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(54) COILED TUBING MODULE FOR RISERLESS SUBSEA WELL INTERVENTION SYSTEM

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(57) ABSTRACT

A method for riserless intervention of a subsea well includes connecting an intervention assembly to a bottom hole assembly (BHA). The BHA is connected to coiled tubing. The method further includes lowering the intervention assembly to a blowout preventer (BOP) fastened to a subsea production tree using an injector of a support vessel engaged with the coiled tubing; fastening the intervention assembly to the BOP; slacking the coiled tubing using the vessel injector; engaging a stripper of the intervention assembly with the coiled tubing; and driving the BHA through the tree and into a wellbore using a subsea injector of the intervention assembly while synchronizing both injectors to maintain the slack in the coiled tubing.

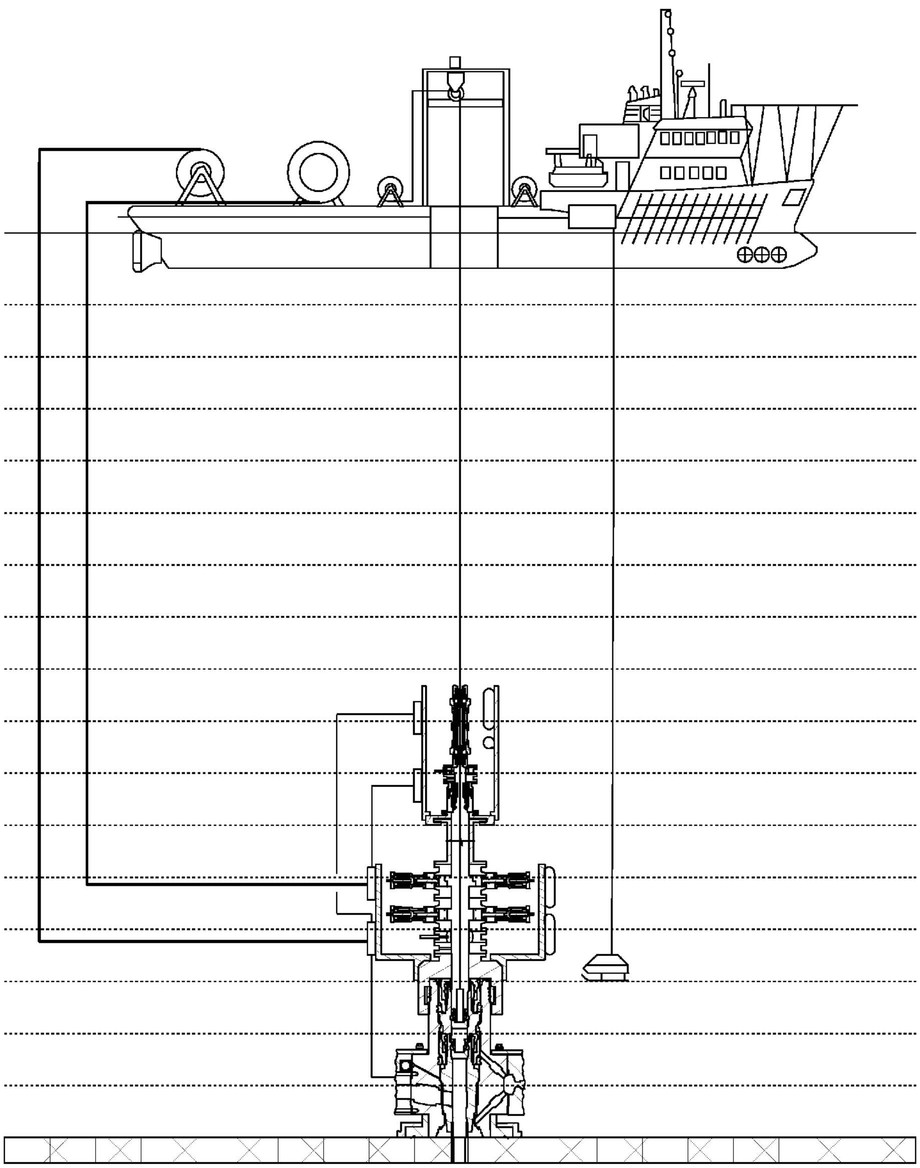
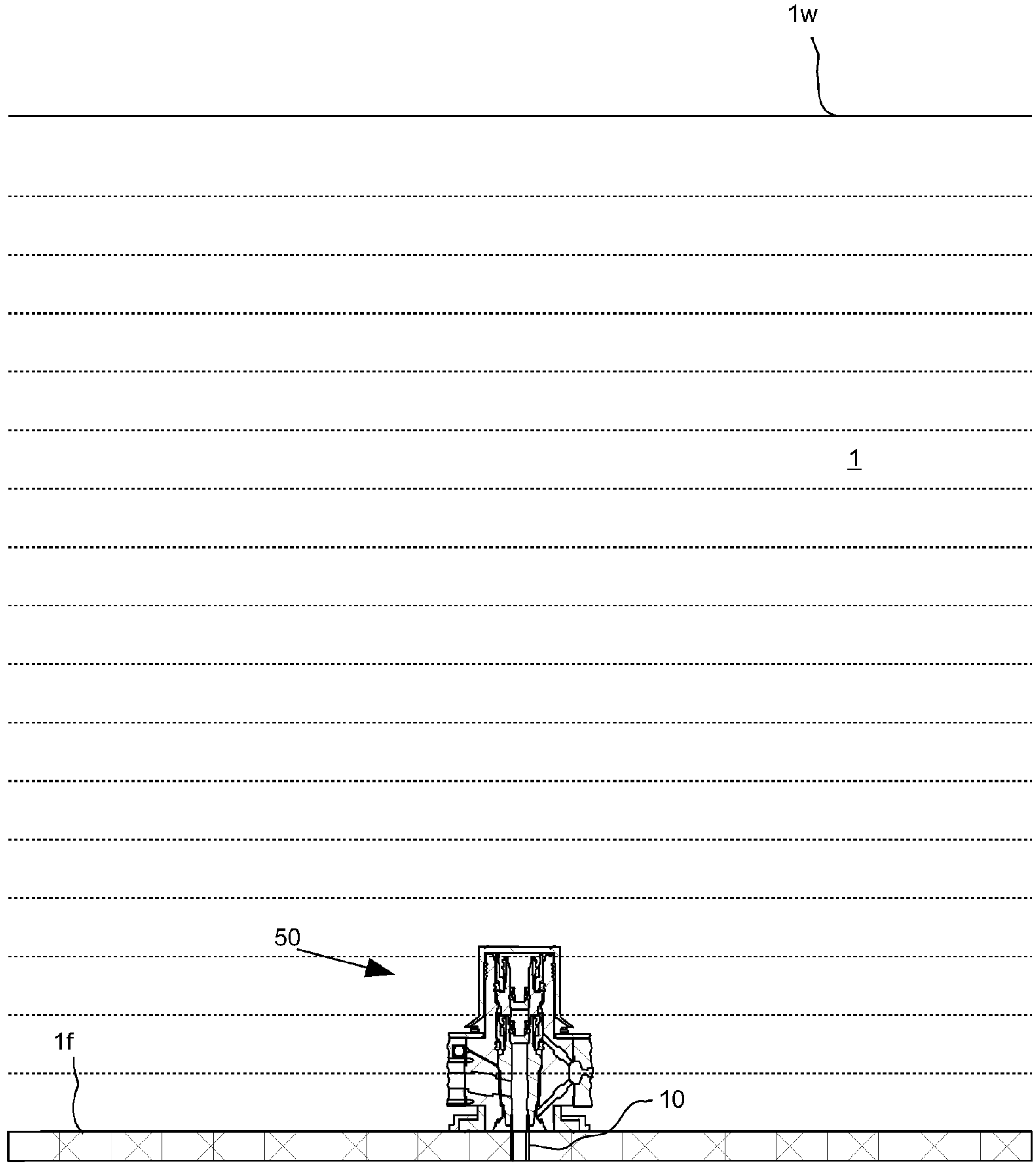


FIG. 1A
(Prior Art)



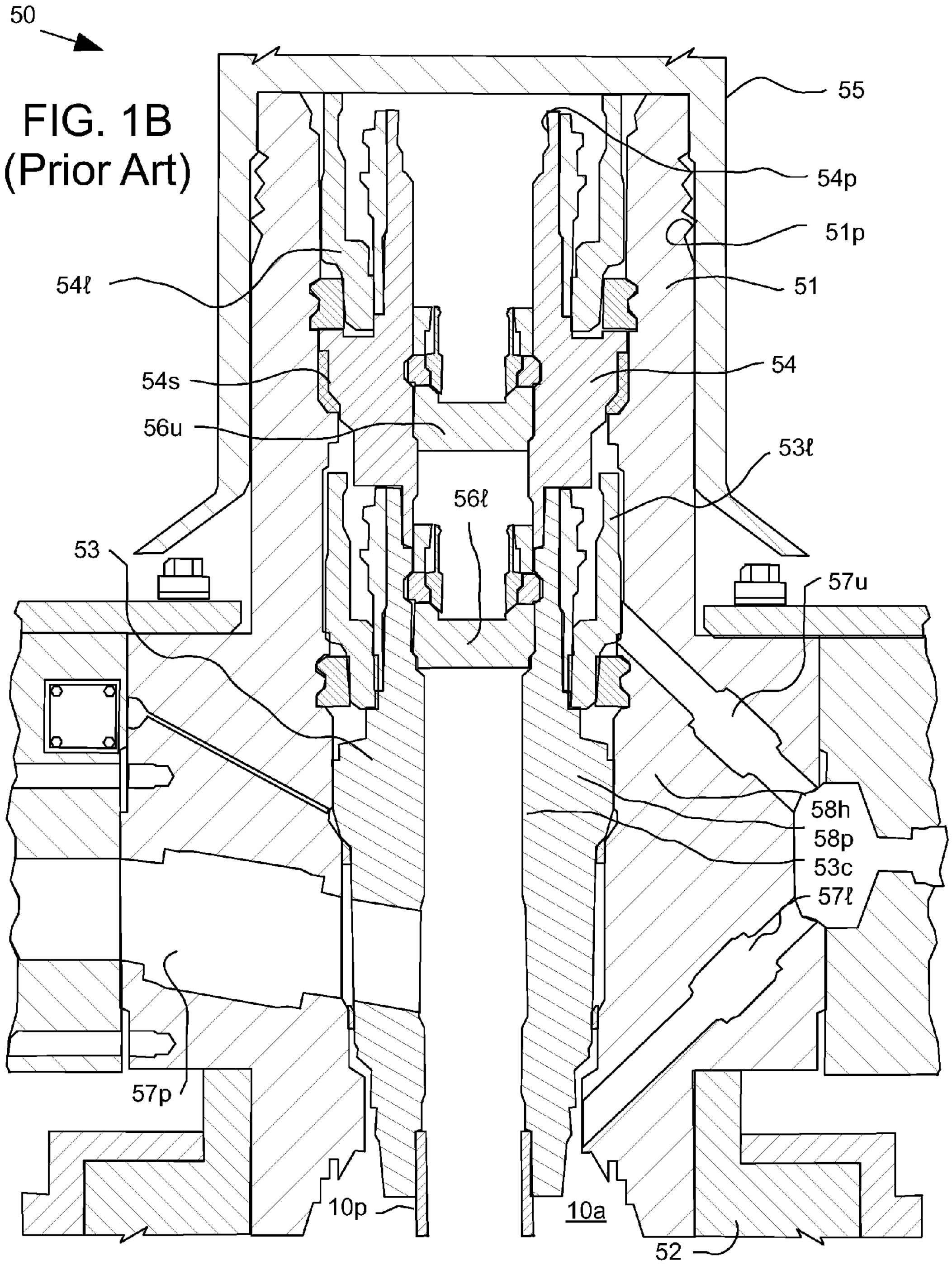


FIG. 1B
(Prior Art)

