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(54) Offshore structure and mooring arrangement

(57) Offshore structure comprising an outer hull having longitudinal sides and at least one fairlead located adjacent a longitudinal side, and a hook, connected to the structure and located inboard relative to the fairlead and being displaced along the hull longitudinally from the fairlead, such that an angle of displacement between a tangent to the outer hull at the centre of the fairlead and the hook, is less than or equal to 45°.

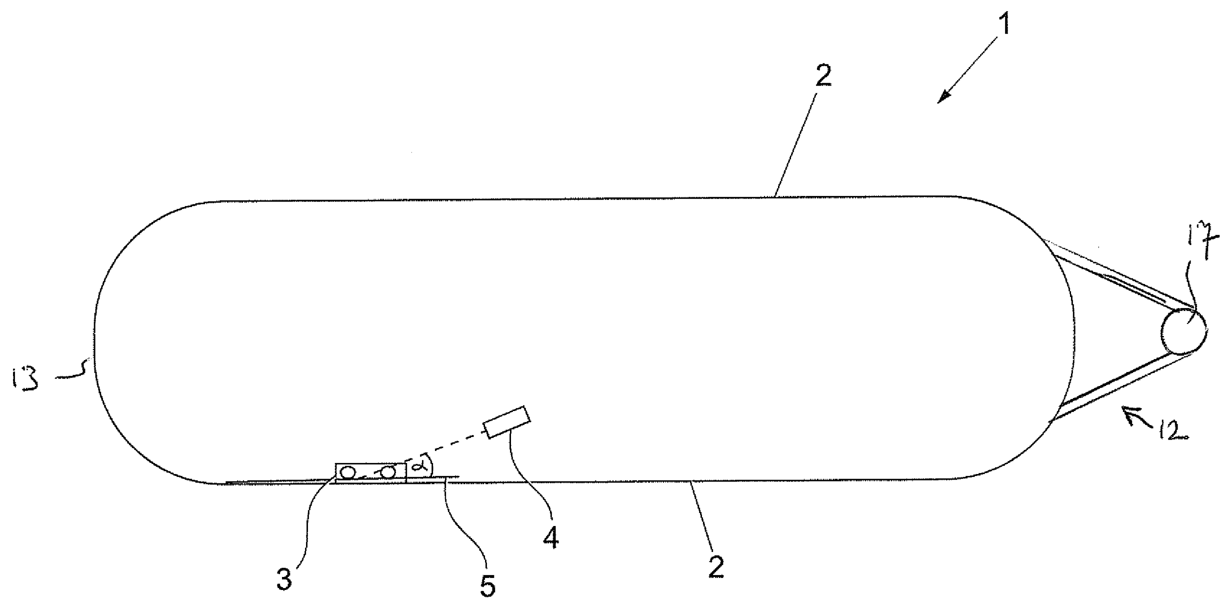

Fig. 1

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Description

[0001] The present invention relates to an offshore structure and a mooring arrangement.

[0002] Such an offshore structure may be used to produce hydrocarbon fluids from a subsea or underwater well and to process these fluids into a transportable form. In some cases, e.g. when a pipe line is not technically and/or commercially feasible, the processed hydrocarbon fluids need to be transferred into a tanker ship for transportation away from the offshore structure to a receiving site. In case of natural gas, for instance, the gas may be first liquefied to produce LNG in which form it can be transported by an LNG tanker, generally referred to as an LNG carrier (LNGC).

[0003] Alternatively, such an offshore structure may be used to receive hydrocarbon fluids that have been transported by a carrier ship from elsewhere, and optionally store and/or process the received hydrocarbon fluids.

[0004] Liquefied natural gas ("LNG") is produced when natural gas is cooled to a cold, colourless liquid at -160°C (-256°F). Storage of LNG requires much less volume for the same amount of natural gas. A number of storage tanks have been developed to store LNG in cryogenic form. In order to use LNG as a power source, the LNG is converted to its gaseous state using a re-vaporisation process. The re-vapoured LNG can then be distributed through pipelines to various end users.

[0005] One advantage of LNG is that LNG may be transported by ship to markets further than would be practical with pipelines. The ability of produce LNG offshore and to bring it onto a transport carrier allows for exploitation of gas reservoirs that would otherwise be too far removed from consumers of natural gas. Importing LNG by ships has led to the establishment of LNG storage and re-vaporisation facilities at on-shore locations that are close to shipping lanes. There is also a desire in the industry to provide offshore capabilities for receiving LNG and LPG producs from a transport carrier. As an example, WO 2006/052896 discloses a floating LNG storage and regasification unit ("FSRU").

[0006] Both types of offshore structures described above may advantageously employ a mooring arrangement in order to enable mooring of carrier ships to the offshore structure during loading and/or offloading of the hydrocarbon fluid(s).

[0007] In WO2006/101395 a mooring arrangement is provided on an offshore structure, for mooring a tanker vessel alongside of the offshore structure. The mooring arrangement uses a quick release coupling hook. The mooring lines are rather short because of the small distance of the side-by-side mooring geometry compared to mooring on-shore on a jetty. A relatively short nylon rope can be used in view of an extendable shock absorber that is provided on the hook in the form of a hydraulic cylinder and an extendable arm.

[0008] In a first aspect, the present invention provides an offshore structure comprising an outer hull having longitudinal sides and at least one fairlead located adjacent a longitudinal side, and a hook, connected to the structure and located inboard relative to the fairlead and being displaced along the hull longitudinally from the fairlead, such that an angle of displacement (α) between a tangent to the outer hull at the centre of the fairlead and the hook, is less than or equal to 45°.

[0009] In a second aspect, the present invention provides a mooring arrangement comprising at least one mooring line having a pennant at an end thereof, and an offshore structure according to the first aspect of the invention, wherein the at least one mooring line is configured to pass inboard of the outer hull through the fairlead and is attachable to the hook such that the angle of displacement of the at least one mooring line between the tangent to the hull at the centre of the fairlead and the hook is less than or equal to 45°.

[0010] The present invention and its advantages will now be further illustrated by means of examples and with reference to the drawing wherein:

Figure 1 shows a schematic plan view of an offshore structure in which the positioning of the fairlead and hook relative to the longitudinal sides of the structure are depicted;
Figure 2 shows a schematic plan view of a section of a mooring deck of the offshore structure of Figure 1;
Figure 3 shows a cross-sectional representation of an offshore structure according to an embodiment of the invention in which the mooring deck is located within the outer hull and is bounded by the hull;
Figure 4 shows a schematic representation of a mooring arrangement according to an embodiment of the invention;
Figure 5a shows a schematic representation of a mooring arrangement with mooring points A to P in operation mooring a LNGC;
Figure 5b shows a schematic representation of the mooring layout of Figure 5a in operation mooring a further LNGC;
Figure 6a shows a schematic representation of the mooring layout of Figure 5a in operation mooring a LPGC;
Figure 6b shows a schematic representation of the mooring layout of Figure 5a in operation mooring a further LPGC; and
Figure 7 shows a schematic representation of a mooring arrangement of the invention for an LNGC mooring position relative to an offshore structure in the form of an FLNG.

[0011] Although the invention will be described in terms of specific embodiments, it will be understood that various elements of the specific embodiments of the invention will be applicable to all embodiments disclosed herein.

[0012] An improved mooring arrangement for mooring a transport carrier to an offshore structure, which offshore structure is typically deployed in a body of water, is proposed. The mooring arrangement is particularly suitable for application on an offshore liquefied natural gas production unit and/or an offshore liquefied petroleum gas production unit. The offshore structure may be a floating structure, preferably moored in a weathervaning arrangement, which facilitates the mooring procedure of the transport carrier to the offshore structure.

[0013] Figure 1 depicts an embodiment of an offshore structure incorporating an embodiment of the invention. The offshore structure, in some embodiments, may be a floating liquefied natural gas production unit ("FLNG"). In other embodiments, the offshore structure is a liquefied petroleum gas production unit ("FLPG"). Often, the offshore structure produces both liquefied natural gas (LNG) as well as liquefied petroleum gases (LPG) and/or other condensate(s). For the purpose of this specification, any floating unit producing LNG and/or LPG will be referred to as an FLNG/FLPG structure. The invention may also be incorporated in an offshore structure capable of receiving of, and optionally storing and/or processing of, LNG or LPG or other hydrocarbon fluids from a transport carrier. An example of such a unit for receiving, storing and regasification of LNG is a floating storage regasification unit ("FRSU").

