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(72) Inventors:
• **Hogervorst, Leonardus Robertus Adrianus**
2215 KT, Voorhout (NL)
• **Zuijderduijn, Willem**
9301 NT, Roden (NL)

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(74) Representative: **Jansen, Cornelis Marinus et al**
VEREENIGDE
Johan de Wittlaan 7
2517 JR Den Haag (NL)

(71) Applicant: **Gouda Geo-Equipment B.V.**
2361 KX Warmond (NL)

(54) **Cone Penetration Testing Pushing Device and System**

(57) A ground penetrating device, comprising a housing, a locking arrangement (6) for locking the housing inside a borehole, a penetration member (5) arranged to move relative to the housing (20) in a penetration direction; and a force transmission element (9) provided movably relative to the housing (2), a conversion mechanism (10) for converting a movement of the force transmission element (9) in a direction different from the penetration direction to a movement of the penetration member (5) in the penetration direction.

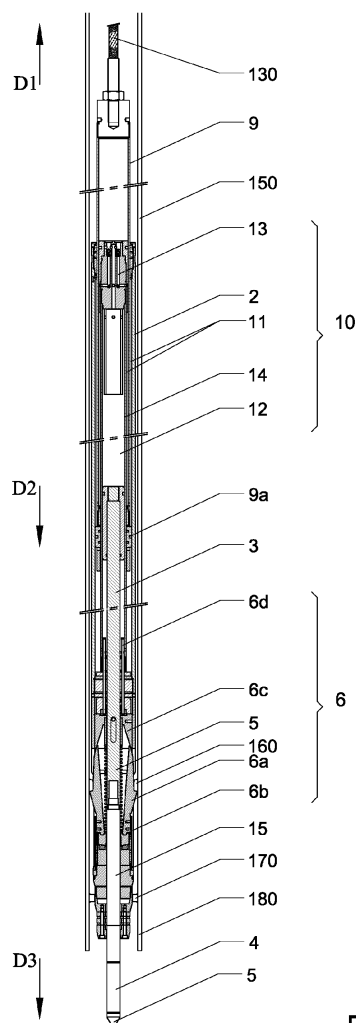


Fig. 2

Description

FIELD OF THE INVENTION

[0001] The invention relates to a device for ground penetration testing, and more specifically to at least one of a ground penetration device for obtaining measurement data or samples by pushing a penetration rod into the ground, a system using such a ground penetration device, a method for executing a ground penetration test and a penetration piston rod to be used in such a ground penetration device.

BACKGROUND ART

[0002] Everywhere in the world firm building lands become scarcer and scarcer. More and more new buildings and structures are being planned on much less favourable building lands. As a result, the demand for high-grade geotechnical soil investigation techniques carried out in order to determine the bearing capacity of the soil increases. With the results of this soil investigation it is possible to calculate accurately the necessary foundations of buildings, constructions and alike.

[0003] Another trend in building that catches the eye is the fact that buildings and structures become larger in size and taller. Also underground space is being used more and more frequently for building activities. The latest upcoming trend is near-shore and off-shore construction, for example airfields, harbours living and working accommodations, recreational areas, energy plants such as windmills and the like. In all these cases a detailed geotechnical soil investigation is inevitable.

[0004] A known geotechnical soil investigation technique is Cone Penetration Testing (CPT). This technique is based on the principle of pushing a probe statically into the ground. The maximally reached testing depth is limited, depending on the ground conditions (soft soils or hard soils). The maximum testing depth recorded up till now using traditional CPT techniques is 25 meter in hard layers up to 68 meter in very soft soils.

[0005] More and more constructions will be built on building lands with less favourable underground conditions or are to be founded at much greater depths because of the shear size of the construction. Other constructions will be realised near- or off-shore. Therefore, the traditional Cone Penetration Testing methods, that can only reach limited testing depths, are no longer sufficient. As a result there is a demand for CPT methods combined with drilling techniques. These so-called down-the-hole CPT tests are performed from within a string of drill pipes. From the ground surface a hole is drilled using conventional drilling techniques and a drill pipe is placed. A CPT pushing device is lowered in to the drill pipe and locks itself in the shoe of the drill pipe. A probe provided on a piston rod is extruded from the pushing device and penetrates the ground at the lower end of the drill pipe. Depending on the type of probe, meas-

urements are performed or a sample is taken. After having completed the test, the device is hoisted back to the surface and the hole will be advanced using classic drilling techniques up to the testing depth that was reached with the CPT pushing device. Then the whole cycle is repeated over and over again until the ultimate testing depth is reached. Depths can be reached of tens to hundreds of meters or more.

[0006] At present there are a number of CPT systems available on the market that can perform CPT tests from within a string of drill pipes. Those systems are all driven either hydraulically or electrically from the ground surface level. The pressure necessary for extruding the piston rod is supplied by a hydraulic power-pack or generator at the ground surface. This implies the use of an expensive and vulnerable umbilical linking the power-pack at the surface to the CPT pushing device lowered through the string of drill pipes. Moreover, a loss of hydraulic power will occur in the umbilical, which will increase with greater testing depths. Therefore, the hydraulic pressure that has to be generated at the ground surface will be excessive.

[0007] The present day CPT systems for CPT testing from within a string of drill pipes can have the following disadvantages. In the first place the conventional systems are expensive. The present day CPT systems generally comprise at least five costly components: (1) the CPT pushing device that is used in the string of drill pipes, (2) an umbilical connecting the CPT pushing device to the power-pack at a surface that supplies power to the device and is also used to lower and hoist the device through the string of drill pipes, (3) a highly-sophisticated winch that is capable of handling the multi-purpose umbilical and can deal with the various umbilical functionalities, such as hoisting, power-supply and data transmission, (4) a hydraulic power-pack or generator, and (5) a data acquisition system.

[0008] The design of the conventional CPT systems makes these systems very vulnerable, especially the multi-purpose umbilical, since it brings together practically incompatible functionalities and is constantly lowered and hoisted through the very narrow string of drill pipes and used under harsh (environmental) conditions and circumstances. In daily practice it means that it is absolutely compulsory to have at least one spare umbilical available on a job.

[0009] Furthermore, the design of the present day CPT pushing device that is lowered through the string of drill pipes does not allow for high testing productivity, because of, for example, the following reasons. (1) The stroke of the CPT pushing device is limited. When a CPT test can be done with a pushing force of 50 kN, the maximum stroke is 3 meter. When the CPT test is to be performed with a pushing force of 100 kN (because of geological conditions), the stroke of the CPT pushing device is limited by the vulnerability of the piston rod with the probe to a maximum of 1.5 meter. (2) The complex design of the umbilical makes it very vulnerable and does there-

fore not allow for high speed lowering and hoisting.

[0010] Either one of these two issues reduces the productivity and usability of present day CPT systems enormously, also contributing negatively to the costs for soil investigation.

[0011] Furthermore, since the design of the present day CPT systems is complex and vulnerable, these systems can only be used by trained and experienced operating personnel. These people are scarce and costly.

