for the first two embodiments, this depicts the deployment of the pressure sensitive ground motion system **120**, in a borehole drilled in a geologic or man made (concrete, etc) environment. A seventh embodiment is depicted in Figures 6 thru 9. This embodiment incorporates a any sleeve or tubing, with a convoluted conduit **130** preferred, around the pressure sensitive device **103** shown here encapsulated in a grout **131**. The usage of a convoluted conduit is recommended with a user specified open annulus **132**, Figure 8. As the ground deforms, with corresponding conduit deformation **142**, annulus **132** closes and convolutions in said conduit impinge **133** on the pressure sensitive device **103**, Figure 9. These impingements increase the local resistance changes resulting in increased cable sensitivity. The downhole end of the conduit is may be equipped with a water sealing end cap **140** to prevent water intrusion into the conduit **130**. An anchoring device **134** may be attached to the bottom of conduit **130** and the pressure sensitive device **103** such that the assemblage will remain in place at the bottom of the drillhole. This anchor can consist of a weight, conical plastic diaphragm, deformed spring hooks (as shown), etc, or essentially any means to prevent the cable from displacing from its placed location in the drillhole **135**. To prevent local kinking at the collar of a drillhole, pressure sensitive device **103** has been electrically coupled to standard coaxial cable **136**. Kinking or damage in this location could produce erroneous readings. A protective shroud **137** has been placed over coaxial cable **136** and conduit **130** to prevent water intrusion into annulus **132**. An additional coaxial or fiber optic cable **108** may be placed adjacent to conduit **103** such that it can be utilized as a stand-alone method of monitoring, either for allowing a greater survivable time or greater accuracy in measuring deformation. This embodiment has application for rock faces in mines, highway cuts, etc. as well as soil faces for any excavation. Alarm activation and monitoring is as for the first listed embodiment.

Heading

TYPICAL EMBODIMENT D

[Para 46] This embodiment is depicted in Figure 5 with sectional representation in Figures 6 thru 9.

[Para 47] As for the first two embodiments, this depicts the deployment of the pressure sensitive ground motion system **120**, in a borehole drilled in a geologic or man made (concrete, etc) environment. A seventh embodiment is depicted in Figures 6 thru 9. This embodiment incorporates a any sleeve or tubing, with a convoluted conduit **130** preferred, around the pressure sensitive device **103** shown here encapsulated in a grout **131**. The usage of a convoluted conduit is recommended with a user specified open annulus **132**, Figure 8. As the ground deforms, with corresponding conduit deformation **142**, annulus **132** closes and convolutions in said conduit impinge **133** on the pressure sensitive device **103**, Figure 9. These impingements increase the local resistance changes resulting in increased cable sensitivity. The downhole end of the conduit is may be equipped with a water sealing end cap **140** to prevent water intrusion into the conduit **130**. An anchoring device **134** may be attached to the bottom of conduit **130** and the pressure sensitive device **103** such that the assemblage will remain in place at the bottom of the drillhole. This anchor can consist of a weight, conical plastic diaphragm, deformed spring hooks (as shown), etc, or essentially any means to prevent the cable from displacing from its placed location in the drillhole **135**. To prevent local kinking at the collar of a drillhole, pressure sensitive device **103** has been electrically coupled to standard coaxial cable **136**. Kinking or damage in this location could produce erroneous readings. A protective shroud **137** has been placed over coaxial cable **136** and conduit **130** to prevent water intrusion into annulus **132**. An additional coaxial or fiber optic cable **108** may be placed adjacent to conduit **103** such that it can be utilized as a stand-alone method of monitoring, either for allowing a greater survivable time or greater accuracy in measuring deformation. This embodiment has application for rock faces in mines, highway cuts, etc. as well as soil faces for any excavation. Alarm activation and monitoring is as for the first listed embodiment.

Heading

TYPICAL EMBODIMENT E

[Para 48] This embodiment, shown in Figure 11, depicts a surface application of the pressure sensitive ground motion system **120**. In this case, the system is deployed on the ground surface over geologic rock blocks or surfaces that may experience motion. Cable **103** is attached to the face by usage of adhesive or mechanical anchors **118**, spanning dislocation area **102**. Alarm activation and monitoring is as for the first listed embodiment.

Heading

TYPICAL EMBODIMENT F

[Para 49] In this embodiment, the system **120** is deployed with cables **103** being located within a trench or drillholes underneath and area to be monitored. The sensing device **103** may be below a roadway, a housing project, etc. If subsurface subsidence (sinkholes, old mining excavations, etc) begin to break through to surface, they will induce motion in the ground, and thus vary resistance in the sensing device **103**, triggering the alarm circuit.

Heading

TYPICAL EMBODIMENT G

[Para 50] This embodiment demonstrates an alternative method of construction of the pressure sensitive device **103**. This is shown in Figure 12. In this embodiment, the pressure sensitive device **103** consists of a sandwich of two metallic conductors **144** (in this case, copper tape) attached to two sides of a pressure sensitive tape **145** (Peratech QTC tape or pressure sensitive underlay). This composite is then encapsulated in a waterproof sheath **139**, consisting of plastic or some other fluid or gas resistant membrane. When said composite structure is subjected to pressure, the electrical resistance of the pressure sensitive tape decreases, resulting in a low electrical resistance pathway between the two conductors **144**. Current flow can then be detected through the completed circuit, allowing it to be used as a pressure sensitive device **103**. Note also that, as the material is constructed from two conductors **144** separated my a dielectric material **145**, that it is possible to locate the distance along the device, at which point electrical bridging is occurring, using standard electrical TDR techniques.

Heading

TYPICAL EMBODIMENT H

[Para 51] Here, the pressure sensitive sensor **103** is be replaced by a length of standard coaxial cable, twisted pair cable, or any other medium that will allow TDR interrogation, with the terminus of the cable pair (for coaxial cable this pair is the inner and outer conductor) is bridged with a resistor **104** of known resistance. A break in the circuit changes the system resistance, resulting in a detectable event for the alarm circuit.

Heading

TYPICAL EMBODIMENT I

[Para 52] A preferred embodiment of the resistance measurement/controller/alarm circuit is described as follows:

[Para 53] In one preferred embodiment of the current invention, CPU **1002**, RAM **1004**, EEPROM **1006**, ADC **1008** and IO **1010** may all be included in a semiconductor chip of a type ATMEGA 32 L manufactured by Atmel Corporation. A crystal of fundamental frequency 32.768KHz manufactured by ECS CORPORATION may provide real time clock oscillator **1022**. Sensors may be of a type described in the body of the patent application (Peratech QTC cable **103** or similar equipped with resistor **104**). Alarm relays **1012** may be of a type DS2Y-SL2—DC5Vmanufactured by Aromat Corporation. Relay power supply **1016** may be of a type MIC2145BMM manufactured by Micrel Corporation and communication interface **1020** may be of a type LMX 9820 manufactured by National Semiconductor Corporation. Alarm indicators **1014** may be comprised of any well-known low power light emitting diode (LED). Any well-known lithium ion battery may provide primary power for entire electronics assembly **1000**.

Heading

OPERATION

[Para 54] The operation of the pressure sensitive cable device for monitoring rock and soil displacement is as follows.

[Para 55] The pressure sensitive sensor **103** is constructed and installed as described in any of, but not limited to, the disclosed embodiments. Continuity and system resistance are checked and stored with the resistance measurement device **105** and controller **106**. Once this has been verified, the alarm level is set through the controller **106** and the alarm circuit **107**. This can be varied from dead short to dead open, or incremental resistance changes in between. The controller 106 then measures the resistance of the circuit at program selected time intervals using the resistance measurement device **106**. The measured resistance is then compared in the controller to the pre-programmed levels of resistance change required to trigger the alarm circuit.

[Para 56] If a resistance level is found that exceeds the programmed alarm criteria for measured resistance, the controller **106** immediately conducts a control measurement of the system resistance. If the value once again indicates that the measured value exceeds pre-set resistance values for alarm, the alarm circuit is activated.

[Para 57] Once the alarm circuit is activated, an alarm is initiated. Said alarm may consist of radio transmission to a base station, flashing lights, stench gas, or whatever alarm is required to provide alert of ground motion to targetted personnel.