[0014] The offshore structure is intended to allow transport carriers, such as for instance LNG and/or LPG carriers (LNGC and/or LPGC), to berth directly alongside the structure and unload and/or load hydrocarbon fluids such as LNG and/or LPG. Such a LNGC or LPGC may be moored alongside the starboard side of the offshore structure, optionally with Yokohama floating fenders protecting each of the (steel) hulls from contact with one another. Mooring of an LNGC or a LPGC with the offshore structure may be accomplished using mooring lines. The mooring lines are deployed from the LNGC/LPGC to the offshore structure in order that the carrier and the offshore structuer be moored alongside one another for transfer of the hydrocarbon fluids.

[0015] In the present example, the offshore structure 1 will be referred to as FLNG/FLPG structure 1 although the basic principles of the invention are not limited to this type of offshore structure. The FLNG/FLPG structure 1 has an outer hull having two longitudinal sides 2. Bow and stern sections join the longitudinal sides 2 to from the outer perimeter of the outer hull. Although not necessary for the invention, the outer hull, when viewed in cross-section from above, is in this particular embodiment a substantially obloid structure, with two parallel longitudinal sides 2, and curved bow 12 and stern 13 sections. In alternative embodiments, the stern and/or bow sections may for instance be a straight hull section between the longitudinal sides of the structure.

[0016] The FLNG/FLPG structure 1 may be moored at a mooring point, for instance in the form of a turret 17, at the bow 12. Preferably, the FLNG/FLPT structure 1 is capable of weathervaning around the mooring point.

[0017] At least one fairlead 3 is positioned adjacent a longitudinal side 2. A hook 4 is connected to the structure 1 and located inboard relative to the fairlead 3 such that the angle of displacement α between a tangent to the outer hull 5 at the centre of the fairlead 3 and the hook 4 is less than or equal to 45°.

[0018] Selecting the angle of displacement to be less than or equal to 45°, allows for using longer mooring lines than is the case in a conventional alongsides mooring arrangement, whilst the mooring arrangement consumes considerably less lateral depth between the fairlead and the hook. Herewith it is possible to avoid needing a special hook with shock absorbing properties, or at least to reduce the shock absorbing capacity, because the mooring line can be long enough to absorb shocks in the conventional way.

[0019] The saving in lateral space between the fairlead and the hook may translate in reducing the inboard space required for the mooring deck within the limits of the outer hull of the structure, which is particurly welcome for an FLNG/FLPG structure or an FSRU structure since the deck space is needed for top sides hydrocarbon processing equipment. Alternatively, the space saving may be translated in reducing the need for outboard space (i.e. protruding out of the perimeter of the hull), which is considered to enhance the safety during approach operations of a transport carrier to the offshore structure.

[0020] Further still, by providing for a greater line length inboard of the fairlead over conventional mooring arrangements, the offshore mooring arrangement of the invention emulates the stability of an on-shore mooring arrangement within a more limited special environment. An angle of displacement less than 45° allows for a longer pennant than in prior known systems, thereby allowing the offshore mooring arrangement to more closely resemble an onshore mooring arrangement in which a more secure mooring is provided due to the longer pennant length applicable to the mooring arrangement.

[0021] When referred to herein, the "pennant" is the tail end of a mooring line or rope. The tail end of the mooring line or rope is the end which is attachable to the hook on the offshore structure or a hook on a liquefied natural gas carrier and/or a liquefied petroleum gas carrier.

[0022] Preferably, the distance from the centre of the fairlead to the hook is in the range of from 10 to 22 metres. This exceeds the distance of conventional arrangements, which rely on an 11 metre pennant length and therefore typically do not employ hooks in excess of 10 m away from the fairlead. The additional available length in excess of 10 m is advantageous for shock absorbing as in offshore alongside mooring the length that need to be brided by the mooring lines from the offshore structure to the transport carrier is relatively small. An inboard length of about 15 m is typically recommended, i.e. the distance from the centre of the fairlead to the hook is preferably about 15 m.

[0023] The angle of displacement α is preferably less than or equal to 25°. Herewith it is possible to maintain approximately 15 m of mooing line length between the fairlead and the hook while consuming less than 7 m of lateral mooring deck depth. This is considered an acceptable lateral space for a mooring deck on an FLSO/FLPG.

[0024] On the other hand, the angle of displacement α is preferably at least 4°. Maintaining at least 4° ensures that a mooring line, passing through the fairlead to the associated hook approximately 15 m away from the fairlead, is displaced sufficiently inboard of the longitudinal side of the structure to enable safe operation of the hook by an operator who may thus be positioned away from the longitudinal side of the structure during the mooring operation. Moreover, the stress on the mooring line is within operating limits by way of ensuring that the mooring line passing through the fairlead does not turn sharply towards the longitudinal side as would be the case with an angle of displacement less than 4°.

[0025] The hook and the fairlead may as shown in Figure 1 may be provided onto a mooring deck. Figure 2 shows a schematic plan view of an example of such a mooring deck 7 being positioned within the perimeter of the outer hull 2 of the FLNG/FLPG 1. The fairlead 3 is located on the mooring deck at the longitudinal side of the outer hull 2, and the associated hook 4 is located on the mooring deck, inboard of the longitudinal side of the outer hull 2 and offset from the position of the fairlead 3 longitudinally of the hull of the FLNG/FLPG. An operator, heaving a mooring line deployed from a LNGC/LPGC to the FLNG/FLPG onto the mooring deck for attachment to the hook 4, will be positioned away from the longitudinal side of the outer hull 2 and is, therefore, protected from the elements and from falling overboard from the FLNG/FLPG.

[0026] As generally depicted in Figure 2, the inboard lateral displacement of the hook 4 from its associated fairlead 3 is in the range of 1 to 5 metres to permit safe access to the hook set inboard of the outer hull 2 of the FLNG/FLPG. In a preferred FLNG/FLPG of the invention, the inboard lateral displacement of the hook from its associated fairlead is 3 metres. The lateral width of the mooring deck 7 itself may be within a range of from 1 to 7, preferably of from 1 to 6 meters.

[0027] In some embodiments, as generally depicted in Figure 3, the mooring deck 7 is bounded by the outer hull 8 on two sides 8a, 8b and is open at the longitudinal side of the outer hull 8c. The outer hull 8c may have a guard means 9, which may be a guard rail, a rope, a steel panel wall, or combinations thereof, at the open longitudinal side thereof. The operator is, thereby, further protected from both the elements and from the risk of a man overboard scenario.

[0028] The FNLG/FLPG depicted in Figure 3, further shows the mooring deck 7 with a hook 4 located thereon and a fairlead 3 located at the longitudinal side of the outer hull 8. The mooring deck 7 in this embodiment is contained within the side ballast tanks 10 of the FLNG/FLPG, therefore the cargo carrying capacity of the FLNG/FLPG is not diminished or comprised by the presence of the mooring deck 7 within the bounds of the outer hull 8. Further, the mooring deck being provided in a recess in the outer hull line provides additional safety for an operator heaving a mooring line onto a hook than would be the case with an exposed decking arrangement.

[0029] By way of providing a mooring deck within the outer hull of the FLNG/FLPG, and integral with the structure, the FLNG/FLPG has a clean hull line and no deck protrusions therefrom. Thus, the risk of a protrusion to the outer hull being broken off due to collision with a LNGC/LPGC is reduced or even eliminated.

[0030] The invention may be implemented on an FLNG/FLPG that is provided with one or more LNG/LPG storage tanks, preferably insulated tanks to hold LNG or LPGs in a cryogenic state. In some embodiments, the offshore structure has a length that is at least equal to a length required to provide sufficient berthing alongside the offshore structure, for a transport carrier, e.g. a tanker, having capacity of greater than about 200,000 cubic metres.