[0012] US5777242 discloses a ground penetrating device, especially a CPT device, for use within a bore hole. This device comprises a piston carrying a rod with a sharpened tip, to be driven into the ground below the lower end of a drill pipe. The piston is mounted inside a cylinder, open towards the lower end, sealing against an inner wall of the cylinder, whereas the lower end of the cylinder rests on and seals against a shoulder within said lower end of the drill pipe. The opposite upper end of the cylinder is closed, such that a chamber is provided above the piston. An upper end of the drill pipe, above the ground, is sealed too, such that the inner volume of the drill pipe can be pressurised by feeding gas under pressure into said drill pipe. In the upper side of the cylinder a passage is provided, with a control device, operable from above ground, for allowing pressurised gas to flow into the chamber, thus pushing the piston down within the housing. This forces the tip of the rod out of the housing and into the ground statically. The drill pipe is held in position axially within the bore hole by its own weight and possibly by friction between the wall of the bore hole and part of the drill pipe.

[0013] NL7108761 discloses a ground penetrating device, comprising a housing to which a cylinder is attached. A locking means is provided in the form of a vacuum chamber, for holding the housing on top of a ground area into which a rod with a sharpened tip is to be driven. The rod is mounted to a piston, which is provided inside a hollow piston rod which in itself has a piston head mounted within the cylinder, such that the device is telescopic and can be driven by a pressure medium fed into the cylinder and the hollow piston rod via a feed opening in the top end of the cylinder.

[0014] US2003/0024713 discloses a ground penetrating device for penetration testing, wherein a hammer is provided for hammering an end of a rod into the ground to be tested.

SUMMARY OF THE INVENTION

[0015] The present invention can be defined by a ground penetrating device according to independent claim 1, a system using this device as can be defined by independent claim 13, a penetration member, which can be according to independent claim 11, and/or a method of performing a cone penetration test according to claim 16.

[0016] The down-the-hole core penetration (DTH-CPT) system presented in the current application can be

simpler by design, sturdier, more productive and/or less complex than conventional systems.

[0017] A DTH-CPT system as described herein can function without the supply of external hydraulic or electric power to the CPT pushing device from ground level. The pushing movement can be generated in the CPT pushing device with the help of means to convert a movement in a direction different from a penetration direction to a movement in the penetration direction. In one embodiment, a pulling force can be supplied down the hole with the help of a relatively simple cable. An umbilical as in the conventional system does not have to be provided. If an umbilical were to be used, it could be of a simpler design, for example without the hydraulic lines as used in conventional systems. The use of a CPT pushing device of this description can allow for a DTH-CPT that needs fewer and less expensive components. In an embodiment using a proposed penetration means, the stroke of the CPT pushing device can be enhanced, so that the number of necessary measurement cycles can be reduced.

[0018] Further aspects and advantages will become apparent from the following description taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The invention will be elucidated with respect to the accompanying drawings. The drawings by themselves are not to be taken as a limitation of the invention.

Fig. 1 illustrates a down-the-hole core penetration testing system according to an embodiment of the invention as it is used at sea.

Fig. 2 illustrates a core penetration testing device according to an embodiment of the invention. Depicted is the state of the device when it is ready to be lowered in a drill pipe.

Fig. 3 illustrates the state of the device according to an embodiment of the invention when at the end of the stroke the locking system is released and the pushing device is unlocked from inside the drill pipe.

Fig. 4 shows the movement conversion system and the locking system of a core penetration device according to an embodiment of the invention in more detail. Fig. 4a shows the situation after passing a ring near the bottom end of the drill pipe, when an upward pulling force is applied. Fig. 4b shows a more detailed magnification of the upper part of the inner and outer chamber and the channels connecting the two chambers. The dimensions in the radial direction are exaggerated.

Fig. 5 illustrates a movement conversion mechanism according to a second embodiment.

Fig. 6 illustrates a movement conversion mechanism according to a third embodiment.

Fig. 7 illustrates a movement conversion mechanism

according to a fourth embodiment.

DESCRIPTION OF THE INVENTION

[0020] The DTH-CPT systems and ground penetrating devices described here are examples of the invention. At least some of the advantages as described can be obtained for all types of ground penetration devices that are to be operated from a distance and require a force to exert pressure or to produce a movement.

[0021] Ground penetration testing has to be understood in this application as testing of characteristics of ground by at least pushing an element into the ground.

[0022] When CPT tests with a system according to an embodiment of the present invention are performed from within a string of drill pipes, a drill pipe is placed in a drilling hole and the CPT pushing device, which can be a ground penetration device according to the invention, is lowered on the end of a cable, preferably a steel wire, with the help of a winch. Fig. 1 shows an example of such a system deployed at sea, for performing CPT tests below the bottom of the sea. Equipment is placed on a jack up barge or platform (100), from which a string of drill pipes or a support tube (140) and drill pipes (150) are placed down to the seabed, at least the drill pipes (150) and/or support tubes (140) extending at least partly into the seabed. A CPT pushing device (1), suspended from a wire (130), is lowered through the drill pipes (150), to a bottom end thereof. The pushing device (1) is operated from the surface. The wire (130) with the CPT pushing device (1) can be lowered and hoisted with a winch (120). The wire (130) can, for example, be a steel or plastic wire. The winch (120) can, for example, be a standard winch. The CPT pushing device (1) comprises a penetration means (5) with a probe or sampler (4) at or near its tip (5a). In embodiments of a system according to the present invention there is no need for an umbilical comprising electric and/or hydraulic supply lines.

[0023] A CPT pushing device (1) that can be used in a system according to the invention, for example as described in Fig. 1, is depicted in more detail in Fig. 2. The pushing device (1) is shown within a drill pipe (150). The pushing device is hanging from a wire (130), e.g. a steel wire, by which it can be lowered and hoisted back up, and by which also a pulling force can be applied to the pushing device (1), as will be described. A main body of the pushing device (1) is formed by a housing (2), here in the form of an outer cylinder (2). In this embodiment, the penetration means (5) comprises a piston rod (3). In Fig. 2 the piston rod (3) is shown in retracted position, as it is when being lowered through the string of drill pipes (150). The wire (130) is attached to a pulling cylinder (9), which is also shown in a retracted position. In this embodiment, the pulling cylinder (9) is at least part of and can form a force transmission means (9).

[0024] When reaching the end (180) of the drill pipe (150), the CPT pushing device (1) can lock itself in the lower part of the drill pipe (150) with the help of a locking

system (6), for example. As depicted in Fig. 2, the locking system (6) can comprise a number of spring loaded latches (6a) that are pushed outwards by leaf springs (6b), for example. Near the bottom of the drill pipe (150) a ring (160) is provided, which the latches (6a) have to pass. Even further down a stabilizing ring (170) is provided, which centres and stabilizes the lower part of the pushing device within the end of the drill pipe (180). While passing the ring (160), the latches (6a) are forced inwards, but after passing the ring (160) the latches (6a) are forced out again by the leaf springs (6b), so that the pushing device (1) is locked below the ring (160) against an upward movement of the pushing device (1). Figs. 2 and 4 show the pushing device in a locked condition. Other known ways of locking the pushing device (1) in the drill pipe (150) can be applied. In this description, locking of the pushing device (1) is to be understood as immobilization of the housing (2) of the pushing device (1) with respect to the drill pipe (150), for example by a friction or a hooking mechanism, or at least preventing undesired upward movement.

