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(54) **Apparatuses for evaluating soil characteristics.**

(57) An apparatus for monitoring geotechnical, geotechnical and structural, hydrogeological and geophysical parameters of soils, rocks and structures in general, which comprises two or more rigid housing elements, at least one sensor for at least one parameter to be monitored being mounted in at least one of them, which at least two or more rigid housing elements are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable connection element, particularly extensible and flexible, being interposed between each rigid housing element and the one immediately next to it, which sensors communicate with means for collecting output signals from said sensors, which may be mounted in the apparatus or in a separate remote station, comprising means for removably securing the apparatus to the soil to be monitored, consisting of anchor elements adapted to radially expand within the bore hole, and a line for feeding a pressurized fluid for radial expansion of said anchor elements, wherein said deformable connection element has said fluid feeding line stably integrated therein, which feeding line has sealed connections with said rigid housing elements and with the outside and communicates with said anchor elements.

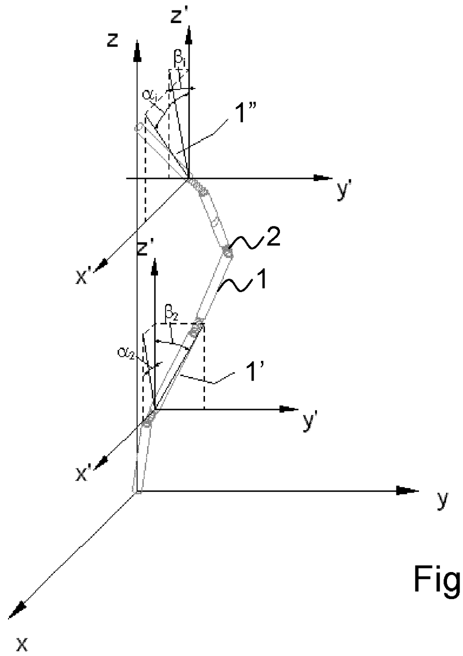

Fig. 1a

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Description

[0001] The present invention relates to an apparatus for monitoring geotechnical, geological and structural, hydrogeological and geophysical parameters of soils, rocks and structures in general,
which comprises two or more rigid housing elements, with at least one sensor for at least one parameter to be monitored being mounted in at least one of them
which at least two or more rigid housing elements are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable connection element being interposed between each rigid housing element and the one immediately next to it,
which sensors communicate with means for collecting output signals from said sensors, which may be mounted in the apparatus or in a separate remote station,
comprising means for removably securing the apparatus to the soil to be monitored, consisting of anchor elements adapted to radially expand within the bore hole, and a line for feeding a pressurized fluid for radial expansion of said anchor elements.

[0002] Such apparatus are known and extensively used for monitoring soils or rocks or structures in general, and are disclosed, for instance, in patents IT0001323688 and IT0001346108 and EP 1,664,486 by the applicant hereof, which are incorporated herein by reference.

[0003] The deformable connection elements include helical spring, which allow the individual rigid housing elements to move with at least one degree of freedom relative to each other, whereby the apparatus is configured as a column that is deformed in response to the movements of the medium to be monitored, in which it is inserted.

[0004] In typical exemplary embodiments, the deformable connection elements may afford two degrees of freedom and hence allow deformations in directions lying on a plane transverse to the longitudinal/axial direction of the succession of rigid housing elements, as the so-called 2D joints, or afford three degrees of freedom and also allow, in addition to the above deformations, deformations in the longitudinal/axial direction of the succession of rigid housing elements, as the so-called 3D joints.

[0005] The selection of either of the 2D and 3D base configurations is made according to the purpose required according to the medium to be monitored and to various technical, economic and construction requirements.

[0006] Namely, for instance for landslide tilt monitoring, which does not require measurement of the changes in the distances between rigid housing elements, but only of deflection between one rigid housing element and the one next to it, a 2D joint should be used, which has a less expensive construction while affording the same effectiveness.

[0007] When both measurements of deflection and monitoring of the distance between successive rigid housing elements are required, e.g. in case of failures due to soil stabilization or in case of underground collapses, or for measuring and dissipating the longitudinally/axially directed deformation component for particular active landslide mechanisms,a 3D joint must be used, which allows measurement of the z axis in addition to the x and y axes, the z axis being defined as the longitudinally/axially directed axis, and the x and y axes being defined as the axes directed transverse to the longitudinal/axial direction, particularly orthogonal to each other and orthogonal to the z axis.

[0008] In a preferred embodiment, the axes may be separated along the azimuthal plane, i.e. the x-y plane, by removably locking the deformable connection element against the soil, the rock or the structure to be monitored.

[0009] As a whole the modules, which consist of rigid housing elements 1 connected together by deformable connection elements 2 and having tilt and strain gage sensors, allows reconstruction of the spatial attitude, in the three x, y, z directions, of the deformations occurring in a medium due to individual and combined deviation, compression and extension actions, as shown in Figure 1a and in Figures 1b, 1c and 1d, which show a projection on the x-y axis, a projection on the z-x axis and a projection on the z-y axis respectively.

[0010] Geometrical assessments can be related to a second module 1' or a general i^{th} module 1".

[0011] Referring to a vertical zero-condition, the deformation components in the three directions, related to the i^{th} module 1" are:

$$x_i = z_i \cdot tg\alpha_i$$

$$y_i = z_i \cdot tg\beta_i$$

$$z_i = \frac{l + l_{mi}}{\sqrt{1 + tg^2\alpha_i + tg^2\beta_i}}$$

where l: length of each module;
l_{mi}: length of the spring for the i^{th} module 1",
α . angle detected by the instrument between the vertical and the projection of the module in the x-z plane,
β . angle detected by the instrument between the vertical and the projection of the module in the y-z plane.

[0012] The resultant for the displacement of the i^{th} module 1" on the horizontal plane is:

$$r_i = \sqrt{x_i^2 + y_i^2} \ ,$$

whereas the vertical component of the deformed profile of a column composed of n modules is:

$$z_n = \sum_{i=1}^{n} z_i$$

[0013] Likewise, the two horizontal components of such deformed profile may be defined, as:

$$x_n = \sum_{i=1}^{n} x_i$$

$$y_n = \sum_{i=1}^{n} y_i$$

[0014] Particularly, prior art 3D joints allow controlled elongation of a mechanical limit stop, which is needed to preserve the function of the apparatus with time; they allow deflection in the azimuthal plane above 90°, thereby maintaining high tensile strength values; they prevent any relative rotation between the rigid housing elements, which is a basic requirement for ensuring consistent sensor measurements in the different rigid housing elements, by preventing rotations between reference coordinate axes; they are hollow and impervious to external fluids.

[0015] It is also known to use anchor elements as mentioned above, comprising an expandable outer surface such that, when the anchor element is fed with a pressurized fluid, said outer surface radially expands and engages with the walls of the bore hole, thereby locking the apparatus.

[0016] The pressurized fluid is fed to the anchor elements using a conduit, particularly a single continuous conduit, extending in each anchor element, parallel to the axis thereof, and having one or more radially directed apertures for communication with the cavity between the two walls.

[0017] At the deformable connection elements, the conduit may be formed by a portion of flexible tube, particularly spiraled with a smaller radius than the helical springs, to be able to accommodate spring deformations with no possible interference therewith.

[0018] The use of a flexible hose has the drawback of exposing the anchor element feeding line to wear, with the risk of failure and leakage of the pressurized liquid, and consequent damages and malfunctioning.

[0019] The present invention has the object of obviating such drawbacks using an apparatus as described hereinbefore, wherein said deformable connection element has said fluid feeding line stably integrated therein, which feeding line has sealed connections with said rigid housing elements and with the outside and communicates with said anchor elements.

[0020] Thus, the pressurized fluid to be fed may be conveyed to the anchor elements arranged over the length of the succession of rigid housing elements without requiring special pipes at the deformable connection elements, the feeding line being stably integrated in the structure of the deformable connection elements.

[0021] In a further exemplary embodiment, the feeding line comprises conduits and chambers integrated in said deformable connection element, particularly formed in the walls of the tubular or rod-like elements that form the deformable connection element itself.

[0022] In a preferred embodiment, the deformable connection element comprises a connecting portion that is deformable in the longitudinal/axial direction of said succession of rigid housing elements and a connecting portion that is deformable in one or more directions transverse to said longitudinal/axial direction, which longitudinally/axially deformable connecting portion comprises a first element that is stably associated with a rigid housing element and a second element that is stably associated with said transversely deformable connecting portion or with a further rigid housing element, said first element having a smaller diameter than the second element and being adapted to freely and sealably slide therein, and the fluid feeding conduits being interrupted by a variable-volume distribution chamber, whose volume changes in response to the axial displacement of both elements, a first conduit being formed in the first element, which first element is sealably guided in an end bushing of said distribution chamber, and which first conduit opens therein, a second conduit being provided, which extends from said distribution chamber to said anchor element.

[0023] Due to the provision of a first element stably associated with a rigid housing element, and a second element stably associated with said deformable portion or with a further rigid housing element, which two elements are engaged with each other while being displaceable in the axial/longitudinal direction of the apparatus or of at least one of the two housing elements, between two limit stop positions corresponding to a maximum spaced-apart distance and to a minimum approach distance of said two housing elements, the longitudinal/axial deformation of the deformable portion is allowed.

[0024] The provision of a variable-volume distribution chamber ensures the continuity of the feeding line, without preventing deformation of the deformable portion in the longitudinal/axial direction and without requiring special pipes. Furthermore, this chamber will act as a small plenum for distribution of the pressurized fluid, compensating for pressure losses generated by the feeding conduits along the joints, i.e. the connection elements.

[0025] Furthermore, in prior art apparatus are only provided at the rigid housing elements.

[0026] This will inevitably lead to an operational limitation in all those cases in which the restraints with the bore holes should be located elsewhere from the rigid housing elements.

[0027] Therefore, the present invention has the further object of obviating this drawback, by providing an apparatus as described hereinbefore, which further comprises at least one anchor element located at least at one deformable connection element and/or located at least at one rigid housing element.

[0028] Thus, anchor elements may be either arranged both at the rigid housing elements and at the deformable connection elements, or only at the rigid housing elements or at the deformable connection elements.

[0029] In one exemplary embodiment, said deformable connection element comprises a portion that is deformable in the longitudinal/axial direction of said succession of rigid housing elements and a portion that is deformable in one or more directions transverse to said longitudinal/axial direction, said at least one anchor element being located at said portion that is deformable in one or more directions transverse to said longitudinal/axial direction.

