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(54) **OFFSHORE FOUNDATION STRUCTURE, OFFSHORE FOUNDATION AND METHOD OF ESTABLISHING THE SAME**

OFFSHORE-FUNDAMENTSTRUKTUR, OFFSHORE-FUNDAMENT UND VERFAHREN ZU SEINER HERSTELLUNG

STRUCTURE DE FONDATIONS EN MER, FONDATIONS EN MER ET SON PROCÉDÉ D'ÉTABLISSEMENT

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WO-A1-2005/040605 **WO-A1-2009/155639**
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Description

[0001] The present invention relates to an offshore foundation structure and, in particular, to a wind turbine offshore foundation structure. In addition, the invention relates to an offshore foundation, in particular to a wind turbine offshore foundation, and to a method of establishing such an offshore foundation.

[0002] 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, a tripod construction, for example, in DE 10 2004 042 066 A1.

[0003] A typical method for establishing a foundation based on a jacketed construction or a tripod construction is to prepare the seabed prior to establishing the foundation which includes levelling out variations of the height of the seabed in 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 seabed.

[0004] GB 2460172 A discloses a method of installing a pile in the seabed in which method a guide structure for the pile is used. The guide structure comprises a tubular column/support that is carried on four footings. A tubular pile which is to be installed into a socket in the seabed is supplied within a vertical column/support, as it is shown in the figure as a hidden component. Each footing stands on an adjustable foot which is capable of being moved through some small distance vertically as well as being attached in the pivotable manner.

[0005] The guide structure will be totally or partly removed after installing the pile.

[0006] WO 2009/155639 A1 describes a drilling platform for geological sample drilling. A plurality of legs extend from the platform to the ground and are of variable lengths, which allows the platform to be set horizontally even on uneven ground.

[0007] WO 2005/040605 A1 describes an offshore foundation for a wind energy plant. The offshore foundation comprises a number of legs with piles located inside the legs. The piles can be rammed into the seabed. From this document the features of the preamble of claim 1 are known.

[0008] EP 1 707 808 A2 describes feet for an offshore wind energy plant which may be anchored in the seabed by use of piles driven through the feet.

[0009] 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 tripod construction) and the space between the leg and the pile is grouted to establish a secure connection.

[0010] With respect to the mentioned state of the art it is an objective of the present invention to provide an ad-

vantageous offshore foundation structure and an advantageous offshore foundation, in particular for wind turbines. It is a further objective of the present invention to provide an advantageous method of establishing an offshore foundation.

[0011] The first objective is solved by an offshore foundation structure as claimed in claim 1 and by an offshore foundation as claimed in claim 5. The second objective is solved by a method of establishing an offshore foundation as claimed in claim 9. The depending claims contain further developments of the present invention.

[0012] An inventive offshore foundation structure which may, in particular, be a wind turbine foundation structure, i.e. a foundation structure for carrying a wind turbine tower comprises at least one leg to be positioned on the seabed. Typically, such a foundation structure is formed as jacket structure or a tripod structure with three legs resting on the seabed. The at least one leg of the inventive offshore foundation structure comprises an adjusting means which is able to, and prepared for, adjusting the axial length of the leg.

[0013] The at least one leg comprises: a main tube extending along an axial direction and a seabed plate which is located at the seabed side end of the main tube and prepared to hold the structure at least temporarily on the seabed. A seabed plate tube extends from said seabed plate into said main tube and is prepared to be moved in relation to said main tube in axial direction of said main tube. An adjusting means is present which is able to, and prepared for, adjusting the relative axial position of the main tube and the seabed plate tube to each other.

[0014] To allow for secure anchoring of the foundation structure in the seabed the at least one leg comprises a pile which is adapted to be driven into the seabed. The pile extends at least partly through the seabed plate tube and the main tube. This allows the pile to be located inside the leg or the legs of the offshore foundation structure when the foundation structure is positioned on the seabed and to drive the piles into the seabed after positioning the foundation structure whereby the piles and the driving means for driving the piles can be guided by the main tube and the seabed plate tube. The piles can be established in the seabed after the foundation structure is placed on the seabed through the main tube and the seabed plate tube.

[0015] In the state of the art, prior to establishing a foundation, variations of the height of the seabed are levelled out in order to achieve a construction in level. Compared to this state of the art the invention is advantageous in that the preparation of the seabed prior to establishing the foundation can be minimized as the adjusting means is able to level out even large variation of the height of the seabed in order to achieve a construction in level. The need for levelling the seabed prior to establishing a foundation can thus be reduced or even completely eliminated.

[0016] The adjusting means can be a jack means

which acts between the seabed plate tube and the main tube. In particular, the seabed plate tube and/or the main tube can comprise a jack base means which is prepared for holding the jack means and/or for providing support for the jack means. Other adjusting means like, for example, gear wheels acting between the seabed plate tube and the main tube, are in general conceivable.

[0017] The adjusting means for adjusting the relative axial position of the main tube and the seabed plate tube to each other can be designed such as to be removable from the leg so that it can be reused in another leg. However, the adjusting means can also be an integral part of the leg so that it remains in the leg after the foundation has been established.

[0018] Although jacket structures and tripod structures have been mentioned as typical offshore foundation structures other structures having two, four, or more legs are also conceivable.

