(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 610 587 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
15.11.2017 Bulletin 2017/46

(21) Application number: **12198998.2**

(22) Date of filing: **21.12.2012**

(51) Int Cl.:
G01C 1/00 *(2006.01)*
E21D 1/14 *(2006.01)*
E21B 47/10 *(2012.01)*
E21D 9/00 *(2006.01)*
E21B 47/022 *(2012.01)*
E21B 7/04 *(2006.01)*
E02D 3/115 *(2006.01)*

(54) **Underground soil excavation**

Unterwasser-Erdabtragung

Excavation de déchets souterrains

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **27.12.2011 EP 11195778**

(43) Date of publication of application:
03.07.2013 Bulletin 2013/27

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Description

[0001] When a tunnel is built in soil, the soil and ground water level above the tunnel may shift. If there is a structure above the tunnel, such as a surface building, the shifting soil or ground water level may cause the overlaying structure also to settle and shift, thus causing damage to the structure. In particular, this is a problem when the soil contains large amounts of sand and the surface building is an older building having wails resting on the ground and not on a concrete slab spreading out the weight of the building. The same problem may be encountered when a tunnel is excavated under other structures, such as another tunnel, a road, the foundation of a bridge, and a football field. It is therefore an object of the present invention to prevent damages to an overlaying structure when an underground space is excavated. Related prior art is found in US 3 528 252 A disclosing an arrangement for freezing earth in a specific formation; in EP 0 774 566 A1 disclosing a method for securing the excavation of a tunnel by drilling and injecting a supporting material into the ground prior to the excavation; EP 1 632 749 A1 disclosing a method for determining shifts in the soil when excavating, and in WO 01/34941 A1 disclosing a self-contained sub-surface drilling machine.
The above object is according to a first aspect of the present invention met by a method of excavating an underground space in the soil below an overlaying structure, the method comprising: providing a compensation liquid, providing a plurality of compensation tubes for conveying the compensation liquid, each of the compensation tubes comprising a number of outlets for allowing the compensation liquid to pass from the compensation tube into the surrounding medium, positioning the plurality of compensation tubes in the soil below the structure, excavating the underground space in the soil below the plurality of compensation tubes, monitoring the overlaying structure for detecting changes in the structure due to the excavating of the underground space, and if any change in the structure is detected: injecting the compensation liquid into the soil through one or more of the plurality of compensation tubes into the soil. The injection of the compensation liquid is for reducing or compensating for the detected change in the structure.

[0002] The impact of the injecting on the overlaying structure injection may be continuously monitored and interrupted when satisfactory compensations have been achieved.

[0003] Soil is here understood as encompassing a soil that to a significant extent is composed of sand or other eroded materials. The soil may be loosely packed with larger pore spaces or tightly packed with smaller pore spaces. The pore space may
contain ground water. There may be stones or other small rock formations in the soil.

[0004] The overlaying structure may be a surface building over ground. Alternatively, the overlaying structure may be a tunnel, a football field, or a road.

[0005] The method according to the first aspect of the present invention may further comprise: excavating a hole in the ground beside the surface building, and the positioning of the plurality of compensation tubes may comprise: inserting the compensation tubes from the hole in the ground into the soil. The method according to the first aspect of the present invention may further comprise: forming a water-impregnable wall at the side of the hole facing the surface building for preventing the hole from draining ground water and/or soil particles from the soil under the surface building. The draining may cause the overlaying structure to change. Consequently, the impregnable wall prevents changes in the overlaying structure. The water-impregnable wall may be a concrete wall. The positioning of the plurality of compensation tubes may comprise: inserting the compensation tubes through the water-impregnable wall into the soil.

[0006] The positioning of the plurality of compensation tubes in the soil may for each compensation tube of the plurality of compensation tubes comprise: providing a first hollow drilling pipe and a first drilling head attached to the first hollow drilling pipe, the first hollow drilling pipe and a first drilling head may be adapted for being drilled into the soil with the first drilling head first, drilling the first drilling head and the first hollow drilling pipe into the soil below the structure, inserting the compensation tube of the plurality of compensation tubes into the hollow drilling pipe, and retracting the first hollow drilling pipe and simultaneously expelling a support material around the compensation tube at the insertion or forward end of the first hollow drilling pipe for preventing a collapsing of said soil. The drilling minimizes the removal of soil from below the overlaying, thus having a minor or insignificant impact on the overlaying structure. Further, the retraction of the hollow drilling pipe allows for an easier flow of compensation liquid into the soil. The first drilling head may be attached at the insertion or forward end of the first hollow drilling pipe.

[0007] The drilling of the first drilling head and the first hollow drilling pipe into the soil may comprise: controlling the direction of the first hollow drilling pipe and/or the first drilling head for positioning the first hollow drilling pipe along a straight line. The drilling head may comprise: a position indicator defining a visible pattern, and the controlling of the direction of the first hollow drilling pipe and/or the first drilling head may comprise: observing the pattern through the first hollow drilling pipe for detecting an offset of the first hollow drilling pipe and/or the first drilling head from the straight line, and if any offset is detected: steering the first drilling head for reducing the offset. The pattern may be an asymmetric pattern and if any offset is detected the controlling of the direction of the first hollow drilling pipe and/or the first drilling head may comprise: observing the asymmetric pattern through the first hollow drilling pipe for determining the angular orientation of the first drilling head, and steering the first drilling based in the angular orientation.

[0008] The drilling along straight lines minimizes the volume of soil removed from under the overlaying building, thus lessening a possible impact on the structure. The asymmetric pattern may be defined by a plurality of electrical light sources. Each of the plurality of light sources may be a light-emitting diode and powered by an electrical battery positioned in the first drilling head. This has the advantage that the controlling of the direction will be cheap, and the first drilling head can be left at the end of the drilling. This is an advantage since e retraction of the drilling head could cause more material to be removed from under the overlaying building.

[0009] Said positioning of the plurality of compensation tubes in the soil may further comprise: providing a first drilling fluid or first drilling mud for aiding the drilling of the first drilling head and the first hollow drilling pipe into the soil, and the drilling of the first drilling head and the first hollow drilling pipe into the soil may further comprise: expelling the first drilling fluid or first drilling mud at the drilling head. The first drilling fluid may be a stabilizer strengthening the surrounding, thus reducing the amount of soil removed. The first drilling fluid or first drilling mud may be water-based mud, oil-based mud, and/or synthetic-based mud. The first drilling fluid may be water and the first drilling mud may be water-suspended bentonite. The first hollow drilling pipe may comprise a first pipe conduit for conveying the first drilling fluid or first drilling mud to the first drilling head.

[0010] The positioning of the plurality of compensation tubes may further comprise: detaching the first drilling head from the first hollow drilling pipe prior to the retracting of the first hollow drilling pipe for forming a first conduit outlet of the first pipe conduit at the forward end of the first hollow drilling pipe, and said expelling of the support material around the compensation tube may comprise: conveying the support material through the first pipe conduit and expelling the support material through the first conduit outlet. The detaching of the drilling head means that the first drilling head can be left at the end of the drilled hole. This is an advantage, since a retraction could cause the drilled hole to collapse or remove more soil from under the overlaying structure. The support material prevents the drilled hole from collapsing, which could cause the soil to settle.

[0011] The first drilling head may comprise a first steering blade for digging the soil and for steering the first drilling head in an off-axis direction upon a forward thrust of the first drilling head, the first steering blade may have a first tip at its forward end, and the first drilling head may further comprise a first head conduit connected to the first pipe conduit and comprising an outlet at the first tip for conveying the first drilling fluid or first drilling mud from the first pipe conduit and for expelling the first drilling fluid or first drilling mud at the tip. This has the effect that the drilling more precisely defines the drilled hole, thus reducing the amount of material removed. The first head conduit may comprise a first non-return valve for preventing a backflow in the first head conduit. This prevents ground water from leaking out through the pipe conduit, which could cause the overlaying structure to settle or shift. The first hollow drilling pipe may comprise a first outer wall portion and first inner wall portion for forming the first pipe conduit between them.

[0012] The first drilling head may comprise a first plurality of teeth and the first hollow drilling pipe may comprise a second plurality of teeth meshing and cooperating with the first plurality of teeth for transferring a rotation of the first hollow drilling pipe to the first drilling head and for allowing them to be detached by pulling the first hollow drilling pipe from the first drilling head, and the positioning of the plurality of compensation tubes may further comprise: cutting the first inner wall portion for detaching the first hollow drilling pipe from the first drilling head prior to the retracting of the first hollow drilling pipe. The detaching of the first hollow drilling pipe from the first drilling head may form a first conduit outlet of the first pipe conduit at the forward end of the first hollow drilling pipe, and the expelling of the support material around the compensation tube may comprise: conveying the support material through the first pipe conduit for expelling the support material through the first conduit outlet. The support material may be deformable and/or permeable to water.

[0013] The excavating of the underground space in the soil below the plurality of compensation tubes may comprise: defining an excavation volume of the soil, providing a plurality of freezing tubes, each of the plurality of freezing tubes may be adapted for conveying a cooling medium along its length and for transferring heat between its surroundings and the cooling medium, positioning the plurality of freezing tubes in the soil below the plurality of compensation tubes and outside the excavation volume, providing a cooling medium for being conveyed through the plurality of freezing tubes and having a temperature that is lower than the freezing temperature of the soil, conveying the cooling medium through the plurality of freezing tubes for freezing at least a portion of the soil surrounding the excavation volume, and removing the soil of the excavation volume. The frozen soil prevents ground water from leaking out into the excavated volume, which could cause the overlaying soil and structure to settle. The positioning of the plurality of freezing tubes in the soil may comprise: positioning the plurality of freezing tubes in a pattern surrounding the excavation volume. This has the advantage that the soil can be frozen around the excavation volume, thus effectively preventing any ground water from leaking out through the excavation volume. The conveying of the cooling medium through the plurality of freezing tubes may further be adapted for freezing the soil to form a shell of frozen soil around the excavation volume. The conveying of the cooling medium through the plurality of freezing tubes may be adapted for freezing the soil of the excavation volume.

[0014] The injecting of the compensation liquid may have a synergetic effect with the freezing of the soil, in particular if the excavation is above the ground water level and the compensation liquid is water that seeps down to the freezing tubes, which would improve the structural strength of the frozen soil.

[0015] The excavation volume may be elongated and the positioning of the plurality of freezing tubes in the soil may comprise: orienting each of the plurality of freezing tubes in the direction of maximum extension of the elongated excavation volume. For example, a tunnel may be built in the excavation volume.

[0016] The positioning of the plurality of freezing tubes in the soil below the structure may for each freezing tube of the plurality of freezing tubes comprise: providing a second hollow drilling pipe and a second drilling head attached to the second hollow drilling pipe, the second hollow drilling pipe and the second drilling head may be adapted for being drilled into the soil with the second drilling head first, the second drilling pipe may be adapted for allowing a heat transport between the outside and the inside of the second hollow drilling pipe, drilling the second drilling head and the second hollow drilling pipe into the soil below the plurality of compensation tubes, inserting the freezing tube of the plurality of freezing tubes into the hollow drilling pipe, providing a bridging medium for transferring heat, injecting the bridging medium between the freezing tube and the second hollow drilling pipe for establishing a heat conduction between the outside of the second hollow drilling pipe and the freezing tube. The drilling minimizes the removal of soil from below the overlaying, thus having a minor or insignificant impact on the overlaying structure, as compared to forming a duct by digging and placing the freezing tube in the duct.

[0017] The bridging medium may transfer heat through convection and/or conduction subsequent to the injecting of the bridging medium between the freezing tube and the second hollow drilling pipe.

[0018] The excavation volume may be elongated and the drilling of the second drilling head and the drilling of the second drilling head and the second hollow drilling pipe into the soil may comprise: controlling the direction of the second hollow drilling pipe and/or the second drilling head for positioning the second hollow drilling alongside the elongated excavation volume. For example, a tunnel may subsequently be built in the excavation volume. The elongated excavation volume may follow a curve and the second hollow drilling pipe may follow the same curve. This has the effect that no additional second hollow drilling pipes need to be inserted into the ground to freeze the soil around the complete length of the elongated excavation space, which would have resulted in the removal of additional soil.

[0019] The method according to the first aspect of the present invention may further comprise: providing a gyro for determining an angular orientation, and positioning the gyro inside the second hollow drilling pipe at the second drilling head, and said controlling of the direction of the second hollow drilling pipe may comprise: determining a specific angular orientation of the drilling head with the gyro, and steering the first drilling head based on the specific angular orientation. Said drilling of the second drilling head and the second hollow drilling pipe into the soil may comprise: retracting the gyro from the second hollow drilling pipe.

[0020] The positioning of the plurality of freezing tubes in the soil below the structure may further comprise: providing a second drilling fluid or second drilling mud for aiding the drilling of the second drilling head and the second hollow drilling pipe into the soil, and said drilling of the second drilling head and the second hollow drilling pipe into the soil may further comprise: expelling the second drilling fluid or second drilling mud at the drilling head. The second drilling fluid may be a stabilizer strengthening the surroundings, thus reducing the amount of soil removed. The second drilling fluid or second drilling mud may be water-based mud, oil-based mud, and/or synthetic-based mud. The second hollow drilling pipe may comprise a second pipe conduit for conveying the second drilling fluid or second drilling mud to the second drilling head. The second drilling fluid may be water and the second drilling mud may be water-suspended bentonite.

[0021] The second drilling head may comprise a second steering blade for digging the soil and for steering the second drilling head in an off-axis direction upon a forward thrust of the second drilling head, the second steering blade may have a second tip at its forward end, and the second drilling head may further comprise a second head conduit connected to the second pipe conduit and an outlet at the second tip for conveying the second drilling fluid or second drilling mud from the second pipe conduit and for expelling the second drilling fluid or second drilling mud at the second tip. This has the effect that the drilling more precisely defines the drilled hole, thus reducing the amount of material removed. The second head conduit may comprise a second non-return valve for preventing a backflow in the second head conduit. This prevents ground water from leaking out through the pipe conduit, which could cause the overlaying structure to settle or shift. The second hollow drilling pipe may be single-walled. This has the effect that the thermal conductivity to the soil is increased.

[0022] The monitoring of the overlaying structure may comprise: detecting movements and/or shifts of the overlaying structure. The monitoring of the overlaying structure may comprise: detecting changes in the internal loads and/or the distribution of the internal loads of the overlaying structure. The detecting of the changes in the internal loads and/or the distribution of the internal loads may involve one or more strain gauges anchored to the overlaying structure.

[0023] Each of the plurality of compensation tubes may comprise a plurality of outlets distributed along its length. The plurality of outlets may be divided into groups located at regular intervals along the length. The plurality of groups may be spaced apart by between 20-40 cm, and/or by approximately 30 cm. The outlets of each group of outlets may be distributed circumferentially around the compensation tube they are located on. Each of the plurality of outlets may be provided with a non-return valve for preventing a backflow of a liquid into the compensation tube.

[0024] The positioning of the plurality of compensation tubes may further comprise: sealing the first hollow drilling pipe to the water-impregnable wall for preventing the ground water and/or soil particles from being expelled from the soil between the first hollow drilling pipe and the water-impregnable wall. This has the effect that ground water and/or soil particles are prevented from leaking out between the first hollow drilling pipe and the water-impregnable wall.

[0025] The forming of the water-impregnable wall may, for each of the plurality of compensation tubes, comprise: providing a first drill having a first diameter, drilling a first hole through the concrete wall with the first drill, measuring the width of the concrete wall through the first hole, providing a first circular cutter having a second diameter that is greater than the first diameter, cutting a second hole in the concrete wall at or centred on the first hole and having a length that is less than the width of the concrete wall, the second hole having an opening and an opposite bottom, sealing the opening of the second hole with a first lock for allowing a sealable access to the second hole, providing a second circular cutter having a third diameter that is greater than the first diameter and smaller than the second diameter, introducing the second circular cutter into the second hole through the first lock, cutting a third hole in the bottom of the second hole having a length that is greater than the difference between the length of the second hole and the width of the concrete wall, retracting the second circular cutter, and closing the first lock for preventing ground water and/or soil particles from escaping through the concrete wall. The forming of the water-impregnable wall may for each of the plurality of compensation tubes comprise, prior to introducing the second circular cutter into the third hole: providing a cutter axle attached to the second circular cutter for driving the second circular cutter, and sealing the cutter axle to the first lock for preventing or reducing a leakage reducing a leakage of said ground water and/or soil particles between them. The positioning of the plurality of compensation tubes may further comprise: sealing the first drilling pipe to the first lock for preventing or reducing a leakage between them, opening the first lock, and introducing the first drilling head through the first lock into the third hole. This has the effect that the amount of ground water and/or soil particles that leak out through the water-impregnable wall is kept low when the compensation tubes are inserted.

[0026] Said positioning of said plurality of freezing tubes may further comprise: inserting said second hollow drilling pipe through said water-impregnable wall into said soil, and sealing said second hollow drilling pipe to said water-impregnable wall for preventing said ground water and/or soil particles from being expelled from said soil between said second hollow drilling pipe and said water-impregnable wall. This has the effect that ground water and/or soil particles are prevented from leaking out between the second hollow drilling pipe and the water-impregnable wall.

[0027] The forming of the water-impregnable wall may for each of the plurality of freezing tubes comprise: providing a fourth drill having a fourth diameter, drilling a fourth hole through the concrete wall with the fourth drill, measuring the width of the concrete wall through the fourth hole, providing a third circular cutter having a fifth diameter that is greater than the fourth diameter, cutting a fifth hole in the concrete wall at or centred on the fourth hole and having a length that is less than the width of the concrete wall, the fifth hole having an opening and an opposite bottom, sealing the opening of the fifth hole with a second lock for allowing a sealable access to the fifth hole, providing a fourth circular cutter having a sixth diameter that is greater than the fourth diameter and smaller than the fifth diameter, introducing the fourth circular cutter into the fifth hole through the second lock, cutting a sixth hole in the bottom of the fifth hole having a length that is greater than the difference between the length of the fifth hole and the width of the concrete wall, retracting the fourth circular cutter, and closing the second lock for preventing ground water and/or soil particles from escaping through the concrete wall. The forming of the water-impregnable wall may for each of the plurality of freezing tubes comprise, prior to introducing the fourth circular cutter into the fifth hole: providing a cutter axle attached to the fourth circular cutter for driving the fourth circular cutter, and sealing the cutter axle to the second lock for preventing or reducing a leakage of said ground water and/or soil particles between them. The positioning of the plurality of freezing tubes may further comprise: sealing the second drilling pipe to the second lock for preventing or reducing a leakage between them, opening the second lock, and introducing the second drilling head through the second lock into the sixth hole. This has the effect that the amount of ground water and/or soil particles that leak out through the water-impregnable wall is kept low when the compensation tubes are inserted.

[0028] The above object is according to a second aspect of the present invention met by a system for implementing the method according to the first aspect of the present invention, the system comprising: a compensation liquid, a plurality of compensation tubes for conveying said compensation liquid, each of said compensation tubes comprising a number of outlets for allowing said compensation liquid to pass from said compensation tube into the surrounding medium, means for positioning said plurality of compensation tubes in said soil below said structure, means for excavating said underground space in said soil below said plurality of compensation tubes, means for monitoring the overlaying structure for detecting changes in the structure due to said excavating of said underground space, and if a change in the structure is detected: means for injecting said compensation liquid into said soil through one or more of said plurality of compensation tubes into said soil.

[0029] The system according to the second aspect of the present invention may further comprise any of the features and/or any means for performing any of the method steps according to the first aspect of the present invention.

