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(54) Title: SEABED DRILL SYSTEM

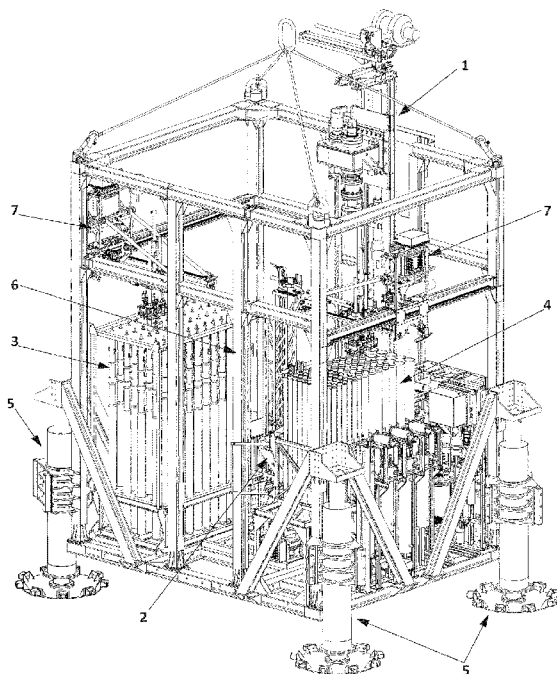


FIG. 1

(57) Abstract: The seabed drill system comprises a drilling mast module (1) for placing drill rods (42), said drill rods (42) drilling the seabed, and it is characterized in that it also comprises: - a core barrel rack module (3) comprising a frame (33) for placing core barrels (31); - a drill rack module (4) comprising a frame (41) for placing the drill rods (42); and - a remotely operated arm module (2) provided with an arm (21) for collecting and moving said drill rods (42) and/or core barrels (31) from the rack modules (3, 4) to the drilling mast, or vice versa. It permits a modular concept, which enables different borehole diameter options and multiple combinations of push-sampler tools in situ test in the same deployment.



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SEABED DRILL SYSTEM

DESCRIPTION

5 The present invention refers to a seabed drill system, for geotechnical site investigation for the installation of an offshore wind park.

Background of the invention

10 The towers, cables and other structures that constitute an Offshore Wind (OW) park are supported on the seafloor. The characteristics of the soils and rocks present at any site are crucial for the OW park design: insufficient site knowledge may seriously jeopardize installation and/or operation. Developers have stopped projects at a very advanced stage quoting poor geotechnical conditions.

15 Geotechnical Site Investigation (GSI) for OW today implies taking soil and rock samples from scarce and expensive jack-up platforms and/or specialist geotechnical drilling vessels in a process that is slow and very sensitive to weather conditions. Geotechnical site investigation is thus a bottleneck for OW park developers.

20 Remotely operated submarine sampling systems make site investigation more resilient to bad weather conditions and use smaller, easily available supply vessels. They can thus offer a substantial reduction in development cost and extend the time window for GSI.

25 OW field developers face increasing construction costs. Substructure optimization is desirable but cannot be easily achieved without enough geotechnical site investigation.

30 Improve acquisition and range of geotechnical data for the OWT design contributes to reducing the safety factors and implies an effective cost reduction in the overall design. The customers of offshore soil investigations for OW developments are ultimately the field developers (utilities, renewable investors). They may act through their in-house technical team or through a subcontractor. In a few cases a contractor

may be responsible for acquiring soil data, but this is still rare.

Several companies provide now subsea drilling on a commercial basis to the offshore GSI market at large, but they have entered the offshore GSI wind market only briefly. There are various reasons for this:

All the existing seabed drilling machines were designed to sustain up to several km of water pressure. While the machines may be conceptually similar, this water depth requirement results in far more expensive components, requiring larger investment and maintenance costs.

Existing seabed drills are all restricted to either wire-line or drill-string perforation. These methods are both capable of perforating most terrains, but they have optimal performance in a more restricted set of circumstances (wire-line in competent rock, drill-string in soft soil). In fact, one complaint levered sometimes at previous seabed drill systems, has been a relatively low recovery rate. OW development sites are very large by offshore standards and in them it is likely to find varied terrains.

Existing seabed drills have not been designed with a modular approach that enables to use smaller and lighter configurations in circumstances when all the depth drilling capability is not required.

Not all the existing seabed drills have the ability to also carry on CPT (Cone Penetration Testing). The inputs from seismic CPT are key to advanced design of monopiles, the foundation of choice for most OW.

Not all the existing seabed drills have developed their own in-house robotics. Using off-the-shelf robotics makes difficult the fast manipulation of drill strings and samplers.

Because of carrying larger in-built costs and because the relative efficiency gains of seabed drilling are even larger in deepwater, these machines have oriented themselves to the deepwater market, where more lucrative rates can be obtained than in OW.

Indeed, information from market sources indicates that the ongoing daily rates commandeered by the more commercially active systems are well above even those of geotechnical drilling vessel. Of course, they compensate this by more efficient performance and, crucially in certain deepwater environments, by their weather resilience.

It should be also noticed that for operators that are heavily invested on geotechnical drilling vessel there is little incentive in developing cheaper systems that might be seen as a market-wide alternative to geotechnical drilling vessel. From that point of view expensive, deepwater oriented, niche seabed units are preferable.

Therefore, the objective of the present invention is to provide a seabed drill system designed with a modular approach that enables to use smaller and lighter configurations in circumstances when all the depth drilling capability is not required.

Description of the invention

With the seabed drill system of the invention said drawbacks can be solved, presenting other advantages that will be described hereinafter.

The seabed drill system according to the invention comprises a drilling mast module for placing drill rods, said drill rods drilling the seabed, and it is characterized in that it also comprises:

- a core barrel rack module comprising a frame for placing core barrels;
- a drill rack module comprising a frame for placing the drill rods; and
- a remotely operated arm module provided with an arm for collecting and moving said drill rods and/or and core barrels from the rack modules to the drilling mast, or vice versa.

Advantageously, the seabed drill system according to the invention can also comprise a base comprising a plurality of adjustable feet and an acoustic sample checker module that detects the presence of a sample inside a core barrel.

Furthermore, the seabed drill system according to the invention can also comprise

two gantry automated arm modules, one for the core barrel rack module and one for the drill rack module, which also collect and move the core barrels and the drill rods, respectively.

5 Preferably, the acoustic sample checker module comprises an acoustic probe, such as a short range acoustic phased-array probe.

According to a preferred embodiment, each gantry automated arm module comprises a grabber for grabbing one drill rod or one core barrel.

10

Preferably, the base can comprise four feet which are independently adjustable in height.

15

Advantageously, the arm of the remotely operated arm module comprises a grabber at one of its ends, said grabber being rotatable, and the arm of the remotely operated arm module is preferably mounted on a position table, which is rotatable.

20

According to a preferred embodiment, the frame of the core barrel rack module and/or the frame of the drill rod rack module comprise security locks for fixing the core barrels and/or the drill rods in their position in the frame.