[0019] According to a second aspect of the present invention, an offshore foundation established on a seabed is provided. The offshore foundation may, in particular, be a wind turbine offshore foundation. The offshore foundation comprises an inventive offshore foundation structure resting on the seabed. The axial length of the at least one leg is so adjusted as to level out variations of the seabed on which the foundation structure rests.

[0020] In a concrete implementation, the length of the leg is adjusted by adjusting a relative axial position of a main tube and a seabed plate tube to each other so as to level out variations of the height of the seabed.

[0021] The inventive offshore foundation reduces, or even eliminates, the need for levelling out the seabed area on which the foundation is to be established.

[0022] A space between the main tube and the seabed plate tube of the offshore foundation structure leg may be grouted in order to increase stability of the foundation.

[0023] The at least one leg of the offshore foundation comprises a pile which is driven into the seabed so as to function as an anchor for the foundation. Such a pile partly extends through the seabed plate tube and the main tube.

[0024] According to a third aspect of the present invention a method of establishing an offshore foundation on the seabed, in particular, a wind turbine offshore foundation as described above is provided. The method comprises the steps of positioning an inventive offshore foundation structure and adjusting the offshore foundation structure by use of the adjusting means. The inventive method further comprise the step of anchoring the offshore foundation structure by driving piles into the seabed.

[0025] The inventive method reduces the need for precisely levelling the seabed since the adjusting means can be designed such as to be able to level out even large variations of height of the seabed in order to achieve a construction in level. Levelling out the seabed before establishing the foundation can therefore be reduced, or even omitted if the seabed variations of the site in which

the foundation is to be established are not too large.

[0026] The foundation structure is first placed on the seabed and then the piles are driven into the seabed through the seabed blade tube and the main tube. The offshore foundation structure, for example a space between the pile and the seabed blade tube and/or the main tube may be grouted in order to increase stability of the structure after the pile has been driven into the seabed or the foundation structure has been placed on the pile.

[0027] 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.

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

Figure 2 shows a tripod structure of an offshore wind turbine foundation in a highly schematic view.

Figure 3 shows a section of an offshore foundation structure.

Figure 4 shows a section of an offshore foundation structure.

Figure 5 shows a section of an offshore foundation structure.

[0028] The present invention will now be described by way of exemplary embodiments. These embodiments are mainly depicted in Figures 3 to 4 and relate in general to an advantageous wind turbine tower offshore foundation structure, an advantageous wind turbine tower offshore foundation established by using the wind turbine tower offshore foundation structure and an advantageous method of establishing an offshore wind turbine tower foundation such as a tripod or jacket structure on the seabed.

[0029] A possible offshore foundation structure by which the invention can be realised is a jacket structure as it is shown in Figure 1 in highly schematic view. The jacket structure shown in this figure comprises three legs 11 each forming a tubular hollow foundation member. 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 11 forming tubular hollow foundation members support a tube 9 carrying an installation like a wind turbine.

[0030] Figure 3 shows a leg 11 of an inventive foundation structure, which could be either a tripod - or jacket type structure. The leg 11 is equipped with an open longitudinal end 12 which is placed on the seabed 6 such that the open longitudinal end 12 shows towards the seabed 6. The legs 11 are slightly tilted with respect to the

vertical direction. Piles 7 may project through the open longitudinal ends 12 of the legs 11 into the seabed 6 to form anchors for the foundation structure. The interior of the longitudinal hollow foundation members 11 may be grouted, in particular the space between the piles 7 and the inside wall of the legs 11, in order to increase stability of the structure. Apart from using piles as anchors securing the foundation structure in place can also be achieved by anchoring means other than piles or by means of gravitation foundations.

[0031] In particular, Figure 3 shows the seabed end of a leg 11 of a wind turbine foundation structure (e.g. tripod or jacket). At its end nearest the seabed 6, one or more of the legs 11 of the wind turbine foundation structure according to the first embodiment comprise(s) for a minimum configuration:

- A main tube 3 of the foundation structure leg 11,
- a seabed plate 1 prepared to hold the structure at least temporarily on the seabed 6,
- a seabed plate tube 2 prepared to be moved in relation to the said main tube 3 in the axial direction of the main tube 3, and
- a jack means 5 which is able to, and prepared for, adjusting the relative axial position of the main tube 3 and the seabed plate tube 2 to each other.

[0032] The seabed plate tube 2 of the present embodiment is located inside the main tube 3.

[0033] For a further embodiment of the invention the main tube 3 and/or the seabed plate tube 2 further comprise(s) jack base means 4 which is prepared for holding the jack means 5 and/or providing support for the jack means 5 and which can withstand the loads applied to the base means 4 by e.g. the weight of the foundation structure through the jack means 5.

[0034] Like Figure 3, Figure 4 shows the seabed end of a leg 11 of a wind turbine offshore foundation structure (e.g. tripod or jacket). In this Figure, the foundation structure is further supported in its position by one or more piles 7 penetrating the seabed 6. The piles 7 can be made of e.g. steel, concrete or reinforced concrete or a combination hereof.

[0035] The piles 7 are established in the seabed 6 after the foundation structure is placed on the seabed such as through the main tube 3 and the seabed plate tube 2 as indicated by the arrow in the figure.

[0036] For various embodiments of the invention the main tube 3 and/or the seabed plate tube 2 may be secured to the pile 7 by grouting the space 10b between the pile 7 and the seabed plate tube 2 and/or the space 10a between the pile 7 and the main tube 3.

