A sub-sea well intervention vessel includes a dynamically positionable tanker and direct well intervention equipment mounted on the tanker deck. The intervention equipment includes drilling equipment for performing underbalanced drilling and hydrocarbon liquid separation. A separate production riser is provided so that simultaneous drilling and production can be performed via separate risers. The driller riser is selectively disconnectable from the well so that the tanker can be dynamically repositioned over the well. A turret mooring system is provided such that the production riser can remain in operation during repositioning about the turret. The hydrocarbon liquid separator is connected to a separator of the production plant.
ABSTRACT

A sub-sea well intervention vessel includes a dynamically positionable tanker and direct well intervention equipment mounted on the tanker deck. The intervention equipment includes drilling equipment for performing underbalanced drilling and hydrocarbon liquid separation. A separate production riser is provided so that simultaneous drilling and production can be performed via separate risers. The driller riser is selectively disconnectable from the well so that the tanker can be dynamically repositioned over the well. A turret mooring system is provided such that the production riser can remain in operation during repositioning about the turret. The hydrocarbon liquid separator is connected to a separator of the production plant.
SUB-SEA WELL INTERVENTION VESSEL AND METHOD

The present invention relates to a sub-sea well intervention vessel and methods used by such a vessel for drilling and production.

The drilling of hydrocarbon production wells by "underbalanced" drilling is known. The technique involves ensuring that the hydrostatic pressure of the drilling fluid column at the well bore is less than the formation pressure so that formation fluid is encouraged to flow up the well bore. The pressure may naturally be less than the formation pressure or can be induced by adding natural gas, nitrogen or air. Underbalanced drilling avoids the invasion of drilling mud filtrate and solids into the formation and thus tends to increase the productivity of the well. It has proved particularly suitable for recovery from depleted fields and thus extends the life of such a field.

Our US Patent No. 6,840,322 describes a sub-sea well intervention vessel that uses underbalanced non-rotating drilling on existing sub-sea oil or gas wells. The vessel is in the form of a tanker that can be dynamically positioned over a well riser and coupled thereto. The multi-phase mixture recovered by underbalanced drilling is separated on the tanker and the separated hydrocarbon liquids are stored on the tanker. This represented a breakthrough in offshore drilling as it enabled the tanker cargo holds to be used to store the oil produced during underbalanced drilling. Previous offshore systems were not able to perform underbalanced coil tubing drilling and separate shuttle tankers were required in the event of simultaneous drilling and production.

The object of the present invention is to provide for an improved, more versatile, sub-sea well intervention vessel and associated drilling methods.

According to a first aspect of the present invention there is provided a sub-sea well intervention vessel comprising a dynamically positionable tanker and direct well intervention equipment mounted on the deck of the tanker, the direct well intervention equipment
including drilling equipment for underbalanced rotating or non-rotating drilling for connection to a drilling riser and a hydrocarbon liquid separator coupled to storage tanks of the tanker such that separated hydrocarbon liquids can be stored in the tanker, wherein there is provided production plant and a coupling arrangement for coupling the plant to at least one production riser that is separate from the drilling riser, the production riser being for connection to a sub-sea manifold associated with the well, thereby allowing simultaneous underbalanced drilling and production via separate risers, the drilling equipment being selectively disconnectable from the drilling riser to allow production only via the production riser.

One of the significant advantages of the present invention lies in the ability of the vessel to perform underbalanced drilling simultaneously with separate production operations from the same field by virtue of a production riser being connected to the sub-sea well, common manifold or similar, and the fact that operations can be selectively determined between this mode of simultaneous drilling and production via separate risers and a second stand-by drilling mode where only production is performed via the separate production riser.

The production plant may comprise a production hydrocarbon separator spaced from the hydrocarbon separator of the drilling equipment, the production hydrocarbon separator being configured to separate hydrocarbon fluids from matter received from the production riser. The drilling equipment separator may have an outlet for separated hydrocarbon liquids, the outlet being coupled to the production plant and, optionally, to the production separator.

The production separator is coupled to storage tanks of the tanker such that processed hydrocarbon fluids can be stored on the tanker.