25

The drill system according to the invention responds to a modular concept, which enables different borehole diameter options and multiple combinations of push-sampler tools in situ (CPT) test in the same deployment. The main features of the drill system according to the invention are:

30

- operational in water depths up to 500 m;
- continuous drilling and/or soft-soil sampling up to 100 m depth below sea floor;
- acoustic sample retrieval check at the seafloor;
- continuous push CPTu unit up to 100 m depth below sea floor;
- seismic measurement unit integrated in CPTu;
- real-time acquisition of drilling and probing (CPTu) parameters;
- selection and installation of the tools to be used. It can be adapted or modified in each investigation to be performed;

- the system lands on the seabed and stabilizes. Two twin overhead lines are used for power cables and lifting;
- drilling: rotation with inverse mud circulation;
- better daily rates than those currently commanded by drilling vessels or large jack-up systems;
- increased flexibility in planning (not need to wait for good weather and/or for specialist drilling vessel);
- health and safety: no drill operators acting on the vessel floor, that results in an intrinsically safer operation;
- better adapted to obtain design parameters of use in OW foundation design, with consequent cost savings in infrastructure design.

Brief description of the drawings

For a better comprehension of what has been disclosed, some drawings are attached in which, diagrammatically and only as a non-limitative example, a practical embodiment is shown.

Fig. 1 is a perspective view of the drill system according to one embodiment according to the invention;

Fig. 2 is a perspective view of the drilling mast module of the drill system according to the invention;

Fig. 3 is a perspective view of the remotely operated arm module of the drill system according to the invention;

Fig. 4 is a perspective view of the core barrel rack module of the drill system according to the invention;

Fig. 5 is a perspective view of the drill rod rack module of the drill system according to the invention;

Fig. 6 is a perspective view of the acoustic sample checker module of the drill system according to the invention;

Fig. 7 is a perspective view of the gantry automated arm module of the drill system according to the invention; and

Figs. 8-12 are perspective views showing how the operation of the drilling system according to the present invention.

Description of a preferred embodiment

The seabed drilling system of the invention according to one non-limitative embodiment is shown in Fig. 1.

5

The drilling system according to this embodiment comprises the following modules:

- a drilling mast 1;
- a remotely operated arm 2 provided with a grabber 22 for collecting and moving drill rods 42 and core barrels 31;
- 10 - a core barrel rack 3 for placing the core barrels 31;
- a drill rock rack 4 for placing the drill rods 42;
- a base 5 comprising feet 51;
- an acoustic sample checker 6 that detects the presence of a sample inside a core barrel 31;
- 15 - two gantry automated arms 7, one for the core barrel rack 3 and one for the drill rock rack 4, which also collect and move the core barrels 31 and the drill rods 41, respectively.

Hereinafter a description of each module is provided:

20

- Drilling mast module 1:

As shown in Fig. 2, the drilling mast module 1 according to this embodiment comprises a winch 11, a plurality of clamps 12, a flushing head 13, a head carriage 14 with side shift, a rotary head 15, a heavy duty mast 16, a feed cylinder 17 and a base support 18.

25

The height of this drilling mast 1 module is variable, e.g. between 3 and 9 meters, and the section of the cylinder can be also changed for providing more or less force. Furthermore, this module can include or not the winch 11.

30

- Remotely operated arm module 2:

As shown in Fig. 3, this module comprises a remote operated hydraulic arm 21, a

heavy duty grabber 22 and a position table 23.

The hydraulic arm 21 can be programmed for carrying out a lot of operations, both manually and automatically. E.g. this hydraulic arm 21 can provide a maximum load of 300 Kg at 2,500 mm, and a closed loop position of each axis permits an easy operator guidance and automation.

The heavy duty grabber 22 provides, e.g. a 75° wrist rotation and a 135 mm opening, and the position table 23 has a fixed height and provides a 350° turn.

- Core barrel rack module 3:

This module comprises a plurality of core barrels 31 and it can comprise several bit outer barrels 32, a rack frame 33 for securing the barrels 31, 32 and a transport and mobilization security lock system 34.

This module is configured according to the scheme of geotechnical provisions, and it can include up to 110 barrels per rack, and each barrel can be of 1,500 mm length.

- Drill rack module 4:

This module comprises a modular frame 41, a plurality of drill rods 42, a security lock 44 and a gliding tray 45.

The modular frame 41 comprises several separated sections, each one for every rod size, which an individual locking device, which is configurable according to the expected operations.

- Base module 5:

This module comprises a plurality of adjustable feet and its main functions are to stabilize the perpendicularity of the drill pipe of the seabed drill on the sea bed, and gently landing on the sea bottom to minimize deformation by impact of the borehole and set the unit to seabed slopes.

- Acoustic sample checker module 6:

5 This module comprises a support frame 61 for recovering a core barrel and an acoustic probe 62. This probe is preferably a short range acoustic phased-array probe that detects in few seconds the presence of soil sample in the core and at which height of recovery has been possible, and it could be also used as a general indicator of soil density and particle size.

10 The main function of this module is to detect the presence of physical sample inside the core barrel, previously to the recovery in the borehole top, in such a way that can be assessed the quality of each partial probe operation and thus allow for corrections in the next operation.

15 With this module it is possible to get the evolution in the effective recovery of each sample (which is very important in soft soils) from the first operation until his complete wireline hoisting inside the borehole, transport operation of core barrels to the samples rack and the hoisting of the complete underwater module up to the surface, with variations of temperature, pressure and water.

20

- Gantry automated arm module 7:

This module comprises a hydraulic system 72 provided with a gearmotor 75 with a closed loop position control mounted on a guided beam 73, and a grabber 74.

25

The grabber 74 is preferably double and grabs a drill rod 42 or a core barrel 31, because the drill system comprises two gantry automated arm modules, one for the core barrel rack module 3 and one for the drill rod rack module 4.

30

The grabber 74 can be moved in any direction along the x, y, z axes, to correctly place the drill rods 42 and the core barrels 31 in position.

Hereinafter the operation of the seabed drill system of the invention according to a preferred embodiment will be described.

- Placement on the seabed

5 Firstly, the drill system according to the invention must be placed on the seabed in a gently manner. To this end, the drill system comprises the base 5 in which the height of the feet 51 is independently adjustable for compensating the slopes or obstacles of the seabed.

- Placement of the bit outer barrels

10

Then, several bit outer barrels 32 are firstly placed by the arm 21 in the drilling mast module 1 (Fig. 8).

- Perforation

15

Once placed, the rotary head 15 rotates and the feed cylinder 17 pushes simultaneously the bit outer barrels 32 (Fig. 9). The rotation speed depends on the kind of seabed.

20

When the bit out barrels 32 arrive to the maximum depth, it is considered that the seabed sample occupies its position inside them.

- Extraction and checking of the samples

25

Once perforated, the rotary head 15 is moved apart, the grabber 74 take the barrels 32 with the samples.

30

The grabber 75 moves the barrels 32 with the sample to the sample checker 6, and once checked, the grabber 75 releases them and the arm 21 places them in the modular frame 41 (Fig. 10).

The check consists in a longitudinal acoustic sweep in different sections, and analyzing the acoustic echo it can be determined if there is a solid sample or just water.

- Placement of a hollow core barrel

5 Once the sample is in its position, the next core barrel 31 will be collected by the grabber 74 to place it in determined position in the rack frame 33, and then it is collected by the arm 21, which will place it inside the several barrels 32.

10 Once placed, the core barrel 31 slides freely inside the barrels 32 up to the rotary head 15, where it is engaged with a section of the barrel 32. Then, the rotary head 15 rotates and pushes again said core barrel 31.

- Placement of a drill rod

15 Then, a drill rod 42 is placed inside the barrels 32 for perforating a next length. The gantry arm 7 is moved to the first available drill rod 42, grabbing it and placing it at a predetermined external zone of the modular frame 41 (Fig. 11).