[0037] An offshore foundation which is not part of the invention as claimed in the appended claims is schematically illustrated in Figure 5. Like Figures 3 and 4, Figure 5 shows the seabed end of a leg 11 of a wind turbine foundation structure (e.g. tripod or jacket). In this kind of offshore foundation, the seabed plate 1 further comprises

a separate pile tube 8 which extends vertically or near vertically from the seabed plate 1 and which is prepared for receiving a pile 7. The piles 7 can be made of e.g. steel, concrete or reinforced concrete or a combination hereof.

[0038] With the kind of offshore foundation shown in Figure 5, the piles 7 may be established in the seabed 6 before the foundation structure and the pile tubes 8 of the seabed plate 1 are placed over the piles. As an alternative, the piles 7 may be established in the seabed 6 after the foundation structure is placed on the seabed such as through the pile tube 8.

[0039] For various embodiments of the invention the pile tube 8 may be secured to the pile 7 by grouting the space 10c between the pile 7 and the pile tube 8.

[0040] For various embodiments of the invention, the jack means 5 may be e.g. hydraulic operated, pneumatic operated or manually operated.

[0041] For even further embodiments of the invention, the jack means 5 may be removable so that it can be removed after positioning and possible grouting, or the jack means 5 may be non-removable so that it stays installed after positioning and possible grouting.

[0042] Examples for advantages which arise from the technical features according to the invention:

The invention is advantageous in that the preparation of the seabed prior to establishing the foundation, can be minimized as the jack means 5 is able to level out even large variations of the height of the seabed 6 in order to achieve a construction in level.

[0043] The invention can furthermore be advantageous in that the piles are established after the foundation structure has been positioned on the seabed. Thereby the piles do not need to be very accurately positioned on/in the seabed prior to positioning the foundation structure such as by a pre-fabricated and prepositioned pile-positioning template structure.

Claims

1. An offshore foundation structure, in particular a wind turbine foundation structure, with at least one leg (11) to be positioned on the seabed (6), wherein the at least one leg (11) comprises:

- a main tube (3) extending along an axial direction,
- a seabed plate (1) which is located at the seabed (6) side end of the main tube (3) and prepared to hold the structure at least temporarily on the seabed (6),

characterised in that

the at least one leg (11) further comprises:

- a seabed plate tube (2) which extends from said seabed plate (1) into said main tube (3) and is prepared to be moved in relation to said main tube (3) in the axial direction of the main tube (3),
 - an adjusting means (5) which is able to, and prepared for, adjusting the axial length of the leg (11) where the adjusting means (5) is able to, and prepared for, adjusting the relative axial position of the main tube (3) and the seabed plate tube (2) to each other, and
 - a pile (7) which is adapted to be driven through the seabed plate tube (2) and the main tube (3) into the seabed (6) and which extends at least partly through the seabed plate tube (2) and the main tube (3).
2. The offshore foundation structure as claimed in claim 1, wherein the adjusting means is a jack means (5) acting between said seabed plate tube (2) and said main tube (3).
 3. The offshore foundation structure as claimed in claim 2, wherein said seabed plate tube and/or said main tube comprise(s) a jack base means (4) which is prepared for holding the jack means (5) and/or for providing support for the jack means (5).
 4. The offshore foundation structure as claimed in any of the claims 1 to 3, wherein the adjusting means (5) is removable.
 5. An offshore foundation, in particular a wind turbine foundation, established on a seabed comprising an offshore foundation structure as claimed in any of the claims 1 to 4 which rests on the seabed (3), wherein the lengths of the leg (11) is so adjusted as to level out variations of the height of the seabed (6).
 6. The offshore foundation as claimed in claim 5, wherein the lengths of the leg (11) is adjusted by an adjusted relative axial position of the main tube (3) and the seabed plate tube (2) to each other.
 7. The offshore foundation as claimed in claim 6, wherein there is a space between the main tube (3) and the seabed plate tube (2) and said space is grouted.
 8. The offshore foundation as claimed in any of the claims 5 to 7, wherein the at least one leg comprises a pile (7) which is driven into the seabed (6).
 9. A method of establishing an offshore foundation, in particular a wind turbine offshore foundation, as claimed in any of the claims 5 to 8 on the seabed, the method comprising the steps of positioning an offshore foundation structure as claimed in any of the claims 1 to 4, adjusting the offshore foundation

structure by use of the adjusting means (5) and the step of anchoring the offshore foundation structure by driving piles (7) into the seabed (6).

