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(54) **MITIGATING HYDRATE FORMATION DURING A SHUTDOWN OF A DEEP WATER FPSO**

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(57) **ABSTRACT**

The present invention relates to a system and method for avoiding hydrate formation during a shutdown of a deep-water floating production, storage and offloading unit with a long distance tie back. In one embodiment the system is configured such that during a shutdown at least a portion of fluids in the production flow loop are delivered to the one or more wash tanks in the hull. Advantageously, this may allow one to avoid having to oversize the expensive top-side equipment.

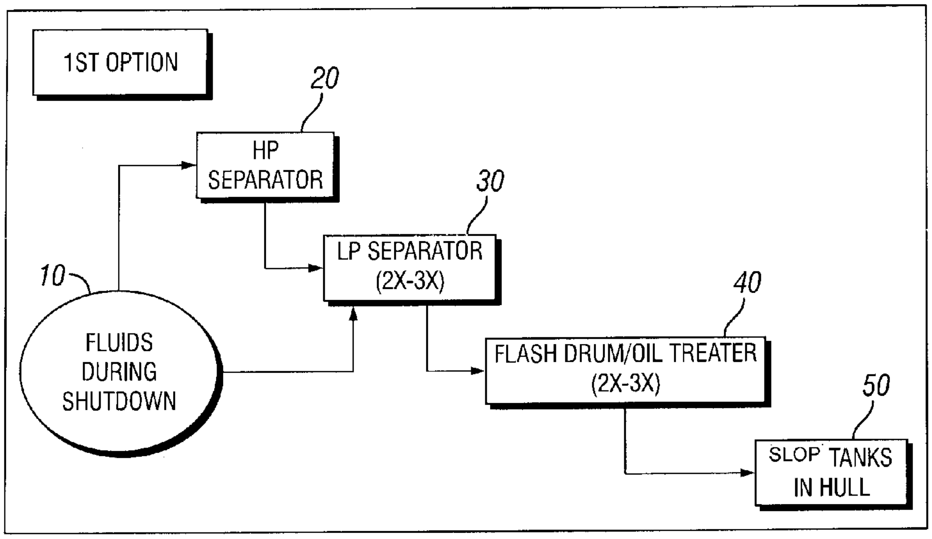
1ST OPTION
20
HP SEPARATOR
30
LP SEPARATOR (2X-3X)
10
FLUIDS DURING SHUTDOWN
40
FLASH DRUM/OIL TREATER (2X-3X)
50
SLOP TANKS IN HULL

FIG. 1

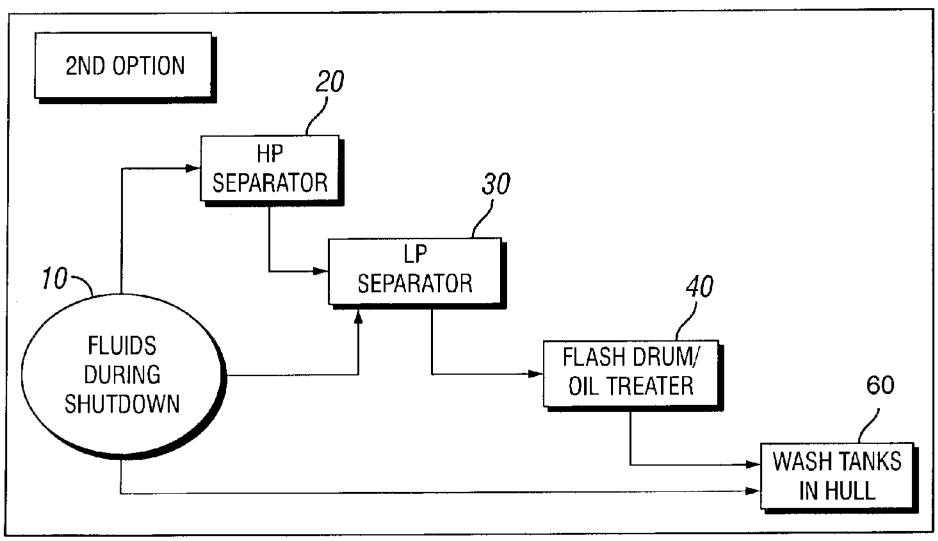
2ND OPTION
20
HP SEPARATOR
30
LP SEPARATOR
10
FLUIDS DURING SHUTDOWN
40
FLASH DRUM/ OIL TREATER
60
WASH TANKS IN HULL

