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

(11) EP 3 363 952 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.08.2018 Bulletin 2018/34

(51) Int Cl.:
E02D 13/04 *(2006.01)* ***E02D 13/06*** *(2006.01)*

(21) Application number: **17157205.0**

(22) Date of filing: **21.02.2017**

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

(71) Applicant: **Seatools B.V.**
3281 NC Numansdorp (NL)

(72) Inventors:
- **Frumau, Johannes Carolus Laurentius**
  3072 WX Rotterdam (NL)
- **Pihl, Hans**
  4381 RL Vlissingen (NL)

(74) Representative: **De Vries & Metman**
Overschiestraat 180
1062 XK Amsterdam (NL)

(54) FOUNDATION PILE

(57) The invention relates to a template (1) comprising a plurality of guide members, preferably guide tubes (2), for guiding foundation elements, such as piles (30), during installation in an underwater ground formation, and a measuring device (10) to measure the height of a foundation element (30) in at least one of the guide members (2). The measuring device (9) comprises a sensor (15) that is attached to an arm (10) that is movable between a retracted position and an extended position. In the extended position of the arm (10), the sensor (15) is positioned inside, above or beneath the guide member (2) and can be lowered or lifted from the arm (10) and inside the guide member (2).

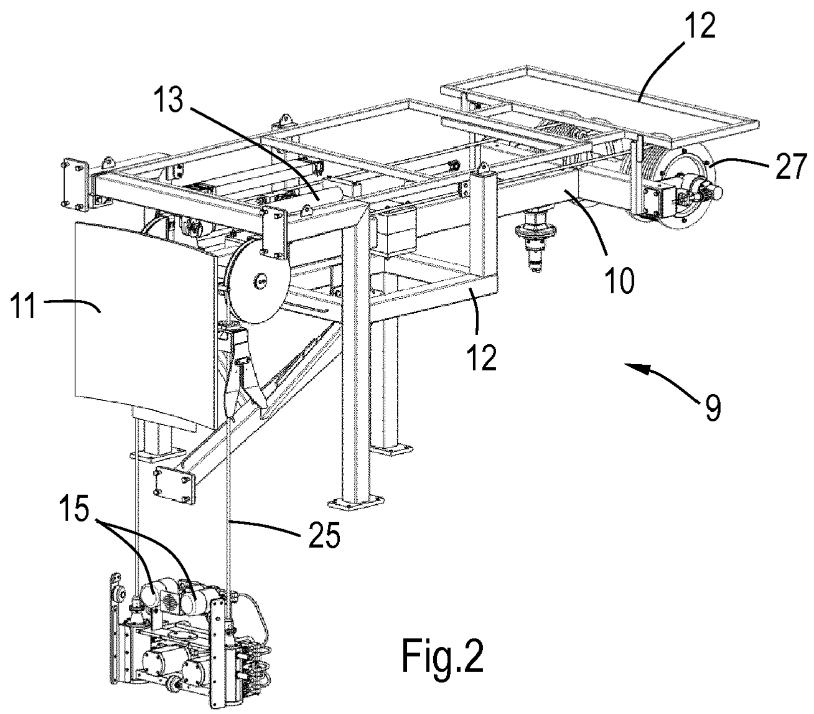

Fig.2

EP 3 363 952 A1

Description

[0001] The invention relates to a template comprising a plurality of guide members, preferably guide tubes, for guiding foundation elements, such as piles, during installation in an underwater ground formation, e.g. a seabed, and a measuring device for measuring the height of a foundation element, e.g. the stickup height of a pile after it has been driven into the underwater ground formation, in at least one of the guide members. The invention also relates to a measuring device for measuring the height of a foundation element in a guide member and to a method of installing a plurality of foundation elements.

[0002] US 5,244,312 relates to a system for installing a drilling template in a level orientation over an ocean floor. The drilling template is supported on a plurality of preset piles. The piles extend above the ocean floor. After the piles are set, their elevations are accurately determined, and pile-receiving sockets in the drilling template are finally fabricated to have depths corresponding to the respective piles to be received therein. Once the drilling template is lowered onto the piles, it is supported in a level orientation.

