(54) Title: METHOD FOR USE IN OFFSHORE LOAD TRANSFER, AND A FLOATER AND HYDRAULIC DEVICE FOR THE SAME

(57) Abstract: A method for offshore load transfer and a floater for use in such load transfer are described. A hydraulic device for use in a horizontal positioning system for keeping the floater in position is also described. During the mounting and dismantling of large structures offshore, the floater will be exposed to wave and wind forces. By means of hydraulic jacks (HPS 1, 2, 3) the floater is kept in a target position, within a horizontal frame. The jacks (HPS 1, 2, 3) act as a positioning system and may also act as a sea fastening or sea securing system for the load when it is carried by the floater.

Declaration under Rule 4.17:
— of inventorship (Rule 4.17(iv)) for US only

Published:
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
Method for use in offshore load transfer, and a floater and hydraulic device for the same

The invention relates to a method for use in offshore load transfer, wherein a floater is taken to a transfer site at sea and loads are transferred between the floater and the transfer site, the floater being positioned horizontally relative to a marine structure at the transfer site before and during the load transfer operation.

The invention relates to a floater having adjustable buoyancy for offshore transport, installation and removal of structural elements. The invention has been especially developed in connection with the need for the mounting and dismantling of large structural elements offshore, in particular in connection with the removal of existing fixed platform installations at sea.

Basically, the floater may have any form that is adapted to or suitable for offshore transport, installation and removal of structural elements. Thus, the floater may, for example, be of the type taught in US Patent No. 6,244,786 B1, which illustrates and describes a column stabilised floater, or it may be a catamaran-like floater, for instance, as taught in US Patent No. 3,078,680. Other embodiments of suitable floaters can be found in EP 000 462 A1, FR 247 992, NO 160424, NO 171495 and NO 135056.

The floater will be deployed for transport and installation (or removal) of large structural elements (hereinafter referred to as "loads") to (from) fixed structures or a floating structure (hereinafter referred to as "marine structures") offshore, in open sea where the floater will be exposed to waves.

The load is preferably supported from underneath by means of beam elements (load-transfer beams) projecting from the floater.

The weight of the load is transferred from the floater to the marine structure by ballasting the floater (filling ballast into the ballast tanks of the floater).

The removal of loads (in most cases so-called topsides or similar structures) from marine structures is a reverse installation operation. The weight of the load is transferred from a marine structure to the floater by deballasting the floater (removing ballast from the ballast tanks).
Various methods for vertical load transfer, motion compensation and load reduction are known.

However, the said methods for load transfer of large structural elements to/from marine structures could introduce huge dynamic horizontal loads from the floater onto the marine structure when such an operation is carried out offshore, in open sea (where the floater is exposed to waves) if the floater is not designed to absorb horizontal motions, especially wave frequency motions, relative to the marine structure during the load transfer operation. This could result in damage to the marine structure, especially to old, corroded oil and gas platforms where the upper parts have to be removed from the platform substructure (jackets). The horizontal dynamic load from the floater could introduce a large bending moment at the bottom of the substructure (that is fixed to the seabed), large shear forces in the substructure as well as large horizontal forces at the contact point between the so-called topsides of the platform and the load-carrying point on the load-transfer beams.

There are a number of known load transfer systems having features which allow motions of the floater relative to the marine structure during the load transfer operation, so as to limit the horizontal dynamic forces between the floater and the marine structure. Fig. 1 shows an example of such a structure, where hinged beams are used.

One of the main objects of the present invention is to be able to reduce the horizontal motions of the floater caused by waves, without thereby introducing large dynamic horizontal loads on the marine structure, and to keep the vessel in a target position, within a horizontal frame, relative to the marine structure. The purpose is to simplify the design of the load transfer system, to reduce the weight and the costs of the load transfer system and to avoid collisions between the floater and the marine structure during the preparations for and the execution of the load transfer operation.

Another feature of the invention is that it will stabilise the load (removed from the marine structure) and secure it horizontally (sea securing) relative to the floater at so-called lift off (after the load transfer operation has been completed).