[0031] Mooring lines may lead from the carrier to fairleads 3 and associated mooring hooks 4 on the FLNG/FLPG as depicted generally in Figure 2. The hook may be a quick release hook operable to receive the mooring line from the FLNG/FLPG side fairlead. The quick release hook may incorporate a powered capstan to heave a mooring line from an LNGC/LPGC to the FLNG/FLPG structure. In some embodiments, the hook will be a twin set quick release hook with an associated powered capstan set.

[0032] In embodiments where all of the mooring lines are passed by the LNGC/LPGC to the FLNG/FLPG, the remote operation of the quick release hooks facilitates release of the carrier vessel from the offshore structure in a single operation in the event of an emergency.

[0033] The hook may comprise a mooring line monitoring load cell. The load cell will be operable to transmit data pertaining to the load applied by the mooring line to the hook to the FLNG/FLPG control room, thereby providing a real time indication and recording of the mooring loads being applied to each and all of the hook sets. Remote release of the mooring hooks may be provided from the control room. Release of the mooring line from the hook under tension may be provided.

[0034] Mooring line load forces should preferably be kept below about 55% of the Minimum Breaking Load. Increasing mooring line length by leading lines through fairleads 3 on the FLNG/FLPG to remote Quick Release Hooks (QRH) may cause chafing. In some embodiments, mooring line flexibility may be in a nylon tail pennant. A mooring line may lead directly from the carrier, through a fairlead 3 to an associated hook 4 as depicted in Figure 2. Mooring lines may be designed to comply with OCIMF guidelines.

[0035] In some embodiments, mooring line flexibility is in the tail pennant. Exemplary materials suitable for use in a tail pennant are polyamide and PET, for example. It is generally appreciated that longer tail pennant lengths reduce line loading and increase fatigue life. The use of more elastic tail materials may increase the line life of the main mooring line due to decreased line loads.

[0036] A mooring line length of at least about 15 metres between the fairlead 3 and the QRH may ensure the nylon pennant and joining shackle are clear of the ship's fairlead and not subjected to chafing. In an embodiment, the minimum safe working load of each mooring hook may be more than the minimum-breaking load of the strongest mooring line anticipated. In some embodiments, the operational mooring line may not exceed the greater of 2.5 times the winch brake holding capacity or 2500 KN. The extreme mooring load may not exceed the greater of 2.5 times the minimum breaking load line or 3125 KN. The capstan barrel may be at a suitable height to permit safe handling of messenger lines. The QRH-assembly may be electrically isolated from the platform decks. The insulation may provide an electrical resistance of at least about 1 mega-Ohm.

[0037] The QRHs may be positioned on the FLNG/FLPG. The mooring lines may lead from the carrier to the fairleads 3 and the QRHs on the FLNG/FLPG. Decks may have rounded edges in front of the mooring hooks to prevent chafing of the mooring lines. In some embodiments the at least one fairlead is connected to the structure. The at least one fairlead may be connected to the structure adjacent a longitudinal side.

[0038] The fairlead may be an open fairlead having an open top. However, a closed fairlead may be preferred, e.g. of the so-called Panama type, in order to avoid the mooring line to be lifted out of the fairlead. This may happen when the relative free boards between the offshore structure and the carrier vary from case to case. whereby a mooring line may be passed through the opening in the fairlead. Particularly, a Panama design, closed fairlead may be fitted at the longitudinal side of the FLNG/FLPG to accept the LNGC/LPGC mooring lines and to direct the mooring lines inboard of the longitudinal side to a quick release mooring hook situate on the mooring deck of the FLNG/FLPG. The specification of the fairlead is preferably consistent with the safe working load (SWL) of the quick release hook set. Exemplary SWLs are 125t, SWL, considering the minimum breaking strain (MBL) of the LNGC/LPGC mooring lines.

[0039] In some embodiments, a single fairlead may exclusively service one single mooring line and hook.

[0040] Fairleads may be mounted in abutment with, and faired to the FLNG/FLPG longitudinal side. The fairlead will preferably have no protuberances or sharp edges on either the inboard or outboard sides in order to avoid additional wearing on the mooring line as it passes through the fairlead.

[0041] A Panama design closed fairlead will typically have a base portion attachable to the offshore structure. The fairlead will be in the form of a ring-shape extending upwards from the base portion and having an annular hole in the centre thereof. The annular hole is generally oval. The base portion is typically 1300mm in length and 560mm in width. From the base portion to the centre of the annular hole is typically 505 mm with the fairlead being 930mm in height. The annular hole is typically 450mm in height and 600 mm in length, with a radius of approximately 225 mm. The internal radius of the fairlead will be as large as practicable to reduce stress on the mooring line.

[0042] The fairlead may be lined with a friction reducing agent or material. The friction reducing agent may be a Nylacast™ protective insert for reduction of chafing of a synthetic mooring line pennant. The Nylacast™ material is a synthetic material incorporating a lubricant that will minimise chafing damage to the LNGC/LPGC mooring pennants in the fairlead.

[0043] Monitoring systems may be provided on the offshore structure, to detect the carrier speed of approach; mooring line loads through strain gauges on QRHs; and/or pressure monitoring system in air block fenders. Data from the monitoring systems may be centrally collected and displayed in a control room.

[0044] An embodiment of an FLNG/FLPG incorporating the invention is depicted in Figure 4. The FLNG/FLPG 1 comprises a plurality of fairleads 3 and associated hooks 4. In the depicted embodiment the fairleads 3 are spaced along the outer hull 8 of the FLNG/FLPG and are configured so as to provide mooring points for a liquefied natural gas carrier 11 and/or a liquefied petroleum gas carrier 11. For ease of reference, the fairleads may be numbered from bow to stern using letters from the alfabeth, in the present case ranging from A to P. A mooring deck may be defined along the starboard side of the hull (assuming the FLNG/FLPG is moored at its bow) to accommodate side fairleads 3 and mooring hooks 4 generally configured as shown in Figure 4. The mooring arrangement of the FLNG/FLPG may typically comprise mooring lines deployed from the LNGC/LPGC. Typical mooring lines may include headlines, sternlines, breast and spring lines.

[0045] The FLNG/FLPG may comprise a loading/offloading connection for transferring the hydrocarbon fluid(s). The connection may comprise a manifold of one or more transfer arms. Such manifolds *per se* are known, and typically an LNG transfer manifold comprises three arms of which the middle one is a vapour arm. An LPG transfer manifold may also comprise one or more transfer arms, but typically a vapour transfer line is combined on an other arm such that no separate vapour arm is provided. The tranfer arms may be Chiksan unloading arms available from FMC Energy Systems. Typical LNG/LPG transfer equipment may include power packs, controls, piping and piping manifolds, protection for the piping from mechanical damage, ship/shore access gangway with an operation cubicle, gas detection, fire detection, telecommunications capabilities, space for maintenance, Emergency Release Systems (ERS), Quick Connect / Disconnect Couplers (QCDC), monitoring systems, and/or drainage systems.

[0046] Assuming mooring on a turret at the bow, the loading/offloading manifold may be suitably located for safety reasons between the offshores structure's mid and aft in order to be removed from as far aft as possible from the process equipement and the turret. Ideally, however, the manifold is also further removed from any crew's quarters on the offshore structure than is the case for a typicall transport carrier.

[0047] For the purpose of illustrating the invention, it is assumed that the transfer manifold comprises both an LNG transfer manifold as well as an LPG manifold. In the examples below, it is assumed that the LNG vapour arm is situated on the FLNG/FLPG at 185 metres from the stern of the structure, with the LPG connection being located some 10 m aft of the LNG vapour arm. Thus, LNGC/LPGC manifold offsets (relative to midships point of the carrier) of up to 25 metres are accommodated. The position of the fairleads 3, referenced to the LNG/LPG vapour arm location, may be configured so as to be capable of receiving mooring lines from an LNGCs ranging from 75,000 cubic metres to 217,000 cubic metres capacity, and from LPGCs ranging from 74,000 cubic metres to 84,000 cubic metres capacity.