[0030] The above object is according to a third aspect of the present invention met by a method for positioning a compensation tube in a soil below a structure, said method comprising: providing said compensation tube, providing a first hollow drilling pipe and a first drilling head attached to said first hollow drilling pipe, said first hollow drilling pipe and a first drilling head being adapted for being drilled into said soil with said first drilling head first, drilling said first drilling head and said first hollow drilling pipe into said soil below said structure, inserting said compensation tube of said plurality of compensation tubes into said hollow drilling pipe, and retracting said first hollow drilling pipe and simultaneously expelling a support material around said compensation tube at the insertion or forward end of said first hollow drilling pipe for preventing a collapsing of said soil. The first drilling head may be attached at the insertion or forward end of the first hollow drilling pipe.

[0031] The method according to the third aspect of the present invention may further comprise any of the features and/or any of the steps according to the first aspect of the present invention.

[0032] The above object is according to a fourth aspect of the present invention met by a method positioning a freezing tube in a soil below a structure, said method comprising: providing said freezing tube, providing a second hollow drilling pipe and a second drilling head attached to said second hollow drilling pipe, said second hollow drilling pipe and said second drilling head being adapted for being drilled into said soil with said second drilling head first, said second drilling pipe being adapted for allowing a heat transport between the outside and the inside of said second hollow drilling pipe, drilling said second drilling head and said second hollow drilling pipe into said soil below said structure, inserting said freezing tube of said plurality of freezing tubes into said hollow drilling pipe, providing a bridging medium for transferring heat, and injecting said bridging medium between said freezing tube and said second hollow drilling pipe for establishing a heat conduction between the outside of said second hollow drilling pipe and said freezing tube.

[0033] The method according to the fourth aspect of the present invention may further comprise any of the features and/or any of the steps according to the first aspect of the present invention.

[0034] The above object is according to a fifth aspect of the present invention met by a drilling head according to the first drilling head of the first aspect of the present invention. The above object is according to a sixth aspect of the present invention met by a drilling head according to the second drilling head of the first aspect of the present invention. The above object is according to a seventh aspect of the present invention met by a drilling pipe according to the first drilling pipe of the first aspect of the present invention. The above object is according to an eighth aspect of the present invention met by a drilling pipe according to the second drilling pipe of the first aspect of the present invention.

[0035] The above object is according to a ninth aspect of the present invention met by a drilling system for drilling in soil, the drilling system comprising: a hollow drilling having a forward end and a backward end, and a drilling head attached to the hollow drilling pipe at its forward end and comprising a plurality of light sources positioned in a pattern for emitting light through the hollow drilling pipe from its forward end to its backward end. Each of the plurality of light sources may be a light-emitting diode and the drilling head may further comprise an electrical battery_for powering the plurality of light-sources. The pattern may be an asymmetric pattern with respect to the central axis of the hollow drilling pipe.

[0036] The above object is according to a tenth aspect of the present invention met by a drilling system for drilling in soil, the drilling system comprising: a hollow drilling pipe and a drilling head attached to the hollow drilling pipe, the hollow drilling pipe and the drilling head being adapted for being drilled into soil with the drilling head first, a gyro positioned inside the hollow drilling pipe at the drilling head for determining the angular orientation and/or position of the drilling head, and a lock comprising a first locking part attached to the gyro and a second locking part attached to the drilling head, the first locking part and the second locking part being adapted for releasably locking the gyro to the drilling head.

[0037] The lock may be a bayonet lock. The bayonet lock may be adapted for unlocking by pushing said gyro towards said drilling head and twisting it relative to said drilling head. The first locking part may be the male bayonet portion and the second locking part may be the female bayonet portion of the bayonet lock. The first locking part may comprise a base portion attached to the gyro, a shaft attached to the base portion and aligned with the central axis of the hollow drilling pipe, and a pin attached to and protruding radially from the shaft, and the second locking part comprising a receptor body defining a pin slot for mutually cooperating with the pin in a locking of the bayonet lock.

[0038] The second locking part may comprise a receptor base and the first locking part may comprise a retaining spring for engaging the receptor base and pushing the pin into the pin slot in the locking of the bayonet lock. The retaining spring may be a coil spring attached to the base portion and centred on the shaft. This means that the shaft is partly positioned inside the coil spring. The first locking part may comprise a spacer for limiting the compression of the retaining spring. The spacer may be a cylinder attached to the base portion and partly surrounding the coil spring. The receptor base may be attached to the drilling head and supporting the receptor body. The receptor body may be positioned on the opposite side of the receptor base from the gyro, and the receptor body may define a receptor aperture for allowing the shaft and the pin to pass through the receptor base for engaging the receptor body.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] A number of embodiments of the different aspects of the present invention are described in conjunction with:

FIG. 1A schematically illustrating a surface building affected by settings of the soil due to the excavation of a tunnel,

FIG. 1B-D schematically illustrating the prevention of the setting of the soil according to the present invention,

FIGS. 2A-H illustrating the installing a lock through a concrete wall for a drilling head and a drilling pipe according to the present invention,

FIGS. 3A-I illustrating the insertion of a compensation tube into the soil according to the present invention,

FIGS. 4A-H illustrating the insertion of a freezing tube into the soil according to the present invention,

FIGS. 5A-E illustrating a drilling head and a portion of a hollow drilling tube according to the present invention,

FIGS. 6A-C illustrating another drilling head and attached to a portion of a hollow drilling tube according to the present invention, and

FIGS. 7A-C illustrating details of the drilling head described in relation to FIGS. 6A-C.

DETAILED DESCRIPTION

[0040] FIG. 1A illustrates a structure 10 in the form of a surface building positioned on the ground 12. The ground is composed of soil 14. An underground space 15 is excavated in the soil 14 below the building 10. A tunnel 16 is built in the underground space 15. The construction of the tunnel 16 including the excavation of the soil causes the soil 14 to settle, which is indicated by arrows in FIG.1A. The settling of the soil causes the ground below the building 10 to shift, thereby causing the load distribution of the overlaying structure 10 to change. This may cause damage to the building 10.

[0041] FIG. 1B illustrates the prevention of the setting of the soil 14. A strain gauge 24 is attached to the building 10 such that changes in the load distribution can be detected. Compensation tubes 22 and freezing tubes 18 are inserted into the soil below the building 10. The compensation tubes 22 are distributed below the building 10. The freezing tubes 18 are positioned such that they surround a volume of the soil and oriented such that they trace approximately similar parallel-transported paths. If a change in the load distribution of the building 10 is detected by the strain gauge when the freezing tubes 18 are inserted, which may be caused by ground water leaking out along the freezing tubes, then a compensation liquid 26 is injected into the soil 14 through one or more of the compensation tubes 22 for reducing or counteracting the change in the load distribution.

[0042] A cooling medium is conveyed through the freezing tubes 18 causing the soil 14 to freeze 20 around the freezing tubes 18, as is illustrated in FIG. 1C. The cooling medium is conveyed sufficiently long for the volume between the freezing tubes to form a cylinder 20 of frozen soil with an unfrozen core 21. If a change in the load distribution of the building 10 is detected by the strain gauge 24, which may be caused by the freezing of the soil 14, then a compensation liquid 26 is injected into the soil 14 through one or more of the compensation tubes 22 for reducing or counteracting the change in the load distribution.

[0043] An elongated underground space 15 is formed by excavating a volume of the unfrozen core 21 between the freezing tubes, which is shown in FIG. 1C. The underground space 15 has self-supporting walls stabilized by the frozen soil 20, which prevents the underground space from collapsing and the ground water from leaking out through the underground space 15. If a change in the load distribution of the building 10 is detected by the strain gauge 24 due to the excavation of the underground space 15, then a compensation liquid 26 is injected into the soil 14 through one or more of the compensation tubes 22 for reducing or counteracting the change in the load distribution caused by the excavation. A tunnel 16 is formed by casting concrete walls that support the walls of the underground space 15, as is_shown in FIG. 1D. The conveying of the cooling medium in the freezing tubes is interrupted so that the frozen soil 20 thaws and the tunnel 16 alone bears the load of the soil 14. If a change in the load distribution of the building 10 is detected by the strain gauge 24, which may be caused by the thawing of the frozen soil 20, then a compensation liquid 26 is injected into the soil 14 through one or more of the compensation tubes 22 for reducing or counteracting the change in the load distribution.

[0044] The underground space 15 and the tunnel 16 are depicted in FIGS. 1C-D as having a cylindrical geometry. In other embodiments of the present invention, the underground space 15 and the tunnel 16 may have different geometries, such as a pair of fused overlapping and parallel cylinders with circular cross-sections, or a cylinder having a rectangular cross-section. The freezing tubes 18 are arranged so that they form a shell of frozen soil around the underground space 15, but the positioning of the freezing tubes 18 is not limited to the cylindrical geometry shown in FIGS. 1B-D.

[0045] In FIGS. 2A-H the installing of a drilling lock 106 through a concrete wall 30 for a drilling head and a drilling pipe is illustrated. An open hole 28 is dug out beside the overlaying structure 10 discussed in relation to FIGS. 1A-D. A concrete wall 30 is formed at the side of the open hole 28 facing the overlaying structure supporting the soil 14 and preventing ground water in the soil 14 from leaking out through the hole 28. A concrete drill 32 is used for drilling a narrow through-going hole 34, e.g. 20 mm in diameter, that is open at both the outer wall surface 29 and the inner wall surface 31 of the concrete wall 30, as is shown in FIG. 2A. The length of the through-going hole 34 is measured for determining the thickness of the wall 30 at the through-going hole 34. A stabilizer 36, for example a prepolymer that reacts with water and spontaneously generates a water impregnable polyurethane foam, such as the sealant Køster KB-PUR® IN I, is injected into the soil 14 through the through-going hole 34. The stabilizer 36 covers an area 37 of the inner wall surface 31 and fills the through-going hole 34, thus stabilizing the soil 14 and preventing ground water of the soil 14 from leaking out through the through-going hole 34.

[0046] A first circular hole cutter 38 is drilled into the concrete wall 30 to a depth that is less than the thickness of the concrete wall 30. The circular hole cutter is bent sideways for breaking off the concrete plug 39 inside the circular hole cutter 38 and then pulled backwards, thus creating a support hole 40 in the concrete wall 30 having a cylindrical wall 44 and a closed bottom 42, as is shown in FIG. 2C. The length of the support hole 40 is measured.

[0047] A support portion 46 of the drilling lock 106 is provided having a hollow cylinder body 47 open at both ends and a flange 48 with bolt holes around one of its openings. The cylinder body 47 is inserted into the support hole 40 with the flange 48 accessible from the outside, as is shown in FIG. 2D. An O-ring 56 on the outside of the cylinder body 47 provides a sealing to the cylindrical wall 44 of the support hole 40. A circumferential support flange 58 on the outside of the cylinder body 47 holds the o-ring 56 in place when it is inserted into the support hole 40. A bushing 52 and a wedge 54 are positioned between the cylinder body 47 and the cylindrical wall 44 at the opening of the support hole 40 for fixing the support portion 46 relative to the concrete wall 30. The space outside the cylinder body 47 and between the o-ring 56 and the opening of the support hole 40 is filled with a sealant, e.g. a hardening foam.

[0048] A support portion 46 of the drilling lock is provided having a gate valve 72 and a forward flange 64 with bolt holes 66 and a backward flange 68 with bolt holes 70. An insertion portion 74 is provided having a hollow body 84 with two opposite open ends and a forward flange 76 at one of the open ends and a backward flange at the other open end. The insertion portion also has a lower outlet and/or inlet 86 and an upper outlet and/or inlet 90 on the hollow body 84 for allowing a flow of a fluid into and out of the hollow body 84. The lower outlet and/or inlet 86 and the upper outlet and/or inlet 90 are provided with a lower valve 88 and an upper valve 92 for controlling the flow of a fluid into and out of the hollow body 84.

[0049] Only two outlets are depicted in FIGS. 2F-G. However, the insertion portion 74 may have additional outlets and/or inlets. One outlet of the insertion portion 74 may be used for expelling drilling liquid. Preferably, this outlet and/or inlet is a lower outlet and/or inlet 86. A number of outlets and/or inlets may be used to put water into the insertion portion 74. Preferably these outlets and/or inlets is an upper outlet and/or inlet 90. A manometer may be coupled to an outlet and/or inlet for determining the pressure inside the insertion portion. Preferably this outlet and/or inlet is an upper outlet and/or inlet 90. The manometer may be used to monitor the pressure to prevent a rising of the overlaying structure.

[0050] As is shown in FIG. 2F, the forward flange 64 of the valve portion 62 is secured to the flange 48 of the support portion 46 via bolts in the bolt holes 50, 64 of the respective flanges, thus sealing the valve portion 62 to the support portion 46. The forward flange 76 of the insertion portion 74 is secured to the backward flange 68 of the valve portion 62 via bolts in bolt holes 70, 78 of the respective flanges, thus sealing the insertion portion 74 to the valve portion 62. A back portion 94 is provided having bolt holes 96 by which it is secured by bolts to the backward flange 80 of the insertion portion 74 via the bolt holes 82 thereof, thus forming the complete drilling lock 106 as is shown in FIG. 2F.

[0051] A second circular hole cutter 102 is provided having a drilling depth that is greater than the difference between the length of the support hole 40 and the thickness of the wall. The diameter of the second circular hole cutter 102 is smaller than the diameter of the first circular hole cutter 38. The second circular hole cutter 102 is attached to and centred on a cutter axle 104. The second circular cutter is positioned in the insertion portion 74 before the back portion 94 is attached to the insertion portion 74. The cutter axle 104 is led out through the back portion 94 via an aperture 98. The aperture 98 is provided with a sealing ring 100 that engages the cutter axle 4 and allows the axle to rotate and at the same time prevents a liquid from escaping the insertion portion 74 via the aperture 98.

[0052] The second circular hole cutter 102 is driven forward through the open gate valve 62 and drilled into the bottom 42 of the support hole 40 until it breaches the inner wall surface 31 of the concrete wall 30. The second circular hole cutter 102 is retracted into the insertion portion 74, thus removing a plug 108 from the concrete wall 30 and generating a break-through hole 110 that is open to both the support hole 40 and the soil 14 with the stabilizer 36 and having a cylindrical wall 112. The gate valve 72 is closed, thus preventing ground water in the soil from leaking into the insertion portion. Thus, the back portion 94 can be removed together with the second circular hole cutter 102 and the cutter axle 104.

[0053] The back portion 94 is replaced with a drilling back portion 114 having a pipe aperture 115 fitted with pipe sealing ring 116, which is show in FIG. 3A. A drilling head 120 is positioned in the insertion portion 74. The drilling head 120 is coupled to a drilling pipe 118, which extends backward out through the pipe aperture 115. The pipe sealing ring 116 prevents a liquid from leaking out from the insertion portion 74 through the pipe aperture 115 when the drilling pipe 118 is rotated. The gate valve 72 is opened and the drilling pipe 118 is pushed forward through the concrete wall under a rotational motion such that the steering blade 122 of the drilling head 120 engages the soil 14, as is shown in FIG. 3B. In the orientation shown, the steering blade 122 will engage the soil 14 and push the drilling head 120 upward upon a forward thrust of the drilling pipe 118. A drilling fluid 128 in the form of water-suspended bentonite is expelled at the forward tip 130 of the steering blade 122. The drilling lock 106 is filled with the drilling fluid 128. A hose 124 is coupled to the lower outlet 86 of the insertion portion 74 and having a hose outlet 125 positioned above the drilling lock 106. The pressure of the drilling fluid 128 is regulated by raising and lowering the hose outlet 125. The drilling fluid 128 is emptied into a container 126 from the hose 124.

[0054] The drilling pipe 118 is double-walled and has an inner wall 132 and an outer wall 134 forming a pipe conduit 140 between. The drilling fluid 128 is led to the drilling head 120 through the pipe conduit 140. The drilling head 120 comprises a non-return valve 136 through which the drilling fluid 128 is led via a tip conduit 138 to the forward tip 130 of the steering blade 122. The drilling fluid 128 is expelled from the drilling head 120 at the forward tip 130. The drilling fluid 128 seeps out into the surrounding soil 14 and also flows back between the drilling pipe 118 and the drilling hole 142. The flow of the drilling fluid 128 is indicated by arrows in FIG. 3C.

[0055] A number of light-emitting diodes 144 and a battery 146 powering the light-emitting diodes 144 are positioned in the drilling head 120. The light-emitting diodes rotate with the drilling pipe 118 and the drilling head 120. The drilling pipe 118 is hollow and the light-emitting diodes 144 are observed through the hollow drilling pipe 118 with a theodolite camera 148 for determining if the drilling head 120 deviates from a straight line. The light-emitting diodes 144 are positioned in an asymmetric pattern so that the angular orientation of the drilling head 120 can be determined with the theodolite camera 148. If deviation from a straight line is detected, then the angular orientation of the drilling head 120 is determined. Then the drilling head 120 is oriented such that the steering blade 122 will push the drilling head 120 upon a forward thrust of the drilling pipe 118 in a direction reducing the deviation. For example, with the angular orientation shown in FIG. 3C, the steering blade 122 pushes the drilling head 120 upward.

[0056] The outer wall 134 is releasably connected to the drilling head 120, while the inner wall 132 is rigidly connected to the drilling head 120. When the drilling is complete, e.g. as in FIG. 3D, when the forward tip 130 of the steering blade 122 reaches a second concrete wall 150, a cutter 152 is introduced into the hollow drilling pipe 118 and cuts the inner wall 132 completely through to release the drilling pipe 118 from the drilling head 120. Subsequently, the cutter 152 is retracted through the hollow drilling pipe 118.

[0057] A compensation tube 22 is introduced into and along the complete length of the hollow drilling pipe 118, as is shown in FIG. 3E. Subsequently, an end fitting 246 is attached at the end of the compensation tube 22. The end fitting 246 comprises an end pipe 248 and a connector 250 interconnecting the end pipe 248 and the compensation tube 22. The connector 250 is screwed onto the compensation tube 22. The connector 250 has an o-ring 252 with a square profile that cooperates with the inner wall 132 of the drilling pipe 118 for preventing leakage between the compensation tube 22 and the inner wall 132. The released drilling pipe 118 is pulled backward while the compensation tube 22 is held in place. Simultaneously a support material 154 is injected through the pipe conduit 140 between the inner wall 132 and the outer wall 134 so that the drilling hole 142 is filled with and supported by the support material 154, as is shown in FIG. 3F. The support material 154 is prevented from leaking out between the compensation tube 22 and the inner wall 132 by the o-ring 252.

[0058] The support material is both permeable to a liquid and has a loose structure such that its shape can be changed. For example, the support material 154 may be a hydraulically-setting premixed mortar with hydraulic binders tailored to the clay components present in the soil, such as Dämmer® from HeidelbergCement. Water is added to the mortar to give a free-flowing suspension.

[0059] After the drilling pipe 118 has been fully removed, the support portion 46 is fitted with a packing disc 260 that is held in place by a locking disc 254. The packing disc 260 is positioned between the support portion flange 48 and the locking disc 254. The locking disc 254 has bolt holes 256 arranged so that it can be secured by nuts and bolts 258 to the bolt holes 50 of the support portion flange 48. The packing disc 260 has an aperture 262 through which the compensation tube 22 passes. The packing disc 260 is made of hard rubber and its aperture 262 provides a close fit to the compensation tube 22 so that a compensation liquid 156 is prevented from leaking out from the support portion 46. The locking disc 254 has an aperture 261 centred on and being larger than the aperture 262 of the packing disc 260 so that the latter aperture 262 can be accessed from the outside of the support portion 48.

[0060] If a change in the load distribution of an overlaying building, as described in relation to FIGS. 1A-D, then a compensation liquid 156 is injected through the compensation tube 22 into the soil 14, as is indicated by arrows in FIGS. 3H-I. For example, the compensation liquid may be water.