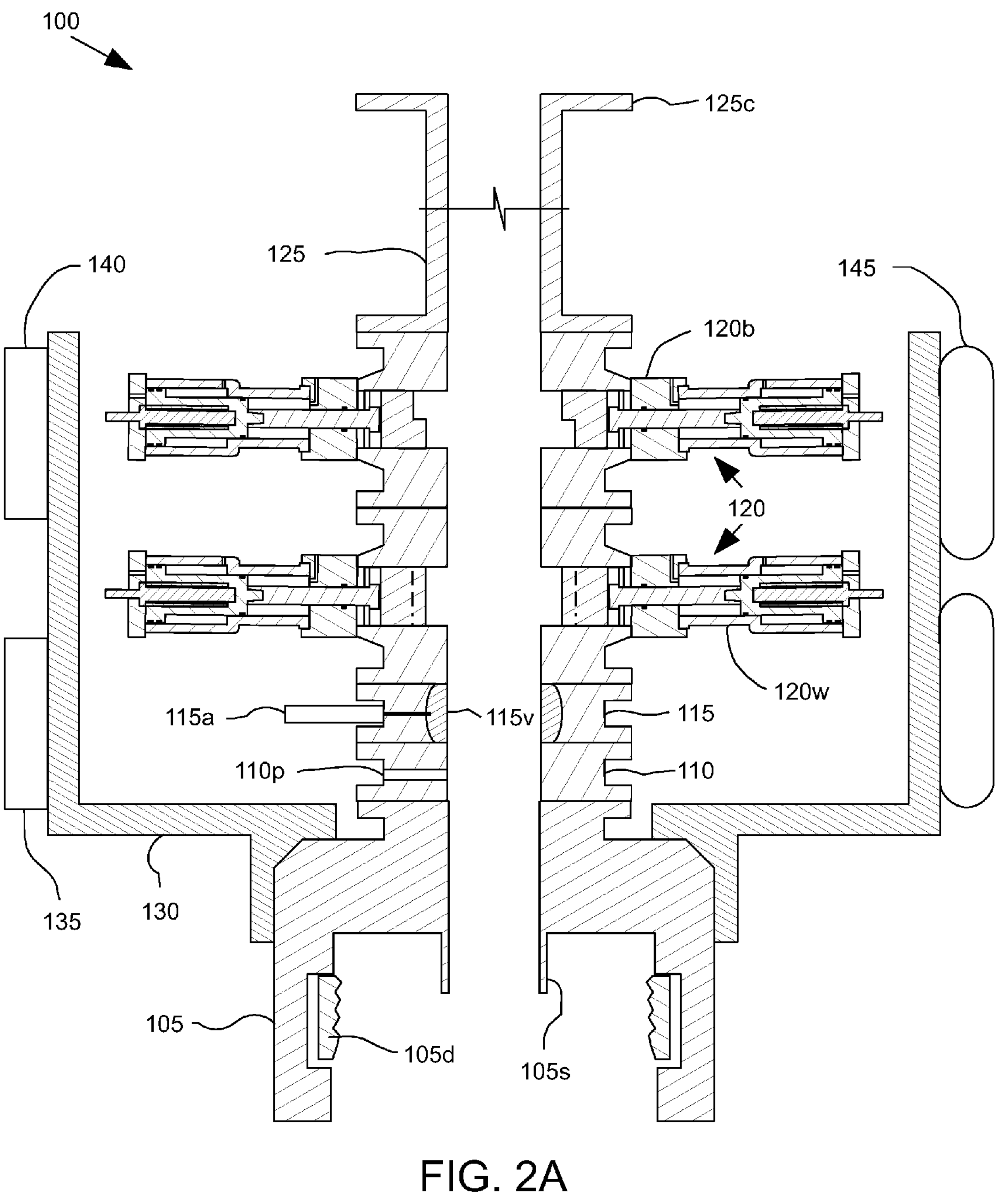

100
125c
125
140
145
120b
120
120w
115a
115v
115
110p
110
135
130
105
105d
105s

FIG. 2A

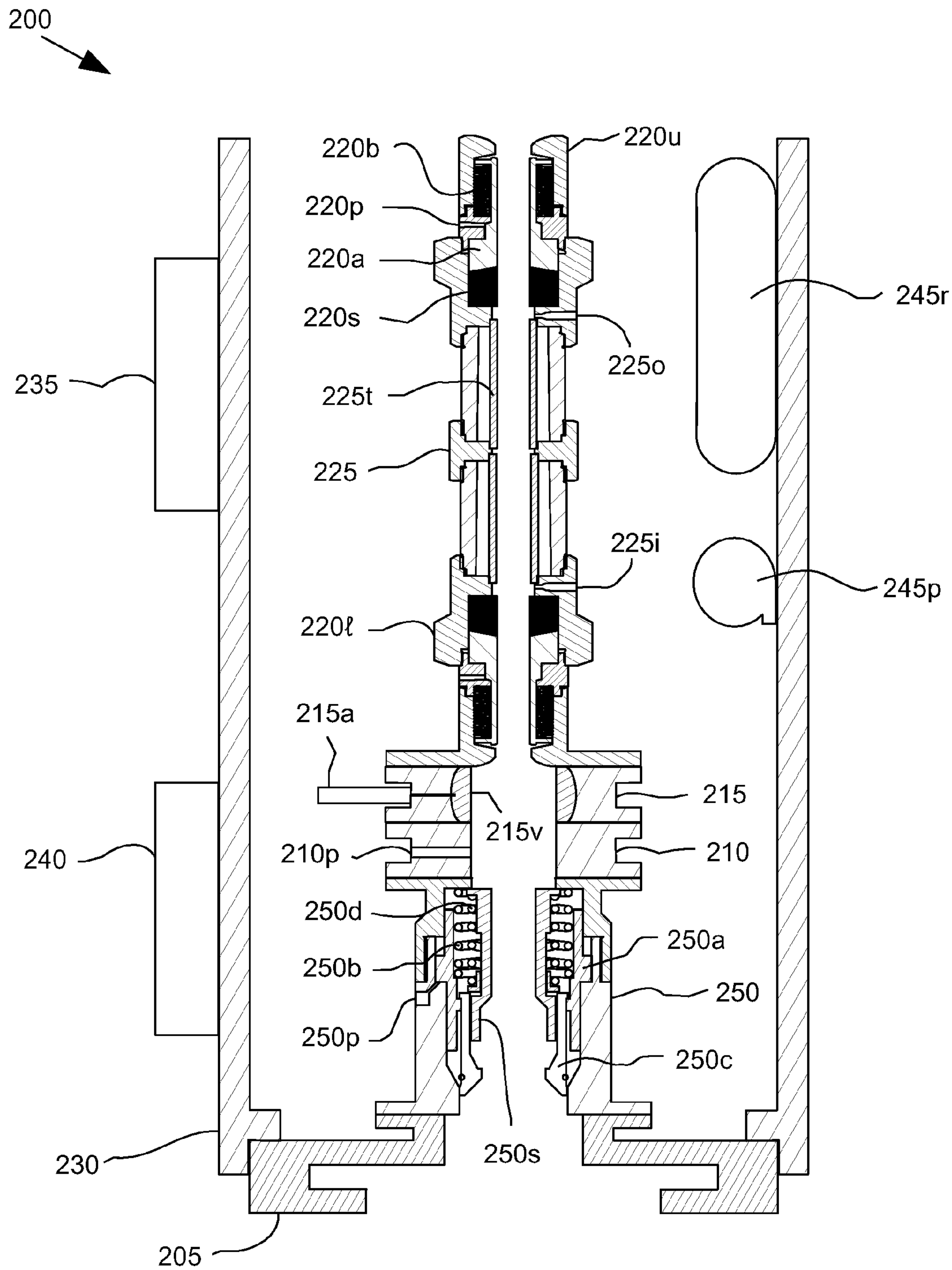

200
220b
220u
220p
220a
245r
220s
225o
235
225t
225
225i
245p
220ℓ
215a
215
215v
210p
210
240
250d
250a
250b
250
250p
250c
250s
230
205

FIG. 2B

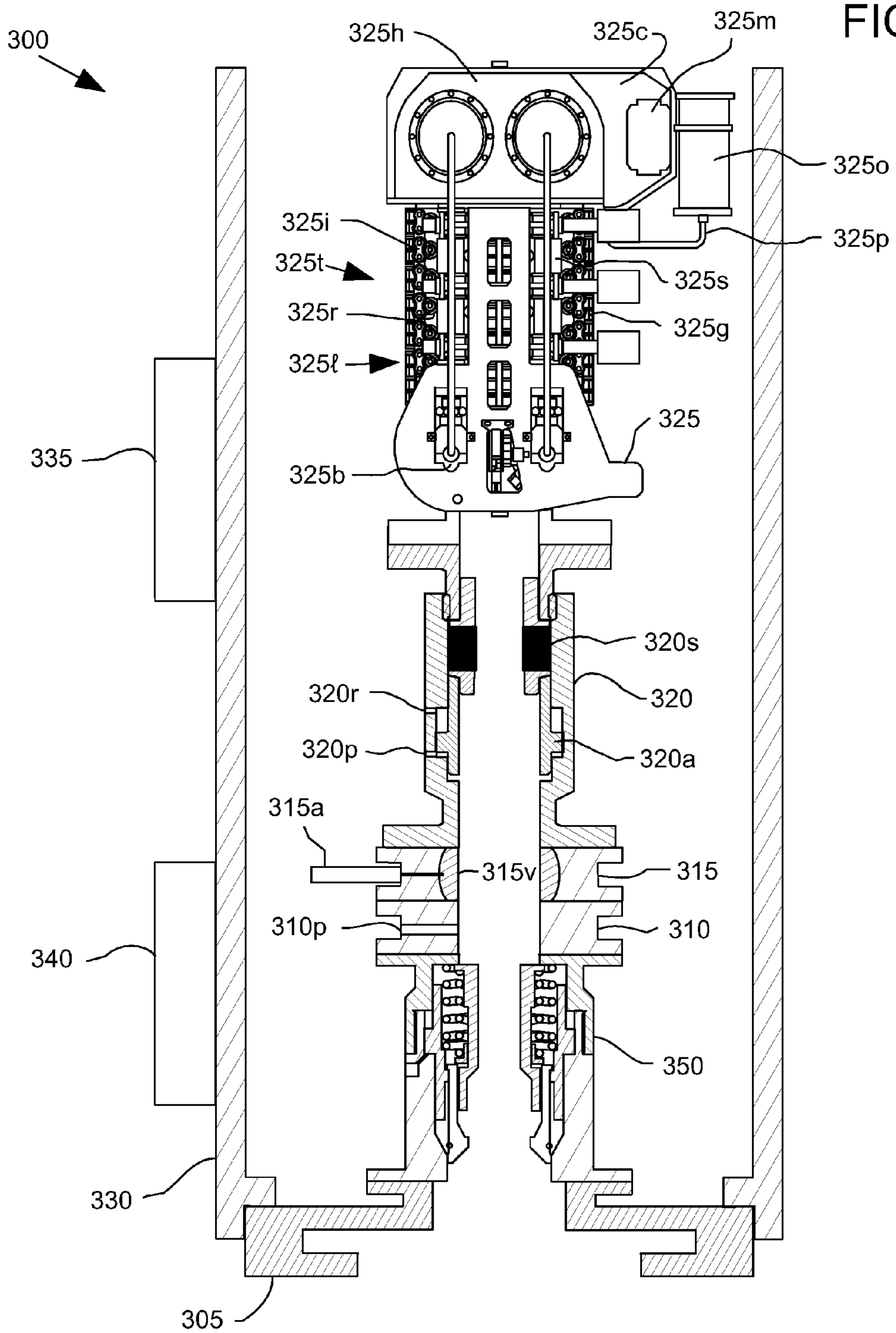

300
325h
325c
325m
325o
325p
325i
325t
325s
325r
325g
325ℓ
325
335
325b
320s
320r
320
320p
320a
315a
315v
315
310p
310
340
350
330
305

