

A Floating Unit and a Method of Stabilizing the Floating Unit**Technical Field**

[0001] The present invention relates to a floating unit and a method of stabilizing the unit.

5 For example, the present invention relates to a floating unit for production and storage of hydrocarbons.

Background

[0002] Offshore marginal oil and gas fields present various challenges for operators. They
10 may have low reserves, uncertain reserves or low production volumes. These make fixed platforms or conventional Floating Production Storage Offtake (FPSO) developments commercially un-attractive. They may also be in deeper water or where seabed conditions make Jack-up or fixed piled platforms undesirable.

[0003] Currently FPSO units are used in the larger and more financially attractive field
15 developments. Almost all FPSO units are based on the conversion, or new build, of an oil tanker which is a 'ship shape' vessel that is designed to provide the most economic means of transporting oil. However, such oil tankers are not designed as a stationary unit moored on location for a number of years. As such, it is necessary to carry out substantial works to moor the oil tankers and it can be very costly, particularly if this involves expensive
20 systems, e.g. a turret and swivel system, that allow the oil tanker to be rotated now and then to maintain a heading into the wind/waves, i.e. to weathervane.

[0004] Further, the FPSO units include risers which are used for importing/exporting hydrocarbon fluids or gasses into and out of the FPSO units. The risers are generally not permitted to rotate. Therefore, to accommodate the risers, costly swivel systems within the
25 mooring turret have to be installed.

Summary

[0005] The invention is based on a realization that changes in the draft of a floating hull during loading and unloading of hydrocarbons provide an opportunity for controlled water
30 flow into and out of a compartment in the unit, without the use of pumps, and that the controlled inflow and outflow of water into the compartment provides an opportunity to optimize the stability of the floating unit.

[0006] The present invention provides a floating unit for producing and storing hydrocarbons that has a compartment and an opening that allows water flow into and out of the compartment. The unit is arranged to selectively control water flow into and out of the compartment and hence control the level of water in the compartment.

- 5 Advantageously, by allowing water flow into and out of the compartment and controlling that flow, the weight of the floating unit can be controlled and hence the draft of the floating unit (i.e. extent to which the floating unit is submerged in the water) can be controlled. That is, the depth at which the floating unit sits in the surrounding water can be controlled via the amount of water in the compartment. Because the draft of the
- 10 floating unit affects the stability (i.e. the heave, pitch and roll) of the floating unit in the water, controlling the draft of the floating unit enables the stability of the floating unit to be optimized.

[0007] The present invention provides a floating unit for producing and storing hydrocarbons the unit comprising:

- 15 a hull that in use floats in water;
at least one tank for storing hydrocarbons;
a compartment having an opening for water flow into and out of the compartment;
and
- a flow controller operable to open the opening to allow water to flow into or out of
- 20 the compartment and to close the opening, wherein the flow controller opens and closes the opening to control the level of water in the compartment to thereby control the stability of the unit in the water.

[0008] Typically, the unit does not include pumps or other devices to force water flow into and out of the plurality of compartments.

- 25 [0009] The compartment may be open to the atmosphere such that the pressure in the compartment is atmospheric pressure.

[0010] The flow controller may be biased towards closing the opening when the level of water in the compartment is higher than the level of water in which the hull floats.

[0011] The unit may comprise a plurality of compartments.

- 30 [0012] The unit may comprise at least three compartments.

[0013] One of the compartments may be located centrally within the hull and the other compartments may be located towards the perimeter of the hull.

[0014] The other compartments may be disposed equidistantly around the perimeter of the hull from each other.

[0015] One or more of the compartments may have a riser extending through the compartment for loading and/or offloading hydrocarbons from the unit.

- 5 [0016] The present invention provides a method of controlling the stability of a floating unit for producing and storing hydrocarbons, the floating unit having a hull that floats in water, the method comprising:

loading and unloading hydrocarbons into and out of at least one tank in the hull;

allowing water to flow into and out of a compartment in the hull through an

- 10 opening in the hull that is in fluid communication with the water in which the hull floats; and

controlling the amount of water in the compartment by selectively opening or closing the opening depending on the amount of hydrocarbons in the at least one tank and thereby controlling the stability of the unit in water.

- 15 [0017] The method may comprise opening the opening and thereby allowing water flow into the compartment and loading hydrocarbons into the at least one tank whereby the water level in the compartment increases as the loading continues and equalises with the level of the water in which the hull floats, with the water in the compartment contributing to the stability of the unit.

- 20 [0018] The method may further comprise closing the opening and thereby preventing water flow from the compartment when the hydrocarbon loading step has been completed.

[0019] The method may comprise offloading hydrocarbons stored in the at least one tank whereby the water level in the compartment becomes higher than the level of the water in which the hull floats, with the retained water in the compartment contributing to the

- 25 stability of the unit.

[0020] The method may further comprise at least partially re-filling the at least one tank with further hydrocarbons and opening the opening during the re-filling step and thereby enabling the water level in the compartment to equalize with the level of the water in which the hull floats.

- 30 [0021] The present invention provides a floating unit adapted for production and storage of hydrocarbons, the floating unit comprising a platform arranged on a top portion of the hull, and a plurality of compartments disposed within the hull, each compartment substantially extending from a bottom portion of the hull to the platform in a vertical

direction, and each compartment having at least one flow controller, for example a flow restrictor, a valve, or system of valves, to control the flow of water into or out of the compartment so as to control the level of water stored in the compartment, and wherein the platform includes a plurality of openings associated with the plurality of compartments, and wherein each flow controller is operable to open a respective opening to allow water to flow into or out of its respective compartment and to close the opening..

[0022] At least one of the plurality of compartments may be adapted to receive at least one riser therethrough, wherein at least one riser extends from outside the hull through the bottom portion and out of the at least one of the plurality of compartments through one of the openings in the platform.

[0023] Each compartment may include a circumferential wall extending from within the bottom portion of the hull to the platform such that the circumferential wall tapers outwardly away from the centre of the compartment as the circumferential wall extends from the platform to the bottom portion of the hull.

[0024] The circumferential wall may include at least one ballast tank adapted to contain ballast.

