(19) DANMARK

(10) **DK/EP 2546829 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: ***G 10 K 11/16 (2006.01)*** ***E 02 D 13/00 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2016-06-06**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2016-03-23**

(86) Europæisk ansøgning nr.: **12004900.2**

(86) Europæisk indleveringsdag: **2012-06-29**

(87) Den europæiske ansøgnings publiceringsdag: **2013-01-16**

(30) Prioritet: **2011-07-11 DE 102011107529**

(84) Designerede stater: **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**

(73) Patenthaver: **Christian-Albrechts-Universität zu Kiel, Olshausenstrasse 40, 24118 Kiel, Tyskland**
Fachhochschule Kiel, Sokratesplatz 1, 24149 Kiel, Tyskland

(72) Opfinder: **Dahmke, Andreas, Prof., Dr., Schlossgebiet 5, 24306 Plön, Tyskland**
Kinias, Constantin, Prof., Dr., Schönkamp 21, 24226 Heikendorf, Tyskland
Ipsen, Janina, Königsweg 60, 24114 Kiel, Tyskland

(74) Fuldmægtig i Danmark: **PATRADE A/S, Fredens Torv 3A, 8000 Århus C, Danmark**

(54) Benævnelse: **Indretning til reducering af støjniveauet af undersøiske lydkilder**

(56) Fremdragne publikationer:
WO-A2-2010/151121
DE-A1-102004 043 128
JP-A- S60 159 218
US-A1- 2011 031 062

The invention relates to a device for reducing the sound level of local underwater sound sources.

The medium water is a good acoustic conductor of sound over a large frequency range. In particular ultrasound sources can be detected over hundreds of kilometres from their point of origin under good propagation conditions and at frequencies which are selected appropriately in terms of propagation.

Many living marine organisms deliberately generate noises for communication purposes and the noises/acoustic signals caused by the body form are utilised by many species to find food; likewise, reflected acoustic signals serve for catching prey and also for recognising obstacles. One species which should be particularly mentioned in this connection is porpoises, which are the sole whale group occurring in the Baltic and the North Sea. Their auditory thresholds - and also those of seals - in the region of less than 400 Hertz lie about 10 to 20 dB higher than at 1000 Hertz, and end at approximately 150 kHz.

For constructing offshore wind farms and offshore platforms, it is necessary for large mooring piles - depending on the depth of the water and the area of use above the sea surface - to have to be driven up to 35 metres deep into the sea bed, for which purpose quite some 15,000 pile-driving blows may be necessary, with an energy of 200 to 950 kJ or kNm being applied for each blow. In such case, sound pressure levels are produced, the pulse intensity of which can be so high that the auditory organs of marine animals which are dependent on their hearing ability for their survival are damaged so severely even by only a few pile-driving blows that it becomes virtually impossible for them to survive.

The sound pressure level L in seawater is described by the sound pressure in pascals [Pa] and measured in decibels [dB]. It can be represented in the form

$$L[dB] = 20 \cdot \lg\left(\frac{\tilde{p}}{p_0}\right)$$, with

1 Pa = 1 N/m^2. The reference pressure p_0 for water is by convention $p_0 = 10^{-6}$ Pa [as dB re 1µPa]. For these measured and reference variables, the measured sound pressure levels at a distance of l = 750 metres are 160 to 174 dB. Investigations have shown that even single sound events, if their energy peak is very high, cause irreversible hearing damage in marine mammals. Since the sound pressure level is determined by averaging, for the single-event sound pressure

level L_{single} a change of definition is effected in the form:

$$L_{\sin gle} = 10 \cdot \lg\left[\frac{l}{T}\int_{T_1}^{T_2}\frac{p(t)^2}{p_0^2}dt\right]$$

. Levels of the order of 190 to 195 dB have been determined according to this definition. The production of sound at the head of the driving pile can be explained by the strain curve, which can also be described approximately as a half-sine.

The guide values currently set for acoustic underwater noise - particularly for single events - during the construction phase of offshore systems at a distance of 750 metres are set at L_{single} = 160 dB, and the peak values at L_{peak} = 180 dB. This is why protective measures to reduce the sound level have to be taken for pile-driving work in contact with seawater.

