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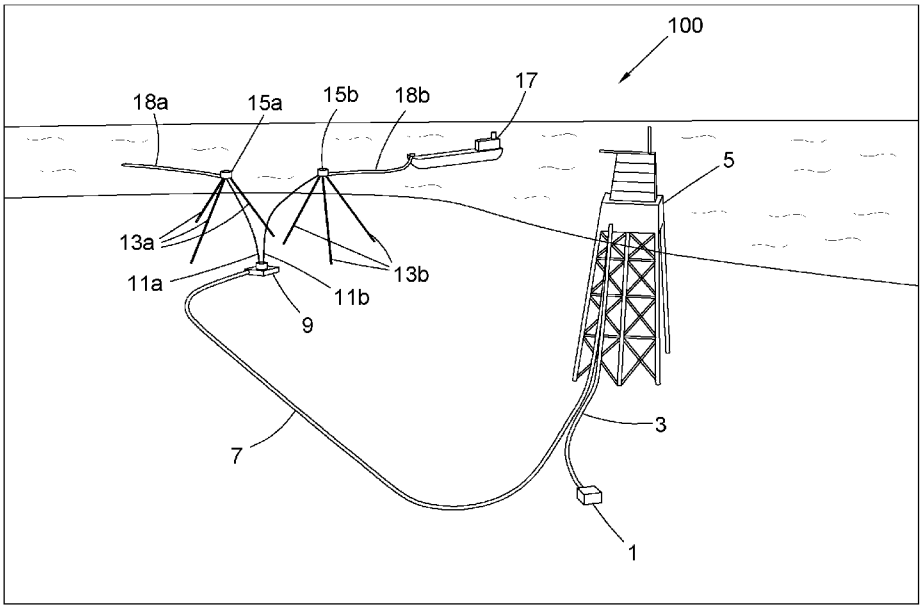


Fig. 1

(57) Abstract: A method of preparing and transporting a fluid produced at an offshore hydrocarbon production facility. The method comprises: part-processing the produced fluid to form a semi-stable hydrocarbon product and a gas product; loading the semi-stable hydrocarbon product and the gas product on to at least one vessel; and transporting the semi-stable hydrocarbon product and the gas product on the at least one vessel. The semi-stable hydrocarbon product and the gas product are maintained separately from one another during the steps of loading and transporting. A system for carrying out the method comprises processing equipment configured to part-process the produced fluid to form the semi-stable hydrocarbon product and the gas product; a first conduit connected to the processing equipment, the first conduit being configured to receive the semi-stable hydrocarbon product therefrom and load the semi-stable hydrocarbon product onto a vessel; a corresponding second conduit being configured to receive the gas product and load the gas product on

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to a vessel; and one or more vessel(s) connectable to the conduits, wherein the vessel (s) i s/a re configured to transport the semi-stable hydrocarbon product and the gas product.

A METHOD AND SYSTEM FOR PREPARING AND TRANSPORTING A FLUID PRODUCED AT AN OFFSHORE PRODUCTION FACILITY.

The present invention relates to a method of preparing a fluid produced at an offshore production facility for transportation and the subsequent transportation operation. The invention also extends to a corresponding system. The disclosed system and method are useful in (but not limited to) the exploitation of marginal sub-sea reserves, in particular marginal sub-sea reserves where the produced fluid has a high gas-to-oil ratio (GOR).

Overcoming current economic difficulties in exploiting marginal reserves is becoming increasingly important as known large reserves are depleted and it becomes more desirable to exploit smaller reserves in remote locations. Such marginal reserves may be considered as such because they are spaced at large distances from any existing local infrastructure that would otherwise allow for easy exploitation of the hydrocarbons at said reserve and/or are in a hard to reach location.

The fluids produced from a hydrocarbon well at a reserve are typically a mixture including gas, oil (collectively termed hydrocarbon fractions) and non-hydrocarbon fractions (e.g. water). The gas fractions (e.g. C_1-C_4) are those fractions that are typically found in the gas phase at atmospheric pressures and temperatures. The oil fractions (e.g. C_5+) of the produced fluid comprise those hydrocarbon fractions that are typically in the liquid phase at atmospheric pressures and temperatures.

Whilst oil fractions and gas fractions are defined by the phase in which they are found at atmospheric temperatures and pressures, depending on the temperature and pressure conditions of the reserve from which the fluid is produced, these fractions may emanate from the well in a phase different to that in which they would be found at atmospheric conditions. For instance, under high pressure conditions, a portion of the produced gas fractions, in particular the heaviest gas fractions (e.g. C_4), may emanate from the well in a liquid phase. When in the liquid phase, such gas fractions may be considered a gas condensate.

The specific makeup/composition of the produced fluid is dependent on the hydrocarbon reserve from which the produced fluid originates. It is also know that for a given reserve, the specific composition of the fluid produced therefrom will fluctuate over time. The general trend for fluid produced from a given reserve over

time is for the GOR of the produced fluid to increase as less oil and more gas is produced.

The specific phase of each of the different fractions within the produced fluid is also dependent on the hydrocarbon reserve from which the produced fluid originates. For instance, reserves having relatively high pressures may comprise a comparatively larger amount of gas fractions in the liquid phase (i.e. gas condensate). This is also true of a reserve where the produced fluid has a higher GOR. It will be appreciated that over time, as the conditions of the reserve vary, and as fluid is removed from the reserve during production, the specific phase of each of the different fractions in the produced fluid may also vary.

A typical production facility, e.g. a facility comprising a manned platform, at a known large reserve, usually comprises sufficient processing equipment such that the fluid produced at the reserve is fully processed in order to separate out the gas fractions and oil fractions, and optionally to prepare the oil and gas fractions for final use, such that the oil fractions may be transported away from the facility (either via pipeline or tanker) for further use. The processing of the produced fluid is also used to separate out non-valuable fractions, e.g. water, from the produced fluid to prevent these non-valuable fractions taking up valuable space within transportation vessels/pipelines.

Where it is viable to do so (i.e. both commercially and technically), the separated gas fractions may also be transported from the production facility via a pipeline for further use. However, where it is not viable to transport produced gas, the produced gas may be used locally at the facility. For instance, the produced gas may be re-injected, used locally as fuel or burned in a flare.

It will be appreciated that the infrastructural demands at typical production facilities are high, not least because of the level of processing equipment that is required in order to prepare the produced hydrocarbons for transportation. Moreover, such infrastructural demands are only further increased in situations where it is desired to transport gas fractions from the production facility in addition to oil fractions. It will not typically be viable, commercially and/or technically, to have such significant infrastructure at marginal reserves given the limited commercial value of the resources at marginal reserves and/or due to the geography of the reserves. For those marginal reserves where the produced fluid has a high GOR (e.g. gas condensate fields), such significant infrastructure will be

particularly commercially unviable given the comparatively low commercial value of gas fractions as compared to oil fractions.

One known approach to exploiting a marginal reserve is to connect ("tie-back") the marginal reserve to an existing platform at another, larger and less remote hydrocarbon reserve. Such an approach thus allows for the recovery of hydrocarbons from marginal reserves whilst benefiting from the already established infrastructure at a larger, established reserve. However, as noted above, the fluid produced from a hydrocarbon reserve is typically a mixture including both gas, oil (collectively termed hydrocarbon fractions) and non-hydrocarbon fractions (e.g. water). Such a mixture of fluid cannot be easily transported by pipeline, at least over long distances, because the multiple phases make it difficult to pump and because hydrates can form and block the pipeline.

Hydrates are ice-like crystalline solids composed of water and gas, and hydrate deposition on the inside wall of hydrocarbon pipelines, processing equipment, transportation vessels etc. is a severe problem in oil and gas production infrastructure. As discussed below with reference to Figure 3, for a given hydrocarbon fluid, hydrates form at higher pressures and lower temperatures. When warm hydrocarbon fluid containing water flows through equipment with cold surfaces, hydrates will precipitate and adhere to the surfaces of the equipment. This reduces the equipment cross-sectional area, which, without proper counter measures, will lead to a loss of pressure, function and ultimately to a complete blockage of the equipment. Transportation and processing of gas therefore normally requires hydrate control.

Thus it will be appreciated that the long distance "tie-back" approach as outlined above is not best suited to marginal reserves of any type, and is particularly not suited to the most marginal of reserves (i.e. those spaced at the greatest distances from any existing infrastructure) and to those reserves at which the produced fluid has a relatively high GOR, given the increased risk of hydrate formation during transportation due to the longer travel distances and higher gas content in the fluid to be transported.

Another proposed solution for exploiting marginal reserves is disclosed in US 4446804. In this document, it is proposed to use a tanker for receiving produced fluid directly from a production well of a marginal reserve without any interim storage or any processing of the produced fluid prior to receipt on the tanker. The produced fluid is loaded onto the tanker whilst being maintained at high (e.g. 100

bar) pressure and is stored thereon under pressurised conditions in order to maintain the produced fluid in a single liquid phase, with the gas fractions from the produced fluid entrained therein. By maintaining the produced fluid at high pressures during loading and storage it is hoped that the gas fractions remain entrained in the oil fractions as a single liquid phase. The tanker can then transport the produced fluid for further processing and use at a different site.

The produced fluid that is received at the tanker thus comprises the whole well-stream, which includes heavier, oil fractions as well as lighter, gas fractions. Thus, this proposal has the benefit of being able to transport both gas and oil fractions via a single infrastructural means, which typical production facilities as discussed above do not. Thus the overall infrastructural demands for the recovery of both oil and gas fractions as compared to typical production facilities are reduced.

However, by virtue of the fact that there is no processing or separation of the produced fluid prior to receipt on the tanker, the produced fluid additionally comprises non-valuable, non-hydrocarbon fractions (e.g. water). This means that valuable storage space on the tanker is wasted by such non-valuable fractions, thus bringing the commercial value of the load of the tanker down. Moreover, the absence of any processing or pre-processing of the produced fluid prior to loading the fluid onto the tanker means that there is no control over the composition of the produced fluid loaded onto the tanker. Therefore, the commercial value of the load on each tanker can vary considerably and may be less than desired. Furthermore, as will be made clearer from the below discussion in relation to Figure 3, the fact that water is not removed from the fluid that is loaded on to the tanker increases the risk of hydrate formation during loading and/or storage thereon. Thus, without additional hydrate control, over time, blockages and improper functioning of the equipment may occur.

