APPARATUS AND A METHOD FOR DEPLOYMENT OF A WELL INTERVENTION TOOL STRING INTO A SUBSEA WELL

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ABSTRACT

The present invention relates to an apparatus and a method for subsea deployment and/or intervention through a wellhead (102) of a petroleum well (112). The apparatus comprises a first module (101) integrated in a portion of a subsea well intervention system assembly (102, 103) and/or a subsea production system assembly, the first module (101) comprising an intervention tool bore (201); a second module (301) comprising a tubular element (302) initially housing an intervention tool (314), wherein the second module (301) being arranged for sliding into releasable engagement with the intervention tool bore (201) of the first module (101), wherein upon the intervention tool (314) is arranged for disengagement from the tubular element (302) for deployment of the intervention tool (314) into the wellbore (112).
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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to and is a U.S. National Phase of PCT International Application Number PCT/NO2006/000087, filed on Mar. 8, 2006, which claims priority under 35 U.S.C. § 119 to Norwegian Application Number NO 20051257 filed on Mar. 11, 2005. The disclosures of the above-referenced applications are hereby expressly incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to an apparatus and a method for deployment of a well intervention tool string into a subsea well associated with the production of hydrocarbons.

[0004] 2. Background

[0005] Numerous of today’s wells related to the production of hydrocarbons are subsea wells, meaning that significant parts of the production hardware such as wellheads, valve arrangements, instrumentation, control systems, production manifolds and other accessories are located on the seabed.

[0006] Subsea field developments are common in the oil industry today. This field development philosophy enables a low capital expense for the initial field development compared to for example a platform solution. Hence, subsea production systems have enabled the development of small fields, remote locations, deep water areas and other fields where traditional platform solutions have been non-feasible due to high costs.

[0007] As they have matured, a significant operational expense problem has emerged for the subsea fields: Well maintenance/service is very expensive compared to platform wells.

[0008] Well maintenance and service comprises a range of methods for deploying relevant tool strings into live wells in order to do work. Traditional methods for deploying/intervening relevant tools into live wells comprise wire line, coil tubing, and wireline. The downhole tools that can be intervened and applied using such methods include perforation guns, zone isolation devices, data recording tools, fluid samplers, a range of mechanical tools and other devices.

[0009] Maintenance from a platform involves rigging up the required equipment (for instance wireline or coil tubing) on an appropriate deck space. Hence, the costs of maintenance are limited to renting/acquiring the equipment that is directly related to the operation of interest.

[0010] On subsea wells, a drilling rig or an intervention vessel must be mobilised in order to do the same work. Hence, rental costs for the rig/vessel comes on top of the cost of renting the intervention service (wireline/coil tubing) itself. This means that maintaining a subsea well is tremendously more expensive, typically ten times or more than maintaining a platform well.

[0011] There has been a large industrial focus on applying tailor-made vessels, typically boats, for the purpose of subsea well intervention. These have a somewhat lower cost than a drilling rig.

[0012] For intervention or maintenance operations to be performed on a live well, lubricator systems are utilised in order to get tools in and out of the well in a controlled manner. Typically, a lubricator system comprises the following:

[0013] A tree connector. This is the interface between the wellhead and the lubricator stack.

[0014] Valve housings, so-called BOP’s (blow out preventers). These include (gate-shaped) valves, that can cut cable and coil tubing and thereupon form a seal against the live well, as well as valves that can close around the cable/coil tubing, without damaging this, and form a seal against the well pressure.

[0015] Riser sections. This is simply spacer pipe. The accumulated length of the riser and BOP determines the length of tool string that can be intervened into the well in one run.

[0016] Top seal assembly. In order to run a cable or a coil tubing in and out of a well environment, a system that seals between the high-pressureised well environment and the atmospheric (for surface operations) or seabed pressure (for subsea operations) conditions on the outside of the lubricator, is needed.

[0017] For coil tubing operations, so-called stripper rubbers, that are ring-shaped moulds of elastomer material, nylon, Teflon or similar are used. Striper rubbers are commonly split in two for mounting purposes and access during the operation.

[0018] Annular bags can also be utilised for coil tubing operations. These are ring-shaped, elastomer-based barrier systems. Rubber elements are inflated around the coil in order to create a seal against it. Annular bags are also commonly used for heavier pipe operations, such as drilling. A major difference between the stripper rubber and the annular bag is the latter’s ability to seal against objects/pipes of various diameter.

[0019] For slick wireline (slickline) analogues to the stripper rubbers may be used, so-called stuffing boxes, which is a stack of elastomer packers that seal around the wire.

[0020] In order to intervene with a braided cable into a well, a so-called grease injection head (GIH) is required. By means of long, narrow pipes (flow tubes) and an injection system using viscous grease, the pressure differential between the well and the atmosphere is overcome and a braided cable intervention can be performed.