[Para 58] Upon alert, site personnel may take whatever action is necessary, such as closing areas to operation, etc. The system **120** has been designed such that it may be monitored with a time domain reflectometery (TDR) such that the location of ground displacement may be identified within the sensor **103**. This function reduces the necessity of reading the sensors or TDR cables on a frequent basis as monitoring the system resistance accomplishes much of the same function by indicating if ground displacement has taken place.

[Para 59] After the alarm has been triggered, if the sensor **103** is still intact and capable of carrying an electrical signal, the alarm circuit **107** may be reset to a new level encompassing the resistance changes that have already occurred.

[Para 60] It should be noted that in the electrical embodiments of the present invention, means for communication for purposes of control, command, and query may be by the means of personal digital assistance (PDA), such as, for example, of a model Tungsten T2 manufactured by Palm, Inc.

[Para 61] While the specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the spirit of the invention, and the scope of protection is only limited by the scope of the accompanying claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

[Claim 1] 1. A substance displacement device comprising:

a sensing unit positionable to sense substance displacement,

a measurement unit operatively connected to said sensing unit, and

a control device operatively connected to said measurement unit for activating an alarm in the event the measurement unit detects a change in resistance exceeding a specified threshold.

[Claim 2] 2. The substance displacement device according to claim 1, wherein said sensing unit further comprises a fixed resistance device across the terminations of an individual pair of monitoring strains within the sensing unit for determining a baseline resistance.

[Claim 3] 3. The substance displacement device according to claim 2, wherein said sensing unit is an electrical sensing unit.

[Claim 4] 4. The substance displacement device according to claim 2, wherein said sensing unit is an optical sensing unit.

[Claim 5] 5. The substance displacement device according to claim 2, wherein said sensing unit comprises a coaxial cable, and wherein the fixed resistance device is connected across the end of the coaxial cable.

[Claim 6] 6. The substance displacement device according to claim 1, wherein the sensing device includes a pressure sensitive cable which has a varying resistance which changes in response to pressure being applied thereto.

