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Liberg

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(54) **CLOSED INCLINATION CHANGE SYSTEM**

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B63B 1/10	(2006.01)
B63B 1/12	(2006.01)
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(52) **U.S. Cl.**
CPC ***B63B 39/03*** (2013.01); ***B63B 1/107*** (2013.01); ***B63B 1/125*** (2013.01); ***B63B 35/44*** (2013.01); ***B63B 43/06*** (2013.01); *B63B 2001/128* (2013.01)

(58) **Field of Classification Search**
CPC B63B 43/00; B63B 43/06; B63B 27/24; B63B 39/03
USPC .... 114/74 R, 125
See application file for complete search history.

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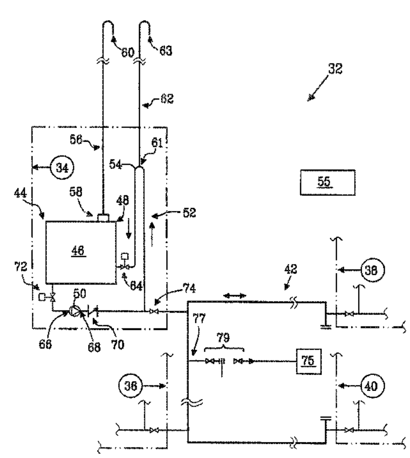
(57) **ABSTRACT**

The present disclosure relates to a closed inclination change system (**32**) for a floating unit (**10**). The inclination change system comprises a plurality of inclination change assemblies (**34**, **36**, **38**, **40**) and each one of the inclination change assemblies (**34**, **36**, **38**, **40**) is adapted to be in fluid communication with each one of the other inclination change assemblies (**34**, **36**, **38**, **40**).
Each one of the inclination change assemblies (**34**, **36**, **38**, **40**) comprises a tank assembly (**44**) comprising a first tank (**46**), the tank assembly (**44**) comprising a tank assembly top portion (**48**).
Moreover, each one of the inclination change assemblies (**34**, **36**, **38**, **40**) further comprises:
- a pump assembly (**50**) arranged to pump the fluid from the tank assembly (**44**), and
- an inlet conduit assembly (**52**) adapted to guide the fluid into the tank assembly (**44**) from another inclination change assembly (**34**, **36**, **38**, **40**), the inlet conduit assembly (**52**) having a conduit top portion (**54**) that is located above the tank assembly top portion (**48**).