FIG. 2

MITIGATING HYDRATE FORMATION DURING A SHUTDOWN OF A DEEP WATER FPSO

FIELD OF THE INVENTION

[0001] Embodiments disclosed herein relate to methods and systems for mitigating hydrate formation during a shutdown of a deep-water floating production, storage and offloading unit with long distance tie backs.

BACKGROUND AND SUMMARY

[0002] Deep-water floating production, storage and offloading (FPSO) units are frequently used in offshore production to process hydrocarbons and store oil until it can be offloaded to a tanker or in some cases transported through a pipeline. In many instances one FPSO unit may be connected to multiple subsea production wells some of which are very remote and some of which may be in very deep water. In such cases the production flow loops connecting the wells and FPSO units may be quite long and are therefore referred to as long distance tie-backs.

[0003] Long distance tie-backs present a number of technical challenges. One challenge is that during a decrease in flow and/or during a complete shut-down of flow in the production flow loop, hydrates may tend to form in the presence of CH_4 and H_2O in a low temperature and/or high pressure environment. Once formed these hydrates may cause significant problems. For example, since the hydrates are ice-like crystals they will often hinder and/or completely block the production flow loop. Once this occurs costly and complicated remediation efforts to unplug the production flow lines to resume production are usually necessary.

[0004] There are different approaches that have been developed to mitigate hydrate formation or avoid hydrate formation. One approach is to employ a fluid such as methanol which mixes with water and assists in preventing freezing. Another approach is to employ electric heating in appropriate portions of the system. Unfortunately, in addition to other disadvantages such approaches are often complex, expensive, or both. What is needed are new, less complex, less expensive methods and systems which assist in managing hydrates during shutdowns. It would be desirable if such new methods and systems could employ conventionally available equipment to solve the hydrate problems encountered in long distance tie-back and other situations when production is disrupted during, for example, a shutdown.

[0005] Advantageously, new subsea production systems and methods for managing hydrates during a shutdown have been discovered which solve many of the prior problems and use conventionally available equipment. In one embodiment the system comprises a production flow loop configured to deliver produced fluids from one or more remote subsea production wells with a long distance tieback (LTDB) to an offshore production facility. The offshore production facility comprises a floating production, storage and offloading (FPSO) unit with (1) top side equipment comprising at least one separation unit for separating oil, gas, and water in the produced fluids and (2) a hull comprising one or more wash tanks and one or more cargo tanks configured for storage of crude oil. The system is configured such that during a shutdown at least a portion of fluids in the production flow loop are delivered to the one or more wash tanks in the hull under conditions such that a minimal amount of hydrates form in the production flow loop.

[0006] In another embodiment the invention relates to a method for managing hydrates in a subsea production system during a shutdown. The method comprises first producing hydrocarbon fluids from one or more remote subsea production wells through a production flow loop to an FPSO. The FPSO comprises top-side equipment and a hull comprising a wash tank and a crude oil cargo tank. Next, the production of hydrocarbon fluids from the one or more remote subsea production wells through the production flow loop is interrupted. A displacement fluid is then pumped from or using the topside equipment, the hull, or both into the production flow loop to transfer at least a portion of the hydrocarbon fluids in the production flow loop to the top-side equipment, the wash tank, or both. This is usually accomplished by the hydrocarbon fluids in the production flow loop being replaced by the displacement fluid such that subsea production flow loop fluids are pushed to the top-side equipment, the wash tank, or both. At least a portion of the transferred hydrocarbon fluids are then dehydrated and degassed in the top-side equipment, the wash tank, or both.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** depicts embodiments pertaining to handling of displaced hydrocarbon fluids during a shutdown with flash drum/oil treater oversized by two to three times.

