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(71) Applicant: **CONOCOPHILLIPS COMPANY** [US/US]; Legal Dept. - Technology and Intellectual Property - Attn: Docketing, 600 N. Dairy Ashford, Houston, Texas 77079 (US).

(72) Inventor: **FOSTER, Ross**; Rubislaw House, Anderson Drive, Aberdeen Aberdeenshire AB156FZ (GB).

(74) Agent: **PIO, Michael Sungjoon**; Conocophillips Company, Technology & Intellectual Property, 600 N. Dairy Ashford, Houston, Texas 77079 (US).

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(54) Title: SUBSEA SYSTEM FOR SEABED OPERATIONS

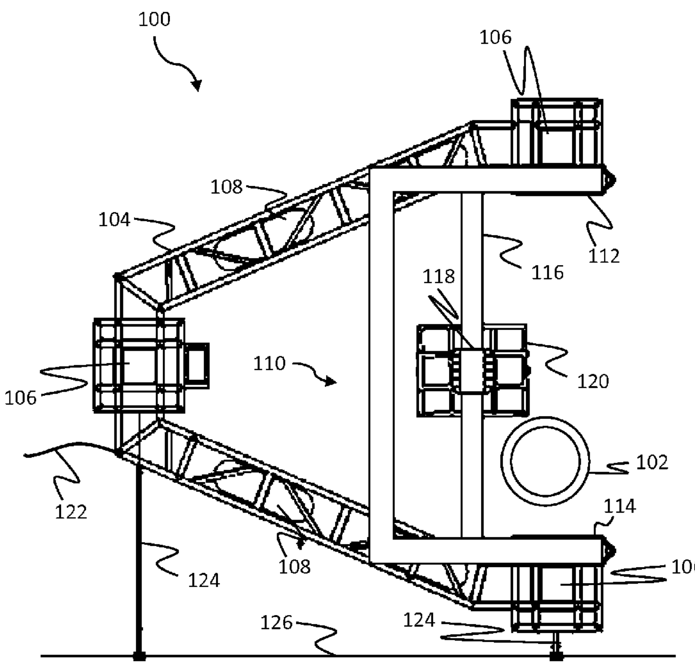

FIG. 1

(57) Abstract: Methods and systems relate to seabed operations, such as well intervention or capping, involving subsea equipment and subsea handling of the equipment, which may be associated with hydrocarbon wells or pipelines. A subsea system submerges during deployment and is landed on the seabed. The system may include a suspension assembly coupled to a frame structure for carrying equipment used in the operations. The deployment of the system may include deploying the frame structure with the equipment from a floating vessel connected to an anchored tether and moving the frame structure under water along the tether toward where anchored and the location for the seabed operations.

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SUBSEA SYSTEM FOR SEABED OPERATIONS

FIELD OF THE INVENTION

[0001] Embodiments of the invention relate generally to operations involving subsea equipment and subsea handling of the equipment, which may be associated with hydrocarbon wells or pipelines.

BACKGROUND OF THE INVENTION

[0002] Deepwater oil and gas developments require wells and pipelines with various components disposed on the seabed. At times, the components require servicing including maintenance or capping a well. Underwater location of the components makes access difficult for supporting, carrying, removing, positioning, installing and/or operating necessary equipment at the seabed.

[0003] A remote operated vehicle (ROV) may work to carry out some tasks but has inherent limits for size and complexity of the functions to be performed. Currents may limit towing and positioning of buoyant structures employed in some prior approaches. Operators rely on conventional rigs, such as floating platforms or jack-up rigs with decks above water, for such operations as interventions.

[0004] However, a blowout situation may require maintaining a safe distance away from the blowout limiting ability to position the rig above where desired. Presence of ice on the sea may also inhibit locating the rig as needed. Avoiding damage to surrounding pipelines and managing currents and possible turbulent flows of escaping hydrocarbons further complicates potential options for servicing the well or pipeline.

[0005] Therefore, a need exists for systems and methods to enable subsea handling of equipment associated with a hydrocarbon well or pipeline located on a seabed.

BRIEF SUMMARY OF THE DISCLOSURE

[0006] For one embodiment, a subsea system for seabed operations includes a frame structure. Buoyancy members attach to the frame structure for submergence of the system and are controllable to set submerged weight of the system on the seabed. A suspension assembly coupled to the frame structure carries equipment used in the operations and moveable by the suspension assembly relative to the frame structure.

[0007] In one embodiment, a method of operating on a seabed with a subsea system includes submerging the system including a frame structure. The method further includes adjusting buoyancy members attached to the frame structure for the submerging and for setting submerged weight of the system on the seabed. Controlling a suspension assembly coupled to the frame structure moves equipment carried by the system relative to the frame structure for operational positioning of the equipment over the seabed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A more complete understanding of the present invention and benefits thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings.

[0009] Figure 1 is a top view of a subsea structure disposed on a seabed in position for work on a well, according to embodiments of the invention.