[0048] With reference to Figures 5a, 5b, 6a and 6b, in certain embodiments of the invention, the locations (A to P) of the mooring points, represented by fairleads 3, relative to the LNG vapour arm 6 are in accordance with

Table 1.

Table 1				
Lead	Distance to LNG vapour arm	Number of leads/hooks	Direction of lead to hook	Distance from lead to hook
A	175.0	Double	Forward	15m
B	155.0	Double	Forward	15m
C	140.0	Double	Forward	15m
D	120.0	Double	Forward	15m
E	100.0	Double	Forward	15m
F	70.0	Double	Towards vapour	15m
G	40.0	Double	Towards vapour	15m
H	20.0	Double	Towards vapour	15m
I	-30.0	Double	Towards vapour	15m
J	-55.0	Double	Towards vapour	15m
K	-80.0	Double	Towards vapour	15m
L	-110.0	Double	Towards vapour	15m
M	-125.0	Double	Towards vapour	15m
N	-145.0	Double	Inboard	15m
O	155.0	Triple	Inboard	15m
P	-175.0	Triple	Inboard	15m

[0049] A positive value for the distance between the mooring point (A to P) and the LNG vapour manifold in Table 1 indicates a mooring lead location forward of the LNG vapour arm (A to H), and a negative value indicates a mooring lead location aft of the LNG vapour arm (I to P).

[0050] In the embodiment of Table 1, each lead location accommodates multiple fairleads. Lead locations A to N each accommodate two fairleads and lead locations O and P each accommodate three fairleads. The direction of lead to hook is indicated, being the direction the mooring line will be led when passing through the fairlead to the associated hook set. The aft three sets of leads N, O and P, situated within the accommodation/service area of the FLNG/FLPG, will be led inboard on the FLNG/FLPG to the associated hook set. In the embodiment described in Table 1, the fairlead to associated hook distance is 15 metres. This distance enables the total LNGC/LPGC mooring line length deployed to be of sufficient length, in combination with the mooring line nylon/polyester pennant, to absorb peak mooring loads in sea states up to 3 m sea height whilst moored.

[0051] In some embodiments an 11 m tail pennant length will be sufficient, however, in certain embodiments a 22 m tail pennant is preferred.

[0052] In embodiments of the invention wherein the lead to hook distance is 15 metres and the pennant length is 22 metres, the 15 metre lead to hook distance allows the 22 metre mooring pennant to be located in the FLNG/FLPG side lead thereby avoiding conflicting damage of alternate LNGC/LPGC synthetic HMPE and wire mooring lines placed in the same leads. In addition, the 15 metre lead to hook configuration will provide for a greater mooring line length (LNGC/LPGC winch to FLNG/FLPG hook) than would typically be the case. In a conventional shore terminal berth, a mooring line length of 35 to 50 metres is typical, which mooring line length typically is not available in a conventional offshore side-by-side mooring configuration.

[0053] In order to maximise the length of mooring line inboard of the fairlead, the distance from fairlead to associated hook is preferably as large as possible.

[0054] As can be seen in Figures 5a, 5b, 6a, 6b, the mooring arrangement allows for alongside berthing of a variety of carrier types and sized while being able to align the carrier's loading/offloading manifold with the corresponding manifold on the FLNG/FLPG structure, even where the carrier's manifold is not located in the centre of the carrier.

[0055] Figures 5a and b depict an FLNG mooring layouts with mooring points A to P, showing that the FLNG is capable of alongside berthing of 290 metre long LNGCs 11 having their loading/offloading manifolds at different positions relative to the carrier's centre. In Figure 5a the manifold 16 is at the carrier's centre c, but in Figure 5b the manifold 16 is some 15 metres ahead of the carrier's centre c. In both cases, a good alignment between the carrier's manifold 16 and the target represented by the LNG vapour arm 6 is achievable.

[0056] Trials using Optimoor analysis tool have shown that even of the LNG manifold on a 290 metre long LNGC is displaced by 24 metre ahead of the carrier's centre line, the carrier can be safely berthed alongside the mooring arrangement. In the latter case, mooring point P is employed. The mooring arrangement is also capable of receiving carriers having their LNG manifold aft of the carrier's centre line, but this situation may be rare in view of the industries desire to remove the manifold as far as possible from the crew's quarters.

[0057] In the embodiments depicted in Figures 6a and 6b, an offshore structure 1 is shown with a mooring layout having mooring points A to P, capable of alongside mooring of LPGCs having lengths of 203 metres and 214 metres, respectively. The carrier's LPG loading/unloading manifolds 16' are in the shown cases relatively close to the carrier's centre lines c, but the target manifold 6' on the offshore structure 1, being the LPG connection, is some 10 m aft of the LNG vapour arm 6. Again, good alignment is achievable.

[0058] Thus, an offshore structure 1 accommodating the mooring arrangement as proposed is adapted to accommodate LNGCs and/or LPGCs of widely differing sizes and designs, including manifold offsets.

[0059] In certain embodiments an FLNG/FLPG accommodating the invention may comprise at least three spring fairlead and associated hook sets. Thus, the mooring layout of the FLNG/FLPG accommodates spring deployment from an LNGC/LPGC. Where weather conditions require, an LNGC/LPGC may deploy two springs from the main deck and one spring from the focsle deck, with a consequential requirement for the corresponding spring lead and hook sets on the FLNG/FLPG.

[0060] Figure 7 shows another example of an FLNG/FLPG 1 being anchored to turret 17 at its bow 12. A mooring deck 7 is provided on the starboard side of the FLNG/FLPG's outer hull. As is generally depicted in Figure 7, the mooring deck will run from the stern of the FLNG/FLPG 1 forward for approximately 380 metres and at 14.5 metres above the operating waterline. In some embodiments, the FLNG/FLPG 1 may have a mooring deck having a width in the range of 1 to 6 metres to permit safe access between the back of the mooring hook sets and the fore and aft bulkhead, to permit sufficient space to gather the mooring messenger when an operator is heaving mooring lines 20 to the FLNG/FLPG, e.g. with a powered capstan. In an embodiment, the FLNG/FLPG may have a mooring deck with a width of 4 metres. As is further illustrated in Figure 7, a number of fenders 22 are positioned between the FLNG/FLPG and the LNGC/LPGC to prevent damage occurring during the berthing and mooring of the carrier 11 alongside the offshore structure 1.

[0061] An offshore structure, e.g. in the case of an FLNG/FLPG, may accommodate LNG/LPG storage tanks and allow LNG/LPG vaporization equipment and/or other process equipment and utilities such as liquefaction equipment, gas treating equipment (e.g. acid gas removal equipment, dehydration equipment, mercury removal equipment and the like), gas intake separators and slug catchers, condensate stabilization equipement, etc., to be positioned on an upper surface of the FLNG/FLPG, and safely enable LNGCs/LPGCs to berth directly alongside the FLNG/FLPG. It is also envisaged to provide equipment for carbon (carbondioxide) capture and sequestration equipment to handle CO_2 removed from post combustion flue gases and/or from the hydrocarbon feed.

[0062] In the case of an FSRU, the offshore structure may accommodate revaporization, heating value control, and metering equipment and other options such as described in for instance WO 2006/052896, the disclosure of which is incorporated herein by reference.

[0063] An external turret system 17 may be a preferred option for anchoring the offshore structure in a typical water depth of greater than 30 metres. An external turret may be preferable to a Yoke Mooring System but may be dependent on water depth and may require a complete riser design as part of the concept selection. A double hump riser configuration may be a feasible arrangement.