In addition, the proposal of US 4446804 is particularly unsuited for transportation of fluids having relatively high GORs. This is in view of the fact that the high gas content of the fluid to be transported makes the fluid particularly volatile and thus highly pressurised conditions (which are technically demanding) would be required to transport the fluid as proposed in US 44446804. Moreover, the high gas content of the fluid makes it particularly susceptible to hydrate formation, which would require significant hydrate inhibition to be implemented during loading and transportation of the fluid. These additional requirements thus make the

proposal of US 4446804 commercially and/or technically unviable for implementation at reserves having high GORs.

WO 2017/048132 A1 discloses a method and system for processing a fluid produced from a well at a gas condensate field (i.e. a reserve having a very high GOR). Gas condensate fields are those fields where the vast majority of the produced fluid comprises gas fractions, with little to no oil fractions being comprised in the produced fluid. Since the proportion of oil fractions produced at gas condensate fields is so low, it is typical for gas condensate production facilities to process the fluid in order to separate out the oil fractions from the gas fractions. The gas fractions are then transported away via a pipeline for further use, whilst the oil fractions are used up locally at the facility.

The method and system proposed in WO 2017/048132 A1 aims at improving the recovery of oil fractions at gas condensate fields. This is achieved by separating out the gas fractions from the produced fluid, and subsequently storing the remainder of the produced fluid (including the oil fractions) as a semi-stabilised fluid. The separated gas fractions are transported away from the facility via pipeline. The semi-stabilised fluid is stored at an elevated pressure subsea in order to maintain the fluid in a semi-stabilised state. Once enough semi-stabilised fluid has been created and stored a vessel may travel to the site of the production facility to retrieve this semi-stabilised fluid.

Whilst the system and method proposed in WO 2017/048132 A1 aims to improve the retrieval of oil fractions from gas condensate fields, the system and method are not suited to marginal reserves since they are reliant on pipeline infrastructure for transporting gas fractions, which may be commercially and/or technically unviable at marginal reserves.

According to a first aspect of the invention, there is provided a method of preparing and transporting a fluid produced at an offshore hydrocarbon production facility, the method comprising: part-processing the produced fluid to form a semi-stable hydrocarbon product and a gas product; loading the semi-stable hydrocarbon product and the gas product onto at least one vessel; and transporting the semi-stable hydrocarbon product and the gas product on the at least one vessel; wherein the semi-stable hydrocarbon product and the gas product are maintained separately from one another during the steps of loading and transporting.

The term "part-processing" herein is used to indicate that, whilst the produced fluid is processed, it is only processed to a limited extent and is not

processed fully. Full processing would involve the preparation of an oil product and a gas product into a final, ready-to-use state. The oil product that results from a full processing would be considered a stabilised oil product. In contrast, the produced fluid in the present invention is only "part-processed" to form a *semi-stable* hydrocarbon product and a gas product, and thus there is not a full processing of the produced fluid.

The term "semi-stable" herein is used to describe a fluid that has been stabilised to a certain extent, but has not been fully stabilised. This means that under certain pressure and temperature conditions (in this case the conditions on the at least one vessel, when loading onto the at least one vessel, and optionally when offloading from the at least one vessel as discussed in further detail below) it will remain in a single (liquid) phase, avoiding evaporation and precipitation (i.e. the precipitation of hydrates in the liquid). However, unlike a fully-stabilised liquid, it must be maintained at a pressure above atmospheric pressure to retain it in that state. Preferably, the semi-stable hydrocarbon product is taken outside of the "hydrate envelope" for the conditions under which it will be held whilst being transported in the at least one vessel.

A semi-stable hydrocarbon product typically comprises gas fractions entrained in liquid product under pressurised conditions, wherein the liquid product may comprise oil fractions and/or some gas factions in the liquid phase (e.g. gas condensate) and optionally may comprise some water.

A hydrocarbon product is semi-stabilised by (part) processing, and such processing typically involves the degassing of the oil product and/or the separation of water from the hydrocarbon product to a certain extent. Degassing of an oil product to a certain extent can be considered as a reduction in its gas composition, in particular a reduction of the gas composition as compared to the produced fluid emanating from the reserve. The degassing may typically involve the removal of the lightest gas fractions since it is these fractions that are most volatile.

The extent of the processing to produce a semi-stable hydrocarbon product may be dependent on the conditions at which the semi-stable hydrocarbon product will be held whilst being loaded onto and transported in the at least one vessel, such that it may be taken outside of the hydrate envelope, as noted above, and preferably throughout the loading and transportation process. As the fluid will cool whilst loaded onto and stored on the at least one vessel, and as its pressure will

reduce whilst being loaded and stored (due to frictional losses and imperfect storage), it is necessary to consider conditions during loading and storage.

Alternatively, the conditions at which the semi-stable hydrocarbon product will be held whilst being loaded onto and transported on the at least one vessel may be dependent on the extent of processing undertaken to form the semi-stable hydrocarbon product. As such, the conditions at which the semi-stable hydrocarbon product are held whilst loaded and transported on the at least one vessel may be adjusted to account for the degree of processing undertaken to form the semi-stable hydrocarbon product (since the degree of processing will define the nature of the semi-stable hydrocarbon product).

The gas product may comprise only the lightest gas fractions. It is known in the art that the lightest gas fractions are those gas fractions that hold the most commercial value in view of the fact that, as compared to heavier gas fractions, lighter gas fractions, after pressurised storage during transportation, can be de-pressurised to a greater extent whilst avoiding the two-phase region to produce an overall greater volume of usable gas. The lightest gas fractions may comprise those fractions that are in the gas phase at atmospheric pressures and temperatures (i.e. C_1-C_4). Alternatively, the lightest gas fractions may be only methane and/or ethane. The gas product may adhere to a rich gas specification, an example of which is set out in table 1 below. Alternatively, the gas product may adhere to a sales gas specification, an example of which is set out in table 2 below. The specification of the gas product may fall somewhere in between a sales gas specification and a rich gas specification. The exact specification of the gas may be selected based on a number of factors and considerations as discussed in further detail below.

The gas product and/or the semi-stable hydrocarbon product may be transported to a facility for further processing, particularly in the case of the semi-stable hydrocarbon product. Alternatively, no further processing of the gas product and/or the semi-stable hydrocarbon product may be undertaken. This may be because the gas product and/or the semi-stable hydrocarbon product may be in a final, ready to use form. The destination for transportation of the gas product and/or semi-stable hydrocarbon product may be onshore, or may be offshore (e.g. an offshore processing facility).

The composition of the semi-stable hydrocarbon product and/or gas product may be dependent on the composition of the fluid produced from the reserve. The

composition of the produced fluid may dictate the final composition of the semi-stable hydrocarbon product. For instance, where the produced fluid has a relatively high gas-to-oil ratio (GOR), wherein GOR is defined as the ratio of the volume of gas in the fluid to the volume of oil in the fluid at standard conditions (i.e. 1 bar and 273.15 K), the GOR of the semi-stable hydrocarbon product may also be relatively high. In essence, the composition of the produced fluid may put a limit on the composition of the gas product and the semi-stable hydrocarbon product that can be formed therefrom.

The composition and makeup of the semi-stable hydrocarbon product and/or the gas product may also be dictated by the desired/required gas product composition and/or the desired/required composition of the semi-stable hydrocarbon product, examples of which are set out below.

For instance, the at least one vessel may only be configured to transport a gas product and semi-stable hydrocarbon product of certain specifications. Therefore, the processing of the produced fluid to create the gas product and/or the semi-stable hydrocarbon product may be dictated by the desired specifications of the gas product and/or the semi-stable hydrocarbon product for transportation.

As another example, as mentioned above, the lightest produced gas fractions are those that hold the most commercial value. Therefore, it may be desired to form a gas product comprising only the lightest gas fractions to improve the commercial value of the load of the, or each, vessel and/or of the equipment used for loading the, or each, vessel. As such, the composition of the semi-stable hydrocarbon product and the gas product may be dictated/controlled to ensure that the gas product comprises only those lightest gas fractions. This in turn may lead to the semi-stable hydrocarbon product comprising those heavier gas fractions that do not meet the desired specification of the gas product (e.g. sales gas specification).

As another example, the composition of the gas product that is formed may be defined to ensure that liquid dropout from/liquid formation within the gas product is prevented during a subsequent offloading operation of the gas product from the at least one vessel. Thus, the produced fluid may be part-processed such that the gas product formed has a dewpoint that is lower than the temperature conditions of the offloading operation at the pressure conditions of the offloading operation.

The temperature conditions during the offloading of the gas product are unlikely to drop below 0 °C and therefore the gas product may have a dewpoint that

is < 0 °C at the given pressure conditions of the offloading operation. Such offloading pressure conditions may be in the region of 1 bar - 50 bar, for instance 10 bar or 20 bar, and therefore the dewpoint of the gas product may be < 0 °C at 1 bar, < 0 °C at 10 bar, < 0 °C at 20 bar or even < 0 °C at 50 bar. Preferably a margin is provided, such that the dewpoint may be <-5 °C or <-10 °C at those pressures.

It is known that lighter hydrocarbon gas fractions (e.g. C_1, C_2) have comparatively lower dewpoints than heavier hydrocarbon fractions (e.g. C_4). Thus, where the gas product is formed to ensure that liquid dropout/liquid formation within the gas product is prevented for the conditions of offload, the part-processing of the produced fluid may be such that the gas product formed therefrom comprises only, or substantially only, the lightest gas fractions (e.g. C_1, C_2) and preferably little to no heavier gas fractions (e.g. C_4). The semi-stable hydrocarbon product formed from the part-processing may instead comprise those heavier gas fractions that do not adhere to the gas product's required dewpoint.