A turret mooring system may be provided that allows the vessel to rotate about the vertical axis of the turret. When the vessel is to be used for simultaneous drilling and production operations using the separate risers, it can be dynamically positioned to hold it in
the correct position over the well of interest whereas in the stand-by mode the drilling riser is disconnected from the sub-sea wellhead and the vessel can freely “weathervane” about the mooring turret. The movement of the vessel allows it to access wellheads disposed in an arc, the position of the arc being governed by distance between a moonpool of the vessel and the vertical axis of the turret. In the stand-by mode, the vessel can remain connected to production riser despite being able to weathervane because the riser is connected to the centre of rotation located at turret.

The vessel is preferably fitted with thrusters by which it may be dynamically positioned.

In simultaneous operation mode the thrusters maintain a “non-weathervane” position for the tanker. The vessel is moved to reposition the drilling moonpool over a sub-sea wellhead. The thrusters maintain it there and enable drilling operations to be conducted. The ability to dynamically position the vessel “off the weathervane” allows it to access multi-well locations within the arc of a vessel about the rotational centre of the turret mooring.

The drilling equipment is located adjacent to a moonpool through which the drilling riser passes. The vessel has an underbalanced drilling separator and a production separator associated with the production riser, the underbalanced drilling separator has an outlet for separated hydrocarbon liquids that is connected to the production process plant. Thus excess hydrocarbons from the underbalanced drilling separation are fed to the production process plant and in particular to a production plant separator.

There may be two options for rotary underbalanced drilling. The first option may comprise a rotating control device (RCD) disposed at or near the surface under the moonpool of the vessel. In this option the drilling riser is de-coupled from the vessel and is therefore not subjected to S-bending loading. Mud and fluid return lines are connected between the riser at a position below the RCD to the underbalanced drilling separator package on the vessel.
In an alternative configuration, an RCD is disposed sub-sea at a Blow Out Preventer (BOP) disposed over the well. In this option there is provided a return flow line that is external to the drilling riser so that mud/fluid returns not up the riser but is diverted from under the RCD to the external flow line to the separator.

According to a second aspect of the present invention there is provided a method for conducting offshore underbalanced drilling, whereby a dynamically positionable tanker having direct well intervention equipment mounted on its deck including underbalanced drilling equipment is dynamically positioned over a well, the drilling equipment is coupled to a drilling riser from said well in order to intervene in said well, a separate production riser is coupled to said vessel from a sub-sea manifold associated with said well and underbalanced drilling is performed simultaneously with production via the separate production riser.

The drilling riser may be selectively disconnectable from the well to allow production only via the production riser. A production plant may be provided on the vessel for separating hydrocarbon fluids from the matter delivered from the production riser. The hydrocarbon liquids may be separated from the mixture delivered from the underbalanced drilling operation and then transferred to the production plant associated with the production riser, and maybe to a production separator of the production plant.

The tanker may be moored via a mooring turret such that the tanker is able to rotate around a vertical axis of the turret. The drilling riser may be may be disconnected from the well and then the vessel dynamically positioned by rotation around the turret such that a moonpool of the vessel is positioned over a selected wellhead and then the drilling riser may be reconnected.

When performing underbalanced drilling the tanker may be dynamically positioned the tanker to hold its geo-position stationary over the well.
Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic side view of a floating vessel incorporating a drilling riser and a production riser (shown connected) in accordance with the present invention;

Figure 2 is a schematic plan view of the vessel of figure 1;

Figure 3 is a schematic side view of the vessel of figure 1 and 2 shown with the drilling riser disconnected;

Figure 4 is a schematic plan view of the vessel of figure 3 illustrating how it is free to weathervane about a turret mooring;

Figure 5 is a schematic side view of the vessel of figures 1 to 5, shown with rotary underbalanced drilling equipment having a rotating control device at or near the surface of the sea;

Figure 6 is a schematic side view of the vessel of figures 1 to 5, shown with rotary underbalanced drilling equipment having a rotating control device disposed sub-sea; and

Figure 7 is a block diagram illustrating the operation of the vessel of figures 1 to 6.