20 Once in this zone, the arm 2 takes the drill rod 42 and it is also grabbed by the grabber 74 of the gantry arm 7 (Fig. 12), and the drill rod 42 is rotated to be threaded, and the drill rod 42 is placed inside the barrels 32 for perforating an additional length.

The recovery of the drill rods 42 is done in the same way, but with inverted steps.

25 Even though reference is made to a specific embodiment of the invention, it is clear for a person skilled in the art that the disclosed seabed drill system is susceptible of variations and modifications, and that all the details cited can be substituted by other technically equivalent ones, without departing from the scope of protection defined by the attached claims.

30

CLAIMS

1. Seabed drill system, comprising a drilling mast module (1) for placing drill rods (42), said drill rods (42) drilling the seabed, characterized in that it also comprises:
- 5 - a core barrel rack module (3) comprising a frame (33) for placing core barrels (31);
- a drill rack module (4) comprising a frame (41) for placing the drill rods (42); and
- a remotely operated arm module (2) provided with an arm (21) for collecting and moving said drill rods (42) and/or and core barrels (31) from the rack modules (3, 4) to the drilling mast, or vice versa.
- 10
2. Seabed drill system according to claim 1, wherein it also comprises a base (5) comprising a plurality of adjustable feet (51).
3. Seabed drill system according to claim 1, wherein it also comprises an acoustic sample checker module (6) that detects the presence of a sample inside a core barrel (31).
- 15
4. Seabed drill system according to claim 1, wherein it also comprises two gantry automated arm modules (7), one for the core barrel rack module (3) and one for the drill rack module (4), which also collect and move the core barrels (31) and the drill rods (41), respectively.
- 20
5. Seabed drill system according to claim 3, wherein the acoustic sample checker module (6) comprises an acoustic probe (62).
- 25
6. Seabed drill system according to claim 5, wherein the probe (62) is a short range acoustic phased-array probe.
7. Seabed drill system according to claim 4, wherein each gantry automated arm module (7) comprises a grabber (74) for grabbing one drill rod (42) or one core barrel (31).
- 30
8. Seabed drill system according to claim 2, wherein the base (5) comprises four feet (51) which are independently adjustable in height.

9. Seabed drill system according to claim 1, wherein the arm (21) of the remotely operated arm module (2) comprises a grabber (22) at one of its ends.

5 10. Seabed drill system according to claim 9, wherein said grabber (22) of the arm (21) is rotatable.

11. Seabed drill system according to claim 1, wherein the arm (21) of the remotely operated arm module (2) is mounted on a position table (23).

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12. Seabed drill system according to claim 11, wherein said position table (23) is rotatable.

15

13. Seabed drill system according to claim 1, wherein the frame (33) of the core barrel rack module (3) and/or the frame (41) of the drill rod rack module (4) comprise security locks (33, 44) for fixing the core barrels (31) and/or the drill rods (42) in their position in the frame (33, 41).