[0021] A lubricator ensures that barrier requirements are complied with during all stages of the well intervention operation. This means that new barriers (between the high-pressureised well fluid and the open environment) are established before old barriers are removed. As an example, a typical well intervention operation involves the following steps:

[0022] Assembly of the lubricator system and mounting of this onto the wellhead;

[0023] Mounting of the tool string inside the lubricator;

[0024] Closing of the lubricator with the tool string inside of it;

[0025] Filling the lubricator with a liquid, for example glycol;

[0026] Pressure testing the lubricator (upon doing this a new barrier has been established and verified);

[0027] Alignment of the lubricator pressure to equal the wellhead pressure;
Opening of the wellhead valves (i.e. the original barrier is removed);

Intervene the tool string into the well to do the required operation;

When bringing tools out of the well, reversed procedures similar to the one above are used to ensure that the original barriers (the wellhead valves) are re-established (closed) before opening the lubricator to take out/replace the tool string.

In relation to the development of subsea intervention vessels (boats), associated subsea lubricator assemblies are developed.

As of current, such subsea lubricator systems have been analogues to lubricator systems for surface/platform operations, as described in the previous section. Hence, a subsea lubricator system, common of today, is simply a “marinized” surface lubricator system, by means of adding features that compensate for the fact that there is a marine environment on the outside of the lubricator rather that atmospheric air.

Subsea lubricators as of today are limited by several factors.

There are height limitations in that the lubricator can not exceed a certain height. This is related to technical as well as economical considerations. For instance, increasing height means increasing bending momentum at the base of the subsea stack where the lubricator is anchored to the subsea wellhead. The latter has been a significant challenge and limitation with today’s lubricators. Also, should the lubricator become too high, big and bulky, this would impose additional requirements to the vessel, which again could make the operation exceed accepted economical limits.

The height restriction imposes direct limitations to tool string length. With current subsea lubricator systems and methods, the wellhead valves can not be opened prior to having connected, closed, performed fluid displacement, and pressure tested the lubricator itself. Hence, the current lubricator technology becomes the limiting factor with respect to tool string length. This again means that operations requiring long tool strings must be performed in several smaller steps. Such steps may drag the operation out in time and increase the costs dramatically. In worst case, operations are not initiated as they become non-economical.

As of today, the length of tool string that can be intervened in one run is limited to approximately 20 metres.

There exist lubricator concepts that apply telescopic joints in order to lengthen the lubricator. Typically, such telescopic joints are elongated downwards through the open wellhead, hence a lengthening of lubricator space by a factor close to 100%, compared to standard subsea lubricator systems, can be achieved.

For platform operations, there exists a deployment system that allows a tool string to be deployed through an open wellhead, and where the downhole safety valve (DHSV) is the only barrier when bringing tools in and out of the top section of the well. The aim with this technology has been to:

- Run (very) long tool strings into a live well
- Reduce the height of the traditional lubricator stack
- Enable operations in wellhead areas with height restrictions
- When using this technology, pressure is bled down above a closed down hole safety valve, DHSV, and the tools are brought into the well through a “wide open wellhead”.

Upon getting the tools in place, the top seal assembly (for example a grease injection head) is mounted on top of the lubricator stack, before the DHSV is opened and the tools are run to the lower sections of the well to do the work.

Here the lubricator stack and its functions are not removed, but the riser section is, and thereby the main component that contributes to height. By means of system features that guarantee that no object can fall into the well and damage the DHSV during rig-up, it is allowed to operate against only one barrier in certain stages of the operation.

Such platform deployment systems are not applicable on subsea wells as they cannot handle the pollution problematic: Well fluids that are present above the downhole safety valve would tend to segregate upwards and pollute the sea because the well fluids are lighter than the sea water.

**SUMMARY OF THE INVENTION**

The invention has as its object to remedy, or at least reduce, one or more drawbacks of the prior art.

The objects is realized through features which are specified in the description below and in the following Claims.

It is an object of the present invention to provide an apparatus for subsea intervention that reduce costs and operational complexity.

A further object of the present invention is to provide a method for utilising the apparatus according to the invention.

The invention aims at reducing lubricator height and, at the same time, dramatically increasing the length of tool string that can be intervened in one operational step.

The invention comprises a subsea deployment system and a method for conducting intervention. The subsea deployment system comprises two main modules, a first module that attaches to the subsea wellhead and/or lubricator assembly, and a second module that attaches to the tool string to be intervened. More specifically, the first module of the invention comprises a subsea deployment lubricator module hereinafter denoted as “SDLM”, which is a system component, or stack of system components, that forms part of a subsea lubricator. The second module of the invention comprises a subsea deployment intervention module hereinafter denoted as “SDIM” which attaches to the tool string to be intervened. The two system modules interface and interact in a manner that enables deployment of long tool strings into wells, with a minimal height subsea lubricator stack.