Referring now to the drawings, figures 1 and 2 illustrate a shuttle tanker 10 having an internal mooring turret 11 located towards the bow 12 of the vessel. The vessel may be purpose built or could be a converted tanker such as a “Suezmax” type. The turret is rotationally disposed in relation to the rest of the vessel and is anchored to the sea bed by a plurality of mooring cables 13 such as anchor chains. The mooring arrangement enables the vessel to rotate about a vertical axis of the mooring turret 11. The mooring cables 13 are arranged in angularly spaced groups that radiate from the turret 11 and are supplied from a winch on the turret in a known manner.
Drilling plant is supported on a derrick 14 that is mounted over a moonpool 15 on the stern side of the mooring turret 11 on or around the midship area. The drilling plant comprises a top drive system that connects to a drilling string 16 depending from the derrick 14 through the moonpool 15, and extending inside a drilling riser 17, to a six wellhead drilling template 18 mounted on the sea bed over the existing well. The drilling riser 17 is connected to sub-sea blow out preventers (BOPs) 19 mounted on the sea bed at the drilling template 18.

The region 20 between the stern and the moonpool 15 is fitted with drilling plant and ancillary drilling support equipment, a skid deck, an adjacent gantry crane and an ROV launch. The area 21 between the moonpool 15 and the mooring turret 11 is furnished with production plant.

The drilling well template 18 is connected via a sub-sea pipeline 22 to a sub-sea manifold 23, which in turn is connected to the mooring turret 11 via a salt water injection production riser 24 of conventional configuration. The coupling of the vessel to the production riser 24 enables it to be used for simultaneous drilling and production in a unique manner.

In a simultaneous operations mode, illustrated in figures 1 and 2, bow and stern thrusters (not shown) are used to dynamically position the vessel 10 by rotating it about the stationary mooring turret 11 in order to hold the vessel in a position such that the drilling moonpool 15 is maintained over the appropriate sub-sea wellhead 25. This ensures that drilling operations can continue. The dynamically positionable feature of the vessel also allows the moonpool 15 to be moved between drilling operations in order to permit access to a selected one of multiple wellheads 25 disposed within an arc of the moonpool 15 of the vessel 10, the arc being centred about the vertical axis of the mooring turret 11 as illustrated by the arrows A in figure 2.
Figures 3 and 4 illustrate the same tanker being used in a stand-by only mode i.e. where the drilling string 16 and riser 17 is disconnected from the drilling template 18 and only production operations are performed. In this mode the vessel 10 is free to rotate about the mooring turret 11 in accordance with the prevailing wind direction as indicated in figure 4 where four different vessel positions are shown whilst still being moored by three groups of mooring cables 13. The ability of the vessel to “weathervane” freely in this manner enables the production operations to continue regardless of the prevailing weather conditions.

The drilling plant is configured to perform underbalanced rotary or non-rotary drilling. An example of non-rotary drilling using coiled tubing equipment was described in our US patent no. 6,840,322, the content of which is incorporated herein by reference. Two examples of rotary drilling plant are illustrated in figures 5 and 6. In a first embodiment (figure 5) the sub-sea riser 30 is configured to permit drilling fluid to return inside the riser and is connected directly to the sub-sea BOP 31. A rotating control device 32 is disposed at the top of the riser 30 and flexible return lines 33 are connected between the riser 30, at a position immediately below the rotating control device 32, and an underbalanced four-phase drilling separator 34 disposed on the vessel, the lines extending through the moonpool 15. The return lines 33 carry the drilling mud and multi-phase hydrocarbon mix to the separator 34 where the hydrocarbons are separated from the mixture. In this arrangement the riser 30 is decoupled from the vessel and associated rig and is therefore not subjected to conventional S-bending loading.

In the embodiment of figure 6, a rotating control device 40 is disposed on the sub-sea BOP 31 and the sub-sea riser 30 is connected between the rotating control device 40 and the vessel 10. The drilling mud and fluid mix is conveyed to the vessel via one or more external flow lines 41 to the underbalanced drilling separator 34 on the vessel. The riser 30 can be
connected to the vessel conventionally as depicted in figure 6 or can be disconnected in the manner shown in figure 5.