As a further example, the composition of the gas product and/or the semi-stable hydrocarbon product that is formed may be dictated by the technical specifications of the at least one vessel. As outlined in further detail below, a semi-stable hydrocarbon product having a higher proportion of gas fractions, in particular lighter gas fractions, comprised therein will need to be pressurised to a greater degree in order to maintain the stability of the product given the increased volatility provided by these lighter gas fractions. Additional hydrate control measures will also be required in view of the higher gas content. Therefore, the loading onto and transportation on the at least one vessel of the semi-stable hydrocarbon product will have to be carried out under more greatly pressurised conditions and with further hydrate control as the gas content of the semi-stable oil product becomes larger and/or lighter.

At a certain point when the gas content of the hydrocarbon product becomes too high and/or light, it may become technically unfeasible to maintain the fluid in a semi-stable state given the pressure and hydrate inhibition required. These technical considerations may thus be used to dictate and control the composition of the semi-stable hydrocarbon product formed and, as a consequence, the composition of the gas product may also be dictated by these considerations in relation to the gas product.

Similar technical considerations in relation to the loading and transportation of the gas product may be also be used to dictate and control the composition of

the gas product. For instance, a gas product that is too light (i.e. comprises only the lightest gas fractions) may be technically unfeasible to transport on a vessel given the pressurisation that would be required for such transportation. Thus, the gas product composition may be controlled to introduce heavier gas fractions therein and thus making the gas product more feasible to transport due to the lower pressurisation required. The control of the composition of the gas product based on these technical considerations may in turn impact on the composition of the semi-stable oil product formed.

The composition of the gas product and/or the semi-stable hydrocarbon product formed from the part-processing may be dependent on one or more of the factors outlined above, and thus the compositions of these products may involve a balancing act between the above-listed considerations/limitations. For instance, the part-processing of the produced fluid may be carried out to form a gas product and a semi-stable hydrocarbon product that have a combined commercial value which, based on the limitations imposed by the composition of the produced fluid, is maximised whilst also being feasibly transportable on the at least one vessel in view of the technical limitations thereon. Consideration may also be given to ensure that the liquid dropout/formation within the gas product is prevented during an offloading operation of the gas product.

The stability of a hydrocarbon product is often described by its true vapour pressure (TVP), with TVP being defined as the equilibrium partial pressure exerted by a given hydrocarbon product at a temperature of 100 °F (37.8 °C). The true vapour pressure of a fully stabilised oil product is typically around 0.97 bar, and such an oil product will be stable under atmospheric conditions. Processing of the produced fluid to form a semi-stable hydrocarbon product may lower the TVP of the hydrocarbon product to below the TVP of fluid in the reserve, but it should remain above 0.97 bar, more usually above 1 bar, and more typically above 1.3 bar. The TVP of the semi-stable hydrocarbon product is proportional to the gas content of the product. Therefore, a semi-stable hydrocarbon product with a high GOR will have a higher TVP, and thus, dependent on the gas content (amongst other factors) the TVP of the semi-stable hydrocarbon product may be significantly higher than 1.3 bar. For instance, the TVP of the semi-stable hydrocarbon product may be at least 10 bar, 20 bar, 30 bar, 40 bar, 50 bar, 60 bar, 70 bar or may even be as high as 80 bar.

Producing such a semi-stable liquid product and a gas product is advantageous since the amount of processing of the produced fluid in the vicinity of the well (e.g. prior to transportation) is reduced compared to production facilities of the type discussed above which process the produced fluid fully to form both a gas product and a stabilised oil product.

Thus, the invention is in part based upon a recognition by the inventors that there is no need to create a fully stabilised oil product prior to transportation of the product away from the production facility via a vessel to allow for the retrieval of those heavier hydrocarbon fractions (e.g. heavy gas fractions, gas condensates and/or oil fractions) produced at the production facility. Instead it has been realised that these fractions can be retrieved as part of a hydrocarbon product that is stabilised to the extent that it can be transported and stored on a vessel as a single phase and outside the hydrate-forming envelope. Producing a semi-stable hydrocarbon product requires fewer processing steps and less equipment than producing a fully stabilised oil product. Thus, by means of the invention it is possible to transport all of the produced fluid over long distances without the need for a local facility to fully stabilise the produced fluids, which may be impracticable and commercially unviable, particularly in the case of a marginal reserve.

The invention also partly resides in the realisation that, by creating a semi-stable hydrocarbon product and by loading/transporting the semi-stable hydrocarbon product as such, and by creating a gas product and by loading/transporting the gas product as such, a single infrastructural means (i.e. a, or a plurality of, vessel(s)) may be utilised for transportation of gas fractions, gas condensates and oil fractions. Thus, the overall commercial value of a marginal reserve can be increased because a greater portion of the well stream may be recovered without the additional costs associated with installing separate infrastructural means for the recovery of different fractions in the produced fluid.

A further advantage of the invention resides in that by part-processing the produced fluid in order to form a semi-stable hydrocarbon product and gas product prior to loading onto the at least one vessel, the composition of the fluids that are loaded onto the at least one vessel and subsequently transported thereon may be better controlled. The part-processing can allow for control of the water, gas and oil content within the semi-stable hydrocarbon product, and can also allow for control over the composition of the gas product. Thus, in the case of the semi-stable hydrocarbon product, not only can hydrate formation be better inhibited as

compared to a scenario where the fluid is not processed at all prior to loading onto a vessel (e.g. as in US 4446804), by controlling the composition (e.g. by reducing the water content), the commercial value of the semi-stable hydrocarbon product that is loaded/transported on the at least one vessel can also be controlled (i.e. increased) as desired. Such control can also ensure that the semi-stable hydrocarbon product has the necessary properties such it can be feasibly transported based on the technical limitations of the, or each, vessel. In the case of the gas product, control over its composition also provides similar advantages.

As indicated above, the method of the first aspect is particularly useful for the exploitation of marginal sub-sea reserves having a high GOR. A reserve having a high GOR may be defined as a reserve where the fluid produced therefrom has gas fractions as its vastly dominant constituent component. GOR values of the produced fluid at the production facilities where the invention of the first aspect is employed may be in excess of 50, in excess of 100, in excess of 1000 and may even be as high as 100,000. Reserves having a GOR in excess of 100,000 are usually considered as gas condensate reserves.

Given the low commercial value of produced gas as compared to produced oil, marginal reserves having a high GOR have not typically been seen as commercially viable to exploit. The significant expense of installing pipeline infrastructure (which, for all intents and purposes, has been seen to be nigh on essential) for gas retrieval from such a remote reserve would not typically be outweighed by the commercial value of the hydrocarbon fluids at such a reserve. Moreover, given the remote nature of the reserve, it may not even be possible to install a pipeline thereto in order to allow for the recovery of hydrocarbons therefrom. Therefore, such reserves in the past have not typically been exploited.

The method of the first aspect allows for the viable recovery of produced gas via a vessel, and thus without the need for expensive pipeline infrastructure. Therefore the expense of recovery of the gas produced at a marginal reserve of high GOR is significantly reduced and hence exploitation of such a reserve is made commercially viable. The technical limitations of installing pipeline infrastructure are also avoided.

Furthermore, the method of the first aspect allows for a greater portion of the produced fluid (i.e. not just the gas fractions) to be retrieved from a reserve as part of the semi-stabilised hydrocarbon product via the same infrastructural means (i.e. one or more vessels) as the gas product. Thus, the commercial value of the

reserve, in particular a reserve having a high GOR, can be even further increased without the additional outlay in expense for further, significant transportation infrastructure, hence making exploitation of such a reserve yet further viable.

As mentioned above, it is typical for the GOR of the produced fluid to increase over the production lifetime of the reserve. Therefore, given that the method of the first aspect is particularly advantageously employed for reserves having a higher GOR, the method of the first aspect may be used for the exploitation of a reserve that is relatively far through its overall production lifetime.

Where the method of the first aspect is only used to exploit a reserve relatively late into its production lifetime a different method of exploitation and retrieval is utilised earlier in the production lifetime of the reserve. Such a different method may be, for instance, the method as set out in Equinor Energy AS's earlier patent application GB 1906716.4.

Whilst the method of the first aspect is particularly advantageously employed in the context of reserves having a high GOR, the method of the first aspect is not limited to such use. The method of the first aspect may thus be employed at reserves having a lower GOR than those values set out above. For instance, a GOR of less than 1000, and even a GOR as low as 100 or 50.

The method of the first aspect is not limited to exploiting reserves relatively far through their production lifetime, and the method of the first aspect may instead be used to exploit reserves earlier in their production lifetime (e.g. at the start of their production lifetime).

As alluded to above, the method of the first aspect may additionally comprise the step of offloading the gas product and/or the semi-stable hydrocarbon product from the at least one vessel at a facility, for further processing and/or use.

During an offloading of the semi-stable hydrocarbon product from the at least one vessel, the semi-stable hydrocarbon product may be maintained as such for the conditions of offloading. Additionally, or alternatively, during an offloading of the gas product from the at least one vessel, liquid dropout from/ liquid formation within the gas product may be prevented for the conditions of offload.

Additional equipment, such as pumps, compressors and/or heating equipment may be employed to assist during an offloading operation of the gas product and/or the semi-stable hydrocarbon product. Such equipment may assist in maintaining the semi-stable hydrocarbon product as such and/or preventing liquid formation within/liquid dropout from the gas product during the offload operation. It

is preferred however to minimise the reliance on additional offloading equipment wherever possible, and the reliance on offloading equipment may be reduced by forming a suitable gas product and/or a suitable semi-stable hydrocarbon product via the part-processing operation.

The gas product and the semi-stable hydrocarbon product may be loaded onto and transported on the same vessel, though being maintained separately whilst being transported, e.g. in separate tanks or other suitable storage compartments. Alternatively, the gas product and the semi-stable hydrocarbon product may be loaded and transported on to separate vessels from one another. Thus, the at least one vessel may be two or more vessels

The at least one vessel may be at least one tanker.

Where the gas product and the semi-stable hydrocarbon product are transported on the same vessel, each vessel may contain a first storage facility for the semi-stable hydrocarbon product and a second, separate storage facility for the gas product.