The main consequential differences between the invention and existing subsea lubricator systems are:

- Eliminate/reduced need for riser joints in the lubricator section, as the tool string is deployed “through the open subsea wellhead” by means of a unique subsea deployment technique.
- Capability to deploy almost unlimited length of tool strings in one run (the upper theoretical limit is given by the distance from the wellhead to the downhole safety valve).
- The main difference from deployment systems for surface/platform applications is a set of novel system components and techniques that ensure a seal to be present between the well and the outer environment (the sea) during deployment, hence well fluids cannot escape during the deployment operation.
- The SDLM is the “lubricator part” of the subsea deployment system. In one embodiment of the invention, the
lower end of the SDLM is attached to the wellhead and the upper end attached to a BOP (Blow Out Preventer) module. In another embodiment of the invention, the lower end of the SDLM is attached to the wellhead indirectly, by means of an interface module, a LRP (Lower Riser Package) or other similar equipment.

[0056] The SDLM comprises a main bore, preferably provided in the centre region, and normally of similar or larger inner diameter than the wellbore itself.

[0057] The SDLM comprises a seal arrangement. In one aspect of the invention the seal is a dynamic seal. In one embodiment, this is a stripper rubber made of elastomer, nylon, Teflon or similar material. By applying radial or axial forces, the seal arrangement according to said aspect is forced radial inwards to seal around any matching object that is inserted in the bore of the SDLM. In another embodiment of the invention, the seal arrangement is an annular bag or similar system that inflates around objects in the centre of the SDLM.

[0058] In one embodiment of the invention, the seal arrangement comprises one of said two sealing elements. In another embodiment of the invention, the seal arrangement comprises a stack of multiple amounts and/or types of sealing elements. In one embodiment of the invention, some of the seals in a stack serve the purpose as a well barrier, whereas other serves the purpose as “vipers” in order to prevent pollution to the sea. In one embodiment of the invention, only the “vipers” are fully active during normal operation, whereas the other sealing arrangements are activated in the case of emergency.

[0059] The SDLM also comprises a valve assembly. This serves the purpose to prevent upward segregating fluids from the well to pollute the marine environment in parts of the operational sequence. Also, the valve assembly serves the purpose of providing a barrier against the well during certain operational stages, and to provide means for pressure testing against, in order to verify seal integrity.

[0060] In a preferred embodiment of the invention, the valve assembly includes a double set of flapper type valves, where the upper is a tri-arm flapper and the lower is a conventional flapper valve. In one embodiment of the invention, the upper tri-arm flapper valve opens by means of forcing the intervention string assembly into it whereupon the lower flapper automatically opens as the two valves are mechanically hinged. Hence, the lower valve may be able to contain elastomer seals, sealing surfaces and other features that should not be exposed to mechanical contact with the intervention string. In summary, for this embodiment, the upper tri-arm flapper is to be considered a mechanical activation mechanism for the lower flapper that is the real barrier/sealing mechanism towards the wellbore. In one embodiment of the invention, the valve/valve assembly is spring-loaded and biases towards a closed position. In this case, should the intervention string be retrieved out of the valve assembly, the valves will automatically close.

[0061] In one embodiment of the invention, the above described valves are complemented with another valve, typically a ball- or a gate valve, located below the other valves. This valve enables pressure testing of seal integrity at the time of stinging the tool string assembly into the SDLM. In another embodiment of the invention, this latter valve fully replaces the need for one or both of the described flapper valves and is the only valve that is required for the described purposes.

[0062] In other embodiments of the invention, the valve assembly includes or comprises alternative valve types, such as ball valves, gate valves and other valves as well as a combination of such type valves. These valves could be operated mechanically, electrically, hydraulically or by means of other relevant forces, using intervention tools or surface operated electrical, hydraulic or other surface operation mechanisms connected to the subsea mounted equipment. Also, wireless activation signals could be applied to activate the valves.

[0063] In one embodiment of the invention, the SDLM comprises an anti-blowout system. In one embodiment of the invention, this is a device that is pre-installed and is centered in the bore of the SDLM, an anti-blowout sub, which attaches to the intervention string assembly during deployment. The anti-blowout sub has an OD that is larger than the ID of the SDLM above the hang-off point of the anti-blowout sub. Hence, the intervention string can not be blown out of the well.

[0064] In one embodiment of the invention, the anti-blowout sub and the matching anti-blowout profile in the SDLM have the shape and characteristics of a damper. In one embodiment of the invention, the two components form the male and female of a hydraulic damper, where fluid becomes trapped between the anti-blowout sub and the anti-blowout profile of the SDLM, and the said fluid only can escape via narrow channels that reduce in size or number the more fluid that is displaced. Hence, a gradual damping pattern is achieved in order to avoid system damage due to hard impacts between the anti-blow-out sub and the SDLM. In other embodiments of the invention, the damper mechanism is based on other known damper principles such as springs, friction dampeners and other.