[0010] Figure 2 is a side view of the subsea structure coupled to a tether, according to embodiments of the invention.

[0011] Figure 3 is a view of a floating vessel and an anchor handler used to pull the tether from the floating vessel, according to embodiments of the invention.

[0012] Figure 4 is a schematic depicting a path of the anchor handler around an exclusion zone to position the tether intersecting the exclusion zone, according to embodiments of the invention.

[0013] Figure 5 is a view of the floating vessel with the tether anchored for deployment of the subsea structure, according to embodiments of the invention.

[0014] Figure 6 is an enlarged view of an anchor next to the well and having a sheave through which the tether passes, according to embodiments of the invention.

[0015] Figure 7 is a side view of the subsea structure during deployment along the tether toward the well, according to embodiments of the invention.

[0016] Figure 8 is a view of a conduit deployment process utilizing the tether in carrying the conduit toward the well, according to embodiments of the invention.

DETAILED DESCRIPTION

[0017] Turning now to the detailed description of the preferred arrangement or arrangements of the present invention, it should be understood that the inventive features and concepts may be manifested in other arrangements and that the scope of the invention is not limited to the embodiments described or illustrated. The scope of the invention is intended only to be limited by the scope of the claims that follow.

[0018] Embodiments of the invention relate to methods and systems for seabed operations, such as well intervention or capping, involving subsea equipment and subsea handling of the equipment, which may be associated with hydrocarbon wells or pipelines. A subsea system submerges during deployment and is landed on the seabed. The system may include a suspension assembly coupled to a frame structure for carrying equipment used in the operations. The deployment of the system may include deploying the frame structure with the equipment from a floating vessel connected to an anchored tether and moving the frame structure under water along the tether toward where anchored and the location for the seabed operations.

[0019] Figure 1 illustrates a subsea structure 100 disposed on a seabed in position for work on a well 102, which is shown as an example only and may represent any subsea apparatus including pipelines requiring work. The structure 100 includes a frame 104 made of a steel structural open network with three jack-up legs 106, buoyancy members 108 and a suspension assembly 110. Given an exemplary C, U or V shape of the frame 104, an open side of the frame 104 enables the structure 100 to be moved sideways as described further herein and be disposed around and receive wellhead components of the well 102 extending from the seabed.

[0020] For some embodiments, the suspension assembly 110 includes a first rail 112 parallel to a second rail 114 and a cross bar 116 spanning, and perpendicular to, the first and second rails 112, 114. A hoist 118 couples equipment 120 to the cross bar 116 for carrying the equipment 120 subsea with the structure 100. Operations with the well 102 rely on the equipment 120, such as a capping and/or containment stack to kill and/or divert flow from a blowout of the well 102. For other examples of installation, removal or repair work to be performed, the equipment 120 may include a rotary drive, a pump or wellbore tools, such as logging, perforating, plugging or stimulation tools.

[0021] The suspension assembly 110 enables movement of the equipment 120 relative to the frame 104, which remains stable and supported on the seabed once in position for the work on the well 102. As with any operation of the structure 100, control of this movement comes from an operator sending commands from above to subsea via a direct umbilical line 122 to the structure 100 or a remote operated vehicle (ROV) having a communication line back to surface. The ROV may interface with the structure 100 for the operation of the structure 100 and may be carried subsea by latching to the structure 100, for example, to limit problems with long distance travel of the ROV.

[0022] An actuation mechanism, such as a piston and cylinder or rack and pinion assembly, may move the cross bar 116 along the first and second rails 112, 114 to facilitate movement of the equipment 120 in a first horizontal direction. Another actuation mechanism may move the hoist 118 along the cross bar 116 for moving the equipment 120 in a second horizontal direction perpendicular to the first horizontal direction. A further actuation mechanism of the hoist 118 may rotate the equipment 120 and/or provide angular motion from the hoist 118 relative to the frame 104.

[0023] A conveyance coupling 124 shown gripping a tether 126 at two locations attaches the frame 104 to the tether 126 for deployment as described herein. In some embodiments, a polyethylene cable or DYNEEMA® rope provides the tether 126 to limit weight relative to steel cables, which could also present problems due to potential for steel cables cutting pipelines on the seabed. A secondary tether used in combination with the tether 126 may function like the tether 126 but attaches to an opposite side of the frame 104 from the coupling 124 in situations where sea current or tide conditions challenge deployment using the tether 126 alone.

[0024] Figure 2 shows the subsea structure 100 coupled to the tether 126. An additional actuation mechanism 214 enables raising and lowering the rails 112, 114 in a vertical direction relative to the frame 104 and thereby adjusts height of the equipment 120 above the seabed once the legs 106 are set in a lowered position. The legs 106 remain retracted upward as depicted during deployment to avoid the system 100 dragging the seabed or hitting pipelines crossed as being deployed.