After the semi-stable hydrocarbon product has been formed, the loading and subsequent transportation of the semi-stable hydrocarbon product on the, or each, vessel may be carried out at pressurised conditions to maintain the semi-stable hydrocarbon product as such. The pressurised conditions may be between 5 bar – 400 bar, optionally 10 bar – 100 bar, optionally 20 bar – 80 bar, and further optionally 40-60 bar. The exact pressurisation during storage may be selected based on the composition of the semi-stable hydrocarbon product (and its TVP) or vice versa.

Similarly, after the gas product has been formed, the loading and subsequent transportation of the gas on the, or each, vessel may be carried out under pressurised conditions. The pressurised conditions may be between 20 bar – 1000 bar, optionally 50 bar – 800 bar, further optionally 100 bar – 500 bar, and even further optionally 200 bar - 250 bar. The exact pressurisation during storage and transportation may be selected based on the composition of the gas product or vice versa.

The produced fluid at the well may typically have a pressure in the range of 100 bar-1000 bar (absolute) and a temperature generally in, but not limited to, the range of 60-130°C. Indeed, the temperature may be as low as 20°C and as high as 200°C in HTHP (high-pressure-high-temperature) wells, for example. In addition to hydrocarbons, the produced fluid will often contain liquid water and water in the gas

phase corresponding to the water vapour pressure at the current temperature and pressure. As discussed above, if the produced fluid is transported in a vessel untreated over long distances and allowed to cool, then the water in the gas phase may condense and, below the hydrate formation temperature, hydrates will form. The hydrate formation temperature is in the range of 20-30°C at pressures of between 100-400 bar. As noted above, these conditions must be considered when determining the degree of processing to provide the semi-stable hydrocarbon product and/or gas product such that these products can be loaded on to and transported by the at least one vessel without hydrate formation. Based on the temperature and pressure conditions during loading and storage on the at least one vessel, these products should remain outside the hydrate formation envelope (i.e. below the hydrate curve – see Figure 3) if hydrate formation is to be prevented.

The production facility may comprise a platform, the platform optionally comprising the necessary processing equipment in order to part-process the produced fluid to form the semi-stable hydrocarbon product and the gas product. Although the invention may be carried out using a conventional manned production platform, since only limited processing of the produced fluid is required, an unmanned production platform (UPP™) is both suitable and preferred. The use of a UPP™ greatly improves the commercial viability of producing at a marginal reserve.

Whilst the system may be used only to provide a semi-stable hydrocarbon product and a gas product, the production facility may be further configured to process the produced fluid to form a water product. Furthermore, the production platform may be configured to re-inject at least part of the gas product and/or at least part of the water product into the subsea reserve.

Additionally or alternatively, the production facility may be configured to generate electrical power by combusting at least part of the formed gas product. This reduces or eliminates the need for a separate source of power for the production facility.

The production wellhead at the production facility may be entirely subsea, but alternatively it may be partially or wholly located at the surface, as in a dry wellhead/tree. Such dry wellheads may be provided on a jacket structure in shallow waters (e.g. less than 150m water depth). The production wellhead is preferably arranged to supply produced fluid to the production facility via subsea flow lines, a riser base and a riser. Likewise, it may be arranged to supply water from the water product and/or a portion of the gas from the gas product to injection wellheads on

the seabed via a riser, riser base and subsea flow lines. Injection wellheads may be configured to inject the water product, gas product, or both, and may inject into the reservoir from which the produced fluid is removed or into a separate, additional well.

As indicated above, the offshore production facility may be situated at a marginal reserve (remote field) such that it can exploit the hydrocarbon reserves thereat. Such a marginal reserve may be situated more than 60 km from the next nearest reserve and/or production infrastructure, optionally more than 100 km, further optionally more than 200 km away. The marginal reserve may be situated at a distance from the next nearest reserve and/or production infrastructure at which it is not suitable to exploit the hydrocarbon fluids at the marginal reserve via a 'typical' production facility and/or a long distance 'tie-back' (see discussion above).

As noted above, the invention is particularly advantageous because the produced fluid need only be partly processed to the extent that a gas product and a semi-stable hydrocarbon product are formed which are stable enough for transportation in a vessel and/or have the desired composition. The minimum degree of stabilisation and processing required therefore depends on these factors. Based on the teaching herein, the skilled person would readily be able to provide such a degree of stabilisation and processing. Thus, the production facility may typically be configured to provide the minimum amount of processing to the fluid to form the requisite semi-stable hydrocarbon product and desired gas product. No further processing of the produced fluid at the production facility need occur other than the processing required to form the requisite semi-stable hydrocarbon product and desired gas product.

Prior to the step of loading the gas product and the semi-stable hydrocarbon product onto at least one vessel, the method may further comprise the step of storing the gas product and/or the semi-stable hydrocarbon product. Such storage may be provided subsea. Storage may be used where the production rate/volume of the reserve is low. In such a low production scenario it will not typically be cost-beneficial to have a, or a plurality of, vessel(s) at the site of the reserve to receive the fluid therefrom given the relatively long time it would take to load the at least one vessel in a low production scenario, and therefore it can be more cost effective to employ temporary storage. Low production rates/volumes are typical of reserves further into their production lifetime, which, as noted above, are the types of reserve where the invention of the first aspect is advantageously employed.

Alternatively, the gas product and/or the semi-stable hydrocarbon product may be loaded directly on to the at least one vessel without any interim storage.

During transportation, the gas product, or a portion thereof, may be used as a fuel supply for the, or each, vessel. The gas product may be used to fuel auxiliary systems of the, or each, vessel by means of, for instance, a generator. An exemplary auxiliary system may be, for instance, an electrical power system on the, or each, vessel. At least a portion of the gas product may additionally or alternatively be used to supplement fuel for the engines of the, or each, vessel.

The part-processing of the produced fluid to form the semi-stable hydrocarbon product and the gas product will typically involve one or more separation step(s). The skilled person may apply a range of designs of separation systems to carry out the one or more separation step(s), which may comprise the use of two-phase separators, three-phase separators, vertical separators, horizontal separators, scrubbers, Joule Thomson separators and/or any combination of these listed separators as is appropriate for the separation step(s) required given the composition of the produced fluid, the desired gas-product and/or the desired semi-stable hydrocarbon product.

A semi-stable hydrocarbon product outlet may be provided from the separation system. The semi-stable hydrocarbon product outlet may lead to one or more further separation devices. Each further separation device may act to further stabilise the semi-stable hydrocarbon product by further degassing the semi-stable hydrocarbon product and/or removing further water from the semi-stable hydrocarbon product. This sequence of stabilisation may lead to the formation of a semi-stable hydrocarbon product having the desired composition and stability suited for loading and transporting on the at least one vessel. At a certain stage of the sequential separation systems, a fully stabilised hydrocarbon product, e.g. a fully stabilised oil product, may be formed. This fully stabilised hydrocarbon product may be used up locally at the production facility, may (in addition to the gas product and the semi-stable hydrocarbon product) be transported by the at least one vessel for further processing and use, and/or may be recombined with at least a portion of the gas product formed from the produced fluid to form a (the) semi-stable hydrocarbon product.

The semi-stable hydrocarbon product formed from the, or the sequence of, separation system(s) may be loaded onto a vessel with or without any interim storage (e.g. subsea storage). A pump may aid the loading of the semi-stable

product on to the at least one vessel. There may be a water product outlet from the one or more separation system(s) that is optionally connected to injection wellheads on the seabed.

With regard to the gas product, the separation system may also comprise a gas outlet. The gas outlet may lead to one or more further separation devices, one or more coolers, and/or one or more gas compressors arranged in series, with the final compressor having an outlet for the gas product. Each further separation device might act to further purify the gas product, and any oil product, gas condensate, water and/or undesired gas fractions may be removed during the, or the sequential, separation process from the gas product.

A portion of the gas product that is outlet from the separation systems/ compressors may be used up locally at the production facility as re-injection gas, as a fuel (e.g. to power a gas engine generator or turbine) or burned in a flare. Thus at least a portion of the gas product may be selectively tapped off such that it is suited for re-injection and/or for use as a fuel.

As mentioned above, additionally or alternatively, a portion of the gas product outlet from the separation system/ compressor may be recombined with a fully stabilised hydrocarbon product (e.g. oil product, gas condensate) produced elsewhere within the separation system to form the semi-stable hydrocarbon product prior to loading the recombined fluid onto the at least one vessel. The recombination will be undertaken at pressurised conditions and may involve dissolving the gas in the fully stabilised product, and may take place in a combination manifold. The portion of the gas that is dissolved in the fully stabilised product and/or the fully stabilised product having the gas dissolved therein can be controllably selected to yield the desired composition of the semi-stable hydrocarbon product produced therefrom. This selection may also be based on the gas fractions that are not desired to be transported away as part of the gas product and/or based on the gas fractions that are not desired to be used up locally at the production facility.

The offshore production facility may be positioned where sea depths are less than 100 metres, optionally less than 70 metres, further optionally less than 50 metres. At such sea depths, subsea storage of the semi-stable hydrocarbon product/ gas product may not be possible and/or feasible since the hydrostatic pressure would be too low at such depths.

The invention also extends to a corresponding system. Thus, a further aspect of the invention provides a system for preparing and transporting fluid produced at an offshore hydrocarbon production facility, the system comprising: processing equipment configured to part-process the produced fluid to form a semi-stable hydrocarbon product and a gas product; a first conduit connected to the processing equipment, the first conduit being configured to receive the semi-stable hydrocarbon product therefrom and load the semi-stable hydrocarbon product onto a vessel; a second conduit connected to the processing equipment, the second conduit being configured to receive the gas product therefrom and load the gas product onto a vessel; and one or more vessel(s) connectable to the first conduit and the second conduit, wherein the vessel(s) is/are configured to receive the semi-stable hydrocarbon product and the gas product from the first and second conduits respectively and to transport the semi-stable hydrocarbon product and gas product thereon whilst maintaining separation of the semi-stable hydrocarbon product and gas product.

It will be appreciated that the system of the second aspect provides many of those advantages as discussed above in relation to the first aspect.

The system of the second aspect may be used to carry out the method of the first aspect, and thus may comprise or benefit from any of those features discussed above in relation to the first aspect.