25 Claims, 7 Drawing Sheets



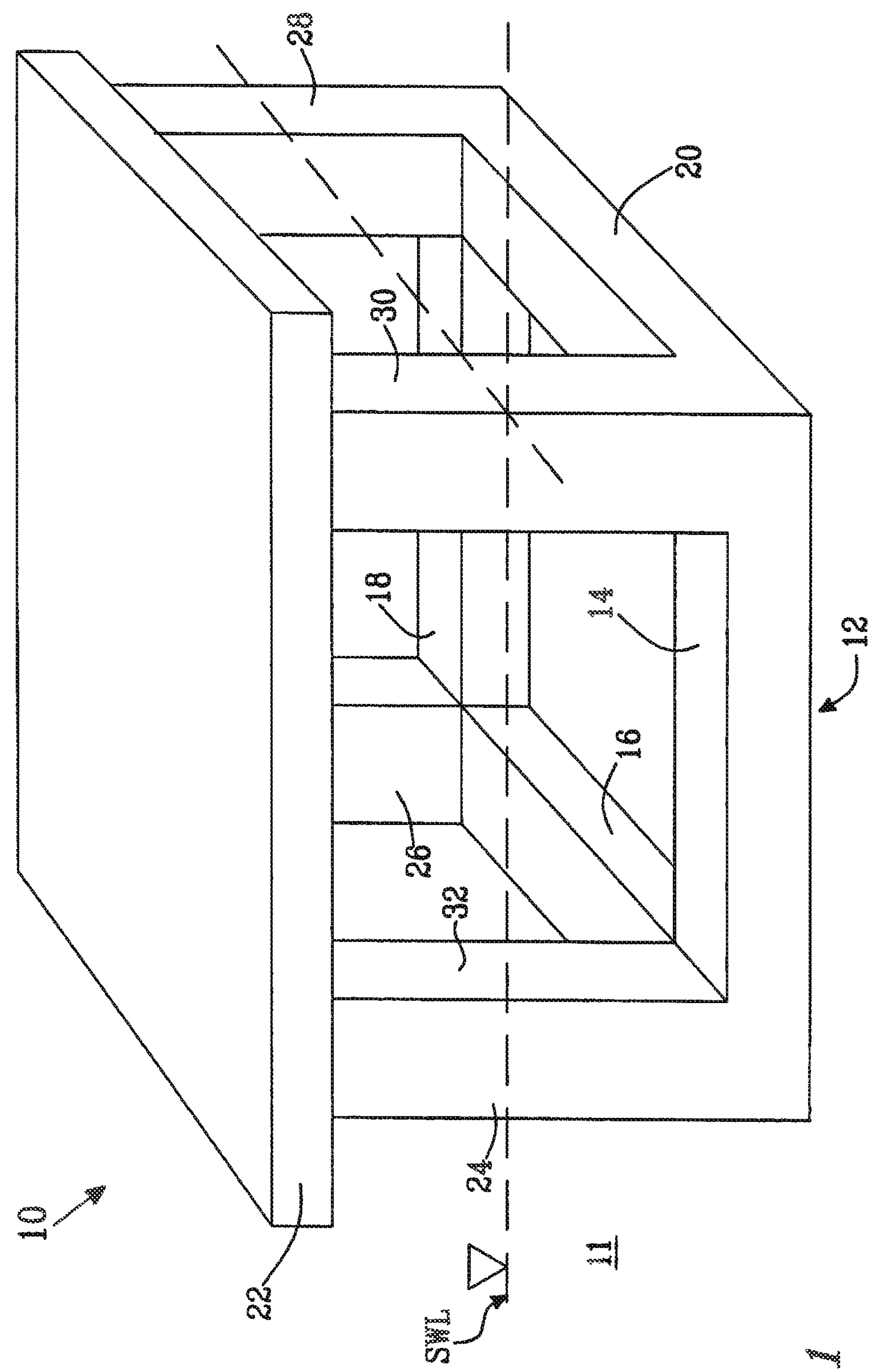


Fig. 1

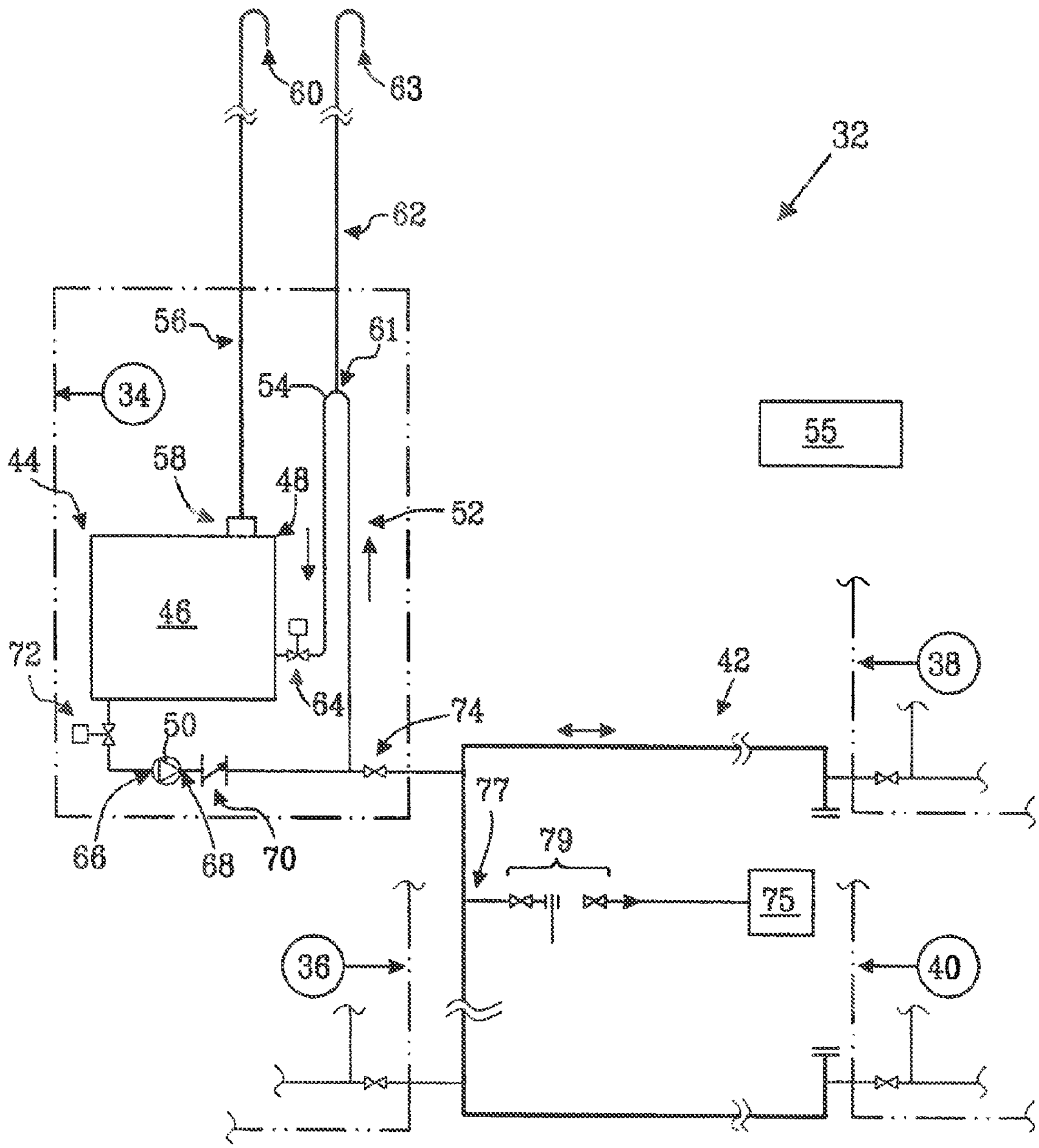

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Fig. 2

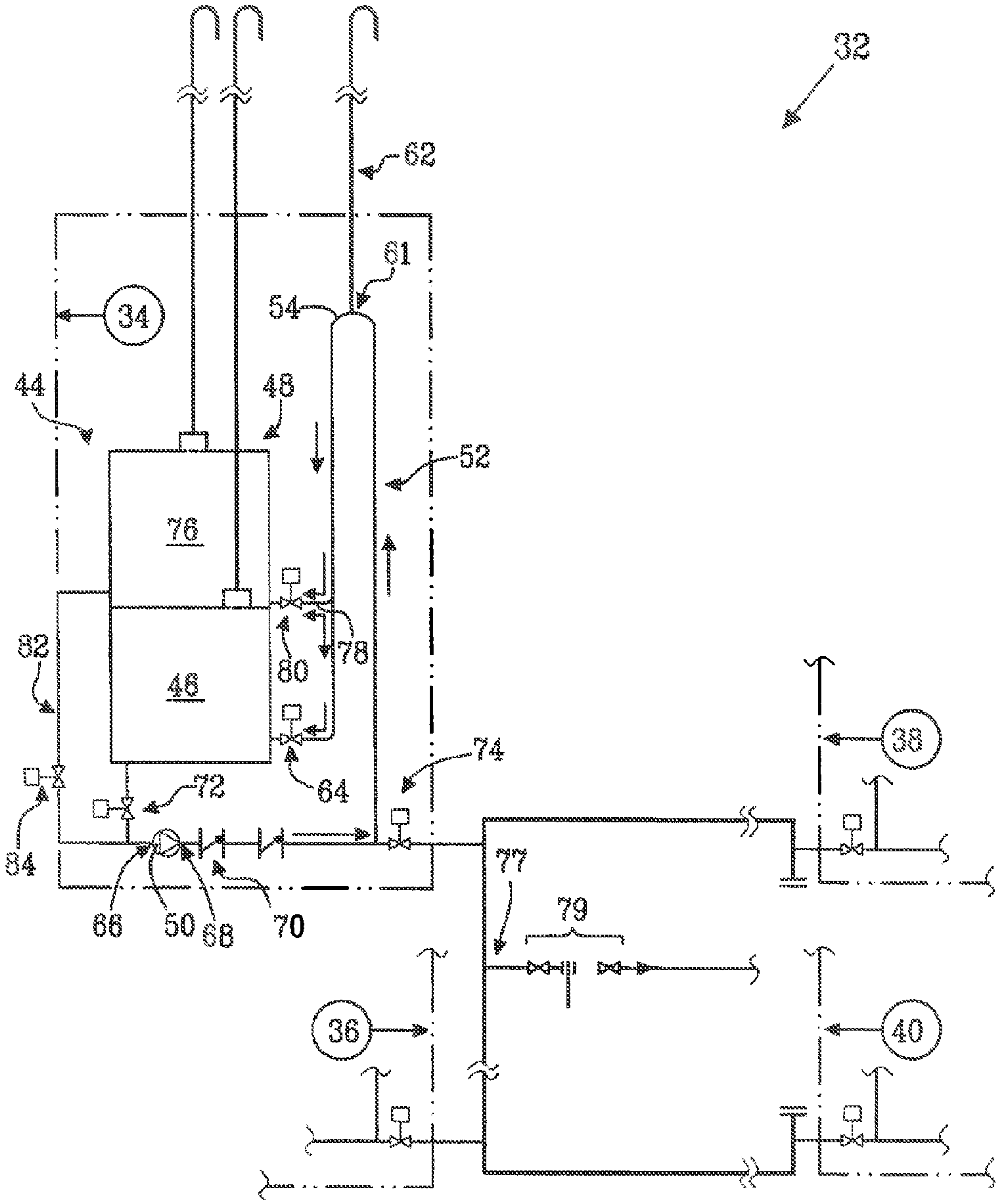
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Fig. 3