In general terms, the inventive idea resides in the use of a floater which is provided with a horizontal positioning system. The system consists of at least three hydraulic jacks with drive and control systems and supporting structures. The jacks are mounted on the floater by cardanic suspension, which allows the jacks to tilt in the vertical and
horizontal plane. Pistons in the hydraulic jacks, or extension beams fitted to the pistons, are connected to the load (or the marine structure). One or more hydraulic jacks regulate the longitudinal position and motions (surge) of the floater relative to the load (or the marine structure), and one or more hydraulic jacks regulate the transverse position and motions (sway) of the floater relative to the load (or the marine structure). A minimum of two jacks control the orientation and the yaw motion relative to the load (or the marine structure).

The horizontal motions of the floater consist of wave frequency motion and low frequency motion. Small forces are required to stop the low frequency motion compared to those required to stop the wave frequency motion (the low frequency forces will only constitute about 10% of the force required to stop wave frequency motions). By eliminating the low frequency motions, the amplitude of the floater's horizontal motions (oscillation) could be reduced by more than 50%. The drive and control systems for the hydraulic jacks will be such that they virtually eliminate the low frequency motion and thus reduce the horizontal motions of the floater considerably, whilst allowing wave frequency motions and preventing a substantial dynamic load from the floater from acting on the load or the marine structure.

To make this possible, each positioning system must first be activated, which means that it has to be coupled between the floater and the load (or the marine structure), whereupon certain operational characteristics have to be activated.

These characteristics of the horizontal positioning system will include one or more spring elements which will constantly try to pull the floater back to its target position, and this will be done with or without damping elements. The spring elements may be in the form of a linear or non-linear spring. The spring characteristic (force/deflection) may have different stiffness in different deflection ranges.

If a damping element is a part of the system, this element may have a speed-independent or speed-dependent force. A combination of these two dependencies may help to obtain an optimal horizontal positioning system.

During operations, it might be necessary to make adjustments of the average floater position relative to the load. Therefore, it is necessary to take measures to change the characteristic within the operating range of the horizontal positioning system.
The maximum forces must also be limited, so as to prevent overload of the system and the surrounding structures in emergency situations.

Fig. 1 shows a known floater with hinged beams;

Fig. 2 is a graph showing the spring characteristic of the new system;

Fig. 3 is a schematic top view of a U-shaped floater;

Fig. 4 shows a hydraulic system according to the invention;

Fig. 5 shows a variant of the hydraulic system, with a special damping effect; and

Fig. 6 is a more artistic presentation of a floater during a load transfer operation.

The U-shaped floater 1 in Fig. 1, see also Fig. 6, is provided with a plurality of hinged beams 2 for supporting a load 3, see also Fig. 6 which shows a load in the form of a superstructure placed on a tower 4.

In principle, the required function of the horizontal positioning system can be achieved by means of electric drive solutions or by means of hydraulic drive solutions, and here a hydraulic drive solution is presented.

Hydrodynamic studies of how to reduce low frequency motions of the floater whilst allowing the larger high frequency motions, show that a minimum requirement for the horizontal positioning system is that there must be a spring characteristic with two different stiffness values in the deflection range. This is shown schematically in Fig. 2. The first part of the characteristic (between position $-x_1$ and position $+x_1$) has a "high" spring stiffness, whilst in other positions there is a considerably lower spring stiffness, with a marked change in stiffness in position $-x_1$ and $+x_1$.

The object of the invention is to provide a system having the aforementioned properties and of the passive type.

Furthermore, adjustment features and a limitation of maximum forces must be incorporated into the system.
An example of a positioning system according to the invention will be described below.

Fig. 3 is a top view of a U-shaped floater 1, which floater 1 is positioned around a load 3, mounted on top of a marine structure 4 (Fig. 6).

The floater 1 can make horizontal movements in three different directions (degrees of freedom). These are motions known as surge, sway and yaw. The first two are linear motions, one in the longitudinal direction and the other in the lateral direction of the floater 1. The last-mentioned motion is rotation about a vertical axis.

For reducing and controlling the three degrees of freedom for the horizontal motion, three individual positioning systems (as a minimum) are required. These systems are designated HPS 1, HPS 2 and HPS 3. HPS 1 is mounted in the longitudinal direction and affects the surge motion, whilst HPS 2 and HPS 3 are mounted in the lateral direction and affect the sway and yaw motions. These systems are also shown in Fig. 1.

Each HPS system has the same mode of operation, but the dimensions and the absolute values of the force deflection characteristics may be different.

The following paragraphs describe an HPS and also explain its operation. Reference is made in particular to Fig. 4.