As noted above, the method of the first aspect is particularly applicable to the exploitation of a mature reserve, i.e. a reserve that is relatively far through its overall production lifetime, and which may have a relatively high GOR. Therefore, the method of the first aspect may be carried out after the same reserve has been exploited via a different method previously, earlier in its production lifetime and/or whilst that reserve has a relatively low GOR. For instance, the method of the first aspect may be carried out after an earlier method of preparing a fluid produced at the offshore hydrocarbon production facility, the method comprising the steps of: part-processing the produced fluid to form a semi-stable oil product; and loading the semi-stable oil product directly onto a vessel without interim storage.

The combination of these two different methods for exploitation of a given reserve over its production lifetime is seen as being patentable in its own right. Thus, from a third aspect of the invention there is provided a method of preparing and transporting a fluid produced at an offshore hydrocarbon production facility, the method initially (in a first stage) comprising the steps of: part-processing the

produced fluid to form a semi-stable oil product; loading the semi-stable oil product directly onto a vessel without interim storage; and transporting the semi-stable oil product on the vessel(s) as such; wherein, at a later time (in a second stage), the method comprises the steps of: part-processing the produced fluid to form a semi-stable hydrocarbon product and a gas product; loading the semi-stable hydrocarbon product and the gas product on to at least one vessel; and transporting the semi-stable hydrocarbon product and the gas product on the at least one vessel; wherein the semi-stable hydrocarbon product and the gas product are maintained separately from one another during the steps of loading and transporting.

The semi-stable oil product produced using the method of the first aspect (i.e. the second stage referred to above) may comprise gas fractions from the produced fluid combined with oil fractions from the produced fluid in a single liquid phase that has a true vapour pressure (TVP) of greater than 1 bar and a TVP of less than the TVP of the produced fluid from the well. The semi-stable oil product may additionally, or alternatively, have a lower gas and/or water content as compared to the produced fluid, such that it is taken outside of the hydrate formation envelope for conditions of loading the semi-stable oil product onto the vessel and, optionally, for the conditions of transportation on the vessel.

The part-processing of the produced fluid that occurs in the first stage of the method of the third aspect may comprise part-processing the produced fluid only to the extent required to form a semi-stable oil product. Thus, in the initial stages of the method of the third aspect, no further processing of the fluid at the production facility may take place other than that required to form the semi-stable oil product.

The part-processing of the produced fluid that occurs in the first stage of the method of the third aspect may comprise at least one of the steps of: separating water from the produced fluid; separating the produced fluid into a first fluid comprising gas fractions and a second fluid comprising oil fractions; and combining at least a portion of the gas fractions with at least a portion of the oil fractions to form the semi-stable oil product.

The method of the third aspect may in the first stage be carried out by a system for preparing a fluid produced at the offshore production facility for transportation, the system comprising: processing equipment configured to part-process the produced fluid to form the semi-stabile oil product fluid; and at least one conduit connected to the processing equipment, the at least one conduit being configured to receive the semi-stable oil product therefrom and being configured to

load the semi-stable oil product directly to the vessel. This system may comprise no interim storage for the semi-stable oil product to be stored in, subsea or otherwise.

It will be appreciated that those steps of the method of the third aspect of the invention that occur in the second stage correspond to the steps of the method of the first aspect of the invention. Thus, these steps of the third aspect of the invention may comprise or benefit from any of those optional features and/or steps set out above in relation to the first aspect of the invention. Moreover, these steps of the third aspect of the invention may be carried out using the system of the second aspect of the invention.

Certain embodiments of the present disclosure will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is a perspective view of an offshore hydrocarbon production facility, including a subsea well and production platform, and vessel loading facility according to an embodiment of the invention;

Figure 2 is a schematic representation of the subsea well and the production platform of Figure 1; and

Figure 3 shows a generic hydrate-formation phase diagram for a hydrocarbon product.

Figure 1 depicts a production facility 100 at a marginal hydrocarbon reserve, whereby the reserve is distanced tens of kilometres from any other production facility. In the depicted embodiment, the hydrocarbon reserve has a high gas-to-oil ratio (GOR).

The production facility 100 comprises a production well 1 connected to a topside of an offshore platform 5 by a conduit 3 that transports produced hydrocarbon fluid from the well 1 to the platform 5. As shown in Figure 1, the offshore platform 5 is an unmanned production platform (UPP™) 5. The UPP™ 5 is in turn connected to a subsea distribution manifold 9 by a conduit 7, the conduit 7 housing a gas output supply line 48 and a semi-stable hydrocarbon output supply line 14 which each allow for the passage of different hydrocarbon fluids as described in more detail below. The hydrocarbon fluids transported within each supply line 14, 48 inside the conduit 7 are delivered from the UPP™ 5 to the distribution manifold 9. The distribution manifold 9 may optionally comprise a pump as discussed in further detail below.

The distribution manifold 9 has a first riser 11a and a second riser 11b attached thereto, the first and second risers 11a, 11b being catenary risers 11a, 11b. Similar to the conduit 7, each riser 11a, 11b houses a gas product output delivery line and a semi stable hydrocarbon delivery line (not shown) which each allow for the delivery of different hydrocarbon fluids therethrough as discussed in further detail below.

The first riser 11a and the second riser 11b are connected to a first buoy 15a floating at sea level and a second buoy 15b floating at sea level respectively. Each of the first buoy 15a and the second buoy 15b are moored by a first set of mooring lines 13a and a second set of mooring lines 13b respectively. The mooring lines 13a, 13b allow for limited movement of the buoys 15a, 15b in both a horizontal and vertical direction due to changing sea conditions and weather, but otherwise the mooring lines 13a, 13b fix the buoys 15a, 15b substantially in place. Each of the buoys comprises an attachment 18a, 18b configured to connect it to a vessel, such as a tanker 17. The gas output delivery lines and the semi-stable hydrocarbon product delivery lines that are housed in each catenary riser 11a, 11b each pass through their respective buoys 15a, 15b to their respective attachment 18a, 18b such that they too can be connected to a vessel and hence and allow for passage of their respective hydrocarbon fluids onto the vessel.

The fluid that is produced at the production well 1 comprises a range of hydrocarbon fractions, including both gas fractions and oil fractions. Since the well 1 exploits a hydrocarbon reserve of relatively high GOR, the produced fluid comprises a significant proportion of gas fractions.

The gas fractions (e.g. C_1-C_4) comprise those fractions that are typically found in the gas phase at atmospheric pressures and temperatures. However, at least a portion of these gas fractions, particularly the heavier gas fractions, may be in the liquid phase (i.e. gas condensate) whilst comprised in the produced fluid due to its elevated pressure, which may for example be 400 bar.

The oil fractions (e.g. C_5+) of the produced fluid comprise those hydrocarbon fractions that are typically in the liquid phase at atmospheric pressures and temperatures. The produced hydrocarbon fluid from the well 1 may additionally comprise non-hydrocarbon constituents, e.g. water.

The produced fluid from the well 1 is transported via the riser 3 to the UPP™ 5 for part-processing to form a semi-stable hydrocarbon product and a gas product in preparation for loading and transportation on a vessel. Figure 2 shows in further

detail the part-processing equipment comprised on the UPP™ 5, with the subsea components (well 1 and riser 3) being shown within a dashed-line box.

The processing equipment on the UPP™ 5 includes a first separator 6 connected to a conduit 8, which in turn connects to a second separator 12 via a control valve 10. Additionally, connected to the first separator 6 is a conduit 16 which in turn connects to a third separator 20 via a cooler 18.

The second separator 12 has two outlets: a conduit 22 which connects to a fourth separator 24 and the semi-stable hydrocarbon product output line 14. The semi-stable hydrocarbon output line 14, as alluded to above, acts as an outlet from the processing equipment on the UPP™ 5, passing through the conduit 7 and to the distribution manifold 9 (see Figure 1).

The third separator 20 has two outlets: a conduit 26 and a conduit 28. The conduit 26 comprises a pump 33 and acts as a return line to the first separator 6. The conduit 28 passes via a cooler 30 and connects to an expander 32. A conduit 34 leads from an outlet from the expander 32 and connects to a fifth separator 36.

The fourth separator 24 has two inlets: the conduit 22, as described above, and a conduit 38, described in further detail below. The fourth separator 24 additionally comprises two outlets: a conduit 25 which connects, via a first compressor 27, to the first separator 6 and a conduit 29 which connects, via a pump 31, to the third separator 20.

The fifth separator 36 has two outlets: a conduit 38 and a conduit 40. The conduit 38 passes via the cooler 30, the control valve 39 and connects to the fourth separator 24. It will be noted that the cooler 30 acts as a heat exchanger between the conduit 28 and the conduit 38. The second conduit 40 connects to a second compressor 42.

The second compressor 42 has an outlet in the form of a conduit 44 that connects to a third compressor 46. The third compressor 46 itself has an outlet in the form of a gas outlet supply line 48 which passes via a cooler 50. As mentioned above, the gas outlet supply line 48 acts as an outlet from the processing equipment on the UPP™ 5 and passes through the conduit 7, connecting to the distribution manifold 9 (see Figure 1).

An anti-surge line 54 connects to the conduit 44 upstream of the third compressor 46 from the conduit 48 downstream of the cooler 50. The anti-surge line 54 over the third compressor 46 functions conventionally and thus a further detailed description of this feature will not be given here.

The part-processing of the fluid on the UPP™ 5 occurs as follows. The fluid produced at the well 1 passes through the riser 3 and to the first separator 6 via the control valve 4. The first separator 6 carries out a separation operation on the produced fluid received therein. The separation operation involves the production from the produced fluid of a first fluid comprising the lightest gas fractions and a second fluid comprising the remainder of the produced fluid, including heavier gas fractions and those fractions in the produced fluid that are in the liquid phase, such as oil fractions, gas condensates and water.

The aim of the separation process carried out at the first separator 6, and sequentially at the third separator 20 and the fifth separator 36 as described in more detail below, is to form a gas product adhering to a desired gas specification for transportation and later use. Such a gas specification may be a rich gas specification, an example of which is set out in table 1 overleaf. Alternatively, such a specification may be a sales gas specification, an example of which is set out in table 2 overleaf. Regardless of the exact desired specification of the gas product to be formed, since the desired product will typically comprise the lightest portion of the produced gas fractions (given their commercial value), the sequential separation processes at each of the first, third and fifth separators 6, 20, 36 will act to separate out and further purify the lightest gas fractions.