[0003] EP 2 492 401 relates to a device for manufacturing a foundation for a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a quantity of piles driven into an underwater bottom in a geometric pattern. As explained in EP 2 492 401, once all the piles have been arranged in the underwater bottom in the desired geometric pattern, thus forming the foundation, the jacket is arranged on the foundation formed by the quantity of piles by arranging legs of the jacket in the piles (also referred to as pin piling) or, in an alternative method, around the piles (also referred to as sleeve piling). The piles are adapted in both cases to be able to receive the legs of the jacket, for instance by providing hollow piles (pin piling) or hollow legs of the jacket (sleeve piling).

[0004] In addition to the correct positions of the piles, it is also important that the piles are arranged at the desired angle, e.g. substantially vertically, and that the height of the foundation piles arranged in the underwater bottom is the same, or in any case precisely known, before the jacket is arranged on the foundation piles. In order to determine the height of the piles arranged in the underwater bottom use is generally made of a diver or underwater robot which maps the situation in situ. This is time-consuming.

[0005] EP 2 492 401 discloses a device comprising a positioning framework of a number of mutually connected guide members, in particular guide tubes, arranged in a geometric pattern and adapted to receive and guide a pile to be driven into the underwater bottom, wherein the guide tubes comprise measuring means adapted to determine the height of a pile present in the guide tubes. In a preferred embodiment, the measuring means comprise a liquid gauge (CLEM unit) adapted to measure the vertical height of a stop which is movable from a lower reference height up to at least the upper edge of a pile present in the guide tube and which can be coupled to the pile.

[0006] It is an object of the present invention to provide an improved template and measuring device for measuring the height of a foundation element in a guide member of a template.

[0007] To this end, the template according to the present invention is characterised in that the measuring device comprises a sensor that is attached to an arm that is movable between a retracted position and an extended position, and in that, in the extended position of the arm, the sensor is positioned inside, above or beneath the guide member and can be lowered or lifted from the arm and inside the guide member. In an embodiment, in the retracted position, the sensor is positioned outside the guide member, at least outside guide cavity of the guide member.

[0008] The measuring system according to the present invention enables measuring a relatively large range, e.g. between 1 and 10 meters, of stickup heights with relatively little interference with the guide member or members. For example, the arm can be extended above the guide member or through a relatively small door in a guide tube and the sensor lowered into the guide member e.g. while suspended from the end of the arm. In another example, the arm can be extended beneath the guide member and the sensor lifted, e.g. by means of a telescoping column, along the outer wall of a foundation element present inside the guide member. In contrast, to measure heights in such a large range with a measuring device comprising a probe, sensor or feeler extending through slot in a guide tube, would require a vertical slot of 9 meters in the tube wall, which would seriously compromise the structural integrity of the guide tube, e.g. effectively render it a bent plate rather than a true tube.

[0009] In an embodiment, the sensor is attached to the arm via at least one flexible element, such as a cable, cord or chain, which preferably is wound on a winch, e.g. attached to the arm and/or with the flexible element being guided via the arm.

[0010] Thus, when the arm is in the extended position, the sensor can be lowered into the guide member and into or along of a foundation element, such as a hollow pile, inside the guide member. Also, after the sensor has been lowered into or along the foundation element, the sensor can be pulled or pushed, i.e. urged, against the wall of the foundation element and hoisted along the wall at least until the sensor signals that the upper end (rim) of the foundation element has been reached.

[0011] In an embodiment, the flexible element is or comprises an umbilical containing e.g. power and data wires, to feed electric, pneumatic and/or hydraulic power to the sensor and other components near the sensor, as will be explained below.

[0012] In another embodiment, the sensor is mounted on or in a frame. The frame can be employed to carry and/or protect the sensor and/or to mount further components. For instance, to facilitate movement of the sensor along the (inner or outer) wall of the foundation element, in an embodiment, the frame comprises one or more rolling or sliding elements, such as wheels or slide pads made of a synthetic material, e.g. a low friction material such as PTFE, preferably at least two slide elements, one of each side of the sensor.

[0013] In another embodiment, the measuring device comprises two or more sensors for detecting the upper rim of a foundation element, which sensors are preferably positioned at different heights. A further sensor provides redundancy and/or increased accuracy and if the sensors are positioned at different heights the detection range of the sensors is increased.