[0064] A further mooring system of an FLNG/FLPG of the invention may be a weathervaning arrangement to obtain a sufficiently high connecting threshold for the berthing operations of an LNGC/LPGC. A further mooring system and high pressure gas export line may be located at the forward end of an FLNG/FLPG of the invention. After selection of the location of an FLNG/FLPG of the invention, an assessment should be made of the technical feasibility of a further mooring system comprising, for example, an external turret system, an internal turret system, a Yoke Mooring System (YMS), and combinations thereof. An example YMS comprises, for example: a jacket (the jacket may comprise a four legged tubular structure that may be fixed to the seabed via one or more, generally four, piles, driven through the corner tubulars), a mooring head (a mooring head may be located on top of the jacket and may be free to rotate; the mooring head may support the pipe work and equipment, including the swivel stack), a yoke (a yoke may be a tubular triangular frame that may be connected to the mooring head via a roll and pitch articulation; permanent ballast tanks may be a part of the yoke structure to provide the required pretension in the mooring legs), mooring legs (the mooring legs may comprise tubular steel members connected to the adjacent structure via uni-joints; an axial thrust bearing may also be included to provide rotational freedom; the mooring legs with the yoke weight suspended underneath may provide the pendulum mechanism of the mooring system), a mooring structure on the FLNG/FLPG (a mooring structure on the FLNG/FLPG may comprise a tubular frame mounted onto the bow of the FLNG/FLPG; the structure may overhang the bow of the vessel to provide clearance for the yoke; lifting means may be provided for handling of one or more jumper hoses), gas transfer may be performed via one or more, generally two, 16" flexible jumper hoses that may provide a 2x 100% capacity.

[0065] A further mooring system comprising a YMS may include a gas swivel to transfer send-out gas from the weathervaning FLNG/FLPG to a fixed pipeline riser. An in-line swivel may be expected to provide sufficient reliability (typical MTTF of 20 Years) but an 'N+l' arrangement of the fluid transfer system may be obtained through additional toroidal swivel modules. The in-line swivel may be used for operation; the toroidal module may provide the back-up. In case of failure, the in-line may be changed out while the send-out gas may be routed through the toroidal swivel path.

[0066] In some embodiments, the height of the upper surface, on which mooring equipment, for example, quick-release hooks (QRHs) are disposed, above the surface of the body of water may be such that an angle of mooring lines extending from the mooring equipment to the liquefied natural gas carrier coupled to the body is less than about 30 degrees.

[0067] The centerline of the unloading arms may be positioned to create a maximum degree of protection for all types of common LNG/LPGC/LPGCs.

[0068] Although a three-unloading arm concept as mentioned above may be technically acceptable, a four- unloading arm concept may have more redundancy. Redundancy may increase the integrity and/or reliability level. The spare unloading arm may be used on a day-to-day basis. This may safeguard the proper functioning of the equipment. The installation of one or more spare unloading arms may increase the normal overall LNG/LPG loading capacity. The design of the FLNG/FLPG may account for severe weather conditions.

[0069] Transfer of LNG/LPG between a LNGC/LPGC and a FLNG/FLPG may be based on traditional hard arms, which are currently used at onshore terminals for ship-shore LNG/LPG transfers. To enable safe and reliable connecting and disconnecting under seaway motions, for floating-to-floating transfer, a guide-wire system may be utilized to guide the loading arm to the ship manifold.

[0070] A suitable overall length of the offshore structure on which the invention is applied may be any length that provides for storing and/or processing of the hydrocarbon fluids such as LNG/LPG as described herein, and is generally at least about 100 metres, specifically at least about 200 metres, more specifically at least about 300 metres, and generally no more than about 1000 metres, specifically no more than about 750 metres, and more specifically no more than about 500 metres.

[0071] A suitable breadth of the offshore structure may be any breadth that provides for storing and/or processing of hydrocarbon fluids, such as LNG/LPG as described herein, and is generally at least about 20 metres, specifically at least about 30 metres, more specifically at least about 40 metres, and generally no more than about 300 metres, specifically no more than about 200 metres, and more specifically no more than about 100 metres.

[0072] A suitable draft of the offshore structure may be any draft that provides for storing and/or processing of hydrocarbon fluids, such as LNG/LPG as described herein, and is generally at least about 5 metres, specifically at least about 7 metres, more specifically at least about 10 metres, and generally no more than about 25 metres, preferably no more than about 20 metres. In one embodiment, the draft may be about 17.6 m.

[0073] A suitable length:depth ratio of the offshore structure may be any length:depth ratio that provides for storing and/or processing of LNG/LPG as described herein and is generally at least about 5, specifically at least about 7, more specifically at least about 10, and generally no more than about 20, specifically no more than about 18, and more specifically no more than about 15.

[0074] An example further mooring system of the offshore structure may be a Yoke Mooring System ("YMS"), because the water depth for an inshore location may be in a range of from about 15 metres to about 30 metres and may not allow for the catenary of an external turret system. Maximum sea states should be obtained to ensure that the further mooring system utilized can meet such maximum sea states.

[0075] An example approach procedure of an LNGC/LPGC to an FLNG/FLPG of the invention may include: about 12 hours before the estimated time of arrival ("ETA"), prevailing weather conditions and status of both FLNG/FLPG and LNGC/LPGC are exchanged; preparations are made, for example testing of LNG/LPG arms, mooring equipment, fenders and selecting LNGC/LPGC approach, about 1 hour before ETA, the LNGC/LPGC will arrive at the agreed entry point, at some 2 to 3 nautical miles from the FLNG/FLPG and with a forward speed, typically 4 knots; berthing master will board and tugs are ready to be connected, the LNGC/LPGC will head for a position off the starboard side of the FLNG/FLPG and target to come to complete stop near parallel to the FLNG/FLPG, at approximately 100 m separation, the LNGC/LPGC will move side-ways, whilst monitoring the applied thruster/tug forces, heading relative to the FLNG/FLPG and approach velocity; if control over the LNGC/LPGC position and heading becomes difficult, the approach will have to be aborted, and pneumatic equipment may be used from the FLNG/FLPG to shoot across messenger lines. It may be expected that mooring lines will be passed after touching the fenders.

[0076] Currently, the significant wave height limit (Hs) for berthing of an LNGC/LPGC alongside an FLNG/FLPG may be considered to be in the range of from about 2.0 to about 2.5 metres, and in the range of from about 2.5 to about 3.0 metres for being moored alongside an FLNG/FLPG of the invention.

[0077] An example departure manoeuvre looks very much a mirror image of the example approach process. At the start of the actual departure, the ESD link systems is disconnected, with radio links maintaining the integrated systems needed for a safe departure. The LNGC/LPGC prepares to start the departure manoeuvre. Then the mooring lines are disconnected, which may be implemented one by one, depending on prevailing weather conditions and final operating procedures.

[0078] An example departure manoeuvre may see the LNGC/LPGC moving the bow clear from the FLNG/FLPG using tugs or carrier bow thruster in combination with wind/wave/current conditions. When the hulls are clear of each other the LNGC/LPGC will use its main propulsion system to move clear and tugs will disconnect.

[0079] An LNGC/LPGC may be moored in the furthest forward and aft positions. A mooring arrangement of the present invention may be utilised together with breast lines, spring lines.

[0080] The description above has made apparent that an offshore structure with a mooring arrangement as described, transport carriers of different sizes and designs can be effectively moored in most sea states up to 2.5 or 3.0 m significant wave height.

[0081] Moreover, the mooring arrangement mimics an on-shore mooring arrangement; that is to say, the moorings deployed from the transport carrier are in a similar plan arrangement to that provided in an on-shore terminal.

[0082] While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and have been described in detail. It should be understood that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

Claims

1. An offshore structure (1) comprising an outer hull having longitudinal sides (2) and at least one fairlead (3) located adjacent a longitudinal side (2), and a hook (4), connected to the structure (1) and located inboard relative to the fairlead (3) and being displaced along the hull longitudinally from the fairlead (3), such that an angle of displacement (α) between a tangent to the outer hull (5) at the centre of the fairlead and the hook (4), is less than or equal to 45°.

2. An offshore structure (1) according to claim 1, wherein the distance from the centre of the fairlead (3) to the hook (4) is in the range from 10 to 22 metres, preferably about 15 metres.

3. An offshore structure (1) according to any one of claims 1 to 3, wherein the angle of displacement (α) is less than or equal to 25°.

4. An offshore structure (1) according to any one of claims 1 to 4, wherein the angle of displacement (α) is at least 4°.

5. An offshore structure (1) according to any one of claims 1 to 4, wherein the inboard displacement of the hook (4) from the centre of the fairlead (3) is in the range from 1 to 5 metres, preferably about 3 metres.