[0008] FIG. **2** depicts embodiments pertaining to handling of displaced hydrocarbon fluids during a shutdown without oversizing the flash drum/oil treater.

DETAILED DESCRIPTION

[0009] The present invention pertains in one embodiment to a method for managing hydrates in a subsea production system during a shutdown. The method comprises first producing hydrocarbon fluids from one or more remote subsea production wells through a production flow loop. By remote subsea production well is meant a subsea well that has a long distance tie-back (LDTB) to the offshore production facility. Such remote wells may often be more than 5000 feet deep and/or more than 20 miles from an offshore production facility, e.g., one comprising one or more FPSO units, and thus the configuration may be referred to as a long distance tie-back. In some example embodiments, the remote wells may be more than 40 miles from an offshore production facility.

[0010] The initial production of hydrocarbon fluids may be typical to what is ordinarily done in that hydrocarbon fluids from one, two, three, four, or even more remote wells flow through a production flow loop to, for example, an FPSO unit for processing. The FPSO unit will typically comprise top-side equipment and a hull.

[0011] The top side equipment may include any units that are useful for processing the hydrocarbon fluids. Such units will vary depending upon, for example, the type of well, composition of fluids, and desired processing. Typically, the top side equipment comprises at least one separation unit for separating oil, gas, and water in the produced fluids. Useful equipment is described in for example, US2011/0309040; WO2005/100512; and US2012/0031621 which for U.S. purposes are incorporated herein by reference. In some instances, the top side equipment may comprise one or more of a high pressure separator, a low pressure separator, a flash drum/oil treater, and a stabilizer.

[0012] The hull of the FPSO unit may be any useful hull that provides the required stability and, of course, its specific configuration may vary depending upon its location, desired functionality, and the top-side equipment that it must support. Typically, the hull comprises a number of tanks that are useful for storage and/or processing of hydrocarbon fluids. In one embodiment herein, the hull comprises one or more wash tanks and one or more cargo tanks which may be configured for storage of crude oil.

[0013] During a shutdown or other disturbance the present method interrupts the production of hydrocarbon fluids from the one or more remote subsea production wells through the production flow loop. Such interruption may be by any convenient manner and may vary depending upon the specifics of the equipment involved, the composition of the fluids, as well as, the length of shutdown or other disturbance. Typically, the interruption may be accomplished via valves, regulators, controllers or other devices within or adjacent the production flow loop.

[0014] Once the production of hydrocarbon fluids is interrupted and after the expiration of any no touch time period, displacement fluids are pumped into the production flow loop. The displacement fluid may be any fluid which is capable of pushing, i.e., transferring, at least the portion of the hydrocarbon fluids in the production flow loop that are potentially subject to hydrate formation out of the production flow loop. The specific type of displacement fluid may vary depending upon the application, equipment, flow loop distance, and hydrocarbon fluids but is typically a fluid that is not amenable to hydrate formation. Suitable displacement fluids may comprise, for example, a degassed oil sometimes referred to as dead oil. Such dead oil may come from the topside equipment, the hull, or both and act to push the hydrocarbon fluids in the production flow loop to the top-side equipment, the wash tank, or both. In one embodiment, crude oil in the cargo tank may be used for at least a portion of the displacement fluid and additionally or alternatively dehydrated and degassed produced hydrocarbon fluids from the wash tank or top-side equipment may be used for at least another portion of the displacement fluid.

[0015] Once the hydrocarbon fluids in the production flow loop have been pushed to the top-side equipment, the wash tank in the hull, or both the fluids may be dehydrated and/or degassed as desired. In the top-side equipment such dehydrating and/or degassing would generally occur in one or more of a high pressure separator, a low pressure separator, a flash drum/oil treater, and a stabilizer. Additionally or alternatively, additional aqueous phase and gaseous phase material may be separated from the liquid hydrocarbon phase at a reduced pressure as necessary and then further dehydrating and degassing of the liquid hydrocarbon phase may occur in a wash tank or other holding vessel. In one particular embodiment, the transferred hydrocarbon fluids are maintained at a temperature in the range from about 25° C. to about 50° C. and for a period of up to 24 hours in the wash tank or other holding vessel for dehydrating and degassing. If necessary or desired, these dehydrated and/or degassed fluids may then be employed to push additional hydrocarbon fluids in the production flow loop to the top-side equipment, the wash tank, or both.