FIG. 2C

FIG. 3A

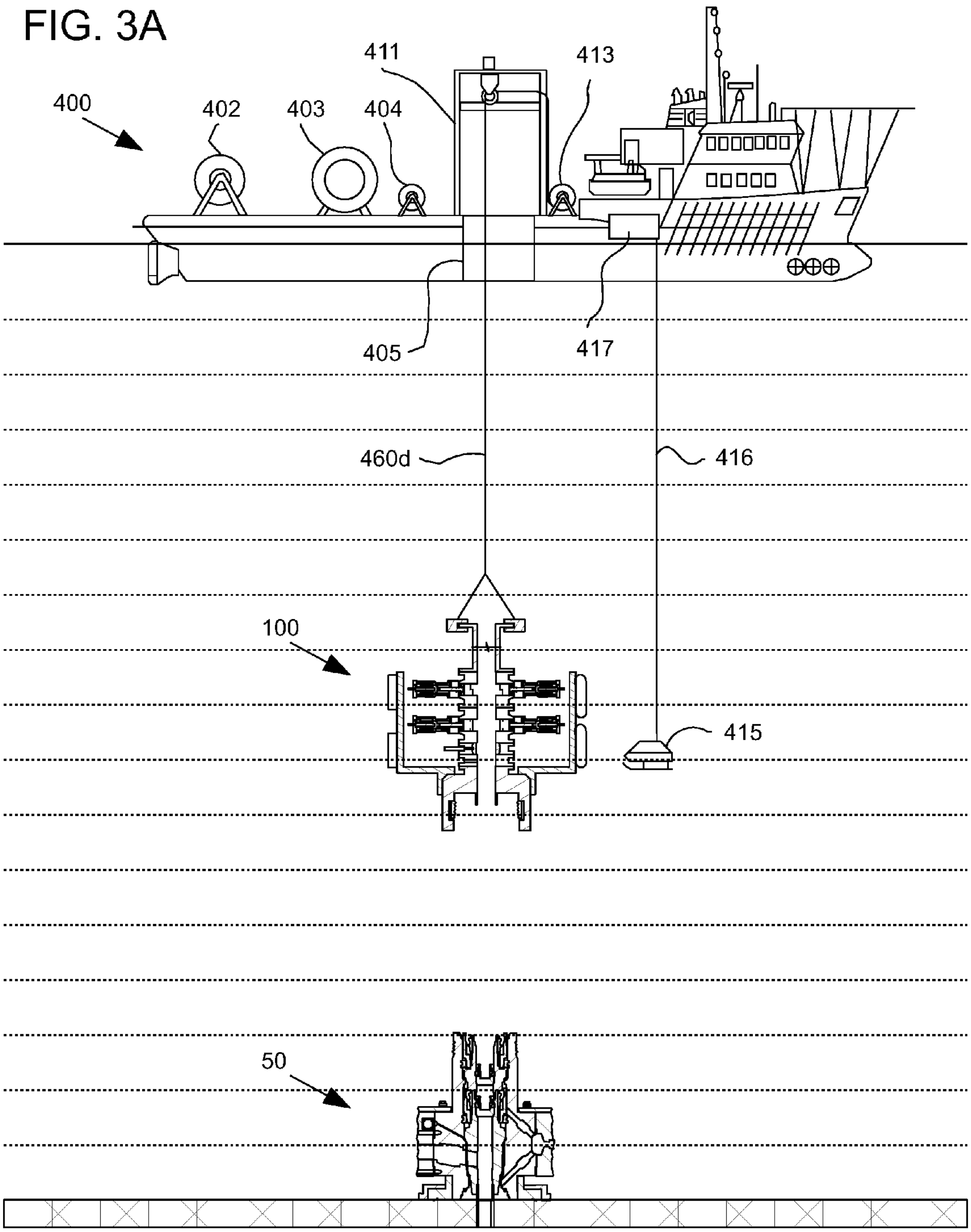


FIG. 3B

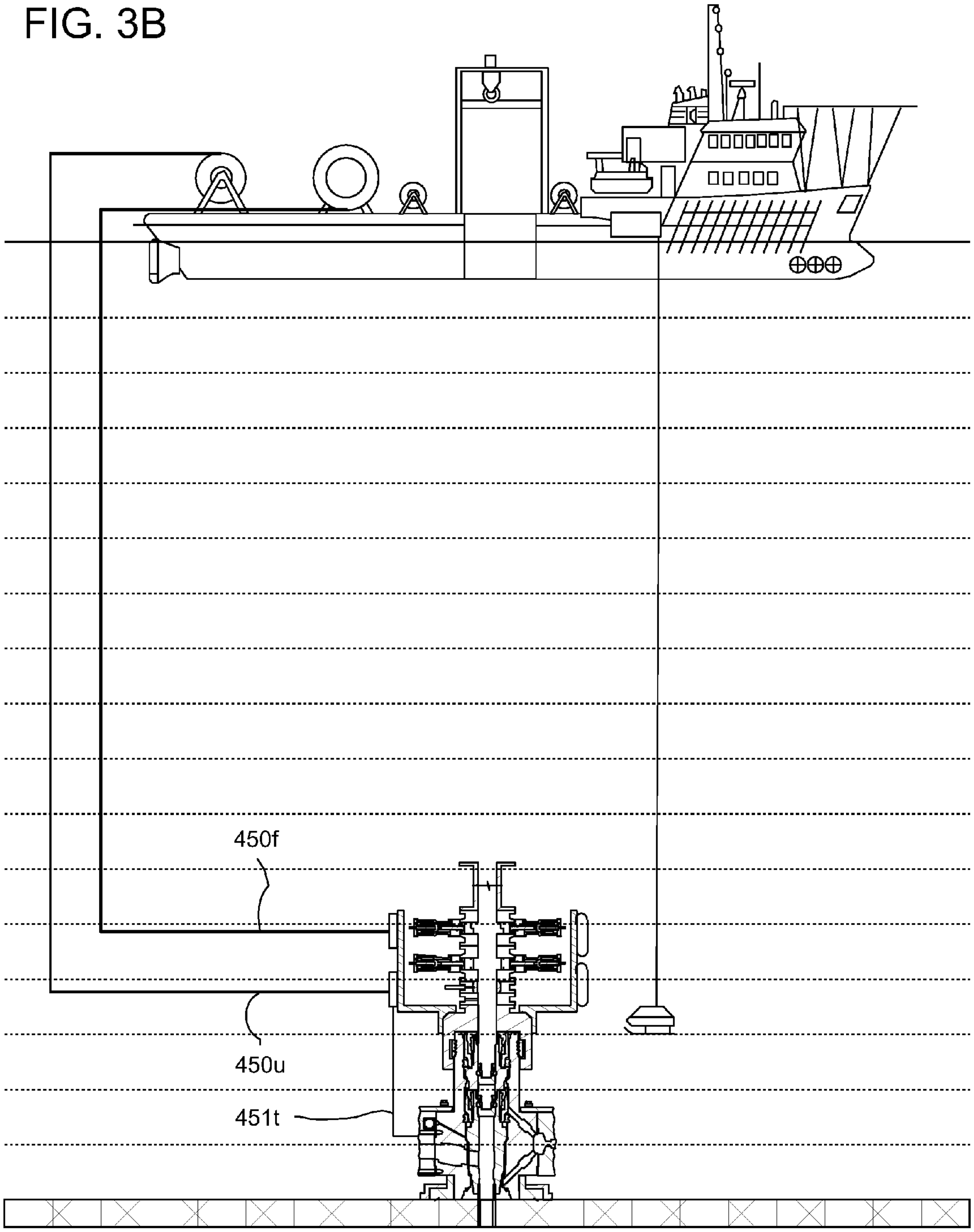


FIG. 4A

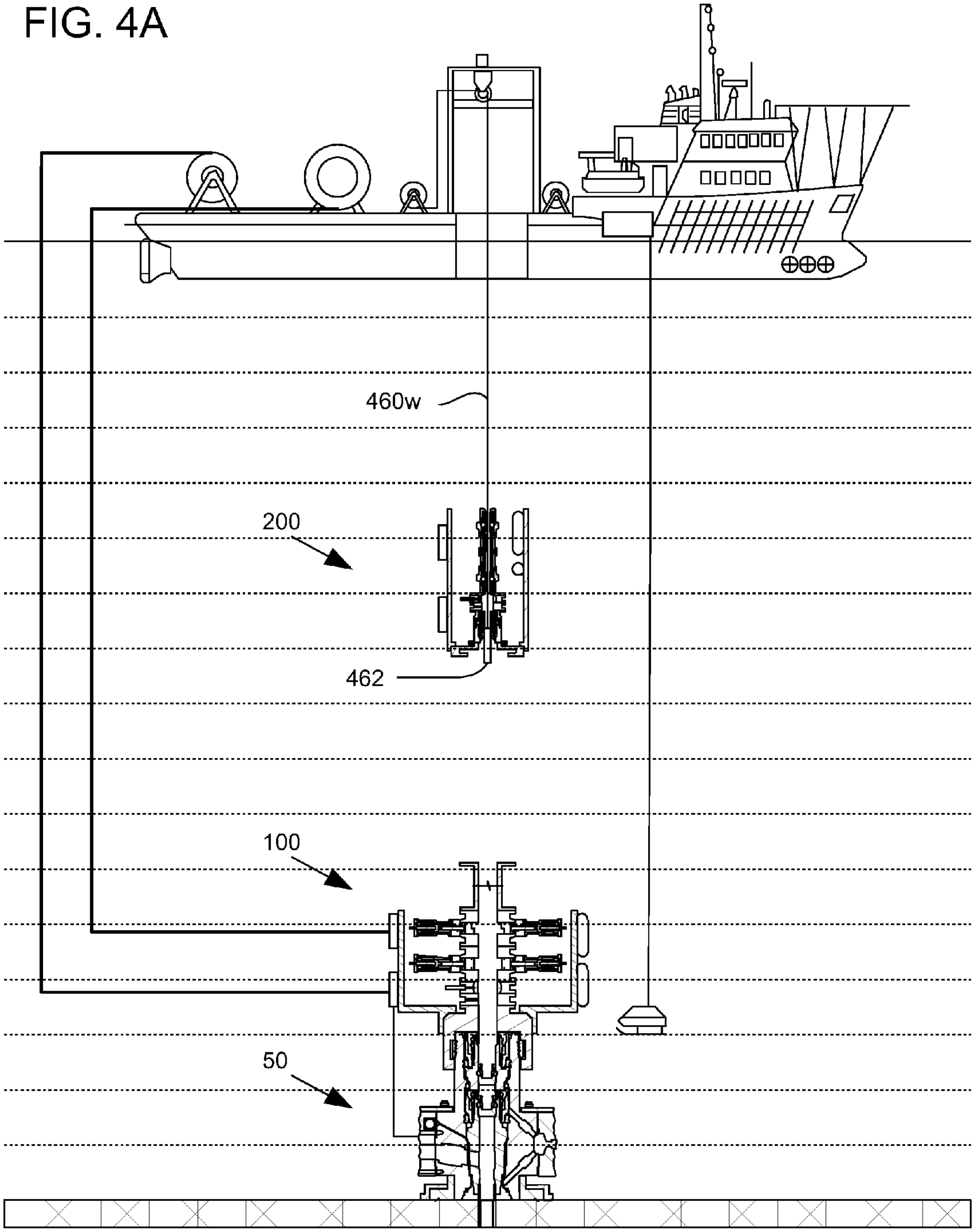


FIG. 4B