10. The method as claimed in claim 9, wherein the offshore foundation structure is grouted.

Patentansprüche

1. Offshore-Fundamentkonstruktion, insbesondere Windturbinenfundamentkonstruktion, mit mindestens einem Bein (11) zum Positionieren auf dem Meeresgrund (6), wobei das mindestens eine Bein (11) Folgendes umfasst:

- ein Hauptrohr (3), das in einer axialen Richtung verläuft,
- eine Meeresbodenplatte (1), die sich an dem am Meeresboden (6) befindlichen Ende des Hauptrohrs (3) befindet und so ausgelegt ist, dass sie die Konstruktion zumindest zeitweise am Meeresboden (6) hält,

dadurch gekennzeichnet, dass

das mindestens eine Bein (11) ferner Folgendes umfasst:

- ein Meeresbodenplattenrohr (2), das von der Meeresbodenplatte (1) aus in das Hauptrohr (3) hinein verläuft und so ausgelegt ist, dass es sich in Bezug zu dem Hauptrohr (3) in dessen axialer Richtung bewegen lässt,
- ein Einstellmittel (5), das in der Lage und dafür ausgelegt ist, die axiale Länge des Beins (11) einzustellen, wobei das Einstellmittel (5) in der Lage und dafür ausgelegt ist, die relative axiale Position des Hauptrohrs (3) und des Meeresbodenplattenrohrs (2) zueinander einzustellen, und
- einen Pfeiler (7), der so ausgelegt ist, dass er durch das Meeresbodenplattenrohr (2) und das Hauptrohr (3) in den Meeresboden (6) getrieben wird, und zumindest teilweise durch das Meeresbodenplattenrohr (2) und das Hauptrohr (3) verläuft.

2. Offshore-Fundamentkonstruktion nach Anspruch 1, wobei es sich bei dem Einstellmittel um ein Hebemittel (5) handelt, das zwischen dem Meeresbodenplattenrohr (2) und dem Hauptrohr (3) wirkt.

3. Offshore-Fundamentkonstruktion nach Anspruch 2, wobei das Meeresbodenplattenrohr und/oder das Hauptrohr ein Hebeansatzmittel (4) umfasst/umfassen, das dafür ausgelegt ist, das Hebemittel (5) zu halten und/oder abzustützen.

4. Offshore-Fundamentkonstruktion nach einem der Ansprüche 1 bis 3, wobei das Einstellmittel (5) entfernbar ist.
5. Auf einem Meeresboden errichtetes Offshore-Fundament, insbesondere Windturbinenfundament, mit einer Offshore-Fundamentkonstruktion nach einem der Ansprüche 1 bis 4, die auf dem Meeresboden (3) liegt, wobei die Länge des Beins (11) so eingestellt ist, dass Unterschiede der Höhe des Meeresbodens (6) ausgeglichen werden.
6. Offshore-Fundament nach Anspruch 5, wobei die Länge des Beins (11) durch eine eingestellte relative axiale Position des Hauptrohrs (3) und des Meeresbodenplattenrohrs (2) zueinander eingestellt ist.
7. Offshore-Fundament nach Anspruch 6, wobei zwischen dem Hauptrohr (3) und dem Meeresbodenplattenrohr (2) ein Zwischenraum besteht und der Zwischenraum vergossen ist.
8. Offshore-Fundamentkonstruktion nach einem der Ansprüche 5 bis 7, wobei das mindestens eine Bein einen Pfeiler (7) umfasst, der in den Meeresboden (6) getrieben ist.
9. Verfahren zum Errichten eines Offshore-Fundaments, insbesondere eines Offshore-Windturbinenfundaments, nach einem der Ansprüche 5 bis 8 auf dem Meeresboden, wobei das Verfahren das Positionieren einer Offshore-Fundamentkonstruktion nach einem der Ansprüche 1 bis 4, das Einstellen der Offshore-Fundamentkonstruktion durch Verwendung des Einstellmittels (5) und das Verankern der Offshore-Fundamentkonstruktion durch Treiben von Pfeilern (7) in den Meeresboden (6) umfasst.
10. Verfahren nach Anspruch 9, wobei die Offshore-Fundamentkonstruktion vergossen ist.

Revendications

1. Structure de fondations en mer, en particulier structure de fondations d'éolienne, avec au moins une jambe (11) destinée à être positionnée sur le fond marin (6), dans laquelle l'au moins une jambe (11) comprend :
- un tube principal (3) s'étendant le long d'un sens axial,
 - une plaque (1) de fond marin qui est située à l'extrémité de côté fond marin (6) du tube principal (3) et préparée pour maintenir la structure au moins temporairement sur le fond marin (6),

caractérisée en ce que

l'au moins une jambe (11) comprend en outre :

- un tube (2) de plaque de fond marin qui s'étend depuis ladite plaque (1) de fond marin jusque dans ledit tube principal (3) et est préparé pour être déplacé par rapport audit tube principal (3) dans le sens axial du tube principal (3),
- un moyen (5) d'ajustement qui est apte à, et préparé pour, ajuster la longueur axiale de la jambe (11) où le moyen (5) d'ajustement est apte à, et préparé pour, ajuster la position axiale relative du tube principal (3) et du tube (2) de plaque de fond marin l'une par rapport à l'autre, et
- un pilier (7) qui est adapté à être conduit à travers le tube (2) de plaque de fond marin et le tube principal (3) jusque dans le fond marin (6) et qui s'étend au moins partiellement à travers le tube (2) de plaque de fond marin et le tube principal (3).