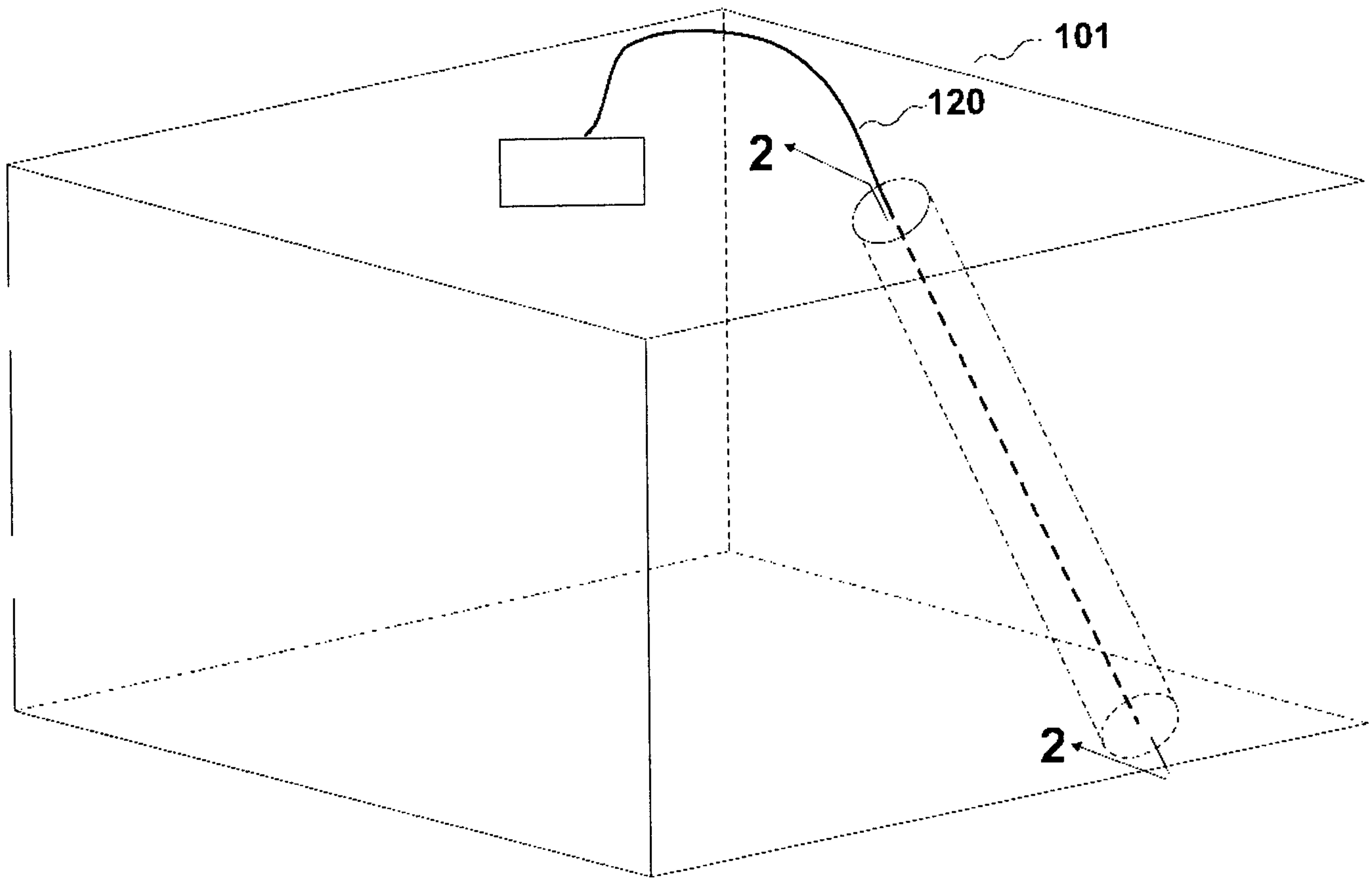


FIG. 1

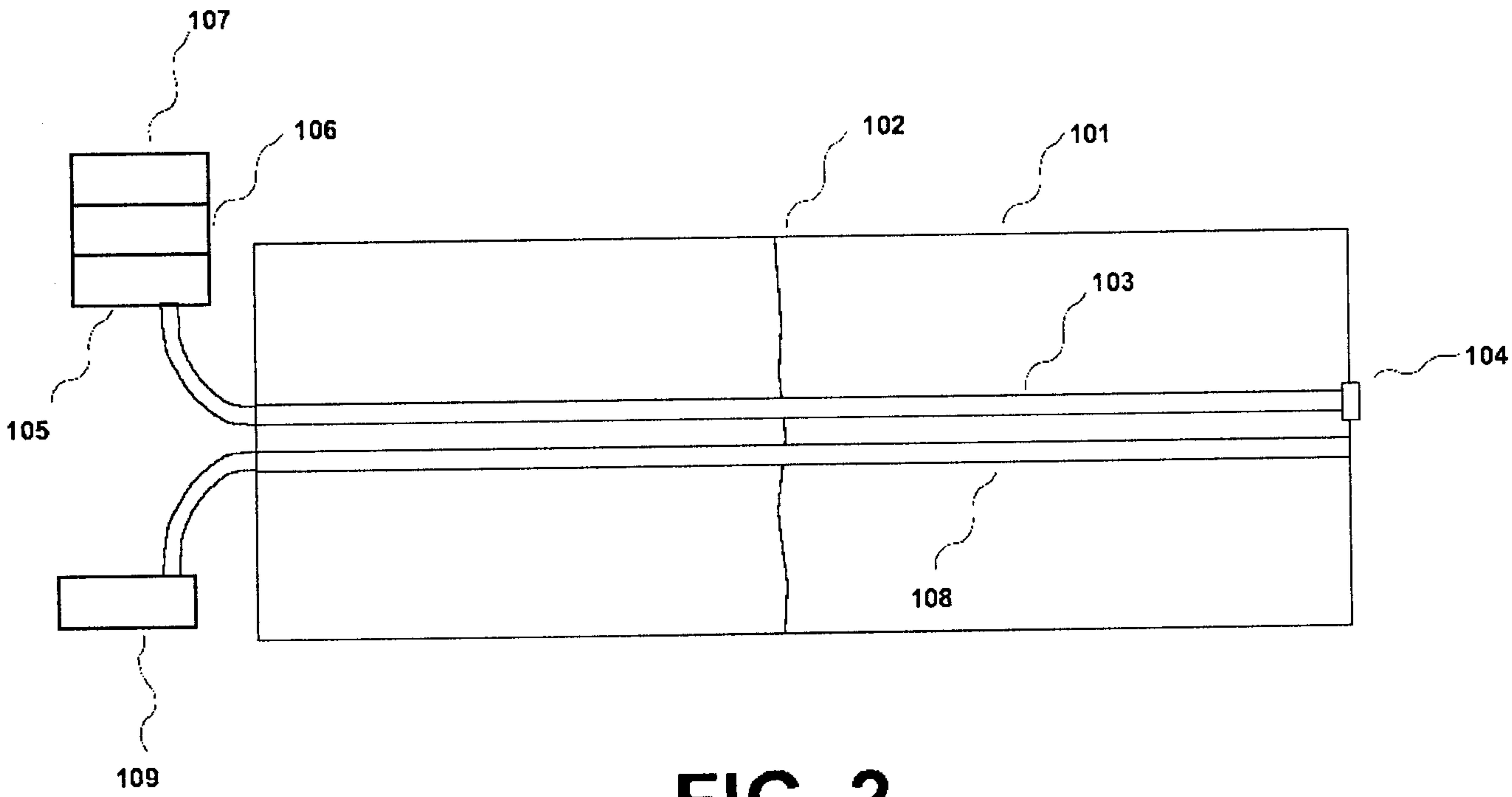


FIG. 2

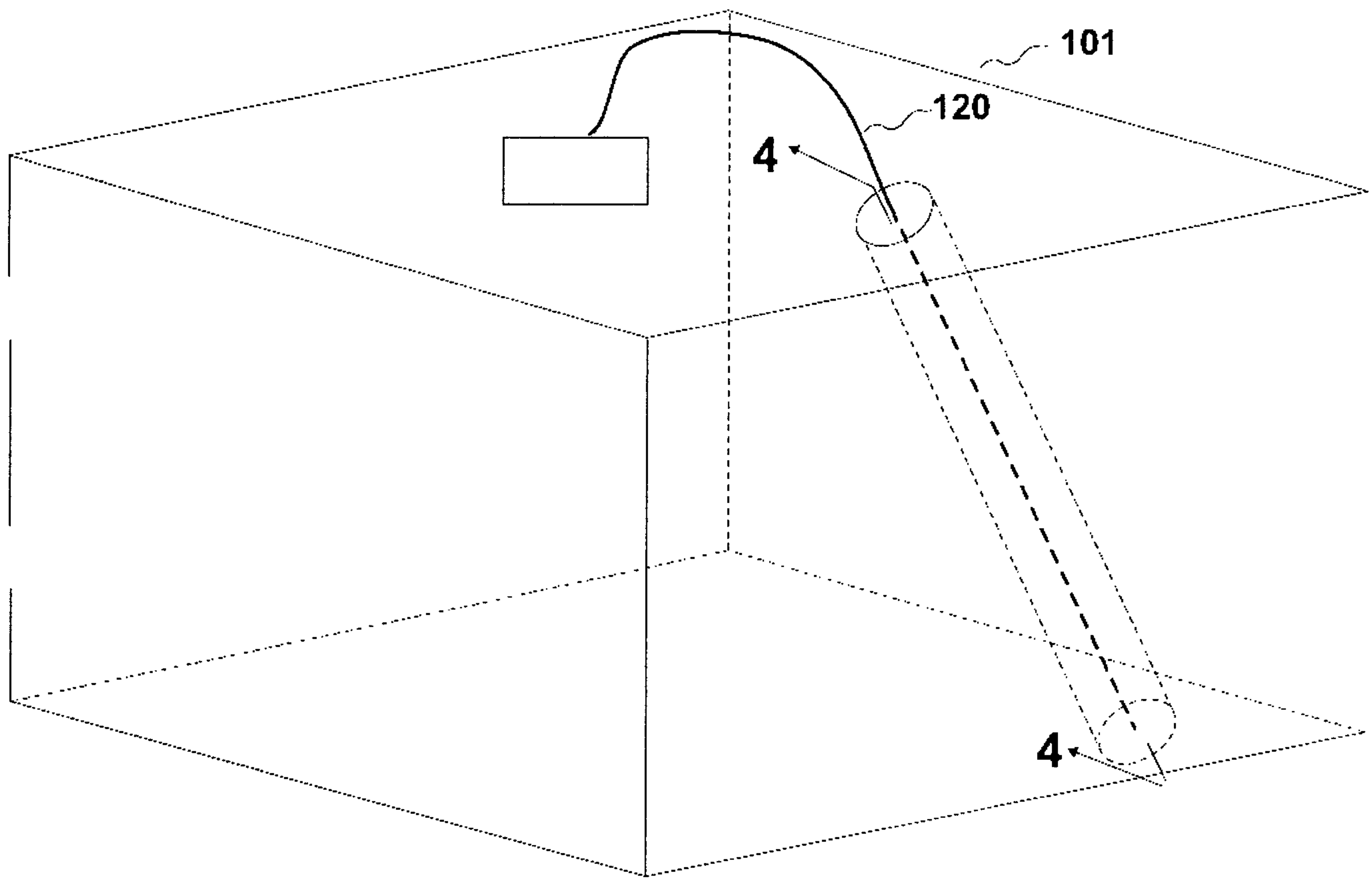

101
120
4
4

FIG. 3