[0030] Thus, the radial expansion of the anchor elements may occur both at the rigid housing elements and at the portion that is deformable in one or more directions transverse to the longitudinal/axial direction, but does not concern the portion that is deformable in the longitudinal/axial direction, so that the deformation thereof and the associated measurements are not affected thereby.

[0031] In yet another embodiment, at least one anchor element located at a rigid housing element comprises means for preventing or restricting the radial expansion of the anchor element.

[0032] These means may be, for instance, a rigid pipe section or reinforcement collars or strips placed around the anchor elements to prevent radial expansion thereof.

[0033] This peculiar feature affords important advantages during installation of a pre-assembled apparatus, whenever special restraints are required at significant layers.

[0034] Moreover, in prior art apparatus, the apparatus may directly lie in the soil without being supported by covering pipes, as it acts itself as a support element for the pre-bored hole which provides a stronger support than the PVC and aluminum pipes that are typically used as covers in geognostic surveys.

[0035] The radial expansion of anchor elements both creates an integral constraint with the various layers, which is required to measure any change in their thickness with time, e.g. caused by compression, like in the case of vertical failure, or decompression, like in the case of tunneling, and also allows effective restoration of the natural groundwater separation, if any.

[0036] The expansion of the various anchor elements allows the bore hole to be completely closed, for differential monitoring of neutral stresses with time over the entire length of the hole to be monitored.

[0037] The expansion of these anchor elements also helps to create a strong coupling between the rigid housing elements and the soil, which is particularly useful for tilt, acceleration or seismic measurements.

[0038] Likewise, in the boring technology, injection of packers is known, both in the oil sector and in soil stabilization, when actions have to be well targeted to various levels.

[0039] Nevertheless, the packers for boring or for geophysical uses are not suitable for the type of confinement required for long line distributions.

[0040] The increase of the diameter of the expandable pipe is typically obtained by sliding a sleeve relative to a central pipe, thereby exerting both a radial and an axial action, the latter being applied along the measurement axis, in the longitudinal/axial direction, which would be incompatible with the required measurement.

[0041] The only action that should be exerted by an anchor for a longitudinally/axially directed monitoring system is a radial effort against the walls of the bore hole; therefore, a simple thick tubular member, e.g. made of rubber or vulcanized rubber, might expand due to an increase in internal pressure, as compared with outer pressure.

[0042] This system, when used individually, with direct observation of expansion by a skilled operator is known and effective.

[0043] In real applications, in case of long chains of elements in contact with soils of different consistencies (e.g. with alternate layers or resistant and very soft materials) or when groundwater is present, multiple elasticity-based anchor systems do not adequately ensure success.

[0044] In practice, different resistances of soils and different external pressures due by the piezometric gradient might cause excessive expansion of certain anchor elements as compared with others, and might lead to bursts or poor expansion; therefore, the need arises for a device for controlling the expansion of the anchor elements.

[0045] The present invention has the object of obviating the above drawbacks, and provides an apparatus as described above, which further comprises means for restricting the radial expansion of said anchor elements, so that said radial expansion is prevented beyond a predetermined limit value.

[0046] These means have the advantage of setting a limit to radial expansion of anchor elements, that cannot be exceeded as pressurized fluid is being fed to the anchor elements.

[0047] According to an exemplary embodiment, said radial expansion restricting means comprise a retention member made of a relatively inelastic material, which is placed around said outer surface, particularly a tubular cable braid.

[0048] In yet another exemplary embodiment, said retention member is surrounded by a tubular elastic element, so that, as the pressure of the pressurized feed-fluid in said anchor element decreases, said tubular elastic element stresses said retention element and said outer surface of the anchor element toward the interior of the anchor element.

[0049] Furthermore, in prior art apparatus a problem is still to be solved about the position of strain gage sensors, especially during assembly, which involves an increased risk of distorted measurements, or even structural failure.

[0050] The present invention obviates the above drawbacks by an apparatus as described hereinbefore, which further comprises a strain gage composed of a stationary part and a control rod that is movable relative thereto, the stationary part being stably connected to a rigid housing element and the control rod being connected to a further rigid housing element or a deformable connection element, means being provided for automatically centering and connecting said control rod to said further rigid housing element or said deformable connection element so that said control rod is allowed to move relative to the deformable connection element or the rigid housing element between the two limit stop positions corresponding to those of the deformable connection element.

[0051] In a preferred embodiment, said centering and connection means include a magnet located at said further rigid housing element or said deformable connection element, the end of the control rod being adapted to engage with said further rigid housing element or with said deformable connection element made of ferromagnetic material.

[0052] Furthermore, in prior art apparatus, electric cables are often used in the deformable connection element for connection of the various rigid housing elements, which cables have a predetermined excess length to accommodate any deformation.

[0053] These cables are often in spiral form, to accommodate any deformation.

[0054] This involves the drawback of exposing electric cables to wear and failures, and consequently breaking the electric contact.

[0055] The present invention has the further object of obviating this drawback, by providing an apparatus as described hereinbefore, in which said deformable connection element allows deformation in the longitudinal/axial direction of said succession of rigid housing elements, telescopic electric connections being provided in said deformable connection element.

[0056] In a further embodiment, said telescopic electric connections consist of microtubes, which are composed of at least one female element made of a highly conductive material and at least one male element made of a highly conductive material, wherein the inside diameter of the female element is adapted to tightly and slideably receive the male element, whose outside diameter substantially fits therewith, to provide an electric wiping contact.

[0057] Telescopic electric connections have the advantage of having small space requirements, of facilitating the connection between the rigid housing element and the deformable connection element and of perfectly accommodating extension.

[0058] Furthermore, in the typical configuration of these apparatus that allow repetitive linking of rigid housing elements and deformable connection elements, electric connection occurs semiautomatically, by only looking for an external reference line during assembly.

[0059] Furthermore, in prior art apparatus, the deformable connection element part that can be deformed in the longitudinal/axial direction is maintained in a neutral reference position for strain gage measurements by two opposed springs, a first tension-operating spring and a second compression-operating spring.

[0060] The use of two springs may be burdensome both in terms of costs and in terms of installation and maintenance.

[0061] The two springs have dimensions that require a predetermined working space, also due to the impossibility of entirely compressing them, which would cause structural failure thereof.

[0062] The present invention also has the object of obviating these drawbacks, by an apparatus as described hereinbefore, in which said deformable connection element comprises a portion that is deformable in the longitudinal/axial direction of said succession of rigid housing elements and a portion that is deformable in one or more directions transverse to said longitudinal/axial direction, which longitudinally/axially deformable portion comprises a single spring operable by tension and compression to define a neutral reference position for strain-gage measurements.

[0063] In a further exemplary embodiment, said spring is a helical spring composed of three different sections having turns with different diameters, the diameter of said turns being smaller in a first end section, intermediate in an intermediate section and greater in the other end section.

[0064] This novel feature is very important, as it allows size reduction and easy spring replacement in case of changes of the neutral reference position, with the possibility of favoring the compression or extension stroke of the lengthening element, by mounting springs of various lengths and strengths.

[0065] The above objects, for which various solutions have been proposed, as described and claimed herein, may be addressed either individually or in combination, whereby the special technical solutions may be implemented either in combination with one or more of the other technical solutions for fulfilling one or more of the other intended objects, or separately, in an apparatus as described hereinbefore, i.e. as defined in the preamble of the main claim.

[0066] These and other features and advantages of the invention will be more apparent from the following description of a few embodiments shown in the accompanying drawings, in which:

Figs. 1a, 1b, 1c and 1d show geometrically schematic views of the apparatus of the present invention;
Figs. 2a, 2b and 2c are schematic views of the ap-

paratus in three different operating steps;

Figs. 3a, 3b and 3c show an intermediate section of the apparatus;

Figs. 4a and 4b show an end section of the apparatus;

Figs. 5a and 5b show a starting section of the apparatus;

Fig. 6a shows an intermediate section composed of two rigid housing elements coupled together by a deformable connection element;

Figs. 6b and 6c show different views of an intermediate section of the apparatus;

Fig. 6d shows a detail of the tilt sensor in a direction transverse to the longitudinal/axial direction;

Figs. 7a, 7b, 7c and 7d show further different views of an intermediate section of the apparatus;

Figs. 8a, 8b, 8c, 8d show different possible configurations of the apparatus;

Fig. 9 shows an exemplary embodiment of means for preventing or restricting the radial expansion of an anchor element.

Figs. 2a, 2b and 2c show the apparatus in three different operating steps.

[0067] The special detailed construction of the apparatus of the present invention is disclosed in IT0001323688 and IT0001346108 and EP 1,664,586, which is incorporated herein in all the common unchanged features of technical principles of the present invention, as described below in greater detail. Certain common features will be also expressly disclosed herein, for better understanding thereof.

[0068] The apparatus comprises a plurality of rigid housing elements 1 containing sensors for monitoring one or more parameters.

[0069] The rigid housing elements 1 are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable connection element 2 being interposed between each rigid housing element 1 and the one immediately next to it.

[0070] The sensors communicate with means for collecting output signals, which may be mounted in the apparatus or in a separate remote station.

[0071] Means are further provided for removably securing the apparatus to the soil to be monitored, consisting of anchor elements 3 adapted to radially expand within the bore hole 4, and a line for feeding a pressurized fluid for radial expansion of said anchor elements.

[0072] In a first operating step, as shown in Figure 2a, the apparatus is introduced into the bore hole 4; then, as shown in Figure 2b, the apparatus receives a pressurized feed fluid, for feeding the anchor elements 3, each of the latter comprising an expandable outer surface such that, when the anchor element 3 is fed with the pressurized fluid, the outer surface radially expands and engages with the walls of the bore hole 4, thereby locking the apparatus; finally, as schematically shown in Figure 2c, deformations of the apparatus with time are monitored, which deformations correspond to deformations of the bore hole 4 in which the apparatus is inserted, and hence to those of the soil in which the bore hole 4 has been formed.

[0073] Figures 3a, 3b and 3c show an intermediate section of the apparatus, with reference to the succession of rigid housing elements as shown in Figures 2a, 2b and 2c.

[0074] Figure 3a is a general view that clearly shows the rigid housing element 1 surrounded by the anchor element 3.

[0075] The top portion contains the sensors and is designed to be introduced into a further rigid housing element 1.