The related prior art includes in particular protective acoustic walls in very varied technical embodiments - what are called bubble curtains, which are laid around the driving piles. For more extensive explanations see in particular: *Maruschek, K., Betke, K.: Measurement of Construction Noise During Pile Driving of Offshore Research Platforms and Wind Farms, NAG/DAGA 2009, pp. 262-265; Schultz-von Glahn, M., Betke, K., Nehls, G.: Minderung des Unterwasserschalls bei Rahmenarbeiten [sic] für Offshore-WEA - praktische Erprobung verschiedener Verfahren unter Offshore-Bedingungen* [Mitigation of underwater noise in frame work [sic] for offshore wind farms - practical testing of various methods under offshore conditions], *UFOPLAN Ref. No. 205 53 113, Umweltbundesamt* [German Federal Environment Agency] *final report, Berlin 2006.*

Reduction of the sound level in the case of these bubble curtains known from the prior art takes place due to the great differences in acoustic impedance of air and water at the plane of separation thereof in the form of a marked jump in impedance. In the vicinity of the resonant frequency of the bubble curtain wall, the acoustic surface of the individual gas bubbles attains a multiple of its geometric surface, as a result of which the bubble curtain achieves particularly great effectiveness in reducing the sound level [because of the steep phase gradient of the oscillating resonance system]. Depending on the frequency and thickness of the curtain, damping from 25 up to 30 dB is possible.

These bubble curtains are formed by perforated hose-type structures, which are laid at a short distance around the driving pile and are supplied continuously with

compressed air. For operation in greater depths of water, a plurality of hose-type or tubular structures are laid at short distances one above another and are mechanically stabilised.

Another embodiment of bubble curtains which is regarded by this party as the closest prior art uses a net structure into which float bodies with air exit openings are introduced and which is stretched around the driving pile. Mechanically filtered ambient air is used as compressed air which is to be fed in for all the bubble-curtain configurations which are to be counted as prior art and have been acknowledged here.

DE 10 2004 043 128 A1 discloses a device which is laid around underwater driving piles in order to reduce the sound pressure level produced by pile-driving blows. This device has an enveloping element which consists of two textile curtains which are fastened with a nozzle arrangement to form a bubble curtain between the textile curtains. The nozzle arrangement has a ballast mass in order to pull the textile curtains vertical.

What all the devices have in common is that they form an annular wall consisting of rising air bubbles around the pile-driving site. What is disadvantageous about all these designs and their variant embodiments is that in the event of a strong oceanic current the bubble curtain locally diffuses or may tear, which may also happen in the event of strong sea-surface waves. The result is greatly reduced acoustic damping values.

A further method known from the prior art for reducing the sound level of local underwater sound sources, what is called the Hydro Sound Damper according to K.-H. Elmer, provides for small, air-filled hollow spheres to be coated with foam and incorporated in nets. The net is then laid around the pile-driving site. This method too is highly dependent on the sea conditions and the tidal range.

In view of the disadvantages known from the prior art hitherto, it is an object of the invention to provide a device for reducing the sound level of local underwater sound sources which permits a high degree of damping even in unfavourable flow and sea-surface wave conditions.

According to the invention, this object is achieved by a device for reducing the sound level of underwater sound sources (see Figure 1), with:

- a sound level-reducing enveloping element (2), having openings (4, 5) for emitting a gaseous substance,
- a central alignment component (1) for the enveloping element (2),
- means (3) for spaced-apart alignment of the enveloping element (2) along the central alignment component (1),

characterised in that

- means (3) for spaced-apart alignment of the enveloping element (2) comprise link elements connected together in chain-like manner, suitable for forming a guide which is extensible in concertina-like manner for the sound level-reducing enveloping element (2).

In one possible embodiment of the invention presented here, the central alignment component (1) is a drilling rod by which mooring piles for offshore systems are introduced into the sea bed. Preferably in the context of the present invention this central alignment component (1) is however formed by the mooring piles themselves.