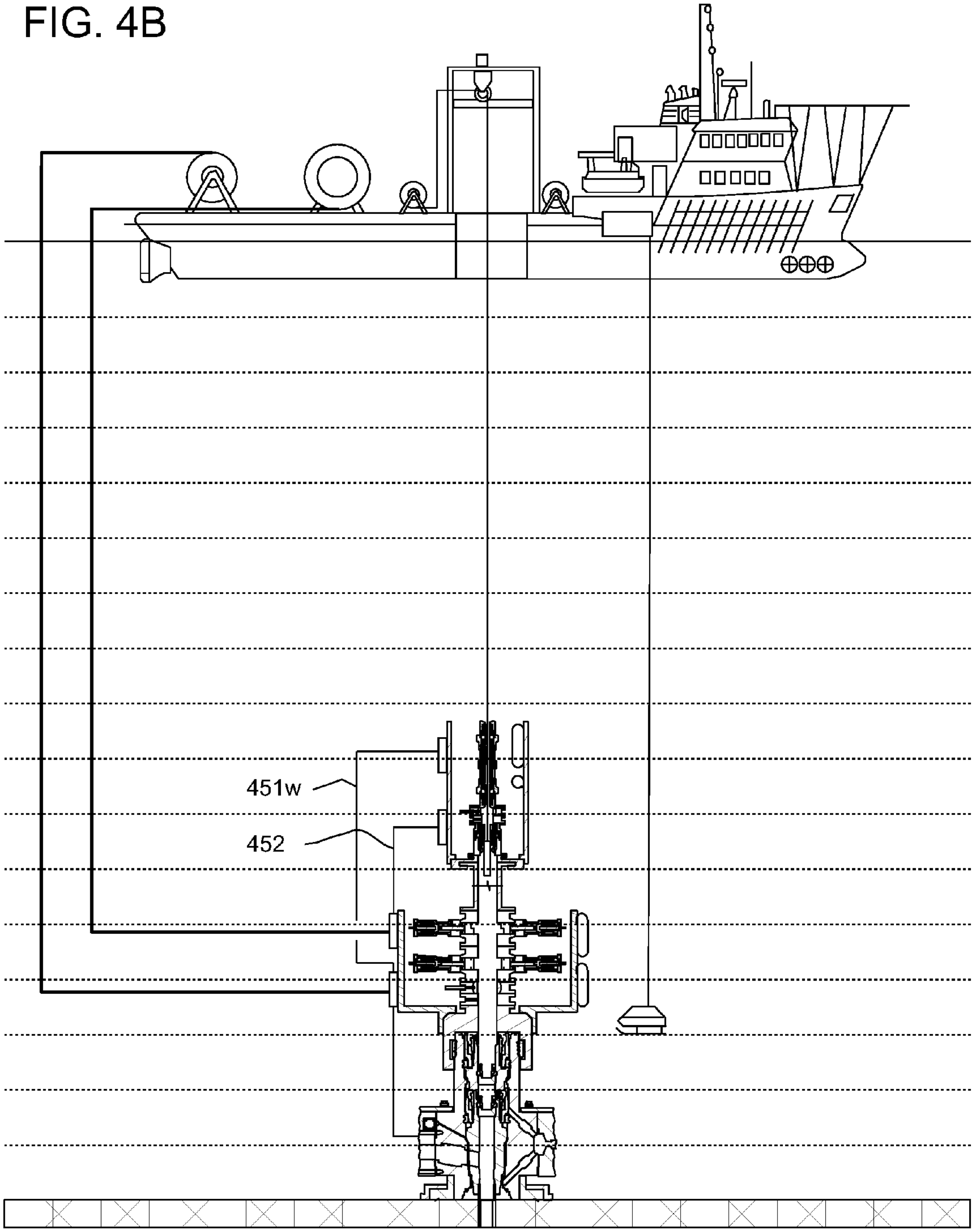


FIG. 4C

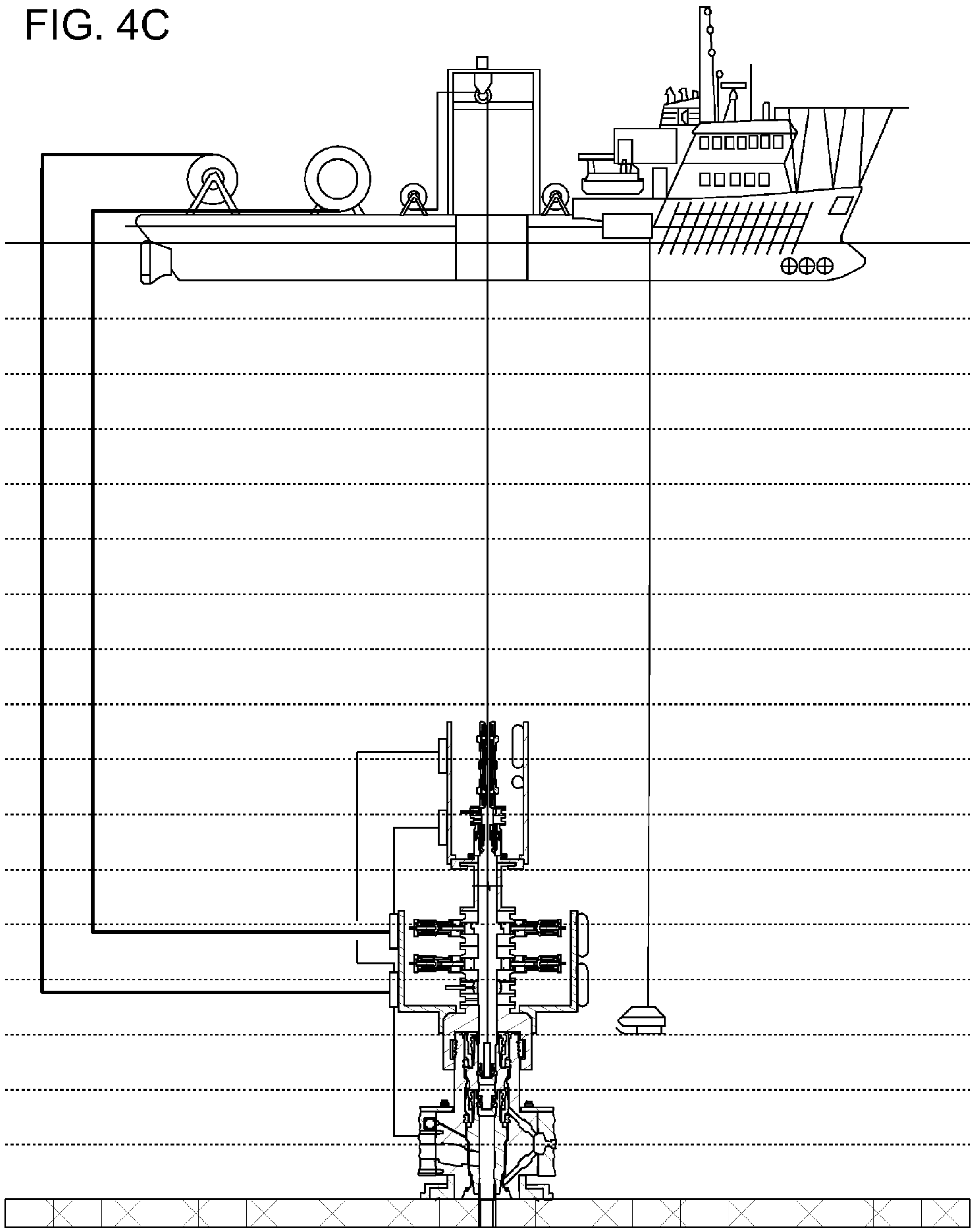


FIG. 4D

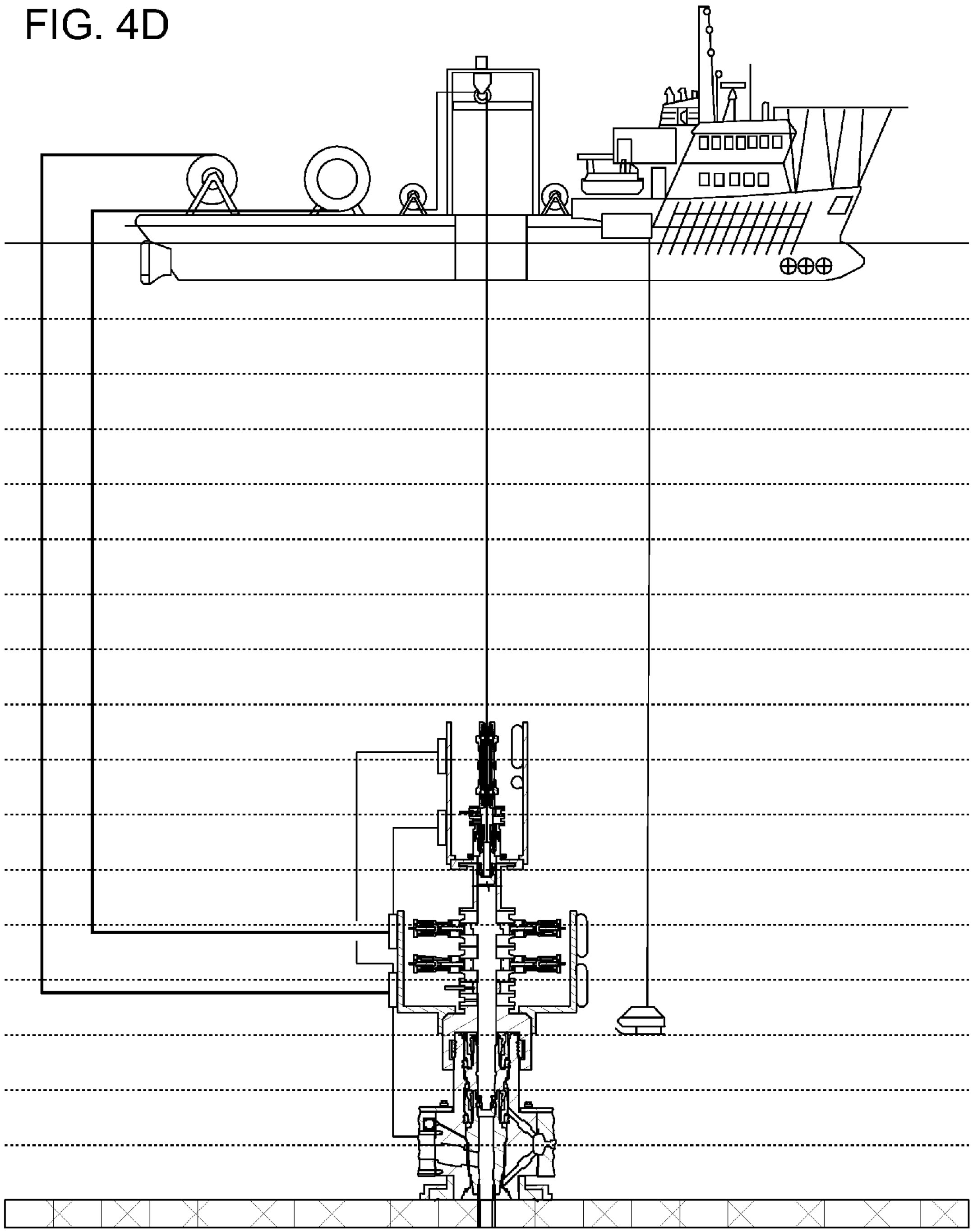
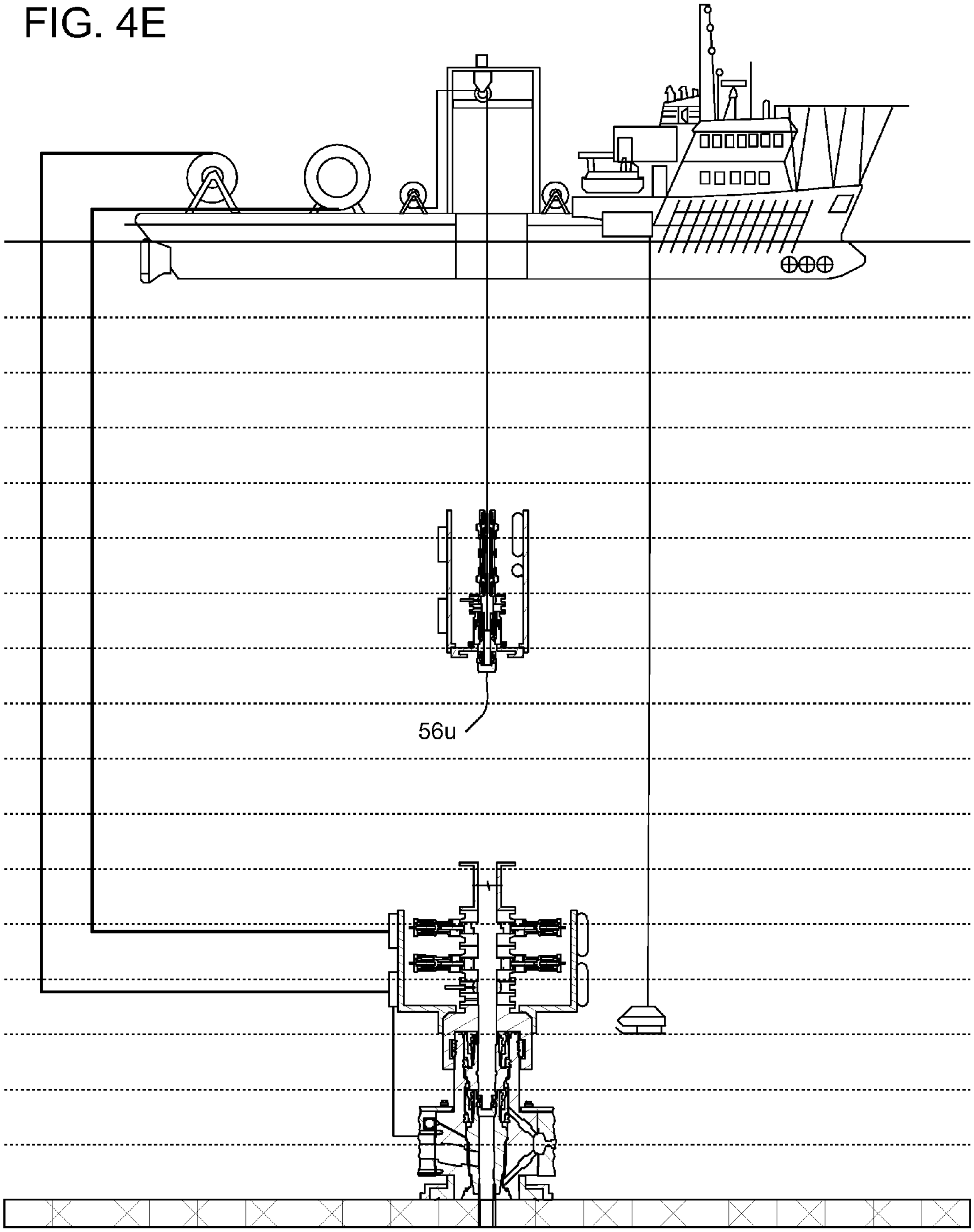