Table 1:

Rich Gas Specification	
Water content	Less than 63 ppm by volume
Carbon Dioxide (CO_2)	Less than 22 mol%
Oxygen content	Less than 7 ppm by volume
Sulphur content	H_2S – Less than or equal to 500 ppm by volume
C_2-C_{12} fraction	10.67-21.82 mol%
Maximum allowable operating pressure	173.4 Bara
Cricondenbar pressure	Less than or equal to 106 bara
Sediment / Metals	Nil
Mercaptans	Nil
Mercury	Nil
Duodecans	Nil
Temperature	50 °C max

Table 2:

Sales Gas Specification	
Hydrocarbon dewpoint	< -10 °C at 50 barg
Water dewpoint	-18 °C at 69 barg
Maximum Carbon Dioxide (CO_2) content	2.50 mol%
Maximum Oxygen	2 ppm by volume
Maximum hydrogen sulphide (H_2S) incl. Carbonyl sulphide (COS)	5 mg/Nm^3
Maximum Mercaptans	6.0 mg/Nm^3
Maximum Sulphur	30 mg/Nm^3
Gross Calorific Value	38.1 MJ/Sm^3 – 43.7 MJ/Sm^3
Gross Calorific Value	40.2 MJ/Nm^3 – 46.0 MJ/Nm^3
Gross Calorific Value	11.17 kWh/Nm^3 – 12.78 kWh/Nm^3
Wobbe Index	48.3 MJ/Sm^3 – 52.8 MJ/Sm^3
Wobbe Index	51.0 MJ/Nm^3 – 55.7 MJ/Nm^3
Wobbe Index	14.17 kWh/Nm^3 – 15.47 kWh/Nm^3

The first fluid is transported away from the first separator 6 via the conduit 16 and is passaged through the cooler 18 where it is cooled. The cooling of the first fluid may lead to a portion of the gas fractions, in particular the heavier gas fractions therein, liquefying.

After passing through the cooler 18, the first fluid reaches the third separator 20. As mentioned above, the third separator 20 acts to further separate out and purify the lightest gas fractions from the first fluid as a sequential part of the formation of a gas product adhering to a desired specification. Those lightest gas fractions separated out at the third separator 20 then exit therefrom through the conduit 28 as part of a third fluid and pass to the cooler 30 as the hot side fluid for heat exchange with those fluids contained in the conduit 38 passing through the cooler 30.

The remainder of the first fluid (i.e. not those fractions forming the third fluid) including water, oil fractions and gas condensate spilt over from the first separator 6, gas condensate formed at the cooler 18 and any gas fractions too heavy for the desired gas product specification are returned from the third separator 20 to the first separator via the conduit 26 and the pump 28 for further separation.

The cooler 30 cools the third fluid output from the third separator 20, and this cooling may cause certain fractions contained within the third fluid to liquefy, in particular the heavier gas fractions contained therein (which may include some spill over from the third separator 20).

The third fluid in the conduit 28 is then passed through the expander 32. The expansion of the cooled, third fluid within the expander 32 may cause yet further fractions therein to liquefy, in particular heavier gas fractions and water within the third fluid.

The third fluid is then sent to the fifth separator 36 which again, as described above, acts as part of the sequential separation process to separate out the lightest gas fractions in the third fluid from those other fractions, such as the liquefied water fractions and/or gas condensate formed at the cooler 30 and the expander 32 and/or any heavier gas fractions that do not adhere to the desired specification (e.g. sales gas specification) of the gas product. The fifth separator 36 forms the final stage in the sequential separation process and therefore the gas product produced therefrom that is output via the conduit 40 is the desired gas product having the desired gas specification (e.g. sales gas specification).

The conduit 40 transports the desired gas product to the second compressor 42 where the gas product is pressurised in preparation for loading onto and transportation on a vessel. From the second compressor, the gas product passes through the conduit 44 and is further compressed/pressurised in the third compressor 46 before passing through the cooler 50. After passing through each of the second compressor 42, the third compressor 46 and the cooler 50, the desired gas product is of a suitable temperature and at a suitable pressure for loading the gas product onto a vessel and transportation thereon.

Those fractions from the third fluid that do not form part of the desired gas product, including the liquefied water produced at the expander 32 and the gas condensate formed at the cooler/expander 30, exit the fifth separator 36 via the conduit 38. These fractions are then passed through the cooler 30 as the cold side fluid (thus providing a cooling to the fractions passing through conduit 28) before being sent to the fourth separator 24 via the control valve 39.

Regarding the second fluid that is separated out at the first separator 6, this fluid is transported therefrom via the control valve 10 to the second separator 12. The second separator 12 performs a separation operation on the second fluid once received therein. The separation operation at the second separator is similar in nature to the separation operation carried out the first separator 6. Thus, the lightest gas fractions in the second fluid, in particular those that have spilt over from the first separator, are separated out at the second separator 12 and are outlet via the conduit 22 to the fourth separator 24.

After removal of the lightest gas fractions at the second separator 12, the resulting hydrocarbon product formed from the remainder of the second fluid is a semi-stable hydrocarbon product. The semi-stable hydrocarbon product formed at the second separator 12 comprises oil fractions and/or gas condensates from the produced fluid as well as a portion of the heavier gas fractions from the produced fluid entrained therein that were not otherwise separated out by the first separator 6 and the second separator 12. The semi-stable hydrocarbon product produced at the second separator 12 is primarily a single liquid phase of gas condensates/oil fractions with other gas fractions from the produced fluid entrained within those liquid phases. As described above, and below in relation to Figure 3, whilst the semi-stable hydrocarbon product produced at the separator 12 is, in essence, a single liquid phase, this is only because the temperature and pressure conditions at the separator 12 allow it to remain as such. A change in these conditions, in

particular a drop in the pressure of the semi-stable hydrocarbon product may lead to the gas fractions and liquid phases within the semi-stable hydrocarbon product separating out into two separate phases, and additionally may lead to an evaporation of gas condensates within the semi-stable hydrocarbon product,

The lightest gas fractions separated from the second fluid at the second separator 12 are sent to the fourth separator 24 where they, along with those fractions sent to the fourth separator 24 via the conduit 38 from the fifth separator 36 undergo a further separation process. The separation process at the fourth separator 24 is similar in nature to those separation processes at each of the other separators, and results in a separation of gas fractions therein from fractions in the liquid phase, including gas condensates, oil fractions, water etc. Those fractions in the liquid phase are sent from the fourth separator 24 via the conduit 29 and the pump 31 to the third separator 20, whilst those gas fractions in the gas phase are sent from the fourth separator 24 via the conduit 25 and the first compressor 27 to the first separator 6. Thus, the products outlet from the fourth separator 24 are returned further back within the processing equipment of the UPP™ 5 to undergo further separation/processing.

The gas product that is formed at the UPP™ 5 is output therefrom via the gas output supply line 48 housed in the conduit 7 (see Figure 1) and is sent subsea to the distribution manifold 9.

Similarly, the semi-stable hydrocarbon product formed and output from the second separator 12 on the UPP™ 5 is output therefrom via the semi-stable hydrocarbon supply line 14 housed in the conduit 7 (see Figure 1) and is sent subsea to the distribution manifold 9.

The hydrocarbon supply line 14 and the gas output supply line 48 maintain the produced semi-stable hydrocarbon product and the gas product separate from one another during transportation to the distribution manifold 9. Moreover, the hydrocarbon supply line 14 and the gas output supply line 28 maintain the semi-stable hydrocarbon product and the gas product respectively under the necessary pressurised conditions to allow these different products to be transported therethrough as such.

Once the semi-stable hydrocarbon product and the gas product reach the distribution manifold 9, the distribution manifold 9 distributes the semi-stable hydrocarbon product to the semi-stable hydrocarbon delivery line in each of the first riser 11a and the second riser 11b all whilst the semi-stable hydrocarbon product is

maintained at its elevated pressure to maintain it as such. The gas product is correspondingly distributed by the distribution manifold 9 to the gas product delivery line in each of the first riser 11a and the second riser 11b whilst also maintained at is elevated pressure. The distribution of the gas product and/or the semi-stable hydrocarbon product at the distribution manifold 9 may involve the use of one or more compressors and/or pumps, which may serve to maintain the necessary pressures in the gas product and/or semi-stable hydrocarbon product to allow them to remain as such, and to allow for subsequent loading and transportation on to the vessel.

After leaving the distribution manifold 9, the gas product and the semi-stable hydrocarbon product are received at the first buoy 15a and the second buoy 15b via the respective gas product delivery lines and the semi-stable hydrocarbon product delivery lines.

A vessel, such as the tanker 17, can connect to either the first attachment 18a of the first buoy 15a or the second attachment 18b of the second buoy 15b. As depicted in Figure 1, the tanker 17 is connected to the attachment 18b of the second buoy 15b. The connection between the tanker 17 and the second attachment 18b allows for the semi-stable hydrocarbon product and the gas product to pass from the second buoy 15b, through the second attachment 18b, via the semi-stable hydrocarbon product delivery line and the gas product delivery line respectively, and onto the tanker 17.

Once received on the tanker 17, the gas product is stored in a first set of storage tanks whilst the semi-stable hydrocarbon product is stored in a second set of storage tanks such that the semi-stable hydrocarbon product is maintained as separate from the gas product on the tanker 17.

The first set of storage tanks are configured to maintain the semi-stable hydrocarbon product at its elevated pressure of, e.g., 60bar, whilst the second set of storage tanks are configured to maintain the gas product at its elevated pressure of, e.g., 200 bar. By maintaining the semi-stable hydrocarbon product at its elevated pressure on the tanker 17, the semi-stable hydrocarbon product is maintained in its single, liquid phase and is thereby prevented from separating out into gas fractions and oil fractions. Hydrate formation is also prevented.