[0076] This is clearly shown in Figure 6a, in which the two rigid housing elements 1 are coupled by a deformable connection element 2.

[0077] Figure 3b is a sectional view that shows the entire deformable connection element 2, which comprises a portion that is deformable in the longitudinal/axial direction 20 of said succession of rigid housing elements and a portion that is deformable in one or more directions transverse to said longitudinal/axial direction 21.

[0078] The deformable connection element 2 is shown in greater detail in Figure 3c.

[0079] Figure 4a shows an end section of the apparatus, with reference to the succession of rigid housing elements as shown in Figures 2a, 2b and 2c.

[0080] Figure 4b is a cross sectional view of a detail of the deformable connection device 1, particularly related to the section of Figure 4a, but substantially identical to what is shown in Figures 3b and 3c.

[0081] The deformable connection element 2 has the fluid feeding line stably integrated therein, which feeding line has sealed connections with said rigid housing elements 1 and with the outside and communicates with the anchor elements 3.

[0082] The feeding line comprises conduits and chambers integrated in the deformable connection element 2, particularly formed in the walls of the tubular or rod-like elements that form the deformable connection element 2 itself.

[0083] Particularly, the longitudinally/axially deformable portion 20 comprises a first element 22 that is stably associated with a rigid housing element 1 and a second 23 element that is stably associated with said transversely deformable portion.

[0084] The first element 22 has a smaller diameter than the second element 23 and is free to slide therein.

[0085] The fluid feeding conduits are interrupted by a variable-volume distribution chamber 24, whose volume changes in response to the axial displacement of both elements, a first conduit 220 being formed in the first element 22, which first element 22 is sealably guided in an end bushing 240 of said distribution chamber 24, and which first conduit 22 opens therein, and a second conduit which extends from said distribution chamber 24 to said anchor element 3.

[0086] The first element 22 is adapted to slide in the second element 23 and the distribution chamber 24 between two end positions, due to a limit stop element 25 operating in both ways of the longitudinal/axial direction.

[0087] The end of the first conduit 220 that does not open into the distribution chamber 24, not shown, is in such position as to open into a further conduit or hole 222 formed in the wall of an additional rigid housing element 1, which may be coupled to the first element 22, and which further conduit or hole 222 communicates with the anchor element 3 located on such additional rigid housing element 1, as clearly shown in Figure 6c.

[0088] Such other end of the first conduit 22 may be also threaded, for attachment of a pressure sensor.

[0089] In the distribution chamber 24, the fluid is retained by seals that allow the first element 22 to slide in the distribution chamber 24, and hence allow the deformable connection element 2 to move in the longitudinal/axial direction.

[0090] Figures 5a and 5b show a starting section of the device, with the injection hole 7 for injection of the pressurized fluid into the apparatus being well visible.

[0091] The construction of the connection element 2 as shown in the above figures allows various connecting combinations of the rigid housing elements, according to the monitoring apparatus and the medium to be monitored, as shown in Figures 8a, 8b, 8c and 8d.

[0092] In Figures 8a, 8b, 8c and 8d, the apparatus is divided into functional structural elements as described above, which may be arranged in different sequences.

[0093] Figure 8a shows a first possible configuration, in which the deformable connection element 2 is composed of a first element 22, a distribution chamber 24, a portion deformable in one or more directions transverse to said longitudinal/axial direction 21, a further distribution chamber 24, and a further first element 22, in this order.

[0094] Each of the first elements 22 is coupled to a rigid housing element 1.

[0095] In this case, the portion deformable in one or more directions transverse to said longitudinal/axial direction 21 consists of a double reinforced elastic tubular member.

[0096] This configuration is suitable for automatic connection of rigid housing elements when important relative movements are expected, with a simple position constraint, particularly one for each combination comprising a rigid housing element 1 and a deformable connection element 2, and is preferred for apparatus whose length exceeds 20 meters, in cohesive deposits and rock, with low permeation or with no groundwater.

[0097] In the second configuration, as shown in Figure 8b, the order of the components of the deformable connection element is the same, but the construction of the portion deformable in one or more directions transverse to said longitudinal/axial direction 21 changes, as it consists of an elastic tubular member with an anchor element 3 attached thereto.

[0098] This configuration may be used for automatic connection of rigid housing elements 1 when large relative movements are expected, or in case of stratified soils that require a double position constraint, particularly two constraints per combination comprising a rigid housing element 1 and a deformable connection element 2 in yielding soils.

[0099] Figure 8c shows the third configuration, in which the deformable connection element 2 is composed of a first element 22, a portion deformable in one or more directions transverse to said longitudinal/axial direction 21, a distribution chamber 24, and a further first element 22, in this order.

[0100] Once again, the portion deformable in one or more directions transverse to said longitudinal/axial direction 21 consists of a double reinforced elastic tubular member.

[0101] This configuration can be used for automatic connection of rigid housing elements 1 when minor relative movements are expected, with a simple position constraint, particularly one constraint for each combination comprising a rigid housing element 1 and a deformable connection element 2 in medium consistency soils and/or with groundwater.

[0102] In the fourth configuration, as shown in Figure 8d, the sequence of the components is the same as in the configuration of Figure 8c, except that the portion deformable in one or more directions transverse to said longitudinal/axial direction 21 consists of a simple reinforced elastic tubular member, and that the an anchor element 3 also covers such elastic tubular member.

[0103] This configuration can be used for connections with an expandable overlay with position adjustable to a maximum surface of about 80% of the total surface, when minor relative movements are expected, and with simple position constraints, but extending in thin stratified low-to-medium consistency soils and/or with one or more groundwaters.

[0104] Figure 8b also shows an embodiment of the inventive apparatus, which comprises at least one anchor element 3 located at least at one deformable connection element 2.

[0105] The anchor elements 3 may be either arranged both at the rigid housing elements 1 and at the deformable connection elements 2, or only at the rigid housing elements 1 or at the deformable connection elements 2.

[0106] Particularly, the anchor element 3 is located at the portion deformable in one or more directions transverse to said longitudinal/axial direction 21.

[0107] Tilt sensors are also provided in a direction transverse to the longitudinal/axial direction, whose position is shown, for instance, in Figure 7b, and which are illustrated in greater detail in Figure 6d.

[0108] Figures 7a to 7d also show two pressure sensors 11, one of which is connected to the first conduit 220 for sensing the pressure of the anchor element 3, and the other is connected to an additional separate conduit, not shown, which is in contact with the outside for measuring, for instance, the groundwater pressure.

[0109] Means may be provided for preventing or restricting the radial expansion of an anchor element 3 at a rigid housing element 1.

[0110] These means, not shown, may be for instance a rigid pipe section or reinforcement collars or strips placed around the anchor elements 3 to prevent radial expansion thereof.

[0111] The present invention further relates to an apparatus as described above, which further comprises means for restricting the radial expansion of said anchor elements, so that said radial expansion is prevented beyond a predetermined limit value, which means comprise a retention member made of a relatively inelastic material, which is placed around said outer surface, particularly a tubular cable braid.

[0112] The anchor element has an expandable outer surface consisting of a coaxial tubular member which directly contacts the rigid housing element, and is made of a high-density elastomeric material, such as neoprene or 68-polyurethane, having excellent elasticity and wear-resistance properties.

[0113] For this purpose natural rubber, synthetic rubber or another elastic material of suitable thickness may be also used.

[0114] Such expandable outer surface expands with the increase of the internal pressure and is restored to the initial configuration when the internal pressure is decreased again.

[0115] The housing for the tubular braid, which is a seamless continuous high-resistance cable, is external to this expandable tubular member.

[0116] High-resistance cables may be of any type and the tubular braid may be formed by a circular knitting machine, to create a knotless elastic net 5, as shown in Figure 9, that can expand and evenly distribute pressure over the entire free surface.

[0117] The tubular braid is further surrounded by a tubular elastic element, so that, as the pressure of the pressurized feed-fluid in said anchor element decreases, the tubular elastic element stresses said retention element and the outer surface of the anchor element toward the interior of the anchor element.

[0118] Therefore, the expandable portion of the anchor element is composed of at least 3 layers, with the elastic element being alternated to the three-dimensional tubular braid of high-resistance cables.

[0119] This construction can restrict the maximum free-way expansion and withstand, under maximum expansion conditions, significant pressure increase values, at least 4-5 times higher than free-way burst pressure.

[0120] As mentioned above, the elastic tubular member has the purpose of stressing the reinforcing braid toward the inner elastic tubular member, thereby generating an evenly reacting assembly of layers, that can retain, protect and restore the original position of the tubular reinforcement by releasing the pressure of the feed fluid.

[0121] The three layers are locked at their ends to one another and to the rigid housing element by the compression of a cylindrical bushing that causes a significant diameter reduction at the ends and is coupled to the rigid housing element by special grooves formed on the body of the rigid housing element, to prevent any lateral sliding displacement during radial expansion.

[0122] As the tubular member is inflated, the diameter progressively expands due to the elasticity of the elastomer, while its thickness is reduced, until the tubular reinforcement braid is tensioned, and effectively restricts expansion.

[0123] The fast pressure increase can be detected by a pressure gage and may confirm expansion of all anchor elements and their firm grip.

[0124] Under these conditions, the anchor elements exert a pressure along the walls of the bore hole and adapt thereto, while generating a containing action required not only for stabilization of the tilt and strain gage measurement system but also for separation of any groundwaters, to allow effective measurement of interstitial pressures and/or other parameters.

[0125] The anchor element is constantly monitored by a series of pressure sensors.

[0126] Long-term maintenance of the inflation pressure may be also obtained by direct connection to an external bottle, equipped with a regulator and/or by a compressor.

[0127] The anchoring effect may be removed by simply releasing the pressure in the anchor elements, thereby restoring the initial diameter conditions; as the external tubular elastic member shrinks, the tubular braid can contract, and the system may be removed from the soil.

[0128] The extraction of the apparatus from the soil is also facilitated by rhythmic expansion of the anchor elements, in combination with tensioning, which expansion may be also enhanced by pressures exceeding the operating pressures of the system, due to the reinforcement with which each anchor element is equipped.

[0129] The present invention also relates to an apparatus comprising a strain gage 6, as shown for instance in Figure 3b.

[0130] Such strain gage 6 is composed of a stationary part and a control rod that can be displaced relative to it, the stationary part being stably connected to a rigid housing element 1 and the control rod being connected to a further rigid housing element or a deformable connection element.