[0065] In another embodiment of the invention, the anti-blowout function is handled by means of a gripping/locking system that prevents upward movement of the intervention string assembly. In one embodiment of the invention, upward movement of the intervention string assembly directly mechanically activates the gripping/locking system. In another embodiment of the invention, the gripping/locking system is activated by means of sensors detecting unwanted situations (leakage, kick, blowout, unexpected upward movement of the intervention string assembly). Such sensors could include detection devices for motion, position, pressure, fluid flowrate, fluid composition, volumetric changes and other. In one embodiment of the invention, the gripping/locking system is operator activated. In another embodiment of the invention, the gripping/locking system comprises a combination of some or all of the herein mentioned activation features.

[0066] In one embodiment of the invention, the gripping/locking system includes slips that slide gently along the intervention string assembly while this is being deployed into the well, but makes a firm grip at the instant this starts to move upwards. For deploying out of the well, the slips are foreseen retrieved/removed radial to some distance away from the intervention string assembly in order to deploy this out of the well (i.e. upward movement), but linked, in a fail-safe mode, to a release mechanism that activate the slips and make them grip the intervention string assembly in case an un-wanted event (e.g. a blowout, a kick or similar) should take place. Such an un-wanted event could be indicated by means of monitoring the speed of the upward movement of the intervention string assembly, the fluid displacement into the well.
during deployment out, acceleration or other indicators of unwanted events, or a combination of such.

[0067] In one embodiment of the invention, the gripping/locking feature is ensured by means of operator activation of the annular bag that in one embodiment forms part of the seal arrangement of the SDLM. Here, the annular bag is not fully inflated against the intervention string assembly during normal operations, but only so in the case of an emergency.

[0068] In a preferred embodiment of the invention, the SDLM comprises flushing systems in order to remove unwanted fluids from contained spaces before opening access to the well, to the open environment, to downflow or similar. In one embodiment of the invention, flushing lines are run and operated from the vessel used for the subsea intervention operation. In another embodiment of the invention, dedicated vessels/tanks and pump systems are used for flushing purposes.

[0069] In one embodiment of the invention, the SDLM and accessories comprises design and system to avoid fluids being trapped in contained spaces, which can prevent system functionality.

[0070] In a preferred embodiment of the invention, the SDLM and accessories comprises means for pressure testing and monitoring of such during all relevant operational stages.

[0071] In a preferred embodiment of the invention, the SDLM and accessories comprises means for monitoring of operational parameters such as pressure, temperature, fluid flow rate, volume displacement and fluid properties during all stages of the operation. In a preferred embodiment of the invention, the SDLM comprise a position indicator system that correlates with the intervention string assembly.

[0072] In a preferred embodiment of the invention, the SDLM comprises a stop arrangement for preventing further insertion of the intervention string assembly into the SDLM. Also, the SDLM comprises means for locking parts of the intervention string assembly in place during certain operational stages.

[0073] In one embodiment of the invention, the SDLM comprises access for a kill line to be attached, should there occur a need to kill the well. In one embodiment of the invention, the kill line is run and operated from the vessel used for the subsea intervention operation.

[0074] In one embodiment of the invention, the whole or parts of the SDLM is incorporated as a part of a permanent subsea wellhead system. Typically, the valve assemblies could form part of such a permanent system.

[0075] The SDLM is a device that, together with the intervention tools themselves, forms an intervention string assembly of the subsea deployment system.

[0076] The SDLM comprises a tubular element, hereinafter denoted as “flush pipe” and inner seal/latch sub to be mounted on the intervention tool string of interest. In one embodiment of the intervention, the tool string is mounted inside the flush pipe with at least one seal/latch sub provided in each endportion of the intervention tool string.

[0077] In a preferred embodiment of the invention, the outer surface of the flush pipe is uniform and smooth and forms a seal against the SDLM’s seal arrangement. Hence, when the SDIM is stung into the dynamic seal of the SDLM, this forms a seal in the annular space between the well and the open environment. Preferably, another seal of similar purpose is provided on the inside of the flush pipe present in the annular space defined by the flush pipe and the seal/latch subs attached to the tool string.

[0078] In one embodiment of the invention, in the bottom of the tool string, there is a connector sub for connecting the tool string to the anti-blowout sub of the SDIM. In one embodiment of the invention, the connector mechanism comprises a standard latch system, such as a GS type latch. In another embodiment of the invention, the anti-blowout sub latches onto the flush pipe of the SDIM (and not the tool string). In this embodiment, the anti-blowout sub is hollow and allows the intervention tool string to be run through it.

[0079] In a preferred embodiment of the invention, at least one of the seal/latch subs comprises a latch that attaches the intervention string to the flush pipe.

[0080] In one embodiment of the invention, the flush pipe does not cover parts of the tool string during installation. Typically, this involves cases where the tool string can be made of similar uniform shape and outer diameter as the flush pipe, and/or cases where said non-covered parts of the tool string are going to be permanently left in the well, such as for zone isolation devices. In one embodiment of the invention, the flush pipe is omitted. This would typically apply for cases where the entire tool string can be made of similar uniform shape and outer diameter as the flush pipe.