[0025] The platform may slope downwards towards the openings in the platform.

[0026] The hull may include a perimeter hull wall and a flat bottom.

[0027] The perimeter hull wall may include at least one ballast tank adapted to contain ballast.

[0028] The hull may include a horizontal cross-sectional area having a shape of a circle, an elliptical, a triangle a quadrilateral or any other shapes according to user requirements.

[0029] The hull may be a cylindrical shape or any other suitable shape according to user requirements.

[0030] The floating unit may further include a bilge keel protruding from the bottom portion of the hull, such that the bilge keel is submerged in the water when the floating unit is floating on water.

[0031] The bilge keel may surround the bottom portion of the hull.

[0032] The bilge keel may be filled with heavy ballast, i.e., concrete or other material heavier, typically substantially heavier, than water.

[0033] The floating unit may further include a bilge plate extending from the bilge keel.

[0034] The bilge plate may include a first portion extending outwardly from the bilge keel in a first direction and a second portion extending outwardly from the first portion in a second direction.

5 [0035] The bottom portion of the hull may include at least one ballast tank adapted to contain ballast.

[0036] The platform may be a deck of the floating unit.

[0037] The at least one corresponding flow controller may include a valve, a flow restrictor or any other suitable controlling means which may allow for control of water flow into and out of the compartments.

10 [0038] Typically, the unit does not include pumps or other devices to force water flow into and out of the plurality of compartments.

[0039] Each of the at least one corresponding flow controller may be simultaneously controlled so as to evenly control the level of water stored in each of the plurality of compartments.

15 [0040] As an alternative, each of the flow controller may also be separately controlled.

[0041] The present invention provides a method of stabilizing a floating unit adapted for production and storage of hydrocarbon fluids, the method comprising loading the floating unit with hydrocarbons; controlling the water flow into the compartment by opening an opening of the compartment to allow water to flow into or out of the compartment from
20 water surrounding the unit so that the level of water therein is the same as or below the water level surrounding the floating unit; and offloading hydrocarbon fluids from the floating unit.

[0042] The method may further include controlling the water flow out of the compartment so that the level of water therein is the same as or above the water level surrounding the
25 floating unit.

[0043] The floating unit of the present invention is a safe and stable unit that supports oil and gas production equipment and during adverse weather conditions does not exhibit such motions as to interfere with or shut down the production processes. At the same time, the floating unit may safely store an amount of processed hydrocarbon fluids until such
30 time as they can be offloaded to a collection tanker.

Brief Description of the Drawings

[0044] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments are described with reference to the following drawings, in which:

Fig. 1 is a sectional view of a floating unit according to various embodiments;

Fig. 2 is a top view of the floating unit of Fig. 1 according to various embodiments;

Fig. 3 is a sectional view of a floating unit with a plurality of ballast tanks

10 according to various embodiments;

Fig. 4 is a top view of the floating unit of Fig. 3 according to various embodiments;

Fig. 5A is a sectional view of a floating unit with a circumferential wall having a taper profile according to various embodiments;

Fig. 5B is a sectional view of a floating unit with a circumferential wall having a stepped profile according to various embodiments;

Fig. 6 is a close-up sectional view of a bilge keel of a floating unit according to various embodiments;

Fig. 7 is a flow diagram of a method of stabilizing a floating unit according to various embodiments;

Fig. 8 is a sectional view of a floating unit with a plurality of compartments according to various embodiments;

Fig. 9 is a top view of the floating unit of Fig. 8 according to various embodiments;

Fig. 10A and Fig. 10B are respective sectional views of a flow controller of a floating unit in an open unsealed position and a close sealed position according to various embodiments.

Detailed Description

[0045] The embodiments of the invention described below are by way of example only.

Furthermore, it will be understood that the embodiments described below may be

30 combined together. For example, a part of one embodiment may be combined with a part of another embodiment. Further, it is understood that the embodiments described below are not the only embodiments of the invention.

[0046] Fig. 1 shows a floating unit 100 adapted for production and storage of hydrocarbons on water. The floating unit 100 is intended for use at marginal oil and gas fields where the volume of hydrocarbons produced is relatively low. Accordingly the floating unit 100 has a relatively small hydrocarbon storage capacity of 100,000 –
5 300,000bbls.

[0047] The floating unit 100 includes a hull 110 having a bottom portion 112 that is submerged in water 10 and a top portion 116 positioned above the water 10 when the floating unit 100 is floating on the water 10. It is to be appreciated that size of the bottom portion 112 of the hull that is submerged in the water (i.e. the 'draft' of the unit) will
10 depend on the mass of the floating unit 100 and will change, for example, as hydrocarbons are loaded and unloaded from the floating unit 100. The hull 110 further includes a platform 114 arranged on the top portion 116 of the hull 110, and a compartment 130 centrally disposed within the hull 100. In addition, the hull 110 has a perimeter hull wall 118 which may extend from the top portion 116 to the bottom portion 112 and a flat
15 bottom 122 which is in contact with the water 10 when the floating unit 100 is submerged in the water 10.

[0048] The compartment 130 extends from a position within the bottom portion 112 of the hull 100 to the top portion 116 of the hull 100 in a vertical direction. The compartment 130 has an upper opening 136 in the top portion 116 of the hull so that atmospheric
20 pressure above the water in the compartment is ambient air pressure. The compartment 130 is open to the surrounding water 10 via a bottom opening 178 in the hull 110 of the floating unit 110 to thereby enable water to enter (and exit) the compartment 130. The compartment 130 thus acts as a selectively fillable ballast tank for the floating unit 100. The compartment 130 has a flow controller 132 disposed in the bottom opening 178 to
25 control the flow of water into or out of the compartment and hence the level of water 10 stored in the compartment 130.

[0049] Advantageously, by allowing water to flow into (and out of) the compartment 130 and controlling that flow, the weight of the floating unit 100 can be controlled and hence the draft of the floating unit 100 can be controlled. That is, the depth at which the floating
30 unit 100 sits in the surrounding water 10 can be controlled using the amount of water in the compartment 130. This control is achieved by selective operation of the flow controller 132 and by taking advantage of changing weight of the unit during loading and unloading of hydrocarbons into and from the unit 100. Because the draft of the floating

unit 100 affects the stability (i.e. the heave, pitch and roll) of the floating unit in the water, controlling the draft of the floating unit 100 enables the stability of the floating unit to be optimized.