[0014] In another embodiment, in addition to one or more sensors for detecting the upper rim of the foundation element, at least one pressure sensor is mounted in or on the frame. The pressure sensor can be employed to measure the height (vertical) position of the (main) sensor, e.g. by comparing the pressure measured at the height position or at a known distance from the height position of the sensor with a reference pressure. In a preferred embodiment, a reference pressure is provided by a further pressure sensor located on or in the template, preferably near the bottom side of the template, i.e. near the seabed. If absolute values for height are required, the height of the reference relative to the seabed can be measured e.g. acoustically or with a clump weight or plummet.

[0015] In a further embodiment, a camera and preferably a light source is mounted in or on the frame. The camera can serve as the sensor for detecting the upper rim of the foundation element and/or provide a back-up system. I.e., the camera can be used to optically find the upper rim of the foundation element or a marker that is located at a known distance from the upper rim of the foundation element.

[0016] In another embodiment, the measuring device comprises one or more proximity sensors for detecting the upper rim of the foundation element. Proximity sensors were found to provide an accurate reading of the height of foundation elements, in particular of the upper rim, i.e. the transition from matter to no matter, also in the presence of dirt on the foundation element or in the water surrounding the foundation element.

[0017] In an embodiment, the measuring device comprises a main sensor, e.g. one or more proximity sensors, and a back-up sensor, e.g. a camera, for detecting directly or via a marker the upper rim of the foundation element. If the main sensor or sensors fail, the back-up sensor or sensors take over. Similarly, in another embodiment, the measuring device comprises a main sensor, e.g. a pressure sensor, for measuring the height (vertical) position of the (main) sensor and a back-up sensor, e.g. a sensor arranged to derive the height position of the (main) sensor from the paid out length of the flexible element from which the (main) sensor is suspended.

[0018] Although in principle a single measuring device can be used for measuring the stickup height in two or more guide members, it is preferred that each of the guide elements is provided with a measuring device to measure the height of a foundation element.

[0019] The invention further relates to a measuring device for measuring the height of a foundation element in a guide member for guiding foundation elements, such as piles, during installation in an underwater ground formation, comprising a sensor, characterised in that the sensor is attached to an arm that is movable between a retracted position and an extended position and in that, in the extended position of the arm, the sensor can be lowered or lifted from the arm.

[0020] Various embodiments of the measuring device comprise one or more elements described above. E.g., in an embodiment, the sensor is attached to the arm via at least one flexible element, such as a cable, cord or chain, and the at least one flexible element is wound on a winch.

[0021] The invention also relates to a method of measuring the height of a foundation element in a guide member, such as a guide tube, after the foundation element has been driven into an underwater ground formation, e.g. a seabed, the method comprising the steps of extending a sensor, preferably a proximity sensor or e.g. a camera, inside, above or beneath the guide member, lowering or lifting the sensor in the guide member alongside a wall of the foundation element, establishing with the sensor the location of the upper rim of the foundation element.

[0022] In an embodiment, the method comprises the further step of urging the sensor towards or against the (inner or outer) wall of the foundation element and pulling the sensor up at least until it reaches the upper rim of the foundation element.

[0023] The invention will now be explained in more detail with reference to the Figures, which show a preferred embodiment of the measuring device according to the present invention.

Figure 1 is a perspective view of a template comprising four guide tubes and a stickup height measuring device for each guide tube.

Figure 2 is a perspective view of a measuring device as used in the template shown in Figure 1.

Figure 3 is a perspective view of the sensor unit that is part of the measuring device shown in Figure 2.

Figures 4A to 4C are cross-sections illustrating a method of measuring stickup height with the device shown in Figure 2.

[0024] It is noted that the Figures are schematic in nature and that details, which are not necessary for understanding the present invention, may have been omitted.

[0025] Figure 1 shows a template 1 comprising a plurality of guide tubes 2 fixed in a geometric pattern by means of beams or trusses 3. The pattern of the centrelines of the guide tubes corresponds to that of foundation piles for e.g. a jacket for a wind turbine to be installed. In this example, the guide tubes are arranged in a square. The template is provided with at least a pressure sensor (not shown) to establish depth and with an inclination sensor.

[0026] The guide tubes 2 have a circular cross-section, an inner diameter larger than 1 meter, e.g. 2 meters, and are provided with internal guide elements 5 to center and support the piles during insertion in the guide tubes.

[0027] Each of the guide tubes 2 comprises at its upper halve, e.g. near its top end, a measuring device 9, shown in detail in Figures 2, 3A, and 3B, to measure the height of a pile in the tube, i.e. after it has been driven into the underwater ground formation. The measuring devices are positioned outside the guide tubes, behind a door or panel 11 in the wall of each of the tubes.