[0025] After this locking, a pulling force is exerted on the wire (130). The same winch (120) that is used to lower the pushing device (1) can be used to exert the pulling force. At that time, the wire (130) attached to the pulling cylinder (9) induces an upward movement of the pulling cylinder (9), which is partly pulled out of the housing (2). By means of an internal mechanism (10) the movement of the pulling cylinder (9) in a first direction (D1) is converted into a movement in an opposite, second direction (D2), forcing the piston rod (3) in a penetration direction (D3) relative to the housing (2) into the ground below the end (180) of the drill pipe (150), so that a core penetration test can be performed. For that purpose a probe (4) is provided on the penetration means (5) that is to be forced from the housing (2). The probe (4) can, for example, comprise a force measuring device or a sampler (4) for taking ground samples. Depending on the kind of probe (4), one or more parameters can be measured, such as tip resistance, local friction, water pressure, temperature, conductivity, inclination etc. A memory module (15) for storing measured data may be provided in or near the penetration means (5), for example close to the probe (4), but a memory module may also be provided elsewhere in the pulling device.

[0026] The following description refers to the situation depicted in Fig. 3. At the end of the stroke of the penetration means (5), when the test is completed, the pushing device (1) unlocks itself from the drill pipe (150) as the winch (120) continues pulling in the wire (130). That is, when the piston rod (3) reaches its most extended position, the latches (6a) are released against the pressure of the springs, for example by a pushing action by the lower part of the piston rod (3) on a plurality of latch release plungers (6d) that push down a hollow-conical latch release ring (6c). The latch release ring (6c) pushes the latches (6a) to the inside against the pressure of the leaf springs (6b), thereby releasing the pushing device (1).

In that case, the release occurs as a result of at least the movement of the piston rod (3) being pushed out as a result of the pulling action on the pulling cylinder (9). After the release, the pushing device (1) is hoisted back to the surface. The sequence of extruding the piston rod (3), unlocking the pushing device (1) from the drill pipe (150) and hoisting the pushing device (1) back up automatically occurs while the wire (130) is pulled in, which can be seen as a continuous movement.

[0027] As described above, the continuous pulling of the wire (130) results consecutively in the locking of the pushing device (1) below the ring (160) in the drill pipe (150), the extrusion of the penetration means (5) from the housing (2), the release of the pushing device (1) from the ring (160) in the drill pipe (150), and hoisting the pushing device (1) back up to the surface.

[0028] Back at the surface the probe (4) can be prepared for the next test or the sample can be removed and the DTH-CPT pushing device (1) can be made ready for the next test. The hole is then advanced using classic drilling techniques up to the last testing depth that was reached with the CPT pushing device (1). The whole cycle is repeated until the ultimate testing depth is reached.

[0029] The following is a description of a mechanism that can be used to obtain the conversion of the movement direction within the CPT pushing device (1). This conversion mechanism (10) makes it possible to obtain a penetration force in the penetration direction (D3) while applying a pulling force on the wire (130) in the opposite first direction (D1). In other words, a movement in a direction (D1) different from the penetration direction (D3) is converted to a movement in the penetration direction (D3).

[0030] A CPT pushing device (1) is shown in Fig. 2 in operational position, with the ground to be penetrated on the lower side and the wire (130) on which it is suspended on the upper side. Upper and lower side of the pushing device (1) are described with reference to normal use of the device (1), the lower side extending closer to the end (180) of the drill pipes (150) than the upper side. As described above, the pushing device (1) comprises a cylinder, which forms at least part of the housing (2) of the pushing device (1). A pulling cylinder (9) is provided at the upper side of the pushing device (1), the pulling cylinder (9) having a smaller diameter than the housing (2). The pulling cylinder (9) is arranged such that it can move from a position having a large overlap with the outside cylinder (2), e.g. extending largely within the housing (2), to a more extended position, e.g. extending largely outside the housing (2). At the lower side of the pushing device (1) the piston rod (3) is provided, having the probe or sampler (4) near or at its tip (5a). In this embodiment, the piston rod (3) is provided concentrically with the housing (2). The piston rod (3) too can move from a position more inside the housing (2) to a more extended position. The locking system (6) for locking the device with respect to the bore hole, more specifically the drill pipe (150), is provided near the lower part on the outside of the pushing

device (1).

[0031] In an embodiment shown in more detail in Figs. 4a and 4b, an outer chamber (11) and an inner chamber (12) are provided near a lower end of the pulling cylinder (9) and an upper end of the piston rod (3), respectively. As shown in Fig. 4b, the outer chamber can comprise two parts, provided on the inside and the outside of the pulling cylinder (9), respectively, and connected by a hole in the wall of the pulling cylinder (9). The chambers (11, 12) are separated by an inner cylinder (14). The chambers (11, 12) contain hydraulic fluid when the pushing device (1) is in operational state. The hydraulic fluid in the outer chamber (11) is forced upwards with an upward movement of the pulling cylinder (9). As can be best seen in Fig. 4b, which is an amplification of part of Fig. 4a, for that purpose a ring (9a) is provided attached to the inside of the pulling cylinder (9), so that the ring can function as a piston in the outer chamber (11). By exerting a pulling force (F1) on the pulling cylinder (9), the pulling cylinder (9) moves to the more extended position and hydraulic fluid is pressed upwards in the part of the outer chamber (11) provided on the inside of the pulling cylinder (9). The hydraulic fluid in the part of the outer chamber (11) provided on the outside of the pulling cylinder (9), is forced through the hole in the wall of the pulling cylinder (9) to enter the part of the outer chamber (11) on the inside of the pulling cylinder (9). The hydraulic fluid then moves under pressure through a channel (13) from the outer chamber (11) to the inner chamber (12). As shown in more detail in Fig. 4b, from the outer chamber (11) the hydraulic fluid enters one of the lateral channels (13a) moves up to opening (13b), where it enters channel (13c), which discharges to the inner chamber (12). A pressure builds up in the inner chamber (12), which urges the piston rod (3) out of the housing (2) in the penetration direction (D3). In that way, the upward movement of the pulling cylinder (9) is converted to a downward movement of the piston rod (3). This mechanism is a first embodiment of the mechanism for converting a movement of a force transmission means to a movement in the opposite direction, more specifically the movement of the piston rod (3) in the penetration direction (D3).

[0032] Where a DTH-CPT pushing device (1) as described can be operated just by means of the wire (130) and winch (120), there is no need for any complex control unit to pilot the winch, no multi-purpose umbilical and no complex winch. A standard winch is sufficient. In addition to that, the testing procedure is much simpler.

[0033] In a second embodiment of the pushing device (1), the mechanism (20) to convert a movement of a force transmission means (29) in one direction (D1) to a movement in the opposite direction (D2) comprises a rack-and-pinion construction (22, 23), as for example depicted schematically in Fig. 5. The pushing device (1) is shown inside a drill pipe (150). The pushing device (1) may again have a housing (2) and an inner cylinder (14) fixed inside the housing (2). The housing (2) and the inner cylinder (14) may be connected such that sufficient rigidity of the

body of the pushing device (1) is achieved. A different construction may be used, as long as sufficient rigidity of the pushing device (1) is achieved. Instead of a cylinder (14), a wall with a different shape and/or cross section may be used. A wire (29), which in this embodiment is the force transmission means (29), is wound on a reel (25) axially connected with a pinion (23). The pinion (23) is arranged to rotate with respect to a line coinciding with its axis (24), the line being in a fixed position relative to the housing (2) and/or the inner cylinder (14). The wire (29) can for example be the hoisting wire (130) used for lowering and hoisting the pushing device (1), but also a separate wire connected directly or indirectly through an intermediate member to the hoisting wire (130). By pulling on the wire (130), the pinion (23) rotates, thereby producing a movement of the rack (22) in the opposite direction (D2) relative to the housing (2) of the pushing device (1). The rack (22) may be provided slideably within the inner cylinder (14) with an appropriate guiding mechanism. The rack (22) may be connected to a penetration member (5), which is consequently extruded from the housing (2) with the same effect as in the first embodiment. The penetration member (5), comprising a pushing rod (3) and a probe (4) at or near its tip (5a) is provided with a guiding mechanism that centres the penetration member (5) in the housing (2) and/or the inner cylinder (14).

