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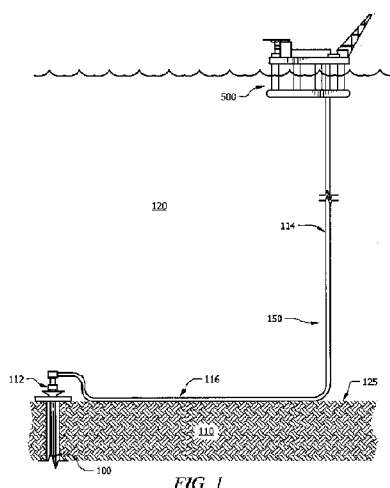
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(54) Title: METHOD AND APPARATUS FOR REMOVING PLUGS FROM SUBSEA EQUIPMENT THROUGH THE USE OF EXOTHERMIC REACTING CHEMICALS



(57) Abstract: A method of servicing subsea equipment comprising positioning a reaction chamber about the subsea equipment having a plug therein, wherein positioning the reaction chamber substantially isolates an area about the subsea equipment from an environment external to the reaction chamber, providing one or more reactants to the reaction chamber, and allowing a reaction to proceed between the reactants, wherein the reaction produces sufficient heat to eliminate the plug. A system for removing plugs from subsea equipment comprising a support vessel, a reaction chamber supported by the support vessel and positioned adjacent the subsea equipment having a plug therein, wherein the reaction chamber is configured to substantially isolate an area about the subsea equipment having a plug therein from an environment external to the reaction chamber, and one or more exothermically-reacting chemical reactants present within the reaction chamber.

METHOD AND APPARATUS FOR REMOVING PLUGS FROM SUBSEA EQUIPMENT THROUGH THE USE OF EXOTHERMIC REACTING CHEMICALS

BACKGROUND

[0001] The following application generally relates to methods, systems, and apparatuses for servicing subsea equipment. Where certain conditions exist, a plug may form within subsea equipment. Often, the plug results from the development of hydrates within an underwater pipeline, wellhead, template, manifold or similar subsea equipment. Hydrates are known to form where water and gas are found in combination with relatively high pressures and relatively low temperatures. In some cases, hydrates can form where the gas is nitrogen gas. In other cases, hydrates can form where the gas is hydrocarbon gas. Thus, subsea equipment provides an optimal environment for the development and maintenance of gas hydrates. Similarly, the plug may form as the result of the agglomeration of paraffin waxes within the subsea equipment. Paraffin wax is present in most crude oil and, if the oil is allowed to cool, the paraffin wax can precipitate out of solution and deposit on the walls of the subsea equipment.

[0002] The development of such a plug within subsea equipment may substantially restrict the flow of hydrocarbons through the subsea equipment. Thus, it is desirable to remove, dissipate, or eliminate such a plug from the subsea equipment and thereby restore the flow of hydrocarbons through the subsea equipment. Accordingly, there is an ongoing need for methods and systems to remove hydrates and other plugs from within subsea equipment which may efficiently, quickly, and inexpensively be employed.

SUMMARY

[0003] Disclosed herein is a method of servicing subsea equipment comprising positioning a reaction chamber about the subsea equipment having a plug therein, wherein positioning the

reaction chamber substantially isolates an area about the subsea equipment from an environment external to the reaction chamber, providing one or more reactants to the reaction chamber, and allowing a reaction to proceed between the reactants, wherein the reaction produces sufficient heat to eliminate the plug.

[0004] In an embodiment, the subsea equipment may comprise any one or more of a pipeline, a tubular, a riser, a flow conduit, a valve, a collar, a joint, a connection, a fitting, a spool, a wellhead, a template, a manifold, an instrument, or a gauge.

[0005] In an embodiment, the reactants may be provided to the reaction chamber by one or more hoses extending from a support vessel to the reaction chamber.

[0006] In an embodiment, the plug may comprise a hydrate, a nitrogen hydrate, or a paraffin wax.

[0007] In an embodiment, the reactants may comprise any one or more of ammonium chloride, sodium nitrite, hydrogen peroxide, ammonium hydroxide, hydrochloric acid, or a metallic ion-containing solution.

[0008] In an embodiment, the method may further comprise providing to within the reaction chamber a catalyst, a retarder, an accelerator, an additive, or any combination thereof.

[0009] Also disclosed herein is a method of servicing subsea equipment comprising locating a plug in the subsea equipment, substantially isolating an area about the subsea equipment containing the plug, and heating the substantially isolated area to remove the plug. In an embodiment, heating the substantially isolated area may be accomplished via heat produced via an exothermic reaction.

[0010] In an embodiment, the method may further comprise monitoring a change in temperature about the subsea equipment. In another embodiment, the method may still further

comprise controlling the progression of the exothermic reaction in response to the changes in temperature monitored about the subsea equipment.

[0011] Also disclosed herein is a system for removing plugs from subsea equipment comprising a support vessel, a reaction chamber supported by the support vessel and positioned adjacent the subsea equipment having a plug therein, wherein the reaction chamber is configured to substantially isolate an area about the subsea equipment having a plug therein from an environment external to the reaction chamber, and one or more exothermically-reacting chemical reactants present within the reaction chamber.

[0012] In an embodiment, the system may further comprise one or more conduits extending between the support vessel and the reaction chamber. The one or more conduits may supply the one or more chemical reactants to the reaction chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Figure 1 is an illustration of a typical working environment for one or more embodiments.

[0014] Figure 2 is an illustration of an embodiment of the system, wherein the reaction chamber substantially isolates the area about a substantially vertically-oriented subsea equipment from the body of water.

[0015] Figure 3 is a schematic cut-away view of an embodiment, wherein the reaction chamber substantially isolates the area about a substantially horizontally-oriented subsea equipment from the body of water.

DETAILED DESCRIPTION

[0016] It should be understood at the outset that although an illustrative implementation of one or more embodiments may be provided below, the disclosed systems and/or methods may be implemented using any number of techniques. This disclosure should in no way be limited

to the illustrative implementations, drawings, and techniques illustrated below, including the exemplary designs and implementations illustrated and described herein, but may be modified within the scope of the appended claims along with their full scope of equivalents.

[0017] In the drawings and description that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. The drawing figures are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness.

[0018] Unless otherwise specified, any use of any form of the terms “connect,” “engage,” “couple,” “attach,” or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described. In the following discussion and in the claims, the terms “including” and “comprising” are used in an open-ended fashion, and thus should be interpreted to mean “including, but not limited to” Reference to up or down will be made for purposes of description with “up,” “upper,” “upward,” or “upstream” meaning toward the surface of the subsea and with “down,” “lower,” “downward,” “downhole”, or “downstream” meaning toward the terminal end of the well, regardless of the wellbore orientation. As used herein, “restored” may mean that any blockage of a given portion of subsea equipment due to a plug has been at least substantially lessened such that the flow of hydrocarbons through that subsea equipment is improved. The various characteristics mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art with the aid of this disclosure upon reading the following detailed description of the embodiments, and by referring to the accompanying drawings.