[0050] Floating unit 100 includes a cargo tank 119 for storing the hydrocarbons that have been produced. The cargo tank 119 is arranged around the compartment 130 between the perimeter hull wall 118 and the compartment 130. The size of the cargo tank 119 and the size of the compartment 130 may vary and can be configured according to user design and operational requirements.

[0051] As the cargo tank 119 is filled with hydrocarbons the weight and draft of the floating unit 100 attributable to the hydrocarbons is increased. That is, the increase in the stored hydrocarbons on board the floating unit 100 will provide a downward bias on the floating unit 100 into the water. This bias provided by the weight of the hydrocarbons can be used to cause water to flow into the compartment through the bottom opening 178 as described above. With the bottom opening 178 open and the compartment 130 under atmospheric pressure due to the upper opening 136 of the compartment, as hydrocarbons fill the cargo tank 119 the floating unit 100 will sink, causing water to flow into the compartment so that water level in the compartment is substantially equivalent to the level of the surrounding water 10. During operation of the floating unit 100 the flow controller 132 can be opened and closed to control water flowing into or out of the compartment 130 depending on the amount of hydrocarbons in the cargo tank 119 and the level of the water in the compartment 130 relative to the level of the surrounding water. In this manner, the draft of the floating unit 100 can be controlled to optimize the stability of the floating unit without requiring the use of any pumps and their associated systems to pump water into and out of the compartment. Advantageously, this simplifies and reduces the cost of construction and operation of the floating unit 100, which as a result increases the economic feasibility of recovering hydrocarbons from marginal oil & gas fields using the floating unit.

[0052] In Fig. 1, the bottom section 134 or more specifically a base 124 of the compartment 130 is shown to be spaced from the bottom 122 of the hull 110. The distance between the base 124 of the compartment 130 and the bottom 122 of the hull 110 may be subject to user design and operational requirements. The base 124 of the compartment 130 is parallel to the bottom 122 of the hull 110. The cross-sectional dimension and shape of the compartment 130 may vary depending on user design and requirements.

[0053] In addition, the bottom 122 of the hull 110 is shown in Fig. 1 to be relatively flat. However, the hull 100 may also include a different shaped bottom 122, for example convex bottom, concave bottom or sloping, etc, depending on user design and operational requirements.

5 [0054] The flow controller 132 may include a flow restrictor or a valve or any other suitable flow control device. The flow restrictor may be of a conical shape such that when the level of the water 10 stored within the compartment 130 is higher than the level of the surrounding water 10 then the difference in the water pressure assists in the sealing of the flow restrictor or valve.

10 [0055] As an alternative, the base 124 of the compartment 130 may also be configured to extend across the whole of the bottom 122 of the hull 110 and the bottom opening 178 and hence the flow controller 132 may be positioned at any suitable location on the bottom 122 or at the perimeter hull wall 118 of the hull 110 (similar to Fig. 3 shown later). Any other positioning of the bottom opening and associated flow controller 132 may also be possible
15 depending on user design and operational requirements.

[0056] The floating unit 100 may include a deck 120 at the top portion 116 of the hull 110. In such embodiments, the opening 136 of the compartment 130 extends through the deck 120. In addition, the deck 120 may be adapted to support processing modules (not shown) thereon for processing hydrocarbons. Typically, the deck 120 is positioned at a minimum
20 of about 2 meters above the platform 114 to provide a safe distance for the process modules to operate and not be affected by any hydrocarbon gas emissions from the storage compartment 119. Typically the deck 120 is supported by up-stands or stools 135 built upon the top of the platform 114.

[0057] Fig. 2 shows a top view of the floating unit 100 of Fig. 1. As shown in Fig. 2, the
25 compartment 130 may be centrally disposed within the hull 110. It may be beneficial to position the compartment 130 at the centre of the hull 110 to provide uniform balance and vertical stability to the hull 110 when water is filled in the compartment 130. Positioning of the compartment 130 at an off-centre position or at any other position as indicated in Fig 9, can be used to give additional stability to the hull 110 in both vertical and rotational
30 planes. The amount of water contained in such off-centre compartments may be varied to provide a balancing (trim) effect to the hull 110. The bottom opening 178 and associated flow controller 132 are shown to be at the center of the base 124 of the compartment 130. However, the bottom opening 178 may also be positioned at any suitable position at the

base 124 of the compartment 130 or at any other suitable position (for example in the position as shown in Fig. 3).

[0058] Fig. 3 shows another embodiment of a floating unit 300. Similar to Fig. 1, the floating unit 300 includes a hull 310 having a top portion 316 and a bottom portion 312 positioned below the top portion 316. The hull 310 has a perimeter hull wall 318. The perimeter hull wall 318 extends from the top portion 316 to the bottom portion 312. The hull 300 also has a flat bottom or base 322. However, the hull 310 may also be configured to have a concave bottom or convex portion for example. The hull 310 is of a cylindrical shape. A cylindrical shape provides the floating unit 300 with uniform stability regardless of the direction of the waves or wind towards it. The hull 310 has a circular sectional shape as shown in Fig. 4. However, in other embodiments the hull may have a horizontal cross-sectional area having a shape of an ellipse, a triangle or a quadrilateral for example to suit the directionality of the waves or wind. The horizontal cross-sectional is considered to be the cross-section through the hull 310 which is substantially parallel to the deck 320 or surface of the water 10.

[0059] The floating unit 300 has a plurality of additional compartments 302 to the central compartment 330 for holding water including perimeter ballast tanks 328 disposed around the perimeter of the floating unit's hull 310 and circumferential ballast tanks 344 disposed around the central compartment 330.

[0060] The top portion 316 of the hull 310 includes the deck 320. The deck 320 is adapted to support processing modules (not shown) thereon.