[0025] During deployment the structure 100 moves along the tether 126. In some embodiments, the conveyance coupling 124 grips the tether 126 pulled in order to move the structure 100. Alternative arrangements may move the structure 100 with a tractor of the conveyance coupling 124 to advance along the tether 126 without movement of the tether 126. The conveyance coupling 124 attaching the frame 104 to the tether 126 may also include a guide through which a returning portion 226 of a loop formed by the tether 126 slides and passes without being gripped.

[0026] Once in position at the well 102 as depicted in Figure 1, control of the buoyancy members 108, e.g., by gas release, sets submerged weight of the structure 100 on the seabed. As used herein, submerged means the structure 100 is completely covered by water. The legs 106 extend downward relative to the frame 104 jacking up the frame 104 over the seabed and supporting the submerged weight.

[0027] Figure 3 illustrates a floating vessel 300 and an anchor handler 302 used to pull the tether 126 from the floating vessel 300 in an initial stage for deployment of the structure 100. An anchor 304 couples to the tether 126 and hooks, as may be assisted by an ROV, to the anchor handler 302. The anchor handler 302 takes the anchor 304 to where desired for being dropped and set.

[0028] Figure 4 shows a path of the anchor handler 302 around an exclusion zone 400. The exclusion zone 400 may represent an area considered unsafe for personnel or equipment due to a well blowout beneath the exclusion zone 400. The exclusion zone 400 could also result from ice on the sea preventing access by the floating vessel 300, provided the anchor 304 may be preset or the anchor handler 302, e.g., a subsea vessel, may still be able to tow the anchor 304 to where desired.

[0029] The anchor handler 302 and the tether 126 move through the path over time and are thus depicted at five distinct times for schematic representation as the anchor handler 302 moves further away from the floating vessel 300. In a final position of the anchor handler 302, the tether 126 intersects the exclusion zone 400 without need to have the anchor handler 302 travel through the exclusion zone 400. For some embodiments, the floating vessel 300 at all times remains disposed at least 1000 meters in a horizontal direction away from above a location for the well 102 or the seabed operations during the deploying of the structure 100 and the operation at the well 102 using the structure 100.

[0030] Figure 5 illustrates a subsequent step in the deployment of the structure 100 with the tether 126 anchored to the seabed 502. Due to the final position of the anchor handler 302, the anchor 304 sets proximate the well 102. In some embodiments, the tether 126 through use of a clump weight 504, for example, fixes to the seabed 502 at another location away from the anchor 304 and in a direction toward the floating vessel 300.

[0031] The floating vessel 300 includes a winch 506 to provide aforementioned pull of the tether 126 used to advance the structure 100. In addition, the operator for the structure 100 and/or the ROV may reside on the floating vessel 300. Once the tether 126 is set as depicted, the structure 100, which is towed by the vessel 300 or a tug or is lifted off a side of the vessel 300, is submerged and attaches to the tether 126.

[0032] Controlling the buoyancy members 108 for submergence of the structure 100 may occur by trimming gas tanks forming the buoyancy members 108. Variable lift provided by the buoyancy members 108 adjusts for weight of the equipment 120 needed to be carried. The winch 506 then takes in the return portion 226 of the tether 126 to cause an advancing portion of the tether 126 let out from another spool on the vessel 300 to advance toward the well 102. While the structure 100 is traveling underwater in a horizontal direction toward the well 102, the buoyancy members 108 may provide neutral buoyancy for the structure 100 or otherwise provide lift selected to maintain the structure 100 submerged and above the seabed without over countering the anchor 304 and weight 504.

[0033] Figure 6 shows a sheave 600 through which the tether 126 passes proximate the well 102 and is an enlarged detailed view around the well 102 in Figure 5. A linker 602, such as a chain, connects the anchor 304 to the sheave 600 held off the seabed by a float 604. The sheave 600 forms the point where the tether 126 loops back toward the vessel 300 as the return portion 226 and may be disposed between the anchor 304 and the well 102 opposite the well 102 from the vessel 300.

[0034] Figure 7 illustrates the subsea structure 100 during deployment along the tether 126 toward the well 102. Final intake of the structure 100 toward the well 102 may employ use of the ROV and a winch between the well 102 and the structure 100. The operations on the seabed then commence with the structure 100 as desired.

[0035] Some embodiments may also utilize the structure 100 to assist with making a conduit connection given the following description regarding conduit deployment. After use, the structure 100 remains secured to the seabed 502 to enable leaving and abandoning the structure 100 without risks from drifting. However, recovery of the structure 100 may take place by reversing the deployment procedure and direction of pull to the tether 126. Compressed air to the buoyancy members 108 may lift the structure 100 for the recovery. In some embodiments, the structure 100 may release from the tether 126 and be picked up from straight above with conventional techniques since risk preventing deployment access is gone due to the operations performed.

[0036] Figure 8 shows a conduit deployment process from a service vessel 800 utilizing the tether 126 to carry a conduit 802 toward the well 102. Buoyancy modules 804 counter weight of the conduit 802. The conduit 802 may connect to the containment stack added to the well 102 to recover escaping hydrocarbons and provide a flow pathway to a vessel capable of handling/processing/storing hydrocarbons.