2. Structure de fondations en mer selon la revendication 1, dans laquelle le moyen d'ajustement est un moyen (5) de vérin agissant entre ledit tube (2) de plaque de fond marin et ledit tube principal (3).
3. Structure de fondations en mer selon la revendication 2, dans laquelle ledit tube de plaque de fond marin et/ou ledit tube principal comprennent/comprend un moyen (4) de base de vérin qui est préparé pour maintenir le moyen (5) de vérin et/ou pour offrir un support pour le moyen (5) de vérin.
4. Structure de fondations en mer selon l'une quelconque des revendications 1 à 3, dans laquelle le moyen (5) d'ajustement est amovible.
5. Fondations en mer, en particulier fondations d'éolienne, établies sur un fond marin comprenant une structure de fondations en mer selon l'une quelconque des revendications 1 à 4 qui repose sur le fond marin (6), dans lesquelles la longueur de la jambe (11) est ajustée de manière à niveler des variations de la hauteur du fond marin (6).
6. Fondations en mer selon la revendication 5, dans lesquelles la longueur de la jambe (11) est ajustée par une position axiale relative ajustée du tube principal (3) et du tube (2) de plaque de fond marin l'une par rapport à l'autre.
7. Fondations en mer selon la revendication 6, dans lesquelles il y a un espace entre le tube principal (3) et le tube (2) de plaque de fond marin et ledit espace est cimenté.
8. Fondations en mer selon l'une quelconque des revendications 5 à 7, dans lesquelles l'au moins une

jambe comprend un pilier (7) qui est conduit jusque dans le fond marin (6).

9. Procédé d'établissement de fondations en mer, en particulier de fondations en mer d'éolienne, selon l'une quelconque des revendications 5 à 8 sur le fond marin, le procédé comprenant les étapes de positionnement d'une structure de fondations en mer selon l'une quelconque des revendications 1 à 4, d'ajustement de la structure de fondations en mer en utilisant le moyen (5) d'ajustement et l'étape d'ancrage de la structure de fondations en mer en conduisant des piliers (7) jusque dans le fond marin (6). 5 10
10. Procédé selon la revendication 9, dans lequel la structure de fondations en mer est cimentée. 15