[0061] The deck 320 is supported on stools 335 above the platform 314 of the floating unit 300. The platform 314 is positioned above the surface level of the water 10. Although in other embodiments, the platform 314 may be lower than the deck 320, the platform 314 would still be above the water 10, e.g. 4-5 meters above, to prevent waves from running onto the platform 314 or the deck 320. As such, the platform 314 may be within the top portion 316 of the hull 310. Platform 314 may slope downwards towards the upper opening 336 of the central compartment 330. Referring to Fig. 3, the platform 314 may have an outer perimeter edge 324 which is closer to the perimeter hull wall 318 and is higher than an inner edge 326 of the platform 314 that is closer to the opening 336. This enables liquid on the platform 314 to flow towards the opening 336 and into the compartment 330. Outer perimeter edge 324 may coincide with the perimeter hull wall 318 and inner edge 326 may coincide with an edge of the opening 336. By sloping the

platform 314 towards the opening 336, fluid, e.g. hydrocarbon fluid spillage, on the platform 314 or the deck 320 may flow towards the opening 336 and into the compartment 330. In this way, the fluid may be prevented from being discharged into the surrounding sea which would cause environmental issues.

5 [0062] The bottom portion 312 of the hull 310 is the portion of the hull 310 which is submerged in the water 10. As such, the size of the bottom portion 312 may vary with respect to the hull 310 depending on the level of submersion of the hull 310 in the water 10. The level of submersion of the hull 310 would be dependent on the amount of fluids stored in the floating unit 300, the weight of the processing modules positioned on the
10 deck 320 and the weight of the floating unit 300 itself.

[0063] The bottom or base 322 of the hull 310 may be a double walled base with a void therebetween. The perimeter ballast tank 328 extends circumferentially along the perimeter hull wall 318 of the hull 310. The perimeter ballast tank 328 may be one single tank or may include a plurality of tanks distributed equidistantly around the perimeter hull
15 wall 318. In one embodiment, the plurality of tanks may be provided in even numbers and arranged in opposed pairs. As such the perimeter tanks opposite each other can be filled concurrently so as to balance the floating unit 300 during the filling process. Ballast in the perimeter ballast tank 328 may be a liquid, such as water or sea water.

[0064] Perimeter hull wall 318 may include additional liquid ballast tanks (not shown in
20 Fig. 3) contained within the perimeter ballast tank 328. Liquid ballast tanks in such a location would provide impact protection for a cargo tank 319 housed within the hull 310 in the event of an impact on the hull 310. The perimeter hull wall 318 is, itself, double walled with a void therebetween to provide impact protection to the cargo tank 319.

[0065] The cargo tank 319 is configured for storing hydrocarbon fluids after processing.
25 The cargo tank 319 is disposed between the perimeter hull wall 318 and the compartment 330 of the floating unit 300 and between the deck 320 and the bottom portion 312 of the hull 310.

[0066] Referring to Fig. 3, the compartment 330 extends from somewhere within the bottom portion 312 of the hull 310 towards the platform 314. If the platform 314 is the
30 deck 320 of the floating unit 300, the compartment 330 extends from within the bottom portion 312 to the deck 320 of the floating unit 300. Compartment 330 may have a top section 338 above the bottom section 334. Top section 338 may be adjacent to the platform 314 such that the upper opening 336 of the compartment 330 is provided in the

top section 338 of the compartment 330. Compartment 330 may include the circumferential wall 340 extending from within the bottom portion 312 of the hull 310 to the platform 314. Circumferential wall 340 is of a cylindrical shape. Compartment 330 includes a flat base 342. The base 342 at the bottom section 334 of the compartment 330 is parallel to the bottom 322 of the hull 310.

[0067] As shown in Fig. 3, the circumferential wall 340 defines an inner wall of the circumferential ballast tank 344. The circumferential ballast tank 344 extends from somewhere in the bottom portion 312 of the hull 310 to the top portion 316 of the hull 310. The circumferential ballast tank 344 may be in the form of a single tank or a plurality of tanks distributed equidistantly around the circumferential wall 340. Ballast in the circumferential ballast tank 344 may be a liquid, such as water or sea water.

[0068] The perimeter ballast tanks 328 and the circumferential ballast tanks 344 within the respective perimeter hull wall 318 and the circumferential wall 340 provide further protection to the cargo tank 319 against impact. This tank arrangement also mitigates leakage of hydrocarbon into the surrounding sea in the event of damage to the cargo tank 319 that contains the hydrocarbons. Each of the the perimeter ballast tanks 328, and the circumferential ballast tanks 344 may be compartmentalized into a plurality of sub-tanks which may be formed into a series of radially spaced tanks.

[0069] The floating unit 300 further includes one or more risers 350 for channeling hydrocarbons to or from the floating unit 300 for processing or export respectively. The compartment 330 is adapted to receive the riser(s) 350 therethrough, such that the riser(s) 350 extend into the compartment 330 from outside the hull 310 through the base 342 of the compartment 330 or the flat bottom 322 of the hull 310 and extend out of the compartment 330 through the upper opening 336 in the platform 314. The compartment 330 thus forms what is known in the art as a 'moonpool'. The riser 350 is a pipeline that contains the incoming raw well fluids or the outgoing produced hydrocarbon fluids. In Fig. 3, only one riser 350 is shown but there may be a plurality of risers 350 within the compartment 330 of the floating unit 300. As mentioned, the riser 350 passes through the base 342 of the compartment 330. The base 342 has sealing mechanisms (not shown in Fig. 3) to prevent water from seeping into or out of the compartment 330 via the interface between the riser 350 and the base 342. Compartment 330 provides protection to the riser 350 wherein the riser 350 is contained safely within the compartment 330 and protected from any accidental impact damage. Riser 350 may be an import riser that conveys fluid

from the wells on the sea floor to the floating unit 300 and/or an export riser that conveys the produced oil from the floating unit 300 to a tanker or export pipeline.