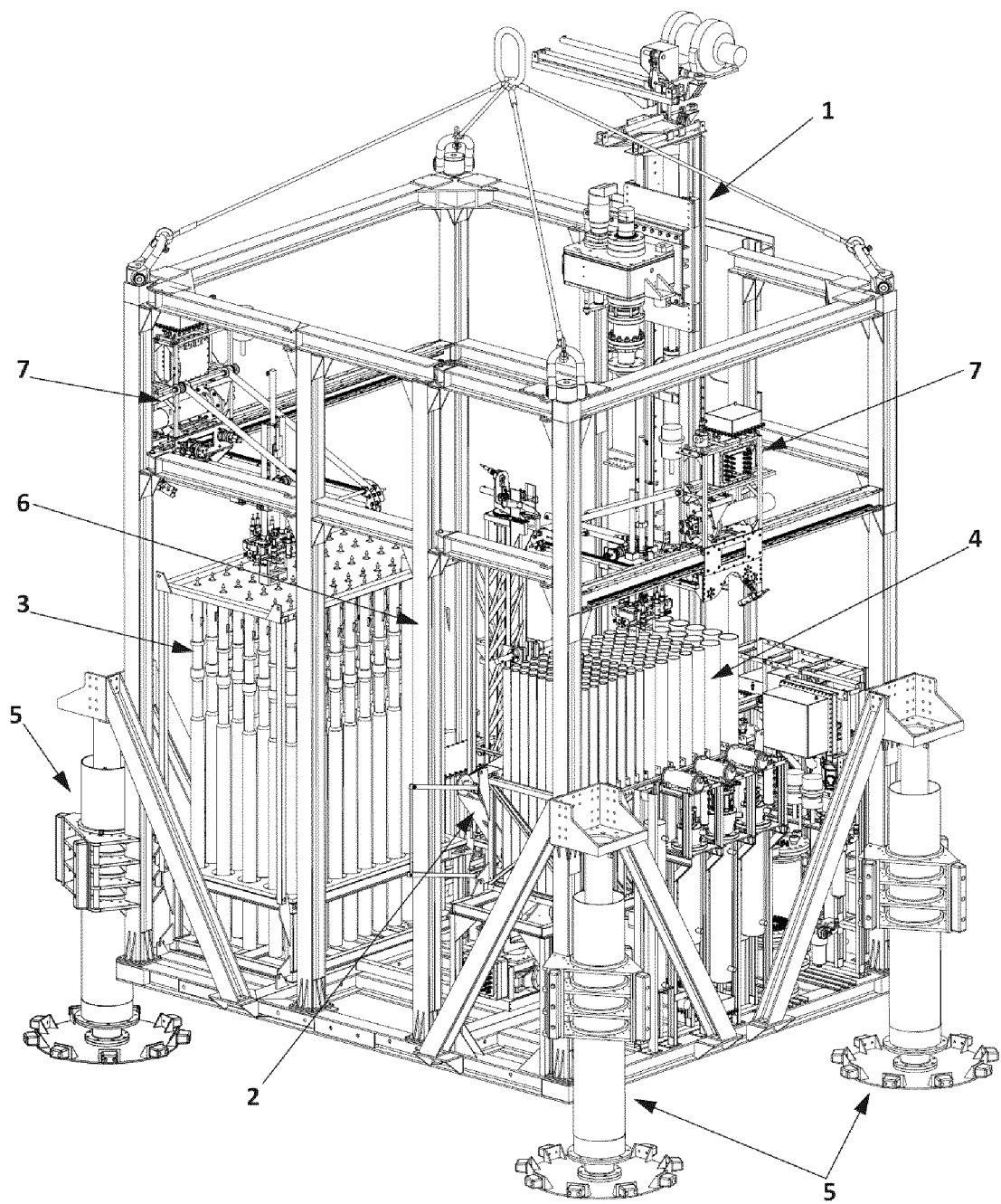


FIG. 1

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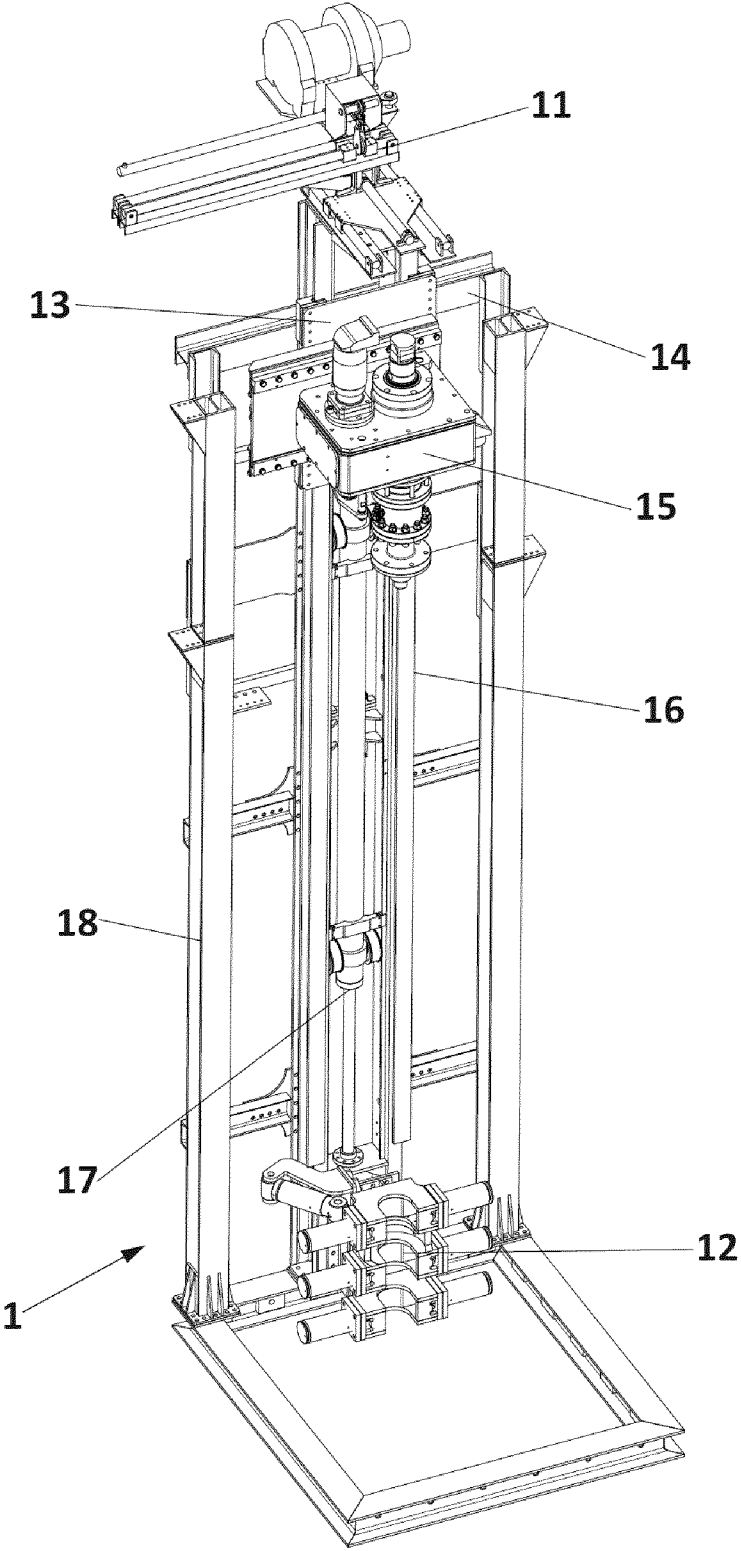
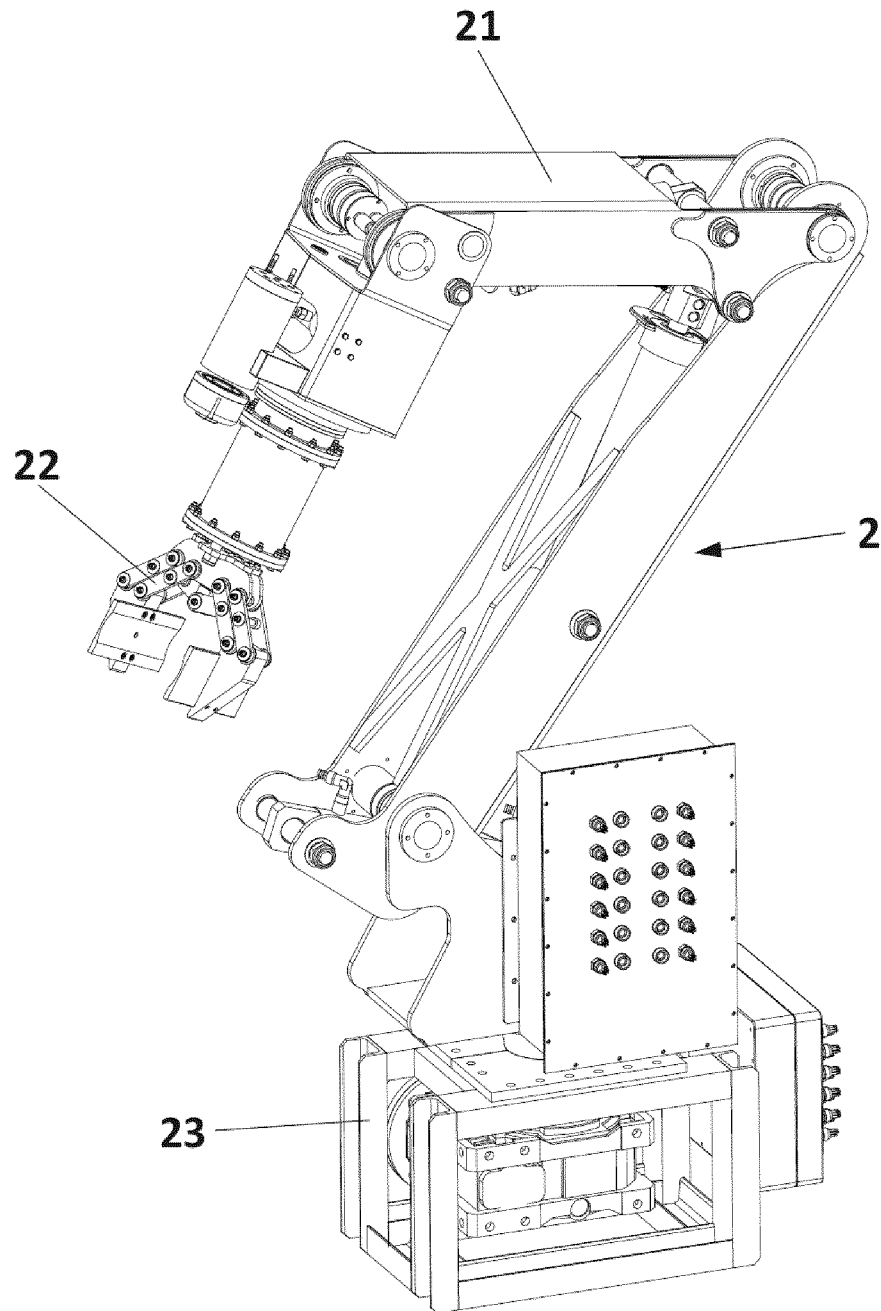