6. An offshore structure (1) according to any one of claims 1 to 5, wherein the hook (4) and the fairlead (3) are located on a deck (7), which deck is within the perimeter of the outer hull (8).

7. An offshore structure (1) according to claim 6, wherein the deck (7) is bounded by the outer hull (8) on two sides (8a, 8b) and is open at the longitudinal side of the outer hull (8c), and further wherein the outer hull has a guard means (9) at the open longitudinal side (8c).

8. An offshore structure (1) according to claim 6 or claim 7, wherein the deck (7) width is within a range of 1 to 6 metres.

9. An offshore structure (1) according to any one of claims 1 to 10, wherein said structure is a floating liquefied natural gas production unit or a floating liquefied petroleum gas production unit.

10. An offshore structure (1) according to claim 9, wherein the deck (7) is bounded by the outer hull (8a, 8b) on two sides and is open at the longitudinal side of the outer hull (8c), and further wherein the outer hull has a guard means (9) at the open longitudinal side (8c) and the deck width is within a range of 1 to 6 metres and contained within the side ballast tanks (10) of the floating liquefied natural gas production unit or the floating liquefied petroleum gas production unit.

11. An offshore structure (1) according to any one of claims 1 to 10, wherein the fairlead (3) is lined with a friction reducing agent or material.

12. An offshore structure (1) according to any one of claims 1 to 11, comprising a plurality of fairleads (3) and associated hooks (4), the fairleads (3) being spaced along the outer hull (8) and being configured so as to provide mooring points (A to P) for a liquefied natural gas carrier (11) and/or a liquefied petroleum gas carrier (11) having a capacity of between 75000 cubic metres and 217000 cubic metres.

13. A mooring arrangement comprising at least one mooring line (20) having a pennant at an end thereof, and an offshore structure according to any one of claims 1 to 12, wherein said at least one mooring line (20) is configured to pass inboard of the outer hull through said fairlead and is attachable to the hook such that the angle of displacement of the at least one mooring line between the tangent to the hull at the centre of the fairlead and the hook is less than or equal to 45°.