[0131] Means are further provided for automatically centering and connecting the control rod to the further rigid housing element 1 or the deformable connection element 2 so that the control rod is allowed to move relative to the deformable connection element 2 or the rigid housing element between the two limit stop positions corresponding to those of the deformable connection element.

[0132] In a preferred embodiment, the centering and connection means include a magnet 8, as shown for instance in Figure 3c, which is located at the further rigid housing element or the deformable connection element, the end of the control rod being adapted to engage with the further rigid housing element 1 or with the deformable connection element 2 made of ferromagnetic material.

[0133] In a preferred configuration, one or more strain gages are mounted in line to the support of the boards and the tilt meters, for perfect centralization of the drive rod and miniaturization of the detection system.

[0134] The drive rod of the strain gage, of preset length, is connected at the sensor end by an m/f joint and contains a ferromagnetic element at the other end, thereby automatically coupling to a magnet 8 accommodated at the center of the support containing the microtubes of the telescopic extensible electric connection 9.

[0135] This can afford a size reduction and ensure easy mounting, according to the degree of mechanical freedom and the position of the sensor.

[0136] The magnet 8 may be mounted in both head and tail positions to the portion of deformable connection element that deforms in one or more directions transverse to the longitudinal/axial direction, for relative and absolute measurements respectively, including any elongation or compression due to the movement in such section.

[0137] In the latter case, a longer connecting rod is provided which also extends through the portion of the deformable connection element that deforms in one or more directions transverse to the longitudinal/axial direction.

[0138] The present invention also relates to an apparatus having telescopic electric connections 9 in the deformable connection element 2.

[0139] Such telescopic electric connections 9 consist of microtubes, which are composed of at least one female element made of a highly conductive material and at least one male element made of a highly conductive material, in which the inside diameter of the female element is adapted to tightly and slideably receive the male element, whose outside diameter substantially fits therewith, to provide an electric wiping contact.

[0140] The telescopic electric connections are shown, for instance, in Figures 7a, 7b, 7c and 7d.

[0141] Figure 6b also shows the contact holder 90 comprising the female elements.

[0142] Such microtubes are preferably made of copper or brass.

[0143] The present invention further relates to an apparatus in which the portion that is deformable in the longitudinal/axial direction 20 comprises a single spring 27, which is clearly shown, for instance, in Figure 4b, operable both by tension and by compression to define a neutral reference position for strain gage measurements.

[0144] The spring 27 is a helical spring composed of three different sections having turns with different diameters, the diameter of the turns being smaller in a first end section, intermediate in an intermediate section and greater in the other end section.

[0145] The spring is held in position by respective ring nuts operating on the diameter change, to ensure proper fixation thereof for compression and tension movements respectively.

Claims

1. An apparatus for monitoring geotechnical, geological and structural, hydrogeological and geophysical parameters of soils, rocks and structures in general, which comprises two or more rigid housing elements, with at least one sensor for at least one parameter to be monitored being mounted in at least one of them
which at least two or more rigid housing elements are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable, particularly extensible and flexible connection element being interposed between each rigid housing element and the one immediately next to it, which sensors communicate with means for collecting output signals from said sensors, which may be mounted in the device or in a separate remote station,
comprising means for removably securing the device to the soil to be monitored, consisting of anchor elements adapted to radially expand within the borehole, and a line for feeding a pressurized fluid for radial expansion of said anchor elements
characterized in that
said deformable connection element has said fluid feeding line stably integrated therein, which feeding line has sealed connections with said rigid housing elements and with the outside and communicates with said anchor elements.

2. An apparatus as claimed in claim 1, **characterized in that** said feeding line comprises conduits and chambers integrated in said deformable connection element, particularly formed in the walls of the tubular or rod-like elements that form the deformable connection element itself.

3. An apparatus as claimed in claim 1 or 2, **characterized in that** said deformable connection element comprises a portion that is deformable in the longitudinal/axial direction of said succession of rigid housing elements and a portion that is deformable in one or more directions transverse to said longitudinal/axial direction, which longitudinally/axially deformable portion comprises a first element that is stably associated with a rigid housing element and a second element that is stably associated with said transversely deformable portion or with a further rigid housing element, said first element having a smaller diameter than the second element and being adapted to freely slide therein, and the fluid feeding conduits being interrupted by a variable-volume distribution chamber, whose volume changes in response

to the axial displacement of both elements, a first conduit being formed in the first element, which first element is sealably guided in an end bushing of said distribution chamber, and which first conduit opens therein, and a second conduit which extends from said distribution chamber to said anchor element.

4. An apparatus for monitoring geotechnical, geological and structural, hydrogeological and geophysical parameters of soils, rocks and structures in general, which comprises two or more rigid housing elements, with at least one sensor for at least one parameter to be monitored being mounted in at least one of them
which at least two or more rigid housing elements are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable, connection element being interposed between each rigid housing element and the one immediately next to it, which deformable connection element provides at least one degree of freedom in the relative motion of the two rigid elements connected thereby,
which sensors communicate with means for collecting output signals from said sensors, which may be mounted in the device or in a separate remote station,
comprising means for removably securing the apparatus to the soil to be monitored, consisting of anchor elements adapted to radially expand within the borehole,
characterized in that
it comprises at least one anchor element located at least at one deformable connection element and/or located at least at one rigid housing element.

5. An apparatus as claimed in claim 4, **characterized in that** said deformable connection element comprises a portion that is deformable in the longitudinal/axial direction of said succession of rigid housing elements and a portion that is deformable in one or more directions transverse to said longitudinal/axial direction, said at least one anchor element being located at said portion that is deformable in one or more directions transverse to said longitudinal/axial direction.

6. An apparatus as claimed in claim 4, **characterized in that** at least one anchor element located at a rigid housing element comprises means for preventing or restricting the radial expansion of the anchor element.

7. An apparatus for monitoring geotechnical, geological and structural, hydrogeological and geophysical parameters of soils, rocks and structures in general, which comprises two or more rigid housing elements, with at least one sensor for at least one parameter to be monitored being mounted in at least one of them
which at least two or more rigid housing elements are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable, connection element being interposed between each rigid housing element and the one immediately next to it, which deformable connection element provides at least one degree of freedom in the relative motion of the two rigid elements connected thereby,
which sensors communicate with means for collecting output signals from said sensors, which may be mounted in the device or in a separate remote station,
comprising means for removably securing the device to the soil to be monitored, consisting of anchor elements adapted to radially expand within the borehole, whose radial expansion is caused by feeding a pressurized fluid into said anchor elements, which have an outer surface made of an expandable elastic material,
characterized in that
it comprises means for restricting the radial expansion of said anchor elements, so that said radial expansion is prevented beyond a predetermined limit value.

8. An apparatus as claimed in claim 7, **characterized in that** said radial expansion restricting means comprise a retention member made of a relatively inelastic material, which is adapted to surround said outer surface, particularly a tubular braid.

9. An apparatus as claimed in claim 8, **characterized in that** said retention member is surrounded by a tubular elastic element, so that, as the pressure of the pressurized feed-fluid in said anchor element decreases, said tubular elastic element stresses said retention element and said outer surface of the anchor element toward the interior of the anchor element.

10. An apparatus for monitoring geotechnical, geological and structural, hydrogeological and geophysical parameters of soils, rocks and structures in general, which comprises two or more rigid housing elements, with at least one sensor for at least one parameter to be monitored being mounted in at least one of them
which at least two or more rigid housing elements are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable, connection element being interposed between each rigid housing element and the one immediately next to it, which deformable connection element provides at least one degree of freedom in the relative motion of the two rigid elements connect-

ed thereby,
which sensors communicate with means for collecting output signals from said sensors, which may be mounted in the device or in a separate remote station,
characterized in that
it comprises a strain gage composed of a stationary part and a control rod that is movable relative thereto, the stationary part being stably connected to a rigid housing element and the control rod being connected to a further rigid housing element or a deformable connection element, means being provided for automatically centering and connecting said control rod to said further rigid housing element or said deformable connection element so that said control rod is allowed to move relative to the deformable connection element or the rigid housing element between the two limit stop positions corresponding to those of the deformable connection element.

11. An apparatus as claimed in claim 10, **characterized in that** said centering and connection means include a magnet located at said further rigid housing element or said deformable connection element, the end of the control rod adapted to engage with said further rigid housing element or with said deformable connection element being made of ferromagnetic material.

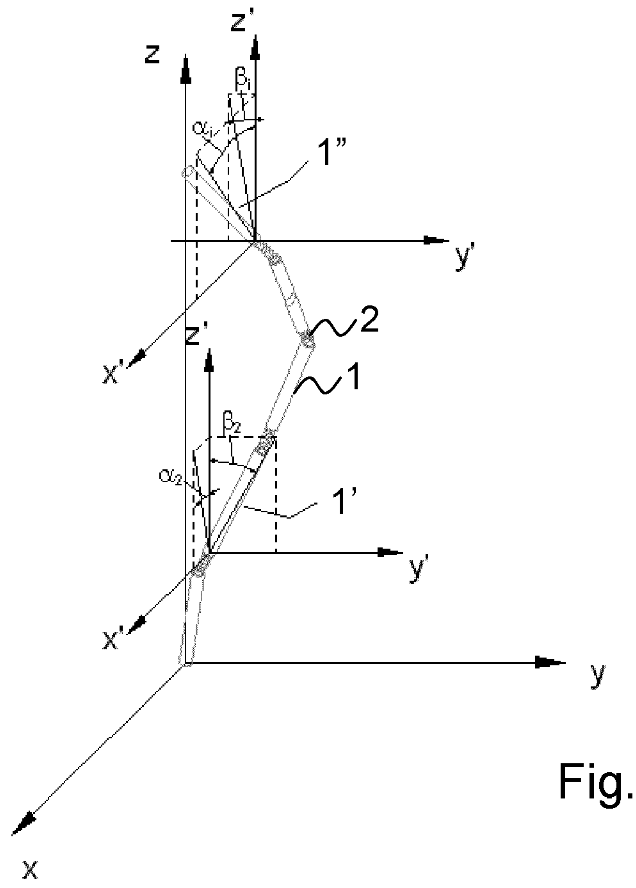
12. An apparatus for monitoring geotechnical, geological and structural, hydrogeological and geophysical parameters of soils, rocks and structures in general, which comprises two or more rigid housing elements, with at least one sensor for at least one parameter to be monitored being mounted in at least one of them
which at least two or more rigid housing elements are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable, connection element being interposed between each rigid housing element and the one immediately next to it, which deformable connection element provides at least one degree of freedom in the relative motion of the two rigid elements connected thereby,
which sensors communicate with means for collecting output signals from said sensors, which may be mounted in the device or in a separate remote station,
characterized in that
said deformable connection element allows deformation in the longitudinal/axial direction of said succession of rigid housing elements, telescopic electric connections being provided in said deformable connection element.