FIG. 2

3/10

**FIG. 3**

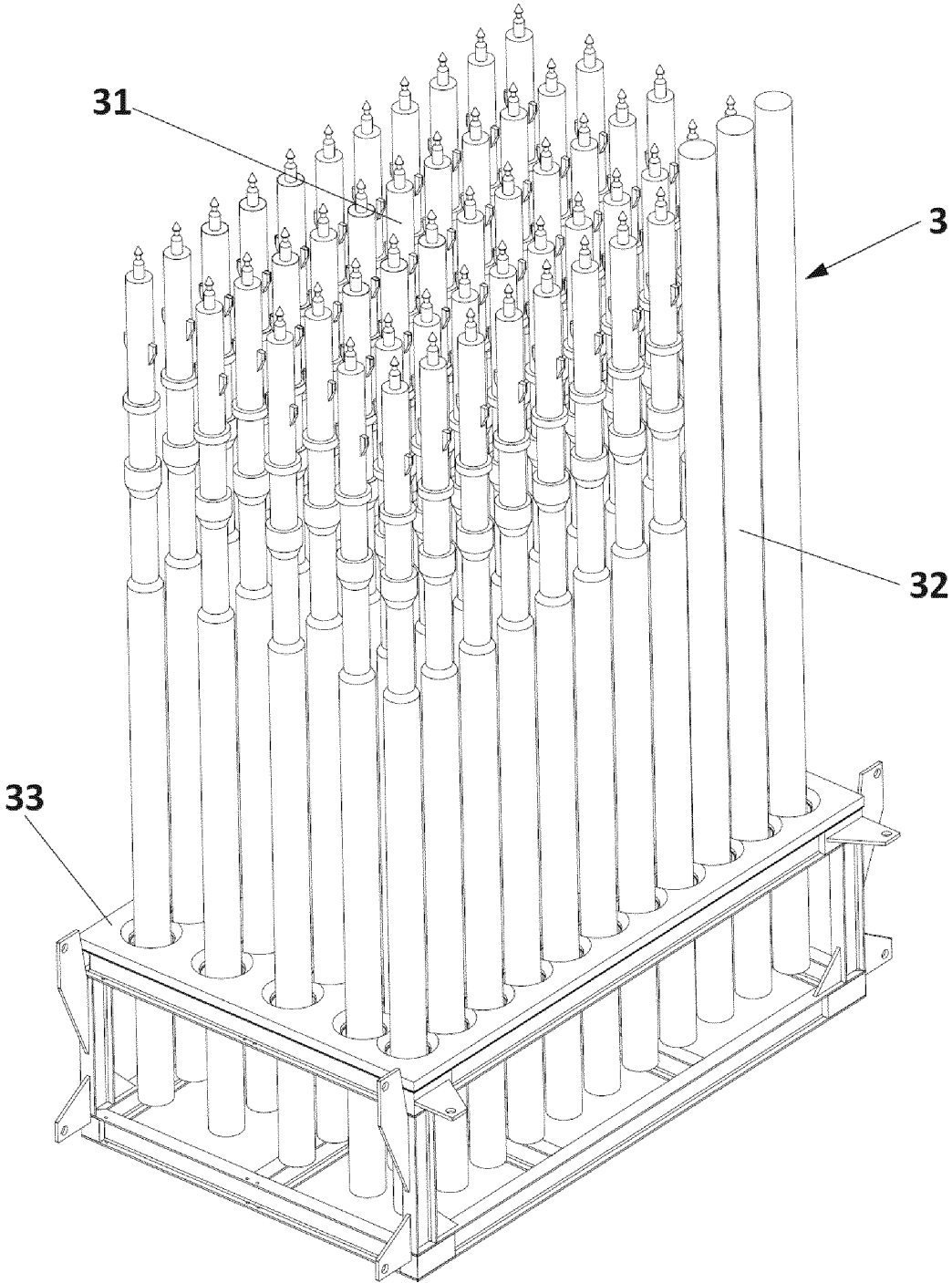


FIG. 4

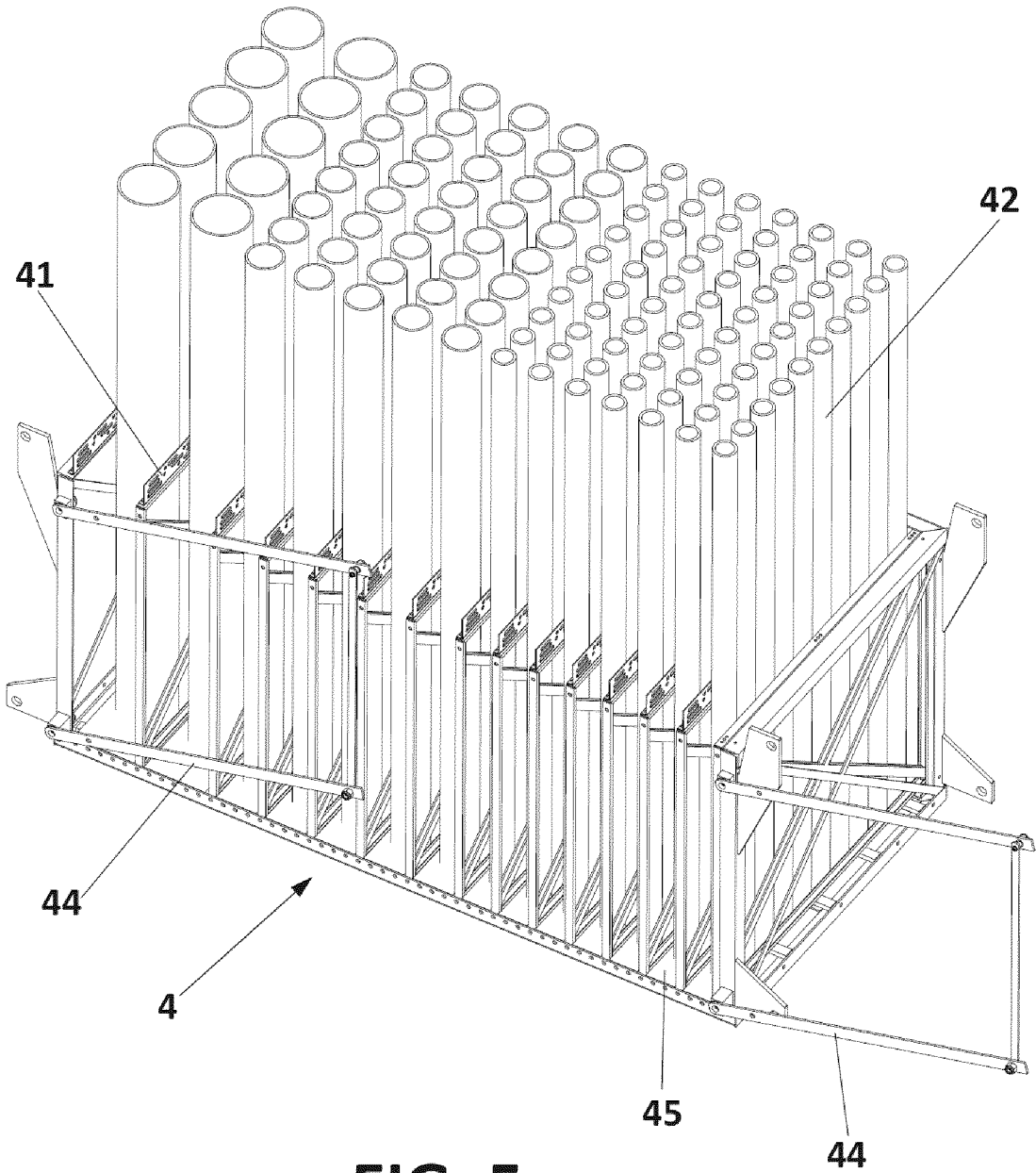


FIG. 5