[0070] The floating unit 300 also includes openings and associated flow controllers 332, for example flow restrictors or valves or other suitable devices, disposed in the openings
5 for controlling water flow into and from the compartment 330. Each of the flow controllers 332 may be adapted to allow flow of water 10 from the sea into the compartment 330 and out from the compartment 330 via the openings. Each of the flow controllers 332 may be disposed along the perimeter hull wall 318 of the hull 310. An example of the flow controller 332 is as shown in Fig. 3 but any other suitable flow
10 controller 332 may also be used as long as the flow controller 332 allow control of the flow of water 10 into and out of the compartment 330 via the associated openings.

[0071] As the floating unit 300 is being loaded with hydrocarbons in the cargo tank 319 for the first time after being towed to a hydrocarbon field and operationally connected to the field, the floating unit 300 will sink further into the water 10 due to the weight of the
15 hydrocarbons. One or more of the flow controller 332 is opened during or after this filling step to allow water 10 into the compartment 330. The compartment 330 may be filled up to the level of the sea water 10 – depending on operational requirements. As the water 10 fills up the compartment 330, the floating unit 300 will sink further into the water 10. When the floating unit 300 is filled by the water 10 and hydrocarbons, the floating unit
20 300 will submerge further into the water 10 and the unit 300 is stabilised as a consequence. As such, the distance between the level of water 10 from the bottom 322 of the hull 310 (i.e. the draft) will increase. Accordingly, the bottom portion 312 of the floating unit 300 will gradually become larger. Bottom portion 312 may become as large as or larger than the top portion 316 of the floating unit 300. As the floating unit 300 is filled with the water
25 10 and hydrocarbons, the floating unit 300 is further stabilized and the pitch, roll and heaving of the floating unit 300 will be reduced. When the hydrocarbon loading is completed, the flow controller 332 is closed to retain the water 10 within the compartment 330. Each of the flow controllers 332 are designed to open and close at various times throughout the loading and offloading of the hydrocarbons to control the flow of water 10
30 in or out of the compartment 330.

[0072] When hydrocarbons are being offloaded from the floating unit 300, the body of water 10 within the compartment 330 is retained in the compartment 330 by maintaining the flow controllers 332 in a closed position, with this weight of water providing

additional ballast effect to the floating unit 300 which provides greater stability to the floating unit 300 than would otherwise be the case if the water was not retained in the compartment 330.

[0073] It can be appreciated that during the offloading step the overall weight of the floating unit 300 decreases, notwithstanding the retained water in the compartment 330, and this results in the draft of the unit 300 decreasing, i.e. the unit floating to be higher in the water. It can also be appreciated that this lifting movement, with the flow controllers 334 closed, results in the water level in the compartment 330 being higher than the water level outside the unit 300. This difference in water levels means that water will flow from the compartment 330 when the flow controllers 334 are opened, whereby the water levels will equalise.

[0074] When further hydrocarbons are loaded into the cargo tank 319, the floating unit 300 will again sink further into the water 10 due to the weight of the hydrocarbons. As this loading step progresses the flow controllers 334 may be opened to allow water to flow from the compartment 330 until the water level equalises with the water level outside the unit 300. This step allows an operator to selectively control the draft of the unit 300 during the loading process. When the loading process is completed, the flow controllers 334 are closed, and the sequence described above is repeated as unloading and loading of the floating unit 300 continues. This sequence is described further in relation to Fig. 7.

[0075] Referring to Fig. 3, floating unit 300 includes a bilge keel 360 protruding from the side of the bottom portion 312 of the hull 310, such that the bilge keel 360 is submerged in the water 10 when the floating unit 300 is floating on the water 10.

[0076] The bilge keel 360 surrounds a part of the bottom portion 312 of the hull 310. Bilge keel 360 is disposed at the bottom portion 312 of the hull 310 so as to create maximum torque from the centre of gravity of the floating unit 300 to counter the rolling and pitching of the floating unit 300. Bilge keel 360 is disposed around the perimeter hull wall 318. The bilge keel 360 is a continuous annular structure, e.g. an annular ring that surrounds the hull 310 so as to provide greater stability against rolling and pitching of the floating unit 300. However, in other embodiments, the bilge keel 360 comprises a plurality of protrusions extending from the bottom portion 312 of the hull 310. The plurality of protrusions deployed on the floating unit 300 may be in even numbers such that a pair of protrusions is disposed opposite each other across the hull 310 along the perimeter hull wall 318 so as to provide balance to the floating unit 300.

[0077] The bilge keel 360 is filled with heavy ballast, e.g. concrete, other heavy ballast material or a substance that has a higher density than water 10, such that filling the bilge keel 360 with ballast 361 (as shown in Fig. 6) provides the floating unit 300 with better stability.

5 [0078] Fig. 4 shows a top view of the floating unit 300. As shown, the cargo tank 319 is disposed between the perimeter hull wall 318 and the circumferential wall 340.

[0079] Fig. 5A shows a sectional view of a floating unit 300 according with a circumferential wall 340 having a taper profile and Fig. 5B shows a sectional view of a floating unit 300 with a circumferential wall 340 having a stepped profile.

10 [0080] Referring to Fig. 5A, the compartment 330 in the illustrated embodiment has a larger cross-sectional area in the bottom portion 312 when compared to the part of the compartment 330 in the top portion 316 of the hull 310. The circumferential wall 340 tapers outwardly away from the centre of the compartment 330 as the circumferential wall 340 extends from the platform 314 towards the bottom portion 312 of the hull 310. The
15 circumferential wall 340 is of a frusto-conical shape.

[0081] Referring to Fig. 5B, the circumferential wall 340 in the illustrated embodiment is a stepped profile as the circumferential wall 340 extends outwardly from the platform 314 towards the bottom portion 312. Circumferential wall 340 extends from the bottom 322 of the hull 310 to the deck 320. When the compartment 330 is filled, the compartment 330
20 having the stepped profile wall when filled with water provides a lower centre of gravity for an equivalent volume of water in the tapered compartment of Fig. 5A and therefore provides a more stable floating unit 300.

[0082] In Fig. 5A and Fig. 5B, the slopped circumferential wall 340 or the stepped circumferential wall 340 are designed, as necessary, to lower the centre of gravity (C of G)
25 of the contained seawater, thereby maximizing the ballast effects.