[0016] Generally, the displacement fluid or fluids are supplied to the production flow loop under conditions such that only a minimal amount of hydrates can form in the production flow loop. A minimal amount of hydrates means preferably no hydrates but certainly less than an amount that hinders flow in the production flow loop. Typically, the conditions are such that the hydrate level in the loop does not increase. Conditions may vary but usually the displacement fluid is supplied to the production flow loop before any hydrate formation at a displacement fluid temperature of greater than 20° C., preferably at a temperature of from about 40° C. to about 70° C. Generally, the process of circulating the displacement fluid, e.g., dead oil, is initiated preferably not more than 4 hours after interrupting the production of hydrocarbon fluids.

[0017] While any convenient manner may be employed to deliver the displacement fluids, convenient systems and methods may use one or more properly configured circulation pumps to deliver displacement fluids from the FPSO to the production flow loop during a shutdown or other interruption. The specific type of the one or more circulation pumps is not particularly critical and the proper number type and number of circulation pumps may change depending upon the equipment, application, and installation.

[0018] The above described systems and methods may be sized appropriately depending upon the equipment and configuration. In one embodiment, the top side equipment is oversized relative to the production and fluid processing rates associated with the production flow loop and one or more remote subsea production wells. In this manner, the top-side equipment can handle a large volume of displaced hydrocarbon fluids from the production flow loop during the shutdown of the long distance tie back. In another embodiment, the top side equipment size is smaller relative to the production and fluid processing rates associated with the production flow loop and one or more remote subsea production wells. Advantageously, the top side equipment size can be made smaller because the system is configured such that during a shutdown at least a portion of produced fluids are delivered to one or more wash tanks in the hull instead of being delivered to top side equipment. In this manner, top-side equipment does not have to be sized to handle the majority to all of the displaced hydrocarbon fluids during shutdown.

[0019] Generally, the system may be configured such that fluids in the production flow loop that are delivered to the one or more wash tanks in the hull during shutdown comprise a gas to liquid ratio that is lower than that of fluids in the production flow loop delivered topside during normal operation. In this manner, displacement fluids may be made suitable to be sent directly to the hull wash tank even though production fluids during normal operation are not suitable.

[0020] Exemplary embodiments of the present disclosure is further illustrated by the following examples which should not be construed as limiting. The contents of all references, patents and published patent applications cited throughout this application, as well as the Figures and Tables are incorporated herein by reference.

[0021] With reference to FIG. **1**, as option **1** during a shutdown hydrocarbon fluids from the production flow loop **10** are pushed by a displacement fluid such as dead oil to a top-side low pressure separator **30** which is followed by a top-side flash drum/oil treater **40**. Once treated, the treated hydrocarbon fluids are transferred to slop tanks **50** in the hull. In this embodiment, fluid processing rates during shutdown may be from about **2** to about **3** times higher compared to normal processing rates. Therefore, the low pressure separator **20** and flash drum/oil treater **40** are sized from about 2 to about 3 times higher to handle this excess capacity.

[0022] A shown in FIG. **2**, as option **2** during a shutdown hydrocarbon fluids from the production flow loop **10** are pushed by a displacement fluid such as dead oil to a top-side low pressure separator **30** and/or a wash tank **60** in the hull. The hydrocarbon fluids may be treated in the wash tank to generate additional dead oil for use as displacement fluid. In this manner, top-side equipment does not have to be increased in size to handle additional capacity.

[0023] The claimed subject matter is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are intended to fall within the scope of the appended claims.