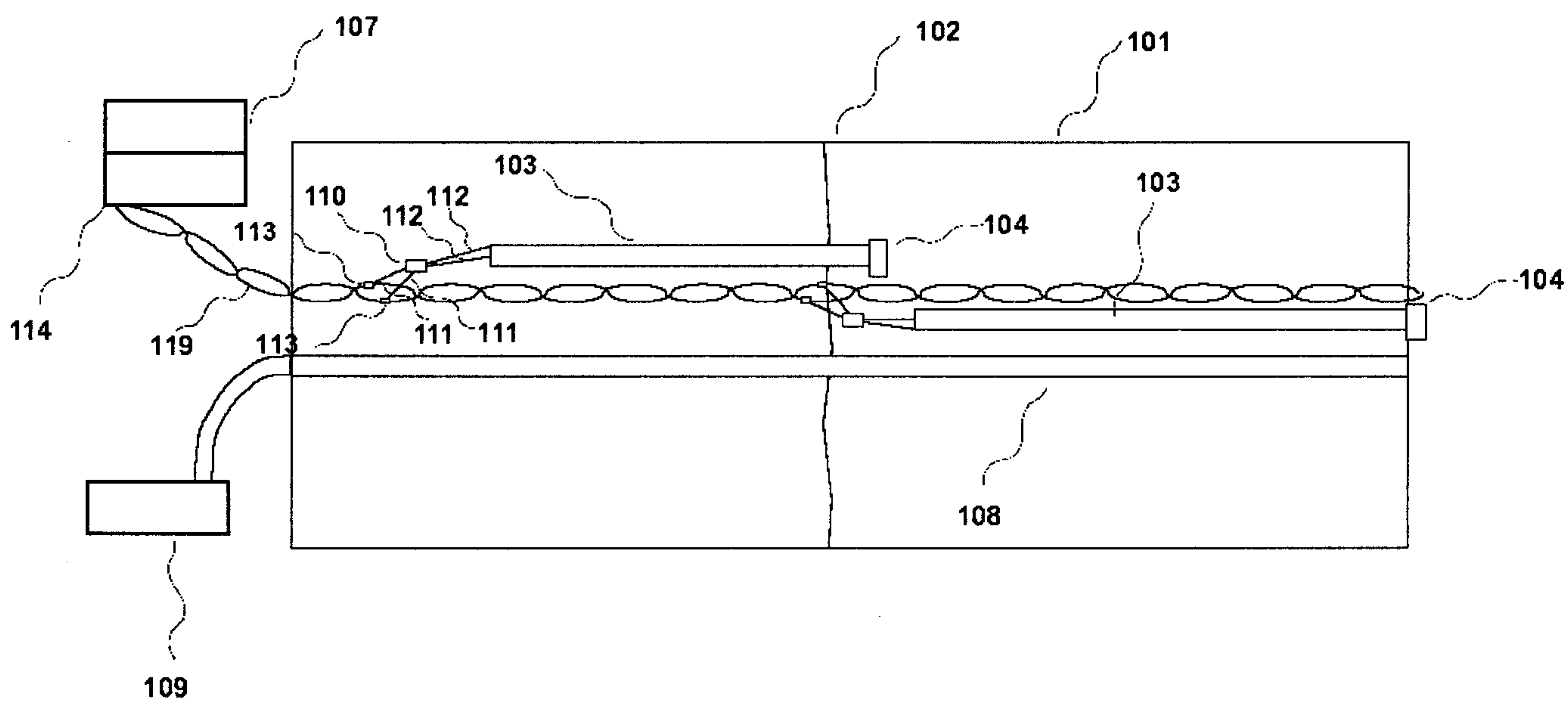

107
102
101
103
103
110
112
112
104
113
104
114
119
113
111
111
108
109

FIG. 4

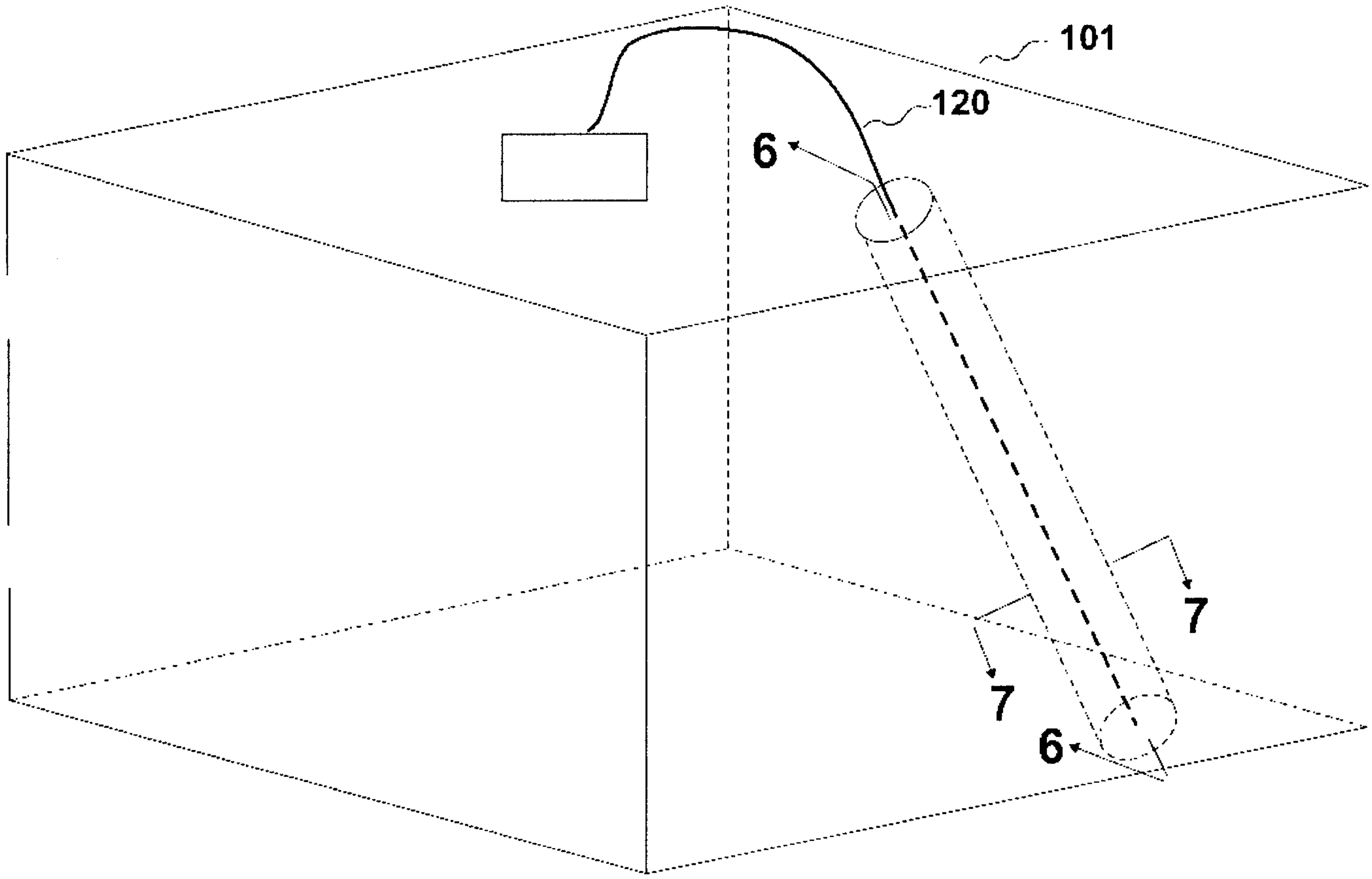


FIG. 5

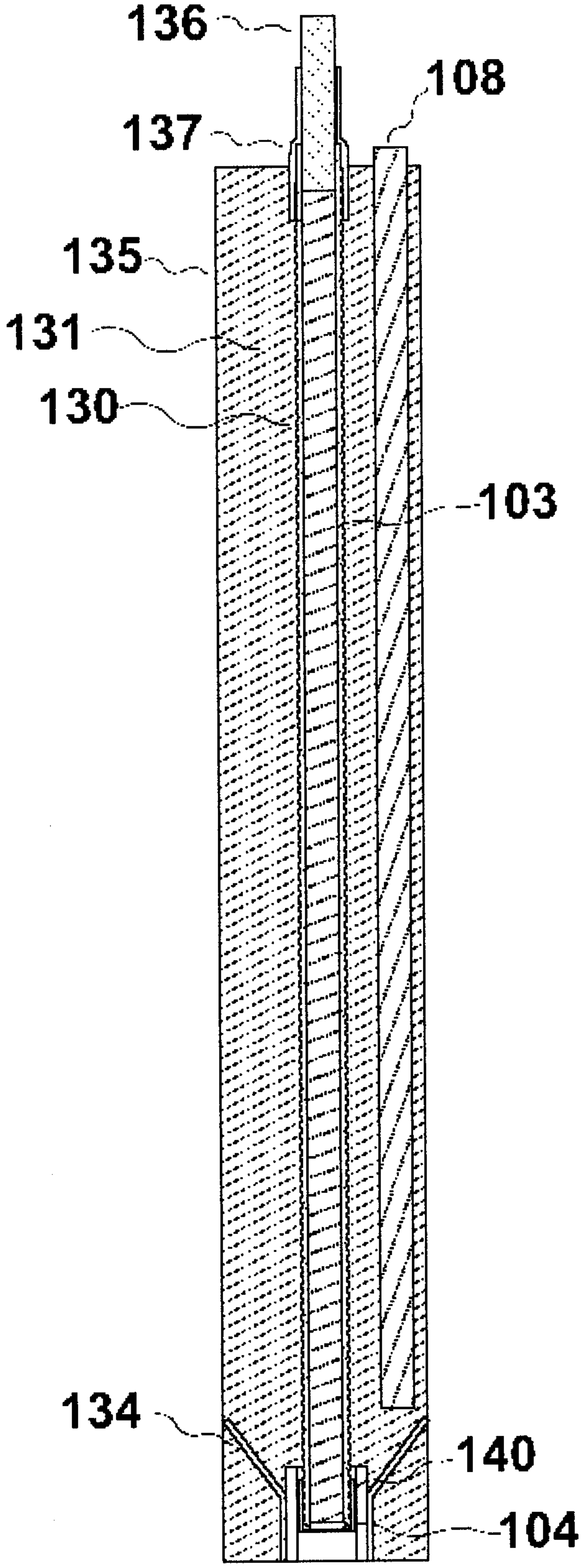