[0019] Referring to Figure 1, an exemplary operating environment of a system for servicing (e.g., removing a plug) subsea equipment 150 is shown. While the subsea equipment 150 servicing system is shown and described with specificity, various other embodiments of subsea equipment 150 servicing systems consistent with the teachings herein are described *infra*. As depicted, the operating environment comprises a wellbore 100 penetrating a subterranean formation 110 beneath a body of water 120 for the purpose of recovering hydrocarbons. The wellbore 100 may be drilled into the subterranean formation 110 using any suitable drilling technique. The wellbore 100 may extend substantially vertically beneath the body of water 120 over a vertical wellbore 100 portion or may deviate at any angle from the earth's surface over a deviated or horizontal wellbore 100 portion. In alternative operating environments, all or portions of the wellbore 100 may be vertical, deviated, horizontal, and/or curved. Subsea equipment 150 may extend through the body of water 120 from the point where the wellbore 100 penetrates the subterranean formation 110, e.g., wellhead 112. The subsea equipment 150 may extend in any direction, at any angle from the surface of the body of water 120, and to any depth within the body of water 120. The subsea equipment 150 may extend to the surface where the subsea equipment 150 is coupled to either a support vessel 300 or a platform 500 (e.g., a drilling and/or production vessel or platform). For example, the subsea equipment may comprise one or more wellheads 112, one or more risers 114, one or more pipelines 116, and various combinations thereof. The subsea equipment 150 may comprise other components as described in more detail herein. The subsea equipment may terminate at and/or be in fluid communication with support vessel 300 or platform 500.

[0020] Referring to Figure 2, an exemplary embodiment of the system disclosed herein is shown. Figure 2 illustrates subsea equipment 150 rising through a body of water 120 from a point where the subsea equipment 150 penetrates the subterranean formation 110. Where

certain subsea conditions exist, a plug 170 may form within subsea equipment 150. The development of such a plug 170 within the subsea equipment 150 may substantially restrict or, in some cases, completely stop the flow of hydrocarbons through the subsea equipment 150. In an embodiment, raising the temperature about the portion of the subsea equipment 150 having the plug 170 will cause the plug 170 to dissociate, thus allowing the flow of hydrocarbons through the subsea equipment 150 to be restored. Raising the temperature about the portion of the subsea equipment 150 having the plug 170 may be accomplished via the disclosed methods, systems, and apparatuses.

[0021] Continuing to refer to Figure 2, in an embodiment a reaction chamber 200 is lowered from a support vessel 300 via a cable 230. The reaction chamber 200 may be positioned about a portion of the subsea equipment 150 where it has been previously determined that the plug 170 is located. The reaction chamber 200 is positioned about the subsea equipment 150 such that an interior section 160 of the reaction chamber 200 is substantially isolated from the body of water 120, which is substantially external to the reaction chamber 200. In other words, the reaction chamber 200 substantially isolates that area which is within the reaction chamber 200 (i.e., the interior section 160) from the environment external to the reaction chamber 200 (i.e., the body of water 120).

[0022] Once the reaction chamber 200 is positioned about the subsea equipment 150, reactants may be introduced into the reaction chamber 200. The reactants may be provided from the support vessel 300. In various embodiments, the reactants will react exothermically such that a reaction between the reactants will result in the production of heat in that same local. Thus, the production of heat from the exothermically-reacting reactants will increase the temperature of the interior section 160. This increase in temperature may be sufficient to increase the temperature of the subsea equipment 150 proximate to the plug 170. The increase

in temperature may further be sufficient to increase the temperature of the plug 170. The increase in the temperature of some portion of the subsea equipment 150 or, alternatively, the increase in the temperature of the plug 170, may cause the plug 170 to be eliminated, to dissipate, or to dissociate. The elimination, dissipation, or dissociation of the plug may allow for the flow through the subsea equipment 150 to be restored. Following the elimination, dissipation, or dissociation of the plug 170, the provision of reactants to the reaction chamber 200 may be ceased and the reaction chamber 200 removed.

[0023] The subsea equipment 150 is typically associated with the production of hydrocarbons or the transport or conveyance of hydrocarbons. For example, the subsea equipment 150 may include one or more wellheads, manifolds, instruments, or templates and associated pipelines or tubulars extending from or between wellbores 100 or any tubular or conduit for the conveyance of hydrocarbons. In various embodiments, the subsea equipment 150 may comprise any one or more of a pipeline, riser, tubular, flow-conduit, fitting, valve, collar, joint, connection, fitting, spool, wellhead, or gauge. In embodiments the subsea equipment 150 may be located at any depth beneath the surface of the water. In embodiments the subsea equipment 150 may be oriented at any angle. In embodiments, the subsea equipment 150 may be formed of any suitable material such as steel or composite materials. The subsea equipment 150 may be assembled in any suitable manner, for example a plurality of jointed or segmented conduits or tubulars. The materials suitable for the manufacture of subsea equipment 150 and suitable methods of assembling the subsea equipment 150 would be readily recognizable by one of ordinary skill in the art.

[0024] In a specific embodiment, the subsea equipment 150 to be serviced may be an underwater pipeline or tubular. The pipeline or tubular may be for the purpose of recovering hydrocarbons from a subterranean formation 110 beneath the water, for conveying or

transporting hydrocarbons, or any other suitable purpose. The pipeline or tubular may extend to any height above the sea floor 125. Alternatively, the pipeline or tubular may extend to the surface of the water. Alternatively, the pipeline or tubular may extend along the sea floor 125 of the body of water 120. The pipeline or tubular may be substantially vertically-oriented. In another embodiment, the pipeline or tubular may be substantially horizontally-oriented. In yet another embodiment, the pipeline or tubular may be oriented at any angle from the surface of the body of water 120. In an embodiment, the pipeline or tubular may be substantially straight. In another embodiment the pipeline or tubular may be substantially curved. The pipeline or tubular may be held in place by any combination of cables, buoys, floats, or anchors. The pipeline or tubular may extend fully to the surface of the body of water 120 or it may extend to some depth below the surface of the body of water 120.