[0037] For the deployment process, a ROV 806 clamps the conduit 802 to the tether 126. The floating vessel 300 then pulls the tether 126 to advance the tether 126 toward the well 102, as described with respect to the structure 100. The conduit 802 upon being taken along the tether 126 to the well 102 may be connected to the well 102 using the ROV 806.

[0038] In closing, it should be noted that the discussion of any reference is not an admission that it is prior art to the present invention, especially any reference that may have a publication date after the priority date of this application. At the same time, each and every claim below is hereby incorporated into this detailed description or specification as additional embodiments of the present invention.

[0039] Although the systems and processes described herein have been described in detail, it should be understood that various changes, substitutions, and alterations can be made without departing from the spirit and scope of the invention as defined by the following claims. Those skilled in the art may be able to study the preferred embodiments and identify other ways to practice the invention that are not exactly as described herein. It is the intent of the inventors that variations and equivalents of the invention are within the scope of the claims while the description, abstract and drawings are not to be used to limit the scope of the invention. The invention is specifically intended to be as broad as the claims below and their equivalents.

CLAIMS

1. A subsea system for seabed operations, comprising:

a frame structure;

buoyancy members attached to the frame structure for submergence of the system and controllable to set submerged weight of the system on the seabed; and

a suspension assembly coupled to the frame structure for carrying equipment used in the operations and moveable by the suspension assembly relative to the frame structure.

2. The subsea system according to claim 1, wherein the suspension assembly is operable via an umbilical line connecting the subsea system to a floating vessel.

3. The subsea system according to claim 1, further comprising jack-up legs extendable from the frame structure for supporting the submerged weight of the system on the seabed.

4. The subsea system according to claim 1, wherein the equipment is movable by the suspension assembly in vertical and horizontal directions relative to the frame structure.

5. The subsea system according to claim 1, wherein the equipment is movable by the suspension assembly in a vertical direction and perpendicular horizontal directions relative to the frame structure.

6. The subsea system according to claim 1, wherein the suspension assembly includes: parallel rails moveable in an up and down direction relative to the frame structure; a cross bar spanning the rails and moveable along the rails; and a hoist coupled to the equipment and moveable along the cross bar.

7. The subsea system according to claim 1, wherein the equipment is movable by the suspension assembly in vertical, horizontal and rotational directions relative to the frame structure.

8. The subsea system according to claim 1, wherein the equipment is movable by the suspension assembly in vertical, horizontal, rotational and angular directions relative to the frame structure.

9. The subsea system according to claim 1, wherein lift provided by the buoyancy members is variable to adjust for weight of the equipment needed to be carried.

10. The subsea system according to claim 1, wherein the frame structure has an open side to enable the system to be moved sideways into position around an object on the seabed for the operations.

11. The subsea system according to claim 1, wherein the equipment includes at least one of a well capping stack and a well containment stack.

12. A method of operating on a seabed with a subsea system, comprising:

submerging the system including a frame structure;

adjusting buoyancy members attached to the frame structure for the submerging and for setting submerged weight of the system on the seabed; and

controlling a suspension assembly coupled to the frame structure in order to move equipment carried by the system relative to the frame structure for operational positioning of the equipment over the seabed.

13. The method according to claim 12, wherein the controlling of the suspension assembly is via an umbilical line connecting the subsea system to a floating vessel.

14. The method according to claim 12, further comprising extending jack-up legs from the frame structure to support the submerged weight of the system on the seabed.

15. The method according to claim 12, wherein the controlling of the suspension assembly moves the equipment in vertical and horizontal directions relative to the frame structure.

16. The method according to claim 12, wherein the equipment is movable by the suspension assembly in a vertical direction and perpendicular horizontal directions relative to the frame structure.

17. The method according to claim 12, wherein the suspension assembly includes: parallel rails moveable in an up and down direction relative to the frame structure; a cross bar spanning the rails and moveable along the rails; and a hoist coupled to the equipment and moveable along the cross bar.

18. The method according to claim 12, wherein the controlling of the suspension assembly moves the equipment in vertical, horizontal and rotational directions relative to the frame structure.

19. The method according to claim 12, wherein the system moves in a horizontal direction into position around an object by an open side of the frame structure receiving the object on the seabed and over which the equipment operates.

20. The method according to claim 12, wherein the equipment includes at least one of a well capping stack and a well containment stack.