FIG. 6

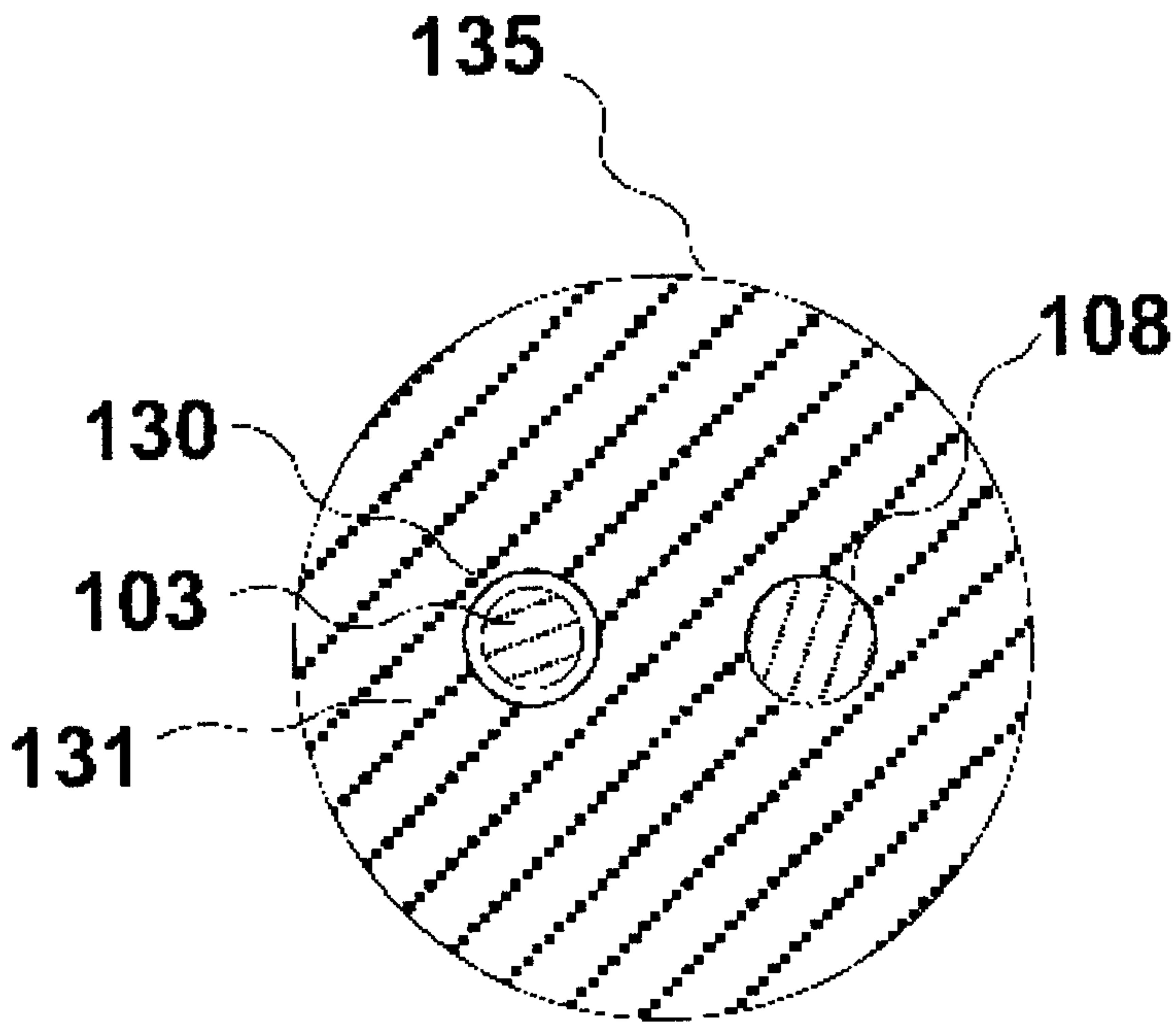


FIG. 7

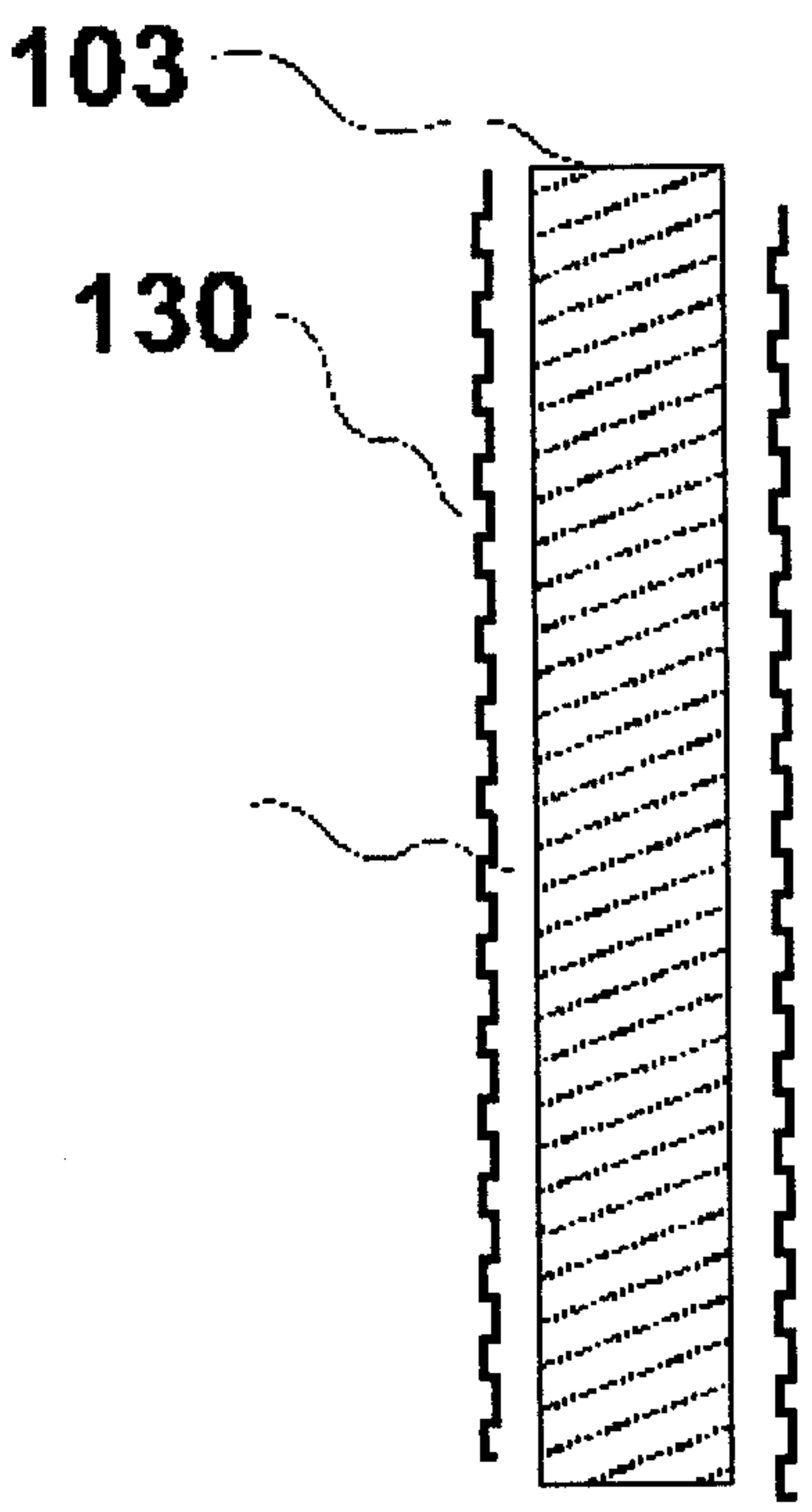


FIG. 8

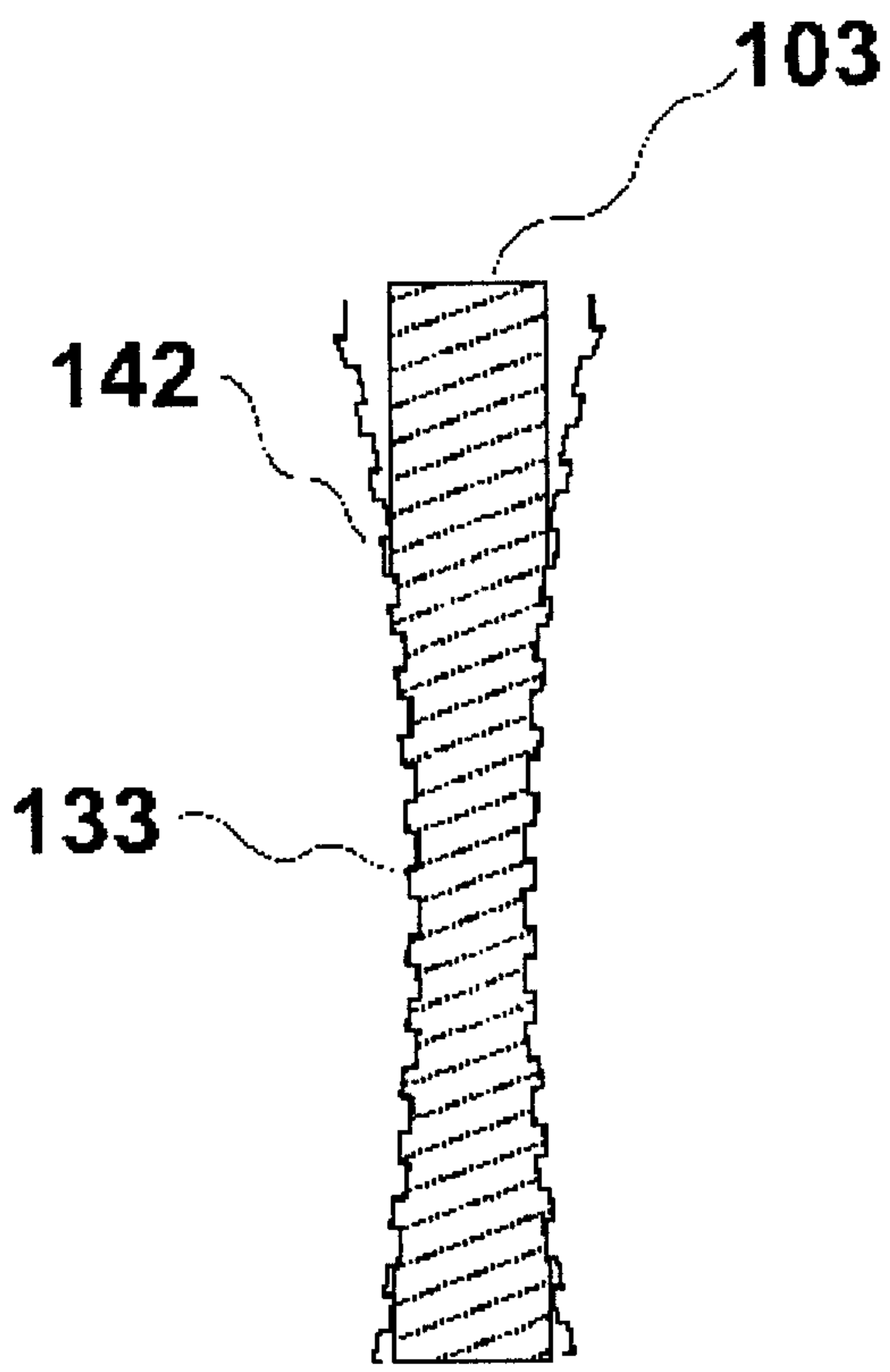


FIG. 9