[0061] The compensation tube 22 has outlets 158 distributed along the compensation tube 22 through which the compensation liquid 156 is expelled. The outlets 158 are divided into groups distributed at regular intervals along the compensation tube 22. For example, the groups may be spaced approximately 30 cm apart. In each group, the outlets 158 are distributed around the circumference of compensation tube 22, thus allowing the compensation liquid 156 to be injected in several different radial directions into the support material 154 and the soil 14.The outlets 158 of each group are positioned between a first annular support flange 160 and a second annular support flange 162. A rubber ring 164 is positioned around the compensation tube 22 and between the first annular support flange 160 and the second annular support flange 162. The rubber ring presses against the compensation tube 22 and covers the outlets 158, thus effectively providing a non-return valve for each outlet 158.

[0062] In FIGS. 4A-F the insertion of a freezing tube 18 into the soil 14 is illustrated. Similar features in FIGS. 3A-G and FIGS. 4A-G have been given the same index and been primed. The same processes as described in relation to FIGS. 2A-H, but at lower level as is indicated in FIG. 1B. The same drilling as described in relation to FIGS. 3A-C is performed, with the difference that another drilling pipe 118' and another drilling head 120' are used, and that a gyro 172 positioned at the drilling head 170 is used for determining the position and orientation of the drilling head 120'. The gyro 172 has a control and power cable connection 174 leading back through the drilling pipe 188. The hollow drilling pipe 118' is single-walled and manufactured of steel for allowing an efficient heat transfer between its interior and the surroundings, and in particular so that heat can be transferred from the soil 14 to the inside of the hollow drilling pipe 118', thus allowing a freezing of the soil 14. The steering of the drilling head 120' is carried out as described in relation to FIG. 3C, but on the basis of readings from the gyro 172 instead of from the theodolite camera 148. The gyro 172 has the ability to detect changes in position and orientation of the drilling head 120'._Thus, the drilling head 120' can drill along a curved path when controlled by the gyro.

[0063] The drilling pipe 118' has a pipe conduit 140' through which the drilling fluid 128' is conveyed to the drilling head 120, as is shown in FIG. 4C. The forward end of the pipe conduit 140' is attached o the backward end of the gyro 172. The pipe conduit 140' is doubled walled with an inner wall for containing the drilling fluid 128 and the cable connection 174 and an outer wall for controlling the movement of the gyro 172 inside the hollow drilling pipe 118'. Radial spacers 176 are attached at regular intervals to the outside of the pipe conduit 140' for positioning it in a central position inside the hollow drilling pipe 118'. Each spacer 176 has three wheels 177 symmetrically positioned around the pipe conduit 140' for engaging the inner wall 132 of the hollow drilling pipe 118' so that the gyro 172 easily can be retracted through the hollow drilling pipe 118'.

[0064] The pipe conduit 140' has a sealing flange 208 for preventing the a backflow of drilling fluid 128' between the outside pipe conduit 140' and the inner wall 132 of the drilling pipe 118'. The drilling fluid 128' is lead to the front of the drilling head 120' in channels 210 between the gyro 172 and the inner wall 132 of the drilling tube 118' and the drilling head 120'. The gyro 172 has a first locking part 212 in the form of a male bayonet portion and a second locking part 214 in the form of a female bayonet portion that mutually cooperate for locking the gyro 172 to the drilling head 120'. The first locking part 212 is locked to the second locking part 214 when drilling.

[0065] The drilling head 120' is rigidly attached to the drilling pipe 118'. When the drilling is complete, e.g. as in FIG. 4D when the forward tip 130' of the steering blade 122 reaches a second concrete wall 150, the first locking part 212 is released from the second locking 214, thereby releasing the gyro 172, which is subsequently retracted through the hollow drilling pipe 118', as is shown in FIG. 4D.

[0066] A freezing tube 18 is introduced into and along the complete length of the hollow drilling pipe 118', as is shown in FIG. 4E. Freezing tube spacers 224 are attached to the freezing tube 18 at regular intervals for positioning the freezing tube in the_centre of the drilling pipe 118'. The freezing tube 18 comprises an outer shell 178 containing a number of circulating tubes 180 that can convey a cooling liquid to the tip 182 of the freezing tube 18 and back again. An injection tube 184 is releasably attached to the freezing tube 18 at its tip 182 such that it is inserted together with the freezing tube 118'. The injection tube 184 is open at the tip 182 of the freezing tube 18.

[0067] The insertion portion 74 and the gate valve 72 are removed. A sealing flange 216 is attached of the support portion flange 48 for preventing ground water from leaking out between the hollow drilling pipe 118' and the cylinder body 47 of the support portion 46. The hollow drilling pipe 118' is cut to a suitable length such that it ends outside the support portion 46. A sealing sleeve 218 is attached at the end of the hollow drilling pipe 118', as is shown in FIG. 4F. The sealing sleeve 218 has a freezing tube aperture 220 through which the freezing tube 18 exits the hollow drilling pipe 118'. Similarly, the sealing sleeve 218 has an injection tube aperture 222 through which the injection tube 184 exits the hollow drilling pipe 118'.

[0068] The injection tube 184 is released from the freezing tube 118' and pulled out back through the hollow drilling pipe 118' via the injection tube aperture 222. Simultaneously, a bridging medium is injected into the hollow drilling pipe 118' such that it fills the space between the freezing tube 18 and the hollow drilling pipe 118', as is shown in FIGS. 4G-H. The sealing sleeve 218 prevents the bridging medium 186 from leaking out from the hollow drilling pipe 118'. The bridging medium 186 establishes a thermal bridge between the freezing pipe 18 and the drilling pipe 118', such that the soil 14 surrounding the drilling pipe 118' may freeze when a cooling liquid is circulated in the circulation tubes 180. For example, the bridging medium 186 4 may be a hydraulically-setting premixed mortar, such as Dämmer® from HeidelbergCement. Water is added to the mortar to make it pumpable.

[0069] FIGS. 5A-E show the drilling head 120 and forward part of the drilling pipe 118 described in relation to FIGS. 3A-G. In FIG. 5A a perspective view of a position indicator 188 defining a visible pattern of light-emitting diodes 190 is shown. A through-cut of the drilling head 120 and forward part of the drilling pipe 118 is shown in FIG. 5B. The position indicator 188 is positioned in and fixated to the drilling head 120 such that the light-emitting diodes are visible from the outside via the hollow drilling pipe 118. The position indicator 188 comprises a housing 194 protecting a battery 192 powering the light-emitting diodes 190. The housing 194 is rigidly attached to the drilling head 120.

[0070] A separation space 196 is defined between the drilling pipe 118 and the drilling head 120. The cutter described in relation to FIG. 3D cuts the inner wall 132 free from the drilling head 120 at the separation space 196. The separation makes the complete separation of the drilling head easier to detect. The outer wall 134 defines a number of forward pointing teeth 202 having a square profile at its forward end. The drilling head defines a number of backward pointing teeth 204 interlocking and cooperating with the forward pointing teeth 202, such that a rotational motion of the drilling pipe 118 can be transferred to the drilling head 120 and the drilling head 120 can be released from the outer wall, thus allowing for the separation described in relation to FIG. 3F.

[0071] The pipe conduit 140 ends in the separation space 196 and a head conduit 198 interconnects the separation space 196 with a forward chamber 206. A non-return valve 136 is coupled with a tip conduit 138 having an outlet at the tip 130 of the steering blade 122. Thus, a drilling fluid can be conveyed from the pipe conduit 140 to the tip 130 of the steering blade, as is described in relation to FIG. 3C.

[0072] A front view of the drilling head 120 is shown in FIG. 5C, and two opposite side views of the drilling pipe 118 and the drilling head 120 are shown in FIGS. 5D-E.

[0073] FIGS. 6A-E show the drilling head 120' and forward part of the drilling pipe 118' described in relation to FIGS. 4A-G. A side view and perspective view are illustrated in FIG. 6A and 6C, respectively, showing the drilling pipe 118', the drilling head 120', the steering blade 122', and the tip 130' of the steering blade 122'. A through-cut is illustrated in FIG. 6B showing the drilling pipe 118', the drilling head 120', the steering blade 122', the tip 130' of the steering blade 122', the gyro 172, the pipe conduit 140', the tip conduit 138', the non-return valve 136', the first locking part 212, and the second locking part 214.

[0074] FIGS. 7A-C illustrate details of the drilling head 120' described in relation to FIGS. 6A-C. A perspective view of the first locking part 212 is shown in FIG. 7A. The first locking part 212 comprises a central shaft 228 with a pair of pins 226 protruding from the sides of the shaft 228. The pair of pins 226 are positioned on opposite sides of the shaft 228. The shaft is attached to a base plate 234 or base portion, which in turn is attached to the gyro, e.g. by bolts going through the base plate 234 into the housing of the gyro. The first locking part 212 also comprises retaining spring 230 in the form of a coil spring centred on the central shaft 228 secured to the base plate 234 such that it can be compressed towards the base plate 234. A spacer 232 in the form of a cylinder centred on the shaft 228 and covering most of the coil spring 230 is attached to the base plate 234 such that the compression of the coil spring 230 is limited.

[0075] A side view of the first locking part 212 and interior of the drilling head 120' with a second locking part 214 is shown in FIGS. 7B-C. The drilling head 120' is hollow such that it can receive the first locking part 212. The second locking part 214 comprises a receptor base 240 attached to the inside of the drilling head 120'. The receptor base 240 has a receptor aperture 244 through which the pins 226 and the central shaft 228 can be inserted. A pair of receptor bodies 242 are positioned on either side of the receptor aperture 244, each having a pin slot 236 for cooperating with one of the pins 226 of the first locking part 212. The gyro 172 is pushed forward such that the pins 266 pass through the receptor aperture 244 until the spacer 232 engages the receptor base 240 and prevents any further forward motion relative to the drilling head 120'. The coil spring 230 engages the receptor base 240 before the spacer 232. The first locking part 212 is rotated subsequent to being inserted through the receptor aperture 244 such that each of the pins 226 falls into a slot 236. In this position, the coil spring 230 engages the receptor body 242 such that the pins 226 are forced into the slots 236. This way, the first locking part 212 and the second locking part 214 define a male connector and a female connector, respectively, of a bayonet lock. The receptor aperture 244 allows for a drilling fluid to pass through the receptor base 240 when the first locking part 212 is locked to the second locking part 214.

[0076] The first locking part 212 is released by pushing it forward until the spacer 232 meets the receptor base 240 such that the pins 226 disengage the slots 236. Subsequently, the first locking part 212 is rotated such that the pins 226 disengages the receptor bodies 242, and the first locking part 212 is pulled backwards from the second locking part 214 such that the central shaft 228 and the pins 226 exit through the receptor aperture 244.

ITEM LIST

[0077]

10 stru ctu re
12 ground
14 soil
15 underground space
16 tunnel

18 freezing tube
20 frozen soil
21 unfrozen core
22 compensation tube
24 strain gauge
26 compensation liquid
28 open hole
29 outer wall surface
30 concrete wall
31 inner wall surface
32 concrete drill
34 through-going narrow hole
36 stabilizer
37 area
38 first circular hole cutter
39 concrete plug
40 support hole
42 bottom
44 cylindrical wall
46 support portion
47 cylinder body
48 support portion flange
50 bolt hole
52 bushing
54 wedge
56 o-ring
58 support flange
60 sealant
62 valve portion
64 forward valve portion flange
66 bolt hole
68 backward valve portion flange
70 bolt hole
72 gate valve
74 insertion portion
76 forward insertion portion flange
78 bolt hole
80 backward insertion portion flange
82 bolt hole
84 hollow body
86 lower outlet and/or inlet
88 lower valve
90 upper outlet and/or inlet
92 upper valve
94 back portion
96 bolt holes
98 aperture
100 sealing ring
102 second circular hole cutter
104 cutter axle
106 drilling lock
108 plug
110 break-through hole
112 cylindrical wall
114 drilling back portion
115 pipe aperture
116 pipe sealing ring
118 drilling pipe
118’ drilling pipe
120 drilling head
120’ drilling head
122 steering blade
122’ steering blade
124 hose
125 hose outlet
126 container
128 drilling fluid
130 forward tip
130’ forwardtip
132 inner wall
134 outer wall
136 non-return valve
138 tip conduit
138’ tip conduit
140 pipe conduit
140’ pipe conduit
142 drilling hole
144 light-emitting diodes
146 battery
148 theodolite camera
150 second concrete wall
152 cutter
154 support material
156 compensation liquid
158 outlets
160 first support flange
162 second support flange
164 rubber ring
166 non-return valve
172 gyro
174 control and power cable
176 spacer
177 spacer wheel
178 outer shell
180 circulation tubes
182 tip
184 injection tube
186 bridging medium
188 position indicator
190 light-emitting diodes
192 battery
194 indicator housing
196 separation space
198 head conduit
200 head chamber
202 forward pointing teeth
204 backward pointing teeth
206 forward chamber
208 sealing flange
210 channels
212 first locking part
214 second locking part
216 sealing flange
218 sealing sleeve
220 freezing tube apperture
222 injection tube apperture

224 freezing tube spacers
226 pin
228 central shaft
230 retaining spring coil
232 spacer
234 base flange
236 pin slot
240 receptor base
242 receptor body
244 receptor aperture
246 end fitting
248 end pipe
250 connector
252 o-ring
254 locking disc
256 bolt hole
258 nut and bolt
260 packing disc
261 locking disc aperture
262 packing disc aperture

Claims

1. Method of excavating an underground space (15) in the soil (14) below an overlaying structure (10), **characterized by** the method comprising:

   providing a compensation liquid (26),
   providing a plurality of compensation tubes (22) for conveying said compensation liquid (26), each of said compensation tubes (22) comprising a number of outlets for allowing said compensation liquid (26) to pass from said compensation tube (22) into the surrounding medium,
   positioning said plurality of compensation tubes (22) in said soil (14) below said structure (10),
   excavating said underground space (15) in said soil (14) below said plurality of compensation tubes (22),
   monitoring the overlaying structure (10) for detecting changes in the structure (10) due to said excavating of said underground space (15), and if a change in the structure (10) is detected:

      injecting said compensation liquid (26) into said soil (14) through one or more of said plurality of compensation tubes (22).

2. The method according to claim 1, **characterized by** said overlaying structure (10) being a surface building (10) over ground (12) and said method further comprising:

   excavating a hole (28) in the ground (12) beside said surface building,

   said positioning of said plurality of compensation tubes (22) comprising:

   inserting said compensation tubes (22) from said hole (28) in the ground (12) into said soil (14),
   forming a water-impregnable wall (30) at the side of said hole (28)facing said surface building (10) for preventing said hole (28) from draining ground water and/or soil particles from said soil (14) under said surface building (10), said water-impregnable wall (30) being a concrete wall (30).

3. The method according to any of the claims 1 to 2, **characterized by** said positioning of said plurality of compensation tubes (22) in said soil (14) for each compensation tube (22) of said plurality of compensation tubes (22) comprising:

   providing a first hollow drilling pipe (118) and a first drilling head (120) attached to said first hollow drilling pipe (118), said first hollow drilling pipe (118) and said first drilling head (120) being adapted for being drilled into said soil (14) with said first drilling head (120) first,
   drilling said first drilling head (120) and said first hollow drilling pipe (118) into said soil (14) below said structure (10),
   inserting said compensation tube (22) of said plurality of compensation tubes (22) into said hollow drilling pipe (118), and
   retracting said first hollow drilling pipe (118) and simultaneously expelling a support material (154) around said compensation tube (22) at the insertion or forward end of said first hollow drilling pipe (118) for preventing a collapsing of said soil (14).

4. The method according to claim 3, **characterized by** said drilling of said first drilling head (120) and said first hollow drilling pipe (118) into said soil (14) comprising:

   controlling the direction of said first hollow drilling pipe (118) and/or said first drilling head (120) for positioning said first hollow drilling pipe (118) along a straight line.

5. The method according to any of the claims 3 to 4, **characterized by** said positioning of said plurality of compensation tubes (22) further comprising:

   detaching said first drilling head (120) from said first hollow drilling pipe (118) prior to said retraction of said first hollow drilling pipe (118) for forming a first conduit outlet of a first pipe conduit (140) at the insertion or forward end of said first hollow drilling pipe (118), and
   said expelling of said support material (154)

around said compensation tube (122) comprising:

conveying said support material (154) through said first pipe conduit (140) and expelling said support material (154) through said first conduit outlet.

6. The method according to any of the claims 1 to 5, **characterized by** said excavating of said underground space (15) in said soil below said plurality of compensation tubes (22) comprising:

defining an excavation volume of said soil (14),
providing a plurality of freezing tubes (18), each of said plurality of freezing tubes (18) being adapted for conveying a cooling medium along its length and for transferring heat between its surroundings and said cooling medium,
positioning said plurality of freezing tubes (18) in said soil (14) below said plurality of compensation tubes (22) and outside said excavation volume,
providing a cooling medium for being conveyed through said plurality of freezing tubes (18) and having a temperature that is lower than the freezing temperature of said soil (14),
conveying said cooling medium through said plurality of freezing tubes (18) for freezing at least a portion of said soil (14) surrounding said excavation volume, and
removing said soil (14) of said excavation volume.

7. The method according to claim 6, **characterized by** said positioning of said plurality of freezing tubes (18) in said soil (14) comprising:

positioning said plurality of freezing tubes (18) in a pattern surrounding said excavation volume, and
said conveying of said cooling medium through said plurality of freezing tubes (18) further being adapted for freezing said soil (14) to form a shell of frozen soil (20) around said excavation volume, and/or for freezing said soil (14) of said excavation volume.

8. The method according to any of the claims 6 to 7, **characterized by** said positioning of said plurality of freezing tubes (18) in said soil (14) below said structure (10) for each freezing tube (18) of said plurality of freezing tubes (18) comprising:

providing a second hollow drilling pipe (118') and a second drilling head (120') attached to said second hollow drilling pipe (118'), said second hollow drilling pipe (118') and said second drilling head (120') being adapted for being drilled into said soil (14) with said second drilling head (120') first, said second drilling pipe (118') being adapted for allowing a heat transport between the outside and the inside of said second hollow drilling pipe (118'),
drilling said second drilling head (120') and said second hollow drilling pipe (118') into said soil (14) below said plurality of compensation tubes (22),
inserting said freezing tube (18) of said plurality of freezing tubes (18) into said hollow drilling pipe (118'),
providing a bridging medium (186) for transferring heat,
injecting said bridging medium (186) between said freezing tube (18) and said second hollow drilling pipe (118') for establishing a heat conduction between the outside of said second hollow drilling pipe (118') and said freezing tube (18).

9. The method according to claim 8, **characterized by** said excavation volume being elongated and said drilling of said second drilling head (120') and said second hollow drilling pipe (118') into said soil comprising:

controlling the direction of said second hollow drilling pipe (118') and/or said second drilling head (120') for positioning said second hollow drilling pipe (118')alongside said elongated excavation volume.

10. The method according to any of the claims 1 to 9, **characterized by** said monitoring of said overlaying structure (10) comprising:

detecting movements and/or shifts of said overlaying structure (10), and/or
detecting changes in the internal loads and/or the distribution of the internal loads of said overlaying structure (10).

11. The method according to claim 2 or any claim depending on claim 2, **characterized by** said forming of said water-impregnable wall (30) for each of said plurality of compensation tubes (22) comprising:

providing a first drill (32) having a first diameter,
drilling a first hole (134) through said concrete wall (30) with said first drill (32),
measuring the width of said concrete wall (30) through said first hole (34),
providing a first circular cutter (38) having a second diameter that is greater than said first diameter,
cutting a second hole (40) in said concrete wall

(30) at or centred on said first hole (34) and having a length that is less than the width of said concrete wall (30), said second hole (34) having an opening and an opposite bottom (42),
sealing said opening of said second hole (34) with a first lock (106) for allowing a sealable access to said second hole (40),
providing a second circular cutter (102) having a third diameter that is greater than said first diameter and smaller than said second diameter,
introducing said second circular cutter (102) into said second hole (40) through said first lock (106) and cutting with said second circular cutter (102) a third hole (110) in said bottom (42) of said second hole (40) having a length that is greater than the difference between the length of the second hole and the width of said concrete wall,
retracting said second circular cutter (102), and closing said first lock (106) for preventing ground water and/or soil particles from escaping through said concrete wall (30).

