



(51) International Patent Classification:
E02B 17/02 (2006.01)

(21) International Application Number:
PCT/EP2010/066814

(22) International Filing Date:
4 November 2010 (04.11.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10164282.5 28 May 2010 (28.05.2010) EP

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

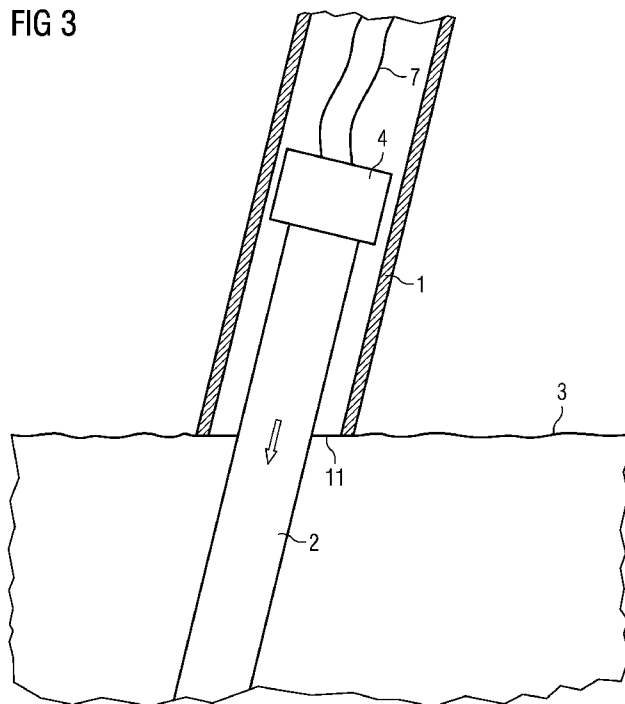
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: OFFSHORE FOUNDATION STRUCTURE, OFFSHORE FOUNDATION USING SUCH A STRUCTURE AND METHOD OF ESTABLISHING AN OFFSHORE FOUNDATION

FIG 3



(57) Abstract: A method of establishing an offshore foundation, in particular an offshore foundation for a wind turbine installation, on the seabed (3), in which at least one pile (2) is driven into the seabed (3) in order to establish an anchor for a foundation structure is provided. In the method, the foundation structure comprises at least one tubular hollow foundation member (1) with a longitudinal axis and an open longitudinal end (11) which is placed on the seabed (3) such that the open longitudinal end (11) shows towards the seabed (3). The pile (2) is located in the tubular hollow foundation member (1) when it is placed on the seabed (3) and is driven out of the tubular hollow foundation member (1) along the longitudinal axis and rammed into the seabed (3) to establish an anchor for the foundation structure after placing the hollow foundation member (1) on the seabed.

Offshore foundation structure, offshore foundation using such a structure and method of establishing an offshore foundation

5 The present invention relates to an offshore foundation structure as well as to an offshore foundation using such an offshore foundation structure. In addition the present invention relates to a method of establishing an offshore foundation.

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It is known to establish jacket constructions or tripod constructions on the seabed as foundations in particular for offshore wind turbine installations. A jacket construction is, for example, shown in US 5,988,949 or in EP 2 067 914 A2, 15 a tripod construction, for example, in DE 10 2004 042 066 A1.

A typical method for establishing a foundation based on a jacked construction or a tripod construction is to prepare the seabed prior to establishing the foundation which includes levelling out variations of the high of the seabed in 20 order to achieve a construction in level. Furthermore, the method comprises establishing piles very accurately positioned in the seabed such as by means of a pre-fabricated and pre-positioned pile positioning template structure on the 25 seabed.

The piles are established by using e.g. hydraulic driven means which literally hammer the pile down into the seabed. When the pile is established, a jacket or a tripod construction is set over a part of the pile (or piles in case of a 30 tripod construction) and the space between the leg and the pile is grouted to establish a secure connection.

With respect to the mentioned state of the art it is an objective of the present invention to provide an advantageous 35 method of establishing an offshore foundation. Further objectives are to provide an advantageous offshore foundation structure and to provide an advantageous offshore foundation.

These objectives are solved by a method of establishing an offshore foundation as claimed in claim 1, by an offshore foundation structure as claimed in claim 9 and by an offshore foundation as claimed in claim 14, respectively. The depend-
5 ing claims contain further developments of the invention.

In the inventive method of establishing an offshore foundation on the seabed, in particular an offshore foundation for
10 a wind turbine installation, at least one pile is driven into the seabed in order to establish an anchor for a foundation structure. The foundation structure comprises at least one tubular hollow foundation member with a longitudinal axis and an open longitudinal end. The tubular hollow foundation mem-
15 ber is placed on the seabed such that the open longitudinal end shows towards the seabed. Note that the longitudinal axis of the tubular hollow foundation member may be oriented vertically or skewed by a small angle, e.g. by an angle of 30° or less, in particular 10° or less as measured from the ver-
20 tical direction when it is placed on the seabed, in particular in tripod constructions. The pile is inside located in the tubular hollow foundation member, when the foundation member is placed on a seabed. After placing the hollow foundation member with the pile located therein on the seabed,
25 the pile is driven out of the tubular hollow foundation member along the longitudinal axis and rammed into the seabed to establish an anchor for the foundation structure.