[0028] The measuring device 9 comprises a mounting frame 12 with which it is mounted in the template and an arm 10 that is movable, i.c. slidable, on or in the frame by means of e.g. an hydraulic cylinder 13, between a retracted position (Figure 4A) and an extended position (Figures 4B and 4C). The measuring device further comprises two proximity sensors 15, in this example SICK IMA30-40NE1ZC0K, located next to each other in a carrying frame 16, with one of the sensors positioned slightly higher, e.g. 1 to 50 millimeters higher, than the other. The frame further carries two pressure sensors 17, positioned a calibrated distance below the proximity sensors 15, a camera 18 at exactly the same height position as the proximity sensors 15, and a lamp integrated in the camera. A reticle 19 is positioned in front of the camera to facilitate optically measuring the height position of a rim or marker of or on a foundation element inside the guide tube 2. Guide wheels 20 are mounted on either side and in the middle, at the bottom side, of the frame 16. The frame is suspended from the arm via a pair of cables 25 that are guided over pulleys 26 at the front end of the arm, i.e. the end closest to the guide tube, and towards winches 27 at the rear end of the arm. The cables are wound on the winches. Also, the cables contain power wires to feed electricity to the sensor, camera, lamp, and pressure sensor and data wires to transmit data from the sensors and camera.

[0029] During operation, illustrated in Figures 4A, 4B, and 4C, after piles 30 have been driven into the underwater ground formation, the arm 10 is extended until the frame 16 carrying the proximity sensors 15 is above the space between the pile and the inner wall of the guide tube. Next, the frame and sensors are lowered by paying out the cables 25 with the winches 27, alongside the outer wall the pile. Next, the arm 10 is extended further until the wheels 20 on the frame 16 rest under some bias against the outer wall of the pile. After the wall of the pile has been detected by the proximity sensors, the frame and sensors are pulled up. When the upper sensor of the two proximity sensors reaches the upper rim of the pile, the sensor will generate a signal. For instance, the output voltage or current of the proximity sensor decreases and a decrease of 50% is considered to correspond to a position of the upper sensor at the rim. At this position, the pressure measured with the pressure sensor 17 on the frame 16 is compared to a reference, in this example the pressure measured by the pressure sensor on the template, to establish the height of the upper rim of the pile. When the stickup height of the first pile has been measured, the other piles are driven into the seabed to the same stickup height as the first. After the heights of these piles have been measured and compared to the stickup height of the first pile, it is decided whether further pile driving, e.g. to achieve an equal height for all piles, is necessary.

[0030] The measuring system according to the present invention enables measuring a relatively large range, e.g. between 1 and 10 meters, of stickup heights with relatively little interference with the guide member or members.

[0031] The invention is not restricted to the embodiment described above and can be varied in numerous ways within the scope of the claims. For example, the arm can be extended beneath the guide member and the sensor lifted, e.g. by means of a telescoping column, along the outer wall of a foundation element present inside a guide member. In another example, the measuring device comprises three or four proximity sensors, e.g. all at different heights.

Claims

1. Template (1) comprising a plurality of guide members, preferably guide tubes (2), for guiding foundation elements, such as piles (30), during installation in an underwater ground formation, and a measuring device (9) for measuring the height of a foundation element (30) in at least one of the guide members (2), **characterised in that** the measuring device (9) comprises a sensor (15) that is attached to an arm (10) that is movable between a retracted position (Figure 4A) and an extended position (Figure 4B), and **in that**, in the extended position of the arm (10), the sensor (15) is positioned inside, above or beneath the guide member (2) and can be lowered or lifted from the arm (10) and inside the guide member (2).

2. Template (1) according to claim 1, wherein the sensor (15) is attached to the arm (10) via at least one flexible element (25).

3. Template (1) according to claim 2, wherein the at least one flexible element (25) is wound on a winch (27).

4. Template (1) according to claim 2 of 3, wherein the at least one flexible element (25) is or comprises an umbilical.

5. Template (1) according to any one of the preceding claims, wherein the sensor (15) is mounted on or in a frame (16).

6. Template (1) according to claim 5, wherein the frame (16) comprises one or more rolling or sliding elements (20), preferably at least two such elements (20), one of each side of the sensor (15).