FIG. 4E



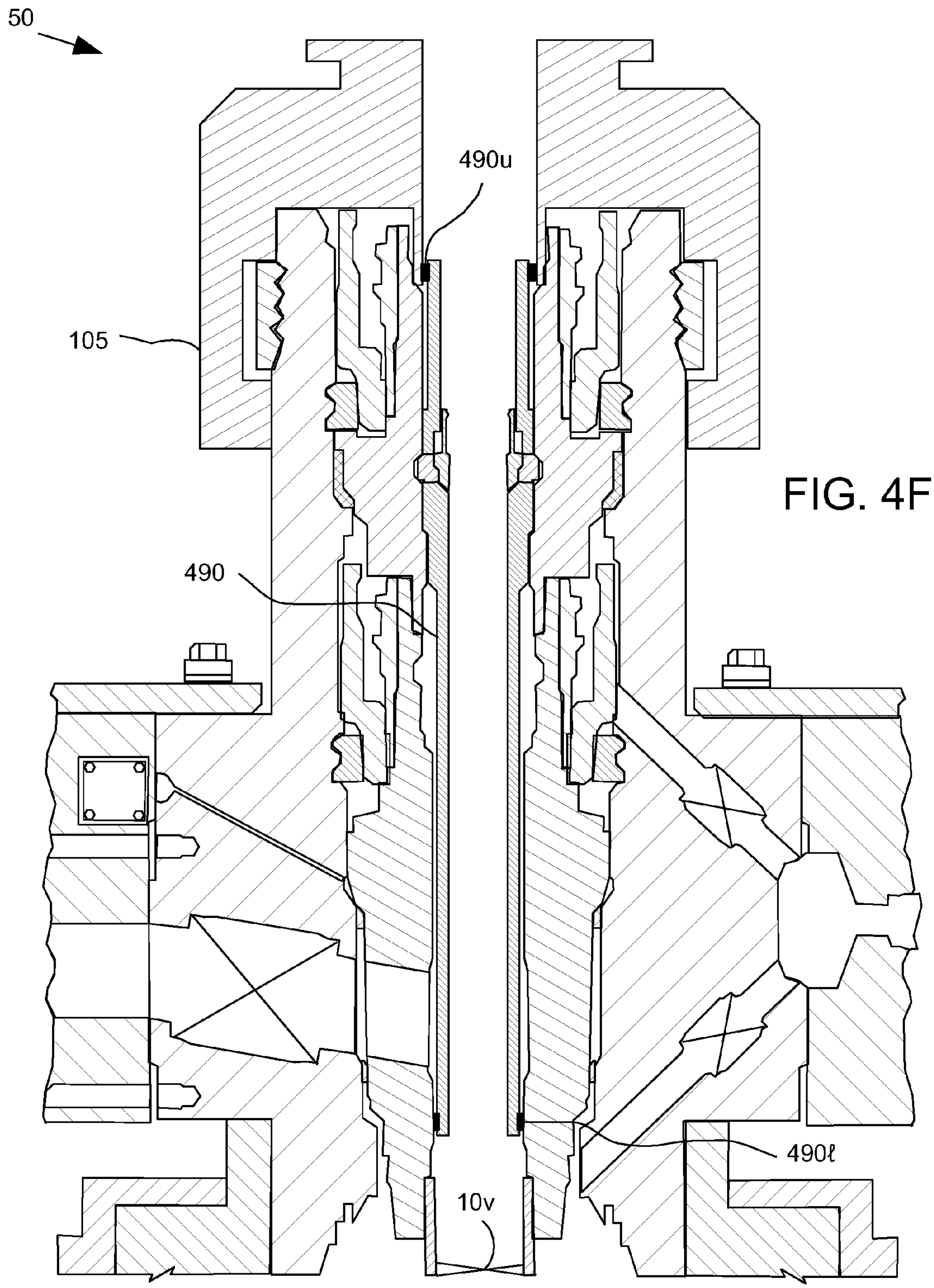


FIG. 4F

FIG. 5A

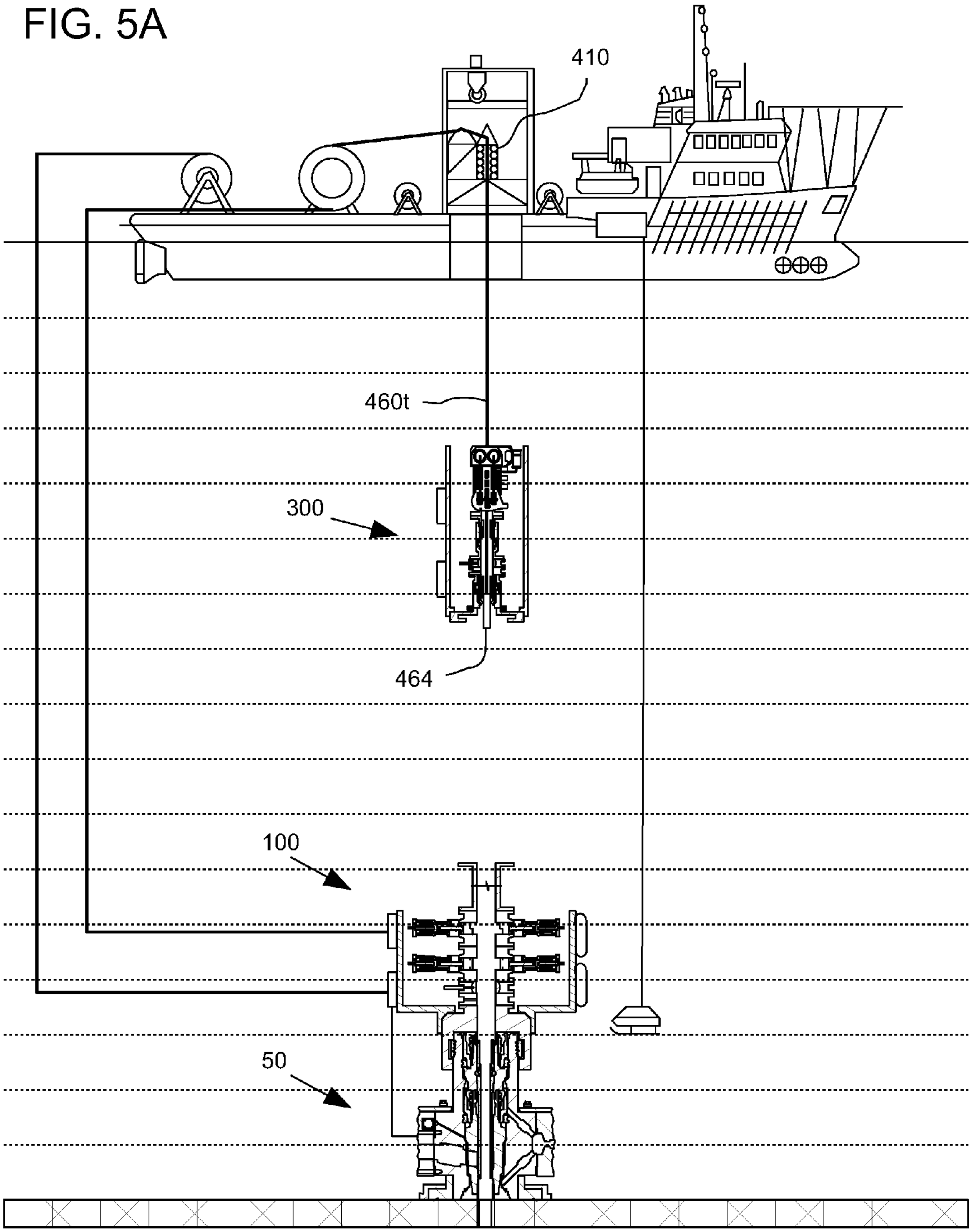
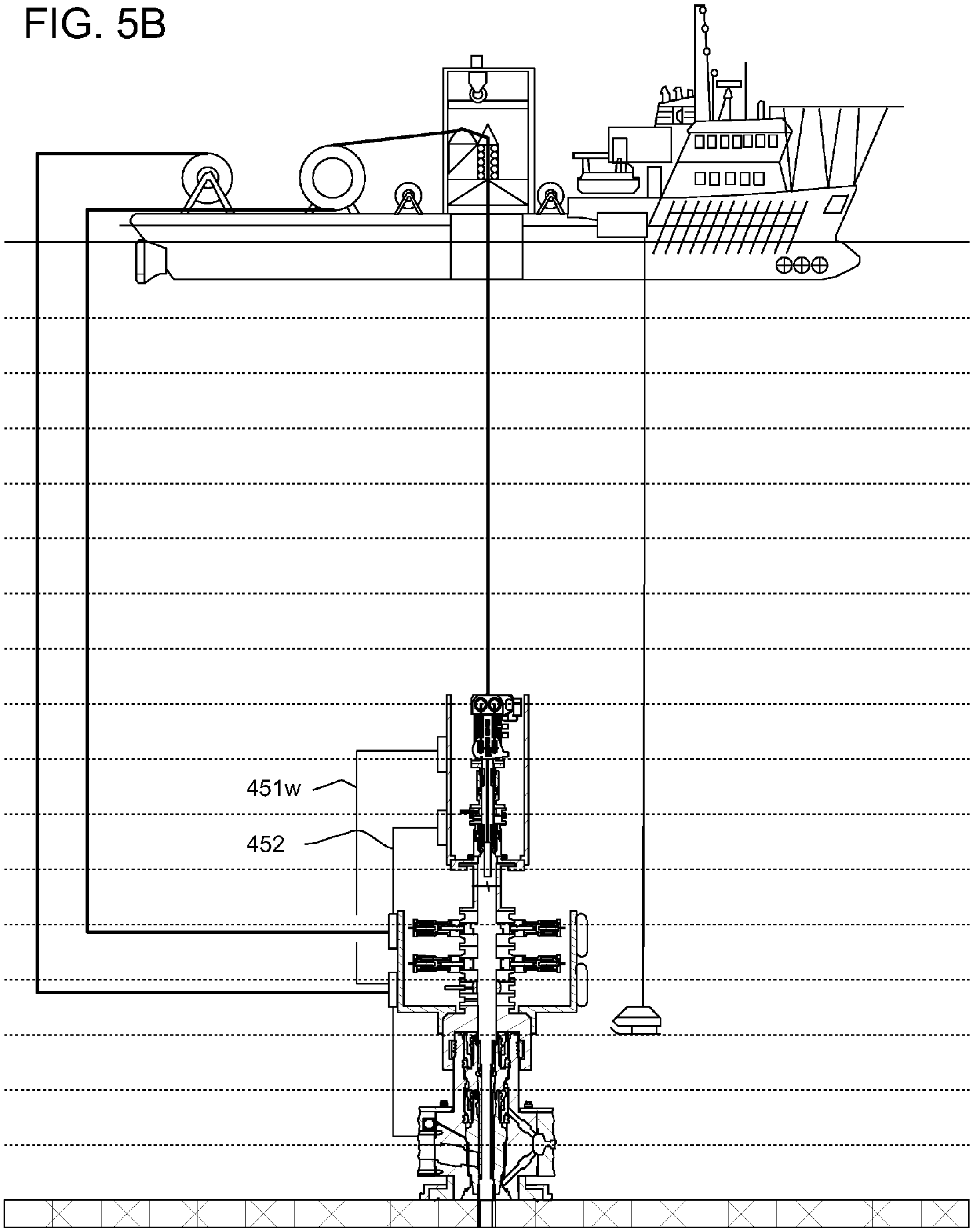