12. The method according to any of the preceding claims depending on both claim 2 and claim 6, **characterized by** said forming of said water-impregnable wall (30) for each of said plurality of freezing tubes (18) comprising:

providing a fourth drill (32) having a fourth diameter,
drilling a fourth hole (34) through said concrete wall (30) with said fourth drill,
measuring the width of said concrete wall through said fourth hole (34),
providing a third circular cutter (38) having a fifth diameter that is greater than said fourth diameter,
cutting a fifth hole (40) in said concrete wall (30) at or centred on said fourth hole (34) and having a length that is less than the width of said concrete wall (30), said fifth hole (40) having an opening and an opposite bottom (42),
sealing said opening of said fifth hole (40) with a second lock (106) for allowing a sealable access to said fifth hole (40),
providing a fourth circular cutter (102) having a sixth diameter that is greater than said fourth diameter and smaller than said fifth diameter,
introducing said fourth circular cutter (102) into said fifth hole (40) through said second lock (106) and cutting with said fourth circular cutter (102) a sixth hole (110) in said bottom of said fifth hole (40) having a length that is greater than the difference between the length of the fifth hole and the width of said concrete wall (30),
retracting said fourth circular cutter, (102) and closing said second lock (106) for preventing ground water and/or soil particles from escaping through said concrete wall (30).

Patentansprüche

1. Verfahren zum Abtragen eines unterirdischen Raums (15) in der Erde (14) unterhalb einer überlagerten Struktur (10), wobei das Verfahren umfasst:

Bereitstellen eines Kompensationsliquids (26),
Bereitstellen einer Mehrheit von Kompensationsröhren (22) zum Zuführen des Kompensationsliquids (26), wobei jedes der Kompensationsröhre (22) eine Anzahl Auslässe umfasst, um es dem Kompensationsliquid (26) zu erlauben, von dem Kompensationsrohr (22) in das umgebende Medium zu fließen,
Positionieren der Mehrheit von Kompensationsröhren (22) in der Erde (14) unterhalb der Struktur (10),
Abtragen des unterirdischen Raums (15) in der Erde (14) unterhalb der Mehrheit von Kompensationsröhren (22),
Überwachen der überlagerten Struktur (10) zum Erfassen von Änderungen in der Struktur (10) wegen des Abtragens des unterirdischen Raums (15), und wenn eine Änderung in der Struktur (10) erfasst ist:

Einspritzen des Kompensationsliquids (26) in die Erde (14) durch ein oder mehrere aus der Mehrheit von Kompensationsröhren (22).

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die überlagerte Struktur (10) ein Oberflächengebäude (10) über dem Boden (12) ist, und das Verfahren ferner umfasst:

Abtragen eines Lochs (28) in dem Boden (12) neben dem Oberflächengebäude,

wobei das Positionieren der Mehrheit von Kompensationsröhren (22) umfasst:

Einführen der Kompensationsröhre (22) von dem Loch (28) in dem Boden (12) in die Erde (14),
Bilden einer wasserundurchlässigen Wand (30) auf der Seite des Lochs (28), die dem Oberflächengebäude (10) zugekehrt ist, um zu verhindern, dass das Loch (28) Grundwasser und/oder Bodenpartikeln von der Erde (14) unter dem Oberflächengebäude (10) abführt, wobei die wasserundurchlässige Wand (30) eine Betonwand (30) ist.

3. Verfahren nach einem der Ansprüche 1 bis 2, **dadurch gekennzeichnet, dass** die Positionierung der Mehrheit von Kompensationsröhren (22) in der Erde (14) für jedes Kompensationsrohr (22) aus der Mehrheit von Kompensationsröhren (22) umfasst:

Bereitstellen eines ersten hohlen Bohrrohrs (118) und eines ersten Bohrkopfs (120), der an dem ersten hohlen Bohrrohr (118) befestigt ist, wobei das erste hohle Bohrrohr (118) und der erste Bohrkopf (120) dazu eingerichtet sind, in die Erde (14) mit dem ersten Bohrkopf (120) zuerst gebohrt zu werden,
Bohren des ersten Bohrkopfs (120) und des ersten hohlen Bohrrohrs (118) in die Erde (14) unterhalb der Struktur (10),
Einführen des Kompensationsrohrs (22) aus der Mehrheit von Kompensationsröhren (22) in das hohle Bohrrohr (118), und
Zurückziehen des ersten hohlen Bohrrohrs (118) und gleichzeitig Ausstoßen eines Trägermaterials (154) um das Kompensationsrohr (22) an dem Einfuhr- oder vorderen Ende des ersten hohlen Bohrrohrs (118), um einen Einsturz der Erde (14) zu verhindern.

4. Verfahren nach Anspruch 3, **dadurch gekennzeichnet, dass** das Bohren des ersten Bohrkopfs (120) und des ersten hohlen Bohrrohrs (118) in die Erde (14) umfasst:

Steuern der Richtung des ersten hohlen Bohrrohrs (118) und/oder des ersten Bohrkopfs (120) zum Positionieren des ersten hohlen Bohrrohrs (118) entlang einer geraden Linie.

5. Verfahren nach einem der Ansprüche 3 bis 4, **dadurch gekennzeichnet, dass** die Positionierung der Mehrheit von Kompensationsröhren (22) ferner umfasst:

Trennen des ersten Bohrkopfs (120) von dem ersten hohlen Bohrrohrs (118) vor dem Zurückziehen des ersten hohlen Bohrrohrs (118) zum Bilden eines ersten Leitungsausgangs einer ersten Rohrleitung (140) an dem Einfuhr- oder vorderen Ende des ersten hohlen Bohrrohrs (118), und
wobei das Ausstoßen des Trägermaterials (154) um das Kompensationsrohr (122) umfasst:

Zuführen des Trägermaterials (154) durch die erste Rohrleitung (140) und Ausstoßen des Trägermaterials (154) durch den ersten Leitungsausgang.

6. Verfahren nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet, dass** das Abtragen des unterirdischen Raums (15) in der Erde unterhalb der Mehrheit von Kompensationsröhren (22) umfasst:

Definieren eines Abtragungsvolumens der Erde (14),
Bereitstellen einer Mehrheit von Gefrierröhren (18), wobei jedes aus der Mehrheit von Gefrierröhren (18) dazu eingerichtet ist, ein Kühlmedium entlang seiner Länge zu fördern und Wärme zwischen seiner Umgebung und dem Kühlmedium zu übertragen,
Positionieren der Mehrheit von Gefrierröhren (18) in der Erde (14) unterhalb der Mehrheit von Kompensationsröhren (22) und außerhalb des Abtragungsvolumens,
Bereitstellen eines Kühlmediums zum Fördern durch die Mehrheit von Gefrierröhren (18) und mit einer Temperatur, die niedriger als die Gefriertemperatur der Erde (14) ist,
Zuführen des Kühlmediums durch die Mehrheit von Gefrierröhren (18) zum Gefrieren von wenigstens einem Teil der Erde (14), die das Abtragungsvolumen umgibt, und
Entfernen der Erde (14) des Abtragungsvolumens.

7. Verfahren nach Anspruch 6, **dadurch gekennzeichnet, dass** die Positionierung der Mehrzahl von Gefrierröhren (18) in der Erde (14) umfasst:

Positionieren der Mehrheit von Gefrierröhren (18) in einem Muster, welches das Abtragungsvolumen umgibt, und
wobei das Zuführen des Kühlmediums durch die Mehrheit von Gefrierröhren (18) ferner dazu eingerichtet ist, die Erde (14) zu gefrieren, um eine Schale von gefrorener Erde (20) um das Abtragungsvolumen zu bilden, und/oder die Erde (14) des Abtragungsvolumens zu gefrieren.

8. Verfahren nach einem der Ansprüche 6 bis 7, dass die Positionierung der Mehrzahl von Gefrierröhren (18) in der Erde (14) unterhalb der Struktur (10) für jedes Gefrierrohr (18) aus der Mehrheit von Gefrierröhren (18) umfasst:

Bereitstellen eines zweiten hohlen Bohrrohrs (118') und eines zweiten Bohrkopfs (120'), der an dem zweiten hohlen Bohrrohr (118') befestigt ist, wobei das zweite hohle Bohrrohr (118') und der zweite Bohrkopf (120') dazu eingerichtet sind, in die Erde (14) mit dem zweiten Bohrkopf (120') zuerst gebohrt zu werden, wobei das zweite Bohrrohr (118') dazu eingerichtet ist, einen Wärmetransport zwischen der Außenseite und der Innenseite des zweiten hohlen Bohrrohrs (118') zu erlauben,
Bohren des zweiten Bohrkopfs (120') und des

zweiten hohlen Bohrrohrs (118') in die Erde (14) unterhalb der Mehrheit von Kompensationsröhren (22),
Einführen des Gefrierrohrs (18) aus der Mehrheit von Gefrierröhren (18) in das hohle Bohrrohr (118'),
Bereitstellen eines Überbrückungsmediums (186) zum Übertragen von Wärme,
Einspritzen des Überbrückungsmediums (186) zwischen dem Gefrierrohr (18) und dem zweiten hohlen Bohrrohr (118') zum Herstellen einer Wärmeleitung zwischen der Außenseite des zweiten Bohrrohrs (118') und dem Gefrierrohr (18).

9. Verfahren nach Anspruch 8, **dadurch gekennzeichnet, dass** das Abtragungsvolumen langgestreckt ist, und das Bohren des zweiten Bohrkopfs (120') und des zweiten hohlen Bohrrohrs (118') in die Erde umfasst:

Steuern der Richtung des zweiten hohlen Bohrrohrs (118') und/oder des zweiten Bohrkopfs (120') zum Positionieren des zweiten hohlen Bohrrohrs (118') längs des langgestreckten Abtragungsvolumens.

10. Verfahren nach einem der Ansprüche 1 bis 36, **dadurch gekennzeichnet, dass** das Überwachen der überlagerten Struktur (10) umfasst:

Erfassen von Bewegungen und/oder Verschiebungen der überlagerten Struktur (10), und/oder Erfassen von Änderungen in den inneren Lasten und/oder der Verteilung der inneren Lasten der überlagerten Struktur (10).

11. Verfahren nach Anspruch 2 oder einem von Anspruch 2 abhängigen Anspruch, **dadurch gekennzeichnet, dass** das Bilden der wasserundurchlässigen Wand (30) für jedes aus der Mehrheit von Kompensationsröhren (22) umfasst:

Bereitstellen eines ersten Bohrers (32) mit einem ersten Durchmesser,
Bohren eines ersten Lochs (134) durch die Betonwand (30) mit dem ersten Bohrer (32),
Messen der Breite der Betonwand (30) durch das erste Loch (34),
Bereitstellen eines ersten Kreismessers (38) mit einem zweiten Durchmesser, der größer als der erste Durchmesser ist,
Schneiden eines zweiten Lochs (40) in der Betonwand (30) an oder auf dem ersten Loch (34) zentriert und mit einer Länge, die weniger als die Breite der Betonwand (30) ist, wobei das zweite Loch (34) eine Öffnung und einen gegenüberliegenden Boden (42) aufweist,
Abdichten der Öffnung des zweiten Lochs (34) mit einem ersten Schloss (106), um einen abdichtbaren Zugang zu dem zweiten Loch (40) zu erlauben,
Bereitstellen eines zweiten Kreismessers (102) mit einem dritten Durchmesser, der größer als der erste Durchmesser ist und kleiner als der zweite Durchmesser ist,
Einführen des zweiten Kreismessers (102) in das zweite Loch (40) durch das erste Schloss (106) und Schneiden eines dritten Lochs (110) mit dem zweiten Kreismesser (102) in dem Boden (42) des zweiten Lochs (40), das eine Länge aufweist, die größer als der Unterschied zwischen der Länge des zweiten Lochs und der Breite der Betonwand ist,
Zurückziehen des zweiten Kreismessers (102), und
Schließen des ersten Lochs (106), um zu verhindern, dass Grundwasser und/oder Bodenpartikeln durch die Betonwand (30) entweichen.

12. Verfahren nach Anspruch 2 oder einem der vorhergehenden von sowohl Anspruch 2 als auch Anspruch 6 abhängigen Ansprüche, **dadurch gekennzeichnet, dass** das Bilden der wasserundurchlässigen Wand (30) für jedes aus der Mehrheit von Gefrierröhren (18) umfasst:

Bereitstellen eines vierten Bohrers (32) mit einem vierten Durchmesser,
Bohren eines vierten Lochs (34) durch die Betonwand (30) mit dem vierten Bohrer,
Messen der Breite der Betonwand durch das vierte Loch (34),
Bereitstellen eines dritten Kreismessers (38) mit einem fünften Durchmesser, der grösser als der vierte Durchmesser ist,
Schneiden eines fünften Lochs (40) in der Betonwand (30) an oder auf dem vierten Loch (34) zentriert und mit einer Länge, die weniger als die Breite der Betonwand (30) ist, wobei das fünfte Loch (40) eine Öffnung und einen gegenüberliegenden Boden (42) aufweist,
Abdichten der Öffnung des fünften Lochs (40) mit einem zweiten Schloss (106), um einen abdichtbaren Zugang zu dem fünften Loch (40) zu erlauben,
Bereitstellen eines vierten Kreismessers (102) mit einem sechsten Durchmesser, der größer als der vierte Durchmesser ist und kleiner als der fünfte Durchmesser ist,
Einführen des vierten Kreismessers (102) in das fünfte Loch (40) durch den zweiten Schloss (106) und Schneiden eines sechsten Lochs (110) mit dem vierten Kreismesser (102) in dem Boden des fünften Lochs (40), das eine Länge aufweist, die größer als der Unterschied zwi-

schen der Länge des fünften Lochs und der Breite der Betonwand ist (30),
Zurückziehen des vierten Kreismessers (102), und
Schließen des zweiten Lochs (106), um zu verhindern, dass Grundwasser und/oder Bodenpartikeln durch die Betonwand (30) entweichen.

Revendications

1. Procédé d'axcavation d'un espace souterrain (15) dans le sol (14) en dessous d'une structure superposée (10), **caractérisé en ce que** le procédé comprend:

    la fourniture d'un liquide de compensation (26),
    la fourniture d'une pluralité de tuyaux de compensation (22) pour transporter ledit liquide de compensation (26), chacun desdits tuyaux de compensation (22) comprenant un nombre de sorties pour permettre audit liquide de compensation (26) de passer dudit tuyaux de compensation (22) dans le milieu environnant,
    le positionnement de ladite pluralité de tuyaux de compensation (22) dans ledit sol (14) en dessous de ladite structure (10),
    l'excavation dudit espace souterrain (15) dans ledit sol (14) en dessous de ladite pluralité de tuyaux de compensation (22),
    la surveillance de ladite structure superposée (10) pour détecter des changements dans la structure (10) à cause de ladite excavation dudit espace souterrain (15), et si un changement dans la structure (10) est détecté:

        l'injection dudit liquide de compensation (26) dans ledit sol (14) à travers au moins une de ladite pluralité de tuyaux de compensation (22).

2. Procédé selon la revendication 1, **caractérisé en ce que** ladite structure superposée (10) est un élément de surface (10) au-dessus du sol (12) et ledit procédé comprenant en outre:

    l'excavation d'un trou (28) dans le sol (12) à côté de l'élément de surface, ledit positionnement de ladite pluralité de tuyaux de compensation (22) comprenant:

        l'insertion desdits tuyaux de compensation (22) à partir dudit trou (28) dans le terrain (12) dans ledit sol (14),
        la formation d'une paroi imperméable(??) à l'eau (30) au côté dudit trou (28) faisant face audit élément de surface (10) pour prévenir ledit trou (28) de drainer l'eau souterraine et/ou des particules du sol dudit sol (14) sous ledit élément de surface (10), ladite paroi imperméable à l'eau (30) étant une paroi en béton (30).

3. Procédé selon l'une quelconque des revendications 1 à 2, **caractérisé par** ledit positionnnement de ladite pluralité de tuyaux de compensation (22) dans ledit sol (14) pour chaque tuyau de compensation (22) de ladite pluralité de tuyaux de compensation (22) comprenant:

    la fourniture d'un premier tuyau de forage creux (118) et une première tête de forage (120) fixée audit premier tuyau de forage creux (118), ledit premier tuyau de forage creux (118) et ladite première tête de forage (120) étant adaptés pour être forés dans ledit sol (14) avec ladite première tête de forage (120) en avant,
    le forage de ladite première tête de forage (120) et ledit premier tuyau de forage creux (118) dans ledit sol (14) en dessous de ladite structure (10),
    l'insertion dudit tuyau de compensation (22) de ladite pluralité de tuyaux de compensation (22) dans ledit tuyau de forage creux (118), et
    la rétractation dudit premier tuyau de forage creux (118) et simultanément expulser un matériau de support (154) autour dudit tuyau de compensation (22) à l'extrémité d'insertion ou d'avant dudit premier tuyau de forage creux (118) pour empecher un effondrement dudit sol (14).

4. Procédé selon la revendication 3, **caractérisé par** ledit forage de ladite première tête de forage (120) et ledit premier tuyau de forage creux (118) dans ledit sol (14) comprenant:

    le contrôle de la direction dudit premier tuyau de forage creux (118) et/ou ladite première tête de forage (120) pour positionner ledit premier tuyau de forage creux (118) le long d'une ligne droite.

5. Procédé selon l'une quelconque des revendications 3 à 4, **caractérisé par** ledit positionnement de ladite pluralité de tuyaux de compensation (22) comprenant en outre:

    le détachement de ladite première tête de forage (120) dudit premier tuyau de forage creux (118) préalablement à ladite rétractation dudit premier tuyau de forage creux (118) pour former une première sortie de conduit d'un premier conduit de tuyau (140) à l'extrémité de l'insertion ou de l'avant dudit premier tuyau de forage creux (118), et
    ledit expulsion dudit matériau de support (154) autour dudit tuyau de compensation (122) com-

prenant:

la transportation dudit matériau de support (154) à travers ledit premier conduit de tuyau (14) et l'expulsion dudit matériau de support (154) par ladite première sortie de conduit.

6. Procédé selon l'une quelconque des revendications 1 à 5, **caractérisé par** ladite excavation dudit espace souterrain (15) dans ledit sol (14) en dessous de ladite pluralité de tuyaux de compensation (22) comprenant:

la définition d'un volume d'excavation dudit sol (14),
la fourniture d'une pluralité de tuyaux de congélation (18), chacune de ladite pluralité de tuyaux de congélation (18) étant adaptée pour transporter un moyen de refroidissement le long de sa longueur et pour transférer de la chaleur entre son environnement et ledit moyen de refroidissement,
le positionnement de ladite pluralité de tuyaux de congélation (18) dans ledit sol (14) entre ladite pluralité de tuyaux de compensation (22) et à l'extérieur dudit volume d'excavation,
la fourniture d'un moyen de refroidissement à être transporter à travers ladite pluralité de tuyaux de congélation (18) et ayant une température qui est inférieure à la température de congélation dudit sol (14),
la transportation ledit moyen de refroidissement à travers ladite pluralité de tuyaux de congélation (18) pour congéler au moins une partie dudit sol (14) autour dudit volume d'excavation, et
l'enlèvement dudit sol (14) dudit volume d'excavation.

7. Procédé selon la revendication 6, **caractérisé par** le positionnement de ladite pluralité desdits tuyaux de congélation (18) dans ledit sol (14) comprenant:

le positionnement de ladite pluralité de tuyaux de congélation (18) dans un motif autour dudit volume d'excavation, et
ladite transportation dudit moyen de refroidissement à travers ladite pluralité de tuyaux de congélation (18) étant en outre adaptée pour congeler ledit sol (14) afin de former une enveloppe de sol congelé (20) autour dudit volume d'excavation, et/ou pour congeler ledit sol (14) dudit volume d'excavation.