The inventive method allows to use the hollow member for
30 guiding the pile and/or the driving means, when the pile it is rammed into the seabed. In this context it is advantageous if the pile is driven out of the tubular hollow foundation member and rammed into the seabed by means of a drive means or hammer means which is located inside the tubular hollow
35 foundation member. In particular, the drive means may be attached to or at least partly integrated into the pile. The drive means or hammer means may stay inside the tubular hollow foundation member after the pile has been driven out of

the tubular hollow foundation member and rammed into the seabed. If the drive means or hammer means is attached to or at least partly integrated into the pile this means that drive means is part of the pile itself. Hence, for driving the pile into the seabed it is not necessary to occupy a vessel like a crane vessel, with a task of holding and operating the driving means. Hence, the vessel can be utilized on other sites. This in turn is cost effective and time saving. Furthermore, since the operation of the driving means or hammer means is not dependent on a vessel it can be operated under substantially any weather conditions, which in turn is also cost effective and time saving. In addition, in case of more than one hollow tubular member the drive means or hammer means can be established and operated in more than one hollow member at a time, i.e. timely parallel, whereas it is known from the prior art to install only one pile at the time as the pile driving of each pile is dependent on driving equipment connected to the crane of a vessel.

The drive means or hammer means can be designed such as to be relative cheap to build and therefore can be left in the construction once used.

As already mentioned, the at least one tubular hollow foundation member used in the inventive method may be a leg of a jacket or a tripod structure. It may be designed such that each leg of the structure is a tubular hollow foundation member with a pile located therein which is driven out of the respective leg and rammed into the seabed after the jacket or tripod structure is set on the seabed. In particular, the piles of the legs may be driven out of the respective leg and rammed into the seabed simultaneously. By this method the legs of a jacket or tripod foundation can be anchored in the seabed simultaneously in a cost effective and time saving manner since it is not necessary to use three vessels to ram the piles into the seabed or to ram the piles into the seabed after each other when only one vessel is available.

After the pile has been driven out of the tubular hollow foundation member and rammed into the seabed the space between the tubular hollow foundation member and a part of the pile remaining inside the tubular hollow foundation member
5 can be grouted in order to increase the stability of the foundation.

According to a further aspect of the present invention, an offshore foundation structure, in particular an offshore
10 foundation structure for a wind turbine is provided. The foundation structure is adapted to being installed on the seabed and comprises at least one tubular hollow foundation member with a longitudinal axis and an open longitudinal end which is designed to be placed on the seabed such that the
15 open hollow end shows towards the seabed. The tubular hollow foundation member may be formed by a leg of a jacket structure or a tripod structure. Note, that the tubular hollow foundation member may be oriented such that the longitudinal axis extends vertically or skewed with respect to the vertical
20 cal direction. If the tubular hollow member is skewed, typical skew angles would be below 30° as measured from the vertical direction. Preferred skew angles are below 10° . A pile and a drive means or hammer means are located inside the tubular hollow foundation member. The drive means or hammer
25 means is designed to drive the pile out of the tubular hollow foundation member along the longitudinal axis and to ram it into the seabed to establish an anchor for the foundation structure.

30 Since the drive means or hammer means is located inside the hollow foundation member. The tubular hollow foundation member can act as a guide for the drive means or hammer means as well as for the pile.

35 The drive means may, in particular, be attached to the pile. Alternatively, it may at least be partly integrated into the pile. By attaching the drive means to or integrating the drive means at least partly into the pile the pile can be

driven into the seabed without the necessity to occupy a crane vessel with a task of holding and operating the drive means. Hence, the vessel can be utilized on other sites. This in turn is cost effective and time saving. Moreover, since
5 the operation of the drive means is not depending on a vessel it can be operated under substantially any weather conditions, which is in turn also cost effective and time saving. In addition, piles and drive means can be established and operated in more than one leg at the same time, i.e. timely
10 parallel, whereas it is known from prior art to install only one pile at the time as the pile driving of each pile is depending on driving equipment connected to the crane of a vessel. Since the driving means can be designed such that it is relatively cheap to build it can be left in the construction
15 once it has been used.

The offshore foundation structure can further comprise at least one control unit for controlling the drive means. In particular, such a control unit may operate two or more drive
20 means, for example the drive means of different piles, so that driving the piles into the seabed can be done in parallel and, hence, in a time saving manner.

According to a third aspect of the present invention, an inventive offshore foundation, in particular an offshore foundation for a wind turbine installation is provided. The offshore foundation may, e.g., be implemented as a jacket structure or as a tripod structure. The offshore foundation is established on the seabed and comprises at least one tubular
25 hollow foundation member with a longitudinal axis and an open longitudinal end which is placed on the seabed such that the open longitudinal end shows towards the seabed. The longitudinal axis of the tubular hollow foundation member may be oriented vertically or skewed. If skewed, the skew angle, as
30 measured from the vertical direction, does not exceed 30° , and does, preferably, not exceed 10° . A pile is partly located in the tubular hollow foundation member and partly projecting out of the tubular hollow foundation member along the

longitudinal axis so that the projecting part is located in the seabed to form an anchor of the foundation. Furthermore, a drive means or hammer means is located inside the tubular hollow foundation member.