Once the first and second set of storage tanks on the tanker 17 are at capacity, the tanker 17 disconnects from the second attachment 18b. This disconnection prevents further semi-stable hydrocarbon product and gas product

passing through the second attachment 18b. The tanker 17 then transports the semi-stable hydrocarbon product and gas product to another facility and/or to shore for further processing and/or use.

Shortly before, shortly after or whilst the tanker 17 is disconnected from the second attachment 18b, a further tanker (not shown) may connect to the first attachment 18a and receive semi-stable hydrocarbon product and gas product therefrom to thereby allow for the continuous, or almost continuous, loading of semi-stable hydrocarbon product and gas product from the production facility 100 to a vessel.

An almost continuous offload of hydrocarbon products from the production facility 100 to one or more vessels may be necessary where there is no interim storage facility provided for the produced hydrocarbon fluids prior to loading on to a vessel such as in the embodiment of Figures 1 and 2. However, where a storage facility is provided, continuous offload of produced and part-processed hydrocarbons may not be required, and there may be a significant time gap between vessels arriving at a site of the facility 100 for the retrieval of the gas product and semi-stable hydrocarbon product.

The significance of the semi-stabilisation process will now be explained further, with reference to Figure 3. This is a hydrate formation phase diagram of a typical hydrocarbon product (which may contain oil, water and gas) can be seen, with the temperature and pressure that the hydrocarbon product may be held at shown on the X and Y axes respectively. There is a hydrate free region 401 on the right hand side of a hydrate dissociation curve 402, a hydrate stable region 403 (i.e. a region where hydrates have formed and are stable in the fluid) on the left hand side of a hydrate formation curve 404 and a metastable region 405 in between the hydrate formation curve and the hydrate dissociation curve where there is a risk of hydrate formation.

A hydrocarbon product held at low pressure and high temperature will reduce hydrate formation, whereas high pressures and low temperatures increase hydrate formation.

The degassing and separation of water from the hydrocarbon product alters the location of the hydrate formation and dissociation curves. Typically, such processing will move the hydrate formation curve to the left of the figure such that the hydrocarbon product can be held at lower pressures and lower temperatures

without the formation of hydrates. Thus, the hydrocarbon product is said to be more stable, or further stabilised, when gas and water is removed therefrom.

In the embodiments of the invention described herein, the produced fluid is part-processed via separation such that a semi-stable hydrocarbon product and gas product is formed.

The semi-stable hydrocarbon product produced from the part-processing is taken outside of the hydrate envelope for the conditions of loading onto the vessel, and storage and transportation on the vessel. As such, the semi-stable oil product does not exhibit significant hydrate formation whilst being loaded onto, and transported on, the vessel. In addition, by only part-processing the produced fluid the use of unnecessary processing equipment at the processing facility is reduced, thus reducing the cost, size and difficulty in setting up and maintaining the production facility, which is particularly beneficial whilst when the facility is located at a marginal reserve.

Claims:

1. A method of preparing and transporting a fluid produced at an offshore hydrocarbon production facility, the method comprising:

part-processing the produced fluid to form a semi-stable hydrocarbon product and a gas product;

loading the semi-stable hydrocarbon product and the gas product on to at least one vessel; and

transporting the semi-stable hydrocarbon product and the gas product on the at least one vessel;

wherein the semi-stable hydrocarbon product and the gas product are maintained separately from one another during the steps of loading and transporting.

2. A method as claimed in claim 1, wherein the semi-stable hydrocarbon product comprises gas fractions from the produced fluid entrained within oil fractions and/or gas condensates from the produced fluid in a single liquid phase, and wherein the semi-stable hydrocarbon product has a true vapour pressure (TVP) of greater than 1 bar and a TVP of less than the TVP of the produced fluid from the well.

3. A method as claimed in claim 1 or 2, wherein the semi-stable hydrocarbon product has a lower gas and/or water content than the produced fluid, such that it is taken outside of the hydrate formation envelope for conditions of loading the semi-stable hydrocarbon product onto the vessel and for the conditions of transportation on the vessel.

4. A method as claimed in any preceding claim, wherein the gas product adheres to a rich gas specification.

5. A method as claimed in any of claims 1 to 3, wherein the gas product adheres to sales gas specification.

6. A method as claimed in claims 1 to 3, wherein a specification of the gas product is between a sales gas specification and a rich gas specification.

7. A method as claimed in any preceding claim, the method further comprising the step of offloading the gas product and/or the semi-stable hydrocarbon product from the at least one vessel.

8. A method as claimed in claim 7, wherein the gas product formed from the part-processing has a composition/specification such that liquid dropout from/liquid formation within the gas product is prevented for the pressure and temperature conditions during the step of offloading the gas product from the at least one vessel; optionally

wherein the pressure of the gas product is maintained above 1 bar and the temperature of the gas product is maintained above 0 °C during the step of offloading the gas product from the at least one vessel.

9. A method as claimed in any preceding claim, wherein the dewpoint of the gas product < 0 °C at 1 bar.

10. A method as claimed in any preceding claim, wherein the composition of the semi-stable hydrocarbon product is dependent on the composition of the gas product and/or the composition of the produced fluid.

11. A method as claimed in any preceding claim, wherein the composition of the gas product is dependent on the composition of the semi-stable hydrocarbon product and/or the composition of the produced fluid.

12. A method as claimed in any preceding claim, wherein the offshore hydrocarbon production facility is situated at a marginal reserve.

13. A method as claimed in any preceding claim, wherein the produced fluid has a gas-to-oil ratio of above 50, optionally above 100.

14. A method as claimed in any preceding claim, wherein the semi-stable hydrocarbon product and the gas product are loaded onto and transported on the same vessel.

15. A method as claimed in any preceding claim, wherein the semi-stable hydrocarbon product is loaded onto and transported on a separate vessel from the gas product.

16. A method as claimed in any preceding claim, wherein no further processing of the produced fluid occurs other than the part-processing of the produced fluid to form the semi-stable hydrocarbon product and the gas product.

17. A method as claimed in any preceding claim, wherein part-processing the produced fluid to form the semi-stable hydrocarbon product and the gas product comprises at least one separation operation performed on the produced fluid to form the gas product and the semi-stable hydrocarbon product.

18. A method as claimed in any preceding claim, wherein the semi-stable hydrocarbon product is directly loaded on to the at least one vessel without any interim storage.

19. A system for preparing and transporting fluid produced at an offshore hydrocarbon production facility, the system comprising:

processing equipment configured to part-process the produced fluid to form a semi-stable hydrocarbon product and a gas product;

a first conduit connected to the processing equipment, the first conduit being configured to receive the semi-stable hydrocarbon product therefrom and load the semi-stable hydrocarbon product onto a vessel;

a second conduit connected to the processing equipment, the second conduit being configured to receive the gas product therefrom and load the gas product on to a vessel; and

one or more vessel(s) connectable to the first conduit and the second conduit, wherein the vessel(s) is/are configured to receive the semi-stable hydrocarbon product and the gas product from the first and second conduits respectively and to transport the semi-stable hydrocarbon product and gas product therein whilst maintaining separation of the semi-stable hydrocarbon product and gas product.

20. A system as claimed in claim 19 used to carry out the method of any of claims 1 to 18.

21. A system as claimed in claim 19 or 20, comprising a plurality of vessels, wherein a first vessel is configured to receive and transport the semi-stable hydrocarbon product and a second vessel is configured to receive and transport the gas product.

22. A system as claimed in claim 21, wherein the first vessel is configured to receive and transport only the semi-stable hydrocarbon product.

23. A system as claimed in 21 or 22, wherein the second vessel is configured to receive and transport only the gas product.

24. A system as claimed in any of claims 19 to 24, comprising a vessel that is configured to receive and transport both the semi-stable hydrocarbon product and the gas product.

25. A method of preparing and transporting a fluid produced at an offshore hydrocarbon production facility, the method initially comprising the steps of:

part-processing the produced fluid to form a semi-stable oil product;

loading the semi-stable oil product directly onto a vessel without interim storage; and

transporting the semi-stable oil product on the vessel as such;

wherein, at a later time, the method subsequently comprises the steps of:

part-processing the produced fluid to form a semi-stable hydrocarbon product and a gas product;

loading the semi-stable hydrocarbon product and the gas product on to at least one vessel; and

transporting the semi-stable hydrocarbon product and the gas product on the at least one vessel;

wherein the semi-stable hydrocarbon product and the gas product are maintained separately from one another during the steps of loading and transporting.

26. A method as claimed in claim 25, wherein, at the later time, the steps of the method are those defined in any of claims 1 to 18.