The enveloping element (2) in a first possible variant embodiment may be a net, into which very particularly preferably in the vertical direction gas-filled hoses with openings (4, 5) for emitting this gaseous substance are threaded. Preferably in the context of the present invention the enveloping element (2) is formed as a woven fabric, very particularly preferably as a woven plastics material. It represents a very particularly preferred embodiment of the invention if this woven plastics material as enveloping element (2) forms a closed body very particularly preferably in the form of a symmetrical cylindrical ring around the central alignment component (1). In a particularly preferred embodiment, a cylindrical ring thus proposed here extends at the bottom from the ground (8) without gaps to the top to the water line (7) (see Figure 3).

Further, a cylindrical ring of this type may have openings (5) on the inside for emitting the gaseous substance and/or openings (4) on the outside for emitting the gaseous substance. In particular compressed air is suitable in this case as gas, which is generated as mechanically filtered ambient air on site, that is to say at the place of use of the device according to the invention.

According to the invention, the means (3) for spaced-apart alignment of the enveloping element (2) comprise link elements which are connected together in

chain-like manner, suitable for forming a guide which is extensible in concertina-like manner for the sound level-reducing enveloping element (2). One very particularly preferred embodiment of the present invention provides for the link elements which are connected together in chain-like manner to be capable of forming at least one holding spindle, this holding spindle being oriented helically about the central alignment component (1) along the longitudinal axis thereof. Owing to the chain-like connection of the link elements, this holding spindle can then be extended or compressed in concertina-like manner in its extent along the longitudinal axis of the central alignment component (1), for which purpose the individual link elements of the holding spindle are folded towards each other, corresponding to Figure 2, or are folded out away from each other, corresponding to Figure 3. To this end, it is preferred if the link elements have pre-stressed spring elements within their mutual chain-like connection.

According to the invention, the problem underlying the invention is accordingly solved in the context of an embodiment by way of example in that a water-impermeable woven plastics-material sheath (2) in the form of a closed body - particularly preferably simply in a cylindrical shape - which is to be filled with air is built up around a mooring pile as central alignment component (1), the woven plastics-material sheath (2) separating the mooring pile (1) medium-wise from the ground (8) up to the upper water line (7). Separating medium-wise in the context of the present invention means that seawater lies against the outside of the cylindrical ring, formed from the air-filled woven plastics-material sheath as sound level reducing enveloping element (2), whereas within the cylindrical ring around the mooring pile as central alignment component (1) the water can be removed, depending on the embodiment, as a result of which only air is still present, or the water within the cylindrical ring is at least decoupled from any current of the water outside the cylindrical ring.

The woven plastics-material sheath (2), which here forms the sound level reducing enveloping element (2), before its deployment is located folded-up around the folded-together link elements (3) in the hull (9). For the operating state, a shut-off means (10) on the underside of the hull (9) opens, and with the aid of spring elements which are connected to the link elements (3) the woven plastics-material sheath (2), formed as an inflatable, dual-walled sheath of cylindrical form, can be extended, as a result of which it is built up along the entire length of the mooring pile (1). Preferably the woven plastics-material sheath (2), which then separates the mooring pile (1) medium-wise from the seawater, can be pro-

vided with holes (5) on the inside, through which air is forced by a compressor (6), so that the bubbles rising directly on the sound protection wall from the ground (8) to the water line (7) form a closely-contacting, rising wall of bubbles which, uninfluenced by seawater movements, brings about an additional reduction in the sound level.

The same woven plastics-material sheath (2) which forms the sound protection wall can also additionally or alternatively be provided with holes (4) on the outside through which air is pressed, which results in additional damping of the sound level. The bubble curtain which is produced on the outside, which lies directly against the woven plastics-material sheath (2), as a continuous bubble curtain is more stable with respect to an existing oceanic current than known designs according to the prior art.

A further embodiment according to the invention by way of example provides for the sound protection wall not to consist of the entire air-filled space between the mooring pile (1) and the woven plastics-material sheath (2), but to be formed as a sandwich structure, in which water is in contact around the mooring pile (1) which is to be driven in, or around the drilling rod, and in which at a certain distance an air-filled dual wall is set up - which therefore consists of one layer filled with air and one layer filled with water - in the inner and outer sheaths of which again a large number of holes (5) on the inside and holes (4) on the outside are introduced through which air can be pressed.