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The inventive offshore foundation can be build by use of an inventive offshore foundation structure so that the inventive offshore foundation offers the possibility to realise the advantages described with respect to the inventive offshore foundation structure when establishing the offshore foundation. Establishing the offshore foundation can be done according to the inventive method.

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In the inventive offshore foundation, a space may be present between the tubular hollow foundation member and the part of the pile which is located inside the tubular hollow foundation member. This space may be grouted to increase stability of the offshore foundation.

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In all aspects of the invention described above the drive means or hammer means may be implemented as a hydraulic means, a pneumatic means, an electrically driven means, a motor driven means, etc. Furthermore, the number of tubular hollow foundation members shall not be restricted to any definite number but can be any number as long as at least one tubular hollow foundation member is present. However, a jacket or tripod structure offers the possibility to set the structure on the ground when driving the piles into the seabed.

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Further features, properties and advantages of the present invention will become clear from the following description of exemplary embodiments in conjunction with the accompanying drawings.

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Figure 1 shows an inventive jacket structure of an offshore wind turbine foundation in a highly schematic view.

Figure 2 shows an inventive tripod structure of an off-shore wind turbine foundation in a highly schematic view.

5

Figure 3 schematically shows driving a pile into the seabed according to a first embodiment of the invention.

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Figure 4 schematically shows driving a pile into the seabed according to a second embodiment of the invention.

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Figure 5 schematically shows driving a pile into the seabed according to a third embodiment of the invention.

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Figure 6 schematically shows driving a pile of a tripod structure into the seabed.

An inventive jacket structure of an offshore foundation, for example for wind turbines, is shown in Figure 1 in highly schematic view. The jacket structure shown in this Figure comprises three hollow legs 1 each forming a tubular hollow foundation member. Each leg 1 is equipped with an open longitudinal end 11 which is placed on the seabed 3 such that the open longitudinal end 11 shows towards the seabed. The legs are slightly tilted with respect to the vertical direction. Piles 2 project through the open longitudinal ends into the seabed 3 to form anchors for the foundation structure. The legs 1 may be grouted, in particular the space between the piles and the inside wall of the legs, in order to increase stability of the structure.

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Another possible offshore foundation structure by which the invention can be realised is the so called tripod structure that is schematically shown in Figure 2. In a tripod structure, three legs 1 forming tubular hollow foundation members

support a main tube 8 carrying an installation like a wind turbine. The three legs 1 are anchored in the seabed by means of piles 2 extending out of the legs into the seabed 3.

5 The present invention also relates in general to an advantageous method of establishing an offshore wind turbine tower foundation such as a jacket or tripod structure as described above with respect to Figures 1 and 2, respectively, on the sea bed.

10 More specifically the invention is explained by the schematically illustrated embodiments shown in Figures 3 to 6.

Figure 3 shows a first embodiment of establishing an offshore foundation as described above with respect to Figures 1 and 2.

15 According to the first embodiment, a pile 2 is inserted in a jacket or tripod leg 1 and forced to penetrate the seabed 3 and to be driven into the seabed 3 in order to establish a secure "anchor" for the foundation construction.

20 This embodiment of the invention is characterized in that the pile 2 comprises a drive means 4 which is directly attached to the pile 2.

25 The drive means 4 is prepared for being able to force the pile 2 into and through the seabed 3 along the longitudinal axis of the pile 2 or the hollow foundation member 1, respectively. The drive means 4 may for various embodiments be hydraulic, pneumatic, electrically and/or fuel driven and can in principle be any type of pile hammer which is known in the art.

35 A second embodiment of establishing an offshore foundation as described above with respect to Figures 1 and 2 is schematically illustrated in Figure 4.

This embodiment of the invention is characterized in that the driving means 4 is at least partly integrated in the pile 2 itself.

- 5 A third of establishing an offshore foundation as described above with respect to Figures 1 and 2 is schematically illustrated in Figure 5.

- 10 This embodiment of the invention is characterized in that the pile 2, inserted in the jacket or tripod leg 1, is driven into the seabed 3 by a hammer means 5.

- 15 This embodiment is further characterised in that the hammer means 5 is operated in the jacket or tripod leg 1 such as by sliding on prepared portions of the wall of the jacket or tripod leg 1, and/or the hammer means 5 is operated by control means such as by one or more wires 6, said control means being external to the hammer means 5.

- 20 The hammer means 5 may be made of e.g. concrete, iron, reinforced concrete etc.

- 25 For various embodiments of the invention, the driving means 4 is dimensioned so that its physical dimensions are smaller than the internal diameter of the jacket or tripod leg 1 and consequently can be positioned and operate inside the jacket or tripod leg 1.

- 30 For various embodiments of the invention the space between the jacket or tripod leg 1 and the pile 2 may be grouted subsequently to the establishment of the pile 2 in the seabed.

- 35 For various embodiments of the invention, the driving means 4 may be removable so that it can be removed after establishing the pile 2 and/or grouting, or the driving means 4 may be non-removable so that it stays installed after establishing the pile 2 and/or grouting.