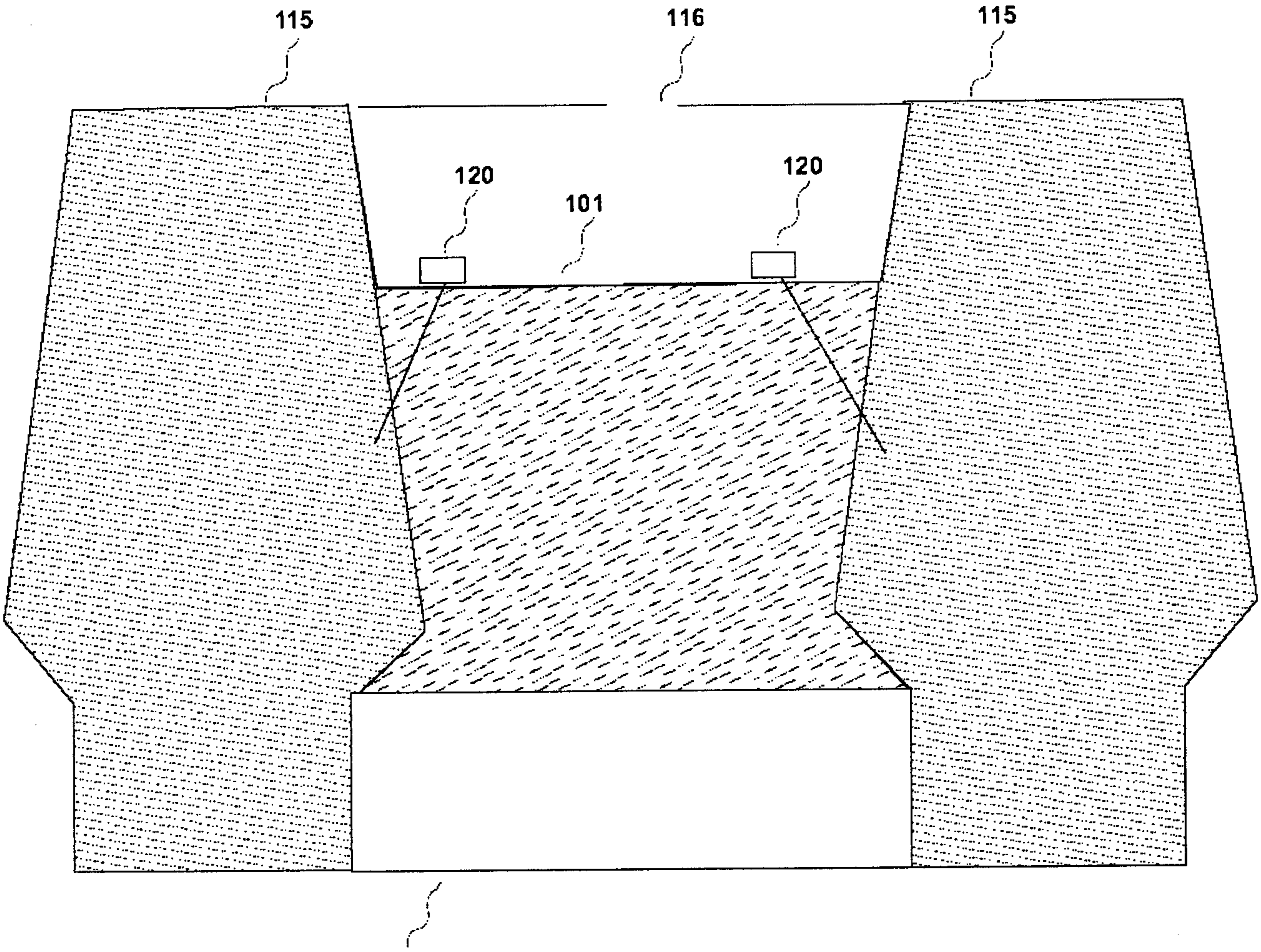


FIG. 10

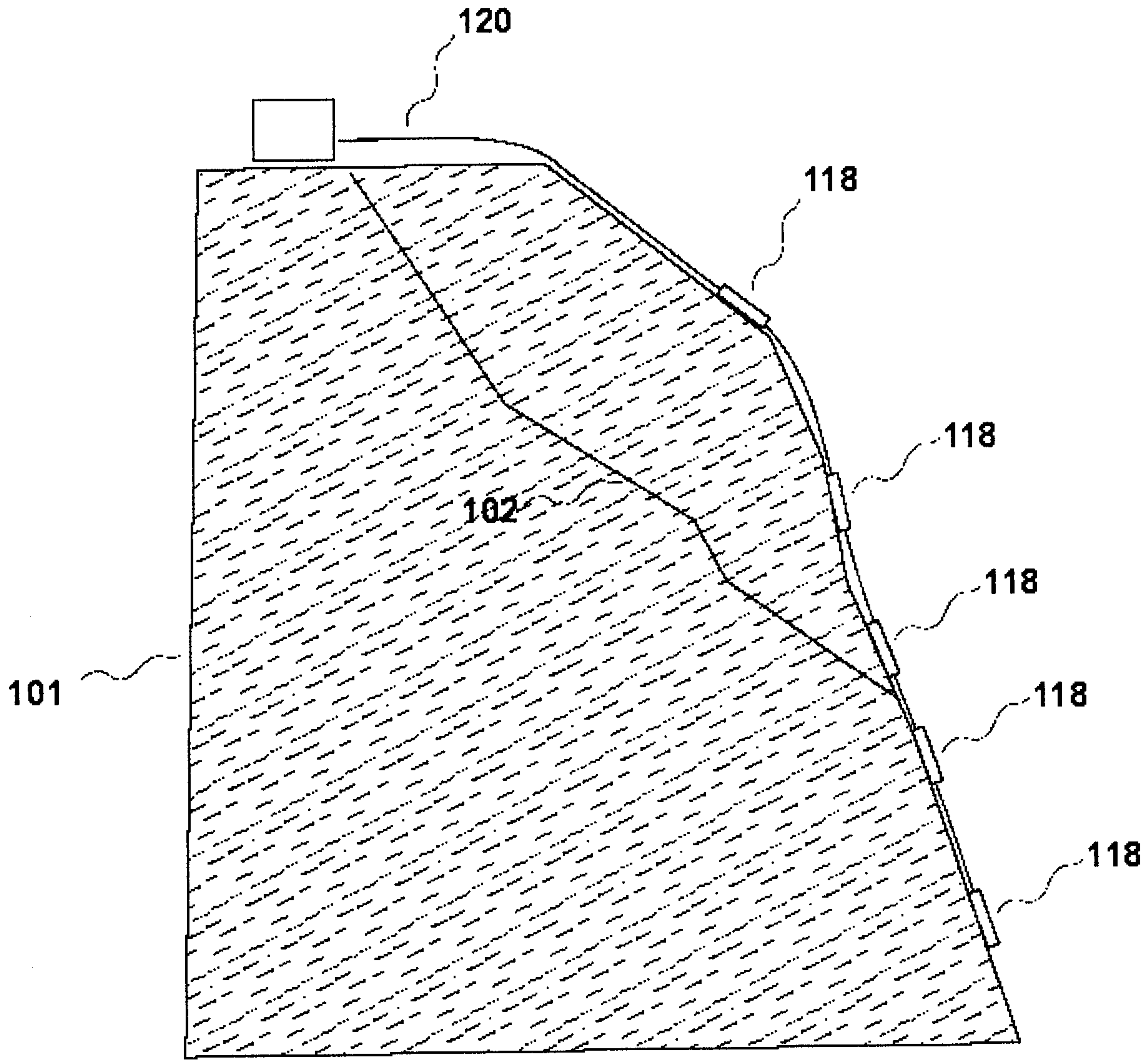


FIG. 11

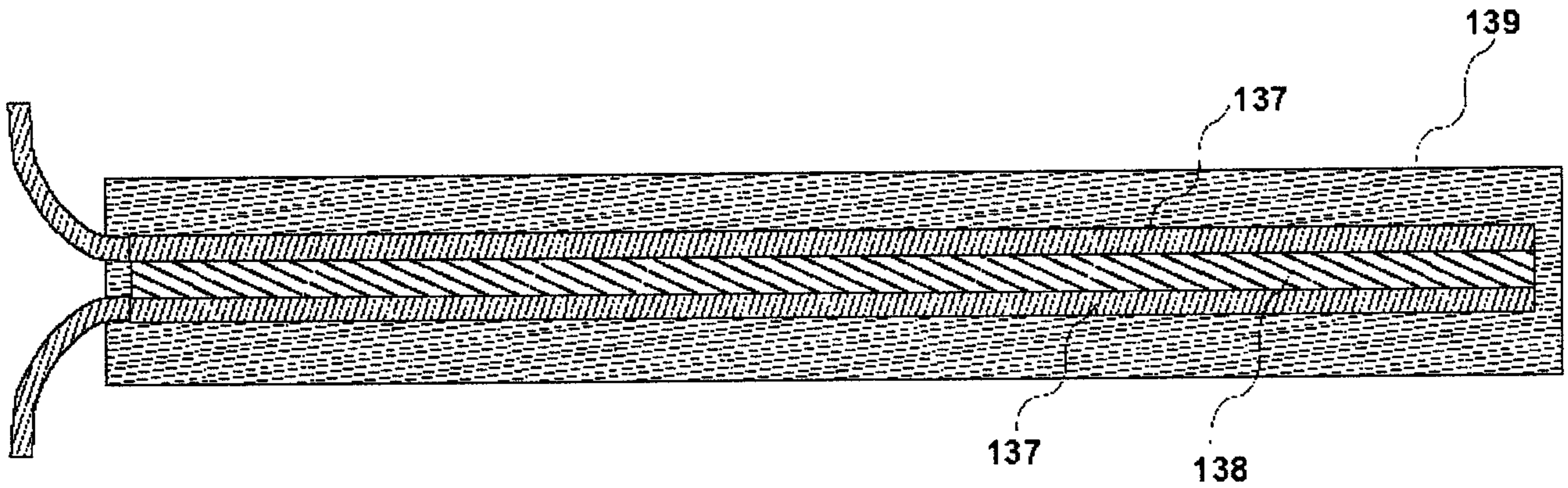


FIG. 12

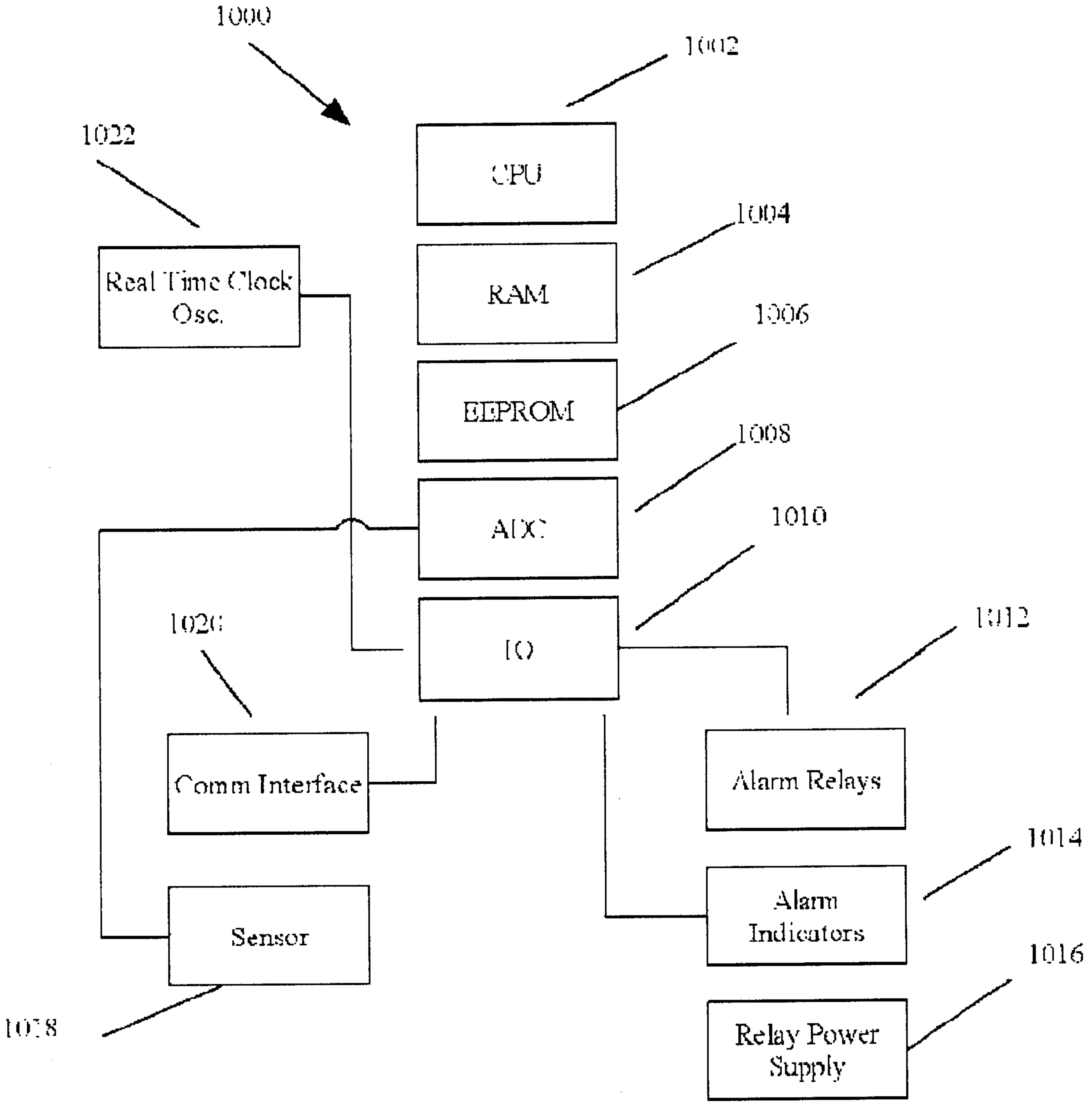

1000
1002
1022
CPU
1004
Real Time Clock Osc.
RAM
1006
EEPROM
1008
ADC
1010
1020
IO
1012
Comm Interface
Alarm Relays
1014
Alarm Indicators
Sensor
1016
1018
Relay Power Supply