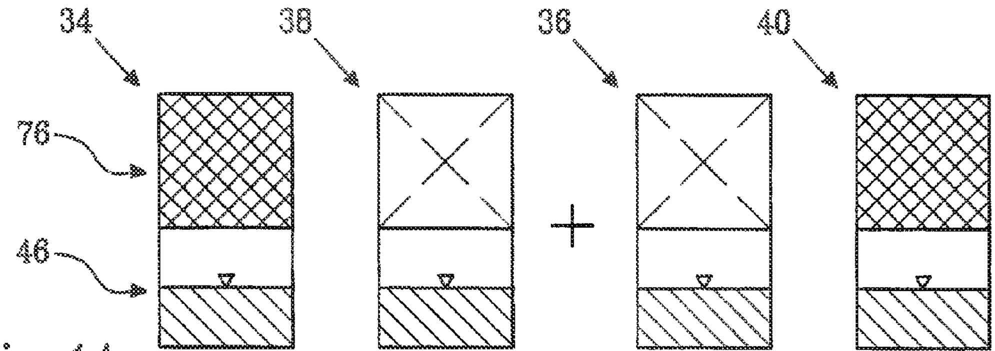

Fig.4A

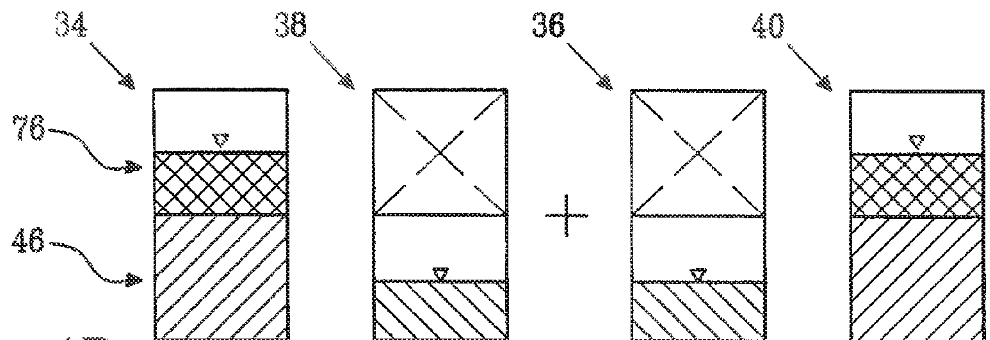

Fig.4B

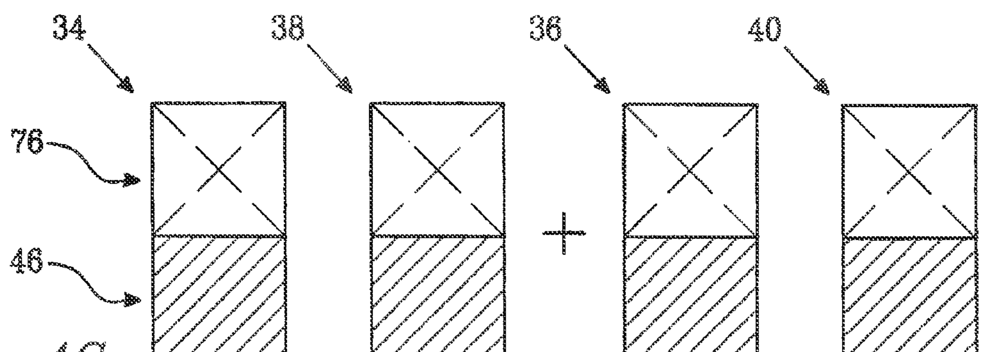

Fig.4C

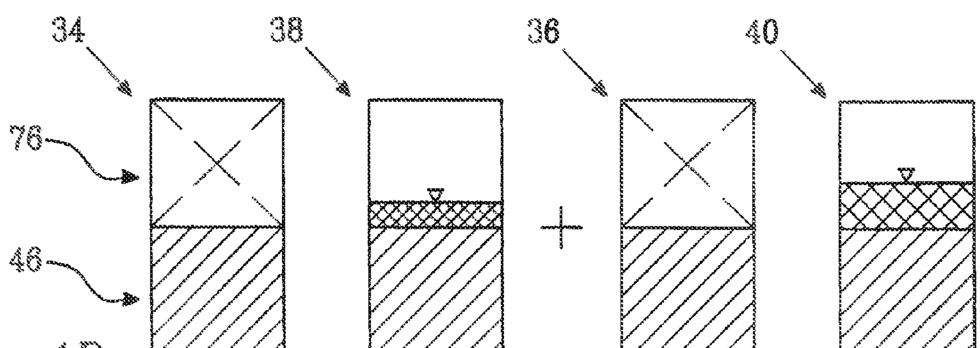

Fig.4D

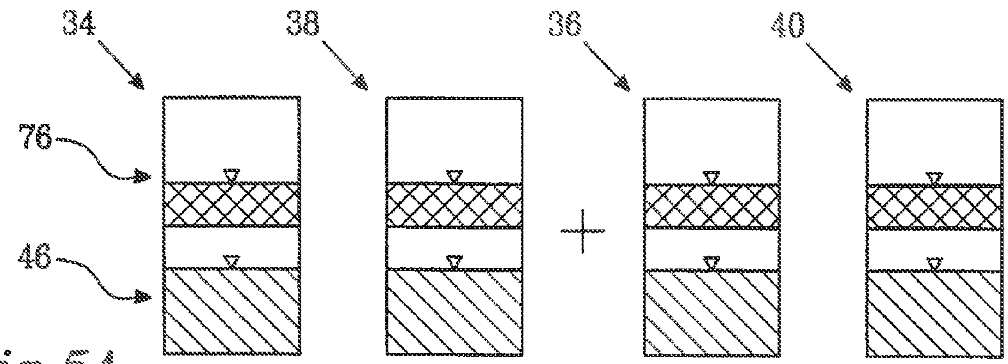

Fig. 5A

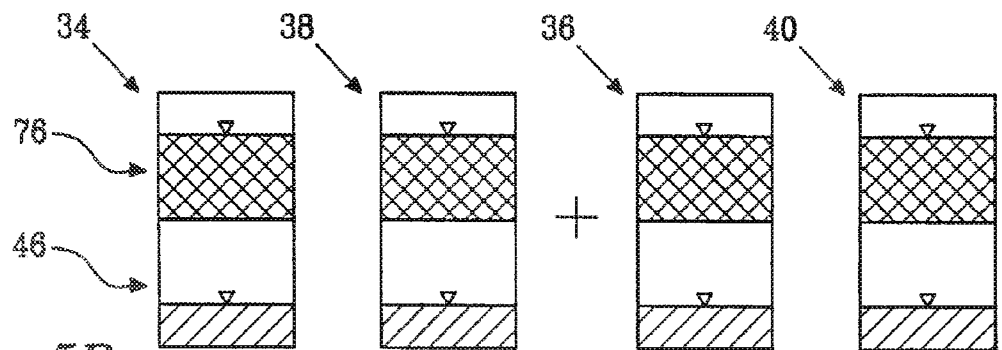

Fig. 5B

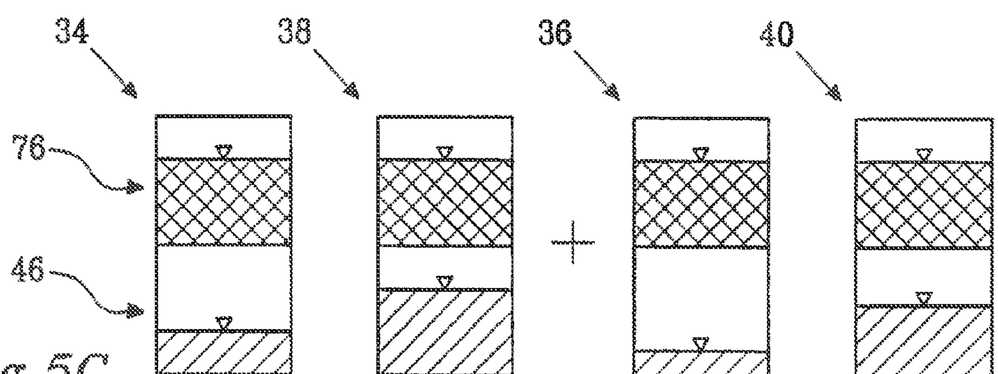

Fig. 5C

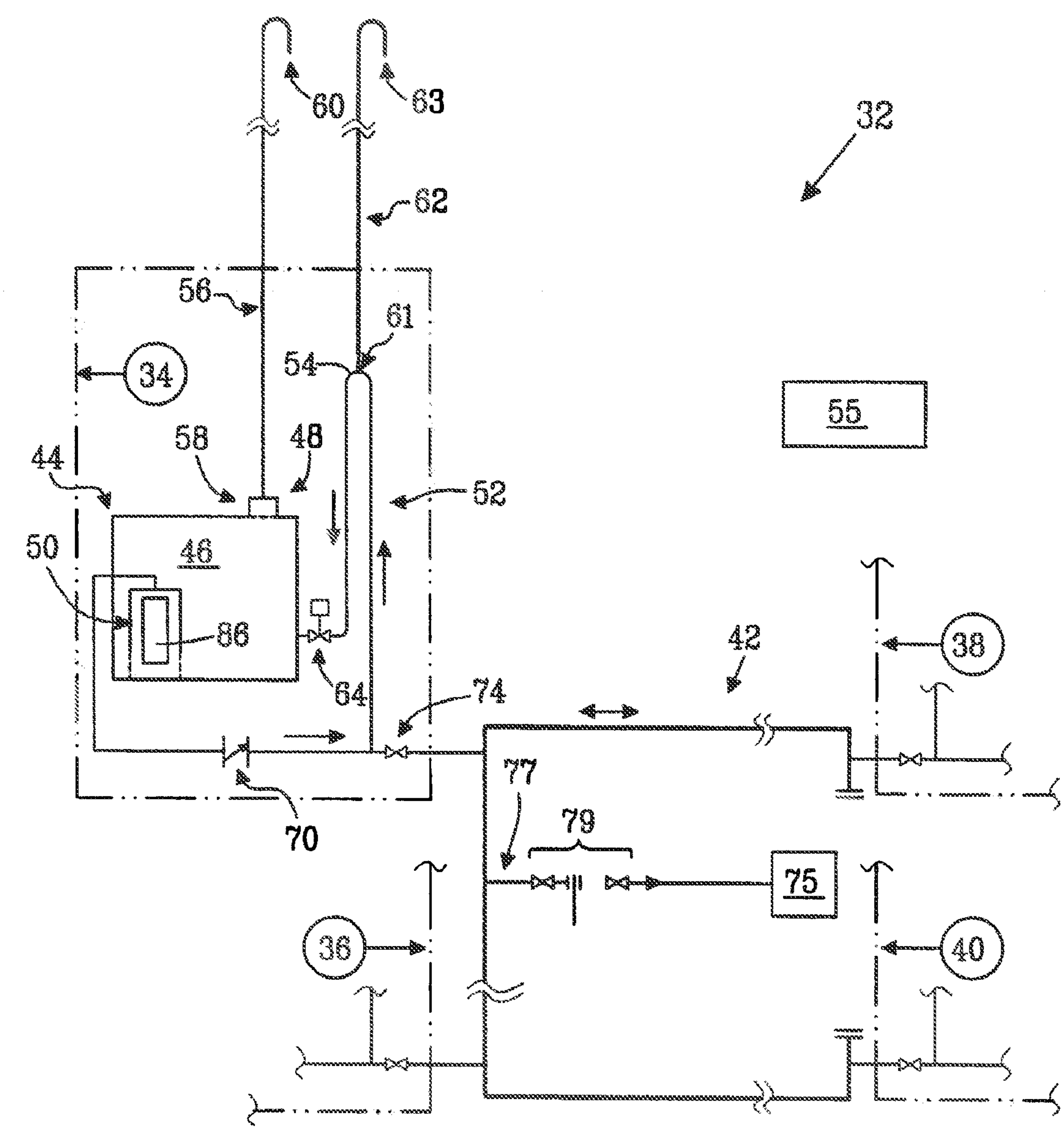
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Fig. 6