[0083] Fig. 6 provides a close up sectional view of the bilge keel 360 of the floating unit 300 of Fig. 3. As shown in the sectional view of the bilge keel 360 in Fig. 6, the bilge keel 360 has a top surface 362, a bottom surface 364 opposite the top surface 362 and an outer side 366 extending from the top surface 362 to the bottom surface 364 and spaced from
30 the perimeter hull wall 318. The outer side 366 terminates at one end of each of the top surface 362 and bottom surface 364 respectively. The top surface 362 is sloped away from the perimeter hull wall 318 and the bottom surface 364 is flush with the flat bottom 322 of the hull 310. The bilge keel 360 may also extend in other directions, e.g. outwardly and

downwardly or upwardly, from the perimeter hull wall 318. In other embodiments, the bilge keel 360 is a weight attached to the hull 310.

[0084] As also shown in Fig. 6 the floating unit 300 further includes a bilge plate 370 extending outwardly from the bilge keel 360 (the bilge plate is not illustrated in Fig. 3).

5 The bilge plate 370 extends along the outer side 366 of the bilge keel 360. Bilge plate 370 includes a first portion 372 extending outwardly from the bilge keel 360 in a first direction and a second portion 374 extending outwardly from the first portion 372 in a second direction. Where the bilge keel 360 is a plurality of protrusions, the bilge plate 370 comprises a plurality of plates, each of the plurality of plates extending outwardly from
10 each of the bilge keel 360. The first direction in which the first portion 372 of the bilge plate extends is along or out of the plane of the top surface 362 of the bilge keel 360. The second direction in which the second portion 374 of the bilge plate extends is at an angle to the first direction. Accordingly, as shown in Fig. 6, the top surface 362 of the bilge keel 360 and first portion 372 of the bilge plate 370 forms a V-shaped channel around the
15 perimeter hull wall 318 of the floating unit 300. Further, the first portion 372 and the second portion 374 forms an inverted V-shaped ridge around the perimeter hull wall 318. Bilge plate 370 may provide resistance to the waves so as to create a dampening function during the pitch, roll and heaving motions of the floating unit 300.

[0085] Floating unit 300 also includes a sub plate 376 extending outwardly from the bilge
20 keel 360. Sub plate 376 extends radially from the outer side 366 near the bottom surface 364 of the bilge keel 360. The sub plate 376 extends in a direction which diverges from the bilge plate 370 or at least from the first portion 372 of the bilge plate.

[0086] As a summary, the function of the perimeter ballast tanks 328, the circumferential ballast tanks 344, the bilge keel 360, the bilge plate 370 and the compartment 330 is to,
25 jointly or individually, stabilize the floating unit 300 and minimize the heaving, pitching and rolling motions of the floating unit 300 in particular under adverse weather conditions.

[0087] Fig. 7 is a flow diagram 1000 illustrating an embodiment, although not the only, embodiment of a method of stabilizing the floating unit 100, 300 adapted for production and storage of hydrocarbon. Initially, all of the compartments will be closed for load out
30 and transportation to minimise the 'float away' draft (1001). Upon arrival at an offshore location the openings to the compartments will be opened and the ballast tanks 328, 344 will be flooded (1002). The floating unit will be anchored on location at this installation draft. After completing the tie in of the risers and other commissioning activities,

hydrocarbon production operations begin. After the production of hydrocarbons to the maximum storage capacity of the floating unit's cargo tanks 119, 319, the floating unit will be at its maximum draft (1003). At this point, the flow controllers 132, 332, will be closed, immediately prior to offloading operations (1004). The hydrocarbons are then exported and the floating unit with the retained water in the compartments will rise to a minimum operational draft (1005).

[0088] Further hydrocarbons are then produced (1006). When the cargo tanks are partially refilled (for example to 60 – 80% capacity) with the further hydrocarbons, the flow controllers are then opened (1007). The floating unit will rise slightly in the water as the water level in the compartments equalize with the surrounding water level. The remaining capacity of the cargo tanks is then filled with further hydrocarbons taking the floating unit back to its maximum draft (1008). At this point the flow controllers are closed again, immediately prior to offloading (1004). This operating cycle continues throughout the field production period (i.e. steps 1004 - 1008). During this operating cycle, the water level in the compartments is preferably kept above the level of hydrocarbons in the cargo tank 119, 319 so that stability and draft of the floating unit can be maximized.

[0089] Fig. 8 shows a sectional view of a floating unit 500 according to another embodiment. The floating unit 500 in Fig. 8 is similar to the floating unit 300 in Fig. 3 with the differences being that the floating unit 500 in Fig. 8 includes a plurality of compartments 530 in the form of moonpools disposed within the hull 510. The floating unit 500 of Fig. 8 is operated in the same manner as described with respect to floating units 100, 300 and illustrated in Fig. 7.

[0090] The plurality of compartments comprises a central compartment and perimeter compartments equidistantly spaced around the central compartment and located towards the perimeter of the floating unit's hull 510. Each of the compartments 530 are fluidly connected to an opening 578 to the surrounding water 10 to enable water to flow into and out of each of the compartments. An associated flow controller 532 is provided in each opening 578 to enable control of the flow of water into and out of the each of the compartments. Each of the compartments 530 also has an upper opening 536 through the top portion of the hull 516 so that the atmospheric pressure above the water in each compartment is ambient air pressure.

[0091] Each of the flow controllers 532 are simultaneously operable so as to evenly control the level of water 10 stored in each of the plurality of compartments 530. However,

each of the flow controllers 532 are independently operable to respectively control the level of water 10 stored in each of the plurality of compartments 530. In Fig. 8, the compartments 530 are shown to be separated from each other but in an alternative embodiment, the compartments 530 may also be in fluid communication with each other such that the water level in the compartments 530 can be equalized and in some embodiments be controlled by a single flow controller 532.

[0092] In addition to the plurality of compartments, the floating unit 500 also comprises a perimeter hull wall 518 that incorporates at least one ballast tank 528 adapted to contain ballast. The ballast tanks 528 each extend circumferentially along the perimeter hull wall 518 of the hull 510 between adjacent compartments 530 which disposed around the perimeter of the hull. Each of the ballast tanks 528 may comprise a single tank or a plurality of tanks distributed along the perimeter hull wall 518. The plurality of ballast tanks 528 may be spaced equally, or in any other suitable arrangement.