[0081] In a preferred embodiment of the invention, the flush pipe includes a so-called “no-go profile” in the top portion that matches a similar profile in the SDIM. This feature physically prevents the flush tube from being deployed lower than the no-go profile permits. One intention with the no-go feature is to ease exact depth determination. Also, the no-go feature is a very important system feature in case of an emergency. Should there occur a need to drop the SDIM, this will stop in a controlled manner in the no-go profile. Otherwise, a falling SDIM could drop through the downhole safety valve and create a severe situation. In one embodiment of the invention, the no-go system includes one or more dampening functions to enable a smooth landing of the SDIM into the SDLM, said functions could be hydraulic, spring-, friction-based or other damper principles.

[0082] In some situations, for example in the case of tool strings of varying outer diameter and shape, like production logging strings, it might not be feasible to use solid, large size seal/latch subs. In particular, such seal/latch subs could conflict with the operational scope if placed in the bottom of such tool strings. In one embodiment of the invention, hollow, fluted, expandable or similar feature seal/latch sub are used. In another embodiment of the invention, instead of a seal/latch sub, the bottom and/or other parts of the flush pipe is provided with a valve system. This could comprise one or more ball valves, gate valves, flapper valves, or other types and/or combination of valves. The operation of the valve system could be by means of a shifting tool located in the bottom of the tool string, or by means of surface operator controls that are mechanical, hydraulic, electrical, fibre-optical and/or wireless activation based. Remote activation techniques, such as wireless signals based on acoustic, electromagnetic, pressure pulse or other methods known per se, could be applied to activate the valve system.

[0083] In one embodiment of the invention, the SDIM comprises a system for fluid displacement. Typically, in order to avoid pollution when deploying out of the hole, this feature could be applied in cases where it is not possible to obtain a good seal between the flush pipe and the seal/latch subs after the tool string has been in the well.

[0084] In a preferred embodiment of the invention, the SDIM comprises passive modules of a position indicator
tool strings in one operational step, the subsea deployment system could be a valuable system component in each and every subsea intervention operation.

The subsea deployment system enables operations, that otherwise would require several runs in the hole, to be performed in only one run. Typically, such operations involve deploying long perforation guns, zonal isolation strings or data logging strings.

In the case of a horizontal x-mas tree, a typical subsea deployment and intervention method according to the invention would include the following steps:

1. Pull the debris cap off the tree.
2. Mount the SDLM on top of the wellhead or equivalent, using an appropriate connector sub.
3. Mount the BOP on top of the subsea lubricator module.
4. Pull the tree plugs of the horizontal x-mas tree. A small riser section on top of the SDLM and BOP might be required to get sufficient space. Upon pulling the tree plugs, the DHSV and the SDLM valve assembly forms the remaining barriers.
5. Mount the tool string inside the flush pipe, assembling component by component, whilst the lower segments are lowered into the sea. Inside the flush pipe, seal/latch joints are attached to the top and bottom of the tool string in order to form seals between the inside of the flush pipe and the outer environment. Typically, the assembly operation is conducted some horizontal distance away from the wellhead in case of accidentally dropped objects.

Prior to building the cable head and mounting this on top of the tool string, the cable is tread through the grease injection head.

When the SDLM is assembled: The vessel is positioned above the well and the SDLM lowered into the sea with the grease injection head following closely behind (above), both held by their respective wires and guiding systems.

The bottom of the SDLM/flush pipe is guided into the BOP and the SDLM. Now, the SDLM forms a seal against the SDLM dynamic seal, whereupon it latches onto the anti-blowout sub.

A pressure test is conducted to confirm seal integrity across the dynamic seal of the SDLM. For horizontal x-mas trees, this pressure test is conducted against a valve in the SDLM valve assembly. For vertical x-mas trees, this pressure test could be conducted against one of the valves in the tree itself.

Sea water that is trapped between the bottom of the SDLM and the SDLM valve assembly is removed by means of the SDLM flushing systems. This is done to avoid hydrate and similar problems that might occur when sea water becomes mixed with well fluids.

The anti-blowout sub is released from the SDLM and the SDLM is continued lowered into the hole.

The SDLM valve assembly is opened and the SDLM is lowered further, until the top of the SDLM is inside the SDLM and the no-go profiles meet.

The SDLM is anchored to the SDLM top section.

The grease injection head is lowered on top of and attached to the BOP. Now, the total “lubricator” is in place.
Sea water that is trapped between the top of the SDIM and the grease injection head is removed by means of the SDLM flushing systems.

The tool string is released from the flush pipe. This can be achieved by means of applying forces to the wireline cable or coil tubing, or by means of applying hydraulic, electrical, mechanical or other forces and/or impulses to the flush pipe through the wireline, coil tubing or directly from the vessel to the SDLM itself. Also, wireless communication methods could be applied for this purpose.