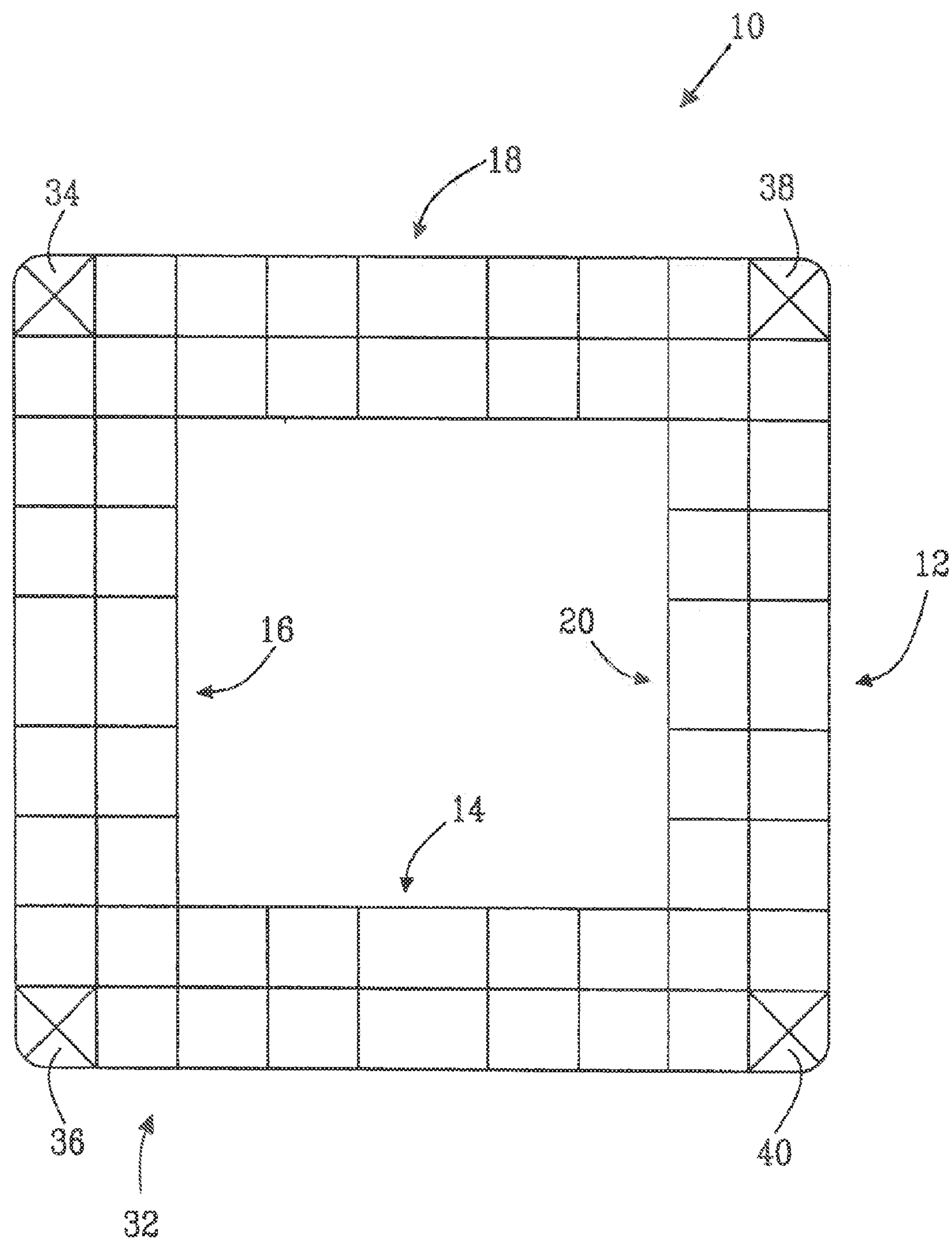

Fig. 7

CLOSED INCLINATION CHANGE SYSTEM

TECHNICAL FIELD

The present disclosure relates to a closed inclination change system according to the preamble of claim **1**. Moreover, the present disclosure relates to a method for imparting an inclination change to a floating unit.

BACKGROUND OF THE INVENTION

A floating unit is generally adapted to float in a floating condition within a predetermined draught range and a predetermined inclination range. As an example, a floating unit may be adapted to float in an operational floating condition with a predetermined operational draught and at even keel, i.e. with an inclination that is substantially zero.

The inclination of a floating unit may change for a plurality of reasons. For instance, if a load is placed on the floating unit, the unit may be imparted an inclining moment which in turn will change the inclination of the unit. As another example, when cranes of the unit are operated in order to lift and/or transfer a load, an inclination change is often obtained. Furthermore, a draught change of the floating unit may result in a change of the inclination of the floating unit.

In order to ensure that a floating unit assumes a floating condition with an inclination within a predetermined inclination range, it is common to engage a ballast system of the floating unit. To this end, ballast water may be transferred between ballast tanks of the floating unit in order to obtain a desired inclination of the floating unit. However, a ballast system is generally adapted to be in direct fluid communication with the water ambient of the floating unit. Moreover, the ballast system is generally designed to alter the draught of the floating unit. As such, if the ballast system is incorrectly operated during an inclination change operation, this may result in an undesired draught and/or an undesirably large inclination of the floating unit.

In order to reduce the risks that may possibly be associated with the above-discussed use of the ballast tanks, GB 2 163 115 proposes the use of an inclination change system with tanks that may be used for altering the inclination of a floating unit. To this end, the '115 system permits water to flow under gravity from one tank to another to influence the heel and/or trim of a floating unit.

Although the '115 system may be suitable for many types of floating units, it may nevertheless be desirable to obtain an inclination change system with a reduced risk of obtaining undesired inclinations in the event of a malfunctioning inclination change system.

SUMMARY OF THE INVENTION

One object of the present disclosure is to provide an inclination change system which may alter the inclination of a floating unit and which also has an appropriately low risk of imparting undesired inclinations to the floating unit.

This object is achieved by a closed inclination change system according to claim **1**.

As such, the present disclosure relates to a closed inclination change system for a floating unit, the inclination change system comprising a plurality of inclination change assemblies. Each one of the inclination change assemblies is adapted to be in fluid communication with each one of the other inclination change assemblies. Moreover, each one of

the inclination change assemblies comprises a tank assembly comprising a first tank. The tank assembly comprises a tank assembly top portion.

According to the present disclosure, each one of the inclination change assemblies further comprises:

- a pump assembly arranged to pump the fluid from the tank assembly, and
- an inlet conduit assembly adapted to guide the fluid into the tank assembly from another inclination change assembly, the inlet conduit assembly having a conduit top portion that is located above the tank assembly top portion.

The closed inclination change system presented hereinabove implies that that fluid may be transferred between the tank assemblies of the inclination change assemblies in order to impart an inclination change to a floating unit hosting the closed inclination change system. Moreover, by virtue of the facts that each one of the inclination change assemblies comprises a pump assembly and that an inlet conduit top portion is located above the tank assembly top portion, an appropriately low risk of imparting undesired inclinations, due to fluid flow by gravity, to the floating unit is obtained.

To this end, it should be noted that the position of the inlet conduit top portion above the tank assembly top portion implies that the risk of obtaining a flow by gravity of fluid from a tank assembly via the inlet conduit assembly associated with the tank assembly is appropriately low.

As used herein, the expression "inclination change system" relates to a system that is adapted to impart an inclination change to a floating unit, e.g. around the longitudinal and/or transversal axis of the unit. Preferably, the inclination change system is adapted to impart the inclination change without a substantial change of the draught of the floating unit. Moreover, the inclination change system is preferably adapted to impart an inclination change to a floating unit around any horizontal axis, i.e. around any azimuth.

Moreover, as used herein, the expression "closed inclination change system" relates to an inclination change system that is adapted to impart an inclination change to a floating unit without the need of adding fluid to, or removing fluid from, the inclination change system as such. In particular, as used herein, the expression "closed inclination change system" relates to a system that is adapted to impart an inclination change to a floating unit without the need of transferring fluid to and/or from the water ambient of the floating unit hosting the inclination change system.

By virtue of the fact that the inclination change system according to the present disclosure may impart inclination changes to a floating unit without the need for adding or removing fluid from the floating unit, the inclination change system according to the present disclosure may also be suitable to be used during an inclination test of the floating unit. During an inclination test, fluid may be transferred between the inclination change assemblies in order to obtain a plurality of floating conditions with different inclinations. Based on information as regards the actual inclinations and information concerning the amount of fluid in each inclination change assembly for each floating condition, it is possible to determine an estimate of the vertical centre of gravity of the floating unit.