FIG. 5B



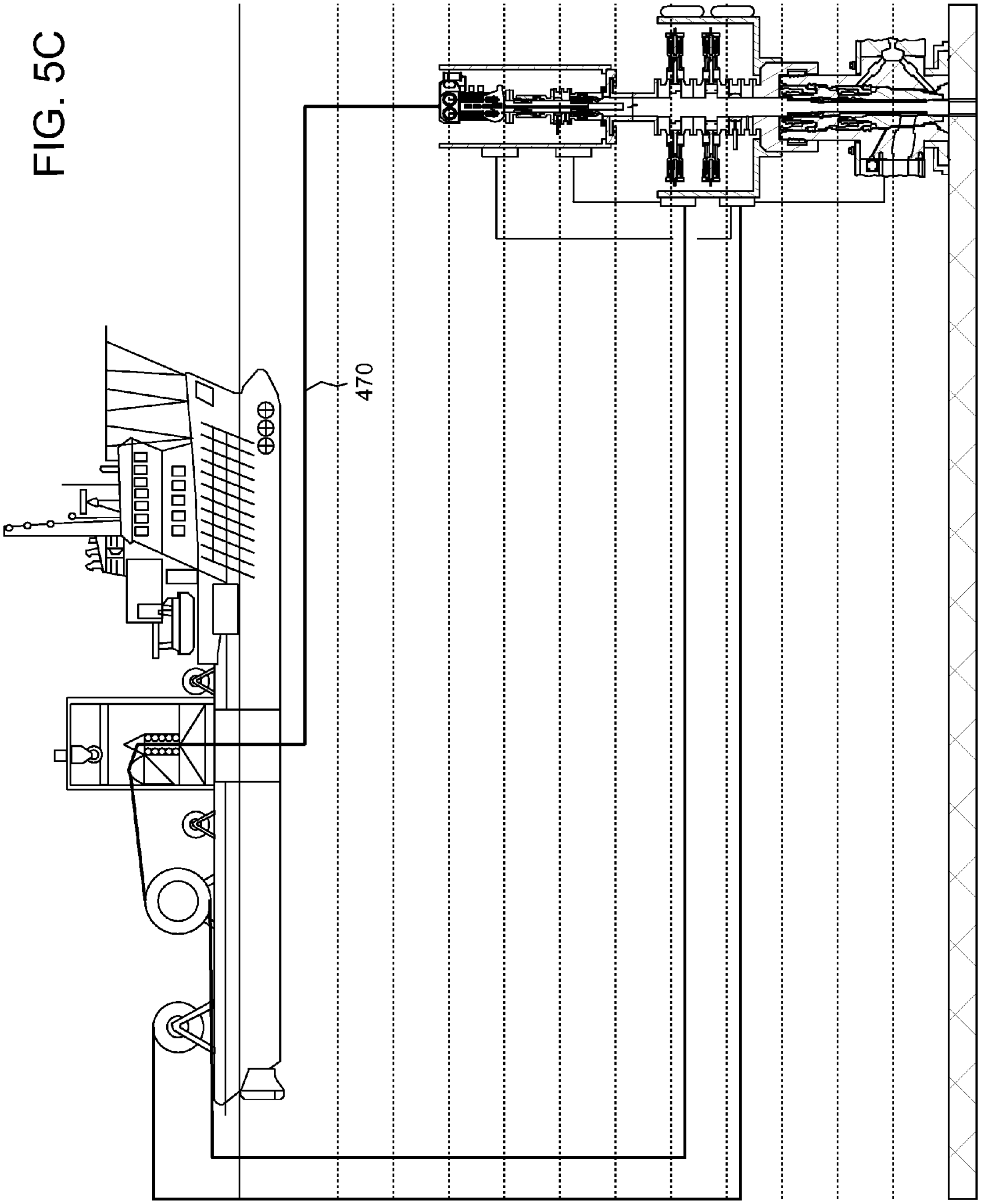
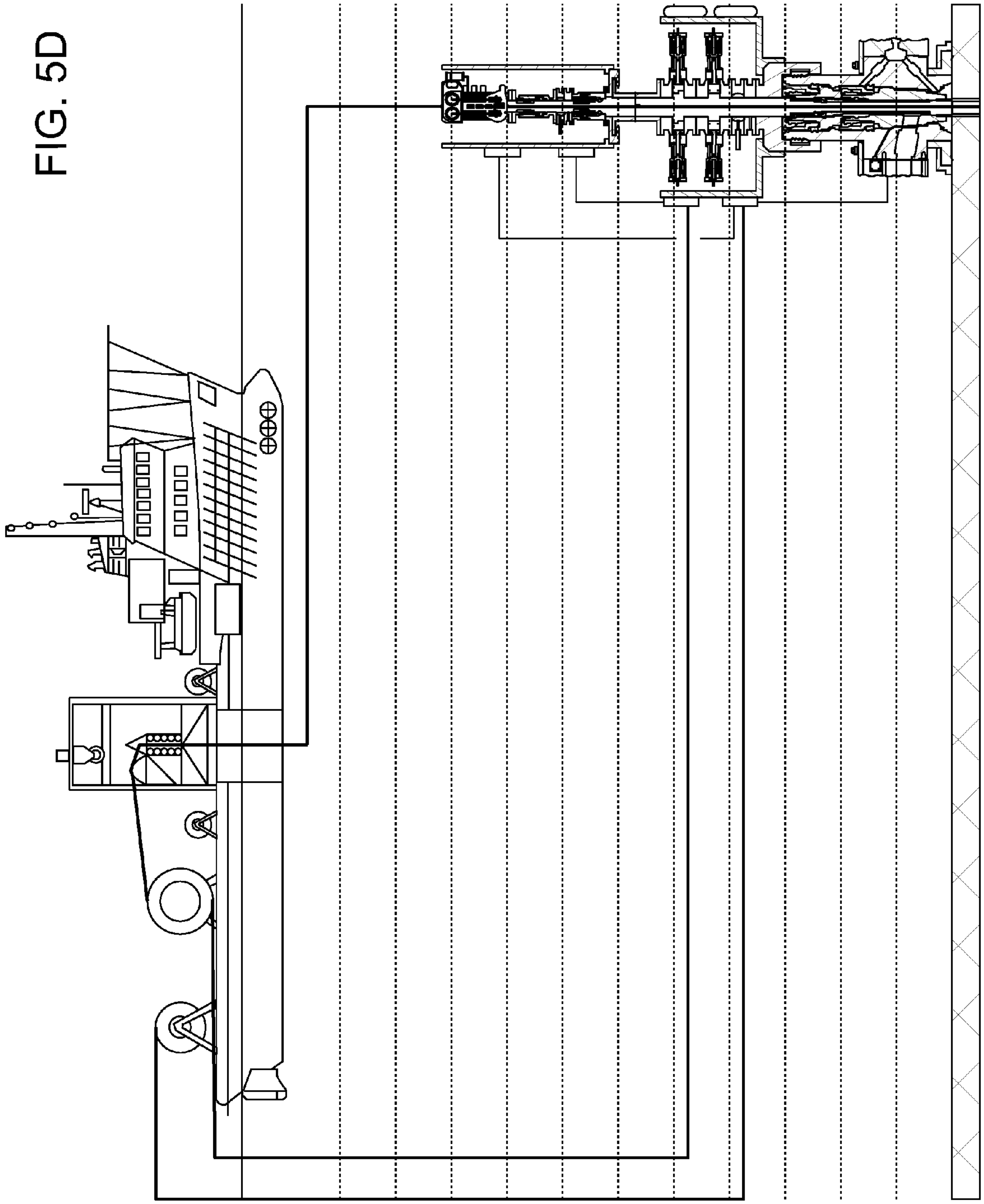


FIG. 5C

FIG. 5D



COILED TUBING MODULE FOR RISERLESS SUBSEA WELL INTERVENTION SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] Embodiments of the present invention generally relate to a coiled tubing module for a riserless subsea well intervention system.

[0003] 2. Description of the Related Art

[0004] Subsea crude oil and/or natural gas wells frequently require workover to maintain adequate production. Workover operations may include perforating, gravel packing, production stimulation and repair of a downhole completion or production tubing. During the workover, specialized tools are lowered into the well by means of a wireline and winch. This wireline winch is typically positioned on the surface and the workover tool is lowered into the well through a lubricator and blowout preventer (BOP). Workover operations on subsea wells require specialized intervention equipment to pass through the water column and to gain access to the well. The system of valves on the wellhead is commonly referred to as a production or Christmas tree and the intervention equipment is attached to the tree with a blowout preventer (BOP).

[0005] The commonly used method for accessing a subsea well first requires installation of a BOP with a pre-attached tree running tool (TRT) for guiding the BOP to correctly align and interface with the tree. The BOP/running tool is lowered from a derrick that is mounted on a mobile offshore drilling unit (MODU), such as a drill ship or semi-submersible platform. The BOP/TRT is lowered on a segmented length of pipe called a workover riser string. The BOP/TRT is lowered by adding sections of pipe to the riser string until the BOP/TRT is sufficiently deep to allow landing on the tree. After the BOP is attached to the tree, the workover tool is lowered into the well through a lubricator mounted on the top of the riser string. The lubricator provides a sealing system at the entrance of the wireline that maintains the pressure and fluids inside the well and the riser string. The main disadvantage of this method is the large, specialized MODU that is required to deploy the riser string and the riser string needed to deploy the BOP.