List of terms:

(1) central alignment component
(2) sound level reducing enveloping element
(3) link elements connected together in chain-like manner
(4) holes on the outside
(5) holes on the inside
(6) compressor
(7) water line
(8) ground
(9) hull
(10) shut-off means

Patentkrav

1. Indretning til sænkning af lydniveauet af undersøiske lydkilder, med
- et lydniveaureducerende omhyldningselement (2) med åbninger (4, 5) til afgivelse af en gasformigt stof,
- en central opretningskomponent (1) for omhyldningselementet (2),
- midler (3) til afstandsmæssig opretning af omhyldningselementet (2) langs den centrale opretningskomponent (1),
kendetegnet ved, at
- midlerne (3) til afstandsmæssig opretning af omhyldningselementet (2) omfatter ledelementer, som er indbyrdes forbundne på kædelignende måde og egnet til dannelse af en harmonikaagtigt strækbar føring for det lydniveaureducerende omhyldningselement (2).

2. Indretning ifølge krav 1, **kendetegnet ved, at** den centrale opretningskomponent (1) er en fortøjningspæl til offshoreinstallationer, der kan sænkes ned i havbunden.

3. Indretning ifølge krav 1 eller 2, **kendetegnet ved, at** det lydreducerende omhyldningselement (2) er et kunststofvæv.

4. Indretning ifølge et af krav 1 til 3, **kendetegnet ved, at** indretningen omfatter et lukket legeme dannet af omhyldningselementet (2) og i form af en symmetrisk cylindrisk ring omkring den centrale opretningskomponent (1).

5. Indretning ifølge krav 4, **kendetegnet ved, at** den cylindriske ring har åbninger (5) på indersiden for afgivelse af et gasformigt stof.

6. Indretning ifølge krav 4 eller 5, **kendetegnet ved, at** den cylindriske ring har åbninger (4) på ydersiden for afgivelse af et gasformigt stof.

7. Indretning ifølge et af krav 1 til 6, **kendetegnet ved, at** det gasformige stof er trykluft.

8. Indretning ifølge et af krav 1 til 7, **kendetegnet ved, at** indretningen omfatter en holdespindel orienteret skrueformet om den centrale opretningskomponent (1) langs dens længdeakse og dannet af ledelementerne, som er indbyrdes forbundne på kædeagtig måde.

9. Indretning ifølge krav 8, **kendetegnet ved, at** holdespindlens enkelte ledelementer er udformet, så de kan foldes mod hinanden og væk fra hinanden.

10. Indretning ifølge et af krav 1 til 9, **kendetegnet ved, at** ledelementerne har forspændte fjederelementer indenfor deres indbyrdes kædeagtige forbindelse.