[0034] In a third embodiment of the pushing device (1), the mechanism (30) to convert a movement of a force transmission means (39) is as shown schematically in Fig. 6. The pushing device (1) is shown inside a drill pipe (150). The pushing device (1) may again have a housing (2) and an inner cylinder (14) or a wall with another shape and/or cross section, fixed inside the housing (2). A gear (33) with a central axis (34) provided at a fixed position relative to the housing (2) is positioned to engage with two parallel racks (32, 39), one on each side of the gear (33). The first rack (39) is connected to the wire (130) and functions as a force transmission means (39). By pulling on the wire (130), a movement of the rack (39) in direction (D1) relative to the housing (2) of the pushing device (1) is converted to rotation of the gear (33). The rotation of the gear (33) results in a movement of the second rack (32) in the opposite direction (D2) of the movement of the first rack (39). The second rack (32) is connected to a penetration member (5), which is consequently extruded from the housing (2) with the same effect as in the first and second embodiments.

[0035] In a fourth embodiment, the pushing device (1) comprises another mechanism to convert a movement of the force transmission means (49) in one direction into a movement in the penetration direction (D2). In that case the force necessary to bring about a movement of the penetration member (5) is not delivered by the wire (130) on which the pushing device (1) is suspended, but is generated by an electromotor (42) provided inside the pushing device (1). Fig. 7 shows one example of such a force transmission mechanism (40). The electromotor (42)

drives a spindle (43) which is connected to a cylindrical part (46) of the penetration member (5) by way of matching threads. A rotary movement of the spindle (43) is thereby transferred to a linear movement of the penetration member (5) bearing the probe or sampler (4). In the example shown in Fig. 7, the spindle (43) is provided inside the electromotor (42). Other configurations are possible, where the spindle (42) and the electromotor (43) are not provided concentrically but as separate units. Only the spindle (42) may be provided concentrically with the threaded part of the penetration means (5), while the rotation of the electromotor (43) is transmitted to the spindle (42) by a known transmission mechanism. When the electromotor (42) is turning in one direction, the penetration member (5) with the probe (4) is pushed out to penetrate the ground. After finishing the testing, the probe (4) can be retracted by turning the electromotor (42) in the opposite direction. In this embodiment the wire is only used to lower the pushing device (1), locking it inside the drill pipe (150) and to hoist it back up after completion of the testing. The electromotor (42) can be provided with a battery pack (not shown) for supplying it with power. The battery pack may be lowered with the pushing device (1). In that case the electromotor (42) can be remote controlled, so that no electrical wire has to be provided to be lowered with the pushing device (1) down the string of drill pipes (150). If the electromotor (42) relies on an external power supply at the surface for its power, an electrical connection does have to be provided. In that case part of the advantage of not having to supply a connection apart from the hoisting wire (130) is lost, but an electrical wire is still easier to handle during lowering and hoisting than a vulnerable hydraulic connection.

[0036] A further aspect of the invention is directed towards a specially adapted penetration member or penetration piston rod (5). Conventional penetration piston rods (5) when subjected to a load of 100 kN, tend to buckle or kink when they are made longer than 1,5 m. The penetration piston rod (5) as described hereafter can comprise a composite material, which makes it stiffer than the conventional rods. Preferably, the penetration piston rod (5) comprises a composite inner core and a metal sleeve. The sleeve is preferably made of steel. It has been found that when the penetration piston rod (5) is constructed of an inner core made of a composite material and a steel sleeve, it is up to 3 times as stiff as a standard full steel penetration piston rod, and it allows for a much longer penetrating stroke than the standard penetration piston rod. In fact it at least doubles the penetration depth when applying the same force, because the penetration piston rod (5) of the invention is resistant to buckling and kinking up to a length that is at least twice as long as in the conventional penetration piston rods. As a result with each stroke at least twice the penetration depth of the conventional penetration piston rod can be reached, so the number of changes between drilling and CPT testing can at least be halved. That considerably enhances the testing productivity. Such a penetration pis-

ton rod (5) is especially advantageous in combination with a device or method of the invention, but can also be applied with conventional CPT devices and methods, with similar effect.

[0037] In the embodiments described, data acquired by the probe can be stored in a back-up memory (15) integrated in the probe or in the pushing device. Stored data can, for example, be read when the CPT pushing device is back at the surface. Alternatively, all data can be sent to the surface in real time, so that they can be read and recorded in real time.

[0038] A DTH CPT system according to the present invention can comprise:

- a CPT pushing device according to one of the embodiments described above
- a winch
- a wire that connects the CPT pushing device to the winch at the surface and which can be used to lower and hoist the device through a string of drill pipes and, in at least one embodiment, to generate the penetrating force
- a data acquisition system or a sampling system

[0039] DTH-CPT is the most refined high-grade geotechnical soil investigation technique available. The improvements introduced by the present invention make it easier to apply the technique and extend its working range.

[0040] In some embodiments, the penetrating force of the piston rod of the DTH-CPT pushing device can be a direct result of the pulling of the wire. It is the DTH-CPT pushing device that converts the pulling force into a penetrating force.

[0041] As described, the design of the piston rod can be such that it allows for much deeper soil penetration in one stroke compared to the present day design.

[0042] A design of a DTH-CPT system presented in the current document can be much less complex than the present day design, and therefore it can be considerably cheaper to build, much more reliable, and can stand for considerably enhanced testing productivity.

[0043] A design of the DTH-CPT pushing system presented in current document can be such that it does not need a complex umbilical with hydraulic hoses, reducing the chance for leakages, thus reducing environmental hazards to a minimum.

[0044] A design of the DTH-CPT system presented in current document can be much less complex than the present day design, reducing the need for highly trained and experienced operating personnel.

[0045] The invention is by no means limited to the specific examples of embodiments of the invention described the foregoing specification. Various modifications and changes may be made therein without departing from the scope of the invention as set forth in the appended claims.

Claims

1. A ground penetrating device for penetration testing and/or ground sampling, comprising:

- a housing (2);
- a locking arrangement (6) for locking the housing (2) inside a borehole;
- a penetration member (5) arranged to move relative to the housing (20) in a penetration direction (D3); and
- a force transmission element (9, 29, 39, 43) provided movably relative to the housing (2),

characterised by

- a conversion mechanism (10, 20, 30, 40) for converting a movement of the force transmission element (9, 29, 39, 43) in a direction (D1) different from the penetration direction (D3) to a movement of the penetration member (5) in the penetration direction (D3).

2. A ground penetrating device according to claim 1, wherein the device is a cone penetration testing device (CPT), especially a down the hole cone penetration testing device (DTH-CPT) capable of doing CPT tests from within a string of drill tubes.