[0006] FIG. **1**A illustrates a prior art completed subsea well. A wellbore **10** has been drilled from a floor if of the sea **1** into a hydrocarbon-bearing (i.e., crude oil and/or natural gas) reservoir (not shown). A string of casing (not shown) has been run into the wellbore and set therein with cement (not shown). The casing has been perforated to provide to provide fluid communication between the reservoir and a bore of the casing. A wellhead (not shown) has been mounted on an end of the casing string. A string of production tubing **10***p* (see FIG. **1**B) may extend from the wellhead (not shown) to the formation to transport production fluid from the formation to the seafloor **1**f. A packer (not shown) may be set between the production tubing **10***p* and the casing to isolate an annulus **10***a* (see FIG. **1**B) formed between the production tubing **10***p* and the casing (not shown) from production fluid.

[0007] FIG. **1**B illustrates a prior art horizontal production tree **50**. The production tree **50** may be connected to the wellhead, such as by a collet, mandrel, or clamp tree connector. The tree **50** may be vertical or horizontal. If the tree is vertical (not shown), it may be installed after the production tubing **10***p* is hung from the wellhead. If the tree **50** is horizontal (as shown), the tree may be installed and then the production tubing **10***p* may be hung from the tree **50**. The tree **50** may include fittings and valves to control production from the wellbore into a pipeline (not shown) which may lead to a production facility (not shown), such as a production vessel or platform. The tree **50** may also be in fluid communication with a hydraulic conduit (not shown) controlling a subsurface safety valve SSV **10***v* (see FIG. **4**F).

[0008] The tree **50** may include a head **51**, a wellhead connector **52**, a tubing hanger **53**, an internal cap **54**, an external cap **55**, an upper crown plug **56**u, a lower crown plug **56***l*, a production valve **57***p*, and one or more annulus valves **57***u,l*. Each of the components **51**-**54** may have a longitudinal bore extending therethrough. The tubing hanger **53** and head **51** may each have a lateral production passage formed through walls thereof for the flow of production fluid. The tubing hanger **53** may be disposed in the head bore. The tubing hanger **53** may support the production tubing **10***p*. The tubing hanger **53** may be fastened to the head by a latch **53***l*. The latch **53***l* may include one or more fasteners, such as dogs, and an actuator, such as a cam sleeve. The cam sleeve may be operable to push the dogs outward into a profile formed in an inner surface of the tree head **51**. The latch **53***l* may further include a collar for engagement with a running tool (not shown) for installing and removing the tubing hanger **53**.

[0009] The tubing hanger **53** may be rotationally oriented and longitudinally aligned with the tree head **51**. The tubing hanger **53** may further include seals **53***s* disposed above and below the production passage and engaging the tree head inner surface. The tubing hanger **53** may also have a number of auxiliary ports/conduits (not shown) spaced circumferentially there-around. Each port/conduit may align with a corresponding port/conduit (not shown) in the tree head **51** for communicating hydraulic fluid or electricity for various purposes to tubing hanger **53**, and from tubing hanger **53** downhole, such as for operation of the SSV **10***v*. The tubing hanger **53** may have an annular, partially spherical exterior portion that lands within a partially spherical surface formed in tree head **51**.

[0010] The annulus **10***a* may communicate with an annulus passage formed through and along the head **51** for and bypassing the seals **53***s*. The annulus passage may be accessed by removing internal tree cap **54**. The tree cap **54** may be disposed in head bore above tubing hanger **53**. The tree cap **54** may have a downward depending isolation sleeve received by an upper end of tubing hanger **53**. Similar to the tubing hanger **53**, the tree cap **54** may include a latch **54***l* fastening the tree cap to the head **51**. The tree cap **54** may further include a seal **54***s* engaging the head inner surface. The production valve **57***p* may be disposed in the production passage and the annulus valves **57***u,l* may be disposed in the annulus passage. Ports/conduits (not shown) may extend through the tree head **51** to a tree controller (not shown) for electrical or hydraulic operation of the valves.

[0011] The upper crown plug **56***u* may be disposed in tree cap bore and the lower crown plug **56***l* may be disposed in the tubing hanger bore. Each crown plug **56***u,l* may have a body with a metal seal on its lower end. The metal seal may be a depending lip that engages a tapered inner surface of the respective cap and hanger. The body may have a plurality of windows which allow fasteners, such as dogs, to extend and retract. The dogs may be pushed outward by an actuator, such as a central cam. The cam may have a profile on its upper end. The cam may move between a lower locked position and an upper position freeing dogs to retract. A retainer may secure to the upper end of body to retain the cam.

SUMMARY OF THE INVENTION

[0012] Embodiments of the present invention generally relate to a coiled tubing module for a riserless subsea well intervention system. In one embodiment, a method for riserless intervention of a subsea well includes connecting an intervention assembly to a bottom hole assembly (BHA). The BHA is connected to coiled tubing. The method further includes lowering the intervention assembly to a blowout preventer (BOP) fastened to a subsea production tree using an injector of a support vessel engaged with the coiled tubing; fastening the intervention assembly to the BOP; slacking the coiled tubing using the vessel injector; engaging a stripper of the intervention assembly with the coiled tubing; and driving the BHA through the tree and into a wellbore using a subsea injector of the intervention assembly while synchronizing both injectors to maintain the slack in the coiled tubing.

[0013] In another embodiment, a coiled tubing module for a riserless subsea intervention system includes: a stripper operable to seal against coiled tubing and a subsea injector. The subsea injector has opposed chain loops having grippers operable to grip the coiled tubing and longitudinally move the coiled tubing; outboard bearing assemblies operable to guide the chain loops; a motor and sealed gear case operable to drive the chain loops, the gear case having lubricant; and a pressure compensator operable to pressurize the lubricant to a pressure equal to or substantially equal to subsea pressure. The module further includes a controller operable to synchronize an injector of a support vessel engaged with the coiled tubing with the subsea injector to maintain slack in the coiled tubing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0015] FIG. **1**A illustrates a prior art completed subsea well. FIG. **1**B illustrates a prior art horizontal production tree.

[0016] FIG. **2**A illustrates a pressure control assembly (PCA), according to one embodiment of the present invention. FIG. **2**B illustrates a wireline module, according to another embodiment of the present invention.

[0017] FIG. **3**A illustrates deployment of the PCA to the subsea production tree. FIG. **3**B illustrates connection of the PCA to the tree and connection of the umbilical to the PCA.

[0018] FIG. **4**A illustrates deployment of the wireline module to the tree. FIG. **4**B illustrates connection of the wireline module to the PCA. FIG. **4**C illustrates deployment of a plug running tool (PRT) into the tree and connection of the PRT with the upper crown plug. FIG. **4**D illustrates retrieval of the PRT and upper crown plug into the tool housing. FIG. **4**E illustrates retrieval of the wireline module to the vessel. FIG. **4**F illustrates the tree ready for intervention.

[0019] FIG. **5**A illustrates deployment of the coiled tubing module. FIG. **5**B connection of the coiled tubing module to the PCA. FIG. **5**C illustrates slacking of the coiled tubing and movement of the vessel away from the tree. FIG. **5**D illustrates deployment of the BHA into the wellbore.

DETAILED DESCRIPTION

[0020] FIG. **2**A illustrates a pressure control assembly (PCA) **100**, according to one embodiment of the present invention. The PCA **100** may include a tree adapter **105**, a fluid sub **110**, an isolation valve **115**, a blow out preventer (BOP) stack **120**, a tool housing (aka lubricator riser) **125**, a frame **130**, a control pod **135**, a manifold **140**, and one or more accumulators **145** (two shown). The tree connector **105**, fluid sub **110**, isolation valve **115**, BOP stack **120**, and tool housing **125** may each include a housing or body having a longitudinal bore therethrough and be connected, such as by flanges, such that a continuous bore is maintained therethrough. The bore may have a large drift diameter, such as greater than or equal to four, five, six, or seven inches to accommodate a bottom hole assembly (BHA) of a workstring (discussed more below) and the crown plugs **56***u,l* of the tree **50**.

[0021] The tree adapter **105** may include a connector, such as dogs **105***d*, for fastening the PCA **100** to an external profile **51***p* of the tree **50** and a seal sleeve **105**s for engaging an internal profile **54***p* of the tree. The tree adapter **105** may further include an electric or hydraulic actuator and an interface, such as a hot stab, so that a remotely operated subsea vehicle (ROV) **415** (see FIG. **3**A) may operate the actuator for engaging the dogs **105***d* with the external profile **51***p*. The frame **130** may be connected to the tree connector **50**, such as by fasteners (not shown). The control pod **135** and manifold **140** may be fastened to the frame **130**. The fluid sub **110** may include a housing having a bore therethrough and a port **110***p* in communication with the bore. The port **110***p* may be in fluid communication with the manifold **140** via a conduit (not shown).

[0022] The isolation valve **115** may include a housing, a valve member **115**v disposed in the housing bore and operable between an open position and a closed position, and an actuator **115***a* operable to move the valve member between the positions. The actuator **115***a* may be electric or hydraulic and may be in communication with the control pod **135** via a conduit/cable (not shown). The actuator **115***a* may fail to the closed position in the event of an emergency. The isolation valve **115** may further operate as a check valve in the closed position: allowing fluid flow downward from the tool housing into the wellbore and preventing reverse fluid flow therethrough. Alternatively, the isolation valve **115** may be bidirectional when closed, the PCA **100** may further include a bypass conduit (not shown) connected to a port of a drain sub (not shown) disposed between the isolation valve and the BOP stack, and the drain port may include a check valve allowing downward flow and preventing reverse flow.

[0023] The BOP stack **120** may include one or more hydraulically operated ram preventers **120***b,w,* such as a blind-shear preventer **120***b* and one or more workstring preventers **120***w,* such as a wireline preventer and a coiled tubing preventer (only one workstring preventer shown) connected together via bolted flanges. Each ram preventer **120***b,w* may include two opposed rams disposed within a body. The body may have a bore that is aligned with the wellbore. Opposed cavities may intersect the bore and support the rams as they move radially into and out of the bore. A bonnet may be connected to the body on the outer end of each cavity and may support an actuator that provides the force required to move the rams into and out of the bore. Each actuator may include a hydraulic piston to radially move each ram and a mechanical lock to maintain the position of the ram in case of hydraulic pressure loss. The lock may include a threaded rod, a motor (not shown) for rotationally driving the rod, and a threaded sleeve. Once each ram is hydraulically extended into the bore, the motor may be operated to push the sleeve into engagement with the piston. Each actuator may include single (shown) or dual pistons (not shown). The blind-shear preventer **120***b* may cut the workstring, such as coiled tubing, wireline, and even drill pipe, when actuated and seal the bore. The coiled tubing preventer may seal against an outer surface of coiled tubing when actuated and the wireline preventer may seal against an outer surface of the wireline when actuated.

[0024] The tool housing **125** may be of sufficient length to contain either a plug running tool (PRT) **462** (FIG. 4A) or a BHA **464** (FIG. 5A) so that the PCA **100** may be closed while deploying either a wireline module **200** (FIG. 2B) or a coiled tubing module **300** (FIG. 2C). The tool housing **125** may have a connector profile **125***c* for receiving an adapter of a workstring module **200**, **300**.

[0025] The subsea control pod **135** may be in electrical and/or hydraulic communication with a support vessel **400** (FIG. 3A) via an umbilical **450***u* (FIG. 3B). The pod **135** may include one or more control valves (not shown) in communication with the BOP stack and the accumulators for operating the BOP stack. Each control valve may include an electric or hydraulic actuator in communication with the umbilical. The umbilical may include one or more hydraulic or electric control conduit/cables for each actuator. The accumulators may store pressurized hydraulic fluid for operating the BOP stack. The accumulators may be charged via a conduit of the umbilical or by the ROV **415**.