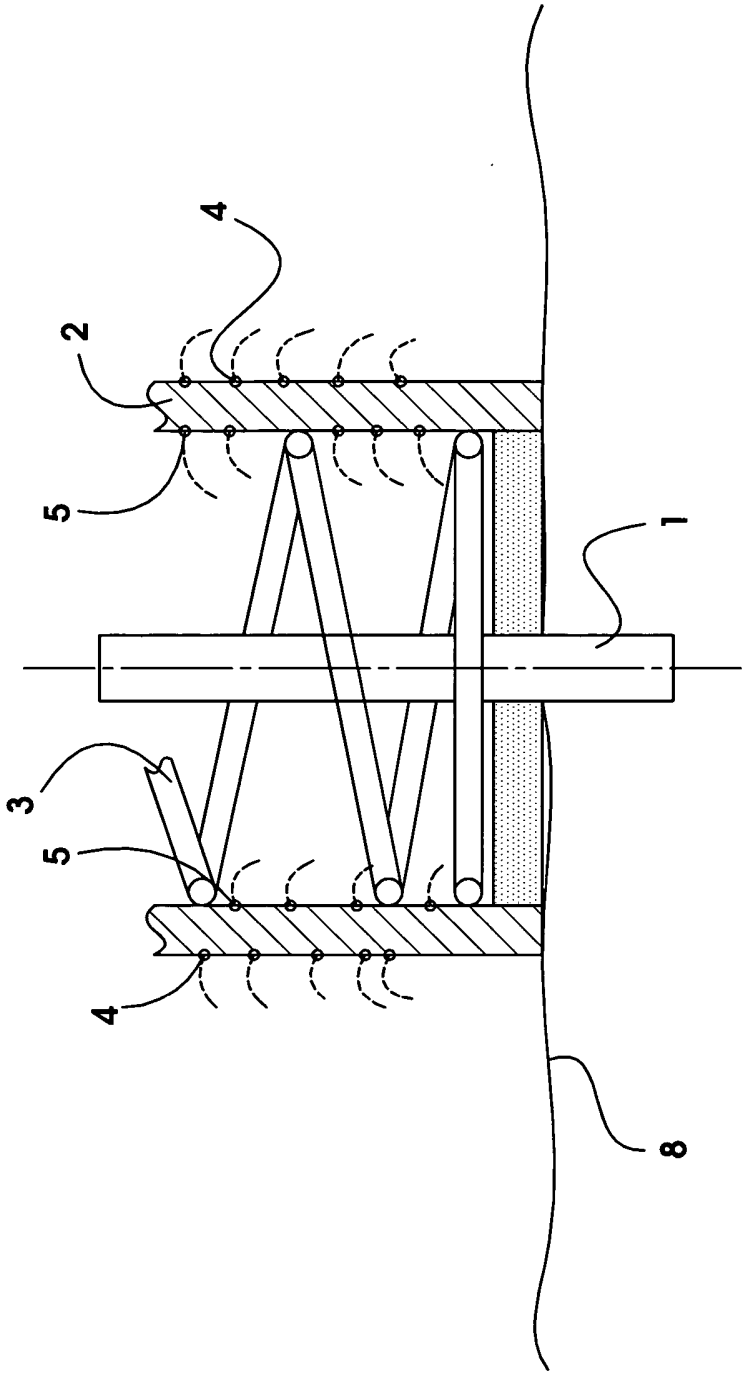

Fig.: 1

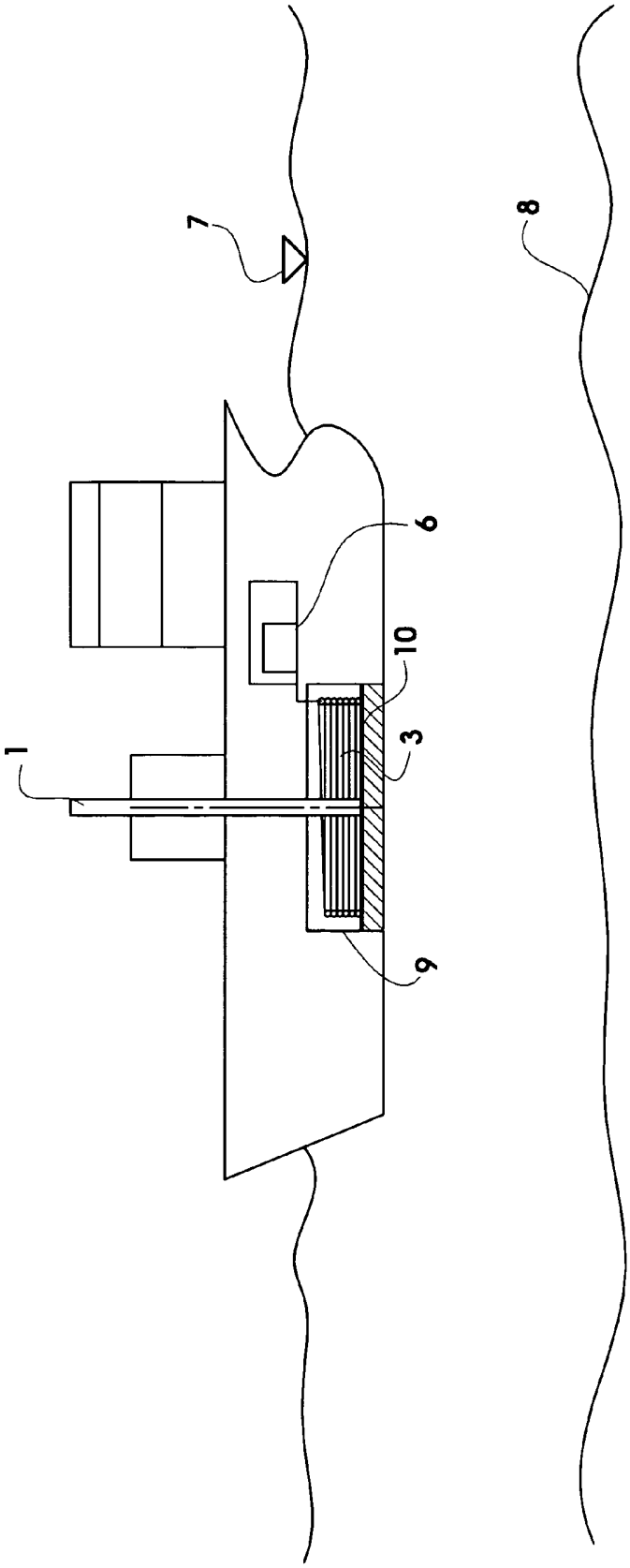