Optionally, at least one of the inclination change assemblies comprises a first vent pipe assembly. The first vent pipe assembly comprises an air inlet located at the upper portion of the tank assembly. The first vent pipe assembly comprises an air outlet which is adapted to be in fluid communication with the environment ambient of the closed inclination change system. The air outlet is located at a position above the tank assembly top portion, preferably above the conduit top portion.

Optionally, at least one of the inclination change assemblies comprises a second vent pipe assembly. The second vent pipe assembly comprises a second air inlet located at the conduit top portion. Moreover, the second vent pipe assembly comprises a second air outlet which is adapted to be in fluid communication with the environment ambient of the closed inclination change system. The second air outlet is preferably located above the inlet conduit top portion. The provision of the second vent pipe may reduce the risk that a suction due to the siphon principle may occur in the inlet conduit assembly.

Optionally, at least one of the inclination change assemblies comprises an inlet cut-off valve located in the tank inlet conduit assembly, the inlet cut-off valve being located between the conduit top portion and the tank assembly.

Optionally, at least one of the inclination change assemblies comprises a pump assembly with a high side and a low side, the at least one inclination change assembly further comprising a check valve located downstream the low side.

By virtue of the fact that at least one of the inclination change assemblies comprises a check valve downstream the low side of its pump assembly, an appropriately low risk is obtained that the outlet of the tank assemblies of two inclination change assemblies will be open simultaneously to thereby allow a fluid communication between the outlets of the tank assemblies.

Optionally, at least one of the inclination change assemblies comprises a pump assembly cut-off valve located between the low side and the tank assembly.

Optionally, at least one of the inclination change assemblies comprises a control valve adapted to control a fluid flow to and from the inclination change assembly.

Optionally, the tank assembly of at least one of the inclination change assemblies comprises a second tank, the second tank being located at least partially above the first tank.

Optionally, the tank assembly of each one of the inclination change assemblies comprises a second tank. The second tank is located at least partially above the first tank.

Optionally, the inlet conduit assembly is also adapted to guide the fluid into the second tank from another inclination change assembly.

Optionally, the first tank assembly is adapted to provide a fluid communication between the second tank and the first tank.

Optionally, the first tank assembly is adapted to transfer fluid from the first tank to the second tank using the pump assembly.

Optionally, the closed inclination change system further comprises a feeding circuit adapted to be in fluid communication with each one of the inclination change assemblies.

Optionally, the pump assembly of at least one of the inclination change assemblies comprises a submersible pump.

A second aspect of the present disclosure relates to a floating unit comprising a closed inclination change system according to the first aspect of the present disclosure.

Optionally, the floating unit comprises a ballast system in addition to the closed inclination change system.

Optionally, the floating unit is a semi-submersible unit.

Optionally, the semi-submersible unit comprises four outermost supporting columns. The closed inclination change system comprises four inclination change assemblies. Each one of the four inclination change assemblies is associated with an individual one of the four outermost supporting columns such that the tank assembly of the inclination change assembly is located at least partially in and/or beneath the supporting column.

Optionally, the semi-submersible unit comprises a ring pontoon.

Optionally, the total volume of the tank assemblies of all the inclination change assemblies of the closed inclination change system may be less than 5%, preferably less than 2%, of the total volume displaced by the floating unit when the floating unit floats at an operational draught.

The fact that the total volume of all the tank assemblies closed inclination change system is below any one of the above limits implies that possible consequences of a malfunctioning closed inclination change system may be relatively moderate.

A third aspect of the present disclosure relates to a method for imparting an inclination change to a floating unit using a closed inclination change system. The inclination change system comprises a plurality of inclination change assemblies. Each one of the inclination change assemblies is adapted to be in fluid communication with each one of the other inclination change assemblies. Moreover, each one of the inclination change assemblies comprises: a tank assembly comprising a first tank, the tank assembly comprising a tank assembly top portion.

Each one of the inclination change assemblies further comprises: a pump assembly arranged to pump the fluid from the tank assembly, and an inlet conduit assembly adapted to guide the fluid into the tank assembly from another inclination change assembly, the inlet conduit assembly having a conduit top portion that is located above the tank assembly top portion.

Moreover, the method comprises:

- providing a fluid communication from the pump assembly of a first of the inclination change assemblies to the tank assembly of a second of the inclination change assemblies, and
- operating the pump assembly such that fluid is pumped from the tank assembly of the first inclination change assembly to the tank assembly of the second inclination change assembly.

Optionally, the tank assembly of each one of the inclination change assemblies comprises a second tank, the second tank being located at least partially above the first tank. The method comprises:

- determining if it is possible to obtain the inclination change by transferring fluid between the first tanks only;
- if it is possible, providing a fluid communication from the pump assembly of a first of the inclination change assemblies to the first tank of the tank assembly of a second of the inclination change assemblies, and
- operating the pump assembly such that fluid is pumped from the first tank of the tank assembly of the first inclination change assembly to the first tank of the tank assembly of the second inclination change assembly.

Optionally, the method comprises transferring fluid that is not needed in order to obtain the inclination change to the second tanks prior to transferring fluid between the first tanks. The feature that not needed fluid is transferred to the second tanks implies that only the amount of fluid that is actually needed for achieving the desired inclination change is present in the first tanks. As such, if the closed inclination change system malfunctions during an inclination change procedure, e.g. due to an incorrect operation of the system and/or due to one or more impaired components of the system, the consequences of such malfunctioning may be relatively low.

Optionally, the method comprises:

determining if it is possible to obtain the inclination change by transferring fluid between the second tanks only;

if it is possible, providing a fluid communication from the pump assembly of a first of the inclination change assemblies to the second tank of the tank assembly of a second of the inclination change assemblies, and

operating the pump assembly such that fluid is pumped from the second tank of the tank assembly of the first inclination change assembly to the second tank of the tank assembly of the second inclination change assembly.

Optionally, the method comprises transferring fluid that is not needed in order to obtain the inclination change to the first tanks prior to transferring fluid between the second tanks.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a more detailed description of embodiments of the disclosure cited as examples.

In the drawings:

FIG. **1** illustrates a floating unit;

FIG. **2** schematically illustrates an embodiment of a closed inclination change system;

FIG. **3** schematically illustrates another embodiment of a closed inclination change system;

FIG. **4** schematically illustrates an inclination change sequence using the FIG. **3** embodiment;

FIG. **5** schematically illustrates another inclination change sequence using the FIG. **3** embodiment;

FIG. **6** schematically illustrates a further embodiment of a closed inclination change system, and

FIG. **7** illustrates a cross-sectional top view of the float of the FIG. **1** floating unit.

It should be noted that the appended drawings are not necessarily drawn to scale and that the dimensions of some features may have been exaggerated for the sake of clarity.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Embodiments of the above discussed aspects will be presented hereinbelow. It should however be realized that the embodiments are included in order to explain principles of the invention and not to limit the scope of the invention, defined by the appended claims.

FIG. **1** illustrates a marine structure **10** of the prior art, which marine structure in FIG. **1** is a semi-submersible unit, adapted to float in a body of water **11** with a still water level SWL. The marine structure comprises a float **12** which is adapted to be located at least partially in the body of water **11** and, in the implementation of the marine structure illustrated in FIG. **1**, the float **12** is adapted to be located below the aforesaid still water level SWL.

In the implementation of the marine structure **10** illustrated in FIG. **1**, the float **12** is of a so called ring pontoon type and is thus constituted by four pontoons **14**, **16**, **18**, **20** connected to one another so as to form the float **12**. However, in other implementations of the marine structure **10**, the float **12** may have a design which differs from the one illustrated in FIG. **1**. As may be gleaned from FIG. **1**, the marine structure **10** also comprises a deck structure **22**, which deck structure **22** generally is adapted to be located above the still water level SWL.

Moreover, the marine structure **10** in FIG. **1** is provided with four supporting members, or supporting columns, **24**, **26**, **28**, **30** extending between the float **12** and the deck structure **22**.

Embodiments of a closed inclination change system according to the present invention will be presented hereinbelow. As a non-limiting example, a closed inclination change system of the present invention may preferably be suitable for a marine structure such as the marine structure **10** illustrated in FIG. **1**. However, it is also envisaged that embodiments of the closed inclination change system of the present invention may be suitable for other types of floating units. Purely by way of example, an embodiment of the closed inclination change system may be suitable for at least one of the following types of floating units: a ship, a floating production storage and offloading unit (FPSO), a tension leg platform (TLP), a spar buoy, a barge and a floating dock.

Moreover, it should be noted that embodiments of the closed inclination change system may be suitable for a semi-submersible unit that has another design than the FIG. **1** implementation of a semi-submersible unit **10**. Purely by way of example, an embodiment of the closed inclination change system may be suitable for a semi-submersible unit that has twin pontoons (not shown) and/or more or less than four supporting columns extending from the float to the deck. As a non-limiting example, an embodiment of the closed inclination change system may be suitable for a semi-submersible unit that has six supporting columns (not shown).