8. Procédé selon l'une quelconque des revendications 6 à 7, **caractérisé par** ledit positionnement de ladite pluralité de tuyaux de congélation (18) dans ledit sol (14) en dessous de ladite structure (10) pour chaque tuyau de congélation (18) de ladite pluralité de tuyaux de congélation (18) comprenant:

la fourniture d'un deuxième tube de forage creux (118') et une deuxième tête de forage (120') fixée audit deuxième tube de forage creux (118'), ledit deuxième tube de forage creux (118') et ladite deuxième tête de forage (120') étant adaptés pour être percés dans ledit sol (14) avec ladite deuxième tête de forage (120') en avant, ledit deuxième tube de forage creux (118') étant adapté pour permettre un transport de chaleur entre l'extérieur et l'intérieur dudit deuxième tube de forage creux (118'),
le forage de ladite deuxième tête de forage (120') et ledit deuxième tube de forage creux (118') dans ledit sol (14) en dessous de ladite pluralité de tuyaux de compensation (22),
l'insertion dudit tuyau de congélation (18) de ladite pluralité de tuyaux de congélation (18) dans ledit tube de forage creux (118'),
la fourniture d'un moyen de pontage (186) pour transférer de la chaleur,
l'injection dudit moyen de pontage (186) entre ledit tuyau de congélation (18) et ledit deuxième tube de forage creux (118') pour établir une condution de chaleur entre l'extérieur dudit deuxième tube de forage creux (118') et ledit tuyau de congélation (18).

9. Procédé selon la revendication 8, **caractérisé en ce que** ledit volume d'excavation est allongé et **en ce que** ledit forage de ladite deuxième tête de forage (120') et ledit deuxième tube de forage creux (118') dans ledit sol comprenant:

le contrôle de la direction dudit deuxième tube de forage creux (118') et/ou ladite deuxième tête de forage (120') pour positionner ledit deuxième tube de forage creux (118') le long dudit volume d'excavation allongé.

10. Procédé selon l'une quelconque des revendications 1 à 9, **caractérisé en ce que** ladite surveillance de ladite structure superposée (10) comprend:

la détection de mouvements et/ou déplacements de ladite structure superposée (10), et/ou la détection de changements des charges internes et/ou de la distribution de charges interns de ladite structure superposée (10).

11. Procédé selon la revendication 2 ou n'importe quelle revendication dépendant de la revendication 2, **caractérisé par** ladite création de ladite paroi imperméable à l'eau (30) pour chacune de ladite pluralité de tuyaux de compensation (22) comprenant:

la fourniture d'une première perceuse (32) ayant un premier diamètre,
le forage d'un premier trou (134) à travers la paroi en béton (30) avec ladite première perceuse (32),
le mesurage de la largeur de ladite paroi en béton (30) à travers ledit premier trou (34),
la fourniture d'une fraise circulaire (38) ayant un deuxième diamètre qui est supérieur audit premier diamètre,
la coupe d'un deuxième trou (40) dans ladite paroi en béton (30) soit auprès dudit premier trou (34), soit centré sur celui-ci, et ayant une longueur qui est inférieure à la largeur de ladite paroi en béton (30), ledit deuxième trou (34) ayant une ouverture et en fond opposé (42),
le scellement de ladite ouverture dudit deuxième trou (34) avec un premier écluse (106) afin de permettre un accès d'étanchéité audit deuxième trou (40),
la fourniture d'une deuxième fraise circulaire (102) ayant un troisième diamètre qui est supérieur audit premier diamètre et inférieur audit deuxième diamètre,
l'introduction de ladite deuxième fraise circulaire (102) dans ledit deuxième trou (40) à travers ledit premier écluse (106) et le coupage d'un troisème trou (110) avec ladite deuxième fraise circulaire (102) dans ledit fond (42) dudit deuxième trou (40) ayant une longueur qui est supérieure à la différence entre la longueur dudit deuxième trou et la largeur de ladite paroi en béton,
la retraction de ladite deuxième fraise circulaire (102), et
la fermeture dudit premier écluse (106) pour empêcher que l'eau souterraine et/ou des particules du sol s'échappe(nt) par ladite paroi en béton (30).

12. Procédé selon l'une quelconque des revendications dépendant de la revendication 2 comme la revendication 6, **caractérisé par** ladite création de ladite paroi imperméable à l'eau (30) pour chacune de ladite pluralité de tuyaux de congélation (18) comprenant:

la fourniture d'une quatrième perceuse (32) ayant un quatrième diamètre,
le forage d'un quatrième trou (34) à travers ladite paroi en béton (30) avec ledit quatrième perceuse,
le mesurage de la largeur de ladite paroi en béton à travers ledit quatrième trou (34),
la fourniture d'une troisième fraise circulaire (38) ayant un cinquième diamètre qui est supérieur audit quatrième diamètre,
le coupage d'un cinquième trou (40) dans ladite paroi en béton (30), soit auprès dudit quatrième trou (34), soit centré sur celui-ci, et ayant une longueur qui est inférieure à la largeur de ladite paroi en béton (30), ledit cinquième trou (40) ayant une ouverture et un fond opposé (42),
le scellement de ladite ouverture dudit cinquième trou (40) avec un deuxième écluse (106) afin de permettre en accès d'étanchéité audit cinquième trou (40),
la fourniture d'une quatrième fraise circulaire (102) ayant un sixième diamètre qui est supérieur audit quatrième diamètre et inférieur audit cinquième diamètre,
l'introduction de ladite quatrième fraise circulaire (102) dans ledit cinquième trou (40) à travers ledit deuxième écluse (106) et le coupage d'un sixième trou (110) avec ladite quatrième fraise circulaire (102) dans ledit fond dudit cinquième trou (40) ayant une longueur qui est supérieure à la différence entre la longueur du cinquième trou et la largeur de ladite paroi en béton (30),
la retraction de ladite quatrième fraise circulaire (102), et
la fermeture dudit deuxième écluse (106) pour empêcher que l'eau souterraine et/ou des particules du sol s'echappente à travers ladite paroi en béton (30).