[0093] A circumferential ballast tank 544 is also provided around the central compartment 530. The circumferential wall 540 of the central compartment 530 defines an inner wall of the circumferential ballast tank. Ballast in the ballast tanks 528 and the circumferential ballast tanks 544 may be a liquid, such as water or sea water.

[0094] Each of the plurality of compartments 530 located at the perimeter hull wall 518 may be separated from the compartment 530 located at the center of the hull 510 by one or more intermediate compartments 576 that are kept as an empty void or are configured to be filled with liquid and thus act as ballast tanks.

[0095] In Fig. 8, only one riser 550 is shown in the compartment 530 located at the centre of the floating unit 500. However, depending on requirements, there may be more than one riser 550 in the compartment 530 which is positioned at the center of the hull 510 or there may be one or more risers 550 located in one or more of the other compartments 530.

[0096] Fig. 9 shows a top view of the floating unit 500 in Fig. 8. As shown in Fig. 9, there are four compartments 530. However, the number of compartments 530 may vary and may be dependent on the user requirements. The arrangement of the compartments 530 may also vary according to design and user requirements. Further, each of the compartments 530 is shown to be substantially cylindrical and equally sized in cross-section. However, the cross-sectional shape and dimension of the compartments 530 may vary according to user requirements.

[0097] The line X-X in Fig. 9 shows the direction in which the cross-sectional view of the floating unit 500 in Fig. 8 has been taken from.

[0098] Fig. 10A and FIG. 10B show respective sectional views of a flow controller 732 of the floating unit 700 in an open position and a closed position respectively.

5 [0099] The flow controller 732 is shaped to correspond with the shape of a channel 776 formed within the perimeter hull wall 718 (or it may also be the bottom of the hull). The direction in which the flow controller 732 is lowered into the channel 776 is as shown by the direction of "F" into the channel 776. In Fig. 10A and Fig. 10B, the flow controller 732 is shown to be trapezoidal or a frustum of a cone but any other suitable shapes may
10 also be utilized as long as a portion of the flow controller 732 is adapted to close off the opening 778 to prevent any water flow when the flow controller 732 is in a close position as shown in Fig. 10B. Also, the water flow through the opening 778 can be controlled by the extent and speed in which the flow controller 732 is lowered into the channel 776. Further, the nearer the flow controller 732 is positioned to the opening 778, the lower the
15 volumetric flow rate of water through the opening 778. Therefore, there is a higher resistance of water flow when the flow controller 732 is positioned closer to the opening 778, thereby providing a damping effect for the water flow.

[00100] The channel 776 may be sized such that the flow controller 732 fits snugly within the channel 776 when the flow controller 732 is activated (or lowered towards the
20 opening 778) to close the opening 778. Alternatively, the channel 776 may be sized such that there is still some allowance on either one side or both sides of the flow controller 732 when the flow controller 732 is activated to close the opening 778. The size and shape of the channel 776 may vary depending on design and user requirements.

[00101] Also, each of the flow controllers 732 may be activated or controlled
25 individually or simultaneously by a control means positioned on the floating unit 700 or positioned at a location remote from the floating unit 700. Simultaneous control of all the flow controllers 732 will ensure an even control of the amount and level of water 10 stored in each compartment.

[00102] The flow controller 732 is provided with a conical shape such that the water
30 pressure on the broader side of the flow controller 732 is higher than that on the narrower side, thereby enabling the flow controller 732 to be biased towards its closed arrangement when water is required to be held or contained within the compartment. A spring may also be provided to bias the flow controller 732 towards its closed arrangement.

[00103] According to various embodiments, a single compartment 130, 330, 530 is typically located in the centre of the floating unit 100, 300, 500, but where a plurality of compartments 130, 330, 530 are used, at least some of these compartments 130, 33, 530 are located in forward, aft, port, or starboard positions of the floating unit 100, 300, 500.

5 [00104] According to various embodiments, the flow controller 132, 332, 532 in the respective compartments 130, 330, 530 are closed when the cargo tanks 119, 319, are full such that when the cargo is offloaded, a more stable draft can be achieved. During the continued production and filling of the cargo tanks 119, 319, the flow controller or valves 132, 332, 532 can be progressively opened to optimise stability and draft.

10 [00105] According to various embodiments, there may be more than one opening and associated flow controller 132, 332, 532 within each compartment 130, 330, and 530. The number of openings and associated flow controllers 132, 332, 532 is dependent on user design and requirements.

[00106] According to various embodiments, the floating unit is dimensioned subject
15 to user design and operational requirements but in general terms is proportioned such that the minimum plan dimension is not greater than twice the depth of the floating unit and the maximum plan dimension is not greater than 4 times the depth of the floating unit. The anticipated diameter range is from about 40 to 60m with depths of about 20 to 30m.

[00107] The floating unit is a safe and stable unit that supports oil and gas
20 production equipment and during adverse weather conditions does not exhibit such motions as to interfere with or shut down the production processes. At the same time, the floating unit may safely store an amount of processed hydrocarbon fluids until such time as they can be offloaded to a collection tanker.

[00108] The floating unit is suitable particularly, although not exclusively, for
25 smaller and more challenging marginal fields. Consequently, the floating unit has a smaller storage capacity than a conventional FPSO unit. The floating unit is specifically designed with a lower centre of gravity (due to the heavy ballast filled bilge keel) and exhibits more regular/uniform motion characteristics, when compared to the oil tanker type of FPSO unit, as the floating unit does not have a long slender ship shape. For
30 example, if the storm wave heights are generally the same from all directions, then the circular shaped floating unit has a more uniform stability profile than a conventional the oil tanker.

[00109] As the floating unit does not need to weathervane, it is not necessary to install expensive mooring/swivel system. Therefore, the floating unit is considerably cheaper than a conventional FPSO unit and is more financially viable for the smaller marginal offshore oil and gas fields.