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FIG 1

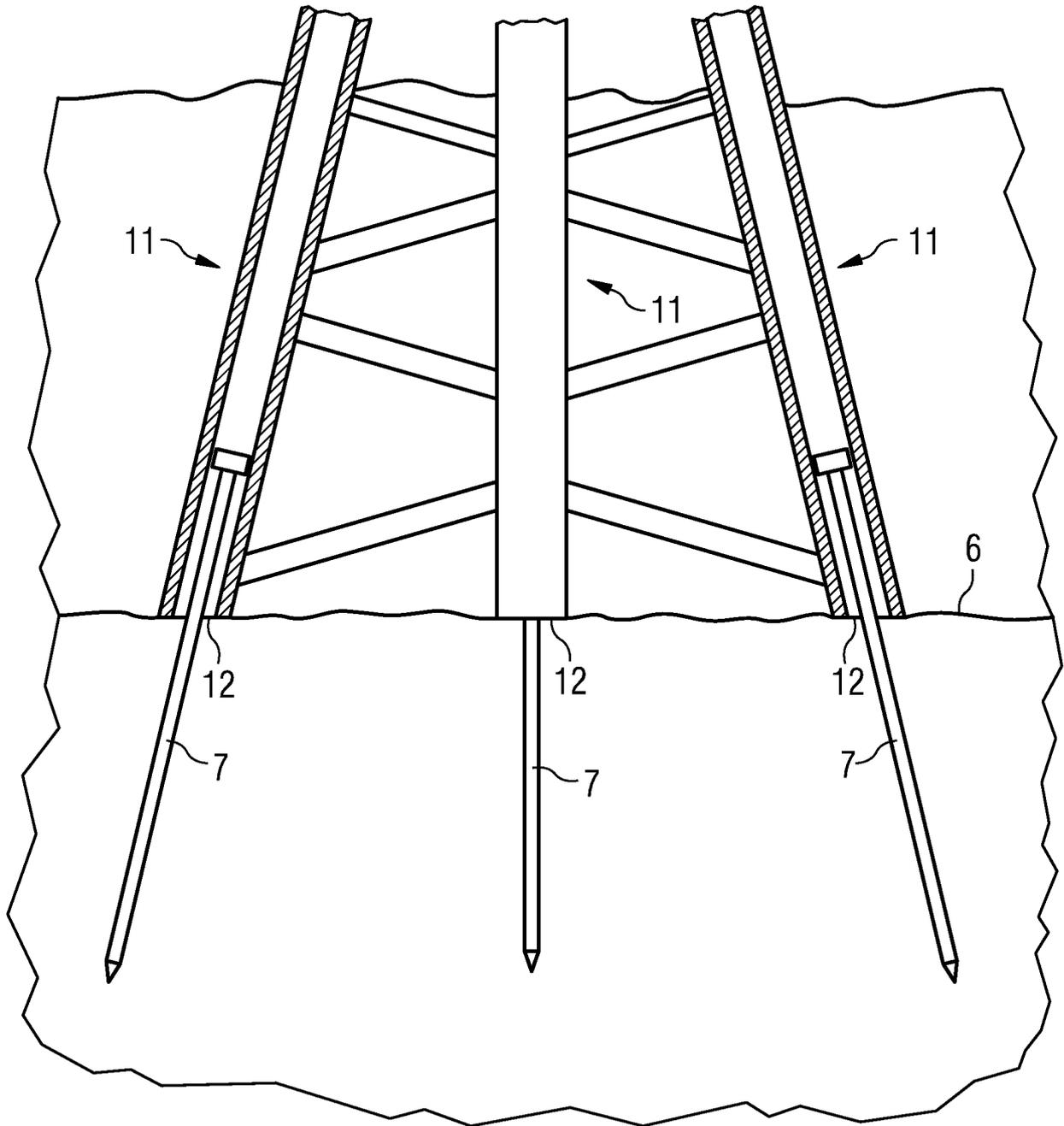


FIG 2

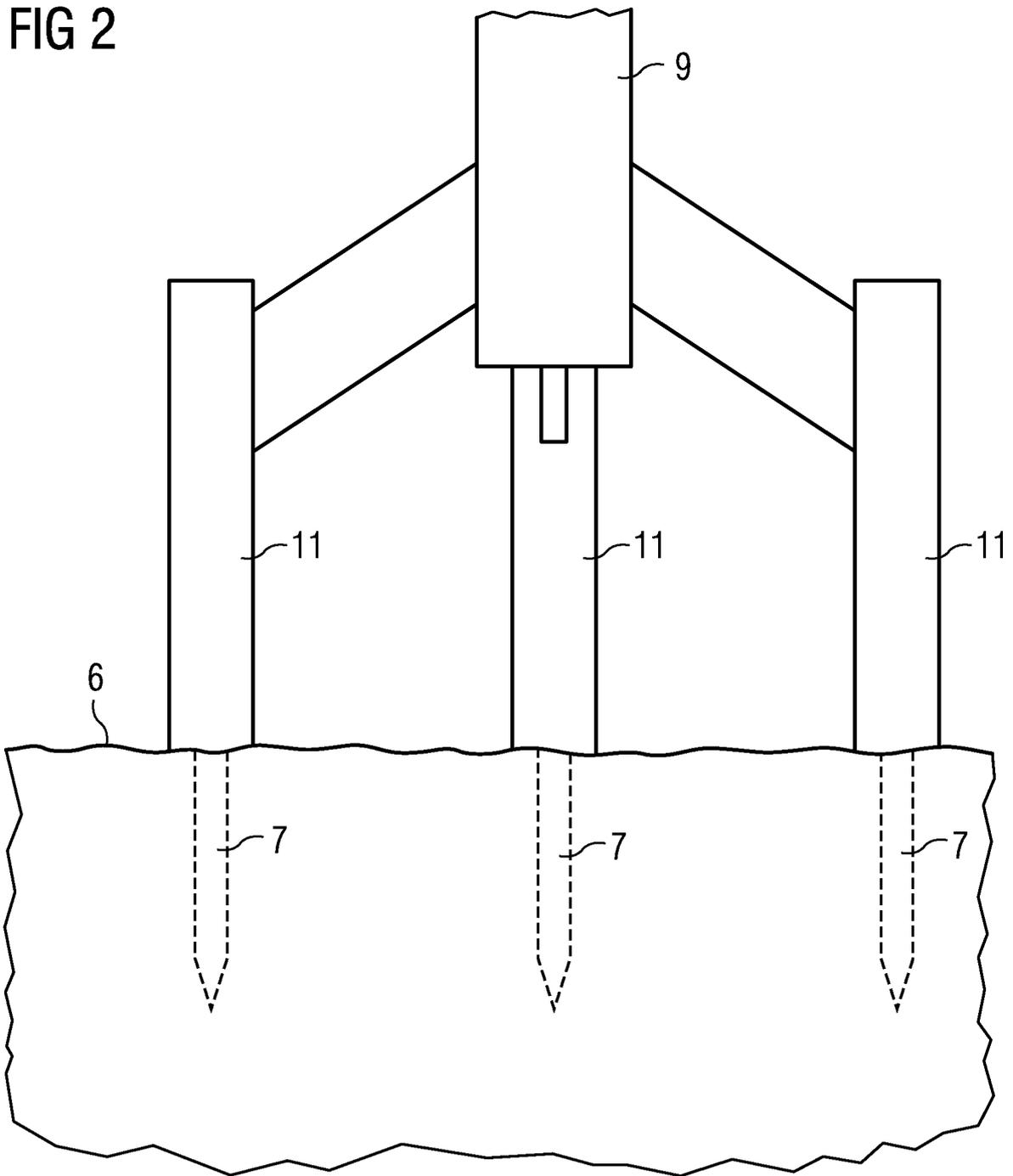