3. A ground penetrating device according to claim 1 or 2, wherein the penetration device (5) comprises a tip (5A) to be pushed into the ground, especially statically.

4. A ground penetrating device according to any one of claims 1 - 3, wherein the direction different from the penetration direction (D3) is a direction (D1) opposite to the penetration direction (D3).

5. The ground penetrating device according to any one of claims 1 - 4, wherein the force transmission element (9, 29) comprises a means for attaching a cable (130).

6. A ground penetrating device according to any of claims 1 to 5, wherein the conversion mechanism (10) comprises a chamber (11, 12) for containing hydraulic fluid and a piston (9a) connected with or forming part of the force transmission element (9), such that a hydraulic fluid that is displaced when the force transmission element (9) moves in the direction (D1) opposite to the penetration direction (D3) pushes the penetration member (5) in the penetration direction (D3).

7. A ground penetrating device according to any of claims 1 to 6, wherein the housing (2) is substantially cylindrical, the force transmission element (9) com-

- prises a substantially cylindrical element and the penetration member (5) comprises a piston rod (3) , wherein preferably a position for the piston rod (3) is concentric with the substantially cylindrical housing (2) and at least part of the chamber (11, 12) for containing the hydraulic fluid is provided between the position for the piston rod (3) and the housing (2). 5
8. A ground penetrating device according to any of claims 1 to 7, wherein the conversion mechanism (20) comprises one of: 10
- a rack-and-pinion construction (22, 23);- a rack-gear-rack construction (32, 33, 34); and
 - a spindle construction (43) , wherein the force transmission element comprises a spindle (43) and an electromotor (42). 15
9. A ground penetrating device according to any of claims 1 to 8, further comprising a measuring device (4) or a sampling device (4) provided at or near a or the tip (5a) of the penetration member (5). 20
10. A ground penetrating device according to any of claims 1 to 9, further comprising a memory device (15) for data acquisition. 25
11. A penetration member (5) for a ground penetration device, comprising an inner core made of a composite material and a steel sleeve. 30
12. A ground penetrating device according to any of claims 1 to 10, comprising a penetration member (5) according to claim 11. 35
13. A system for ground penetration testing, comprising: 40
- a ground penetrating device according to any of claims 1 to 10 or claim 12;
 - a cable (130); and
 - a hoisting device (120) for lowering the cable (130) and exerting a pulling force on the cable (130). 45
14. A system for ground penetration testing according to claim 13, further comprising a drill pipe (140, 150), wherein the locking arrangement is preferably provided for locking the housing (2) relative to the drill pipe. 50
15. A system for ground penetration testing according to claim 13 or 14, further comprising a device for reading and recording measured data at the surface in real time. 55
16. Method for executing a ground penetrating test, comprising the steps of:
- lowering a ground penetrating device (1) suspended on a cable (130) in a drill pipe (140, 150),
 - locking the ground penetrating device (1) in the drill pipe (150) near the bottom of the drill pipe (140, 150),
 - moving a penetration member (5) by converting a movement in a direction (D1) other than a penetration direction (D3) in a movement of the penetration element (5) in the penetration direction (D3).
17. Method of claim 16, wherein the step of moving the penetration member includes moving the penetration member in the penetration direction (D3) by moving a force transmission element in the direction (D1) other than the penetration direction (D3) and converting movement in the direction (D1) in a movement in direction (D3) resulting in a ground penetrating action of the penetration member.