What is claimed is:

1. A subsea production system for managing hydrates during a shutdown, the system comprising:

a production flow loop configured to deliver produced fluids from one or more remote subsea production wells with a long distance tie-back (LTDB) to an offshore production facility;

an offshore production facility comprising a floating production, storage and offloading (FPSO) unit;

wherein the FPSO unit comprises (1) top side equipment comprising at least one separation unit for separating oil, gas, and water in the produced fluids and (2) a hull comprising one or more wash tanks and one or more cargo tanks configured for storage of crude oil;

wherein the system is configured such that during a shutdown at least a portion of fluids in the production flow loop are delivered to the one or more wash tanks in the hull under conditions such that a minimal amount of hydrates form in the production flow loop.

2. The system of claim **1**, further comprising one or more circulation pumps configured to deliver one or more displacement fluids from the FPSO to the production flow loop during a shutdown.

3. The system of claim **1**, wherein said displacement fluid comprise a degassed oil.

4. The system of claim **1**, wherein the top side equipment comprises one or more of a high pressure separator, a low pressure separator, a flash drum/oil treater, and a stabilizer.

5. The system of claim **4**, wherein the top side equipment is oversized relative to the production and fluid processing rates associated with the production flow loop and one or more remote subsea production wells.

6. The system of claim **4**, wherein the top side equipment size is smaller relative to the production and fluid processing rates associated with the production flow loop and one or more remote subsea production wells and wherein said top side equipment size is made smaller because the system is configured such that during a shutdown at least a portion of produced fluids are delivered to one or more wash tanks in the hull instead of being delivered to top side equipment.

7. The system of claim **1**, wherein the system is configured such that fluids in the production flow loop that are delivered to the one or more wash tanks in the hull during shutdown comprise a gas to liquid ratio that is lower than that of fluids in the production flow loop delivered topside during normal operation.

8. A method for managing hydrates in a subsea production system during a shutdown wherein said method comprises:

producing hydrocarbon fluids from one or more remote subsea production wells through a production flow loop to an FPSO comprising top-side equipment and a hull comprising a wash tank and a crude oil cargo tank;

interrupting the production of hydrocarbon fluids from the one or more remote subsea production wells through the production flow loop;

pumping a displacement fluid from the topside equipment, the hull, or both into the production flow loop to transfer at least a portion of the hydrocarbon fluids in the production flow loop to the top-side equipment, the wash tank, or both;

dehydrating and degassing at least a portion of the transferred hydrocarbon fluids in the top-side equipment, the wash tank, or both.

9. The method of claim **8**, wherein the step of dehydrating and degassing the liquid hydrocarbon phase during shutdown comprises:

separating additional aqueous phase and gaseous phase material from the liquid hydrocarbon phase at a reduced pressure;

further dehydrating and degassing the liquid hydrocarbon phase in a holding vessel.

10. The method of claim **8**, further comprising using at least a portion of the dehydrated and degassed produced hydrocarbon fluids as at least a portion of the displacement fluid.

11. The method of claim **8**, further comprising using crude oil in the cargo tank as at least a portion of the displacement fluid.

12. The method of claim **8**, further comprising using crude oil in the cargo tank as at least a portion of the displacement fluid and using at least a portion of the dehydrated and degassed produced hydrocarbon fluids as at least a portion of the displacement fluid.

13. The method of claim **9**, wherein the holding vessel is the wash tank in the hull of the FPSO.

14. The method of claim **8**, wherein the displacement fluid is supplied to the production flow loop under conditions such that a minimal amount of hydrates form in the production flow loop.

15. The method of claim **8**, wherein the transferred hydrocarbon fluids are maintained at a temperature in the range from about 25° C. to about 50° C. and for a period of up to 24 hours in a wash tank for dehydrating and degassing.

16. The method of claim **8**, wherein the displacement fluid is supplied to the production flow loop at a temperature of greater than 20° C.

17. The method of claim **8**, wherein the displacement fluid is supplied to the production flow loop at a temperature of from about 40° C. to about 70° C.

18. The method of claim **8**, wherein after interrupting the production of hydrocarbon fluids the displacement fluid is supplied to the production flow loop before hydrate formation.

19. The method of claim **8**, wherein the displacement fluid is supplied to the production flow within no more than about **4** hours after interrupting the production of hydrocarbon fluids.

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