Fig.: 2

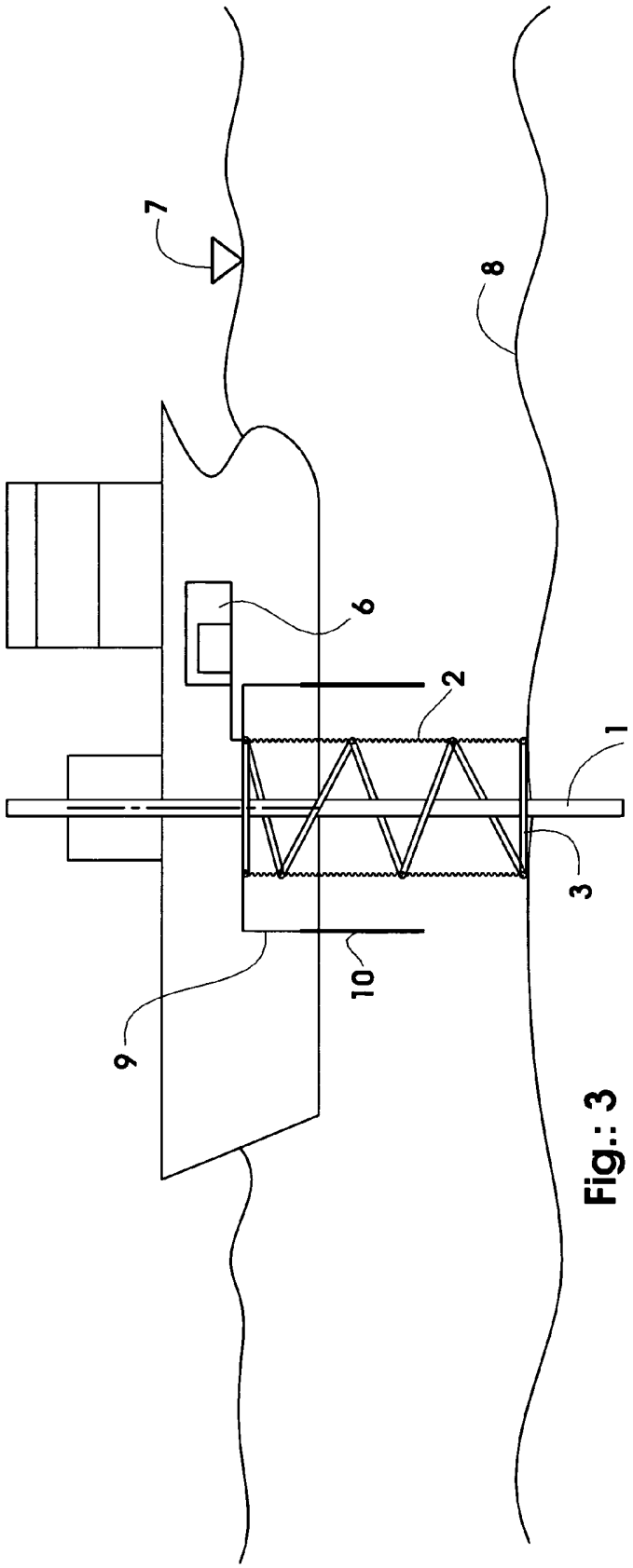

Fig.: 3