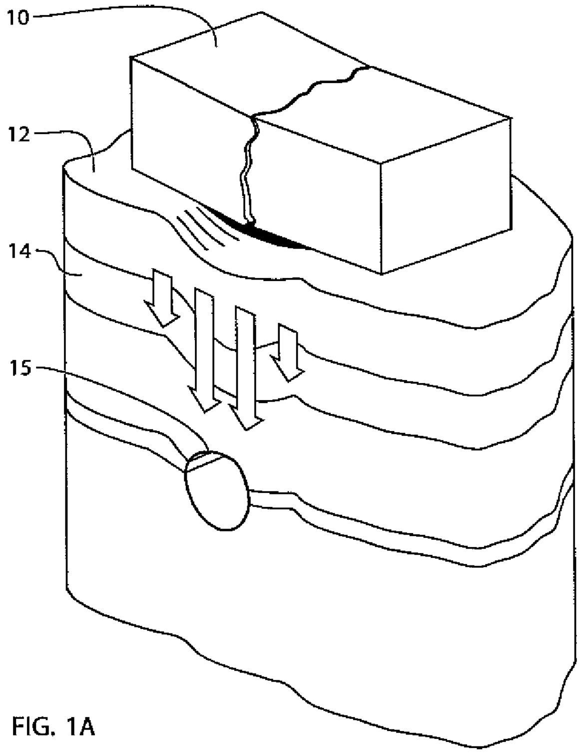


FIG. 1A

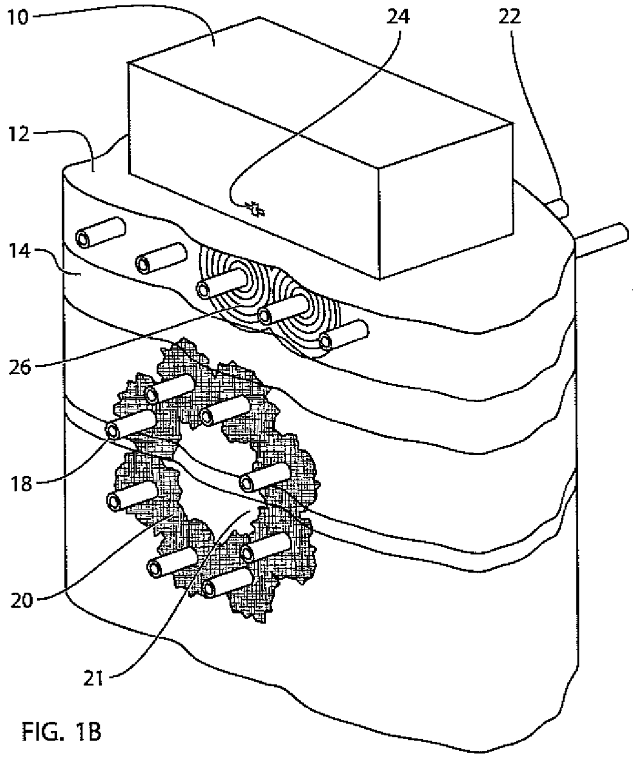


FIG. 1B

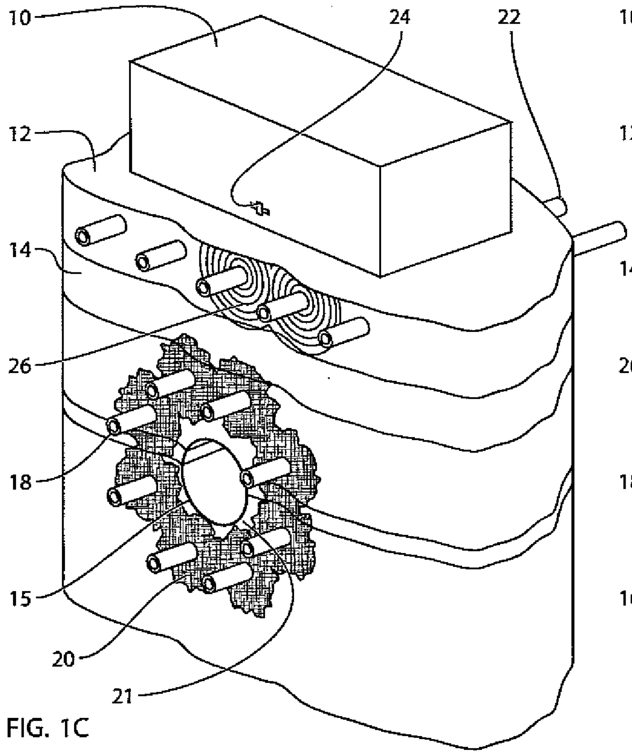


FIG. 1C

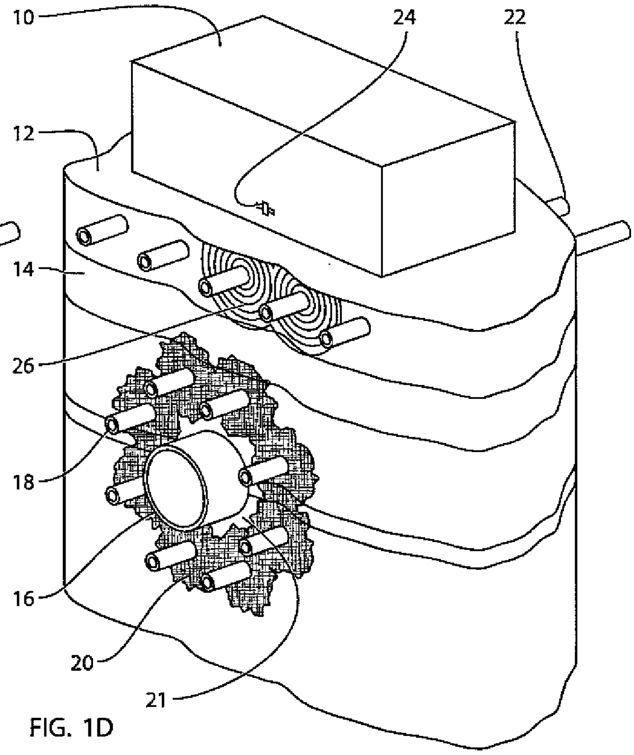


FIG. 1D

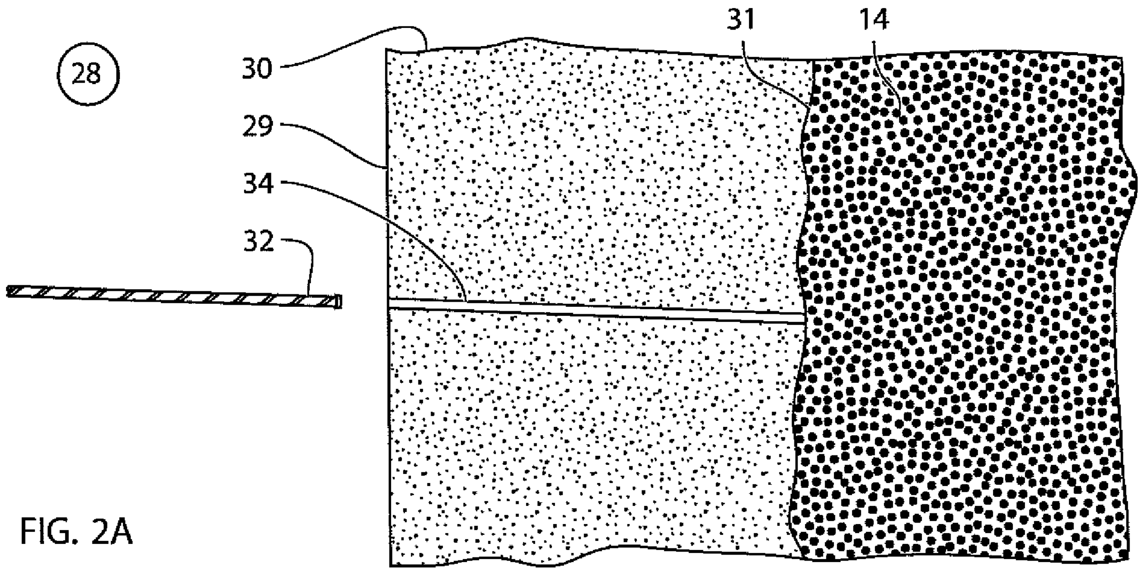


FIG. 2A

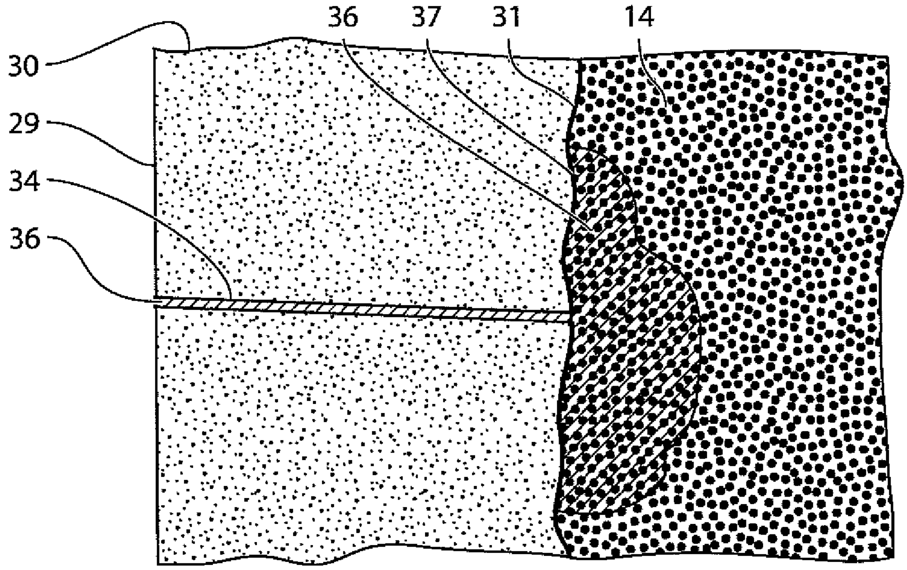


FIG. 2B

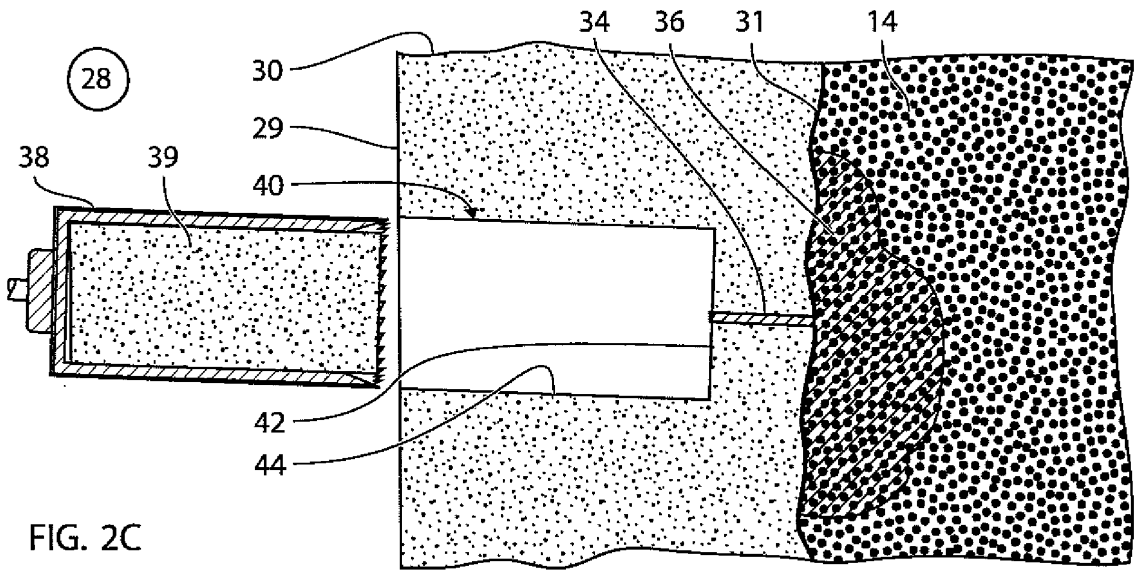


FIG. 2C

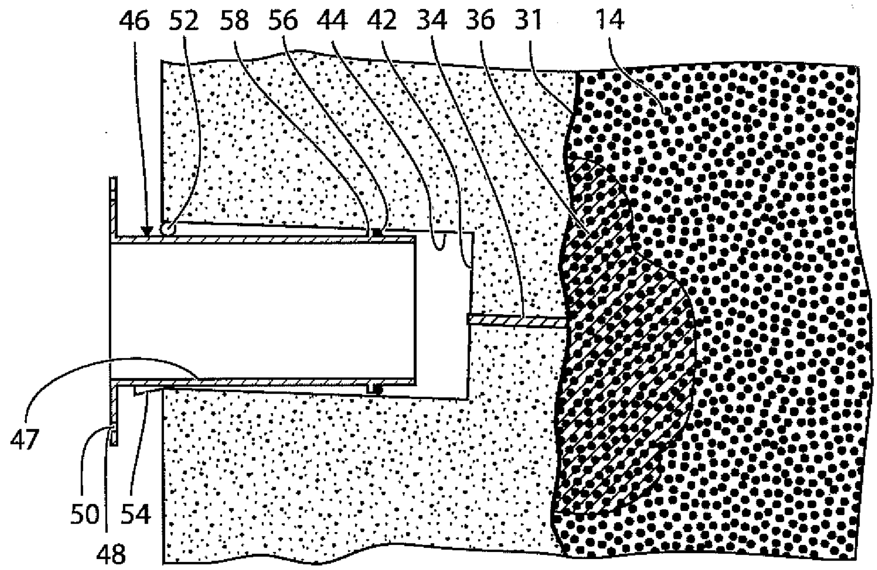


FIG. 2D

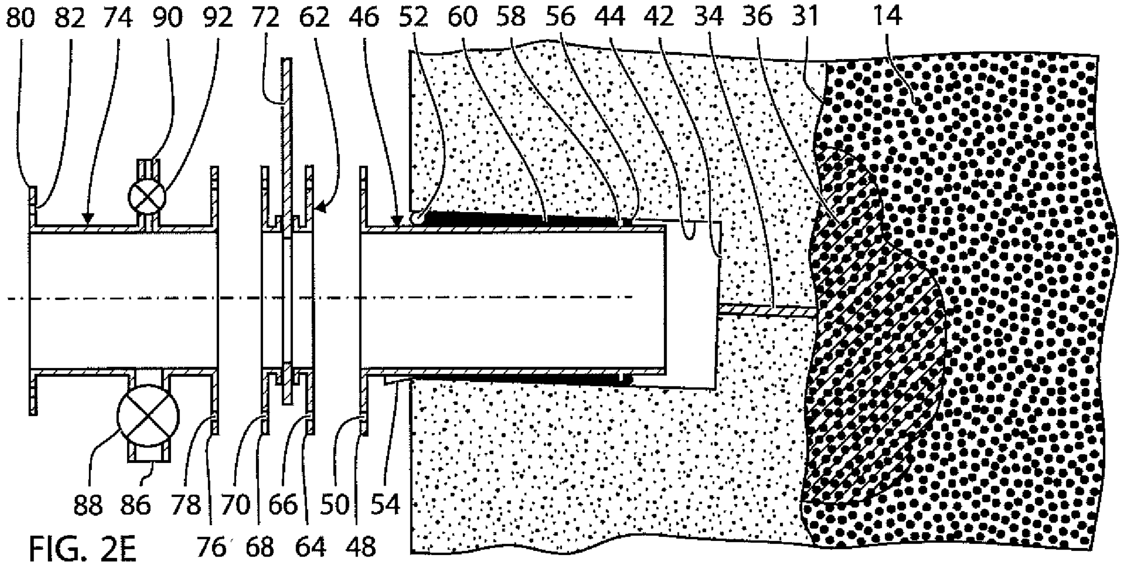


FIG. 2E

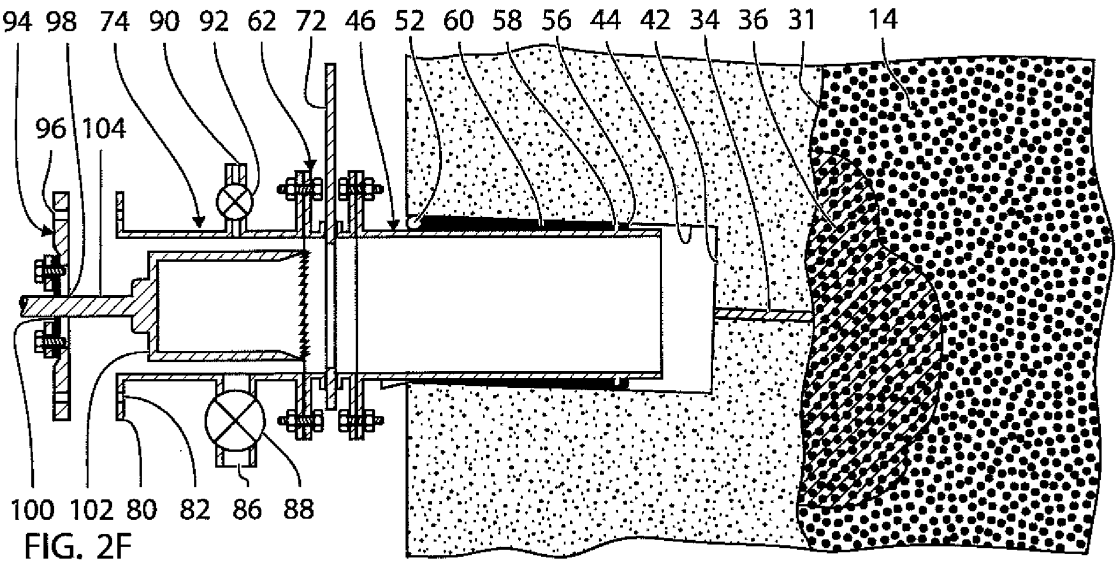
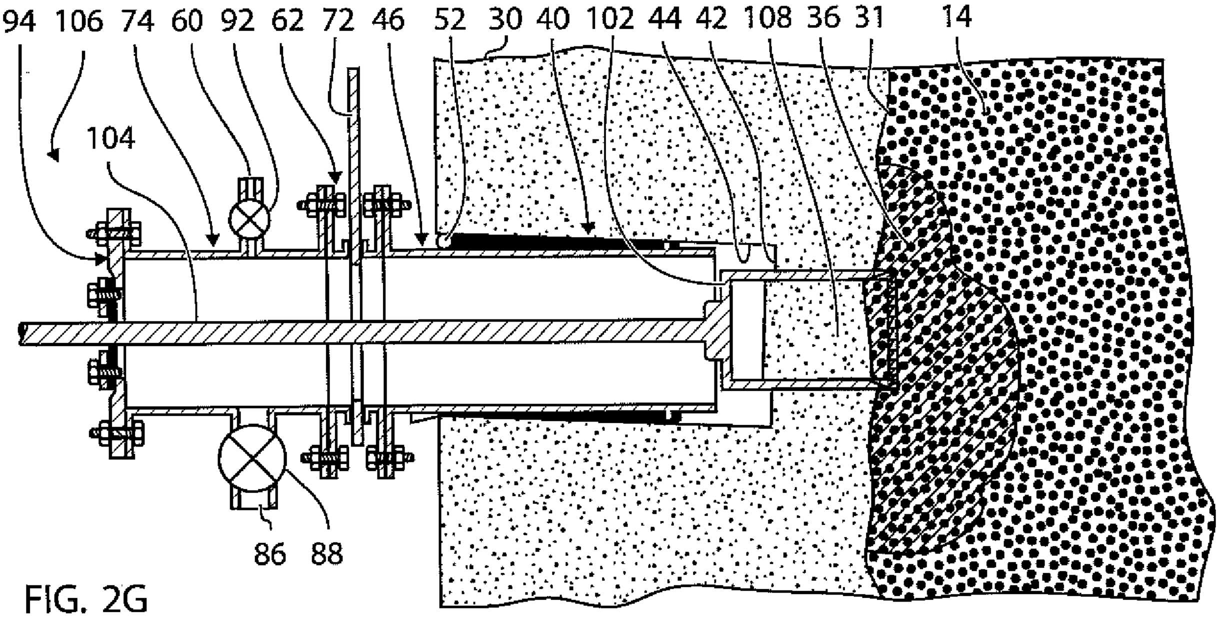


FIG. 2F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86 88

FIG. 2G

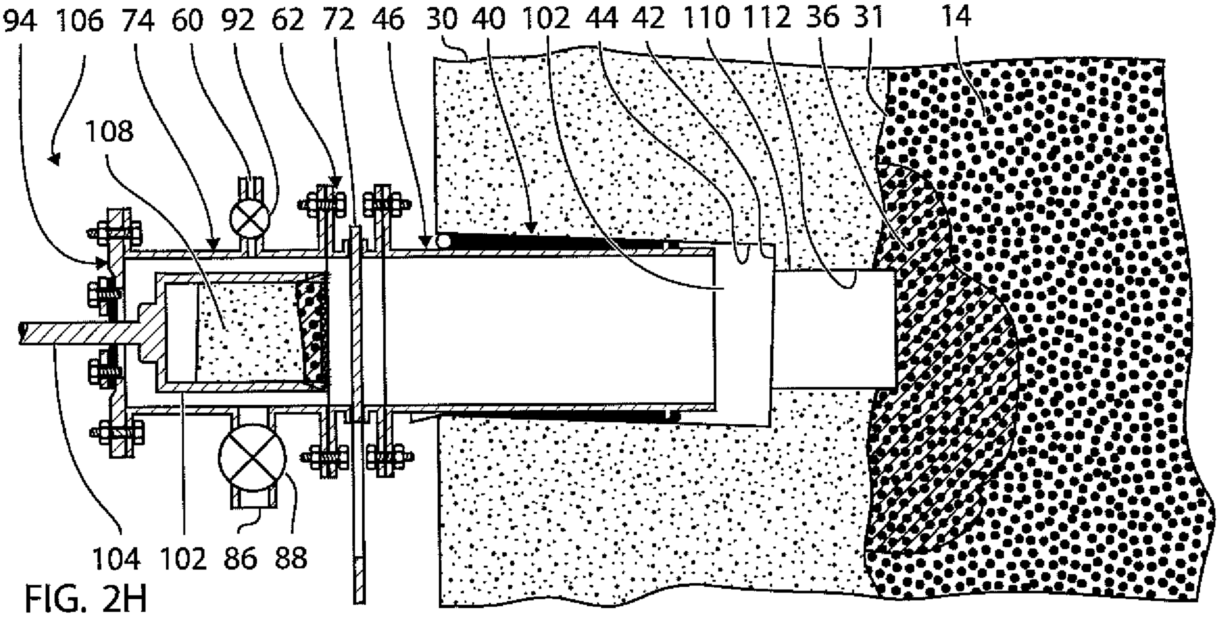
94 106 74 60 92 62 72 46 30 40 102 44 42 110 112 36 31 14
108
104 102 86 88