The tool string is run to the well section of interest, whereupon it performs the relevant operation, before it is retrieved out of the well.

The tool string is pulled into the flush pipe and latches onto the flush pipe's seal/latch sub profiles. The seals in the seal/latch subs in the top and bottom of the tool string ensures that pollutants from the well that might have attached to the tool string are now contained inside the flush pipe while deploying this out of the well and through open water.

Prior to disconnecting the grease injection head (GIIH) and pulling the flush pipe with the tool string out of the BOP, the volume between the grease injection head and the flush pipe is flushed with a fluid that replaces all well fluids and other contaminants. Typically, the replacement fluid is characterised by being harmless to the environment as well as being of a hydrate preventive nature.

In one embodiment of the invention, the flush pipe and the SDIM are flushed with a fluid that replaces most of the well fluids in order to avoid excessive exposure of such on the vessel.

The grease injection head (GIIH) is loosened from the BOP and lifted slightly above the rest of the lubricator stack.

The SDIM is loosened from the SDLM and retrieved out of the well.

The grease injection head (GIIH) is retrieved in the same operation.

Upon having passed the SDLM valve housing the anti-blowout sub connected to the SDIM lands in the anti-blowout profile of the SDLM.

The SDLM valve assembly is closed.

The volume between the SDLM valve assembly and the bottom of the SDIM is flushed with a fluid that replaces all well fluids and other contaminants.

The SDIM is released from the anti-blowout sub. This can be achieved by means of applying forces to the wireline cable or coil tubing, or by means of applying hydraulic, electrical, mechanical or other forces and/or impulses to the flush pipe through the wireline, coil tubing or directly from the vessel to the SDLM itself. Also, wireless communication methods could be applied for this purpose.

The SDIM is pulled out of the lubricator stack, whereupon the SDIM and the grease injection head are retrieved to the intervention vessel and disassembled.

The x-mas tree plugs are reinstalled and pressure tested.

Thereupon the BOP module and the subsea deployment lubricator module are retrieved.

The debris cap is reinstalled and the operation is finished.

BRIEF DESCRIPTION OF THE DRAWINGS

In what follows is described a non-limiting exemplary embodiment of a preferred embodiment which is visualized in the following drawings, in which:

FIG. 1 shows a simplified illustration of the overall lubricator system according to the present invention as it appears when rigged up at the seabed, with an intervention operation in progress.

FIG. 2 shows in a larger scale and partly in cross section the Subsea Deployment Lubricator Module (SDLM) with schematically illustrated internal features.

FIG. 3 shows in smaller scale a view of the Subsea Deployment Intervention Module (SDIM).

FIG. 4 shows partly in cross section a view of the SDIM in FIG. 3 with a wireline tool string (perforation gun) mounted inside.

FIG. 5 shows partly in cross section and in smaller scale a view of the SDLM and SDIM in a 1st step in the process of deploying in a wireline tool string.

FIG. 6 shows partly in cross section a view of the SDLM and SDIM in a 2nd step in the process of deploying in a wireline tool string.

FIG. 7 shows partly in cross section a view of the SDLM and SDIM in a 3rd step in the process of deploying in a wireline tool string.

FIG. 8 shows partly in cross section a view of the SDLM and SDIM in a 4th step in the process of deploying in a wireline tool string.

FIG. 9 shows partly in cross section a view of the SDLM and SDIM in a 5th step in the process of deploying in a wireline tool string.

DETAILED DESCRIPTION OF SOME PREFERRED EMBODIMENTS

FIG. 1 illustrates the system overview as it appears at the seabed with a wireline intervention in progress. The Subsea Deployment Module (SDLM) 101 is attached to the X-mas tree or wellhead 102. Alternatively there could be a separate module, for example a wellhead connector, between the SDLM 101 and the X-mas tree/wellhead 102, but that is not illustrated here. A BOP ( Blow Out Preventer) 103 is provided on top of the SDLM 101. A Grease Injection Head (GIH) 104 is provided on top of the BOP 103. A wireline cable 105 enters the GIH 104 in a top portion of the GIH 104. Inside the illustrated subsea stack, the intervention string assembly is located. However, this is not shown in FIG. 1. The Volume Monitoring and Storage Module (VMSM) 107 is connected to the production flowline 108. The VMSM comprises a volume tank 109 as well as instrumentation 110. A kill line 111 to the vessel is shown connected to the SDLM 101. Below the X-mas tree/wellhead 102, the wellbore 112, i.e. the well itself is illustrated.