For various embodiments of the invention, the driving means 4 may further receive control 7 from one or more control units 10 external to the means 4. The control may be communicated between the control unit and the driving means 4 such as by one or more electrical wire, hydraulic hose, pneumatic hose or the like.

For various embodiments of the invention, the said one or more control units 10, when operated, may be positioned on the foundation structure, in the means 4 itself, in the jacket or tripod leg 1 or on a separate construction such as a vessel.

For various embodiments of the invention, the said control unit 10 may operate two or more driving means 4. This is schematically illustrated in Figure 6.

In the embodiment shown in Figure 6 the driving means 4 of different piles 2 are connected to a common control unit 10. It can further be schematically seen, that when a first pile 2 with driving means 4 is prepared and set to operate in one leg (left), a second pile can be prepared and set to operate in another leg (right) at the same time when the first pile is working i.e. driving one pile is not dependent on driving another pile, so the driving process may be regarded as if it may be done in parallel. Although a jacket structure is shown in Figure 6 the features and function described with respect to this Figure can also be realised with a tripod structure.

Examples for advantages which arise from the technical features according to the invention:

The invention is advantageous in that the driving means 4 is part of the pile 2 itself. This means that for operating the invention it is not necessary to occupy a (crane) vessel with a task of holding and operating the driving means. Hence the vessel can be utilized on other sites. This in turn is cost effective and time saving.

The invention is furthermore advantageous in that as the operation of the driving means is not dependent of a vessel, the means can be operated under substantially any weather condition. This in turn is cost effective and time saving.

The invention is furthermore advantageous in that piles (and driving means) can be established and operated in more than one leg at a time i.e. timely parallel, whereas it is known from prior art to install only one pile at the time as the pile driving of each pile is dependent of driving equipment connected to the crane of the vessel.

The invention is furthermore advantageous in that the driving means 4 is relative cheap to build and therefore can be left in the construction once used.

With the present invention it becomes possible to anchor a pre-fabricated jacket or tripod structure with two or more legs by use of piles that are not oriented vertically but skewed in different directions, e.g. towards a common centre. If pre-positioned piles were skewed it would not be possible to set a pre-fabricated jacket or tripod with two or more legs that are skewed according to the skew of the piles over the pre-positioned piles.

Claims

1. A method of establishing an offshore foundation, on the seabed (3) in particular an offshore foundation for a wind turbine installation, in which at least one pile (2) is driven into the seabed (3) in order to establish an anchor for a foundation structure, wherein
- the foundation structure comprises at least one tubular hollow foundation member (1) with a longitudinal axis and an open longitudinal end (11) which is placed on the seabed (3) such that the open longitudinal end (11) shows towards the seabed (3),
 - the pile (2) is located in the tubular hollow foundation member (1) when it is placed on the seabed (3),
 - the pile (2) is driven out of the tubular hollow foundation member (1) along the longitudinal axis and rammed into the seabed (3) to establish an anchor for the foundation structure after placing the hollow foundation member (1) on the seabed.
2. The method as claimed in claim 1, wherein the pile (2) is driven out of the tubular hollow foundation member (1) and rammed into the seabed (3) by means of a drive means (4) or hammer means (5) which is located inside the tubular hollow foundation member (1).
3. The method as claimed in claim 2, wherein the drive means (4) or the hammer means (5) stays inside the tubular hollow foundation member after the pile (2) has been driven out of the tubular hollow foundation member (1) and rammed into the seabed (3).
4. The method as claimed in claim 2 or claim 3, wherein the pile (2) is driven out of the tubular hollow foundation member (1) and rammed into the seabed (3) by means of a drive means (4) which is attached to or at least partly integrated into the pile (2).

5. The method as claimed in any of the preceding claims, wherein the at least one tubular hollow foundation member (1) is a jacket or a leg of a tripod structure.

5

6. The method as claimed in claim 5, wherein each leg of a tripod structure is designed as a tubular hollow foundation member (1) with a pile (2) located therein that is driven out of the respective leg and rammed into the seabed (3) after the tripod structure is set on the seabed (3).

10

7. The method as claimed in claim 6, wherein the piles (2) of the legs are driven out of the respective leg and rammed into the seabed simultaneously.

15

8. The method as claimed in any of the preceding claims, wherein a space between the tubular hollow foundation member (1) and a part of the pile (2) remaining inside the tubular hollow foundation member after its has been driven out of the tubular hollow foundation member (1) and rammed into the seabed (3) is grouted.

20

9. An offshore foundation structure, in particular an offshore foundation structure for a wind turbine, which is adapted to being installed on the seabed (3), comprising:

- at least one tubular hollow foundation member (1) with a longitudinal axis and an open longitudinal end (11) which is designed to be placed on the seabed (3) such that the open longitudinal end (11) shows towards the seabed;
- a pile (2) located in the tubular hollow foundation member (1);
- a drive means (4) or hammer means (5) being located inside the tubular hollow foundation member (1) and being designed to drive the pile (2) out of the tubular hollow foundation member (1) along the longitudinal axis and to ram it into the seabed (3) to establish an anchor for the foundation structure.

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10. The offshore foundation structure as claimed in claim 9, in which the foundation structure comprises a jacket with legs at least one of which forming a tubular hollow foundation member (1).