FIG. **2** illustrates an embodiment of a closed inclination change system **32** for a floating unit (not shown in FIG. **2**). The closed inclination change system **32** of the present invention comprises a plurality of inclination change assemblies and the FIG. **2** embodiment comprises four inclination change assemblies, viz a first **34**, a second **36**, a third **38** and a fourth **40** inclination change assembly.

It should be noted that other embodiments of a closed inclination change system **32** may include fewer or more inclination change assemblies than four. As a non-limiting example, an embodiment of a closed inclination change system (not shown) may include only three inclination change assemblies. As another non-limiting example, an embodiment of a closed inclination change system (not shown) may comprise five or more inclination change assemblies.

FIG. **2** illustrates preferred features of an inclination change assembly using the first inclination change assembly **34** as an example. However, it should be noted that each one of the other inclination change assemblies **36**, **38**, **40** may comprise the same, or at least similar features, as the first inclination change assembly **34**.

FIG. **2** illustrates that each one of the inclination change assemblies **34**, **36**, **38**, **40** is adapted to be in fluid communication with each one of the other inclination change assemblies **34**, **36**, **38**, **40**. To this end, the FIG. **2** closed inclination change system **32** comprises a feeding circuit **42** adapted to be in fluid communication with each one of the inclination change assemblies **34**, **36**, **38**, **40**.

In the FIG. **2** embodiment of the closed inclination change system **32**, each one of the inclination change assemblies **34**, **36**, **38**, **40** comprises a tank assembly **44** comprising a first tank **46**. The tank assembly **44** comprises a tank assembly top portion **48**. The top portion **48** is located in the uppermost region of the tank assembly **44**.

Moreover, each one of the inclination change assemblies **34**, **36**, **38**, **40** further comprises a pump assembly **50** arranged to pump the fluid from the tank assembly **44**. Further, each one of the inclination change assemblies **34**, **36**, **38**, **40** comprises an inlet conduit assembly **52** adapted to guide the fluid into the tank assembly **44** from another inclination change assembly. The inlet conduit assembly **52** has a conduit top portion **54** that is located above the tank assembly top portion **48**.

The fluid used in the closed inclination system **32** may be a liquid. Purely by way of example, the fluid used in the closed inclination change system **32** may be at least one of the following: fresh water or oil. The use of fresh water or oil may have the advantage that corrosion in the closed inclination change system **32** is relatively low. As another option, the fluid used in the closed inclination change system **32** may be sea water. The use of sea water may have the advantage that the sea water may be supplied from e.g. a ballast system of the floating unit as will be discussed hereinbelow.

The closed inclination change system **32** according to the present invention may be used for imparting an inclination change to a floating unit hosting the system **32**. As such, the closed inclination change system **32** may be operated so as to provide a fluid communication from the pump assembly **50** of the first inclination change assembly **34** to the tank assembly of a second of said inclination change assemblies **36**, **38**, **40**.

Moreover, the closed inclination change system **32** may be operated such that fluid is pumped from the tank assembly **44** of the first inclination change assembly **34** to the tank assembly of a second one of said inclination change assemblies **36**, **38**, **40**.

The above discussed operation of the closed inclination change system **32** may be performed manually. As such, one or more operators may decide between which inclination change assemblies a fluid communication is to be provided. Moreover, the one or more operators may operate the pump assembly of one of the inclination change assemblies such that an appropriate amount of fluid is pumped from the tank assembly of the first inclination change assembly to the tank assembly of a second of said inclination change assemblies.

As another option, the closed inclination change system **32** preferably comprises a control unit **55**, such as an electronic control unit. Purely by way of example, the control unit **55** may receive input as regards a desired inclination change to be imparted to the floating unit hosting the closed inclination change system **32**. The control unit **55** may then automatically decide between which inclination change assemblies a fluid communication may be provided.

Moreover, although purely by way of example, the control unit **55** may be adapted to communicate with other portions of the closed inclination change system. As a non-limiting example, the control unit **55** may be adapted to communicate with other portions of the closed inclination change system **32** via electronic and/or hydraulic signals. As such, the control unit **55** may be adapted to control e.g. one or more valve assemblies of the closed inclination change system **32** in order to provide the desired fluid communication between two inclination change assemblies.

Additionally, although purely by way of example, the control unit **55** may also be adapted to control at least one pump assembly **50** of at least one of the inclination change assemblies **34**, **36**, **38**, **40** such that fluid may be pumped from one inclination change assembly to one or more of the other inclination change assemblies.

The FIG. **2** embodiment of the closed inclination change system **32**, at least one of the inclination change assemblies **34** comprises an first vent pipe assembly **56**. The first vent pipe assembly **56** comprises an air inlet **58** located at the upper portion **48** of the tank assembly **44**. The first vent pipe assembly **56** comprises an air outlet **60** located at a position above the tank assembly top portion **48**. The air outlet **60** is adapted to be in fluid communication with the environment ambient of the closed inclination change system **32**. FIG. **2** illustrates a preferred implementation of the first vent pipe assembly **56** in which the air outlet **60** is located above the conduit top portion **54**.

FIG. **2** further illustrates that at least one of the inclination change assemblies **34** may comprise a second vent pipe assembly **62** providing a fluid communication between the conduit top portion **54** and ambient environment. To this end, the second vent pipe assembly **62** comprises a second air inlet **61** located at the conduit top portion **54**. Moreover, the second vent pipe assembly **62** further comprises a second air outlet **63** which is in fluid communication with the environment ambient of the closed inclination change system **32**. The second air outlet **63** is preferably located above the conduit top portion **54**.

The provision of the second vent pipe **62** may reduce the risk that a suction due to the siphon principle may occur in the inlet conduit assembly **52**. A suction in the inlet conduit assembly **52** may occur when fluid flows from the conduit top portion **54** to the tank assembly **44** and creates a negative pressure in the inlet conduit assembly **52**. Such a negative pressure may result in that fluid in the portion of the inlet conduit assembly **52** that is located between the conduit top portion **54** and the feeding circuit **42** may be forced towards the tank assembly **44**. The risk of obtaining such a negative pressure in the inlet conduit assembly is reduced by the provision of the second vent pipe assembly **62**.

FIG. **2** further illustrates that the at least one of the inclination change assemblies **34**, **36**, **38**, **40** may comprise an inlet cut-off valve **64** located in the tank inlet conduit assembly **52**. Moreover, as may be gleaned from FIG. **2**, the inlet cut-off valve **64** may preferably be located between the conduit top portion **54** and the tank assembly **44**.

Moreover, FIG. **2** illustrates that at least one of the inclination change assemblies **34**, **36**, **38**, **40** comprises a pump assembly **50** with a low side **66** and a high side **68**. Moreover, in the FIG. **2** embodiment, at least one inclination change assembly **34**, **36**, **38**, **40** further comprises a check valve **70** located downstream the high side **68**.

Furthermore, FIG. **2** illustrates that at least one of the inclination change assemblies **34**, **36**, **38**, **40** may comprise a pump assembly cut-off valve **72** located between the low side **66** and the tank assembly **44**.

Moreover, in the FIG. **2** embodiment of the closed inclination change system **32**, at least one of the inclination change assemblies **34**, **36**, **38**, **40** comprises a control valve **74** adapted to control a fluid flow to and from the inclination change assembly **34**.

FIG. **2** further illustrates that the closed inclination change system **32** may be arranged so as to selectively be in fluid communication with a ballast system **75**. The selective fluid communication in FIG. **2** is achieved by the connection of a ballast system communication conduit **77** to the feeding circuit **42**. The ballast system communication conduit **77** may for instance comprise a valve assembly **79** adapted to control any flow through the ballast system communication conduit **77**.

Purely by way of example, the valve assembly **79** may be operated so as to allow a fluid communication between the closed inclination change system **32** and the ballast system **75** in an initial condition for the closed inclination change system **32**, e.g. before or when the closed inclination change system **32** is to be used for the first time. However, during operations of the closed inclination change system **32** as such, the valve assembly **79** is preferably closed such that fluid communication between the closed inclination change system **32** and the ballast system **75** is prevented.

The closed inclination change system **32**, such as the embodiment of the closed inclination change system **32** illustrated in FIG. **2**, is preferably used in a method for imparting an inclination change to a floating unit.

The method comprises providing a fluid communication from the pump assembly **50** of a first **34** of the inclination change assemblies to the tank assembly of a second of the inclination change assemblies **36**, **38**, **40**. Generally, the choice between which inclination change assemblies **34**, **36**, **38**, **40** to provide a fluid communication may be dependent on the desired direction and magnitude of the inclination to be imparted to the floating unit. Purely by way of example, the choice between which inclination change assemblies **34**, **36**, **38**, **40** to provide a fluid communication may be performed manually or automatically.