FIG 3

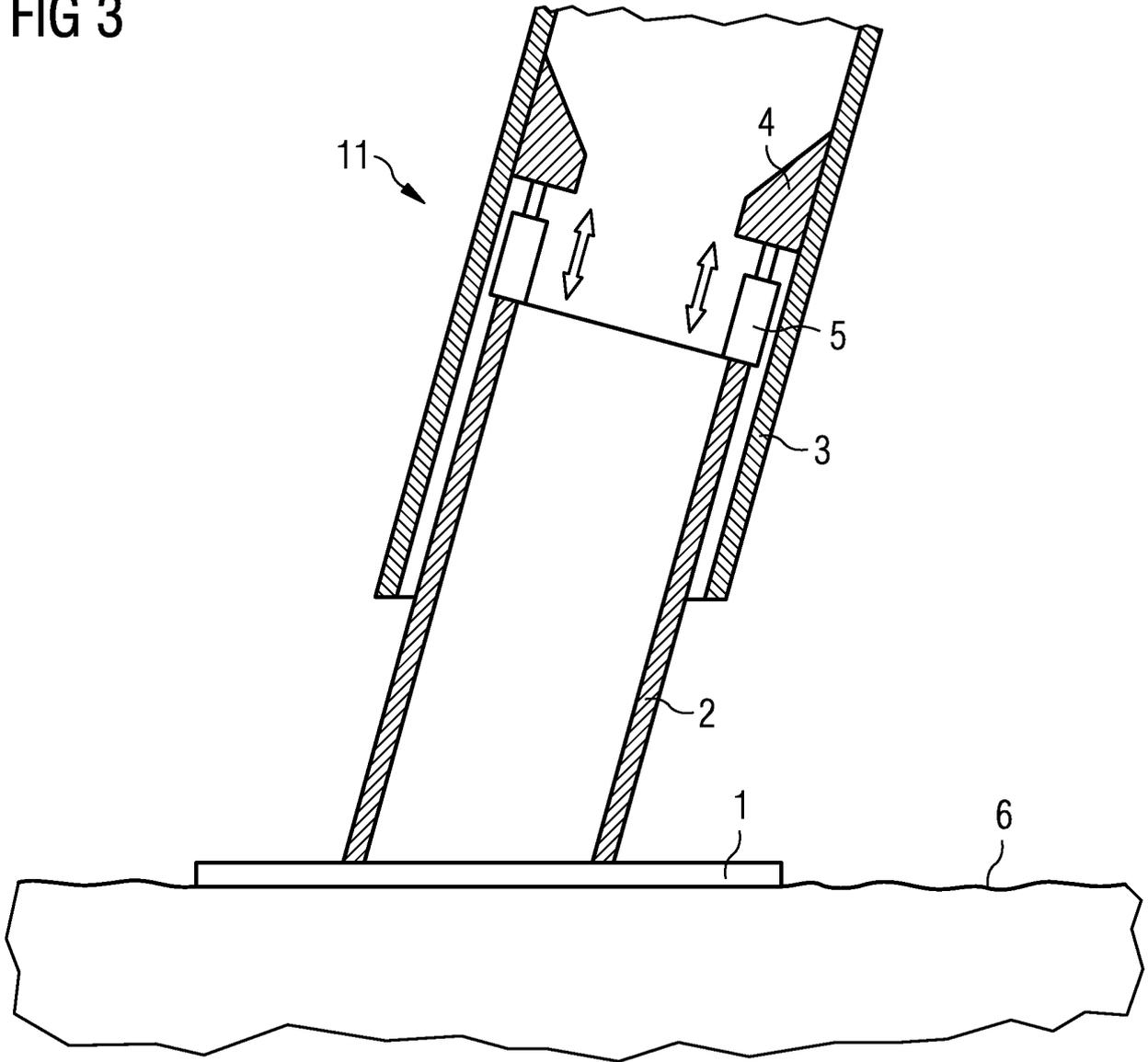


FIG 4

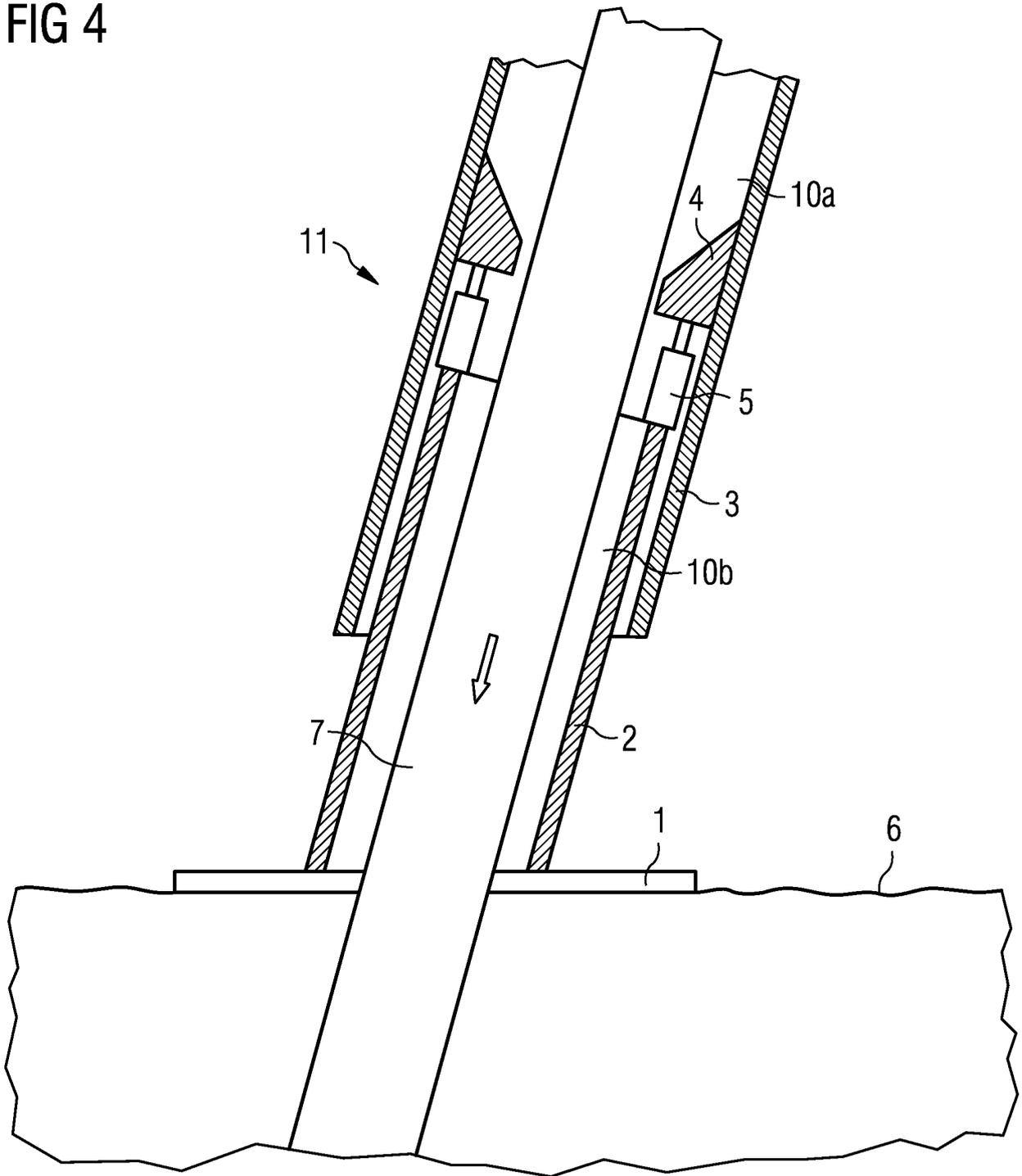