14. A mooring arrangement according to claim 13, wherein the pennant is 22 metres in length.

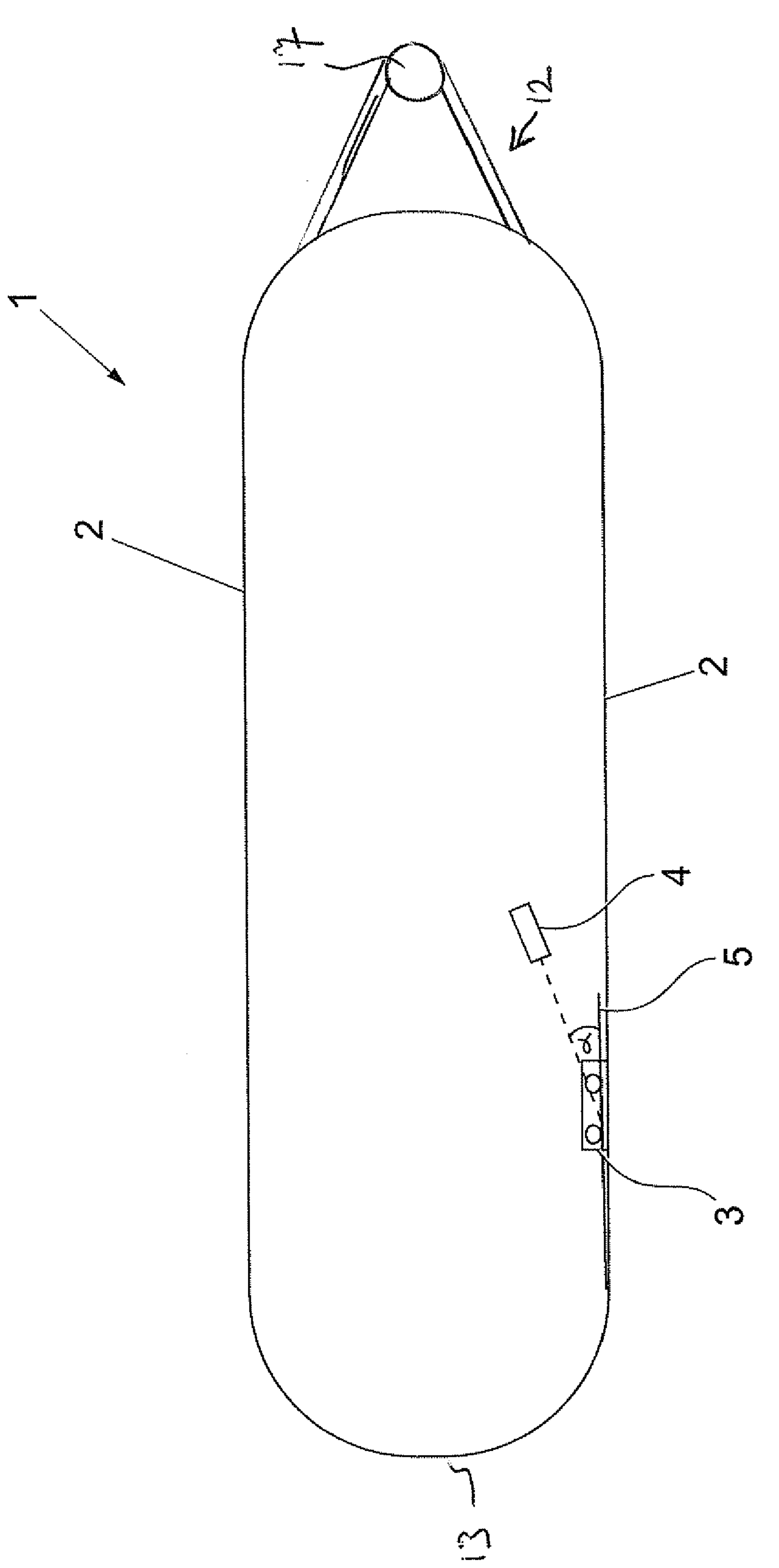

Fig. 1

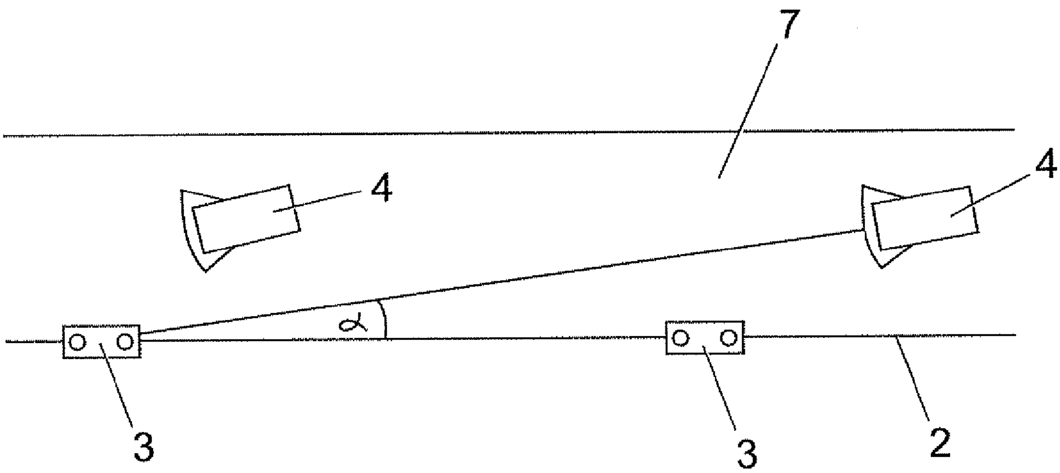

Fig. 2

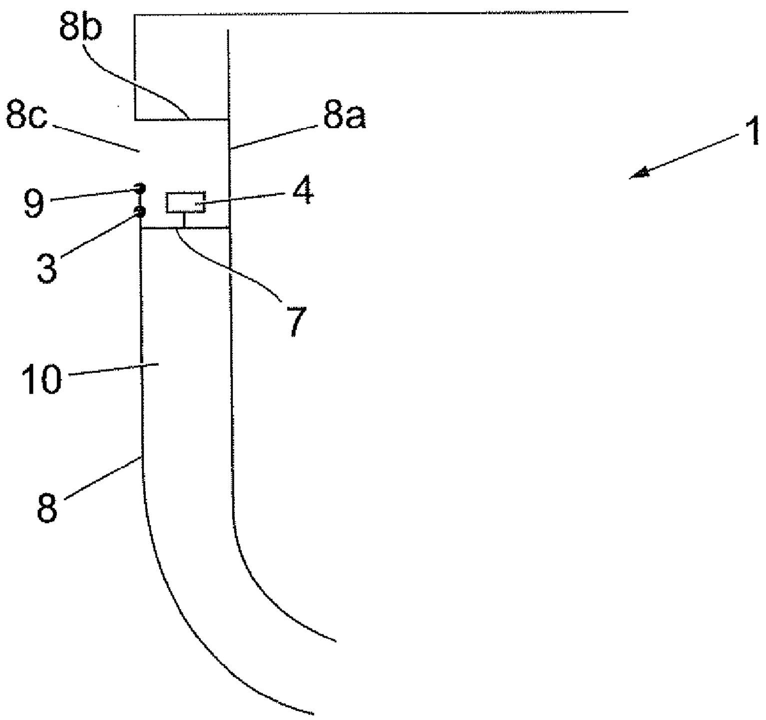

Fig. 3

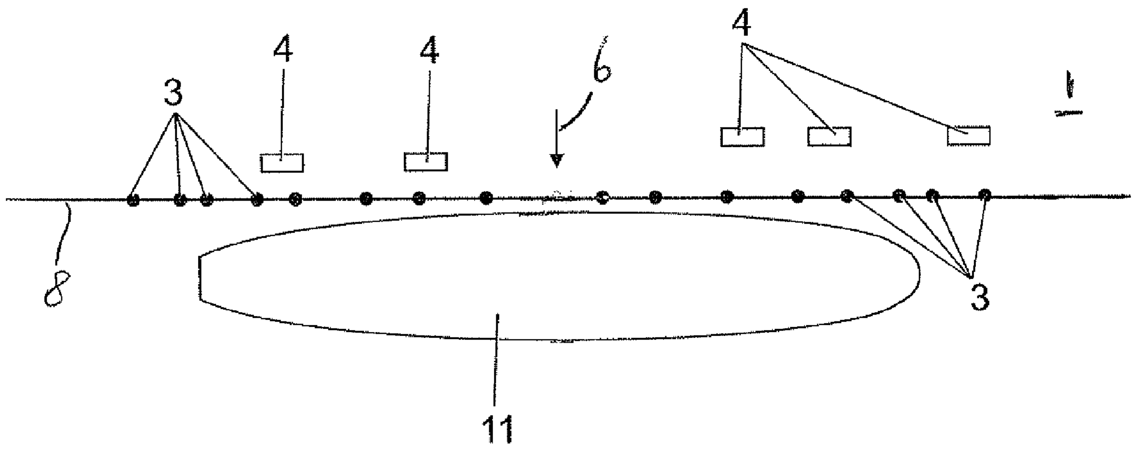

Fig. 4

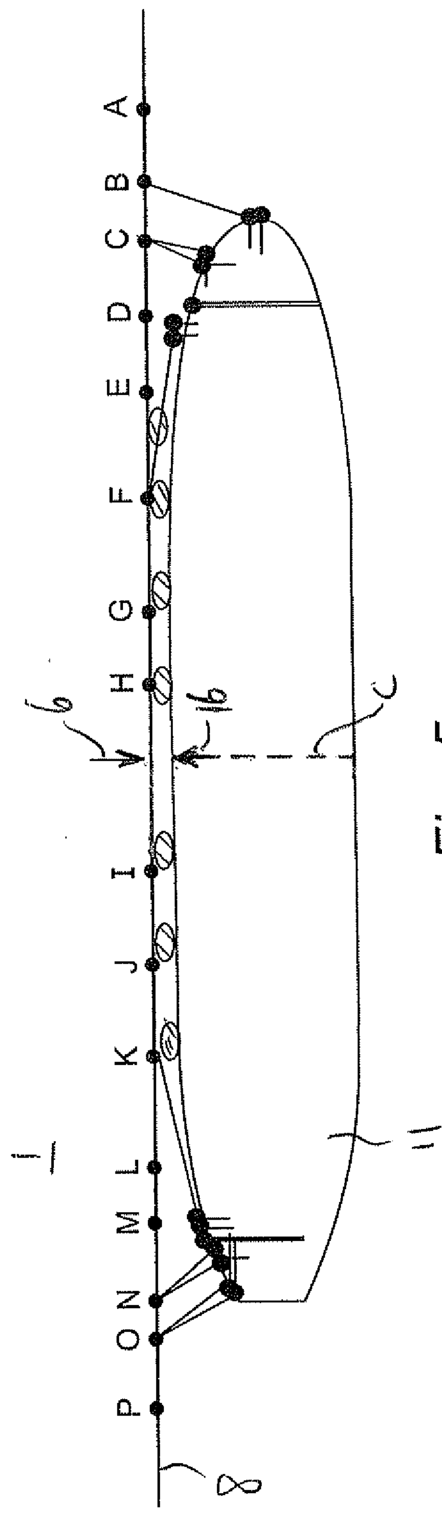

Fig. 5a

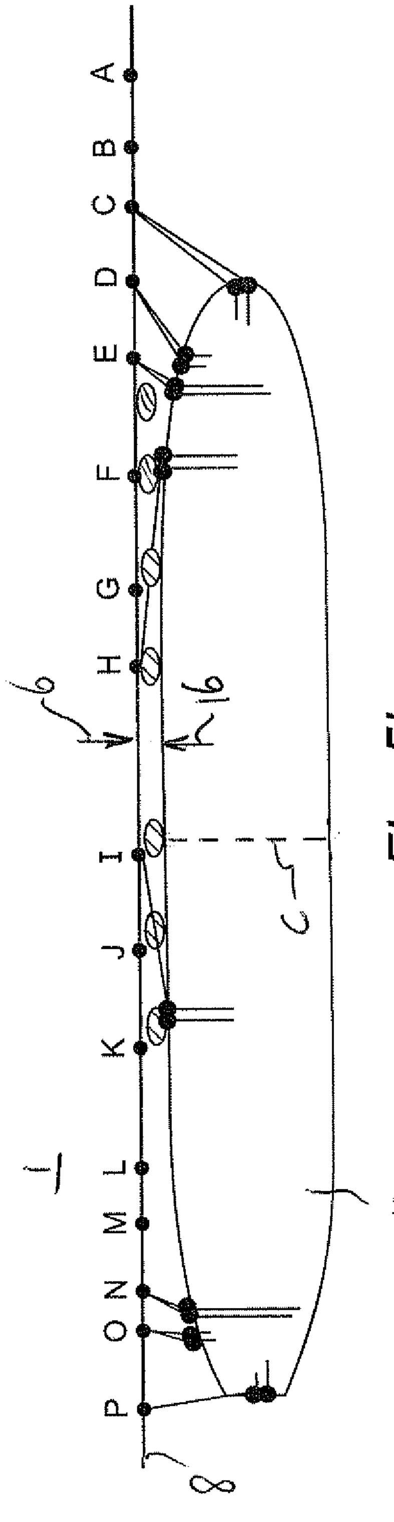

Fig. 5b

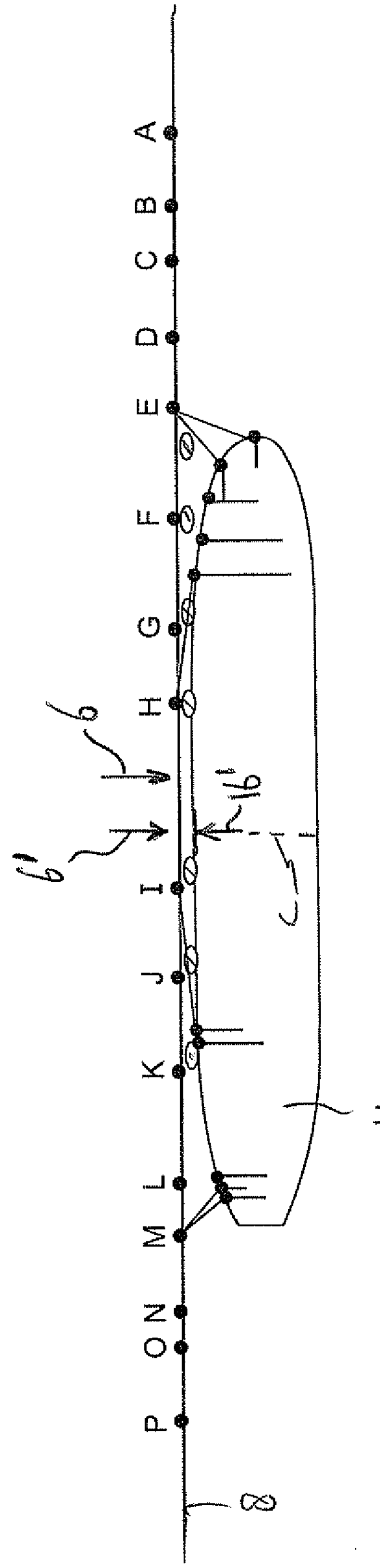

Fig. 6a

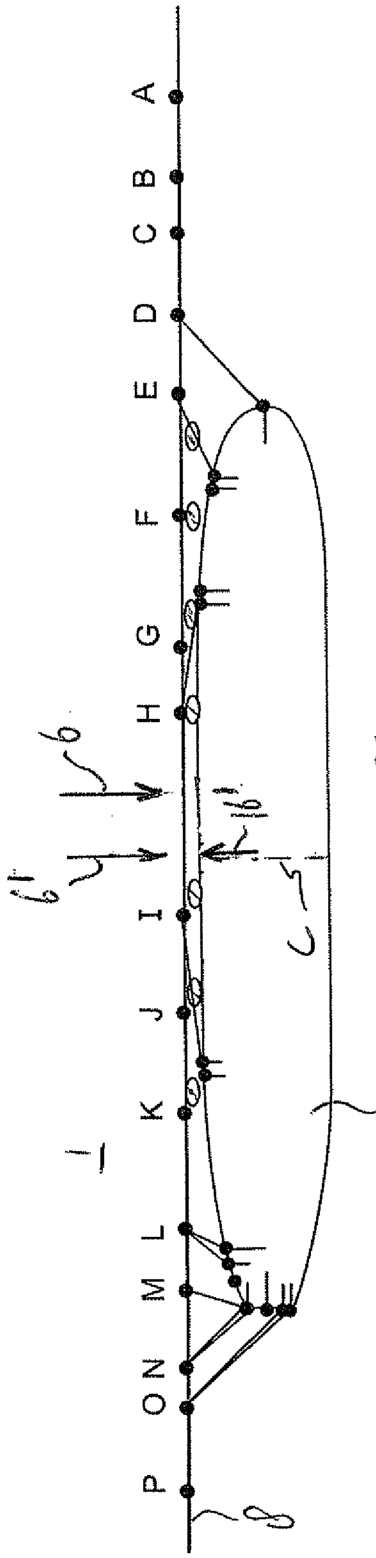

Fig. 6b

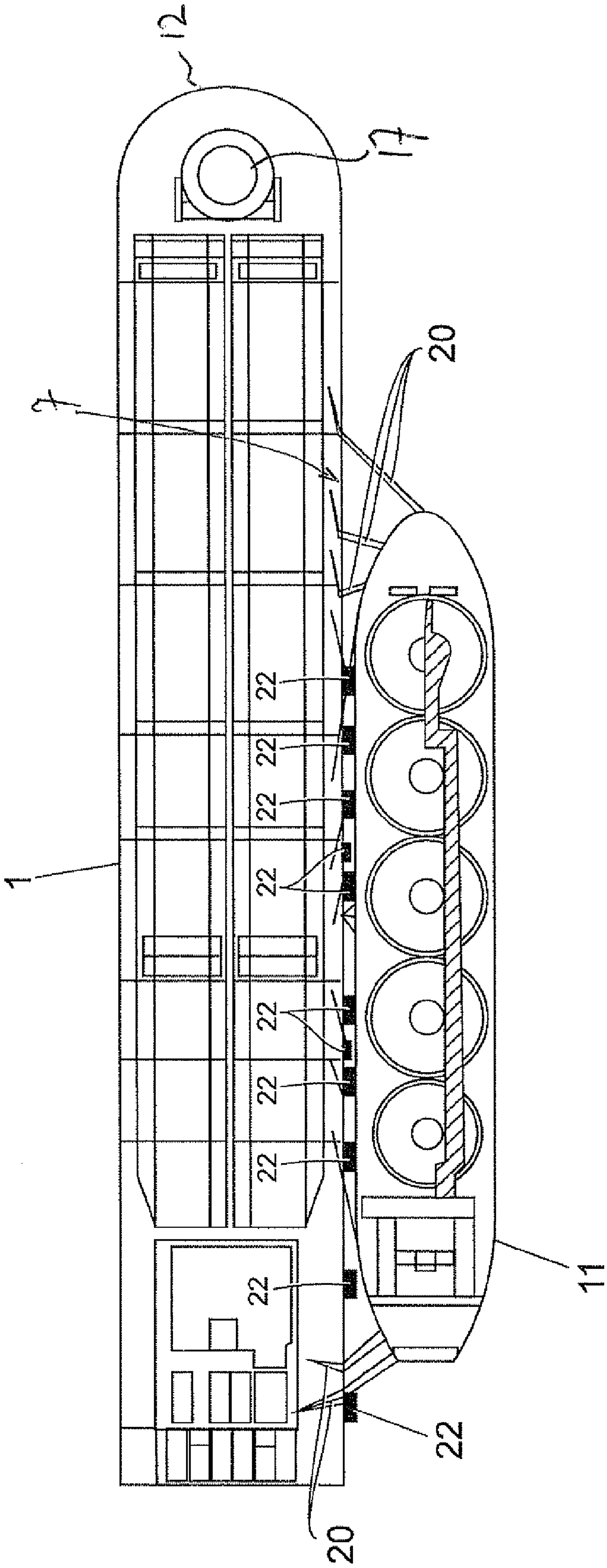

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 09 16 1127

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
D,X	EP 1 705 112 A (SINGLE BUOY MOORINGS [CH]) 27 September 2006 (2006-09-27) * figures 1,4,5,8 * -----	1-14	INV. B63B21/50
X	US 2008/295526 A1 (BOATMAN L TERRY [US] ET AL) 4 December 2008 (2008-12-04) * figures 1,6g * -----	1-14	
X	FR 2 916 732 A (DORIS ENGINEERING [FR]) 5 December 2008 (2008-12-05) * figure 1 * -----	1-14	
X	US 2007/289517 A1 (POLDERVAART LEENDERT [MC] ET AL) 20 December 2007 (2007-12-20) * figure 6e * -----	1-14	

TECHNICAL FIELDS SEARCHED (IPC)

B63B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 October 2009	van Rooij, Michael

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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15-10-2009

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1705112	A	27-09-2006	AU	2006225421	A1	28-09-2006
			CN	101163622	A	16-04-2008
			JP	2008534349	T	28-08-2008
			WO	2006101395	A1	28-09-2006
			US	2009078185	A1	26-03-2009
US 2008295526	A1	04-12-2008	WO	2008150820	A1	11-12-2008
FR 2916732	A	05-12-2008	SG	148139	A1	31-12-2008
US 2007289517	A1	20-12-2007	AU	2005237929	A1	10-11-2005
			CN	1946606	A	11-04-2007
			JP	2007534556	T	29-11-2007
			WO	2005105565	A1	10-11-2005

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

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Patent documents cited in the description

- WO 2006052896 A **[0005] [0062]**
- WO 2006101395 A **[0007]**