FIG. 2H

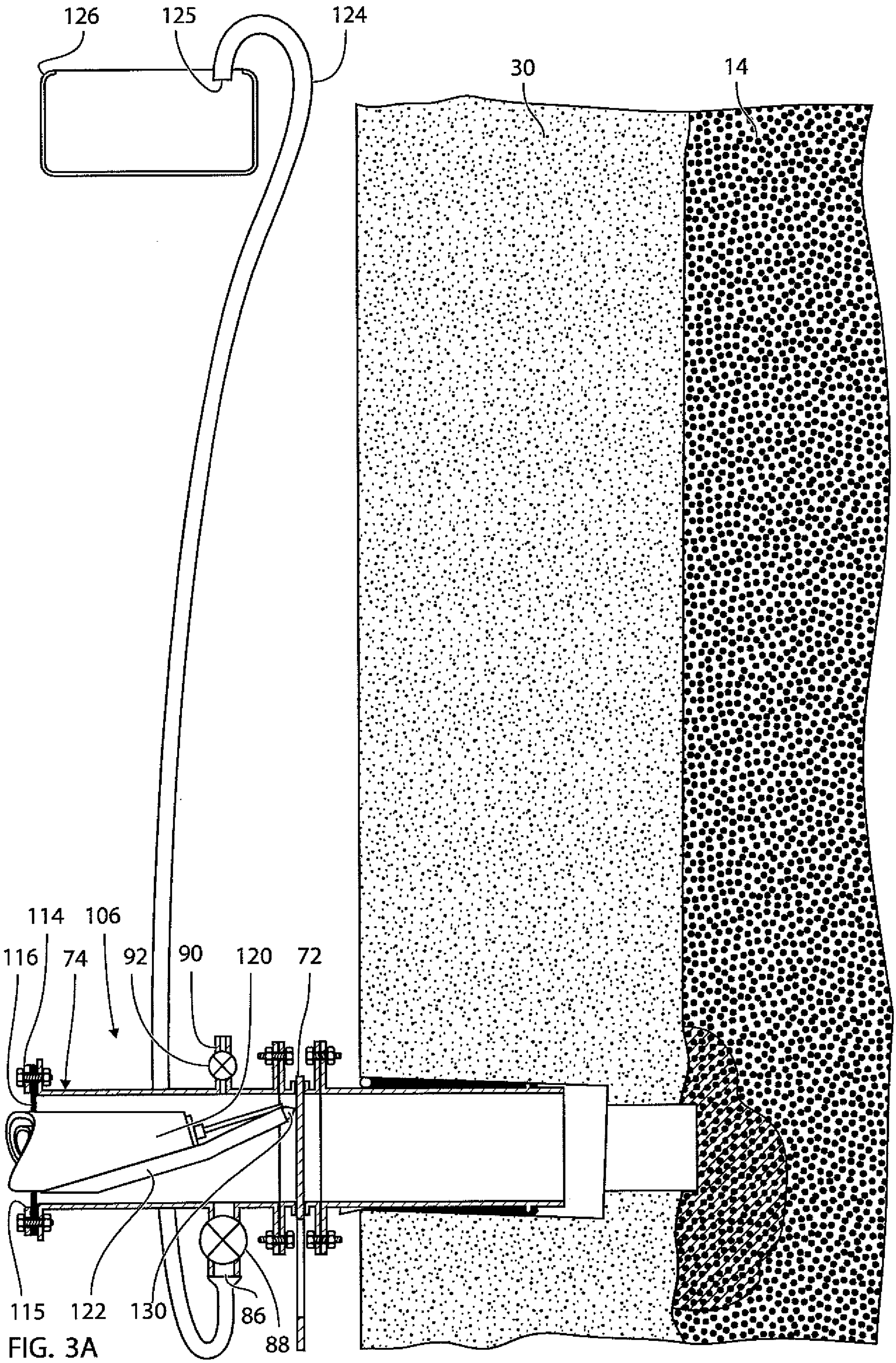

FIG. 3A

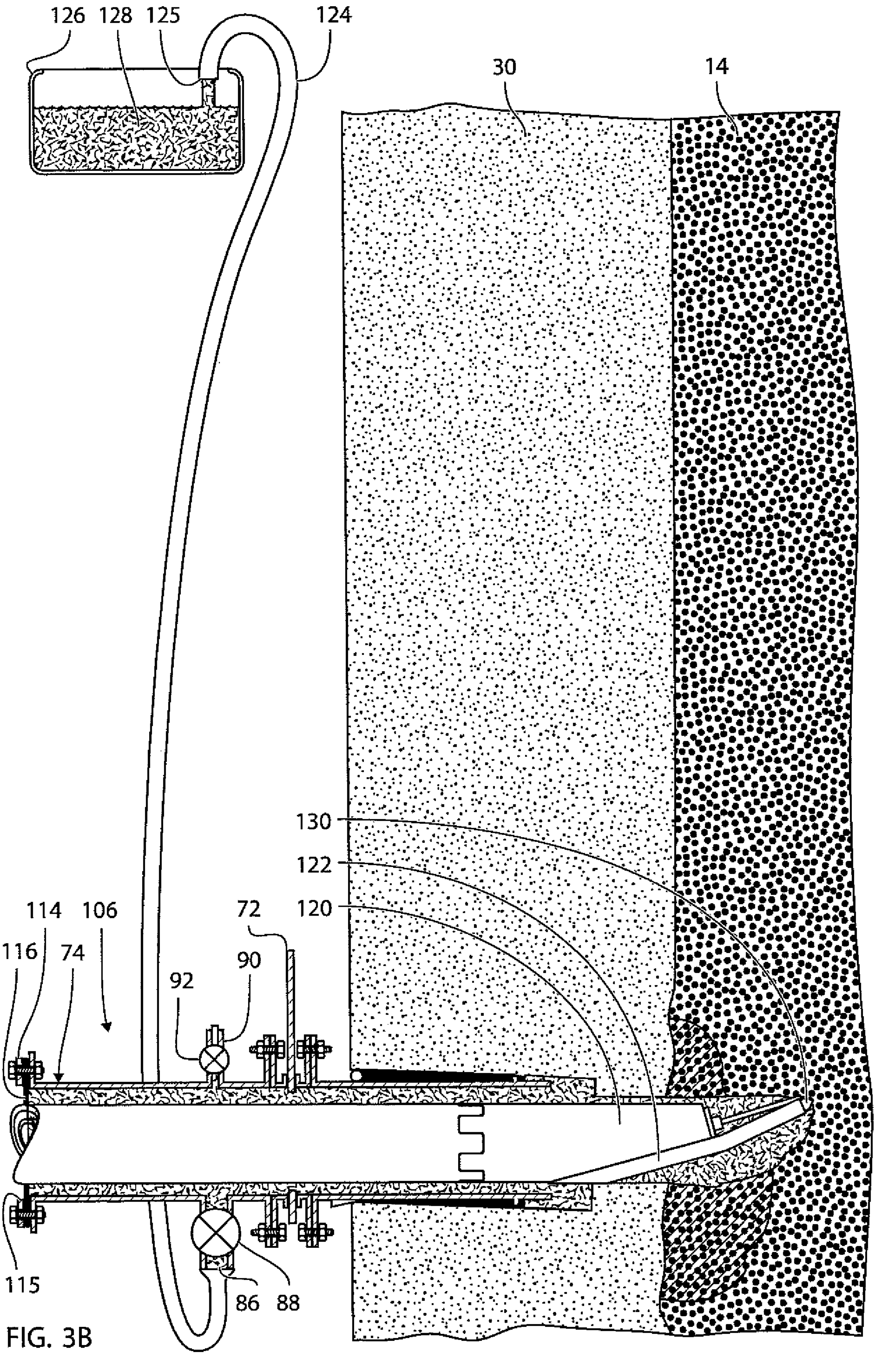

FIG. 3B

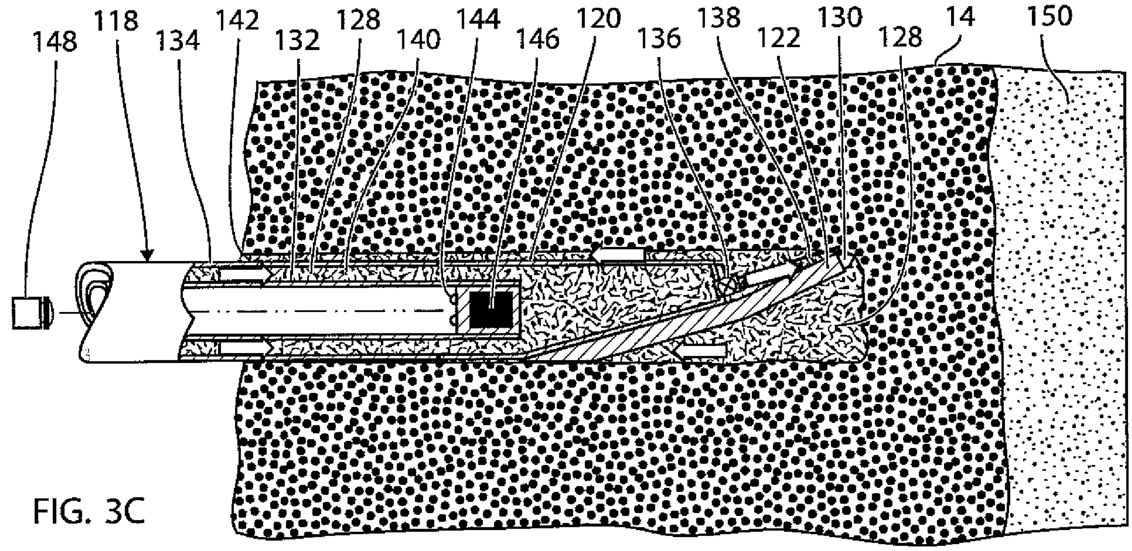

FIG. 3C

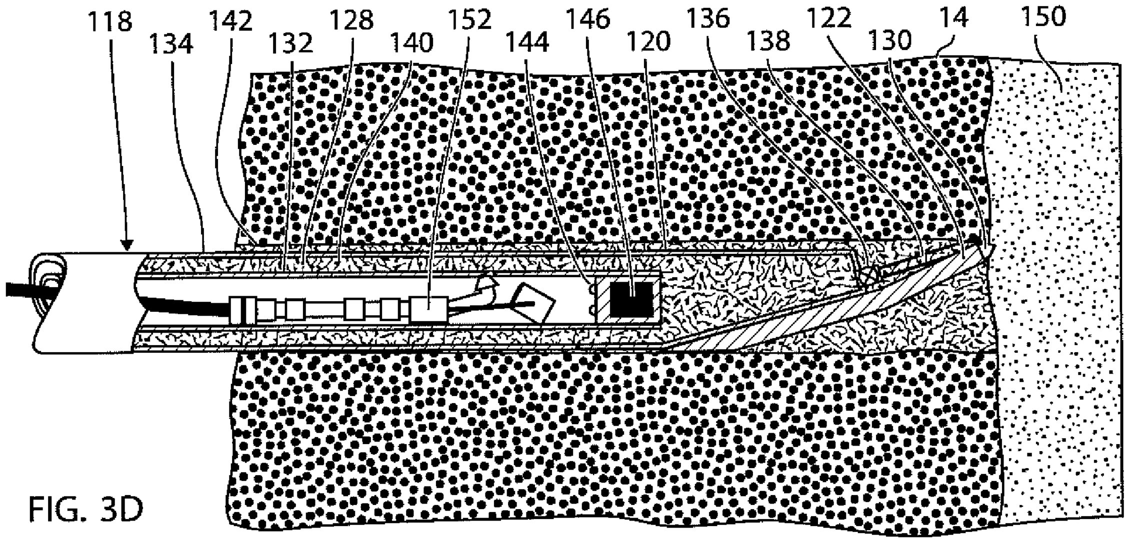

FIG. 3D

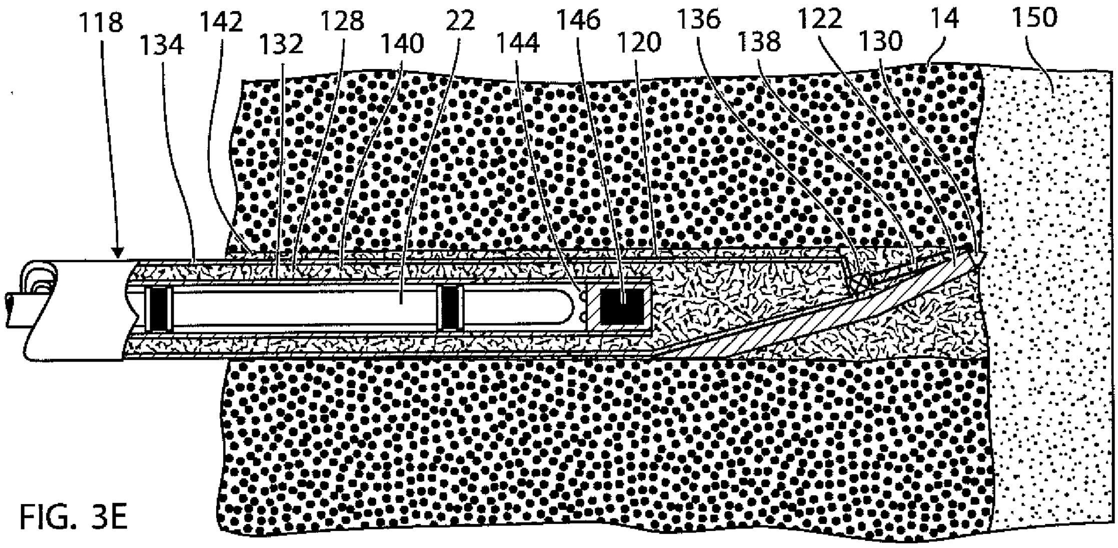

FIG. 3E

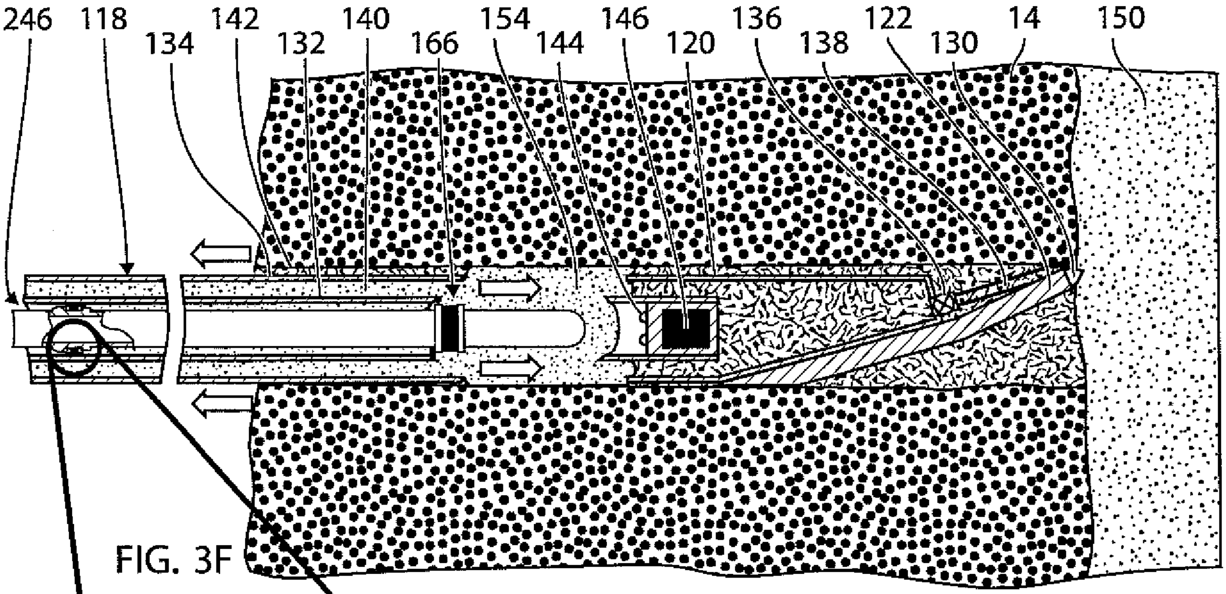
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FIG. 3F

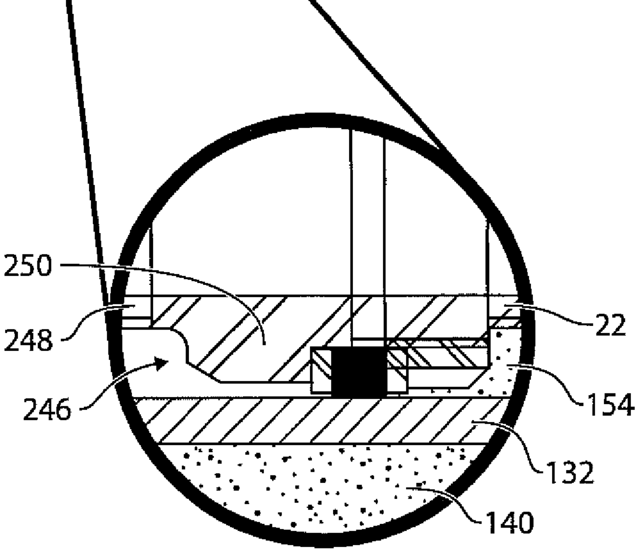
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FIG. 3G

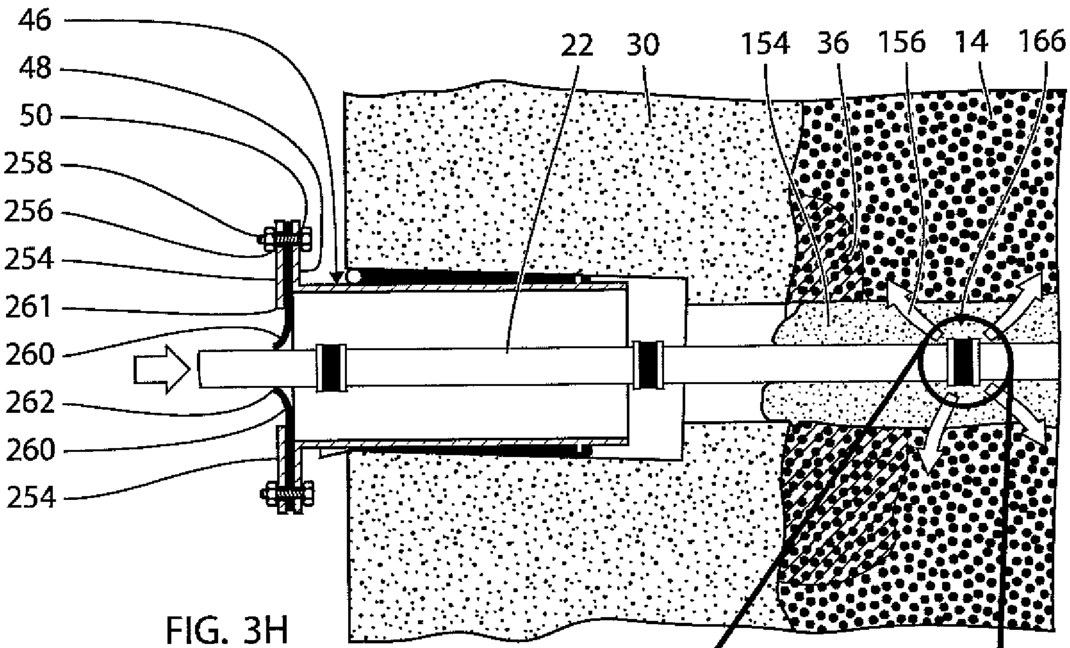
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FIG. 3H

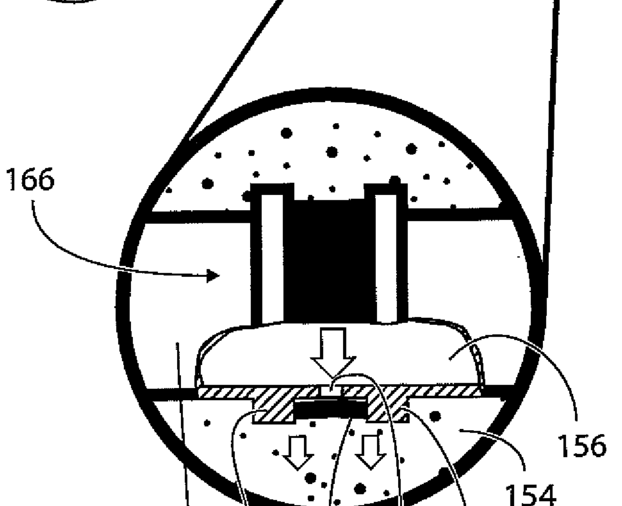
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FIG. 3I

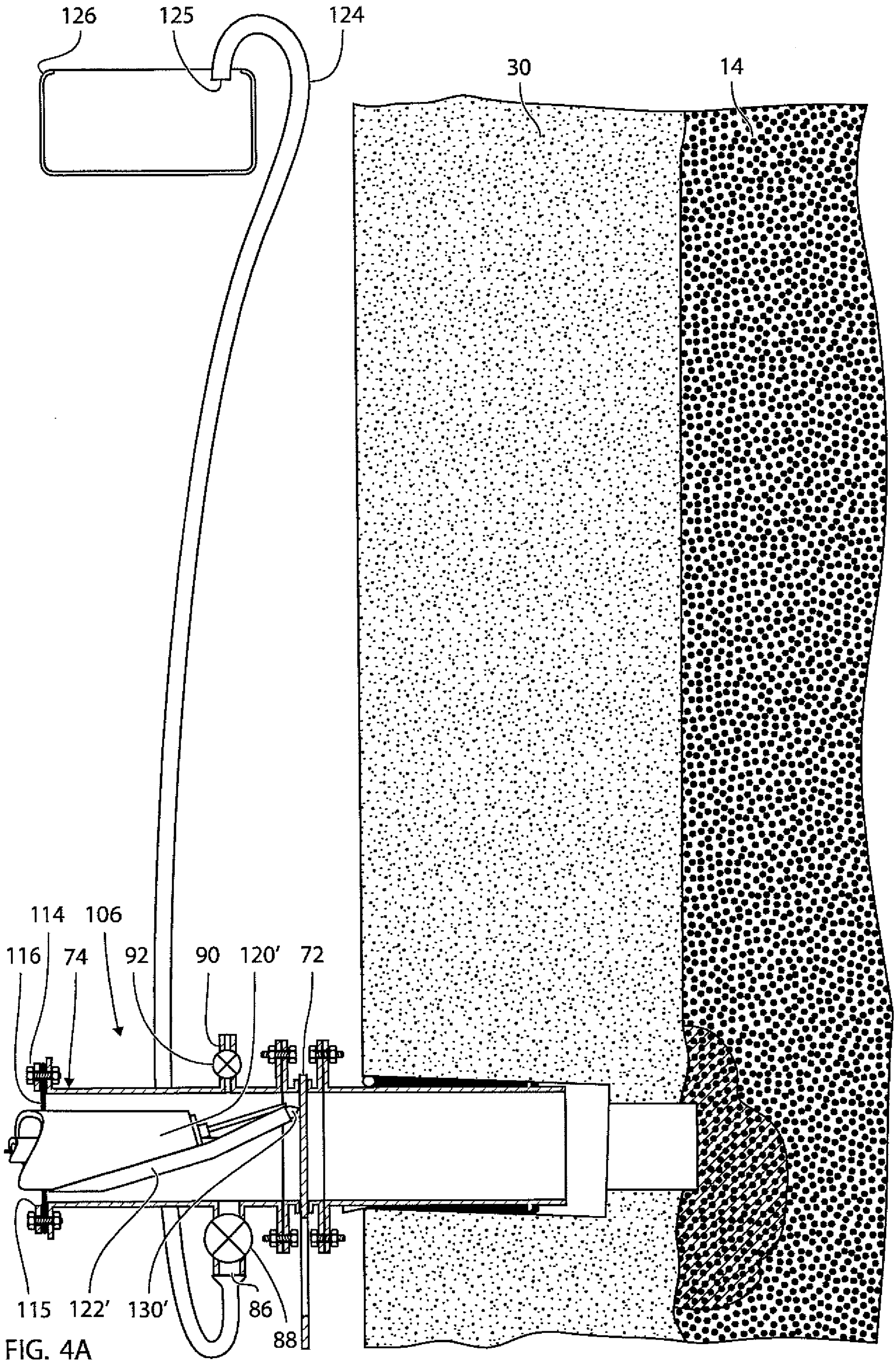

FIG. 4A

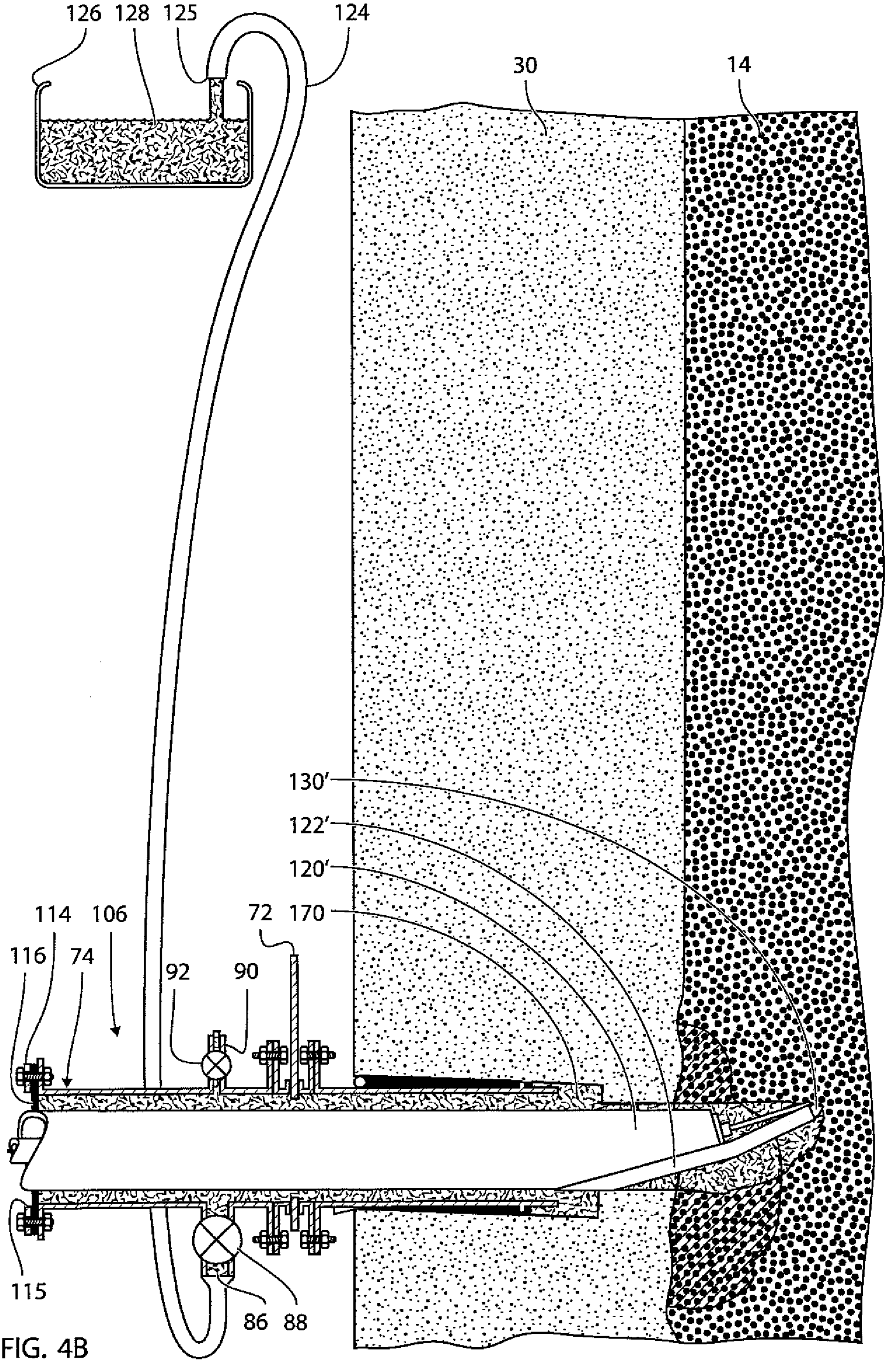
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FIG. 4B