Moreover, the method comprises operating the pump assembly such that fluid is pumped from the tank assembly of the first inclination change assembly to the tank assembly of the second inclination change assembly. Purely by way of example, the operation of the pump assembly may be performed manually or automatically.

FIG. **3** illustrates another embodiment of a closed inclination change system. The FIG. **3** embodiment comprises features that are identical, or at least similar, to features of the FIG. **2** embodiment and such features have the same reference number in FIG. **3** as they do in FIG. **2**.

As may be gleaned from FIG. **3**, the embodiment of the closed inclination change system **32** disclosed therein comprises at least one inclination change assembly **34**, **36**, **38**, **40**, the tank assembly **44** of which comprises a second tank **76**. Thus, in the FIG. **3** embodiment, the tank assembly **44** of at least one of the inclination change assemblies **34**, **36**, **38**, **40** comprises two tanks **46**, **76**. Preferably, the second tank **76** is located at least partially above the first tank **46**.

Moreover, in the FIG. **3** embodiment, the inlet conduit assembly **52** is also adapted to guide the fluid into the second tank **76** from another inclination change assembly. To this end, the tank inlet conduit assembly **52** preferably comprises a second conduit portion **78** adapted to guide fluid into the second tank **76**. The second conduit portion **78** may preferably comprise a second inlet cut-off valve **80**.

Purely by way of example, the first tank **46** and the second tank **76** may be in a permanent fluid communication with one another. As another non-limiting example, the first tank **46** and the second tank **76** may be arranged so as to selectively be in fluid communication with one another. To this end, although purely by way of example, the first inclination change assembly **34** may comprise a conduit (not shown) providing a fluid communication between the first and second tanks **46**, **76** and the inclination change assembly **34** may also comprise a valve (not shown) by which the fluid communication between the first and second tanks **46**, **76** may be controlled.

Instead of, or in addition, to the above-discussed conduit between the first and second tanks, a fluid communication between the first tank **46** and the second tank **76** may be provided via the inlet conduit assembly **52**. As such, if the first inlet cut-off valve **64** and the second inlet cut-off valve **80** are open, a fluid transfer from the second tank **76** to the first tank **46** may be achieved. To this end, it may be preferred that the second conduit portion **78** is connected to the lowermost portion of the second tank **76**.

Moreover, the implementation of the first inclination change assembly **34** illustrated in FIG. **3** is adapted to transfer fluid from the first tank **46** to the second tank **76** using the pump assembly **50**. Such a fluid transfer may be achieved by closing valves **64**, **74** and **84** and opening valves **72** and **80**. The pump assembly **50** may thereafter be operated so as to pump fluid from the first tank **46** to the second tank **76**.

In the FIG. **3** embodiment of the closed inclination change system **32**, the first inclination change assembly **34** comprises a second tank conduit portion **82** adapted to provide a fluid communication between the second tank **76** and the low side **66** of the pump assembly **50**. Moreover, the first inclination change assembly **34** comprises a second tank conduit valve **84** adapted to control the fluid communication via the second tank conduit portion **82**.

Embodiments of the closed inclination change system **32** that comprises at least two inclination change assemblies **34**, **36**, **38**, **40** wherein each one of these inclination change assemblies in turn comprises a first and a second tank **46**, **76** may preferably be used in a method for imparting an inclination change to a floating unit using a closed inclination change system and an embodiment of such a method will be presented hereinbelow.

Purely by way of example, a starting configuration of the closed inclination change system **32** may be that any direct fluid communication between the first and second tanks **46**, **76** is prevented within each one of the inclination change assemblies **34**, **36**, **38**, **40** which comprises a first and second tank. An example of such a starting configuration is illustrated in FIG. **4**A.

As may be gleaned from FIG. **4**A, the second tank of each one of the first **34** and the fourth **40** inclination change assemblies is substantially completely filled whereas the second tank of each one of the second **36** and third **38** inclination change assemblies is substantially empty. A configuration of the second tanks, such as the one illustrated in FIG. **4**A, is generally preferred since completely filled or completely empty tanks will not significantly contribute to a reduced stability of the floating unit due to the so-called free liquid surface effect.

Moreover, the first tank of each one of the four inclination change assemblies is substantially half-filled.

The method comprises the step of determining if it is possible to obtain the desired inclination change by transferring fluid between the first tanks only. If it is determined that it actually is possible to impart the desired inclination change to the fluid unit by using the first tanks only, the method proceeds in a manner similar to the manner of the method that has been discussed hereinabove with reference to FIG. **2**, i.e. the method comprises providing a fluid communication from the pump assembly of a first of the inclination change assemblies to the first tank of the tank assembly of a second one of the inclination change assemblies and operating the pump assembly such that fluid is pumped from the first tank of the tank assembly of the first inclination change assembly to the first tank of the tank assembly of the second inclination change assembly.

As an alternative, the method may also comprise

- determining if it is possible to obtain the inclination change by transferring fluid between the second tanks only, and
- if it is possible, providing a fluid communication from the pump assembly of a first of the inclination change

assemblies **34**, **36**, **38**, **40** to the second tank of the tank assembly of a second of the inclination change assemblies **34**, **36**, **38**, **40**;

operating the pump assembly such that fluid is pumped from the second tank of the tank assembly of the first inclination change assembly to the second tank of the tank assembly of the second inclination change assembly.

However, if it is determined that the use of both the first and the second tanks is required in order to impart the desired inclination change to the floating unit, the method preferably comprises providing a fluid communication between each one of the first tank **46** and its corresponding second tank **76**. An example of a condition in which the above discussed configuration has been assumed is illustrated in FIG. **4**B.

When the fluid communication between the first and second tanks **46**, **76** of each one of the tank assemblies has be obtained, the appropriate fluid communication(s) is provided between selected inclination change assemblies and fluid is pumped therebetween. An example of a fluid distribution that could result from such a fluid transfer is illustrated in FIG. **4**D. The FIG. **4**D fluid distribution could be obtained directly from the FIG. **4**B distribution. Optionally, the method could comprise a neutral fluid distribution, e.g. substantially the same amount of fluid in each one of the inclination change assemblies, being obtained before the FIG. **4**D distribution is attained. An example of such a neutral fluid position is illustrated in FIG. **4**C.

FIGS. **5**A to **5**C illustrate another embodiment of the method for imparting an inclination change to a floating unit. As in the FIG. **4** embodiment, the FIG. **5** embodiment of the method uses a closed inclination system that comprises inclination change assemblies each one of which having a first tank **46** and a second tank **76**. In each inclination change assembly, the second tank **76** is located above the first tank **46**.

FIG. **5**A illustrates a starting condition for an embodiment of the method of imparting an inclination change to a floating unit. In the condition illustrated in FIG. **5**A, the first tanks **46** contain a certain amount of fluid and the second tanks **76** contain a certain amount of fluid. Purely by way of example, substantially one third of each one of the second tanks **76** and approximately two thirds of each one of the first tanks **46** may be filled with fluid.

The embodiment of the method illustrated in FIG. **5** may also comprise that the amount of fluid that is needed in the first tanks **46**, in order to be able to obtain the desired inclination change, is determined. Purely by way of example, the amount of fluid that is needed may be dependent on the magnitude and direction of the desired inclination. The FIG. **5** embodiment may also comprise that fluid that is not needed in order to obtain the desired inclination change is transferred to the second tanks **76** prior to pumping fluid between the first tanks, i.e. prior to transferring fluid in order to obtain the desired inclination change.

FIG. **5**B illustrates a condition in which it has been determined that the desired inclination change may be obtained if substantially one third of each one of the first tanks **46** is filled with fluid. Thus, the residual fluid, i.e. the fluid that is not needed in order to obtain the desired inclination change, is transferred to the second tanks **76**. Thus, FIG. **5**B illustrates a condition in which substantially one third of each one of the first tanks **46** is filled with fluid whereas approximately two thirds of each one of the second tanks **76** is filled with fluid.

Fluid transfer between the first tanks **46** may thereafter commence in order to obtain the desired inclination change. However, in the FIG. **5** embodiment of the inclination change method, no fluid is transferred between the second tanks **76** during the inclination change procedure. FIG. **5**C illustrates a condition in which fluid has been transferred between the first tanks **46** of the inclination change assemblies **34**, **36**, **38**, **40**.

It should be noted that although the FIG. **5** embodiment of the method uses fluid transfer between the first tanks **46** and stores residual fluid in the second tanks **76**, it is also envisaged that embodiments of the method may store residual fluid in the first tanks **46** and transfer fluids between the second tanks **76** in order to impart an inclination change to a floating unit.

FIG. **6** illustrates another embodiment of the closed inclination change system **32**. In FIG. **6**, the pump assembly **50** of at least one of the inclination change assemblies comprises a submersible pump **86**.