13. An apparatus as claimed in claim 12, **characterized in that** said telescopic electric connections consist of microtubes, which are composed of at least one female element made of a highly conductive material and at least one male element made of a highly conductive material, wherein the inside diameter of the female element is adapted to tightly and slideably receive the male element, whose outside diameter substantially fits therewith, to provide an electric wiping contact.

14. An apparatus for monitoring geotechnical, geological and structural, hydrogeological and geophysical parameters of soils, rocks and structures in general, which comprises two or more rigid housing elements, with at least one sensor for at least one parameter to be monitored being mounted in at least one of them
which at least two or more rigid housing elements are arranged in succession one after the other along a predetermined line or a predetermined axis, a deformable, connection element being interposed between each rigid housing element and the one immediately next to it, which deformable connection element provides at least one degree of freedom in the relative motion of the two rigid elements connected thereby,
which sensors communicate with means for collecting output signals from said sensors, which may be mounted in the device or in a separate remote station,
characterized in that
said deformable connection element comprises a portion that is deformable in the longitudinal/axial direction of said succession of rigid housing elements and a portion that is deformable in one or more directions transverse to said longitudinal/axial direction, which longitudinally/axially deformable portion comprises a single spring operable by tension and compression to define a neutral reference position for strain-gage measurements.

15. An apparatus as claimed in claim 14, **characterized in that** said spring is a helical spring composed of three different sections having turns with different diameters, the diameter of said turns being smaller in a first end section, intermediate in an intermediate section and greater in the other end section.

16. An apparatus as claimed in one or more of the preceding claims **characterized in that** it comprises a combination of claims 1 to 4 with any one or more of claims 5 to 15 or a combination of claim 5 or 6 with one or more of claims 1 to 4 and 7 to 15, or a combination of claims 7 to 9 with one or more of claims 1 to 6 and 10 to 15 or a combination of claim 10 or 11 with one or more of claims 1 to 9 and 12 to 15 or a combination of claim 12 or 13 with one or more of claims 1 to 11 and 14 to 15 or a combination of claim 14 or 15 with one or more of claims 1 to 13.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z'
β_i
α_i
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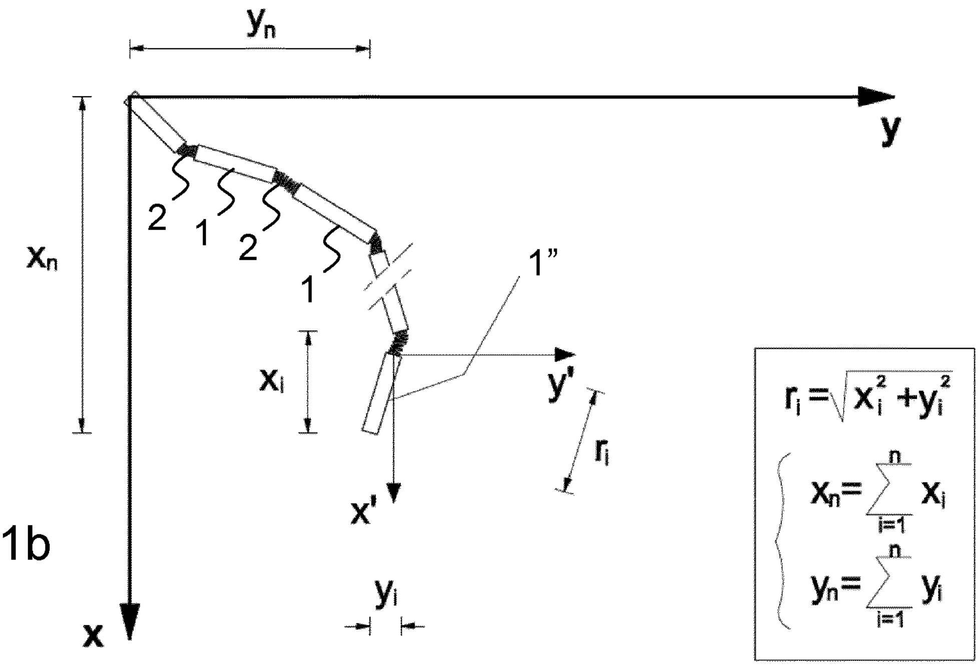
y
x

Fig. 1a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2
1
2
1
1"
x_i
y'
r_i
x'
y_i
x
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$x_n = \sum_{i=1}^{n} x_i$
$y_n = \sum_{i=1}^{n} y_i$

Fig. 1b

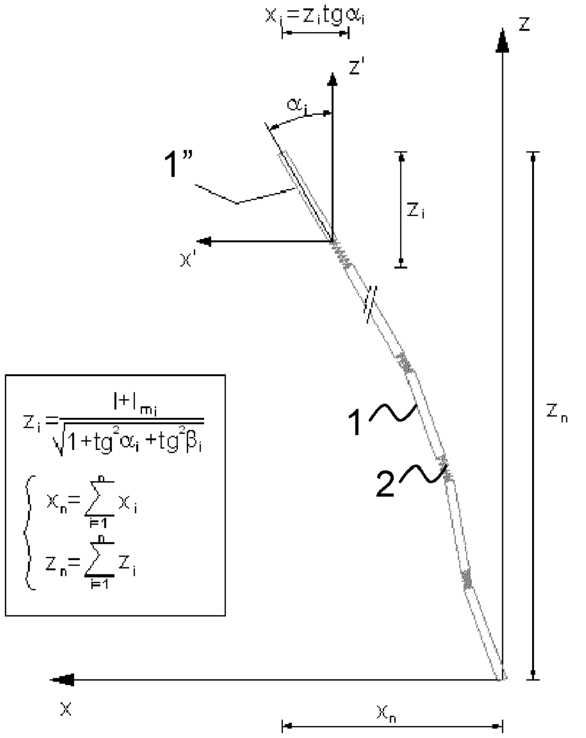
$x_i = z_i tg\alpha_i$
z
z'
α_i
1"
z_i
x'
$z_i = \frac{l + l_{mi}}{\sqrt{1 + tg^2\alpha_i + tg^2\beta_i}}$
$x_n = \sum_{i=1}^{n} x_i$
$z_n = \sum_{i=1}^{n} z_i$
1
2
z_n
x
x_n

Fig. 1c

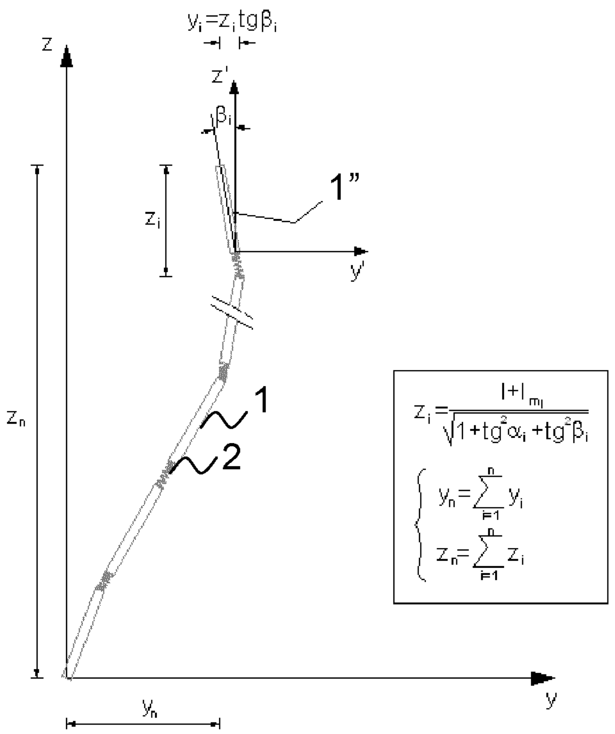
$y_i = z_i tg\beta_i$
z
z'
β_i
1"
z_i
y'
z_n
1
2
$z_i = \frac{l + l_{mi}}{\sqrt{1 + tg^2\alpha_i + tg^2\beta_i}}$
$y_n = \sum_{i=1}^{n} y_i$
$z_n = \sum_{i=1}^{n} z_i$
y
y_n