A hydraulic cylinder 5 with two piston rods 6 and 7 and with a piston 16 is connected to the floater 1 by means of a cardanic suspension 8 (or other device that allows the hydraulic cylinder 5 to tilt horizontally and vertically), and the piston 7 is connected to the load 3 (or the marine structure). Other types of cylinders and fixing means may also be used. A hydraulic pump/motor 9 with variable displacement is used for the transfer of hydraulic oil from one side of the cylinder to the other. This pump/motor is advantageously driven by an electric motor (m), and this combination is suitable for 4-quadrant operation, which means that all force directions and speed directions are possible. By means of this arrangement, it is possible to move the piston rods 6, 7 in a controlled manner at all times.

Each cylinder side is connected to a set of (at least) three hydro-pneumatic accumulators 10, 11 and 12. The number of accumulators is related to the number of the different spring characteristics.
The accumulator 10 is a low-pressure piston accumulator with a built-in mechanical end stop 14. In Fig. 4, the low-pressure piston 15 has been shifted into a position resting against the mechanical end stop 14.

The accumulator 11 is used for a low to medium pressure range, and may be of the membrane or piston type. The accumulator 12 is for the medium to high pressure range and is of the piston type. These are the preferred accumulator types. Other types may be used providing they have the same properties.

In the stationary position, the pressure on both sides of the cylinder 5 is the same, so that the pulling or pushing force (F) of the cylinder is zero. The accumulators 10, 11, 12 in the state shown in Fig. 4, i.e., accumulator 10 is full (resting against the end stop 14), whilst the accumulators 11 and 12 are completely empty (the gas pressure is higher than the oil pressure in the system).

Given that the piston 16 in the cylinder 5 is stationary in the middle position (as shown) and that this is the reference point \( x = 0 \), and given that the hydraulic motor 9 is inactive, and that there is no movement of the floater which generates a piston movement to the right, the oil from the right-hand chamber in the cylinder 5 will automatically be forced into the accumulator 11 only. This is due to the fact that the pre-fill pressure in the accumulator 12 is much higher than the pre-fill pressure in accumulator 11, and also to the fact that the accumulator 10 cannot absorb any oil because the piston 15 is already in its end position.

A movement of the piston 16 to the right will cause the left-hand chamber of the cylinder 5 to increase in volume and the required volume of oil will then flow out of the accumulator 10. As a result of the properties of the accumulators, the pressure in the right-hand chamber of the cylinder 5 will increase, whilst the pressure in the left-hand chamber will fall. The force \( F \) on the piston rod 7 thus increases when the movement is to the right. Depending on the accumulator sizes and the gas pre-fill pressures, the desired spring stiffness in the first part of the deflection range \((0 - x_1)\) can be obtained. Beyond this range, the force \( F \) will change from 0 to \( F_1 \).

After further deflection \((x \equiv x_1)\), the pressure in the accumulator 11 will be practically identical to the pre-fill pressure in the accumulator 12, and now (at deflection \( x > x_1 \)) the oil will flow into this last-mentioned accumulator from the right-hand cylinder chamber in the cylinder 5. The size and the pre-fill pressure of the accumulator 12 are chosen so
that the spring stiffness (force deflection curve) will have a different, lower value than the value in the small deflection range (here reference is being made to "one" stiffness related to the accumulator 12).

After the maximum deflection has been reached and the floater 1 reverses its movement, i.e., the floater moves in the opposite direction, the sequence described will be repeated in the reverse order.

When the cylinder/piston combination reaches the starting position $x = 0$, the accumulators 11 and 12 arranged on the right-hand side will be empty and the accumulator 10 will be filled.

On the left-hand side, the accumulators 11 and 12 will still be empty. The accumulator 10 will again be filled and the piston 15 will have come to rest against the mechanical stop.

Because the movement to the right continues (as a result of the floater's behaviour in the sea), the procedure described above (for movement to the right-hand side) will now be repeated in an identical manner on the left-hand side.

The maximum stroke length of the cylinder 5 is greater than the maximum stroke length required by the motions of the floater.

By means of the pump/motor 9, the oil on one side of the system can be transferred to the other side, and in this way the position of the spring characteristic can be shifted to the extent required, without the piston 16 reaching its end positions in the cylinder 5.