In operation, underbalanced drilling is performed i.e. the pressure of the drilling fluid is designed to be less than the pressure of the formation fluid at the bottom of the well where the drilling is taking place. This ensures that the hydrocarbon fluids flow into the well and pass up the riser 30 (or external flow lines 41 in the embodiment of figure 6) conveying with it solids produced by the drilling process. The returns are passed to the four-phase separator 34 where excess hydrocarbons are separated from the mixture and are transferred to a main production plant 35 for clean up prior to storage in the tanker's cargo tanks.

Figure 7 illustrates the drilling and production process. The drilling fluid used in underbalanced drilling is a mixture of drilling mud and nitrogen gas. Nitrogen from storage container 50 is introduced into drilling mud from tank 51 before it is passed to a pump in the drilling plant 52. The returns from the drilling operation are passed to the four-phase separator 34 that separates the multi-phase mixture into solids and sediments, drilling mud, nitrogen, hydrogen and crude oil. The drilling mud is returned to the mud storage tank 51, the sediment to storage and the nitrogen and hydrogen to a flare vent 53 for burning off the unwanted gasses. The crude oil from the underbalanced (UB) drilling process is passed to the production process plant 54 where it meets the wellhead fluids returned from the production riser 24. The production process plant comprises a production separator 55 of conventional configuration that separates out the crude oil (and/or other desirable hydrocarbon fluids) and transfers it to onboard cargo holds for storage before subsequent offloading to a dynamically positionable shuttle tanker.

The floating, drilling, production, storage and offloading vessel provides for a unique operation that is versatile, mobile, multipurpose and exhibits operational flexibility. The vessel can give direct access to test sub-sea wells for extended durations and is particularly
suitable for intervention in marginal or depleted fields that were previously not considered to be commercially viable using conventional drilling. The vessel can be used for an extended water injection test and allows for the disposal of waster into a sub-sea well. Furthermore, the original structure and features of a converted vessel can be retained so that it can still be employed in the charter market when not being used for direct well interventions. The vessel thus represents a solution to the problem of achieving direct well interventions without the major costs associated with building and operating specialist vessels. Production revenue is generated as soon as the first well is brought on-stream. It is therefore a cost effective alternative to conventional drilling rigs.
CLAIMS

1. A sub-sea well intervention vessel comprising a dynamically positionable tanker and direct well intervention equipment mounted on the deck of the tanker, the direct well intervention equipment including drilling equipment for underbalanced rotating or non-rotating drilling for connection to a drilling riser and a hydrocarbon liquid separator coupled to storage tanks of the tanker such that separated hydrocarbon liquids can be stored in the tanker, wherein there is provided production plant and a coupling arrangement for coupling the plant to at least one production riser that is separate from the drilling riser, the production riser being for connection to a sub-sea manifold associated with the well, thereby allowing simultaneous underbalanced drilling and production via separate risers, the drilling equipment being selectively disconnectable from the well to allow production only via the production riser.

2. A sub-sea well intervention vessel according to claim 1, wherein the production plant comprises a production hydrocarbon separator spaced from the hydrocarbon separator of the drilling equipment, the production hydrocarbon separator being configured to separate hydrocarbon fluids from matter received from the production riser.

3. A sub-sea well intervention vessel according to claim 2, wherein the drilling equipment separator has an outlet for separated hydrocarbon liquids, the outlet being coupled to the production plant.
4. A sub-sea well intervention vessel according to claim 3, wherein the drilling equipment separator outlet is coupled to the production separator.

5. A sub-sea well intervention vessel according to claim 2 or 3, wherein the production separator is coupled to storage tanks of the tanker such that hydrocarbon fluids can be stored on the tanker.

6. A sub-sea well intervention vessel according to any preceding claim, wherein there is provided a turret mooring system comprising a mooring turret and mooring lines, the vessel being able to rotate about the vertical axis of the mooring turret.

7. A sub-sea well intervention vessel according to claim 6, wherein the mooring turret is mounted in the vessel for rotation and there are a plurality of mooring lines extending therefrom that, in use, are anchored to the sea bed.

8. A sub-sea well intervention vessel according to claim 6 or 7, wherein the turret mooring system is spaced from the drilling equipment.