[0025] In an embodiment, the plug 170 to be eliminated may form within the subsea equipment 150. The plug 170 may reduce, hinder, or restrict the flow of hydrocarbons through the subsea equipment 150. In some instances, the plug 170 may result in a complete blockage of all flow of hydrocarbons through the subsea equipment 150. The plug 170 may be located by any variety of known or yet unknown methods. Locating the plug 170 may be accomplished via the implementation of any suitable technique or method for locating such plugs 170. Non-limiting examples of methods of plug 170 detection include the volumetric measurement of the pipeline section up to the blockage, the use of radioactive density measurement systems, and the induction of a pressure pulse into the system. Services for locating such a plug 170 in such subsea equipment 150 are provided commercially.

[0026] In an embodiment, the plug 170 may comprise a formation of hydrates (e.g., hydrocarbon and/or nitrogen). For example, the hydrates may be formed and exist within subsea equipment 150 where water and gaseous hydrocarbons are found within certain

temperature and pressure ranges. In an embodiment, a plug 170 comprised of hydrates may be eliminated by altering the temperature of the area about the subsea equipment, the subsea equipment 150, or the plug 170. For example, by raising the temperature about the subsea equipment 150 where the plug 170 is located, the temperature of the subsea equipment 150 and of the plug 170 may also be raised, thus resulting in the dissociation or elimination of the plug 170.

[0027] In an embodiment, the plug 170 may comprise a formation of nitrogen hydrate. The nitrogen hydrate may be formed and exist within subsea equipment 150 where water and gaseous nitrogen are found within certain temperature and pressure ranges. In an embodiment, a plug 170 comprised of nitrogen hydrate may be eliminated by altering the temperature of the area about the subsea equipment, the subsea equipment 150, or the plug 170. For example, by raising the temperature about the subsea equipment 150 where the plug 170 is located, the temperature of the subsea equipment 150 and of the plug 170 may also be raised, thus resulting in the dissociation or elimination of the plug 170.

[0028] In an alternative embodiment, the plug 170 may comprise paraffin wax. Paraffin waxes may form a plug 170 where relatively low temperatures allow the waxes to agglomerate and form solid masses. In an embodiment, a plug 170 comprised of paraffin wax may be eliminated by raising the temperature of the subsea equipment 150 and thus, of the plug 170, such that the plug 170 melts.

[0029] Referring to Figures 2 and 3, in an embodiment, a support vessel 300 is positioned substantially proximate to the subsea equipment 150 to be serviced. A reaction chamber 200 is then provided from the support vessel 300 to the subsea equipment 150. The reaction chamber 200 may be positioned to partially or fully enclose the interior section 160 and substantially isolate that area from the environment external to the reaction chamber 200 (i.e., the body of

water 120). One or more means for positioning the reaction chamber 200 may be employed so as to achieve placement of the reaction chamber 200 about the subsea equipment 150 to be serviced, thereby substantially isolating interior section 160 from the environment external to the reaction chamber 200.

[0030] The support vessel 300 may be the same or different from platform or vessel 500. In an embodiment, the support vessel 300 may comprise one or more boats, barges, hovercrafts, or platforms located at the surface of the body of water 120. Additionally, the support vessel 300 may comprise a submersible water vehicle, such as a manned or unmanned submersible vessel (e.g., a mini submarine) or a remotely operated underwater vehicle (ROV) 240. Additionally, in an embodiment the support vessel 300 may comprise a helicopter. Further, one or more support vessels 300 may work jointly or cooperatively to position of the reaction chamber 200.

[0031] In a specific embodiment, the means for positioning the reaction chamber 200 may comprise one or more cables 230 extending from the support vessel 300, said one or more ropes (e.g., wire or nylon rope), chains, or cables 230 allowing for the placement and/or retrieval of the reaction chamber 200. In such a scenario, the reaction chamber 200 may be lowered from the support vessel 300 via one or more cables 230 attached to the reaction chamber 200 and extending from the support vessel 300.

[0032] Additionally or alternatively, the means for positioning the reaction chamber 200 may comprise an ROV 240 operating beneath the surface of the water. The reaction chamber 200 may be attached to the ROV 240, which may position the reaction chamber 200 about the subsea equipment 150 to be serviced. In an embodiment, the ROV 240 may be used to position the reaction chamber 200, to attach or couple the reaction chamber 200 to subsea equipment 150, or to assemble pieces or units of the reaction chamber 200. In an embodiment, the ROV

240 may be used to assemble the reaction chamber 200 about the subsea equipment 150. Additionally, the ROV 240 may be used to both position and assemble the reaction chamber 200. Further still, the ROV 240 may be used to attach the reaction chamber 200 to the subsea equipment 150.

[0033] Additionally or alternatively, the means for positioning the reaction chamber 200 may comprise divers positioning the reaction chamber 200 about the subsea equipment 150 or assembling the reaction chamber 200 about the subsea equipment 150.

[0034] In still a further embodiment, the one or more means for positioning the reaction chamber 200 may be employed cooperatively. As a non-limiting example, the reaction chamber 200 might be lowered from any one or more support vessels 300 at the surface of the body of water 120 while an ROV 240 monitors positioning below while a second ROV 240 and/or divers are employed to make fine adjustments to the positioning of the reaction chamber 200.

[0035] In an embodiment, the reaction chamber 200 may be configured to isolate the area immediately about or nearly adjacently to the subsea equipment 150, i.e., the interior section 160, from the surrounding environment, which may comprise the body of water 120.

[0036] In an embodiment as shown in Figure 3, the reaction chamber 200 is placed over the subsea equipment 150 extending along the floor of a body of water 120 (i.e., the sea floor 125). In an embodiment, the reaction chamber 200 comprises one or more outer walls defining a concave or recessed interior space (e.g., interior section 160) and having one or more openings to allow portions of the subsea equipment to extend through the walls of the reaction chamber. That is, the reaction chamber 200 may be configured such that the subsea equipment 150 will extend through the slots, grooves, or openings 215 in the reaction chamber 200 and the reaction chamber 200 will rest on the sea floor 125. Where the reaction chamber 200 rests against the

sea floor 125, a seal or partial seal will be formed, thus limiting the exchange of fluids between the interior section 160 of the reaction chamber 200 and the environment exterior to the reaction chamber 200. Thus, the reaction chamber 200 may substantially seal the interior section 160 by forming a seal with the sea floor 125.