Fig. 1d

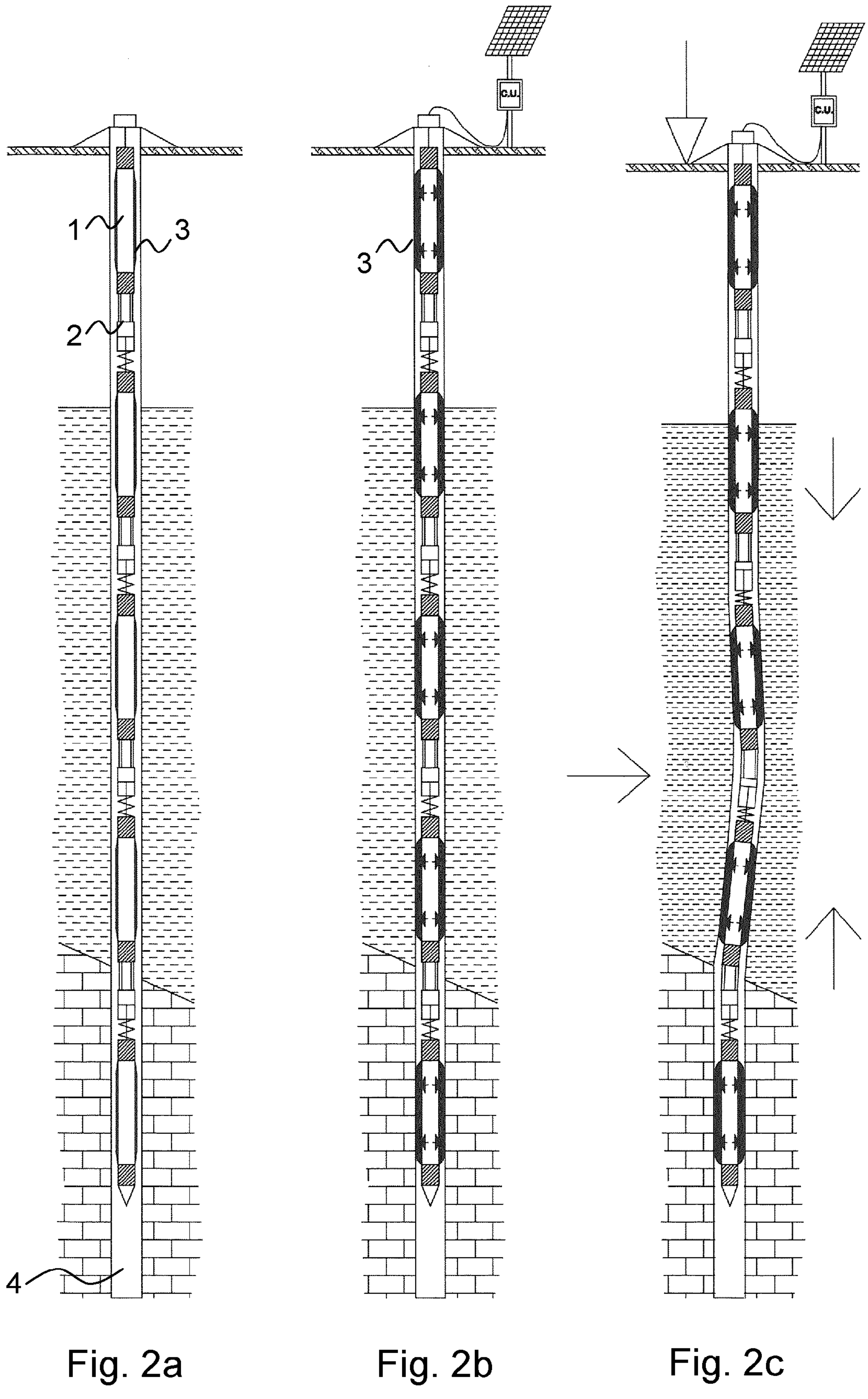

Fig. 2a Fig. 2b Fig. 2c

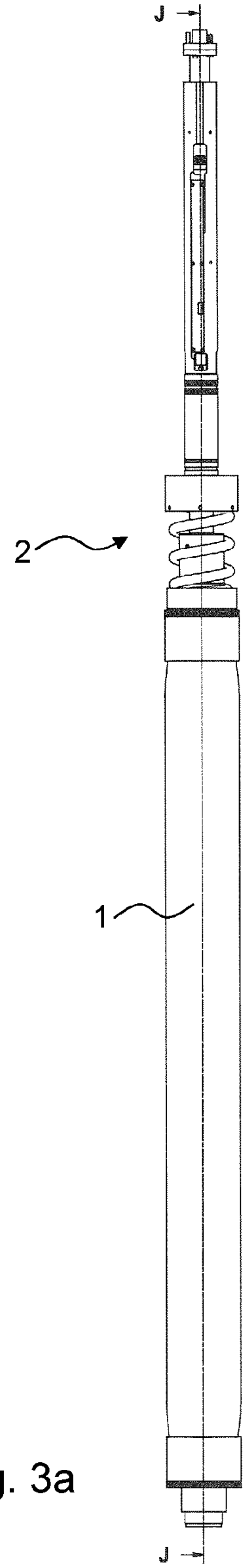

Fig. 3a

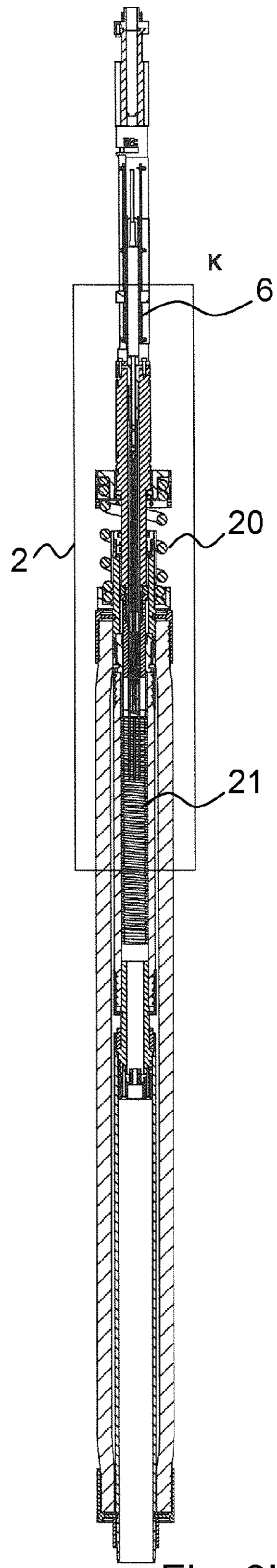

Fig. 3b

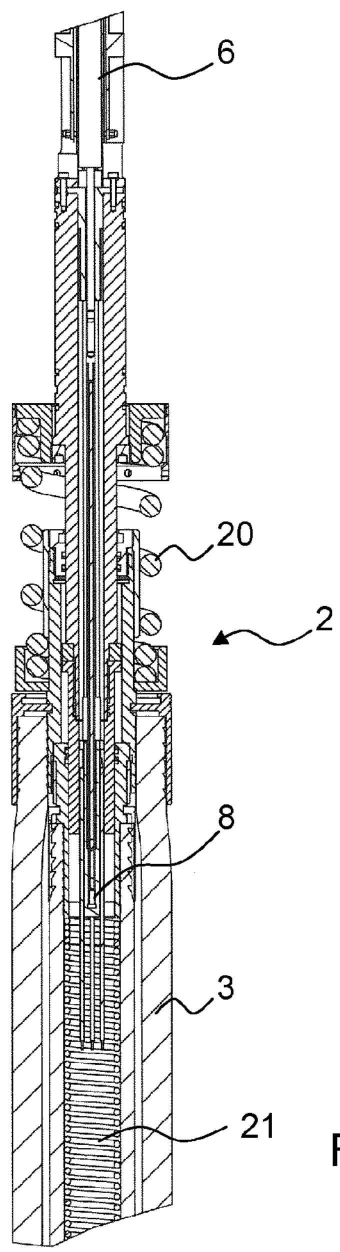

Fig. 3c

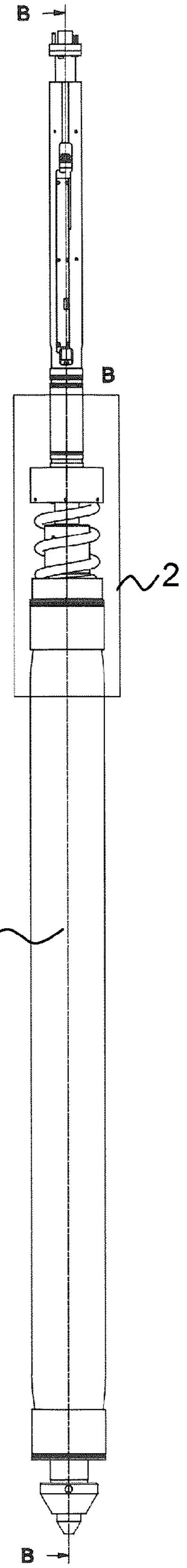

Fig. 4a

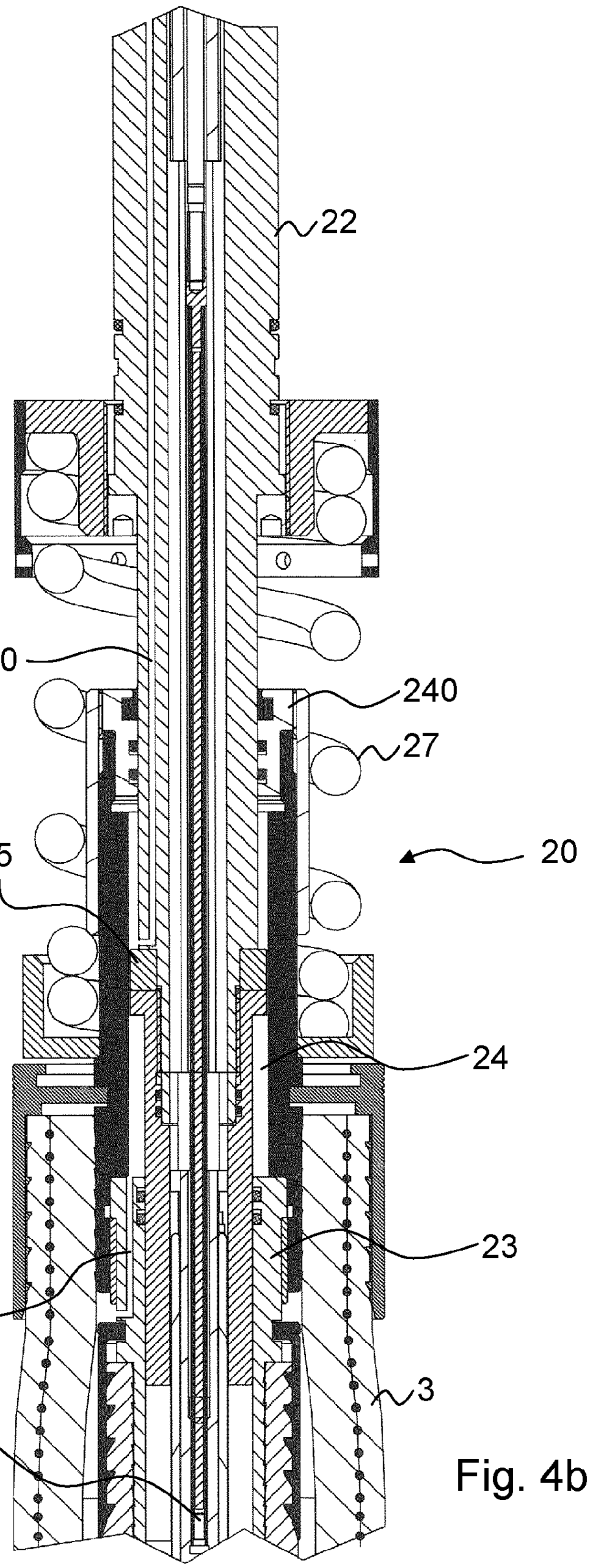

Fig. 4b

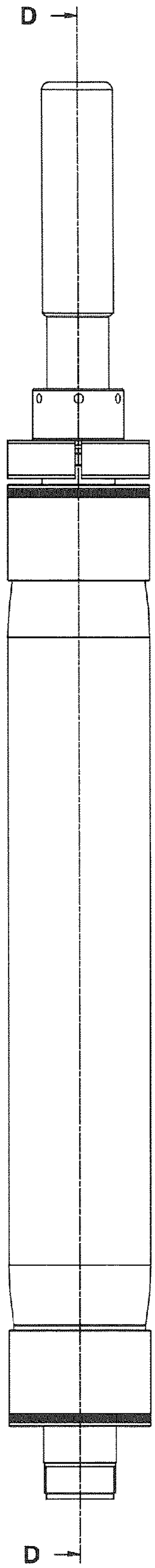

Fig. 5a

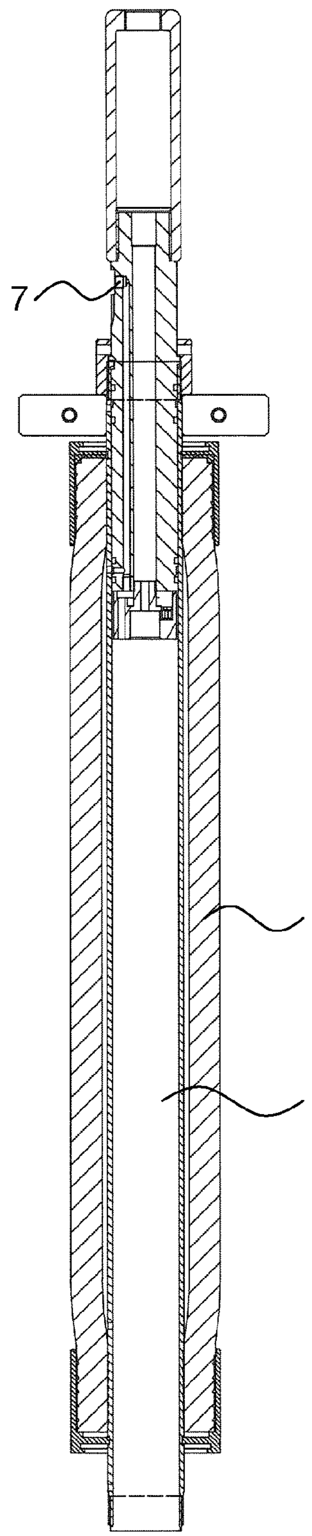

Fig. 5b

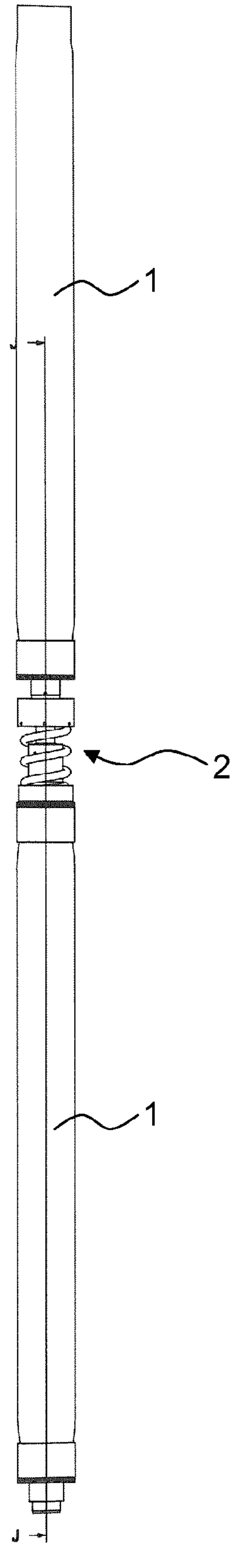

Fig. 6a

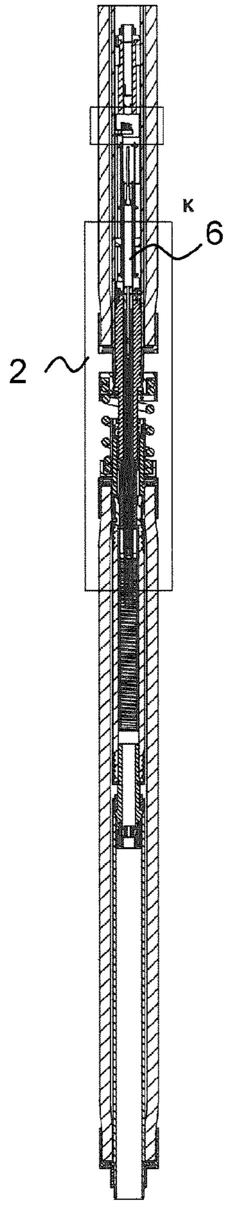

Fig. 6b

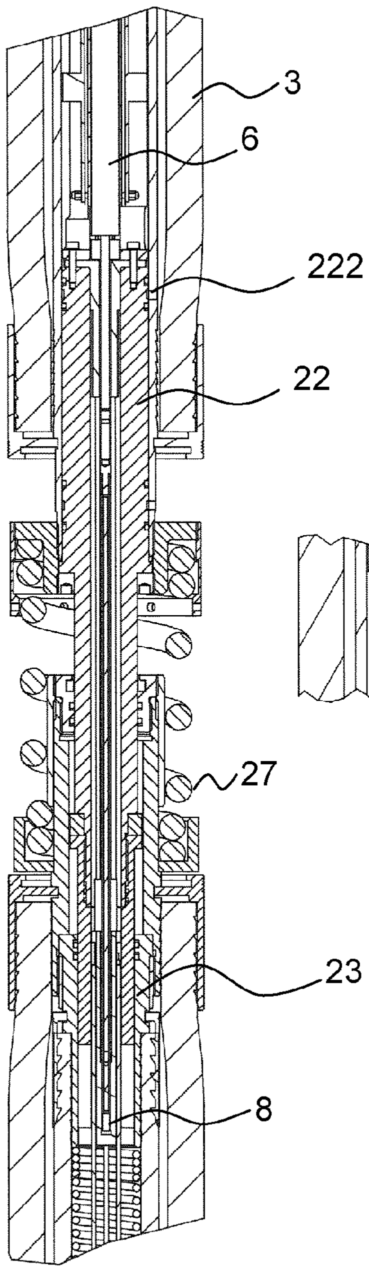

Fig. 6c

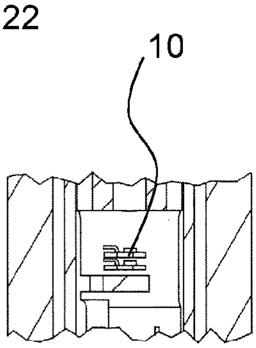

Fig. 6d

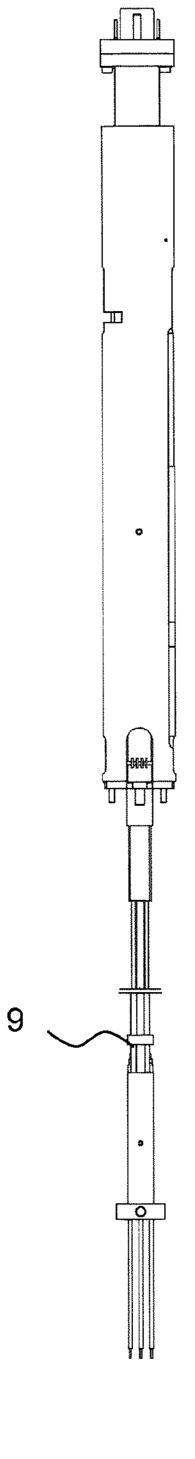

Fig. 7a

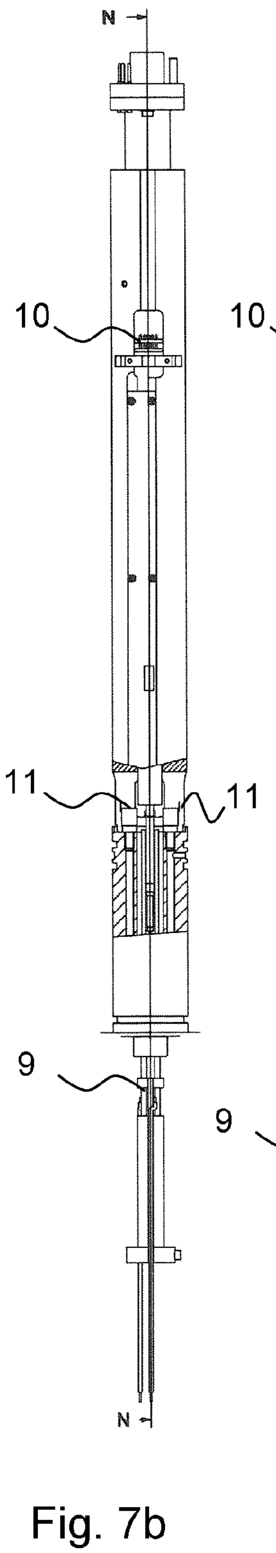

Fig. 7b

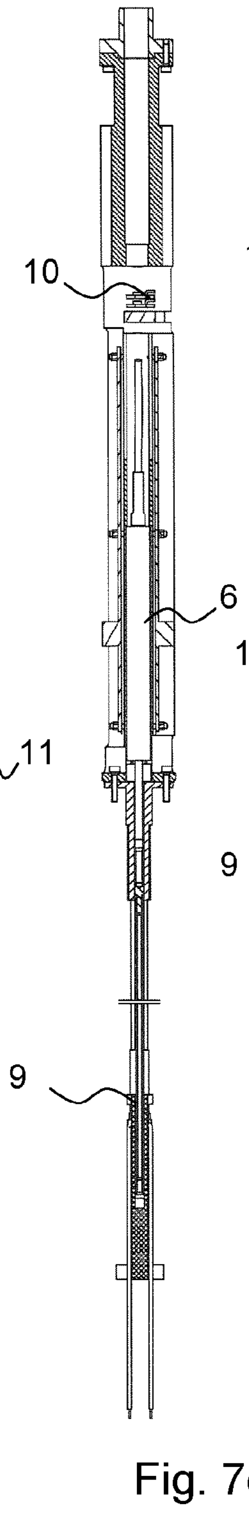

Fig. 7c

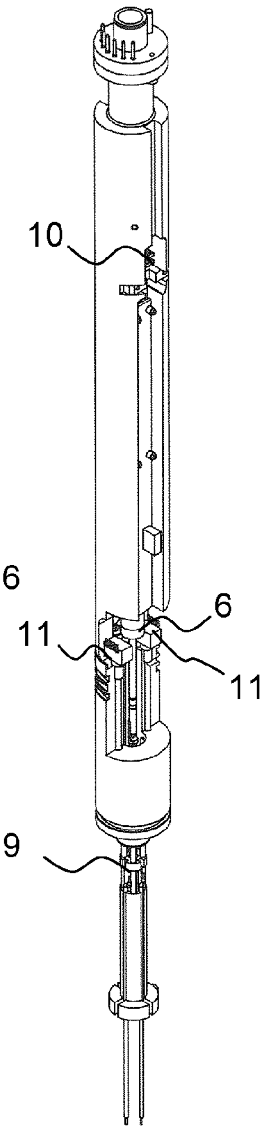

Fig. 7d

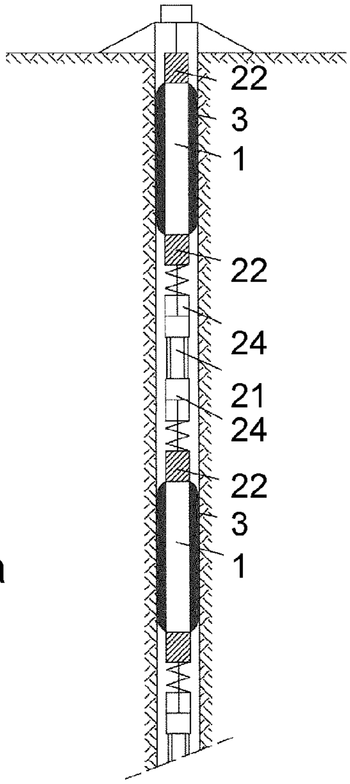

Fig. 8a

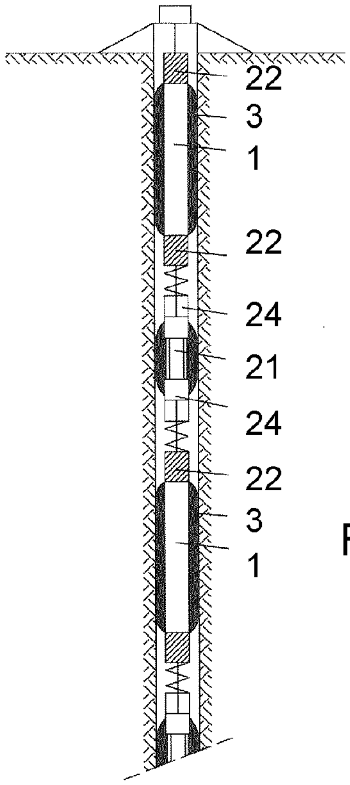

Fig. 8b

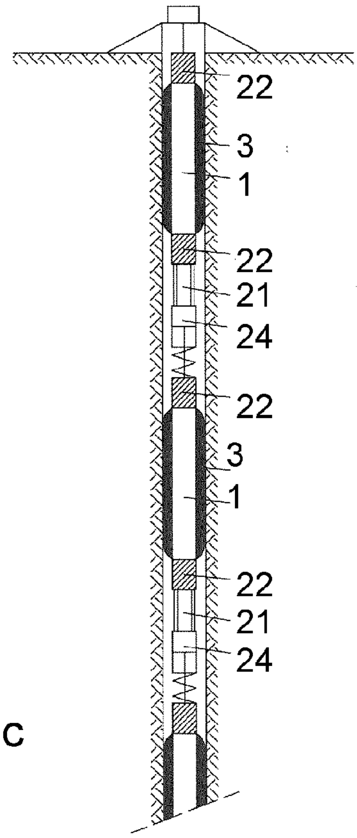

Fig. 8c

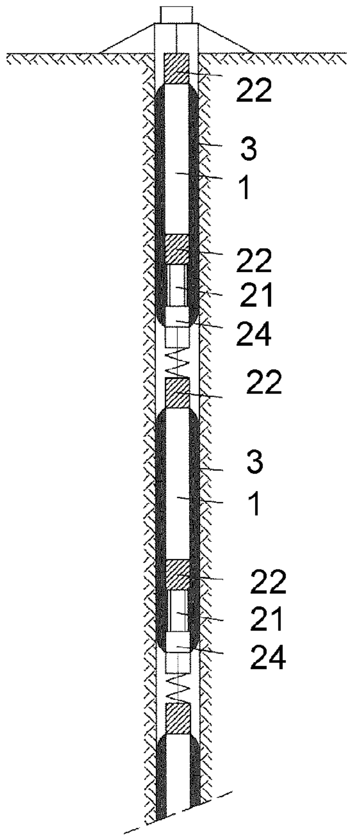

Fig. 8d