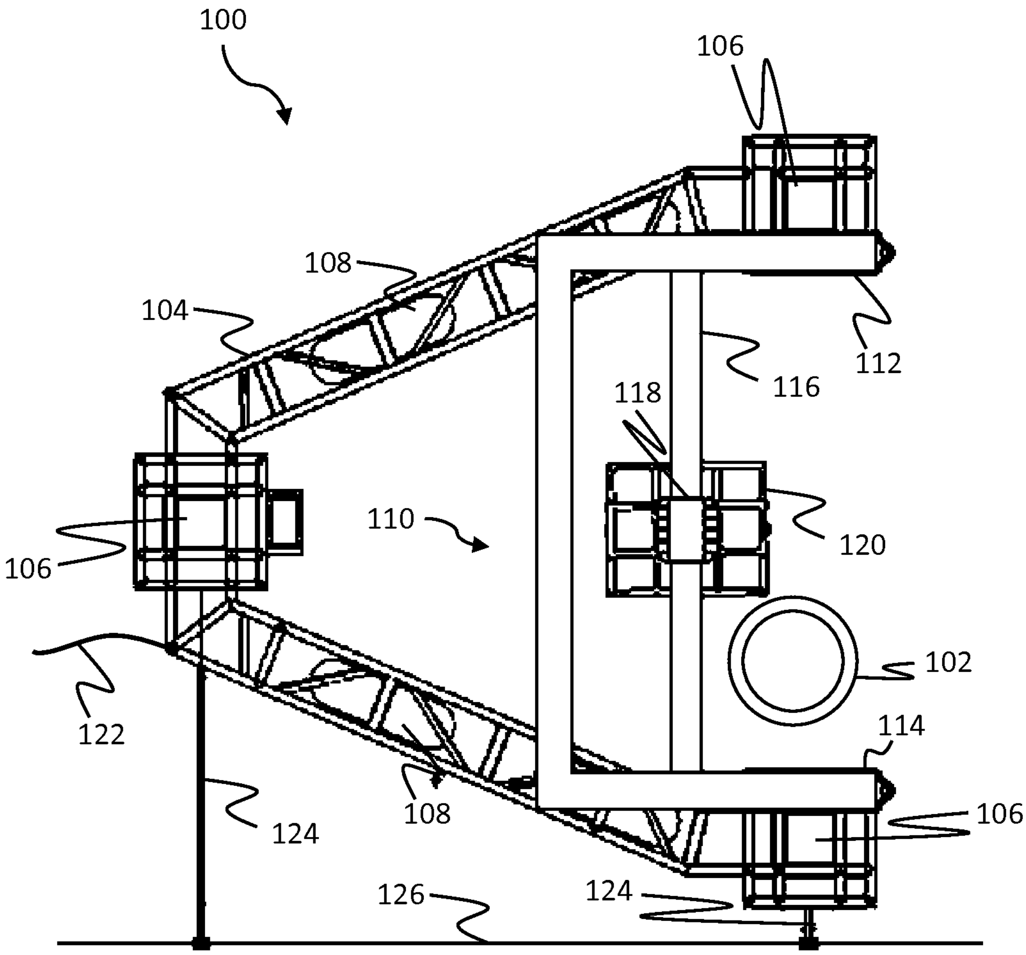
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FIG. 1