[0037] In an embodiment, the reaction chamber 200 may be configured so as to completely envelop a portion of the subsea equipment 150. In an alternative embodiment, the reaction chamber 200 may only partially enclose the interior section 160 of the reaction chamber 200. In such an embodiment, the chemical reactants provided to the reaction chamber 200 may be provided at such a rate that fluids external to the reaction chamber 200 will not flow into the interior section 160 of the reaction chamber 200, but that fluids will only flow out (i.e., upon having reacted, the reaction products will flow out of the reaction chamber 200). That is, the reactants may be pumped into the interior section 160 of the reaction chamber 200 so as to create a positive pressure differential between the interior section 160 and the environment exterior to the reaction chamber 200. Where the pressure within the reaction chamber 200 is greater than the pressure exterior to the reaction chamber 200, fluids within the reaction chamber 200 will flow out. In an embodiment where the reaction chamber 200 is not completely enclosed or sealed, fluids within the reaction chamber 200 may flow out of the reaction chamber 200 via space between openings 215 and the subsea equipment 150, via gaps in the seal between the bottom of the reaction chamber 200 and the sea floor 125, and/or via the seal 215 between the reaction chamber 200 and the subsea equipment 150, and/or via other openings in the reaction chamber, e.g., fluids may flow out via vents 205 in the reaction chamber.

[0038] The reaction chamber 200 may comprise any suitable shape. A suitable shape or configuration for the reaction chamber 200 may be any such configuration providing for the

substantial isolation of some area substantially interior to the reaction chamber 200, (i.e., the interior section 160) from some area substantially exterior to the reaction chamber 200 (i.e., the body of water 120). In an embodiment, the reaction chamber 200 may fully enclose the isolated area which is the interior section 160. In an alternative embodiment, the reaction chamber 200 may only partially enclose the isolated area which is the interior section 160. In such an embodiment, depicted in Figure 3, the lower end of the reaction chamber 200 is partially or completely open. The interior section 160 of reaction chamber 200 is substantially isolated from the environment external to the reaction chamber 200 in that reactants introduced into the interior section 160 of the reaction chamber 200 will disperse within the surrounding body of water 120 only upon flowing out any openings of the reaction chamber 200.

[0039] In an embodiment, the reaction chamber 200 may be substantially bell-shaped. Alternatively, the reaction chamber 200 may be a half-sphere or half-ellipsoid having a generally concave interior portion defining interior section 160. When the reaction chamber 200 is deployed, it may extend over and/or around the subsea equipment 150 to be serviced. The reaction chamber 200 may comprise one or more slots, grooves, or openings 215 adapted to receive the subsea equipment 150. The reaction chamber 200 may be configured such that it is open on the bottom such that the products of the chemical reaction may flow out of the reaction chamber 200.

[0040] In an example illustrated by Figure 3, where the subsea equipment 150 (shown in a non-limiting example as a pipeline or tubular although potentially embodied as a wellhead, template, instrument, or manifold) is substantially horizontally-oriented (e.g., resting on the sea floor 125), the reaction chamber 200 may comprise one or more slots, grooves, or openings 215 such that the reaction chamber 200 extends over and around the pipeline or tubular and isolates the area about the pipeline or tubular from the environment external to the reaction chamber

200. In an embodiment, each of a pair of u-shaped openings 215 is located substantially opposite the other in bell-shaped walls to form a saddle-shaped reaction chamber that extends over the subsea equipment 150 while providing for substantial or partial isolation of the interior section 160.

[0041] In an embodiment, the reaction chamber 200 may be box-like in shape, comprising a top and multiple sides. The reaction chamber 200 may be substantially square or rectangular. The reaction chamber 200 may comprise one or more slots, grooves, or openings 215 adapted to receive the subsea equipment 150. Again, the bottom of the reaction chamber 200 may be open such that the fluids may flow out of the reaction chamber 200.

[0042] In an example illustrated by Figure 2, where the subsea equipment 150 is substantially vertically-oriented, the reaction chamber 200 may comprise a slot, groove, or opening 215 such that the portion of the subsea equipment 150 known to contain the plug 170 may be substantially isolated from the body of water 120, which is external to the reaction chamber 200, while the subsea equipment 150 extends through the reaction chamber 200. As such, the methods and systems of servicing the subsea equipment 150 disclosed herein may, in embodiments, be achieved without any disassembly of the subsea equipment 150.

[0043] In an embodiment, the reaction chamber 200 may comprise multiple parts. In an embodiment where the reaction chamber 200 comprises multiple component parts, those multiple parts may be configured such that the parts may be assembled around the subsea equipment 150 to form the reaction chamber 200. In an embodiment, the reaction chamber 200 may comprise two or more component pieces configured to be assembled around the subsea equipment 150. For example, in an embodiment, the body of the reaction chamber 200 may comprise two halves (e.g., like the halves of a clam-shell). These two halves may be attached to each other via one or more hinges, latches, or similar means. The component pieces of the

reaction chamber 200 may be assembled or closed around the subsea equipment 150. For example, a “clam-shell-like” reaction chamber 200 might comprise two hinged halves which may be closed (e.g., by an ROV 240 or diver) around the subsea equipment 150. Such a clam-shell configuration could be employed in a vertical embodiment as shown in Figure 2 (e.g., a clam shell having oppositely positioned openings closes around or “clamps” onto a portion of conduit) or in a horizontal embodiment as shown in Figure 3 (e.g., a clam shell having oppositely positioned opening hinges over a portion of conduit without completely closing or clamping shut).

[0044] In embodiments, the reaction chamber 200 is a rigid structure. In an embodiment, the reaction chamber 200 may entirely or in part be constructed of wood, a wooden composite material, concrete, plastic, foam, a metal (e.g., steel), composite materials, glass, or any combination thereof. In an embodiment, the reaction chamber 200 may comprise an insulating material surrounded by a rigid outer structure. As a non-limiting example, the reaction chamber 200 may comprise a structure having a thermally-insulating core comprised of wood, a composite material, foam, or plastic enclosed by a structural material comprising a metal or concrete.

[0045] In an embodiment, the reaction chamber 200 may comprise a rigid frame and a flexible skin. For example, a frame may impart shape to the reaction chamber 200 and the skin may thus be conformed to the shape of the frame. The skin may comprise a thermally-insulating material.

[0046] Alternatively, the reaction chamber 200 may be conformable to different shapes. In an embodiment, the reaction chamber 200 may be expandable or contractible. In an embodiment, the reaction chamber 200 may be entirely non-rigid and conformable to any variety of shapes. For example, the reaction chamber might comprise a woven material, a

plastic material, a fibrous material, a vinyl material, a rubbery material, or any such suitable material.

[0047] For example, in an embodiment the reaction chamber 200 may be draped over the subsea equipment 150 like a blanket. Reactants might be pumped into the reaction chamber 200 such that the non-rigid reaction chamber 200 fills and is thus inflated by the inflow of the fluid reactants.

[0048] In another embodiment, a conformable reaction chamber 200 may be attached to the subsea equipment 150 and expanded via the introduction of the fluid reactants. For example, where the subsea equipment 150 is substantially vertically-oriented, a conformable reaction chamber 200 might be wrapped around the subsea equipment 150 and sealed at the top and/or bottom such and then inflated via the introduction of the fluid reactants. That is, the reaction chamber 200 acts like a “jacket” which surrounds the subsea equipment 150. In such an embodiment, the reaction chamber 200 might be latched or “zippered” in place by an ROV 240 or diver.