The diagram in Fig. 4 also shows two (remotely) adjustable safety relief valves 17. These have a number of functions:

1. They limit the maximum forces in the cylinder 5, the valves 17 being set at the desired high opening pressure.
2. They provide a "free float" or by-pass condition when the valves 17 are opened fully.
3. They permit a gradual transition from "free float" to "spring" operation by means of a controlled increase of the opening pressure.
The hydraulic elements 18 will include stop valves (manually or electrically operated) to enable the cylinder position to be "frozen" when the system is out of operation.

The box 19 represents standard hydraulic equipment, which is used for filling the system, for pressurising the system, flushing, filtering and cooling. This equipment is not described in more detail because it does not constitute essential elements of the invention.

In the above, a solution is described that has a certain spring characteristic, without a special damping effect. If an additional damping effect is required, a cylinder configuration as shown in Fig. 5 may be used. This configuration includes an "inner" cylinder 20 with two pistons 21 and 22 which are connected to the rod 31, and four oil chambers or sub-chambers 23, 24, 25 and 26. The two central sub-chambers 24, 25 are connected to a hydraulic system with multiple hydro-pneumatic accumulators, as shown in Fig. 4. In this figure only one accumulator 27, 28 is shown symbolically for each sub-chamber. The two outer sub-chambers 23 and 26 in the "inner" cylinder 20 are connected to each other via a fixed or (proportionally controlled) adjustable flow restrictor 29. This serves as a damping element in the system. By means of a suitable control algorithm and control system, the damping characteristic is "freely programmable".

In addition, there is an "outer" cylinder 30 which utilises the same piston rod 31. The ends of the "inner" cylinder 20 form a piston which can move within the "outer" cylinder 30. The oil chambers 32, 33 in the "outer" cylinder 30 can be used as (extra) safety relief valves or for adjusting purposes. In Fig. 5 the two chambers 32 and 33 are flow-connected with valves as shown.

An important advantage that is obtained with the invention is the possibility of dampening the relative motions between the floater and the load from the time of the so-called lift off of the load from the marine structure and until the moment this phase is complete (on condition that the piston rod is connected to the load and not the marine structure).

The horizontal motion of the structural element relative to the floater will then be dampened by the spring characteristics of the hydraulic jacks. The structural element can then be fastened to the floater (sea secured) by closing the valves 18. When these valves are closed, possible high loads are limited by the pressure relief valves 17.
2.

A method according to claim 1, characterised in that after the floater (1) has lifted the load (3) from the marine structure, the horizontal motion of the load (3) relative to the floater is dampened by the spring characteristics of the hydraulic jacks (HPS 1, 2, 3).

3.

A method according to claims 1 and 2, characterised in that the load (3) is secured to the floater (1) by closing stop valves (18) to the hydraulic cylinder (5).
4. A floater for offshore installation and removal of structural elements on/from a marine structure, characterised by a horizontal positioning system for keeping the floater (1) in a target position, within a horizontal frame, relative to the marine structure (3), which horizontal positioning system has the additional function of reducing low frequency motions by small forces and allowing wave frequency motions through limited forces, thereby protecting marine structures from large bending moments and high shear forces, which system comprises a plurality of hydraulic jacks (HPS 1, 2, 3) mounted on the floater by means of cardanic suspension (8) or similar devices which allow the jacks to tilt in the vertical and horizontal plane, each hydraulic jack (HPS 1, 2, 3) including a cylinder (5) and a piston (16) with a piston rod (7) intended for connection to the marine structure, which piston (16) is movable longitudinally in the cylinder (5), the cylinder (5) on each side of the said piston (16) being hydraulically parallel connected to a plurality of hydro-pneumatic accumulators (10, 11, 12) which have different gas pressure, the number and type of accumulators (10, 11, 12) being related to the required number of different spring characteristics to be obtained in the hydraulic jacks (HPS 1, 2, 3), wherein the spring characteristics are obtained by a combination of accumulators having a high spring stiffness from neutral position up to a certain deflection value (related to both sides of the neutral position), and a lower spring stiffness in other parts of the deflection range.

5. A hydraulic device for use in a horizontal positioning system for keeping a floater in a target position, within a horizontal frame, relative to a marine structure, characterised in that it comprises:
a cylinder (5) having two opposite ends;
a piston (16) movable longitudinally in the cylinder (5) between the said two ends;
a piston rod (6, 7) connected to the piston (16) and projecting from the cylinder at both ends thereof;
which piston (16) defines two opposite chambers in the cylinder (5), each of these chambers being hydraulically parallel connected to a first hydro-pneumatic accumulator (10) which has a first, lower gas pressure;
a second hydro-pneumatic accumulator (11) which has a second, medium gas pressure; and
a third hydro-pneumatic accumulator (12) which has a third, higher gas pressure, the spring characteristic provided by the combination of the accumulators (10, 11, 12) having a higher spring stiffness from a neutral position up to a certain deflection value
(related to both sides of the neutral position), and a lower spring stiffness in other parts of the deflection range.