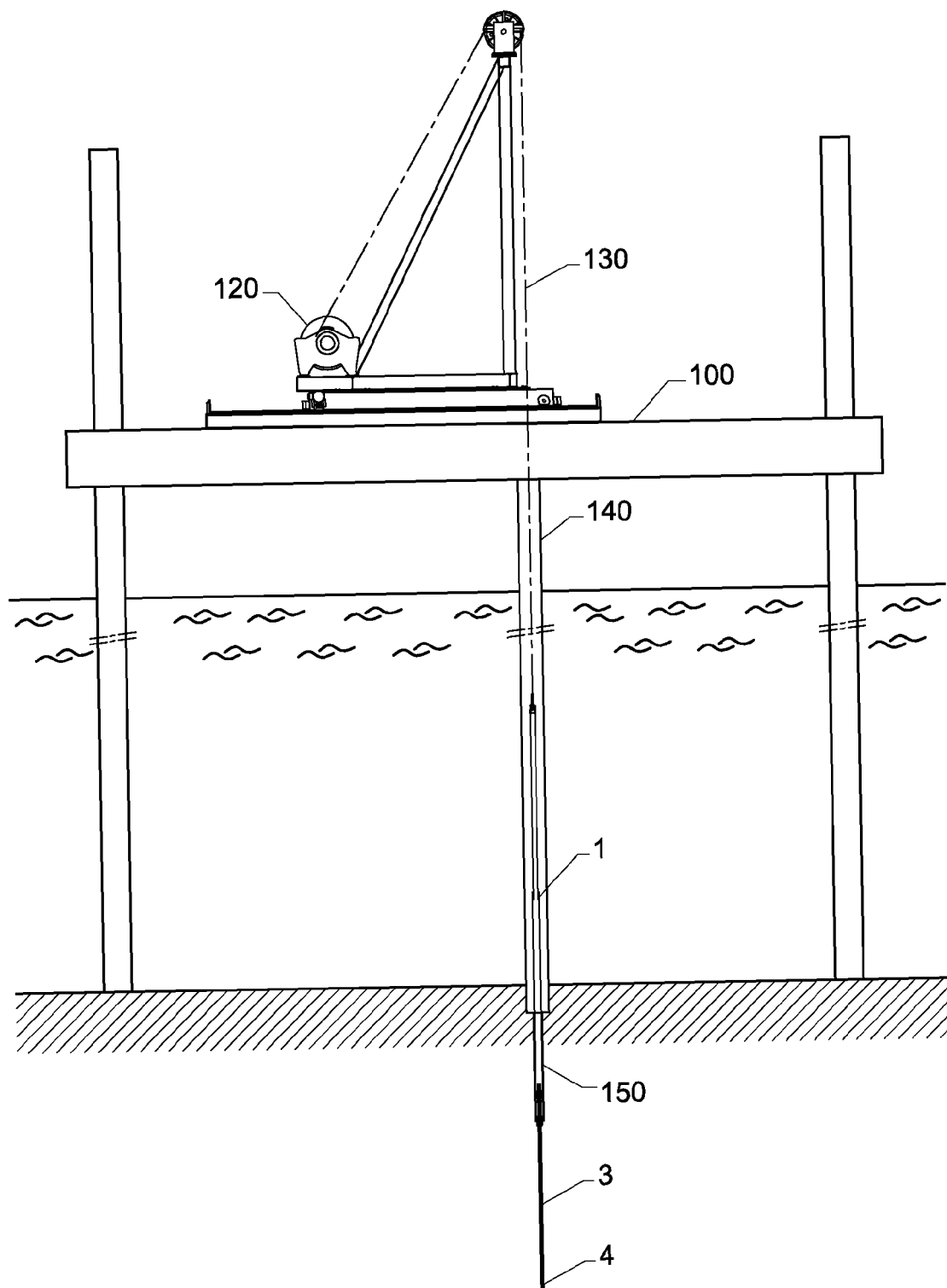


Fig. 1

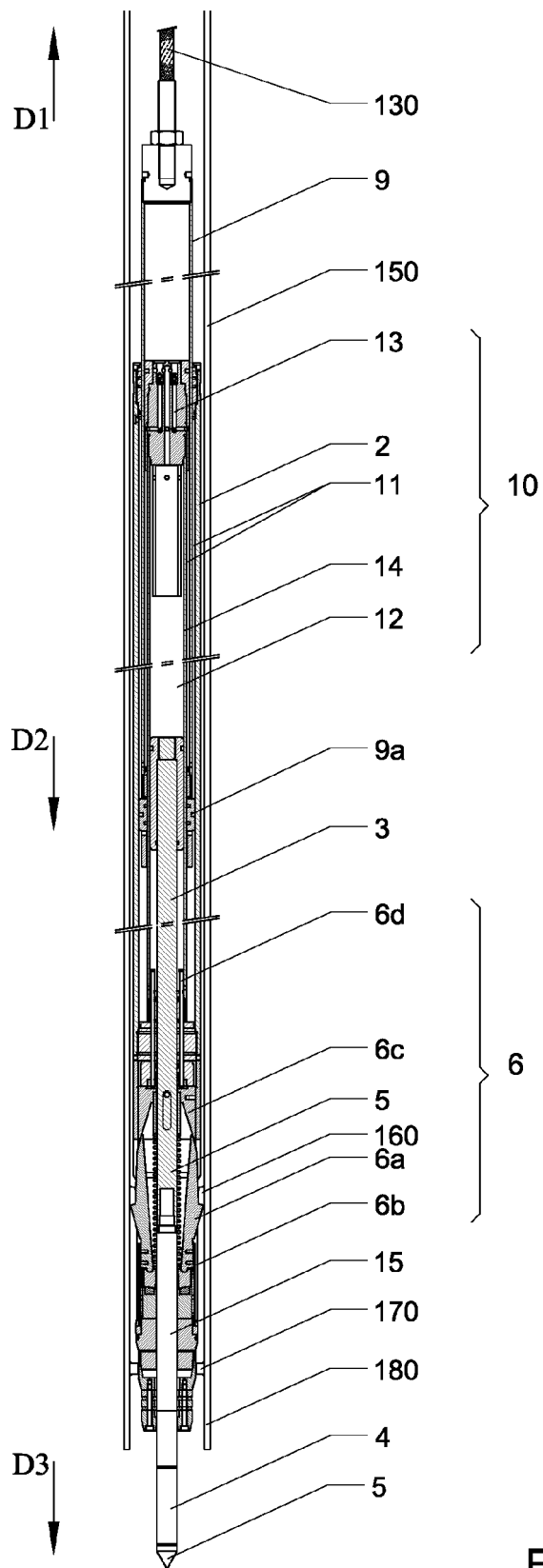


Fig. 2

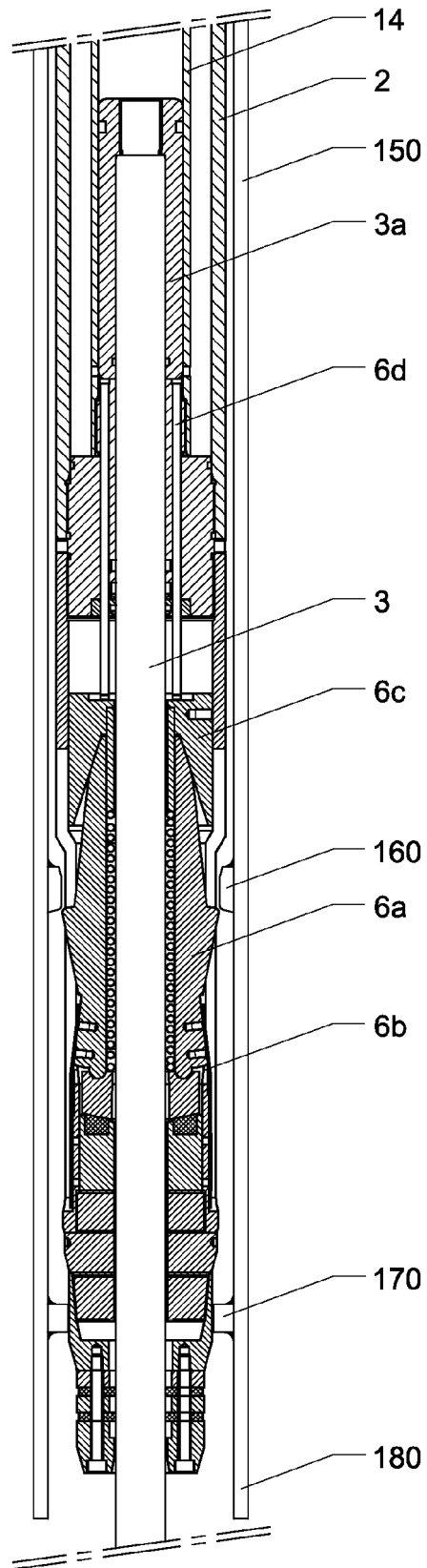


Fig. 3