[0049] In another embodiment, a conformable sealed reaction chamber 200 may be wrapped around the subsea equipment 150 and expanded via the introduction of the fluid reactants. For example, where the subsea equipment 150 is substantially vertically-oriented, a conformable reaction chamber 200 that is hose-like in appearance might be wrapped around the subsea equipment 150 and enclosed in a secondary chamber 200 and then inflated via the introduction of the fluid reactants. That is, the reaction chamber 200 acts like a “jacket” which surrounds the subsea equipment 150. In such an embodiment, the reaction chamber 200 might be latched or “zippered” in place by an ROV 240 or diver.

[0050] The reaction chamber 200 may be configured for use at any depth below the surface of the body of water 120. The temperature may be very cold at certain depths. For example, at

a depth of 5,000 ft., the ambient temperature of the body of water 120 may be 4°C or lower. Because it may be desirable to retain the heat produced via the exothermic reaction with the reaction chamber 200, the reaction chamber 200 may be comprised of a material or materials having sufficient thermal-insulating properties to retain the heat produced by the chemical reaction within the reaction chamber 200.

[0051] The reaction chamber 200 may be configured for the introduction of the one or more chemical reactants. The conduit or hose 220 may comprise any appropriate flow conduit, tubing, tubular, hose, or the like. For example, one or more conduits or hoses 220 may be attached to the reaction chamber 200. The conduits or hoses 220 may be attached such that fluids pumped through the conduits or hoses 220 will be introduced into the interior portion of the reaction chamber 200. In an embodiment, the conduits or hoses 220 may comprise one or more valves or check-valves to limit the back-flow of any liquid through the conduits or hoses 220.

[0052] In an embodiment, the reactants may be supplied from the support vessel 300. A pump or transport device on the support vessel 300 may be used to provide the reactants to the reaction chamber 200 via one or more conduits or hoses 220. In another embodiment, the reactants may be mixed on the support vessel 300 and introduced into the reaction chamber 200 via a single conduit or hose 220.

[0053] In an alternative embodiment, the reactants may be introduced into the reaction chamber 200 via separate conduits or hoses 220 and mixing may occur only upon introduction in the reaction chamber 200. In such an embodiment, a first reactant may be pumped down a first conduit or hose 220 at a first rate while a second reactant may be pumped down a second conduit or hose 220 at a second rate. In still another embodiment, the reactants may be introduced into the reaction chamber 200 via a single divided conduit or hose 220, the single

divided conduit or hose 220 comprising multiple, separate, and distinct flowpaths therethrough. That is, a first reactant will be pumped down a first flowpath within the conduit or hose 220 and released into the interior section 160 of the reaction chamber 200 while a second reactant will be pumped down a second flowpath and released into the interior section 160 of the reaction chamber 200. The first flowpath may be within the same conduit or hose 220 as the second flowpath, although the reactants may not be mixed or intermingled until reaching the interior section 160 of the reaction chamber 200.

[0054] A variety of reactants may be suitably employed in accordance with the methods, systems, and apparatuses disclosed herein. In an embodiment, the reaction between the reactants employed will be exothermic. The heat generated by the exothermic reaction between the reactants may be sufficient to increase the temperature of the interior section 160. In an embodiment, the heat generated by the exothermic reaction between the reactants will be sufficient to increase the temperature of the interior section 160 above the ambient temperature. In various embodiments, the heat generated by the exothermic reaction between the reactants will be sufficient to increase the temperature of the interior section 160 by equal to or greater than about 10 °F, 15 °F, 20 °F, 25 °F, 30 °F, 40 °F, 50 °F, 60 °F, 70 °F, 80 °F, 90 °F, 100 °F, 125 °F, 150 °F, 175 °F, 200 °F, 225 °F, 250 °F, 275 °F, 300 °F, 325 °F, 350 °F, 375 °F, 400 °F, 425 °F, 450 °F, 475 °F, or 500 °F.

[0055] In an embodiment, the reactants may be chemical species which are not harsh, dangerous, or toxic to the environment. In such an embodiment, any reactants provided to the reaction chamber 200 which fail to react will not be toxic or dangerous to the surrounding environment. In another embodiment, the end products of the reaction may not be harsh, dangerous, or toxic to the environment. Thus, on completion of the reaction, no harsh,

dangerous, or toxic materials will enter the environment as a result of these methods or systems.

[0056] Generally, any combination of reactants which reacts exothermically, which result in non-environmentally harmful products may be utilized in accordance with the methods, systems, and apparatuses disclosed herein.

[0057] In an embodiment, the reactants may comprise water (which may be present within the reaction chamber 200) and a single reactant provided within the reaction chamber 200 which will react exothermically with the water. In another embodiment, the reactants may comprise two reactants provided to interior section 160 of the reaction chamber 200. In still another embodiment, the reactants may comprise three or more reactants provided within the reaction chamber 200.

[0058] In an exemplary embodiment, a first reactant may comprise ammonium chloride and a second reactant may comprise sodium nitrate. The reaction between ammonium chloride and sodium nitrate is exothermic. A reaction between a solution comprising 20-40% ammonium chloride and solution comprising 20-40% sodium nitrate is sufficient to produce sufficient heat to raise the temperature about the subsea equipment 150 by the amount previously disclosed herein. In an embodiment, the reaction may be sufficient to raise the temperature by equal to or greater than about 10 °F, 20 °F, 30 °F, 40 °F, 50 °F, 60 °F, 70 °F, 80 °F, 90 °F, or 100°F. The reaction between ammonium chloride and sodium nitrate yields salt water and nitrogen gas as end products.

[0059] In another embodiment, the reactants may comprise hydrochloric acid and ammonium hydroxide. In such an embodiment, the provision of hydrochloric acid and ammonium hydroxide may result in an exothermic reaction wherein the hydrochloric acid and ammonium hydroxide are neutralized.

[0060] In still another embodiment, the reactants may comprise hydrogen peroxide and a solution containing metal ions. In such an embodiment, the provision of hydrogen peroxide and metallic-ion solution may result in an exothermic reaction wherein the hydrogen peroxide is decomposed by the metal ions.