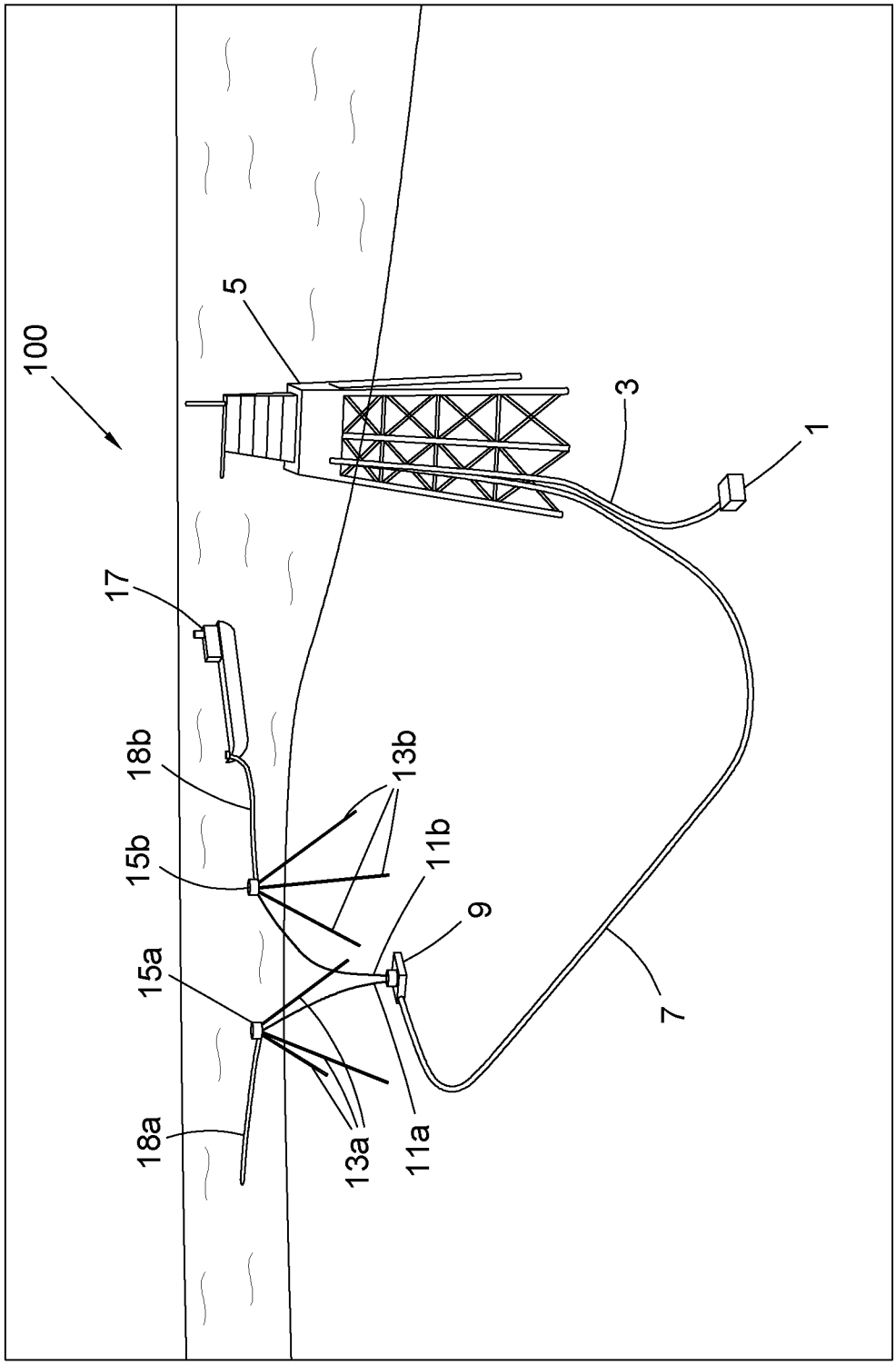


Fig. 1

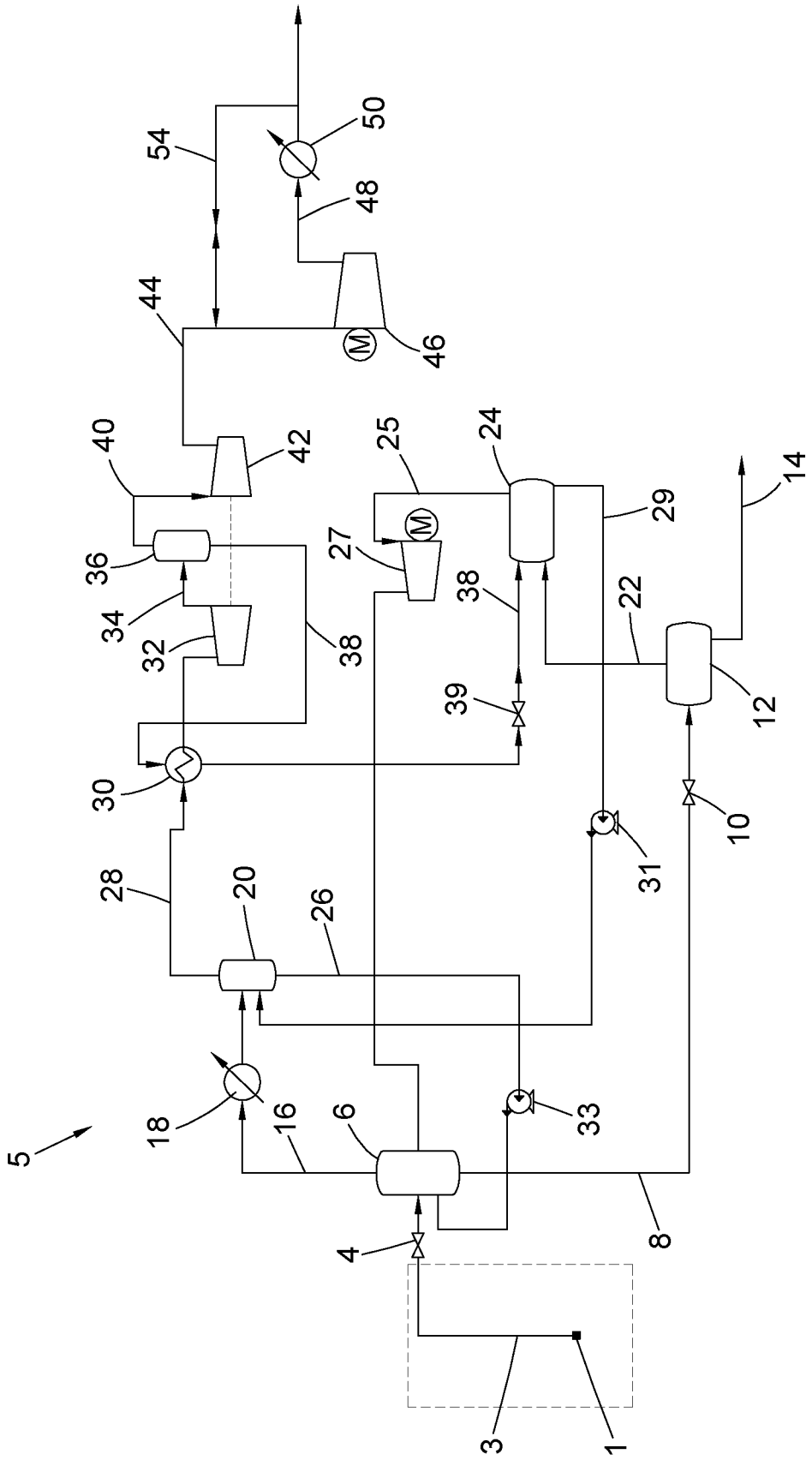

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Fig. 2

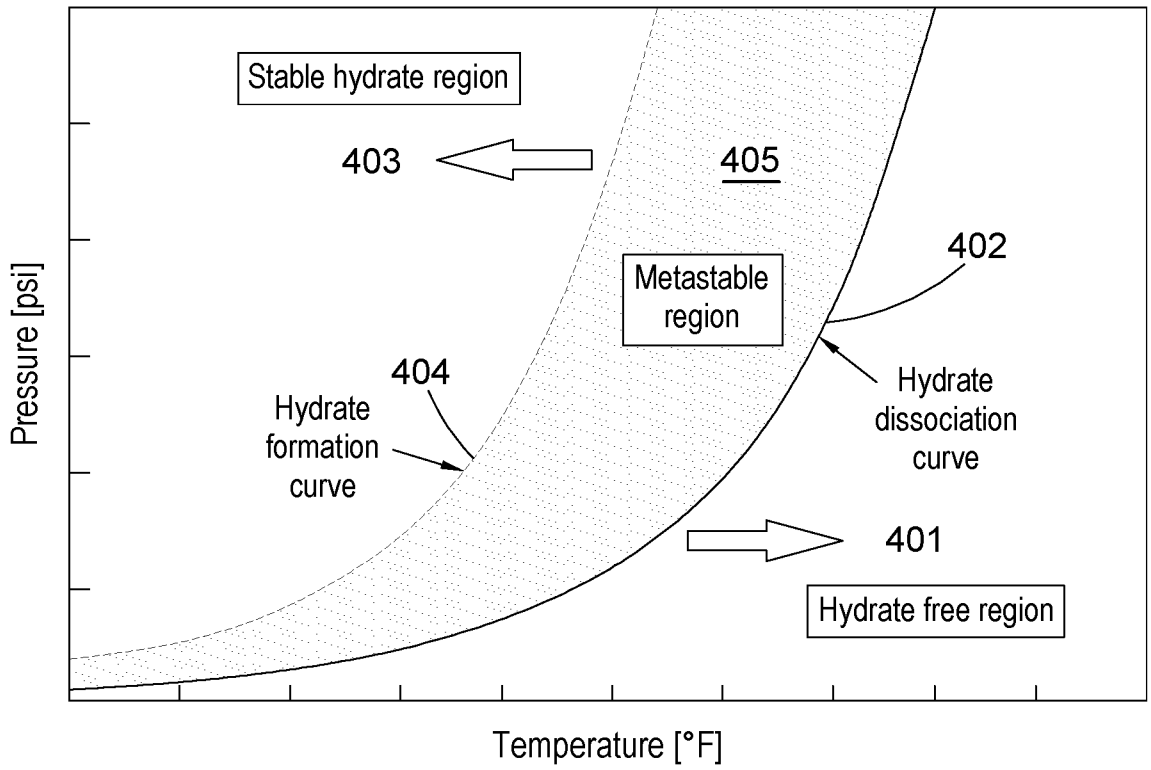

Stable hydrate region
403
405
402
Metastable region
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Hydrate formation curve
Hydrate dissociation curve
401
Hydrate free region
Pressure [psi]
Temperature [°F]

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2020/050175

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/01 (2006.01), E21B 43/017 (2006.01), E21B 43/34 (2006.01), B63B 27/24 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B, B63B

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

DK, NO, SE, FI: Classes as above.

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI, FULL TEXT: ENGLISH, GERMAN, FRENCH

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2018/139939 A1 (EQUINOR ENERGY AS) 2018.08.02. Abstract; figures 1-4; page 5, lines 7-14; page 8, lines 24-30; page 9, lines 8-16.	1, 2, 19-24
Y	>>	3, 7
Y,D	WO 2017/048132 A1 (EQUINOR ENERGY AS) 2017.03.23. Abstract; figures 1-3; page 2, paragraph 4; page 4, paragraph 3-4; page 22, paragraph 5.	3, 7
A	>>	1-26
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21/08/2020	25/08/2020
Name and mailing address of the ISA Nordic Patent Institute Helgeshøj Allé 81 DK - 2630 Taastrup, Denmark. Facsimile No. -	Authorized officer Solomon, Sirak Zere Telephone No. +47 22 38 75 21

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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