7. Template (1) according to any one of the preceding claims, comprising two sensors (15), preferably positioned at different heights.

8. Template (1) according to any one of the preceding claims, wherein at least one pressure sensor (17) is mounted in or on the frame (16).

9. Template (1) according to any one of the preceding claims, wherein a camera (18) is mounted in or on the frame (16).

10. Template (1) according to any one of the preceding claims, wherein the measuring device (9) comprises one or more proximity sensors (15).

11. Template (1) according to any one of the preceding claims, wherein each of the guide elements (2) is provided with a measuring device (9) to measure the height of a foundation element (30).

12. Measuring device (9) for measuring the height of a foundation element (30) in a guide member (2) for guiding foundation elements, such as piles (30), during installation in an underwater ground formation, comprising a sensor (15), **characterised in that** the sensor (15) is attached to an arm (10) that is movable between a retracted position (Figure 4A) and an extended position (Figure 4B) and **in that**, in the extended position of the arm (10), the sensor (15) can be lowered or lifted from the arm (10).

13. Measuring device (9) according to claim 12, wherein the sensor (15) is attached to the arm (10) via at least one flexible element (25) and the at least one flexible element (25) is wound on a winch (27).

14. Method of measuring the height of a foundation element (30) in a guide member, such as a guide tube (2), after the foundation element (30) has been driven into an underwater ground formation, the method comprising the steps of
extending a sensor (15) in, above or beneath the guide member (2),
lowering or lifting the sensor in the guide member (30) alongside a wall of the foundation element (30),
establishing with the sensor (15) the location of the upper rim of the foundation element (30).

15. Method according to claim 14, comprising the step of urging the sensor (15) towards or against the wall of the foundation element (30) and
pulling the sensor (15) up at least until it reaches the upper rim of the foundation element (30).