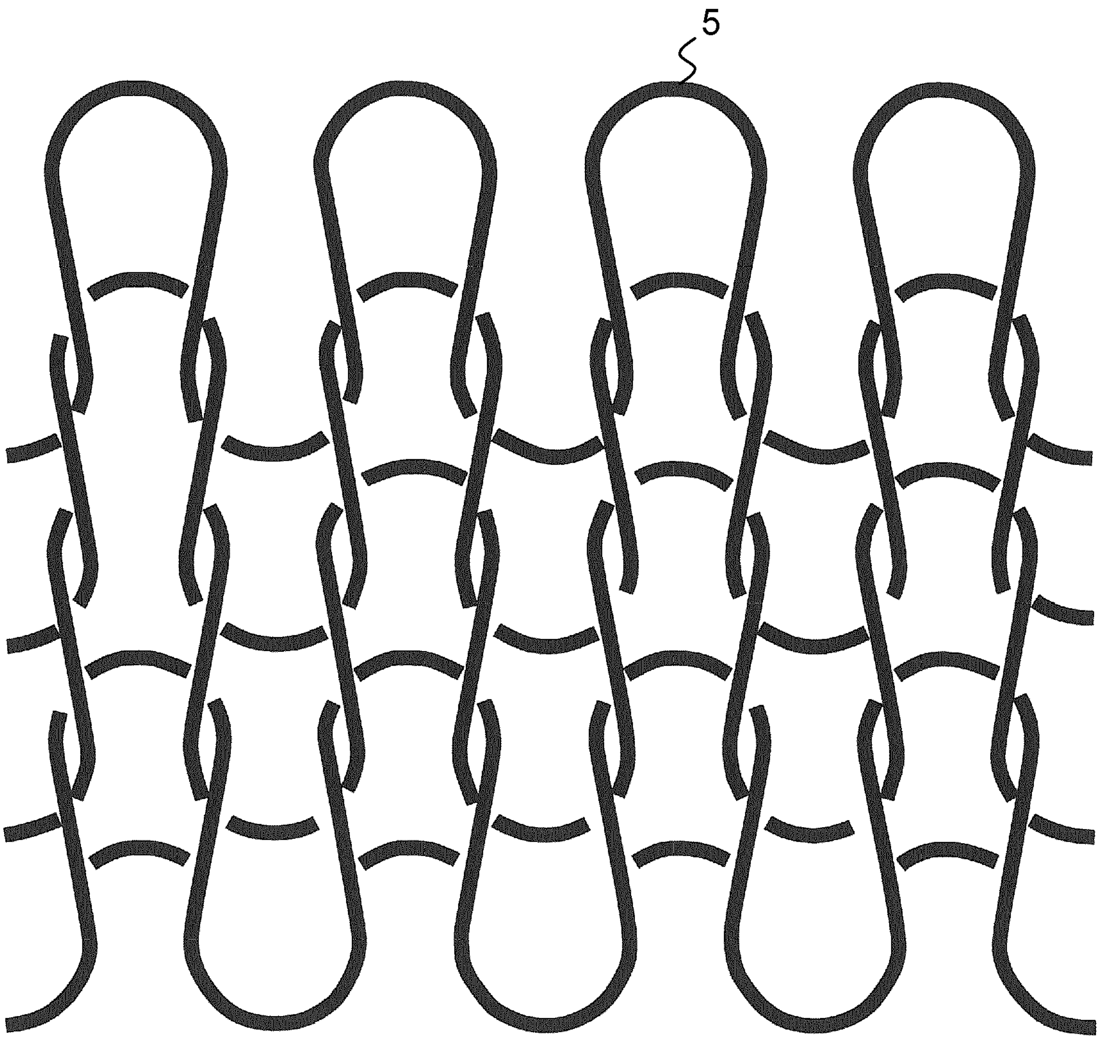

Fig. 9

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PARTIAL EUROPEAN SEARCH REPORT

under Rule 62a and/or 63 of the European Patent Convention. This report shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 12 16 4497

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2005/024415 A2 (C S G S R L [IT]; FOGLINO LUIGI [IT]; FOGLINO DANIELA [IT]; LOVISOLO M) 17 March 2005 (2005-03-17) * the whole document * -----	1-3	INV. E02D1/00
A	GB 2 036 136 A (WESTBAY INSTR LTD) 25 June 1980 (1980-06-25) * the whole document * -----	1-3	
A	EP 1 662 225 A1 (GLOETZL BAUMESSTECH [DE]) 31 May 2006 (2006-05-31) * the whole document * -----	1-3	
			TECHNICAL FIELDS SEARCHED (IPC)
			E02D

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

1

Place of search	Date of completion of the search	Examiner
Munich	8 October 2012	Geiger, Harald

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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INCOMPLETE SEARCH SHEET C

Application Number
EP 12 16 4497

Claim(s) completely searchable:
1-3

Claim(s) not searched:
4-16

Reason for the limitation of the search:

According to the response to the objection under Rule 62a EPC the applicant requested with letter dated 26.10.2012 only he subject matter of claims 1-3 to be searched.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 16 4497

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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08-10-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2005024415 A2	17-03-2005	EP 1664486 A2	07-06-2006
		WO 2005024415 A2	17-03-2005
GB 2036136 A	25-06-1980	CA 1112558 A1	17-11-1981
		GB 2036136 A	25-06-1980
		JP 1224096 C	15-08-1984
		JP 55089597 A	07-07-1980
		JP 59001880 B	14-01-1984
		US 4204426 A	27-05-1980
EP 1662225 A1	31-05-2006	AT 357645 T	15-04-2007
		DE 102004057642 A1	01-06-2006
		EP 1662225 A1	31-05-2006
		ES 2284118 T3	01-11-2007

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- IT 0001323688 **[0002] [0067]**
- IT 0001346108 **[0002] [0067]**
- EP 1664486 A **[0002]**
- EP 1664586 A **[0067]**