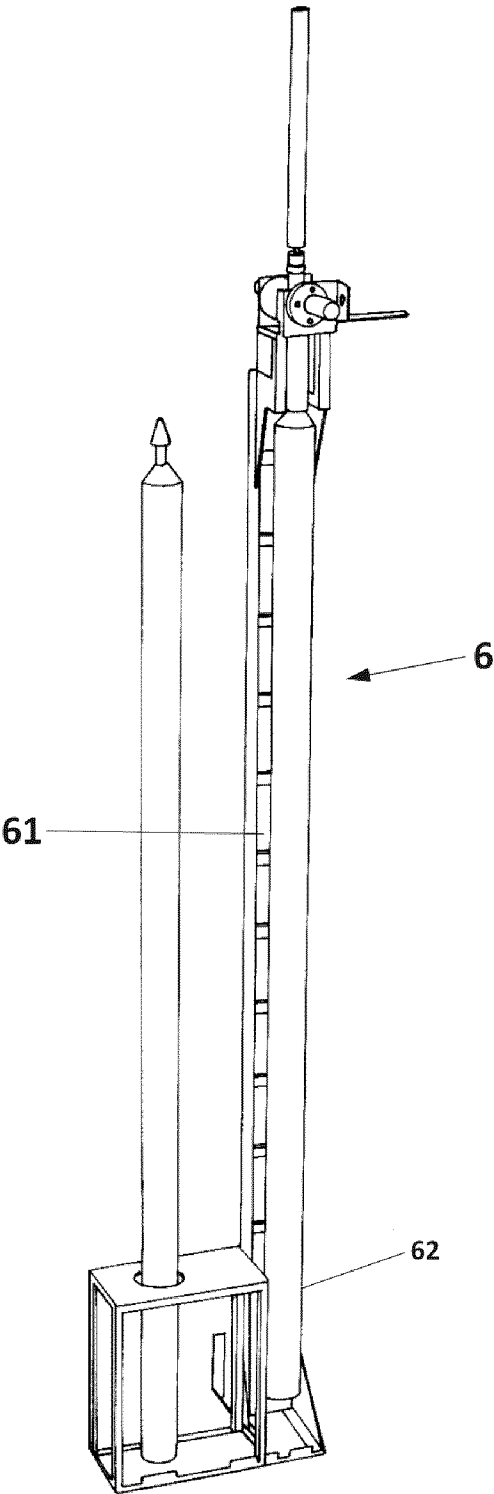


FIG. 6

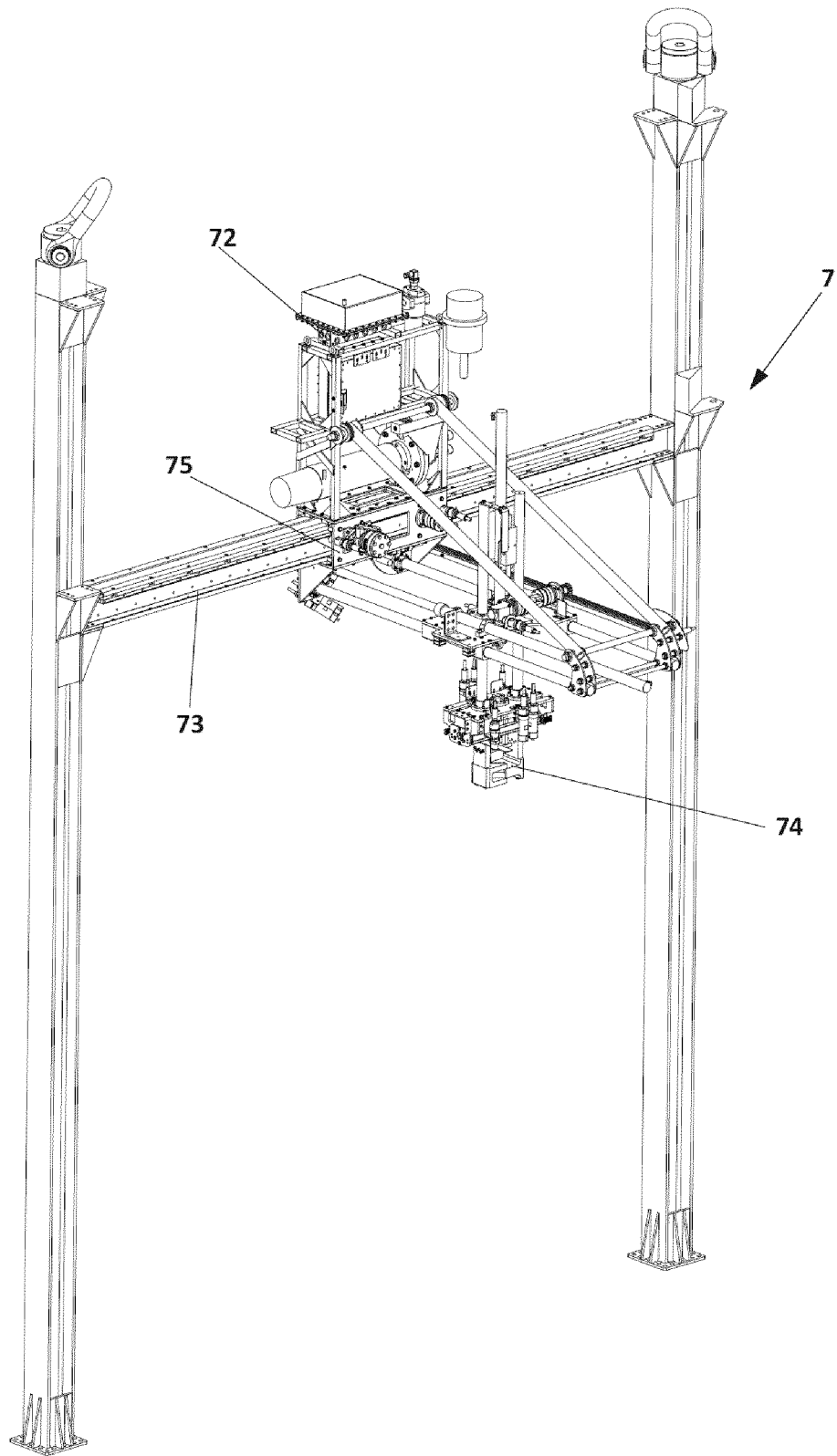


FIG. 7

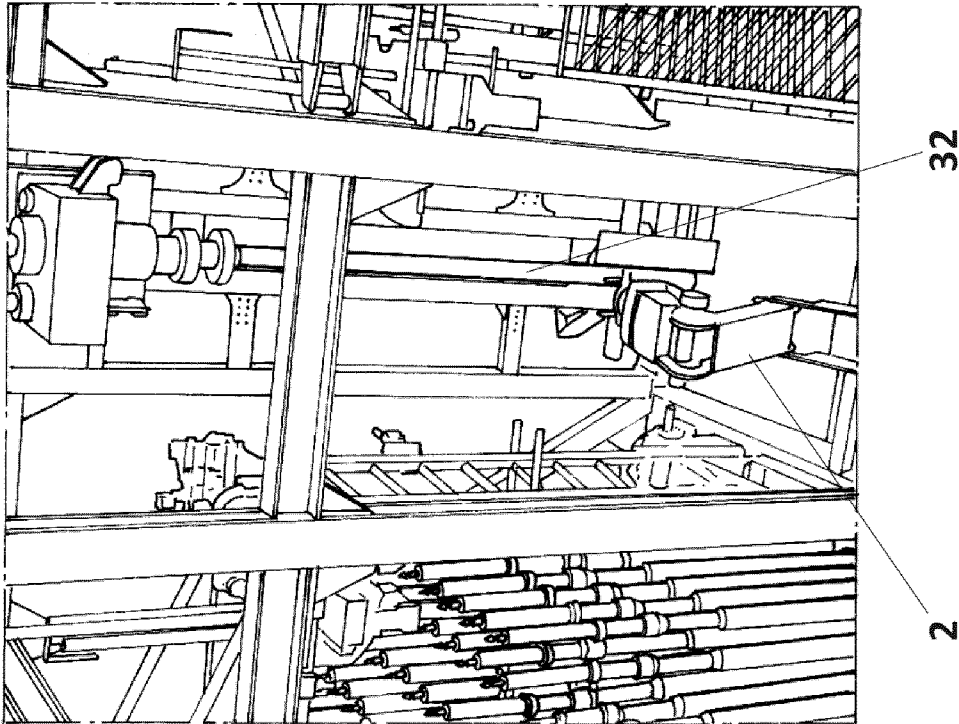


FIG. 9