[0061] As illustrated by Figure 3, in an embodiment, the reaction chamber 200 may comprise a vent 205. The vent 205 may be configured to allow for the dissipation of gaseous products formed during the progression of the reaction. The vent 205 may be automatically or selectively opened or closed. In a particular embodiment, the vent 205 may allow for the dissipation of a gas (e.g., gaseous nitrogen) formed during the reaction. In alternative embodiments, one or more vents 205 may be used to release reactants or reaction products from the interior section 160 of the reaction chamber 200 and/or to allow water from outside the reaction chamber into the interior section 160 (e.g., where an exothermic reaction includes water as a reactant or where the reaction progresses too quickly, as a means of slowing or controlling the rate of reaction by allowing an influx of water).

[0062] In the embodiment illustrated by Figure 3, the reaction chamber 200 may comprise one or more temperature monitoring devices 210. The temperature monitoring devices 210 may be located within the interior section 160. The temperature monitoring device 210 may comprise a thermocouple, a thermometer, or any combination thereof. The data obtained via the temperature monitoring device 210 may be provided, either wirelessly or via a wired connection, to an operator. In a specific embodiment, the operator may be located on-board the support vessel 300. The temperature monitoring device 210 may be used to monitor the progression of the reaction. In an embodiment, the progression of the reaction may be controlled in response to the information obtained via the temperature monitoring device 210. In a specific embodiment, the information obtained via the temperature monitoring device 210

may be provided to a worker or operator who utilizes this information in manually adjusting the rate of reactions (e.g., by adjusting the rate at which reactants are provided to the reaction chamber 200 or by providing one or more additives to the reaction chamber 200, discussed *infra*). In an alternative embodiment, the information obtained via the temperature monitoring device 210 may be supplied directly to a computation means which then automatically controls the rate of reaction.

[0063] In various embodiments, the rate at which the reaction progresses may be controlled. It may be necessary to vary the rate at which the reaction progress so that the temperature of the subsea equipment 150 is not changed too quickly or too slowly. The rate of reaction may be varied by altering (either by concentrating or diluting) the concentration of the reactants. The rate of reaction may also be varied by adjusting (either increasing or decreasing) the pumping rate of the reactants, that is, the rate at which the reactants are provided to the reaction chamber 200. In another embodiment, the rate of reaction may further be controlled through the addition of a catalyst, a retarder, an accelerator, or an additive. In further embodiments, the rate of reaction may be controlled via any combination of varying the concentration of the reactants, adjusting the pumping rate of the reactants, or adding a catalyst, a retarder, an accelerator, or an additive.

[0064] In an embodiment, the increase in temperature in the interior section 160 due to the reaction will cause the plug 170 to dissociate, melt, dissipate, or otherwise be eliminated. The dissociation or elimination of the plug 170 may allow the flow of hydrocarbons through the subsea equipment 150 to be restored.

[0065] In an embodiment, when it is determined that the plug 170 has dissipated, the flow of reactants to the reaction chamber 200 may be ceased. Alternatively, the flow of reactants may be ceased when a certain temperature has been attained within the interior section 160 of

the reaction chamber 200 for a given period of time. The reaction chamber 200 may be removed from the area about the subsea equipment 150. The reaction chamber 200 may be stored and later reused elsewhere. In a specific embodiment, removal of the reaction chamber 200 may comprise reattachment to one or more cables 230 and hoisting the reaction chamber 200 back to the support vessel 300. Alternatively, the reaction chamber 200 may have remained attached to the cable 230 and, thus, the cables 230 may be used to hoist the reaction chamber 200 out of the body of water 120 or to remove the reaction chamber 200 to another location. In a similar embodiment, removal may comprise reattachment to the ROV 240. In another embodiment, removal may comprise disassembly of the reaction chamber 200. In another embodiment the reaction chamber 200 may be made buoyant via the generation and collection of nitrogen gas within the reaction chamber 200. That buoyancy may be used to recover the reaction chamber 200 to surface. In an alternative embodiment, the reaction chamber 200 may be allowed to remain in place about the subsea equipment 150. Where multiple plugs 170 have formed within a length of subsea equipment 150, the reaction chamber 200 may be repositioned about the subsea equipment 150 proximate to a second plug 170 and the foregoing process repeated a second, third, fourth, etc. time.

[0066] While embodiments of the disclosure have been shown and described, modifications thereof can be made by one skilled in the art without departing from the spirit and teachings of the disclosure. The embodiments described herein are exemplary only, and are not intended to be limiting. Many variations and modifications of the disclosure disclosed herein are possible and are within the scope of the disclosure. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes, 2, 3, 4, etc.; greater than 0.10

includes 0.11, 0.12, 0.13, etc.). For example, whenever a numerical range with a lower limit, R_L , and an upper limit, R_U , is disclosed, any number falling within the range is specifically disclosed. In particular, the following numbers within the range are specifically disclosed: $R = R_L + k * (R_U - R_L)$, wherein k is a variable ranging from 1 percent to 100 percent with a 1 percent increment, i.e., k is 1 percent, 2 percent, 3 percent, 4 percent, 5 percent, ...50 percent, 51 percent, 52 percent,, 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, or 100 percent. Moreover, any numerical range defined by two R numbers as defined in the above is also specifically disclosed. Use of the term "optionally" with respect to any element of a claim is intended to mean that the subject element is required, or alternatively, is not required. Both alternatives are intended to be within the scope of the claim. Use of broader terms such as comprises, includes, having, etc. should be understood to provide support for narrower terms such as consisting of, consisting essentially of, comprised substantially of, etc.

[0067] Accordingly, the scope of protection is not limited by the description set out above but is only limited by the claims which follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated into the specification as an embodiment of the present disclosure. Thus, the claims are a further description and are an addition to the embodiments of the present disclosure. The discussion of a reference in the Description of Related Art is not an admission that it is prior art to the present disclosure, especially any reference that may have a publication date after the priority date of this application. The disclosures of all patents, patent applications, and publications cited herein are hereby incorporated by reference, to the extent that they provide exemplary, procedural, or other details supplementary to those set forth herein.

CLAIMS

What is claimed is:

1. A method of servicing subsea equipment comprising:
positioning a reaction chamber about the subsea equipment having a plug therein,
wherein positioning the reaction chamber substantially isolates an area about the subsea equipment from an environment external to the reaction chamber;
providing one or more reactants to the reaction chamber; and
allowing a reaction to proceed between the reactants, wherein the reaction produces sufficient heat to eliminate the plug.
2. The method of claim 1, wherein the subsea equipment comprises a pipeline, a tubular, a riser, a flow conduit, a valve, a collar, a joint, a connection, a fitting, a spool, a wellhead, a template, a manifold, an instrument, a gauge, or combinations thereof.
3. The method of claim 1, wherein the plug comprises a hydrate.
4. The method of claim 1, wherein the plug comprises a paraffin wax.
5. The method of claim 1, wherein the reactants are provided to the reaction chamber by one or more hoses extending from a support vessel to the reaction chamber.
6. The method of claim 1, wherein the reaction chamber comprises a material suitable for thermally insulating an interior portion of the reaction chamber from the environment external to the reaction chamber.