FIG. 13

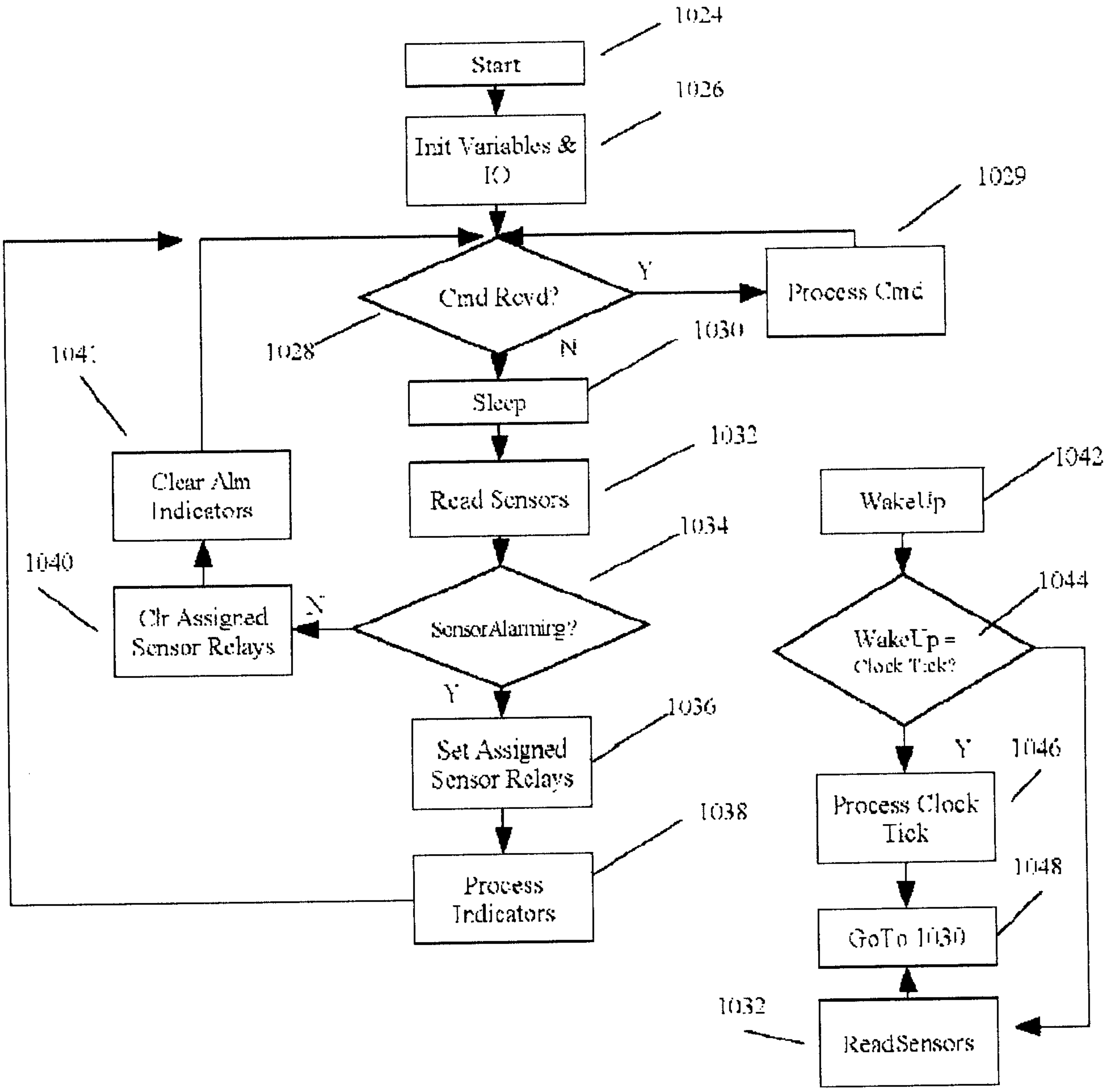
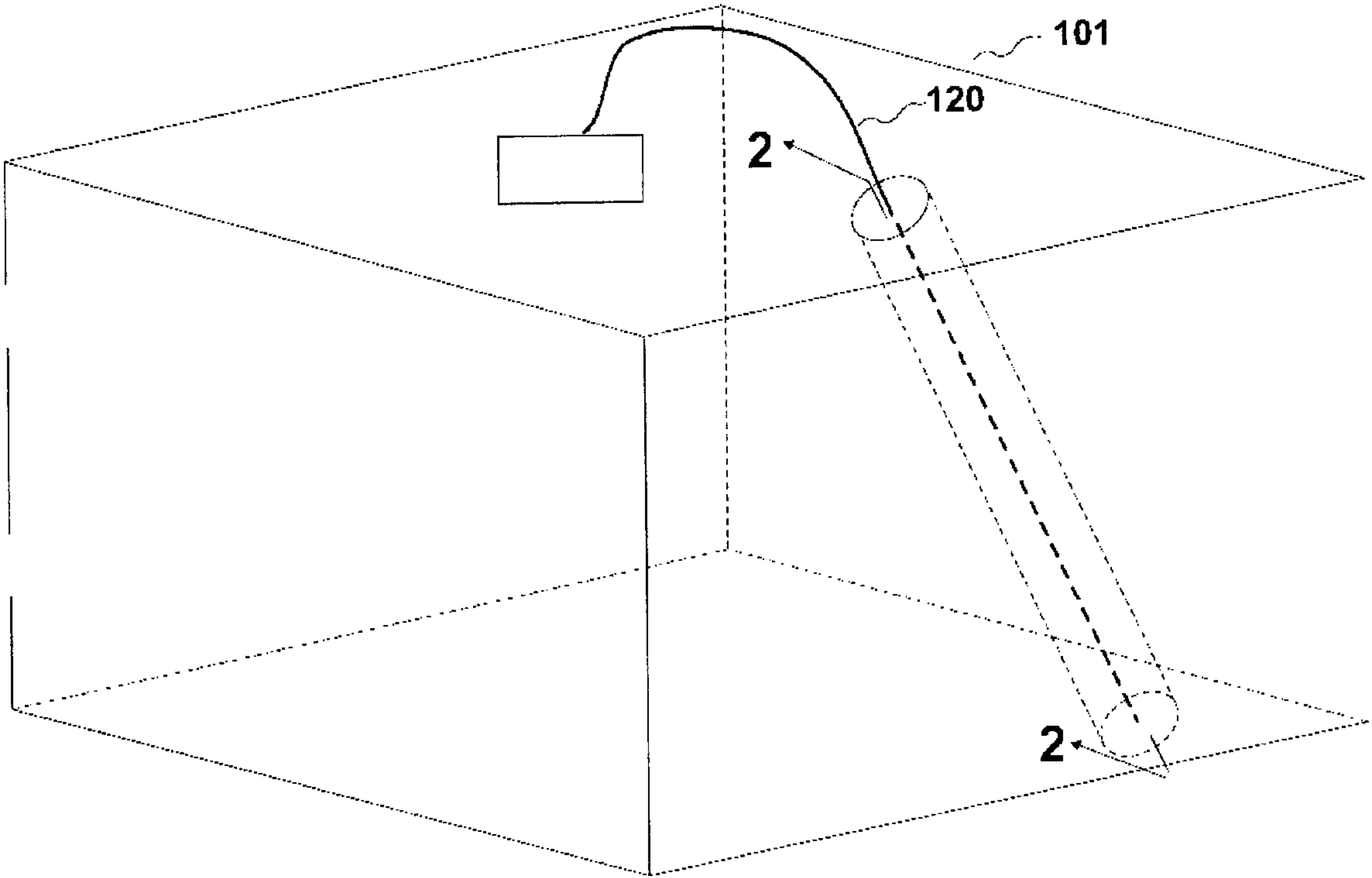

1024
Start
1026
Init Variables & IO
1029
Cmd Rcvd?
Y
Process Cmd
1028
N
1030
1041
Sleep
1032
Clear Alm Indicators
Read Sensors
1042
WakeUp
1034
1040
N
Clr Assigned Sensor Relays
SensorAlarming?
1044
WakeUp = Clock Tick?
Y
1036
Set Assigned Sensor Relays
Y
1046
Process Clock Tick
1038
Process Indicators
1048
GoTo 1030
1032
ReadSensors

FIG. 14


101
120
2
2