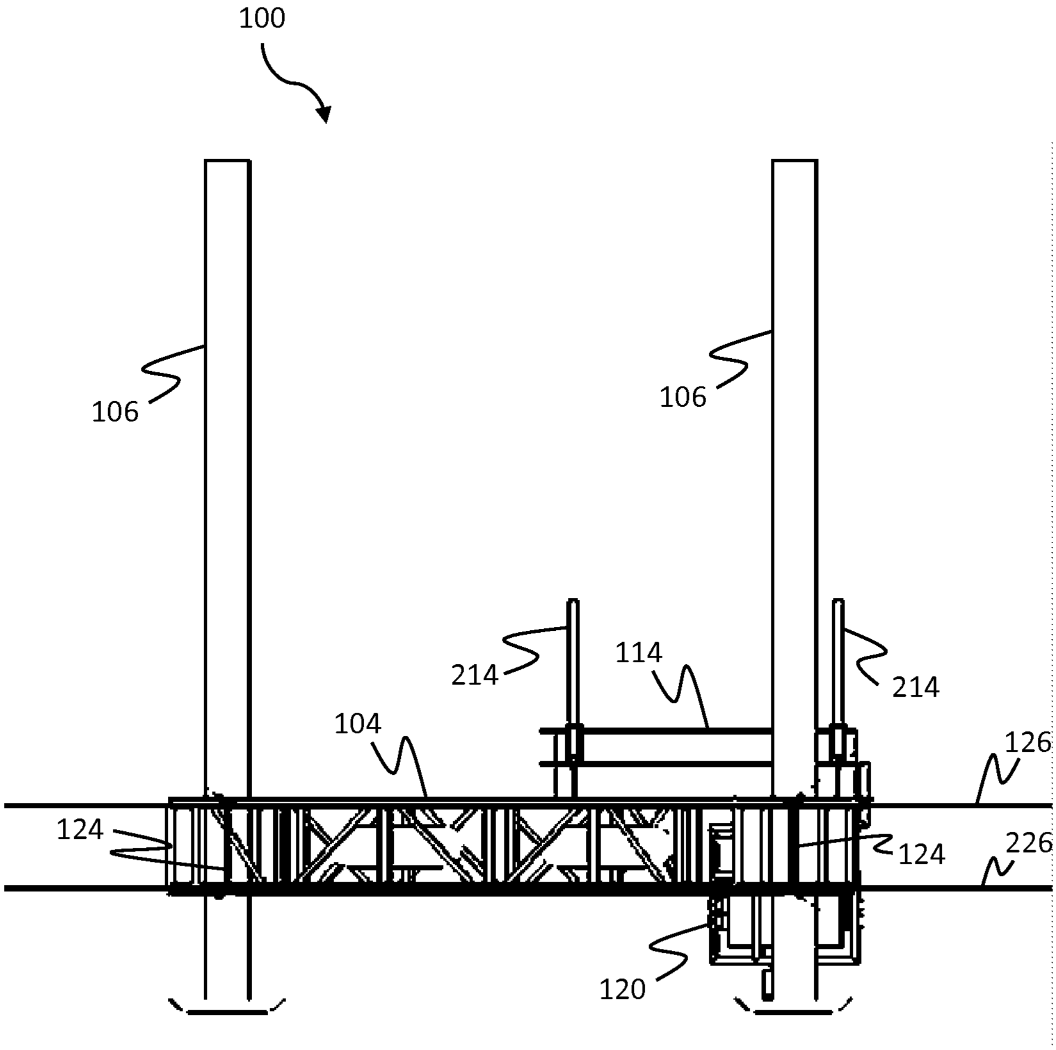

FIG. 2

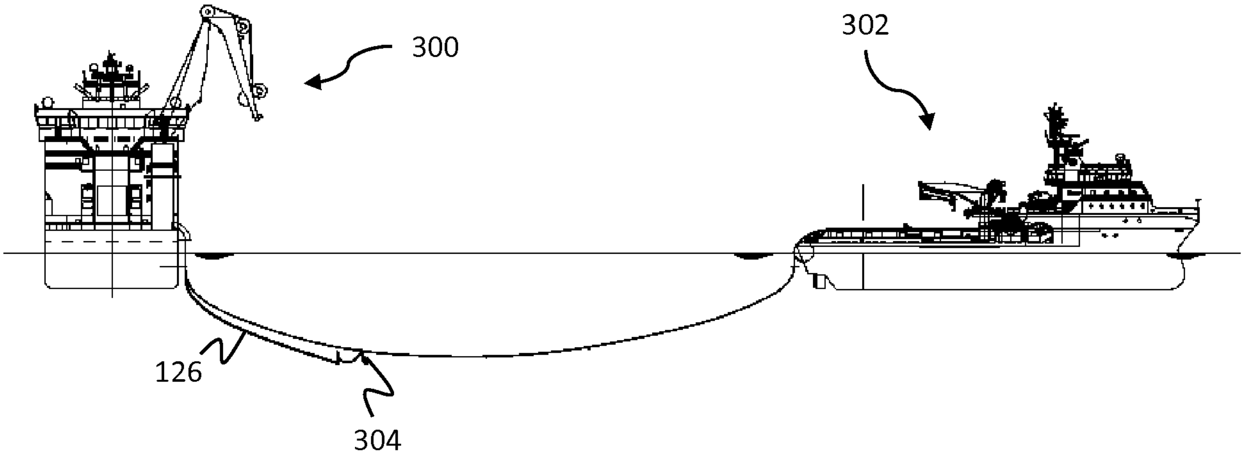

FIG. 3

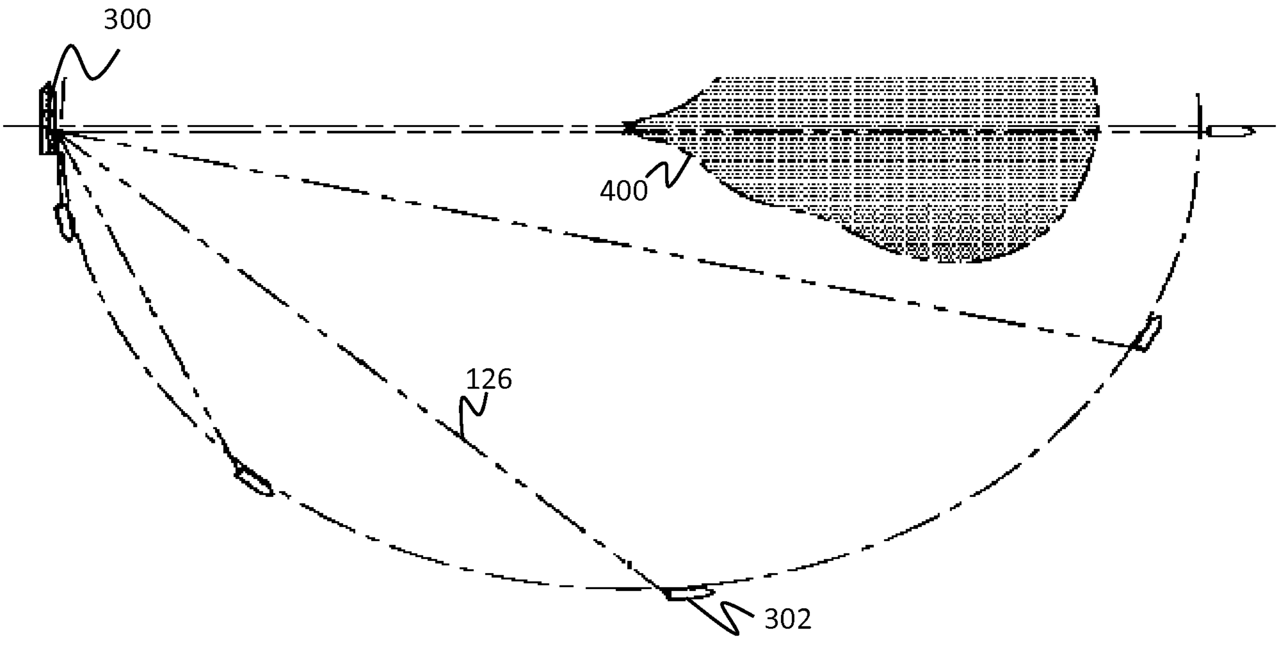

FIG. 4

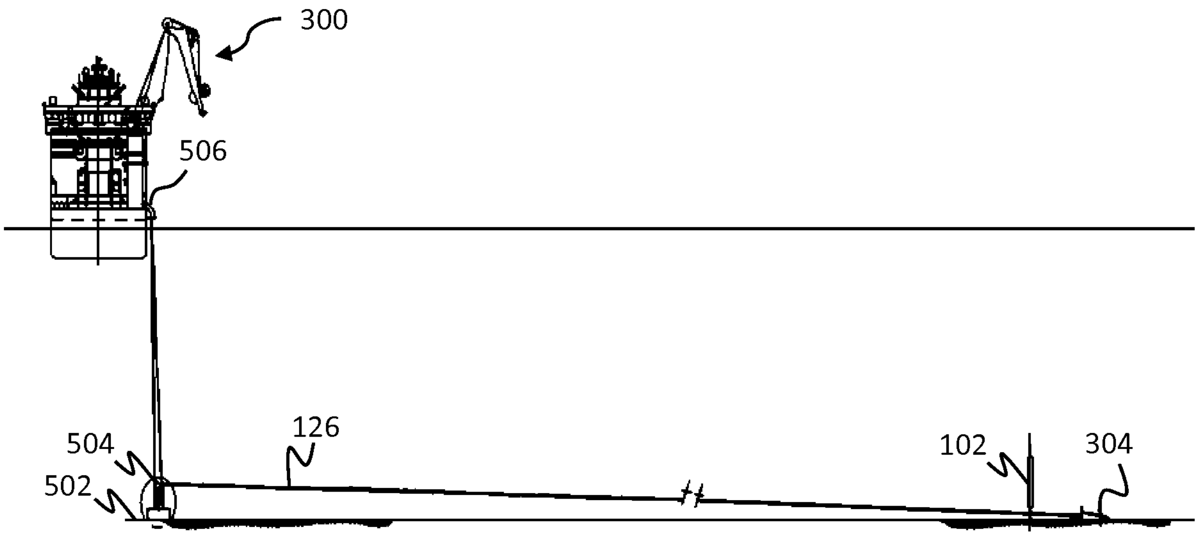

FIG. 5

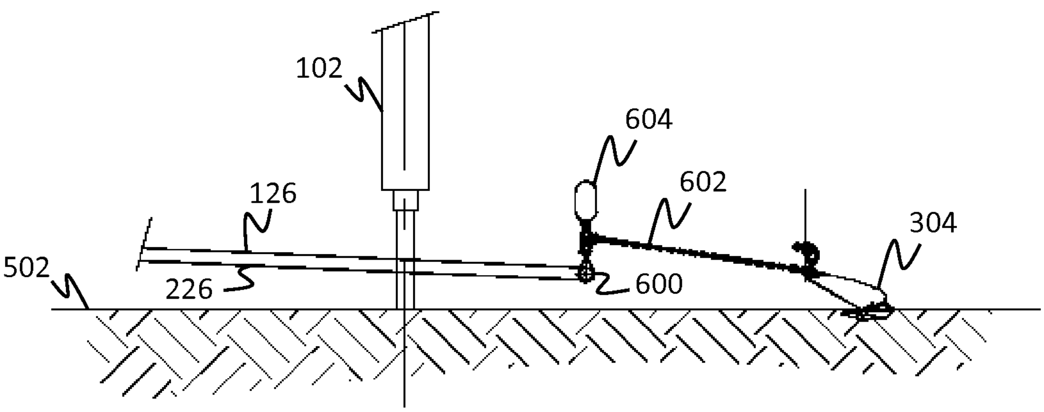

FIG. 6

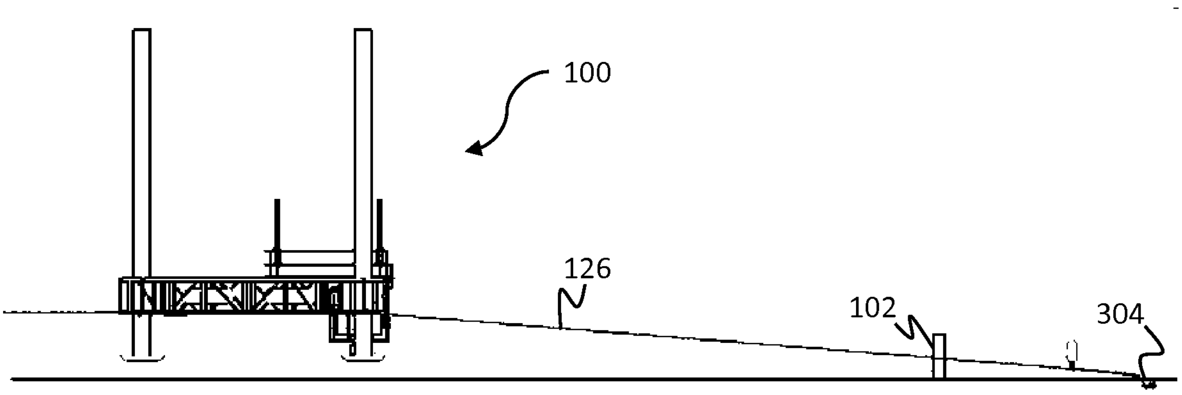

FIG. 7

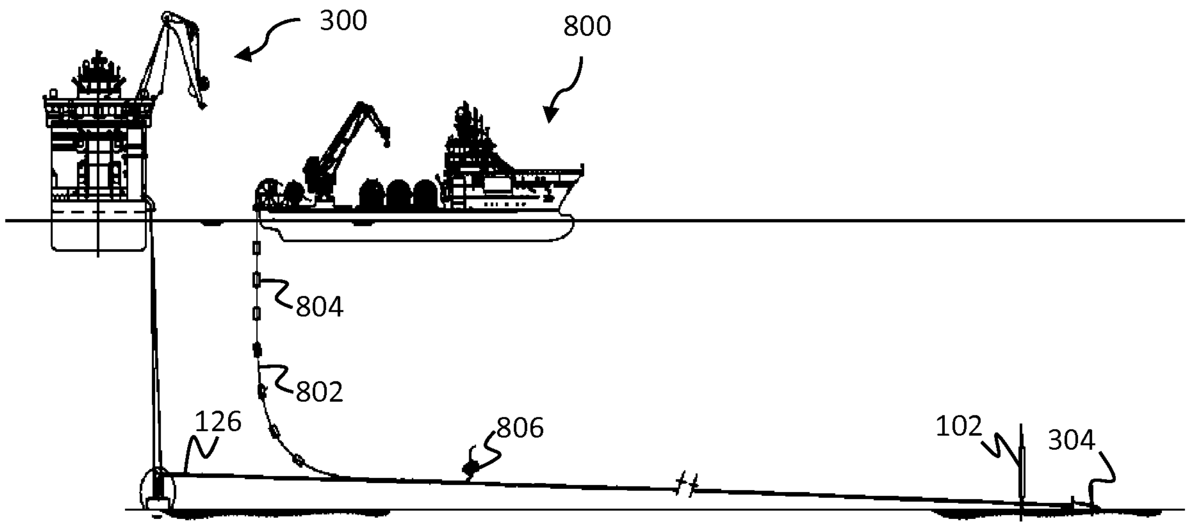

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/046978

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 43/01 (2015.01)
CPC - E21B 43/01 (2015.10)
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)
IPC(8) - E21B 17/01, 43/01, 43/36 (2015.01)
USPC - 166/79.1, 268, 335, 350, 351, 352, 367; 405/60, 171, 205

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - E21B 17/01, 17/012, 43/01 (2015.10) (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patents, Google Scholar, Google.
Search terms used: subsea, seabed, frame, installation, placement, system, well, capping, containment, stack, equipment, buoyancy, deployment, intervention, rov, tools, positioning, hoist, suspension

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 8,695,711 B2 (KOCAMAN et al) 15 April 2014 (15.04.2014) entire document	1-6, 9-17, 19, 20 ------------------------ 7, 8, 18
Y	US 4,149,818 A (HETTINGER et al) 17 April 1979 (17.04.1979) entire document	7, 8, 18
A	US 7,516,795 B2 (LOPES EUPHEMIO et al) 14 April 2009 (14.04.2009) entire document	1-20
A	US 5,190,107 A (LANGNER et al) 02 March 1993 (02.03.1993) entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"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
13 October 2015	12 NOV 2015

Name and mailing address of the ISA/	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Blaine Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774