7. The method of claim 1, wherein the reactants comprise ammonium chloride, sodium nitrite, hydrogen peroxide, ammonium hydroxide, hydrochloric acid, a metallic ion-containing solution, or combinations thereof.
8. The method of claim 1, wherein the reactants comprise ammonium chloride and sodium nitrite.
9. The method of claim 1, wherein the reaction between the reactants will yield non-toxic, non-environmentally hazardous end products.
10. The method of claim 1, further comprising providing to within the reaction chamber a catalyst, a retarder, an accelerator, an additive, or combinations thereof.
11. A method of servicing subsea equipment comprising:
 - locating a plug in the subsea equipment;
 - substantially isolating an area about the subsea equipment containing the plug; and
 - heating the substantially isolated area to remove the plug.
12. The method of claim 11, wherein the heating is produced via an exothermic reaction.
13. The method of claim 12, further comprising monitoring a change in temperature about the subsea equipment.

14. The method of claim 13, further comprising controlling the progression of the exothermic reaction in response to the monitoring the change in temperature.
15. A system for removing plugs from subsea equipment comprising:
- a support vessel;
 - a reaction chamber supported by the support vessel and positioned adjacent the subsea equipment having a plug therein, wherein the reaction chamber is positioned to substantially isolate an area about the subsea equipment having a plug therein from an environment external to the reaction chamber; and
 - one or more exothermically-reacting chemical reactants present within the reaction chamber.
16. The system of claim 15, further comprising a one or more conduits extending between the support vessel and the reaction chamber, wherein the one or more conduits supply the one or more chemical reactants to the reaction chamber.
17. The system of claim 15, wherein the subsea equipment comprises a pipeline, a tubular, a riser, a flow conduit, a valve, a collar, a joint, a connection, a fitting, a spool, a wellhead, a template, a manifold, an instrument, a gauge, or combinations thereof.
18. The system of claim 16, further comprising a pump coupled to the one or more flow conduits.

19. The system of claim 16, further comprising one or more remotely operated vehicles to position the reaction chamber adjacent the subsea equipment having a plug therein.

20. The system of claim 16, further comprising means for locating the plug in the subsea equipment.

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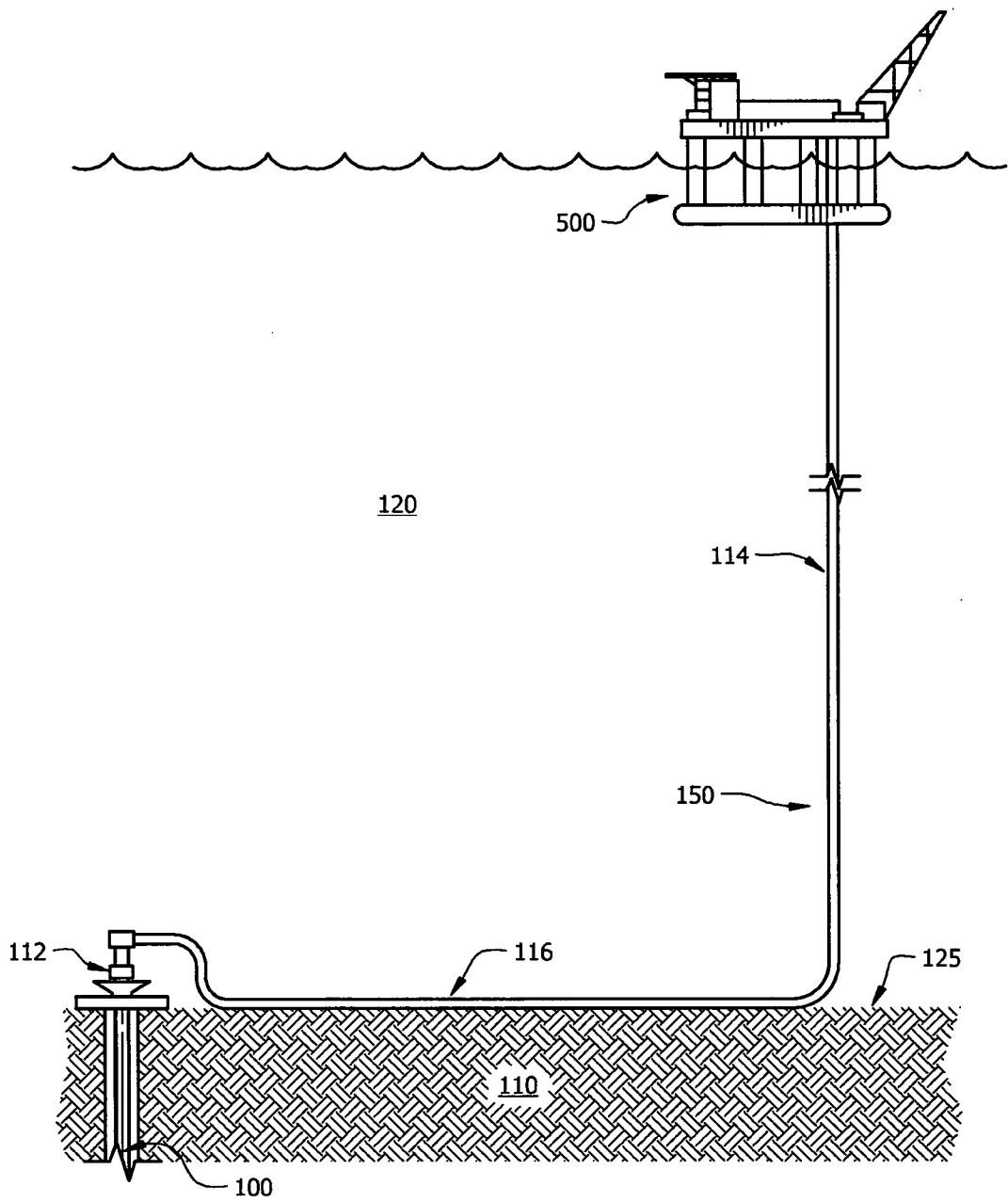