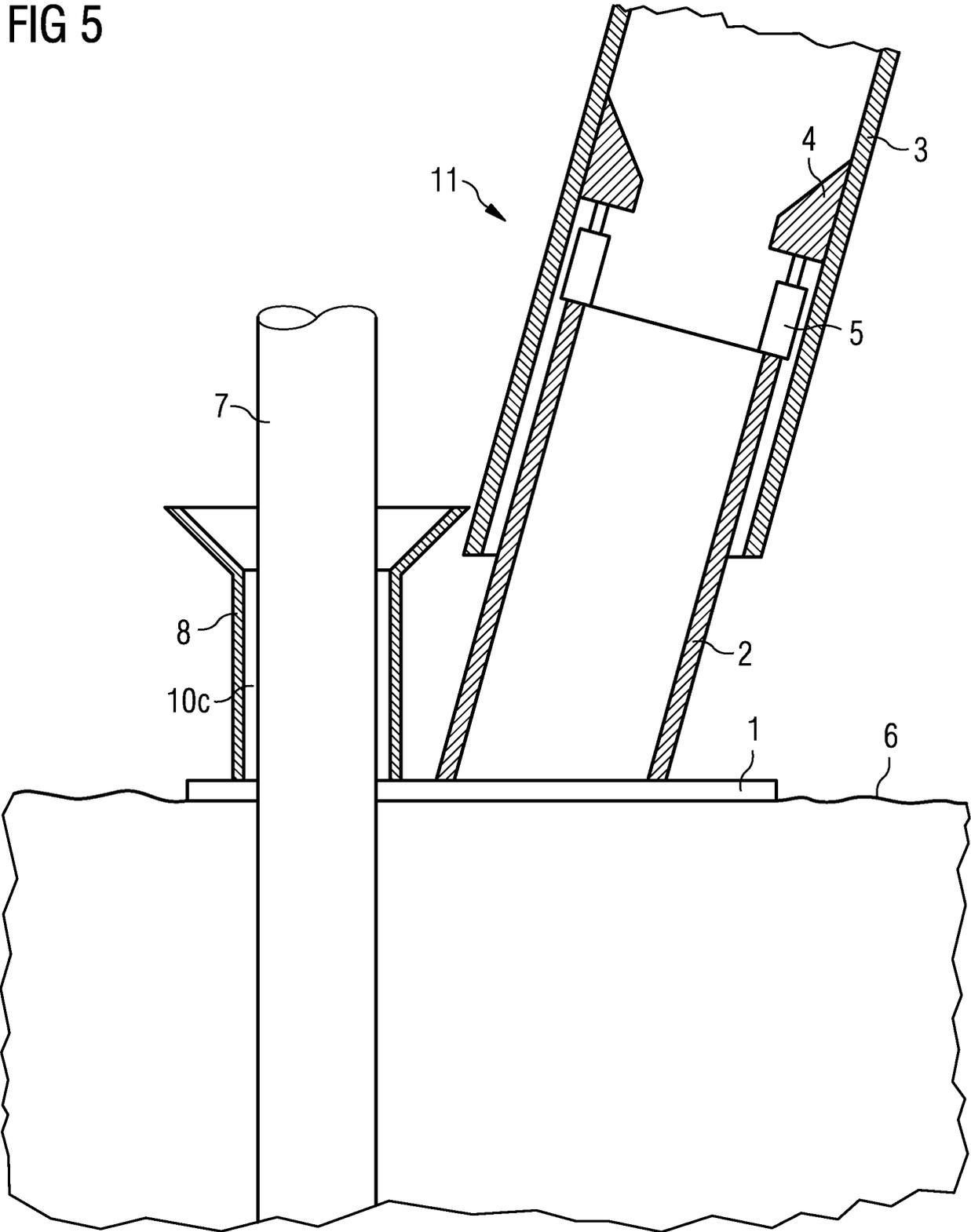


FIG 5



REFERENCES CITED IN THE DESCRIPTION

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