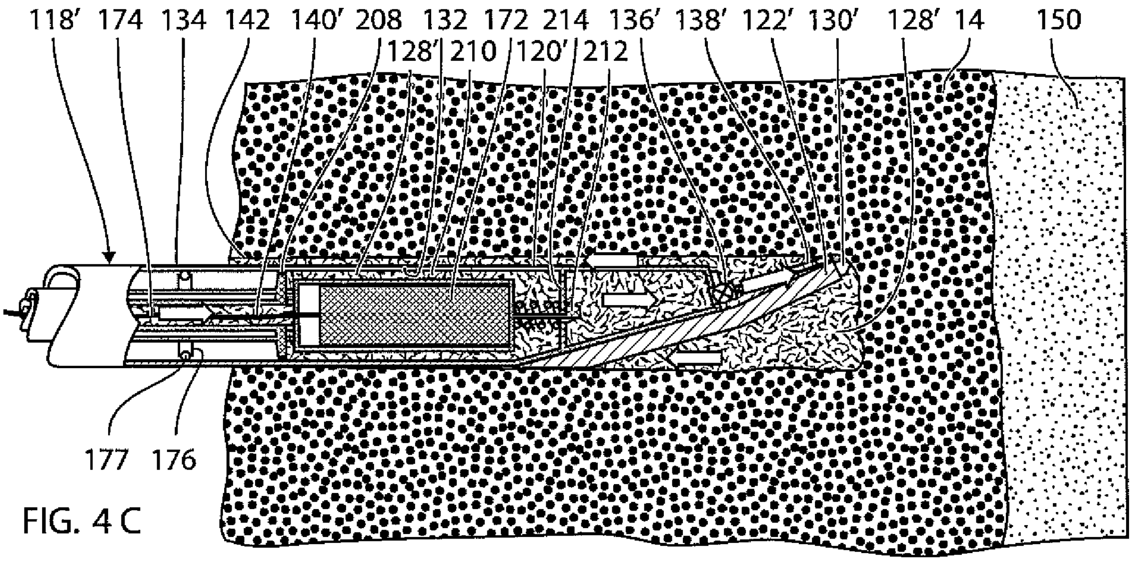

FIG. 4 C

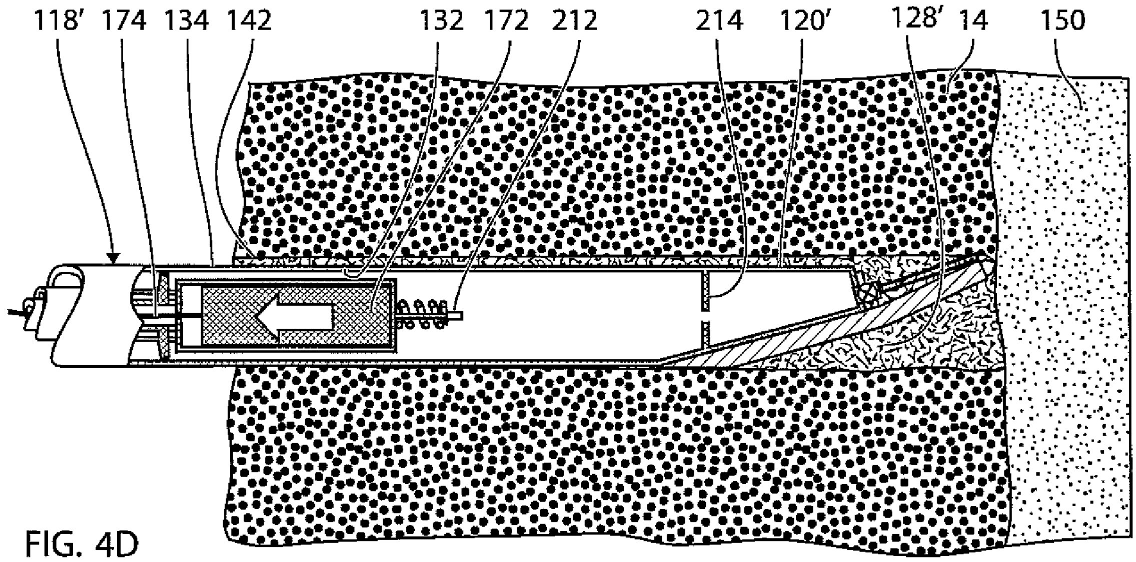

FIG. 4D

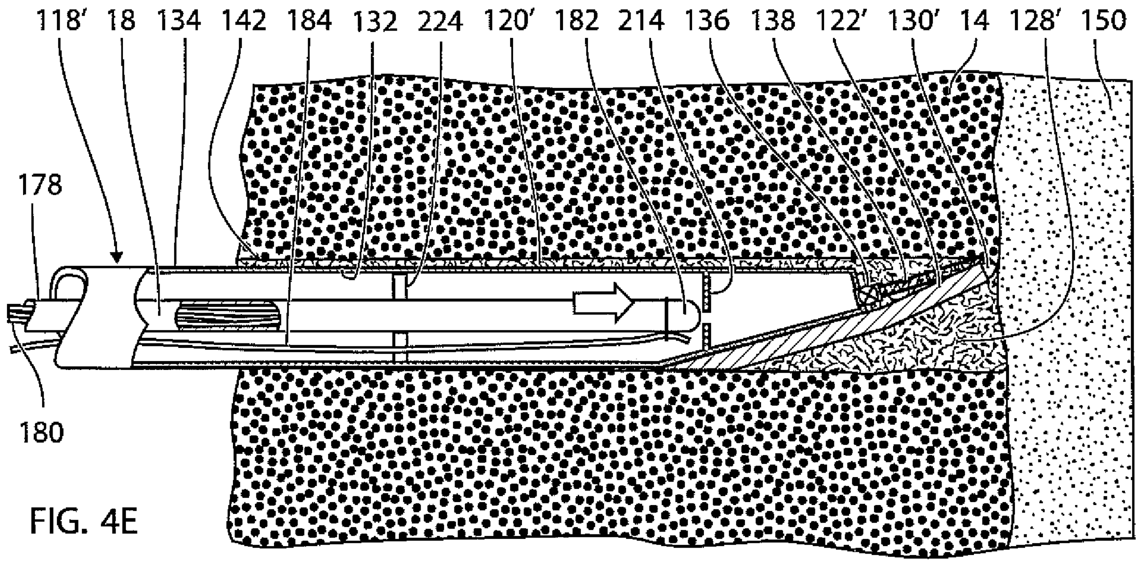

FIG. 4E

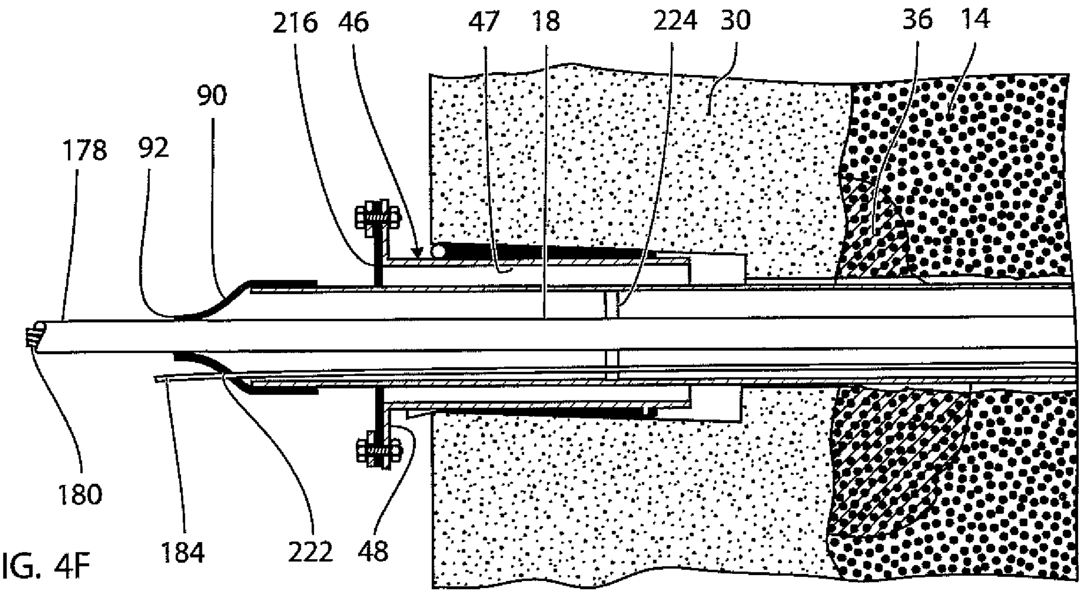

FIG. 4F

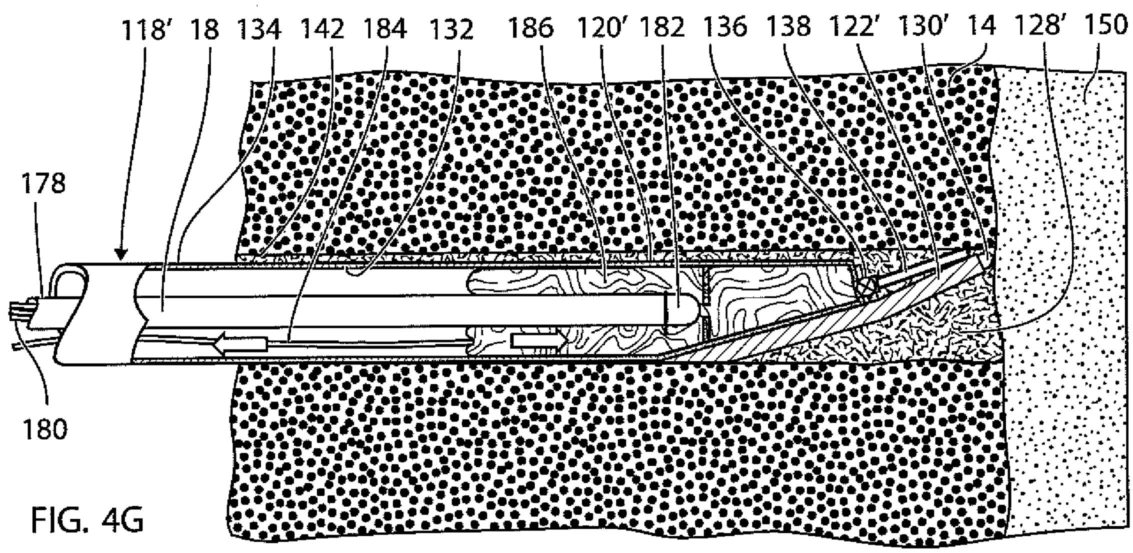

FIG. 4G

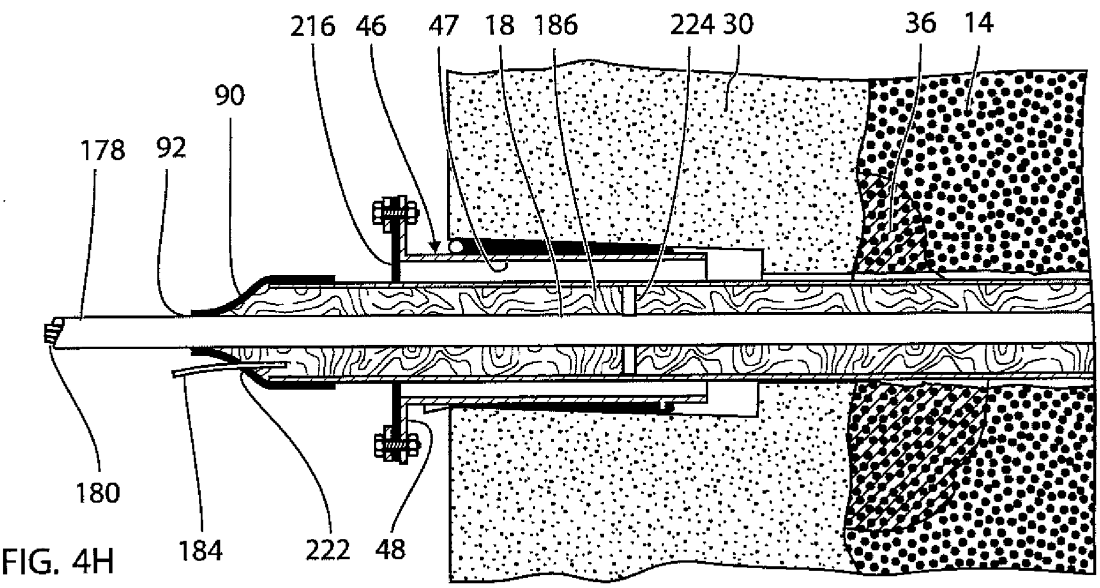

FIG. 4H

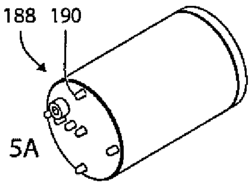

FIG. 5A

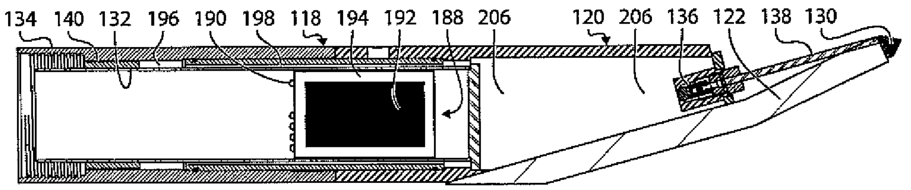

FIG. 5B

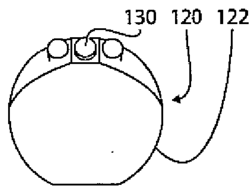

FIG. 5C

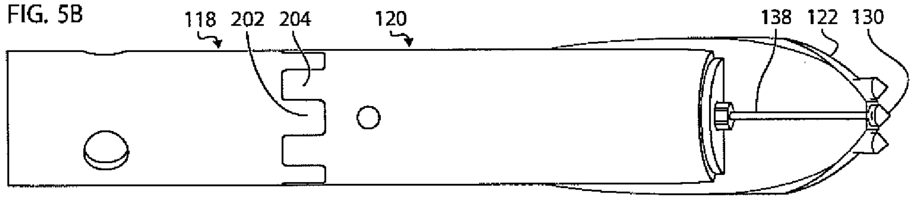

FIG. 5D

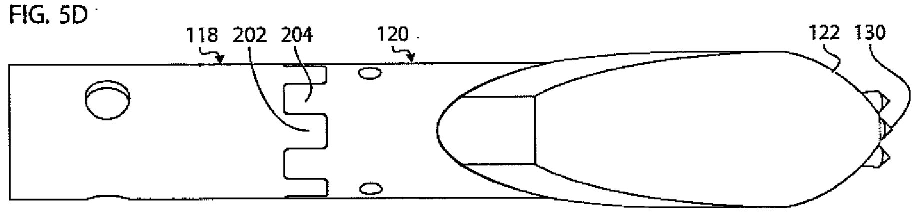

FIG. 5E

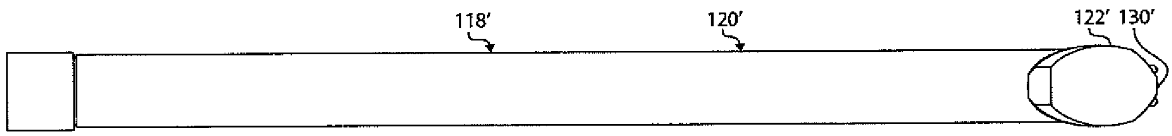

FIG. 6A

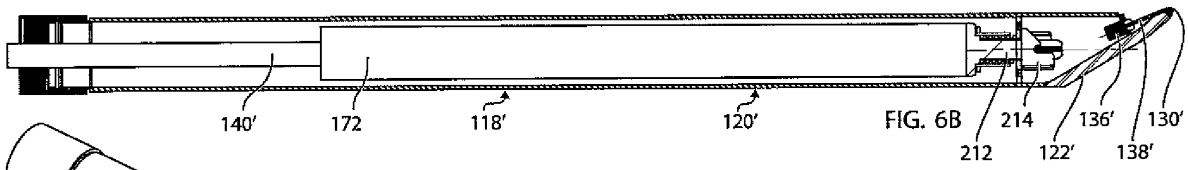

FIG. 6B

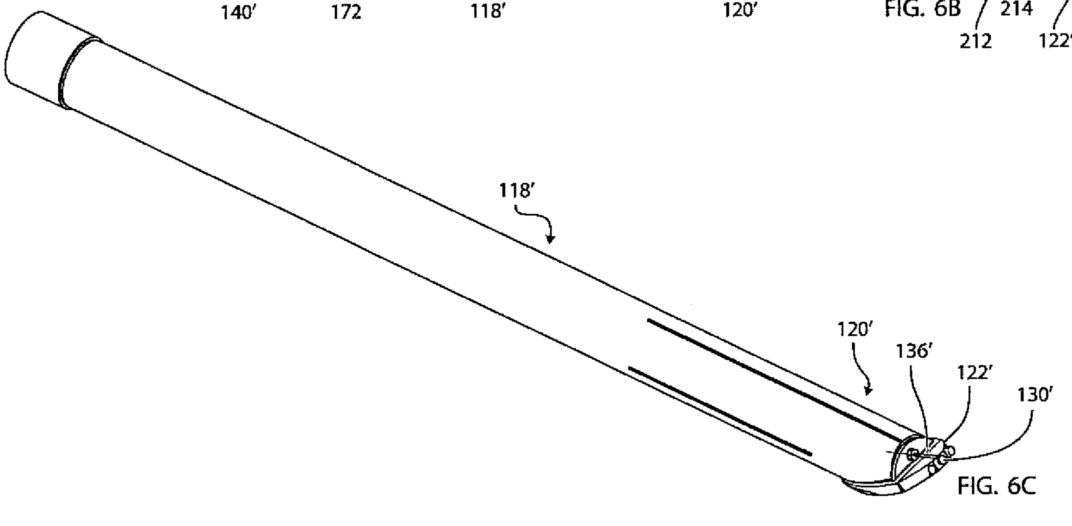

FIG. 6C

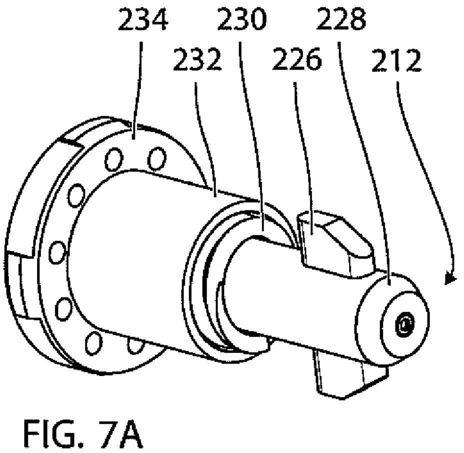

FIG. 7A

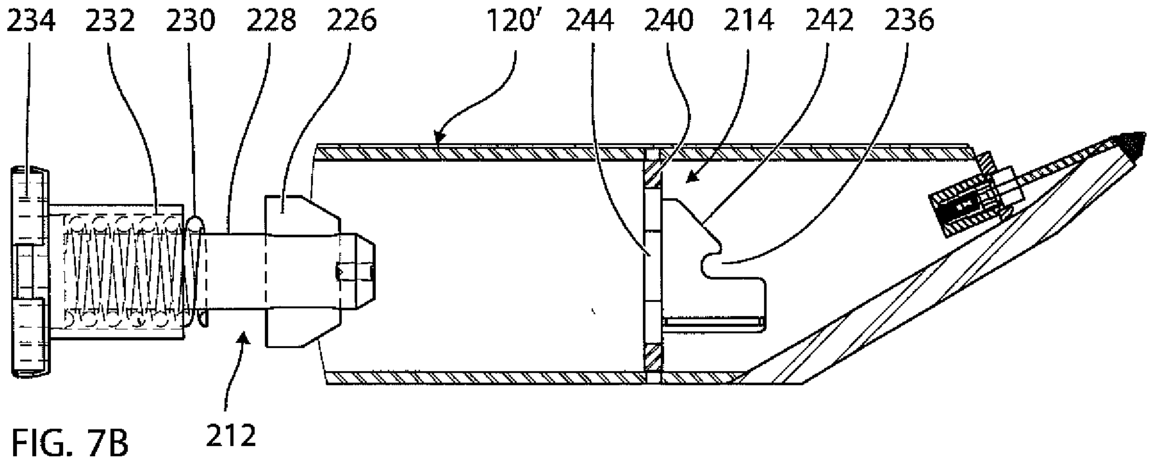

FIG. 7B

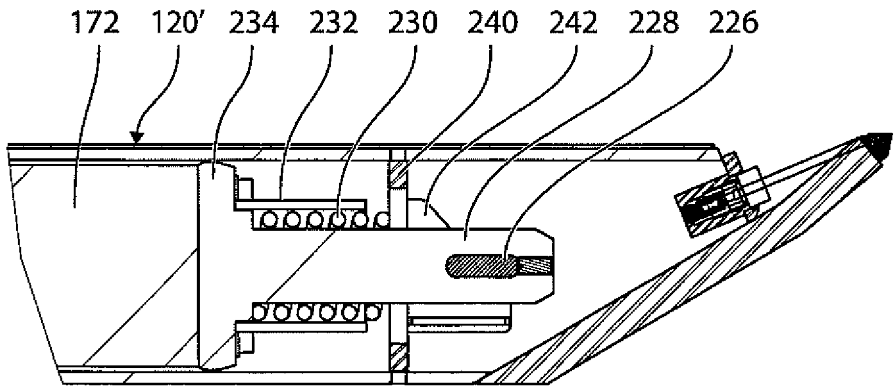

FIG. 7C

REFERENCES CITED IN THE DESCRIPTION

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- EP 0774566 A1 **[0001]**
- EP 1632749 A1 **[0001]**
- WO 0134941 A1 **[0001]**