FIG. 1

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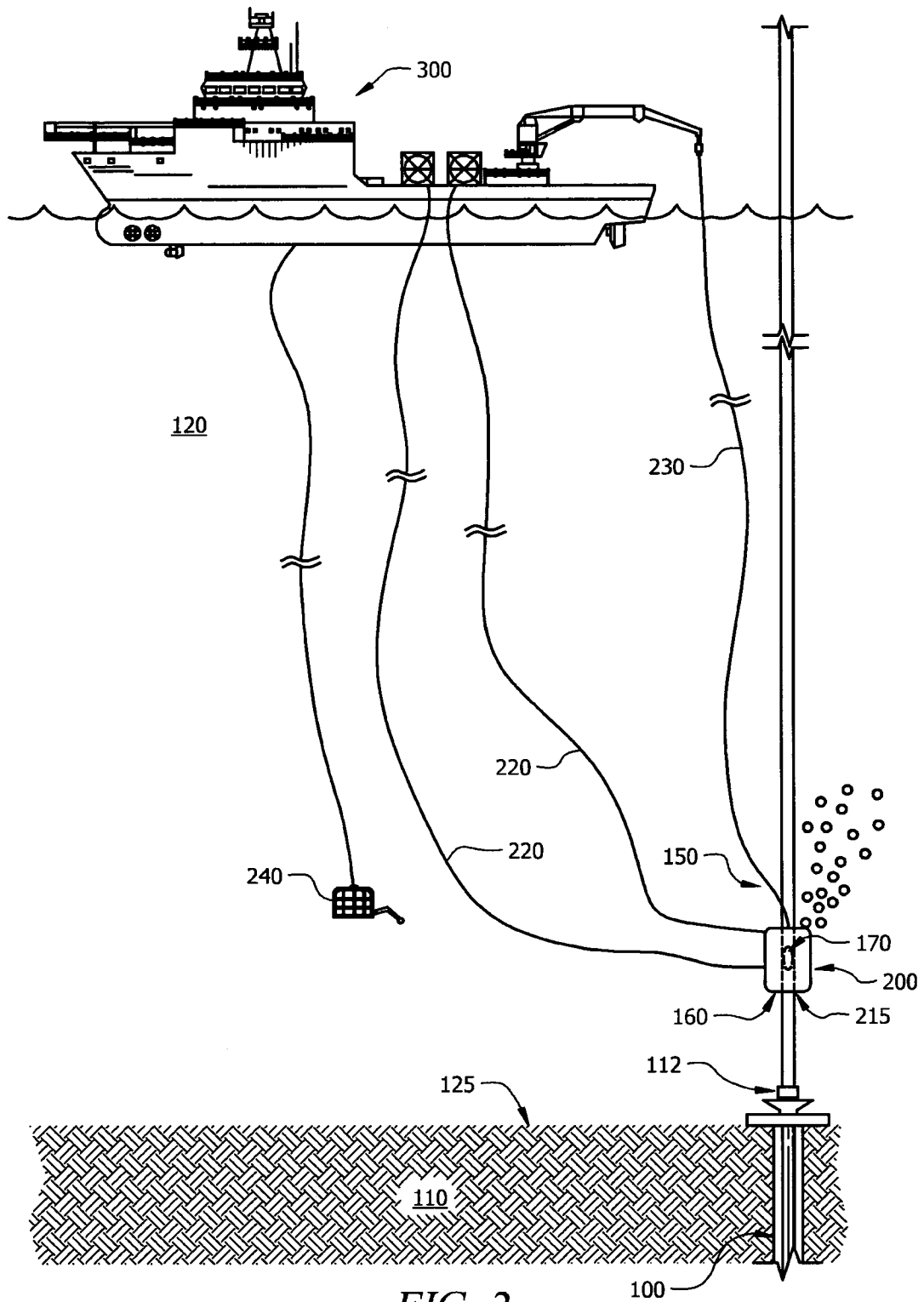


FIG. 2

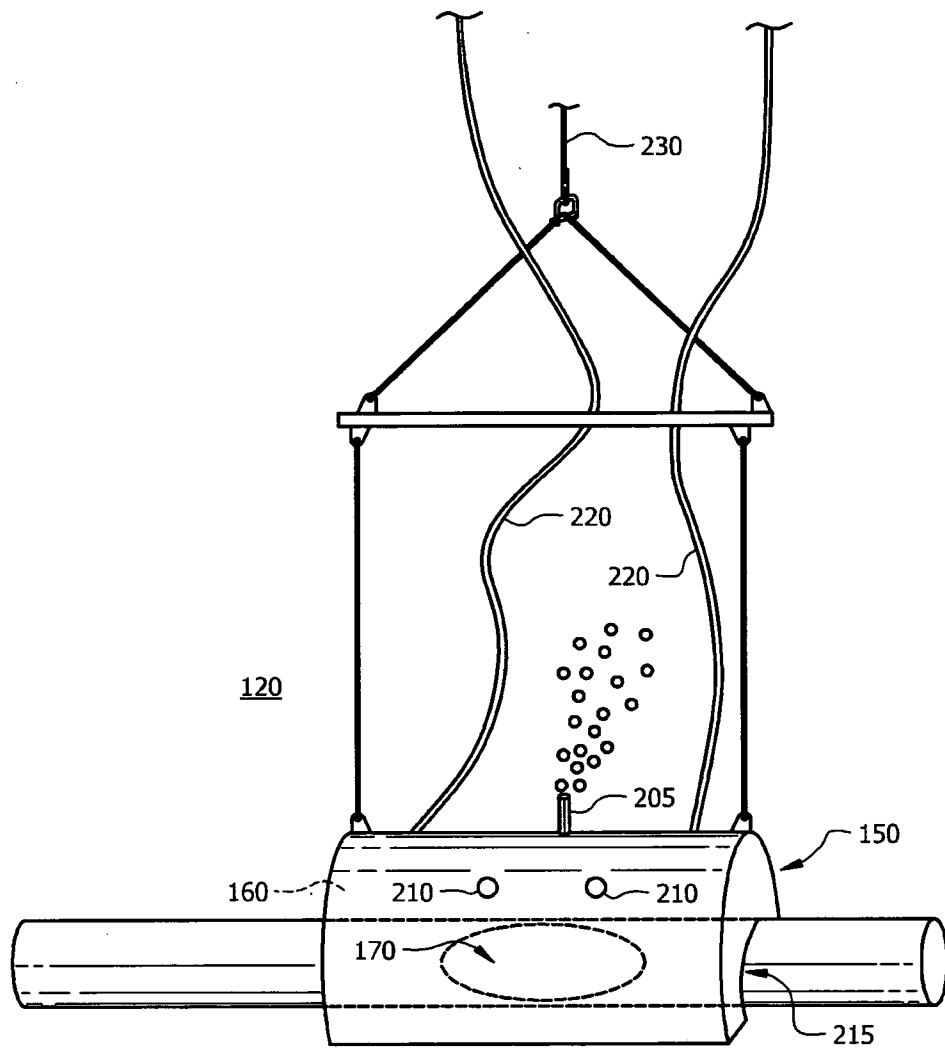


FIG. 3