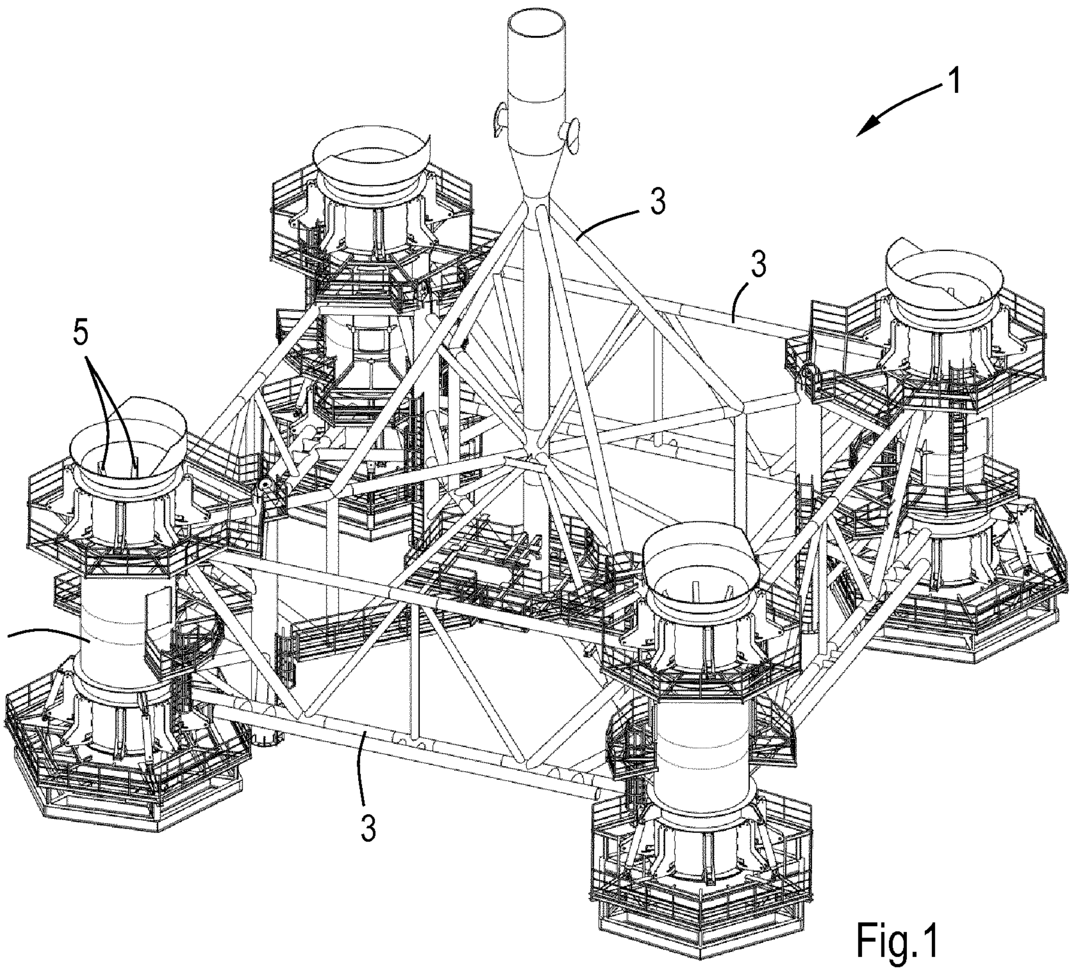

Fig.1

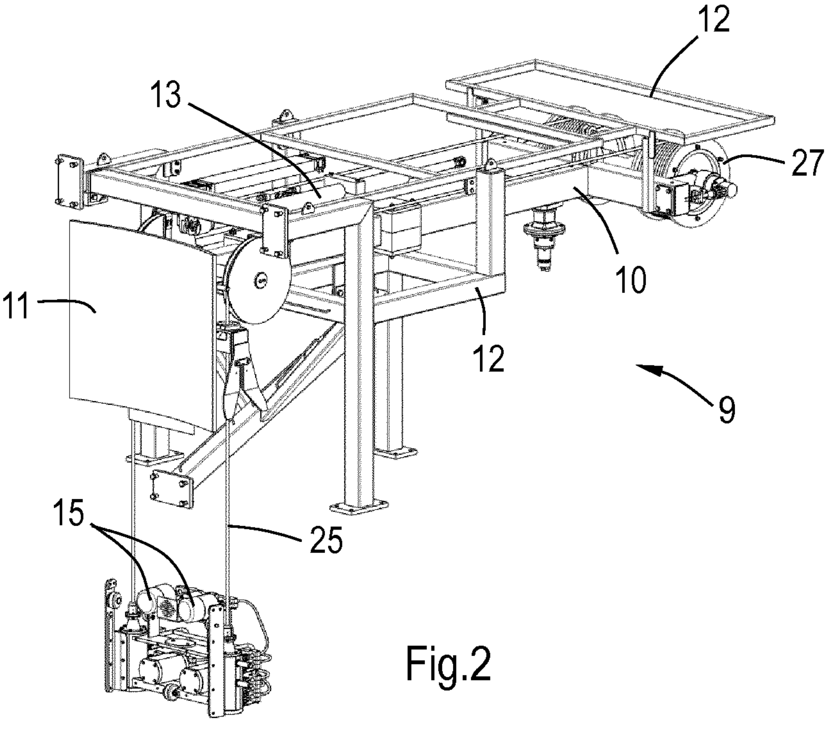

Fig.2

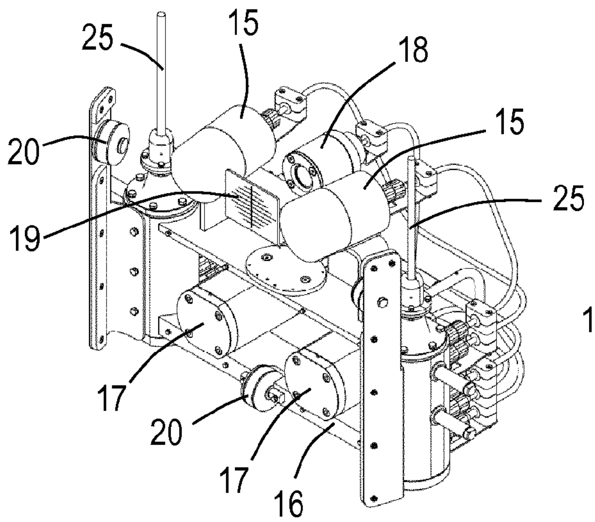

Fig.3A

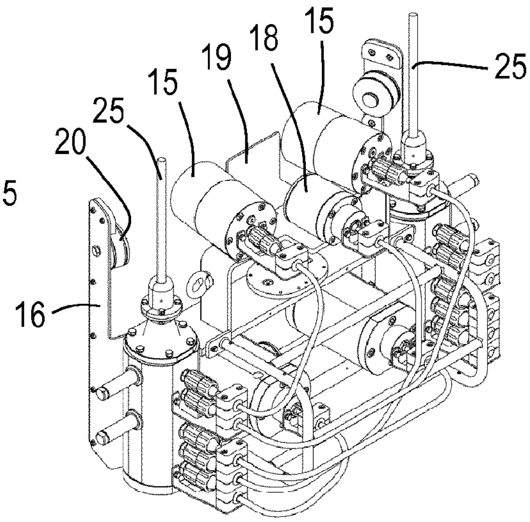

Fig.3B

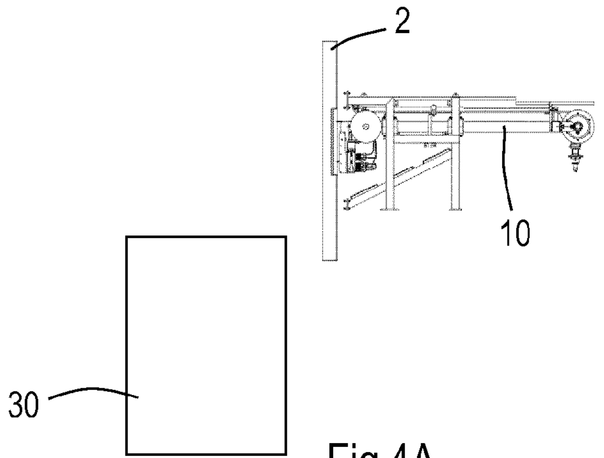

Fig.4A

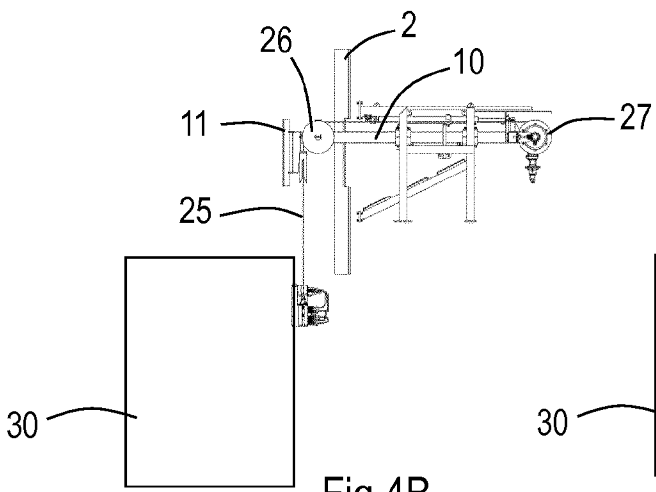

Fig.4B

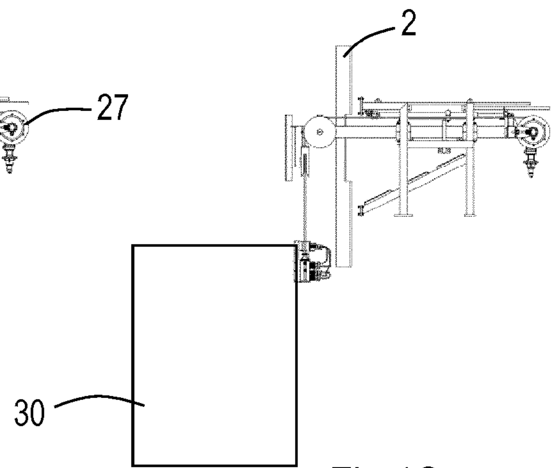

Fig.4C

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 15 7205

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D A	US 5 244 312 A (WYBRO PIETER G [US] ET AL) 14 September 1993 (1993-09-14) * page 2, line 16 - page 8, line 12; figure 1 *	14 1-13,15	INV. E02D13/04 E02D13/06
A	EP 2 851 472 A1 (GEOSEA NV [BE]) 25 March 2015 (2015-03-25) * the whole document *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

E02D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	25 April 2017	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
P : intermediate document

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
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 15 7205

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-04-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5244312 A	14-09-1993	NONE	
EP 2851472 A1	25-03-2015	DK 2851472 T3	16-01-2017
		EP 2851472 A1	25-03-2015

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

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 5244312 A **[0002]**
- EP 2492401 A **[0003] [0005]**