The submersible pump **86** illustrated in FIG. **6** is associated with the first inclination change assembly **34**. However, in other embodiments of the closed inclination change system **32**, each one of the inclination change assemblies **34**, **36**, **38**, **40** may comprise a submersible pump.

In the implementation of the first inclination change assembly **34** illustrated in FIG. **6**, the submersible pump **86** is located in the first tank **46** of the first inclination change assembly **34**.

However, in other embodiments of a closed inclination change system **32**, an inclination change assembly may comprise a submersible pump that is located in a conduit (not shown) outside of the tank or tanks of an inclination change assembly.

As has been intimated hereinabove, a closed inclination change system **32** may preferably be used in a semi-submersible unit. FIG. **7** is a top view of the float **12** of the FIG. **1** semi-submersible unit **10**. The float **12** of the FIG. **7** unit **10** is of a so-called ring pontoon type in which four pontoons **14**, **16**, **18**, **20** are connected to one another so as to form a closed rectangle.

Moreover, the semisubmersible unit **10** illustrated in FIG. **7** comprises four outermost supporting columns (not shown in FIG. **7**, see instead FIG. **1**) **24**, **26**, **28**, **30**.

In an embodiment of the closed inclination change system **32**, the system **32** comprises four inclination change assemblies **34**, **36**, **38**, **40**, each one of the four inclination change assemblies **34**, **36**, **38**, **40** being associated with an individual one of the four outermost supporting column such that the tank assembly of the inclination change assembly is located at least partially in and/or beneath the supporting column. In FIG. **7**, each one of the inclination change assemblies **34**, **36**, **38**, **40** is located at an outer corner of the rectangular float **12**.

Generally, as regards the volume of the closed inclination change system **32**, the total volume of the tank assemblies of all the inclination change assemblies **34**, **36**, **38**, **40** of the closed inclination change system **32** may be less than 5%, preferably less than 2%, of the total volume displaced by the floating unit **10** when the floating unit **10** floats at an operational draught.

Finally, it should be recognized that structures and/or elements and/or method steps shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or embodiment as a general matter of design choice. For instance, although a semi-submersible unit has been used as an example of a floating unit in the description presented hereinabove, a closed inclination change system could also be used in another type of floating unit, such as an FPSO, a barge, a tension leg platform, a SPAR buoy, a ship or the like. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

The invention claimed is:

1. A closed inclination change system for a floating unit, comprising:

a plurality of inclination change assemblies, each one of said inclination change assemblies in fluid communication with each one of the other inclination change assemblies, each one of said inclination change assemblies comprising:

a tank assembly comprising a first tank having a fluid,

a tank assembly top portion of the first tank;

a pump assembly arranged to pump said fluid from said tank assembly, and

an inlet conduit assembly guiding said fluid into said tank assembly from another inclination change assembly, said inlet conduit assembly having a conduit top portion that is located above said tank assembly top portion

wherein the plurality of inclination change assemblies cooperate to change an inclination of the floating unit without transferring fluid to and from a water ambient to the floating unit.

2. The closed inclination change system according to claim **1**, wherein at least one of said inclination change assemblies comprises a first vent pipe assembly, said a first vent pipe assembly comprising an air inlet located at the upper portion of said tank assembly in fluid communication with the environment ambient of said closed inclination change system, said air outlet being located at a position above said conduit top portion.

3. The closed inclination change system according to claim **1**, wherein at least one of said inclination change assemblies comprises a second vent pipe assembly, said second vent pipe assembly comprising a second air inlet located at said conduit top portion, said second vent pipe assembly further comprising a second air outlet which is adapted to be in fluid communication with the environment ambient of said closed inclination change system said second air outlet being located above said conduit top portion.

4. The closed inclination change system according to claim **1**, wherein at least one of said inclination change assemblies comprises an inlet cut-off valve located in said tank inlet conduit assembly said inlet cut-off valve being located between said conduit top portion and said tank assembly.

5. The closed inclination change system according to claim **1**, wherein at least one of said inclination change assemblies comprises a pump assembly with a low side and a high side said at least one inclination change assembly further comprising a check valve located downstream said high side.

6. The closed inclination change system according to claim **5**, wherein at least one of said inclination change assemblies comprises a pump assembly cut-off valve located between said low side and said tank assembly.

7. The closed inclination change system according claim **1**, wherein at least one of said inclination change assemblies comprises a control valve adapted to control a fluid flow to and from said inclination change assembly.

8. The closed inclination change system according to claim **1**, wherein said tank assembly of at least a first tank assembly of said inclination change assemblies comprises a second tank, said second tank being located at least partially above said first tank.

9. The closed inclination change system according claim **1**, wherein said tank assembly of each one of said inclination change assemblies comprises a second tank said second tank being located at least partially above said first tank (**46**).

10. The closed inclination change system according to claim **8**, wherein said inlet conduit assembly is also adapted to guide said fluid into said second tank from another inclination change assembly.

11. The closed inclination change system according to claim **8**, wherein said first tank assembly is adapted to provide a fluid communication between said second tank and said first tank.

12. The closed inclination change system **923** according to claim **1**, wherein said first tank assembly is adapted to transfer fluid from said first tank to said second tank using said pump assembly.

13. The closed inclination change system according to claim **1**, wherein said closed inclination change system further comprises a feeding circuit adapted to be in fluid communication with each one of said inclination change assemblies.

14. The closed inclination change system according to claim **1**, wherein said pump assembly of at least one of said inclination change assemblies comprises a submersible pump.

15. The closed inclination change system according to claim **1**, further comprising a floating unit associated with the closed inclination change system.

16. The closed inclination change system according to claim **15**, wherein said floating unit comprises a ballast system separated from said plurality of inclination change assemblies.

17. The closed inclination change system according to claim **1**, further comprising a semi-submersible unit having four outermost supporting columns, said closed inclination change system comprising four inclination change assemblies, each one of said four inclination change assemblies being associated with an individual one of said four outermost supporting columns such that said tank assembly of said inclination change assembly is located at said supporting column.

18. The closed inclination change system according to claim **17**, wherein said semi-submersible unit comprises a ring pontoon.

19. The closed inclination change system according to claim **17**, wherein the total volume of the tank assemblies of all the inclination change assemblies of said closed inclination change system is less than 5% of the total volume displaced by the floating unit when the floating unit floats at an operational draught.

20. A method for imparting an inclination change to a floating unit using a closed inclination change system comprising a plurality of inclination change assemblies, each one of said inclination change assemblies in fluid communication with each one of the other inclination change assemblies, each one of said inclination change assemblies comprising: a tank assembly comprising a first tank and a tank assembly top portion; wherein each one of said inclination change assemblies further comprises: a pump assembly arranged to pump said fluid from said tank assembly, and an inlet conduit assembly guiding said fluid into said tank assembly from another inclination change assembly, said inlet conduit assembly having a conduit top portion that is located above said tank assembly top portion said method comprising:

providing a fluid communication from said pump assembly of a first of said inclination change assemblies to the tank assembly of a second of said inclination change assemblies and

operating said pump assembly to pump said fluid from the tank assembly of said first inclination change assembly to the tank assembly of said second inclination change assembly, wherein the plurality of inclination change assemblies cooperate to change an inclination of the floating unit without transferring fluid to and from a water ambient to the floating unit.

21. The method according to claim **20**, wherein said tank assembly of each one of said inclination change assemblies comprises a second tank, said second tank being located at least partially above said first tank, and comprising:

determining if it is possible to obtain said inclination change by transferring fluid between said first tanks only, and if it is possible, providing a fluid communication from said pump assembly of a first of said inclination change assemblies to said first tank of the tank assembly of a second of said inclination change assemblies;

operating said pump assembly such that fluid is pumped from the first tank of said tank assembly of said first inclination change assembly to said first tank of the tank assembly of said second inclination change assembly.

22. The method according to claim **21**, further comprising:

transferring fluid that is not needed in order to obtain the inclination change to said second tanks (**76**) prior to transferring fluid between said first tanks.

23. The method according to claim **21**, further comprising:

determining if it is possible to obtain said inclination change by transferring fluid between said second tanks only, and

if it is possible, providing a fluid communication from said pump assembly of a first of said inclination change assemblies to said second tank of the tank assembly of a second of said inclination change assemblies

operating said pump assembly such that fluid is pumped from the second tank of said tank assembly of said first inclination change assembly to said second tank of the tank assembly of said second inclination change assembly.

24. The method according to claim **23**, further comprising:

transferring fluid that is not needed in order to obtain the inclination change to said first tanks prior to transferring fluid between said second tanks.

25. The method according to claim **20**, further comprising:

providing a ballast system separate from the plurality of inclination change assemblies for the floating unit.

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