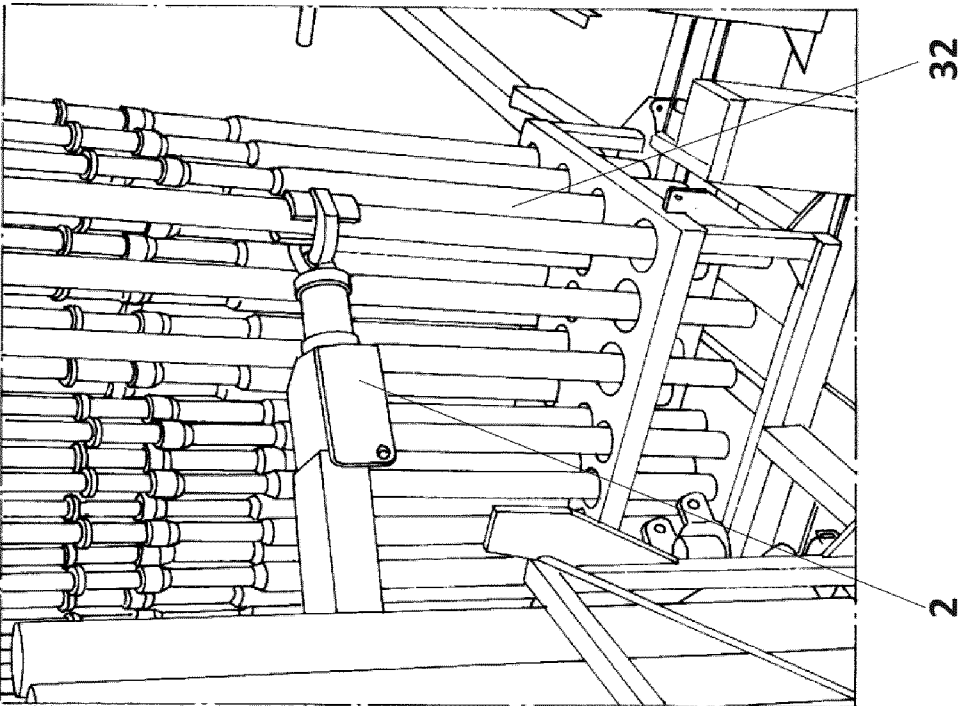


FIG. 8

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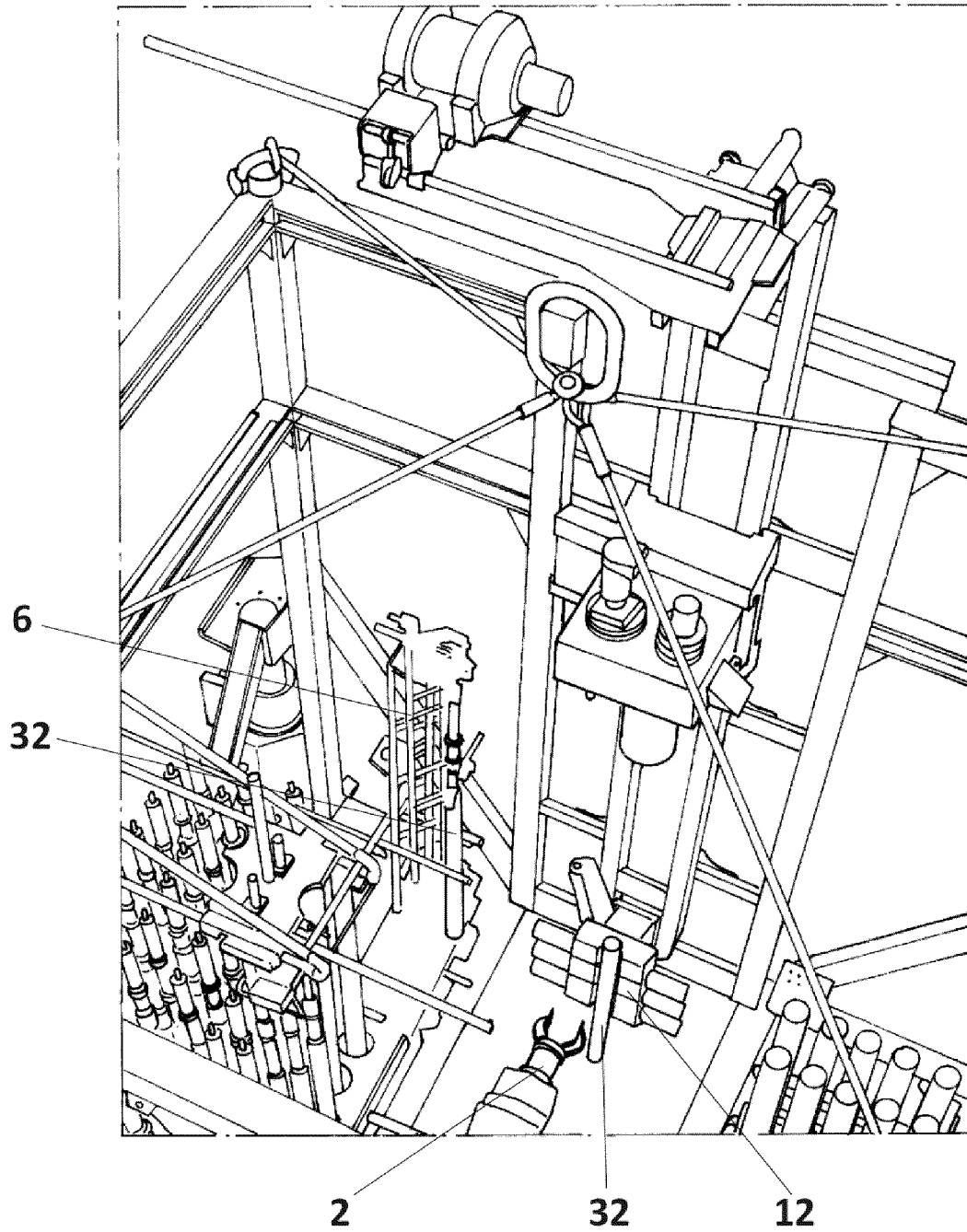