9. A sub-sea well intervention vessel according to claim 7 or 8, wherein the vessel is dynamically positionable to hold it in the correct position over the well during drilling.

10. A sub-sea well intervention vessel according to any one of claims 6 to 9, wherein the tanker comprises a moonpool for location over the well, and wherein the
drilling riser is disconnectable from the well such that the tanker can be dynamically positioned by rotation about a vertical axis of the mooring turret in order to position the moonpool over a desired wellhead.

11. A sub-sea well intervention vessel according to claim 10, wherein the moonpool is spaced from the mooring turret such that it movable in an arc about the vertical axis.

12. A sub-sea well intervention vessel according to any one of claims 6 to 11, wherein the production riser is connected to the mooring turret such that it can remain operable when the tanker is being dynamically positioned about the mooring turret.

13. A sub-sea well intervention vessel according to any preceding claim, wherein the tanker is fitted with a plurality of thrusters by which it is dynamically positioned.

14. A sub-sea well intervention vessel according to any one of claims 1 to 9, wherein the drilling equipment is located adjacent to a moonpool of the vessel.

15. A sub-sea well intervention vessel according to any preceding claim, wherein the drilling equipment further comprises a rotating control device (RCD) that, in use, is disposed at or near the surface of the sea.
16. A sub-sea well intervention vessel according to claim 15, wherein a fluid return line is connectable between the drilling riser at a position below the RCD and the drilling separator on the tanker.

17. A sub-sea well intervention vessel according to any one of claims 1 to 14, wherein a rotary control device (RCD) is disposed, in use, sub-sea at or adjacent to a Blow Out Preventer (BOP) disposed over the well.

18. A sub-sea well intervention vessel according to claim 17, wherein there is provided a return flow line that is external to the drilling riser and is designed for transporting drilling mud and/or fluid return.

19. A sub-sea well intervention vessel according to claim 18, wherein the return flow line is connectable between a position under the RCD and the drilling separator.

20. A method for conducting offshore underbalanced drilling, whereby a dynamically positionable tanker having direct well intervention equipment mounted on its deck including underbalanced drilling equipment is dynamically positioned over a well, the drilling equipment is coupled to a drilling riser from said well in order to intervene in said well, a separate production riser is coupled to said vessel from a sub-sea manifold associated with said well and underbalanced drilling is performed simultaneously with production via the separate production riser.

21. A method according to claim 20, wherein the drilling riser is selectively disconnectable from the well to allow production only via the production riser.
22. A method according to claim 20 or 21, further comprising the step of using a production plant on the vessel for separating hydrocarbon fluids from the matter delivered from the production riser.

23. A method according to claim 20, 21 or 22, wherein hydrocarbon liquids are separated from the mixture delivered from the underbalanced drilling operation and are transferred to the production plant associated with the production riser.

24. A method according to claim 23, wherein the separated hydrocarbon liquids are transferred to a production separator of the production plant.

25. A method according to any one of claims 20 to 24, further comprising the step of mooring the tanker via a mooring turret such that the tanker is able to rotate around a vertical axis of the turret.

26. A method according to claim 25, further comprising the step of disconnecting the drilling riser from the well, dynamically positioning the vessel by rotation around the turret such that a moonpool of the vessel is positioned over a selected wellhead and then reconnecting the drilling riser.

27. A method according to any one of claims 20 to 25, further comprising the step of dynamically positioning the tanker to hold its geo-position stationary over the well whilst performing underbalanced drilling.
28. A method according to any one of claims 20 to 27, further comprising the step of disposing a rotating control device (RCD) at the top of the drilling riser at or near the surface of the sea.

29. A method according to claim 28, wherein at least one fluid return conduit is connected between the drilling riser at a position below the RCD and the drilling separator on the tanker and matter from the underbalanced drilling is transported in said conduit from the riser to the separator.

30. A method according to any one of claims 20 to 27, further comprising the step of disposing a rotary control device (RCD) sub-sea at or adjacent to a Blow Out Preventer (BOP) disposed over the well.

31. A method according to claim 30, further comprising the step of connecting a return flow conduit external to the drilling riser between the RCD and the drilling separator for transporting drilling mud and/or fluid return.