FIG. 2 shows in a larger scale and partly in cross section the SDLM 101. This comprises a centre bore 201, a dynamic seal 202, a valve assembly 203 and an anti-blowout system 206. The valve assembly 203 comprises an upper, tri-arm flapper valve 204 and a lower, conventional flapper valve 205. Also, in this illustration, the anti-blowout system 206 comprises an anti-blowout sub 207 and a SDLM anti-blowout profile 208. In order to clean the system for unwanted
fluids at given operational stages, a flushing system comprising an upper flushing bore 209 and a lower flushing bore 210 are applied. For illustrative purposes the flushing system is only indicated by bores 209, 210 in the SDLM 101. However, a person skilled in the art will be familiar with such a flushing system. The SDLM 101 also comprises a dynamic seal activation system 212 for operating (activating/deactivating) the dynamic seal 202 also known to a person skilled in the art. In the upper portion of the SDLM 101, there is a SDIM latch 211 arranged for attaching to the intervention string assembly. Also, a lip or “no-go profile” 213 extending from the surface in the top portion of the bore 201 of the SDLM 101 is provided for receiving a corresponding profile of the SDIM 301, thereby preventing further deployment of the SDIM 301 in the bore 201 of the SDLM 101. The kill line 111 to the vessel is also illustrated. Accessories such as access lines, pumps, fittings, check valves, seals and similar are not shown. However, such accessories are known to a person skilled in the art.

FIG. 3 shows the SDIM 301 as it appears when assembled. In the upper portion, this module has an outer latch profile 312 and the SDIM no-go profile 313 as mentioned above. In the bottom, sticking out of the SDIM 301, a GS latch 311 is illustrated. The function and purpose of the components herein are explained in connection with FIGS. 5-9. A portion of a wireline cable 105 extending to the surface is also illustrated in the figures.

FIG. 4 illustrates the internal system components of the SDIM 301. The flush pipe 302 forms the outer body of the SDIM 301. This is a pipe element having an outer surface finish that enable the dynamic seal 202 of FIG. 2 to provide a seal against it. A wireline tool string 314 is mounted inside the flush pipe 302. Said tool string 314 comprises a cable head 303, an upper seal/latch sub 304 with its seal 305 and latch 306, the wireline tool 314 itself, in this example a perforation gun 307, a bottom seal/latch sub 308 with a seal 309 (no latch included on this sub) and a GS Latch 311. The GS latch 311 is provided for connecting the wireline tool string 314 onto the anti-blowout sub 207 illustrated in FIG. 2. In the upper end of the flush pipe 302, there is an outer latch profile 312 that allows the flush pipe 302 to be anchored to the SDLM 101 (cf. FIG. 2—the SDIM 209). The SDIM 301 is provided for receiving a wireline tool string 314 that matches the SDLM no-go profile 213 of FIG. 2.

FIG. 5 shows the 1st step in the process of deploying in a well service tool string using the Subsea Deployment Module. In the figure, the SDIM 301 is being lowered into the bore 201 of the SDLM 101, whereupon the GS latch 311 attaches to the anti-blowout sub 207.

FIG. 6 shows the 2nd step of the operation. Upon a successful connection of the GS latch 311 onto the anti-blowout sub 207, the anti-blowout sub 207 is released from the SDLM 101. The connection and release mechanism between the anti-blowout sub 207 and the SDLM 101 is not shown. However, such a release mechanism is known to a person skilled in the art and could for example, but not limited to, be a latch mechanism operated by applying forces on the wireline wire, or a release mechanism operated from the vessel or another remote location by means of hydraulic, electrical or mechanical impulses and/or activation mechanisms, or other known attachment/release mechanisms. Further, the SDIM 301 with the anti-blowout sub 207 is lowered further until it contacts the tri-arm flapper valve 204. This also forces the conventional flapper valve 205 to open, whereupon the SDIM 301 with the anti-blowout sub 207 is further lowered towards and into the wellbore.

FIG. 7 shows the 3rd step in the process. Here, the SDIM 301 with the anti-blowout sub 207 is further lowered towards and into the wellbore until the flush pipe 302 lands inside the SDLM 101. This takes place when the SDIM no-go profile 313 has made a physical step in the SDLM no-go profile 213. Now, the SDIM latch 211 of the SDLM 101 is aligned with the Outer Latch Profile 312 of the flush pipe 302.

FIG. 8 shows the 4th step of the operation. Here, the SDIM latch 211 of the SDLM 101 is activated to attach onto the outer latch profile 312 of the flush pipe 302, hence the flush pipe 302 becomes attached to the SDLM 101.

FIG. 9 shows the 5th step in the process. Here, the wireline tool 314 is released from the flush pipe 302 by means of releasing latch 306 of the upper seal/latch sub 304. When the latch 306 is disconnected, the wireline tool 314 is free to be intervened into the well. Prior to releasing the latch 306, the Grease Injection Head (GIH, cf. 104 in FIG. 1) is mounted on top of the SDLM 101 in order to ensure that all required barriers between the well and the outer environment are in place prior to the well intervention. In this example, the anti-blowout sub 207 follows the wireline tool 314 into the well during the well intervention. In a preferred embodiment of the invention, the anti-blowout sub 207 attaches to the flush pipe 302 directly and does not follow the wireline tool 314 into the well. When deploying out of the well, the sequence described in FIGS. 5-9 is mainly reversed, with some minor variations. Flushing to displace unwanted fluids might be required in one or more steps to avoid pollution to the sea when pulling the SDIM 301 out of the SDLM 101 after ended operation.