6. A hydraulic device according to claim 5, characterised by a hydraulic pump (9) with variable displacement and hydraulically connected to each of the said chambers in the cylinder (5).

7. A hydraulic device according to claim 6, characterised in that the said hydraulic pump (9) is reversible, with two opposite outlets/inlets, that the pump (9) is hydraulically connected to a respective one of the said chambers in the cylinder (5) via a line from a respective outlet (inlet), and that two adjustable safety relief valves (17) are connected between these lines.

8. A hydraulic device according to claim 7, characterised by a flow restrictor (18) in each of the said lines.

9. A hydraulic device for use in a horizontal positioning system for keeping a floater in a target position, within a horizontal frame, relative to a marine structure, characterised in that it includes a cylinder (20) having two opposite ends; a transverse wall in the cylinder (5), between the said ends, whereby two chambers are formed in the cylinder (20); a respective piston (21, 22) movable longitudinally in a respective chamber; a piston rod (31) connected to the two pistons (21, 22) and projecting from the cylinder (20) at both ends thereof; each piston (21, 22) defining two respective sub-chambers (23, 24 and 25, 26) in the respective cylinder chambers, between the transverse wall and the respective piston (21, 22) and between the respective piston (21, 22) and a respective one of the said cylinder ends, each of the said sub-chambers (24, 25) adjacent to the transverse wall being hydraulically parallel connected to a first hydro-pneumatic accumulator which has a first, lower gas pressure; a second hydro-pneumatic accumulator which has a second, medium gas pressure; and
a third hydro-pneumatic accumulator which has a third, higher gas pressure, wherein the
spring characteristic provided by the combination of the accumulators (27, 28) has a
higher spring stiffness from a neutral position up to a certain deflection value (related to
both sides of the neutral position), and a lower spring stiffness in other parts of the
deflection range, the two other sub-chambers (23, 26) being connected to each other via
a fixed or adjustable flow restrictor (29).

10.
A hydraulic device according to claim 9, characterised in that each of the said cylinder
ends forms a piston in a respective external chamber (32, 33).

11.
A hydraulic device according to claim 10, characterised in that the said external
chambers (32, 33) are flow-connected to each other.

12.
A hydraulic device according to claims 5-11, characterised in that the first hydro-
pneumatic accumulator (10) comprises a first accumulator cylinder having two opposite
first accumulator cylinder ends, a first accumulator piston (15) movable longitudinally
in the first accumulator cylinder and defining a first hydraulic chamber and a first gas
chamber in the first accumulator cylinder, and an end stop (14) in the first accumulator
cylinder for the first accumulator cylinder piston (15) between the said first accumulator
ends; the second accumulator (11) comprises a second accumulator cylinder and a
second accumulator piston movable longitudinally in the second accumulator cylinder
and defining a second hydraulic chamber and a second gas chamber in the second
accumulator cylinder; and that the third accumulator (12) comprises a third accumulator
cylinder and a third accumulator cylinder piston movable longitudinally in the third
accumulator cylinder and defining a third hydraulic chamber and a third gas chamber in
the third accumulator cylinder, the dimensions and fill pressures being chosen so that
the spring characteristics defined in claim 1 are obtained.

13.
The use of a hydraulic device according to one of claims 5-12 for dampening the
horizontal motion of a load (3) relative to a floater (1) and securing the load (3) (sea
securing) relative to the floater (1).
Figure 3
**INTERNATIONAL SEARCH REPORT**

**International application No.**
PCT/NO 03/00047

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**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC7:** B63B 27/00, B63B 35/44
According to International Patent Classification (IPC) or to both national classification and IPC

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**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**IPC7:** B63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**EPO-INTERNAL, WPI DATA, PAJ**

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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Further documents are listed in the continuation of Box C. See patent family annex.

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**Authorized officer**

Carl Fröderberg/EK

**Facsimile No.** +46 8 666 02 86

**Telephone No.** +46 8 782 25 00

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