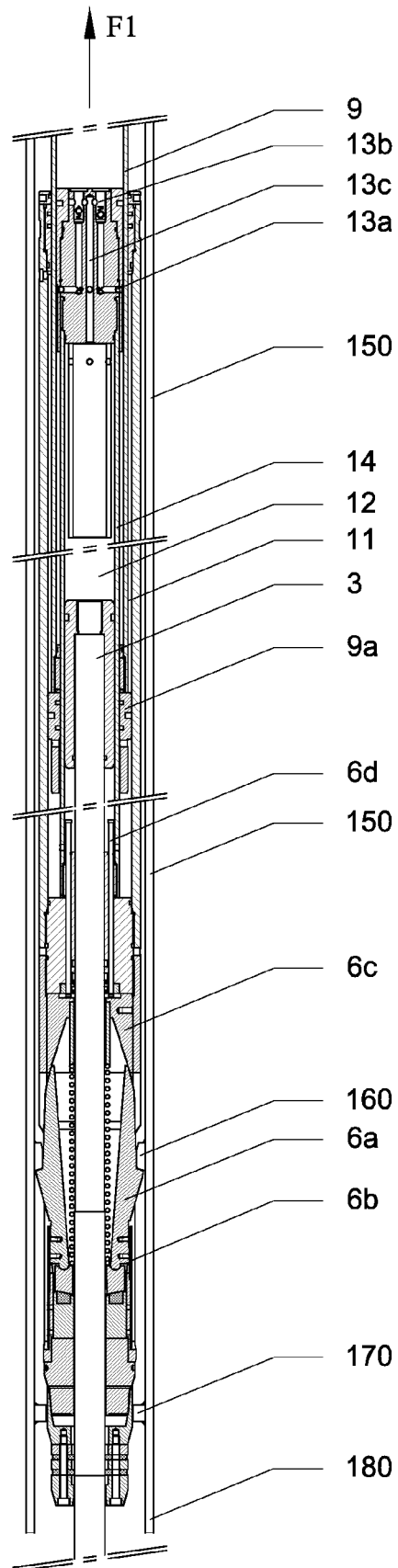


Fig. 4A

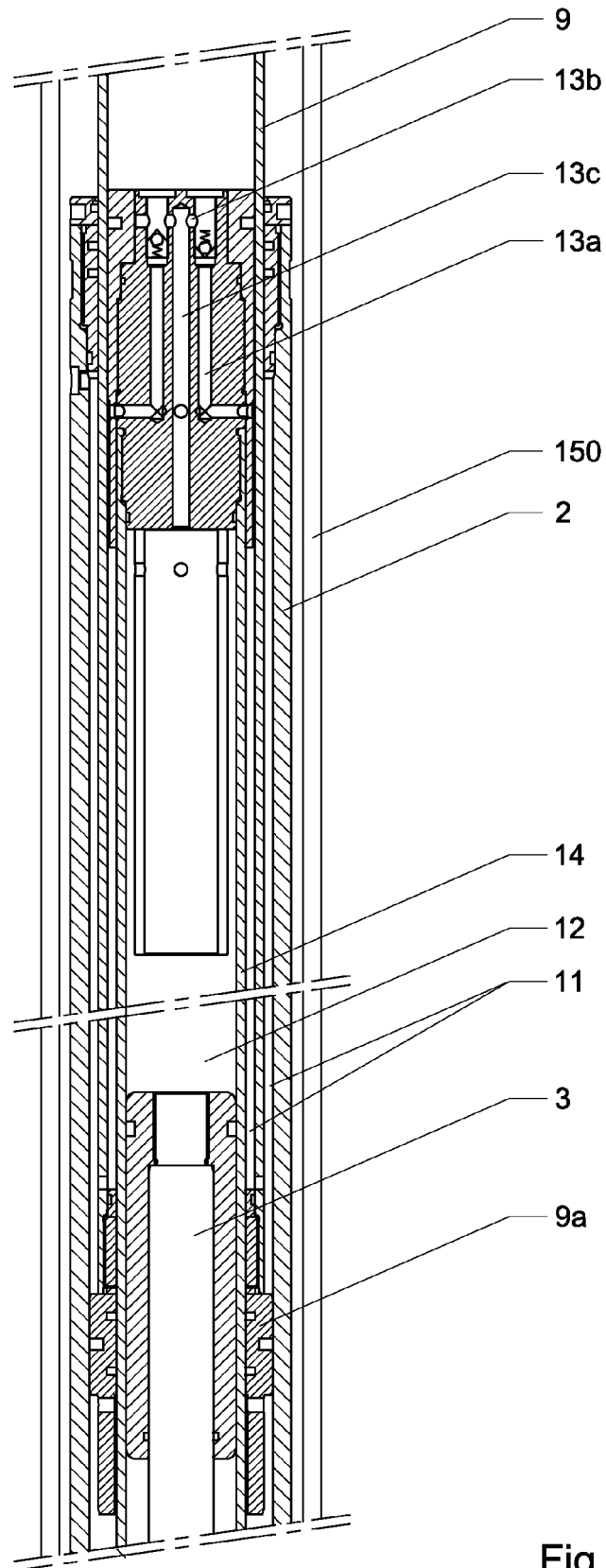


Fig. 4B

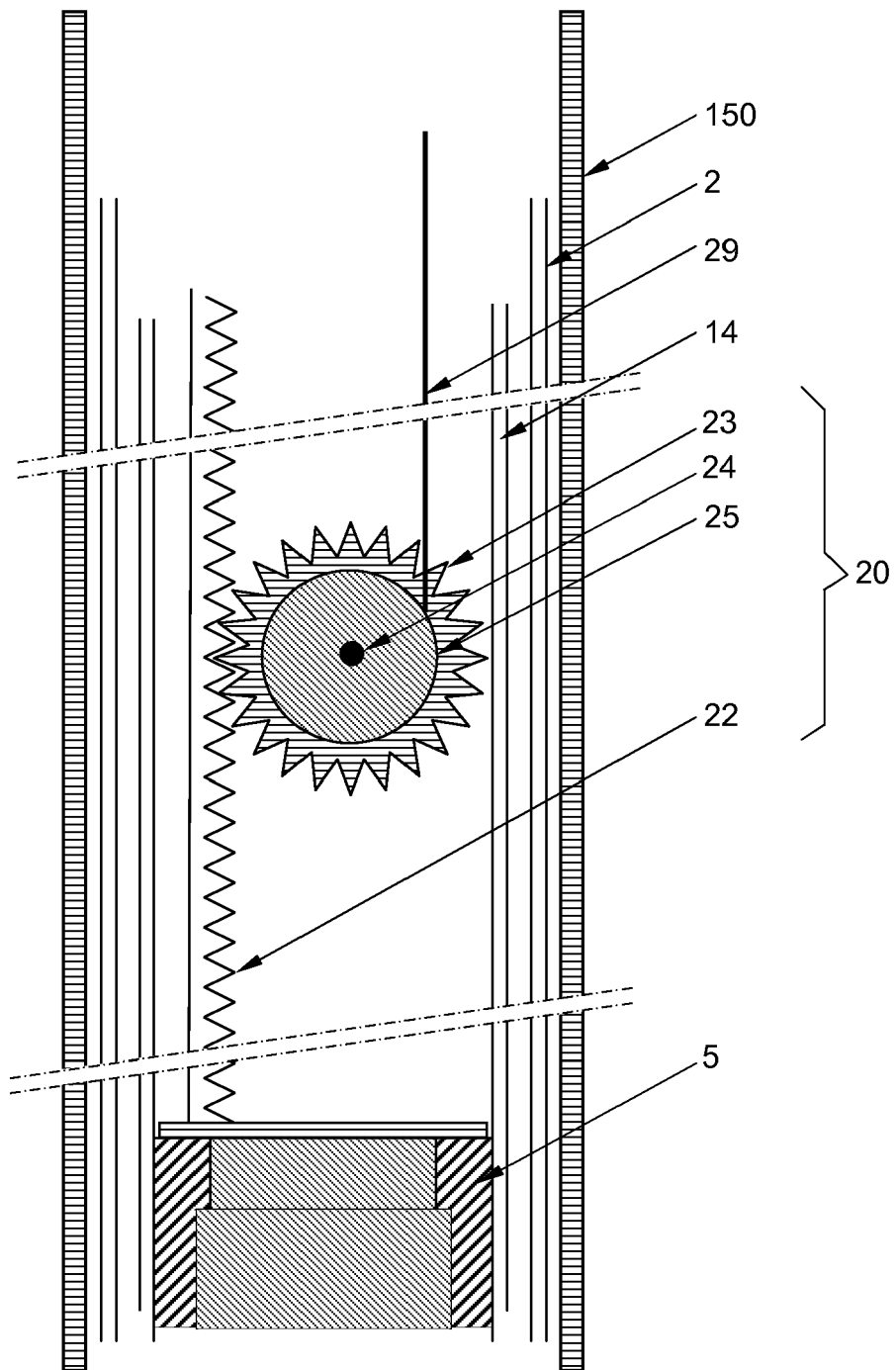


Fig. 5

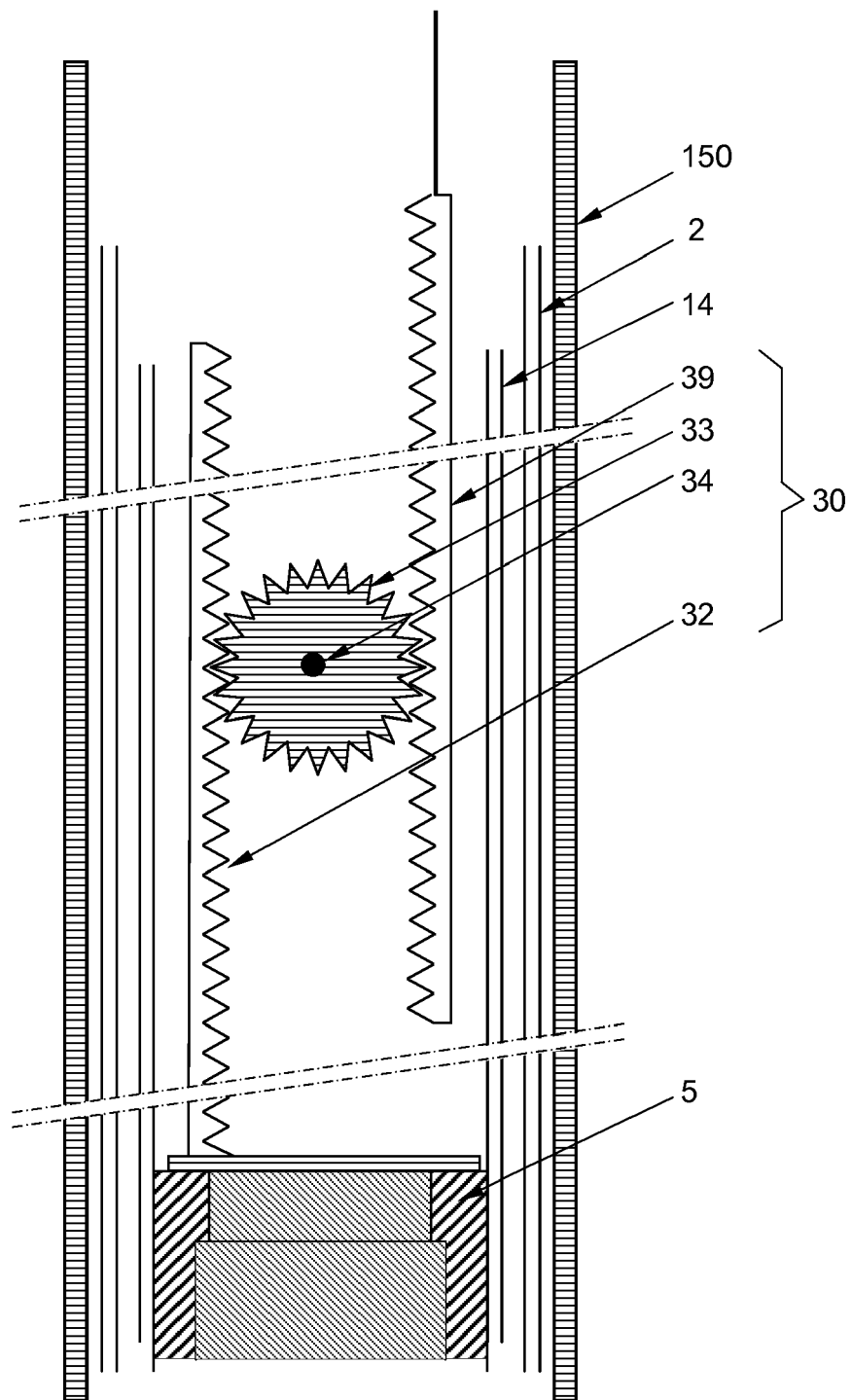