5 [00110] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

[00111] The scope of the invention is indicated by the appended claims and all
10 changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

Claims

1. A floating unit for producing and storing hydrocarbons the unit comprising:
a hull that in use floats in water;
at least one tank for storing hydrocarbons;
5 a compartment having an opening for water flow into and out of the compartment;
and
a flow controller operable to open the opening to allow water to flow into or out of
the compartment and to close the opening, wherein the flow controller opens and closes
the opening to control the level of water in the compartment to thereby control the stability
10 of the unit in the water.
2. The unit defined in claim 1 wherein the compartment may be open to the
atmosphere such that the pressure in the compartment is atmospheric pressure.
3. The unit defined in claim 1 or claim 2 wherein the flow controller is biased
towards closing the opening when the level of water in the compartment is higher than the
15 level of water in which the hull floats.
4. The unit defined in any one of the preceding claims comprises a plurality of
compartments.
5. The unit defined in claim 4 comprises at least three compartments.
6. The unit defined in claim 5 wherein one of the compartments is located centrally
20 within the hull and the other compartments may be located towards the perimeter of the
hull.
7. The unit defined in claim 6 wherein the other compartments are disposed
equidistantly around the perimeter of the hull from each other.
8. The unit defined in any one of the preceding claims wherein one or more of the
25 compartments comprises a riser extending through the compartment for loading and/or
offloading hydrocarbons from the unit.
9. A method of controlling the stability of a floating unit for producing and storing
hydrocarbons, the floating unit having a hull that floats in water, the method comprising:
loading and unloading hydrocarbons into and out of at least one tank in the hull;
30 allowing water to flow into and out of a compartment in the hull through an
opening in the hull that is in fluid communication with the water in which the hull floats;
and

controlling the amount of water in the compartment by selectively opening or closing the opening depending on the amount of hydrocarbons in the at least one tank and thereby controlling the stability of the unit in water.

10. The method defined in claim 9 comprises opening the opening and thereby
5 allowing water flow into the compartment and loading hydrocarbons into the at least one tank whereby the water level in the compartment increases as the loading continues and equalises with the level of the water in which the hull floats, with the water in the compartment contributing to the stability of the unit.

11. The method defined in claim 10 further comprises closing the opening and thereby
10 preventing water flow from the compartment when the hydrocarbon loading step has been completed.

12. The method defined in claim 11 comprises offloading hydrocarbons stored in the at least one tank whereby the water level in the compartment becomes higher than the level of the water in which the hull floats, with the retained water in the compartment
15 contributing to the stability of the unit.

13. The method defined in claim 12 comprises at least partially re-filling the at least one tank with further hydrocarbons and opening the opening during the re-filling step and thereby enabling the water level in the compartment to equalize with the level of the water in which the hull floats.

20 14. A floating unit adapted for production and storage of hydrocarbons, the floating unit comprising a platform arranged on a top portion of the hull, and a plurality of compartments disposed within the hull, each compartment extending from a bottom portion of the hull to the platform in a vertical direction, and each compartment having at least one flow controller, for example a flow restrictor, a valve, or system of valves, to
25 control the flow of water into or out of the compartment so as to control the level of water stored in the compartment, and wherein the platform includes a plurality of openings associated with the plurality of compartments, and wherein each flow controller is operable to open a respective opening to allow water to flow into or out of its respective compartment and to close the opening.

30 15. The unit defined in claim 14 wherein at least one of the plurality of compartments is adapted to receive at least one riser therethrough, wherein at least one riser extends from outside the hull through the bottom portion and out of the at least one of the plurality of compartments through one of the openings in the platform.

16. The unit defined in claim 14 or claim 15 wherein each compartment comprises a circumferential wall extending from within the bottom portion of the hull to the platform such that the circumferential wall tapers outwardly away from the centre of the compartment as the circumferential wall extends from the platform to the bottom portion of the hull.
17. The unit defined in claim 16 wherein the circumferential wall comprises at least one ballast tank adapted to contain ballast.
18. The unit defined in any one of claims 14 to 17 wherein the platform may slope downwards towards the openings in the platform.
19. The unit defined in any one of claims 14 to 18 comprises a perimeter hull wall and a flat bottom.
20. The unit defined in claim 19 wherein the perimeter hull wall includes at least one ballast tank adapted to contain ballast.
21. The unit defined in any one of claims 14 to 20 wherein the hull comprises a horizontal cross-sectional area having a shape of a circle, an elliptical, a triangle a quadrilateral or any other shapes according to user requirements.
22. The unit defined in any one of claims 14 to 21 comprising a bilge keel protruding from the bottom portion of the hull, such that the bilge keel is submerged in the water when the floating unit is floating on water.
23. The unit defined in claim 22 wherein the bilge keel surrounds the bottom portion of the hull.
24. The unit defined in claim 22 or claim 23 wherein the bilge keel is filled with heavy ballast, i.e. concrete or other material heavier, typically substantially heavier, than water.
25. The unit defined in any one of claims 22 to 24 comprises a bilge plate extending from the bilge keel.
26. The unit defined in claim 25 wherein the bilge plate comprises a first portion extending outwardly from the bilge keel in a first direction and a second portion extending outwardly from the first portion in a second direction.
27. The unit defined in any one of claims 14 to 26 wherein the bottom portion of the hull comprises at least one ballast tank adapted to contain ballast.
28. The unit defined in any one of claims 14 to 27 wherein the at least one corresponding flow controller comprises a valve, a flow restrictor or any other suitable

controlling means which may allow for control of water flow into and out of the compartments.

29. A method of stabilizing a floating unit adapted for production and storage of hydrocarbon fluids, the method comprising loading the floating unit with hydrocarbons;
- 5 controlling the water flow into the compartment by opening an opening of the compartment to allow water to flow into or out of the compartment from water surrounding the unit so that the level of water therein is the same as or below the water level surrounding the floating unit; and offloading hydrocarbon fluids from the floating unit.
- 10 30. The method defined in claim 29 comprises controlling the water flow out of the compartment so that the level of water therein is the same as or above the water level surrounding the floating unit.