1. An apparatus for subsea deployment and/or intervention through a wellhead (102) of a petroleum well (112), characterized in that the apparatus comprises:

a. a first module (101) integrated in a portion of a sub-sea well intervention system assembly (102, 103) and/or a subsea production system assembly, the first module (101) comprising an intervention tool bore (201);

b. a second module (301) comprising a tubular element (302) initially housing an intervention tool (314), the second module (301) being arranged for sliding into releasable engagement with the intervention tool bore (201) of the first module (101), whereupon the intervention tool (314) is arranged for disengagement from the tubular element (302) for deployment of the intervention tool (314) into the wellbore (112).

2. The apparatus according to claim 1, characterized in that at least one portion of the tool bore (201) is provided with at least one seal element (202) arranged for sealing an annulus defined by the tool bore (201) and the second module (301).

3. The apparatus according to claim 2, characterized in that the at least one seal element is a dynamic seal (202).

4. The apparatus according to claim 1, characterized in that the second module (301) is provided with a seal arrangement (305, 309) for sealing off an annular space defined by the tubular element (302) and the intervention tool (314).

5. The apparatus according to claim 1, characterized in that a portion of the tool bore (201) of the first module (101) comprises a valve assembly (203) which in a closed position provides a barrier between the well (112) and a downstream portion of said first module (101).

6. The apparatus according to claim 1, characterized in that the second module (301) is provided with at least one latch
device (306, 310) arranged for selectively disengaging the intervention tool (314) from the tubular element (302).

7. The apparatus according to claim 1, characterized in that the first module (101) is provided with a bore (111) for connection of a kill line (111).

8. The apparatus according to any of the preceding claims, characterized in that the apparatus is provided with an anti-blowout device (206).

9. The apparatus according to claim 8, characterized in that the anti-blowout device (206) comprises an anti-blowout sub (207) and an anti-blowout profile (208), said profile (208) being provided within or being an integrated part of a portion of the bore (201) of the first module (101), said profile (208) being arranged downstream of said sub (207), wherein an outside diameter of said sub is larger than the internal diameter of said profile (208).

10. The apparatus according to claim 9, characterized in that the sub (207) is hollow and is arranged to engage with a portion of the tubular element (302).

11. The apparatus according to claim 8, characterized in that the anti-blowout device (206) comprises means arranged for gripping and locking the movement of the second module (301) in the first module (101).

12. The apparatus according to claim 11, characterized in that the anti-blowout device (206) comprises a slips module comprising slips arranged to glide along the outside of the second module (301) during deployment into the well (112) and, if the second module (301) is instantly moved in an upward direction out of the well (112), is arranged to grip around a portion of the second module (301).

13. The apparatus according to any of the preceding claims, characterized in that the first module (101) is provided with at least one flushing system (209, 210) for removing unwanted fluids from contained spaces before providing access to the well.

14. The apparatus according to any of the preceding claims, characterized in that the first module (101) is provided with a stop arrangement (213) for engaging a substantially corresponding stop arrangement (313) in the second module (301), thereby preventing further insertion of the second module (301) beyond an ultimate insertion position of the second module (301) in the bore (201) of the first module (101).

15. A method for subsea deployment and/or intervention of a petroleum well (112) through a wellhead (102), characterized in that the method comprises the following steps:

   1. integrating a first module (101) that comprises an intervention tool bore (201), in a portion of a subsea well intervention system assembly (102, 103) and/or a subsea production system assembly;
   2. lowering a second module (301) comprising a tubular element (302) sealingly housing an intervention tool (314) engaged with the tubular element (302) into engagement with the tool bore (201) of the first module, at least a portion of the annulus defined between the tool bore (201) and the tubular element (302) being sealed;
   3. disengaging the intervention tool (314) from the tubular element (302), and
   4. running the intervention tool (314) into the wellbore (112).

16. A method for retrieval and/or deploying out of an intervention tool (314) through a wellhead (102) of a subsea petroleum well (112), characterized in that the method comprises the following steps:

   1. pulling the intervention tool (314) into engaging connection inside a tubular element (302) of a second module (301), the annulus defined by the tubular element (302) and the intervention tool (314) being sealed at a top portion and a bottom portion of the second module (301), a portion of which being in engagement with and sealingly housed in a tool bore (201) of a first module (101);
   2. disengaging the second module (301) sealingly housing the intervention tool (314), and
   3. retrieving the second module (301) out of the first module (101) through open water and to a surface.

17. The method according to claim 14, characterized in that flushing operations are executed during the retrieval of the second module (301) from the first module (101) in order to avoid any well fluid to communicate into the environment outside the well.

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