5

11. The offshore foundation structure as claimed in claim 9, which comprises a tripod with legs at least one of which forming a tubular hollow foundation member (1).

10 12. The offshore foundation structure as claimed in any of the claims 9 to 11, wherein the drive means (4) is attached to or at least partly integrated into the pile (2).

15 13. The offshore foundation structure as claimed in any of the claims 9 to 12, further comprising at least one control unit (10) for controlling the drive means (4).

14. An offshore foundation, in particular an offshore foundation for a wind turbine, which is established on the seabed, comprising:

- 20 - at least one tubular hollow foundation member (1) with a longitudinal axis and an open longitudinal end (11) which is placed on the seabed (3) such that the open longitudinal end (11) shows towards the seabed (3);
- 25 - a pile (2) partly located in the tubular hollow foundation member (1) and partly projecting out of the tubular hollow foundation member (1) along the longitudinal axis so that the projecting part is located in the seabed (3) to form an anchor for the foundation; and
- 30 - a drive means (4) or hammer means (5) being located inside the tubular hollow foundation member (1).

15. The offshore foundation as claimed in claim 14, wherein a space between the tubular hollow foundation member (1) and the part of the pile (2) located inside the tubular hollow foundation member (1) is grouted.

35

FIG 1

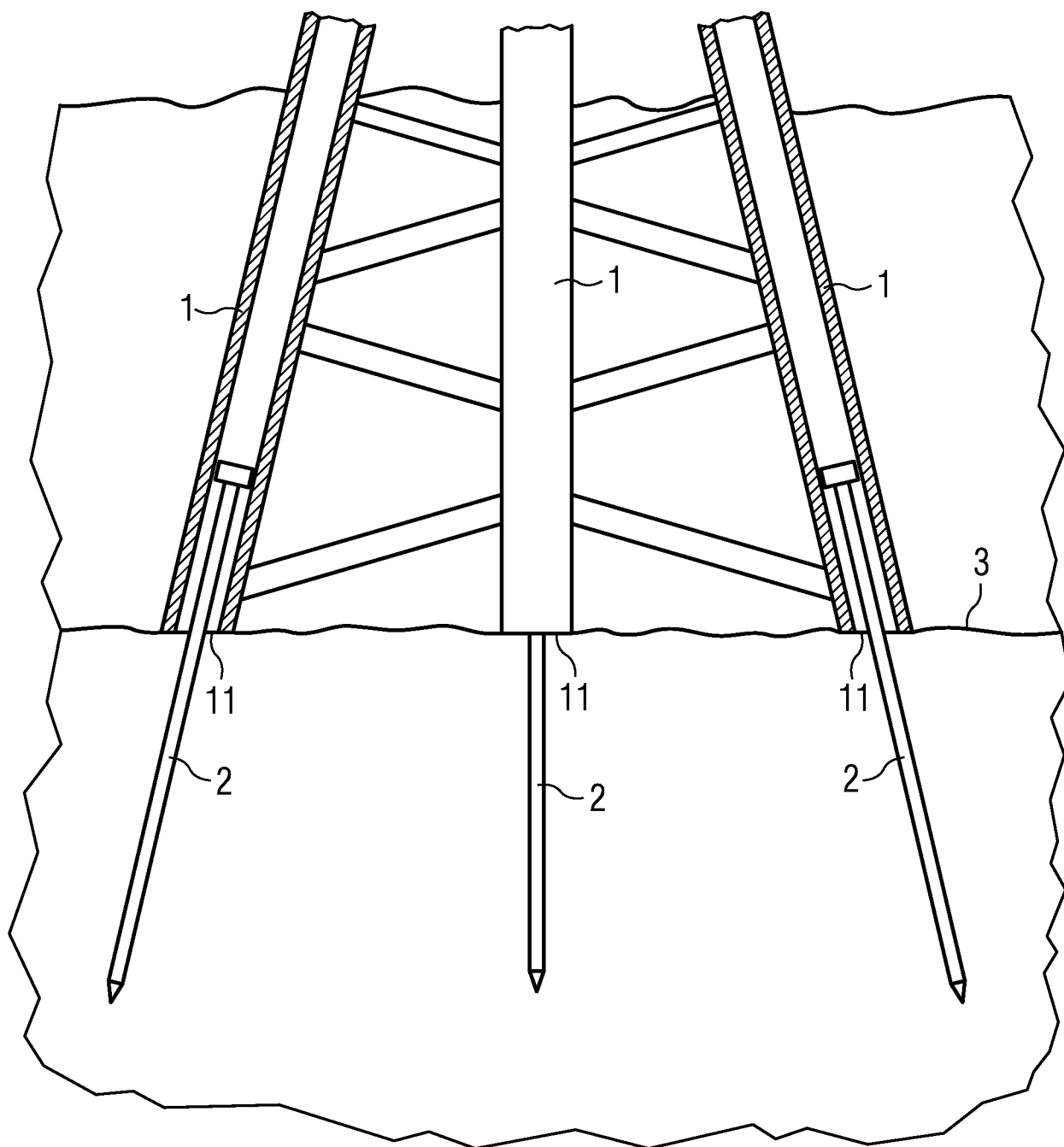


FIG 2

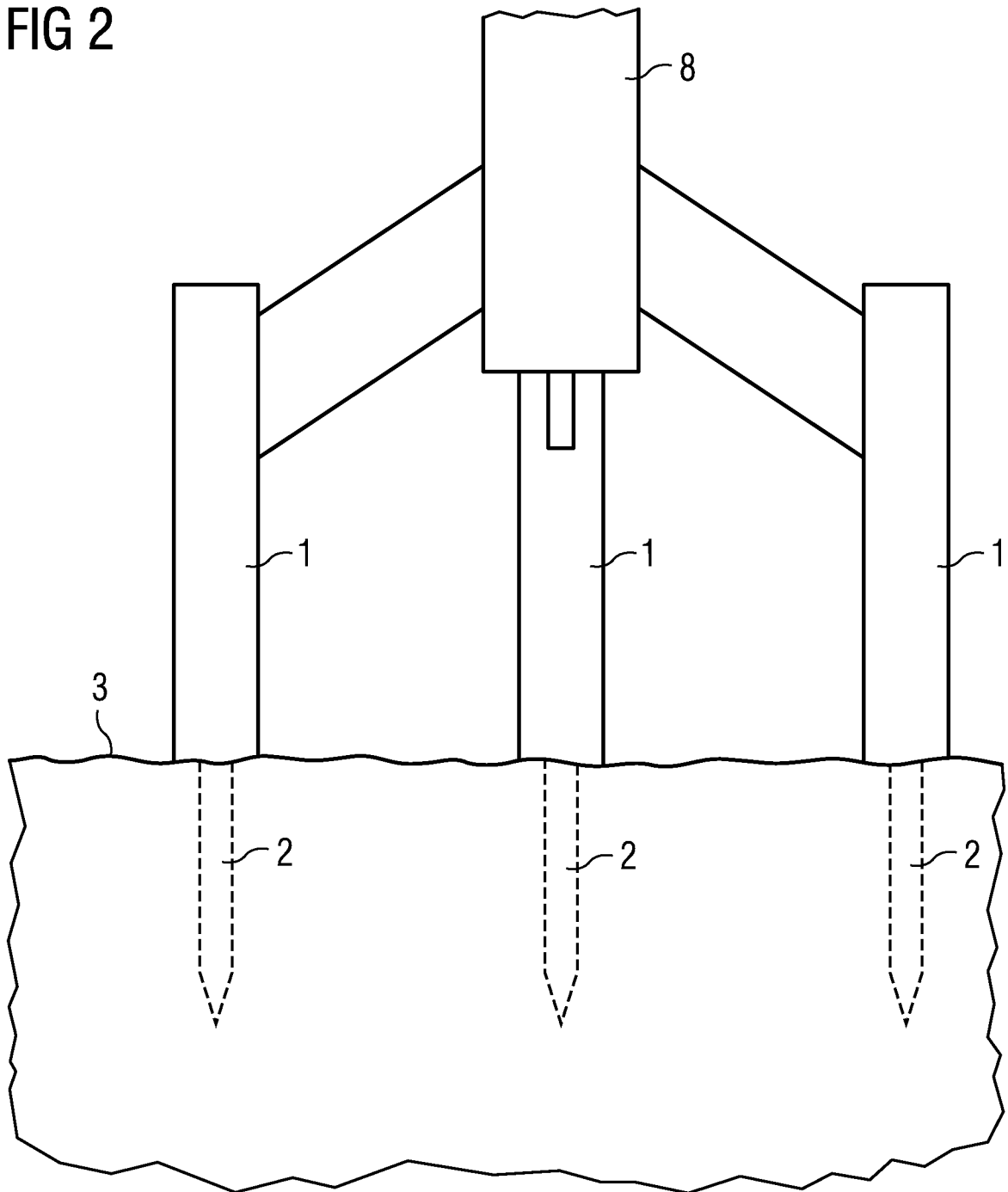


FIG 3

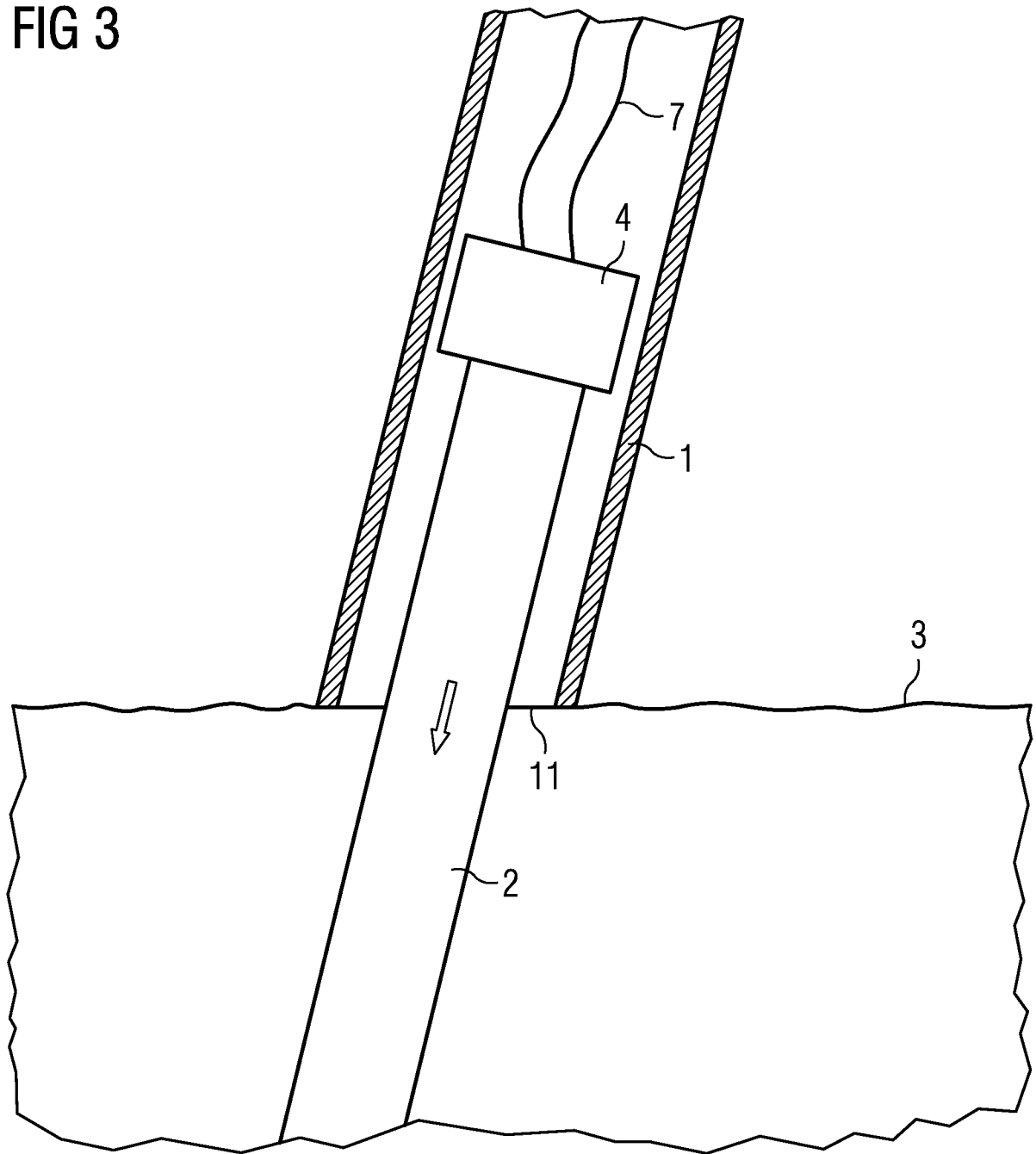


FIG 4

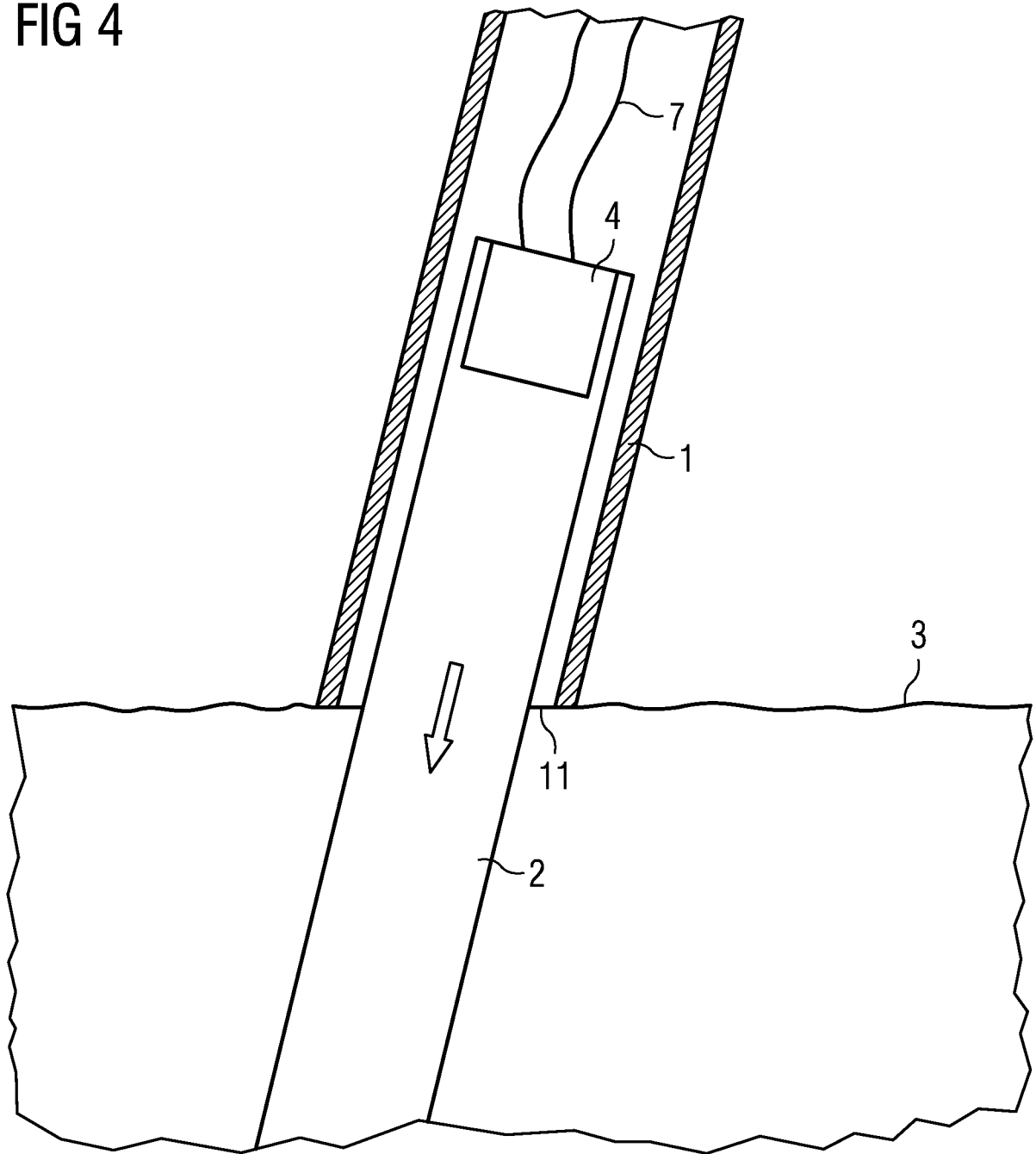


FIG 5

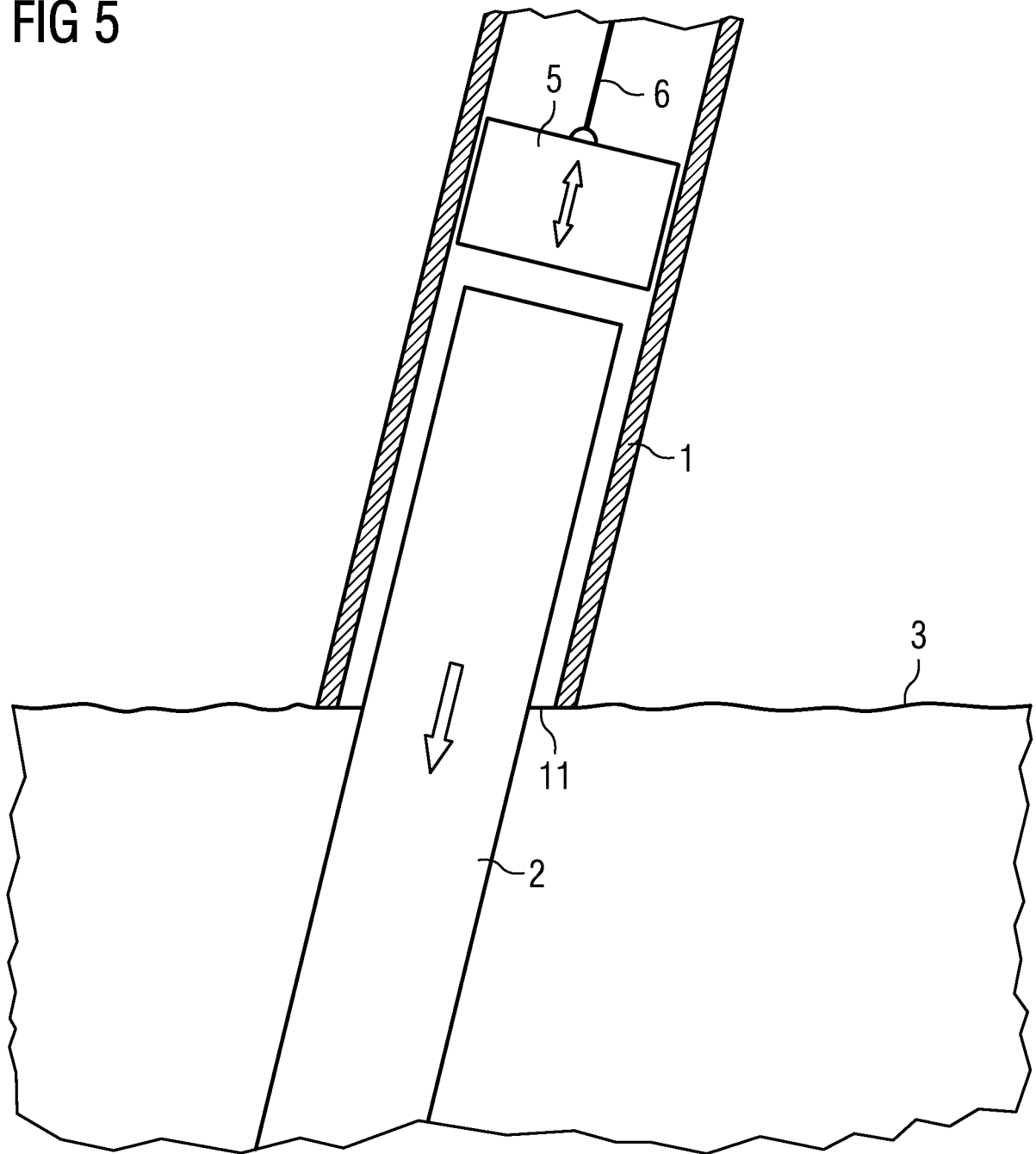


FIG 6