FIG. 10

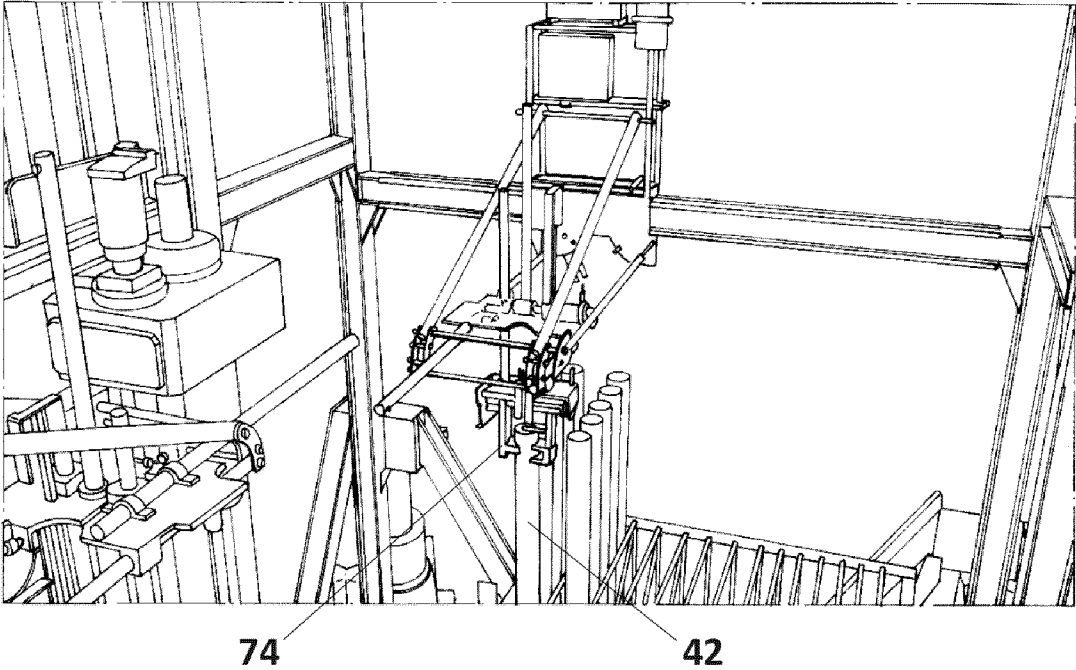


FIG. 11

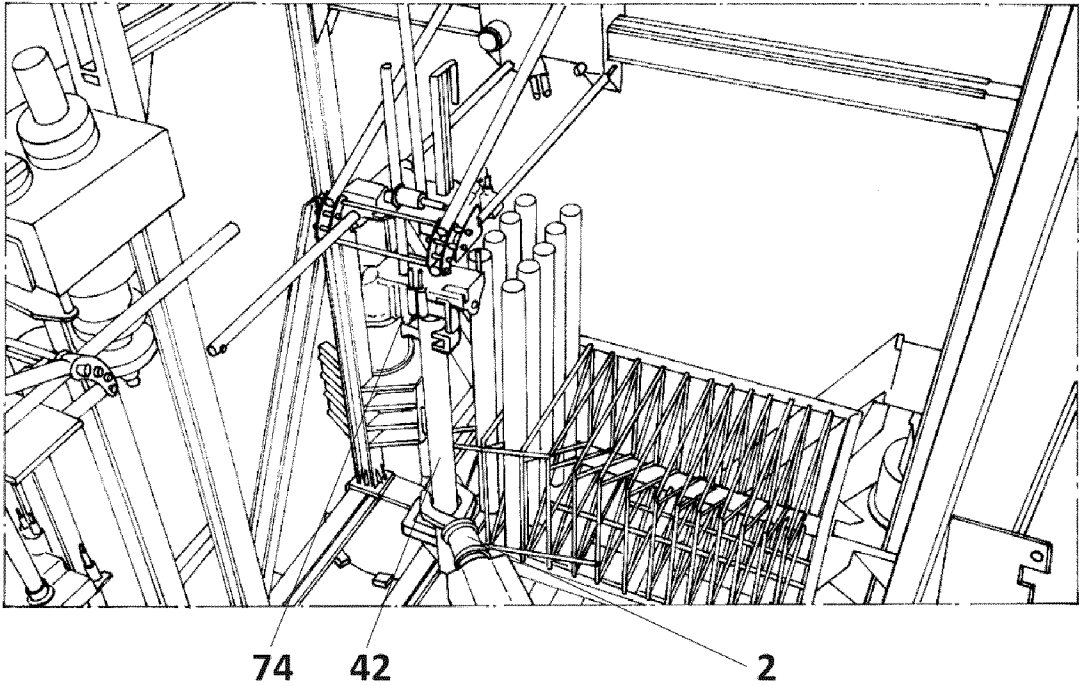


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/080997

A. CLASSIFICATION OF SUBJECT MATTER INV. E21B7/02 E21B7/124 E21B15/02 E21B19/14 E21B49/02 E02B17/00 ADD. According to International Patent Classification (IPC) or to both national classification and IPC														
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) E21B E02B Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data														
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td>US 2013/206476 A1 (INNES RONALD W [CA] ET AL) 15 August 2013 (2013-08-15) paragraph [0109] - paragraph [0118]; figures 1-4 paragraph [0162] - paragraph [0169]; figure 5 paragraph [0178]; figure 6 -----</td> <td style="text-align: center; vertical-align: top;">1,2,4, 7-12</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td>EP 2 860 341 A1 (SOIL MACHINE DYNAMICS LTD [GB]) 15 April 2015 (2015-04-15) paragraph [0027]; figure 1 -----</td> <td style="text-align: center; vertical-align: top;">1,9-12</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">X</td> <td>US 2009/255728 A1 (SPENCER ALLAN [US] ET AL) 15 October 2009 (2009-10-15) paragraph [0036]; figure 1 ----- -/-</td> <td style="text-align: center; vertical-align: top;">1,2,8</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	US 2013/206476 A1 (INNES RONALD W [CA] ET AL) 15 August 2013 (2013-08-15) paragraph [0109] - paragraph [0118]; figures 1-4 paragraph [0162] - paragraph [0169]; figure 5 paragraph [0178]; figure 6 -----	1,2,4, 7-12	X	EP 2 860 341 A1 (SOIL MACHINE DYNAMICS LTD [GB]) 15 April 2015 (2015-04-15) paragraph [0027]; figure 1 -----	1,9-12	X	US 2009/255728 A1 (SPENCER ALLAN [US] ET AL) 15 October 2009 (2009-10-15) paragraph [0036]; figure 1 ----- -/-	1,2,8
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X	US 2013/206476 A1 (INNES RONALD W [CA] ET AL) 15 August 2013 (2013-08-15) paragraph [0109] - paragraph [0118]; figures 1-4 paragraph [0162] - paragraph [0169]; figure 5 paragraph [0178]; figure 6 -----	1,2,4, 7-12												
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X	US 2009/255728 A1 (SPENCER ALLAN [US] ET AL) 15 October 2009 (2009-10-15) paragraph [0036]; figure 1 ----- -/-	1,2,8												
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.														
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Date of the actual completion of the international search 16 August 2016		Date of mailing of the international search report 24/08/2016												
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Strømmen, Henrik												

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/080997

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 741 320 A (HILFING K) 26 June 1973 (1973-06-26) column 3, line 54 - column 4, line 14; figure 12	1
A	----- CN 102 220 841 A (UNIV CHINA GEOSCIENCES WUHAN) 19 October 2011 (2011-10-19) abstract; figure 1 -----	1-13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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