Fig. 6

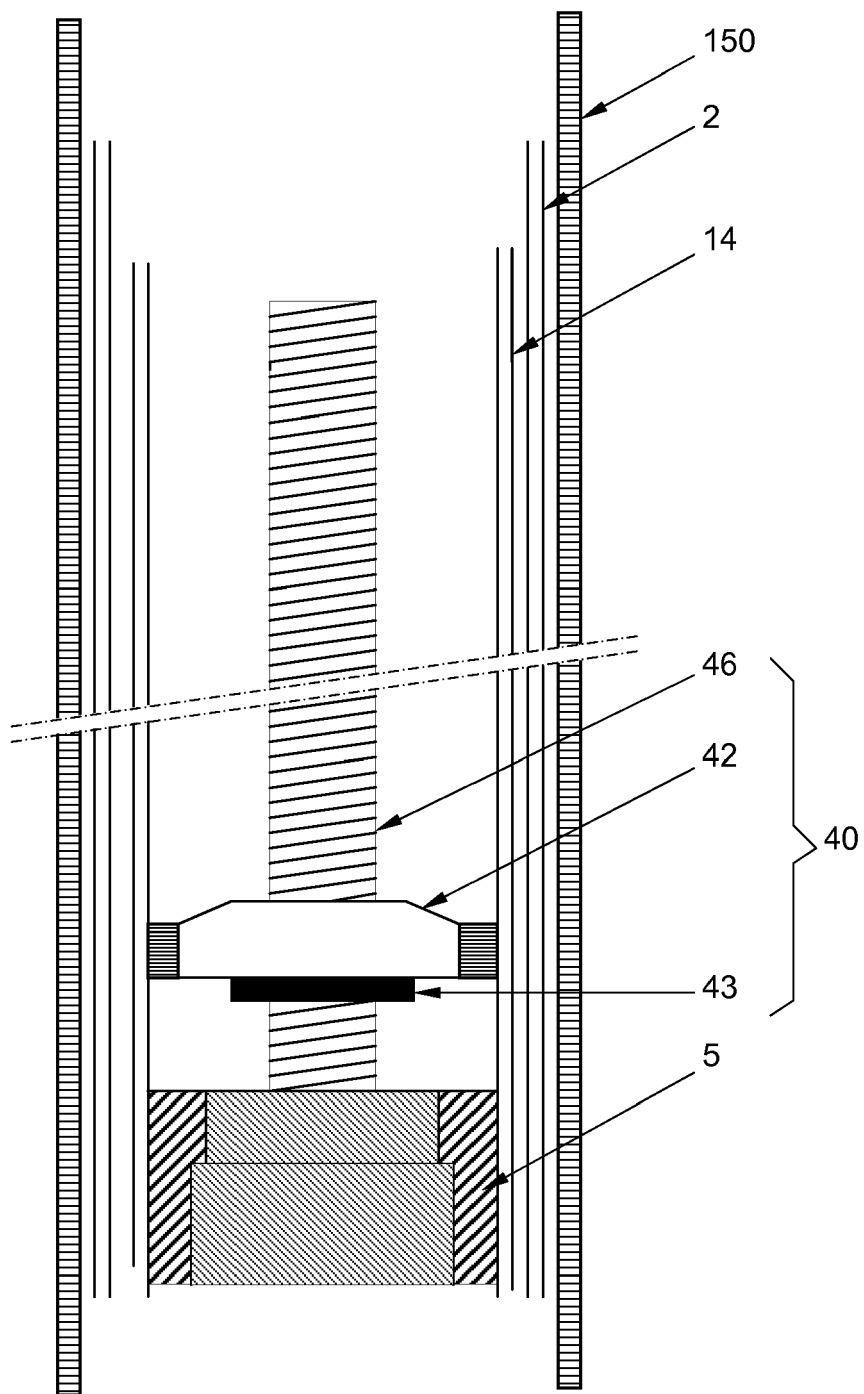


Fig. 7

REFERENCES CITED IN THE DESCRIPTION

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