[0026] The umbilical **450***u* may further include hydraulic or electric control conduit/cables for operating valves of the manifold **140**, the actuator **115***a*, tree valves **57***p,u,l* and the various functions of the workstring modules **200**, **300** (discussed below). The control pod **135** may further include an output for the workstring modules **200**, **300** and an output for the tree **50**. Each output may include an ROV operable connector for receiving a respective jumper **451***t,w* (aka flying lead) (FIG. 4B). The ROV **415** may connect the tree jumper **451***t* to a control panel (not shown) of the tree **50** and the workstring jumper **451***w* to a control relay **235**, **335** of one of the workstring modules **200**, **300**.

[0027] The subsea control pod **135** may further include a microprocessor based controller, a modem, a transceiver, and a power supply. The power supply may receive an electric power signal from a power cable of the umbilical **450***u* and convert the power signal to usable voltage for powering the pod components as well as any of the PCA components. The PCA **100** may further include one or more pressure sensors (not shown) in communication with the PCA bore at various locations. The workstring modules **200**, **300** may also include one or more pressure sensors in communication with a respective bore thereof at various locations. The pressure sensors may be in data communication with the pod controller. The modem and transceiver may be used to communicate with an operator on the vessel via the umbilical. The power cable may be used for data communication or the umbilical **450***u* may further include a separate data cable (electric or optic). The vessel may include a control system (not shown) so that the various functions of the PCA, the tree, and the workstring modules may be operated by an operator on the vessel.

[0028] The control pod **135** may also include a dead-man's switch (not shown) for closing the BOP stack in response to a loss of communication with the vessel. Alternatively, instead of having individual conduits/cables for controlling each function of the PCA **100**, tree **50**, and workstring modules **200**, **300**, the pod controller may receive multiplexed instruction signals from the vessel operator via a single electric, hydraulic, or optical control conduit/cable of the umbilical **450***u* and then operate the various functions using individual conduits/cables extending from the control pod **135**.

[0029] The manifold **140** may include one or more control valves and one or more ROV operable connectors, such as hot stabs, for receiving a respective fluid conduit **450***f* (FIG. 3B) from the vessel **400**. Actuators of the control valves may be in electric/hydraulic communication with the control pod **135**. Two fluid conduits **450***f* (only one shown) may extend from the vessel **400** to the manifold **140** for fluid circulation. The fluid conduits **450***f* may each be coiled tubing. A first one of the control valves may be in fluid communication with a first one of the connectors and a fluid conduit extending to the port **110***p*. A second one of the control valves may be in fluid communication with a second one of the connectors and another ROV operable connector for receiving a jumper **452** (FIG. 4B) providing fluid communication with one of the junction plates **240**, **340** of the workstring modules **200**, **300**.

[0030] FIG. 2B illustrates a wireline module **200**, according to another embodiment of the present invention. The wireline module **200** may include an adapter **205**, a fluid sub **210**, an isolation valve **215**, one or more stuffing boxes **220***u,l*, a grease injector **225**, a frame **230**, a control relay **235**, an interface **240**, such as a junction plate, a grease reservoir **245***r*, a grease pump **245***p*, and a tool catcher **250**. The adapter **205**, fluid sub **210**, isolation valve **215**, stuffing boxes **220***u,l*, grease injector **225**, and tool catcher **250** may each include a housing or body having a longitudinal bore therethrough and be connected, such as by flanges, such that a continuous bore is maintained therethrough.

[0031] The adapter **205** may include a connector for mating with the connector profile **125***c*, thereby fastening the wireline module **200** to the PCA **100**. The connector may be dogs or a collet. The adapter **205** may further include a seal face or sleeve and a seal. The adapter **205** may further include an actuator, such as a piston and a cam, for operating the connector. The adapter **205** may further include an ROV interface so that the ROV **415** may connect to the connector, such as by a hot stab, and operate the connector actuator. Alternatively, the adapter **205** may have the connector profile instead of the connector and the tool housing **125** may have the connector in communication with the control pod **135** for operation by the vessel operator.

[0032] The fluid sub **210** may include a housing having a bore therethrough and a port **210***p* in communication with the bore. The port **210***p* may be in fluid communication with the junction plate **240** via a conduit (not shown). The frame **230** may be fastened to the adapter **205** and the relay **235** and interface **240** may be fastened to the frame. The pump **245***p* and reservoir **245***r* may also be fastened to the frame **230**.

[0033] The isolation valve **215** may include a housing, a valve member **215***v* disposed in the housing bore and operable between an open position and a closed position, and an actuator **215***a* operable to move the valve member between the positions. The actuator **215***a* may be electric or hydraulic and may be in communication with the control relay **235** via a conduit (not shown). The actuator **215***a* may fail to the closed position in the event of an emergency. The isolation valve **215** may be further operable to cut wireline **460***w* (FIG. 4A) when closed or the wireline module **200** may further include a separate wireline cutter. The isolation valve **215** may further operate as a check valve in the closed position: allowing fluid flow downward from the stuffing box **220***l* toward the PCA **100** and preventing reverse fluid flow therethrough.

[0034] Each stuffing box **220***u,l* may include a seal **220***s*, a piston **220***a*, and a spring **220***b* disposed in the housing. A port **220***p* may be formed through the housing in communication with the piston **220***a*. The port **220***p* may be connected to the control relay **235** via a hydraulic conduit, not shown. When operated by hydraulic fluid, the piston **220***a* may longitudinally compress the seal **220***s*, thereby radially expanding the seal inward into engagement with the wireline **460***w*. The spring **220***b* may bias the piston **220***a* away from the seal **220***s* and be set to balance hydrostatic pressure. Alternatively, an electric actuator may be used instead of the piston **220***a*.

[0035] The grease injector **225** may include a housing integral with the stuffing box housing and one or more seal tubes **225***t*. Each seal tube **225***t* may have an inner diameter slightly larger than an outer diameter of the wireline, thereby serving as a controlled gap seal. An inlet port **225***i* and an outlet port **225***o* may be formed through the grease injector/stuffing box housing. A grease conduit (not shown) may connect an outlet of the grease pump **245***p* with the inlet port **225***i* and another grease conduit (not shown) may connect the outlet port **225***o* with the grease reservoir **245***r*. Another grease conduit (not shown) may connect an inlet of the pump **245***p* to the reservoir **245***r*. Alternatively, the outlet port **225***o* may discharge into the sea **1**. The grease pump **245***p* may be electrically or hydraulically driven via cable/conduit connected to the control relay **235** and may be operable to pump grease from the grease reservoir **245***r* into the inlet port **225***i* and along the slight clearance formed between the seal tube **225***t* and the wireline to lubricate the wireline **460***w*, reduce pressure load on the stuffing box seals **220***s*, and increase service life of the stuffing box seals. The grease reservoir **245***r* may be recharged by the ROV **415**.

[0036] The tool catcher **250** may include a piston **250***a*, a latch, such as a collet **250***c*, a stop **250***s*, a piston spring **250***b*, and a latch spring **250***d* disposed in a housing thereof. The collet **250***c* may have an inner cam surface for engagement with a fishing neck of the PRT **462** and the catcher housing may have an inner cam surface for operation of the collet. The latch spring **250***d* may bias the collet **250***c* toward a latched position. The collet **250***c* may be movable from the latched position to an unlatched position either by engagement with a cam surface of the fishing neck and relative longitudinal movement of the fishing neck upward toward the stop **250***s* or by operation of the piston **250***a*. Once the cam surface of the fishing neck has passed the cam surface of the collet **250***c*, the latch spring **250***d* may return the collet to the latched position where the collet engages a shoulder of the fishing neck, thereby preventing longitudinal downward movement of the PRT **462** relative to the catcher **250**. The catcher housing may have a hydraulic port **250***p* formed through a wall thereof in fluid communication with the piston **250***a*. A hydraulic conduit (not shown) may connect the hydraulic port **250***p* to the control relay **235**. The piston **250***a* may be biased away from engagement with the collet **250***c* by the piston spring **250***b*. When operated, the piston **250***a* may engage the collet **250***c* and move the collet upward along the housing cam surface to a latched position. Alternatively, an electric actuator may be used instead of the piston **250***a*.

[0037] FIG. 2C illustrates a coiled tubing module **300**, according to another embodiment of the present invention. The coiled tubing module **300** may include an adapter **305**, a fluid sub **310**, an isolation valve **315**, a stripper **320**, a subsea coiled tubing injector **325**, a frame **330**, a control relay **335**, an interface **340**, such as a junction plate, and a tool catcher **350**. The adapter **305**, fluid sub **310**, isolation valve **315**, stripper **320**, and tool catcher **350** may each include a housing or body having a longitudinal bore therethrough and be connected, such as by flanges, such that a continuous bore is maintained therethrough. The adapter **305** may be similar to the adapter **205**. The frame **330** may be fastened to the adapter **305** and the relay **335** and interface **340** may be fastened to the frame. The fluid sub **310** may include a housing having a bore therethrough and a port **310***p* in communication with the bore. The port **310***p* may be in fluid communication with the junction plate **340** via a conduit (not shown). The tool catcher **350** may be similar to the tool catcher **250**.

[0038] The isolation valve **315** may include a housing, a valve member **315***v* disposed in the housing bore and operable between an open position and a closed position, and an actuator **315***a* operable to move the valve member between the positions. The actuator **315***a* may be electric or hydraulic and may be in communication with the control relay **335** via a conduit (not shown). The actuator **315***a* may fail to the closed position in the event of an emergency. The isolation valve **315** may be further operable to cut coiled tubing **460***t* (FIG. 5A) when closed or the coiled tubing module **300** may further include a separate coiled tubing cutter. The isolation valve **315** may further operate as a check valve in the closed position: allowing fluid flow downward from the stripper **320** toward the PCA **100** and preventing reverse fluid flow therethrough.

[0039] The stripper **320** may include a seal **320***s* and a piston **320***a* disposed in the housing. A hydraulic packoff port **320***p* and a hydraulic release port **320***r* may be formed through the housing in fluid communication with a respective face of the piston **320***a*. Each port **320***p,r* may be connected to the control relay **335** via a respective hydraulic conduit (not shown). When operated by pressurized hydraulic fluid via the pack-off port **320***p*, the piston **320***a* may longitudinally compress the seal **320***s*, thereby radially expanding the seal inward into engagement with the coiled tubing **460***t*. The seal **320***s* may be released by application of pressurized hydraulic fluid via the release port **320***r*. Alternatively, an electric actuator may be used instead of the piston **320***a*. Alternatively, the stripper **320** may include a spring instead of the release port **320***r*.

[0040] The injector **325** may include a traction assembly **325***t* to engage the coiled tubing **460***t* and drive the coiled tubing into or out of the wellbore **10**. The traction assembly **325***t* may include opposing chain loops **325***l* guided by bearing assemblies **325***b*. Gripping members **325***g* may be secured to individual links **325***i* of the chain loops, so as to grip the coiled tubing. The gripping members **325***g* and the chain loops **325***l* may thus move together longitudinally at the area of contact with the coiled tubing **460***t* to move the coiled tubing into or out of the wellbore **10**. A plurality of rollers **325***r* may be secured to the links **325***i* of the chain loops **325***l*, and roll along support members **325***s*. The support members **325***s* may be moved laterally inwardly to urge the gripping members **325***g* into engagement with the coiled tubing **460***t* with sufficient force to grip the coiled tubing. The rollers **325***r* may allow for a large lateral load to be applied without inducing a significant longitudinal drag load.

[0041] The bearing assemblies **325***b* and an injector gear case **325***c* may both be sealed to retain lubricant and prevent intrusion of seawater. The bearing assemblies **325***b* may be outboard bearing assemblies because the portion of the housing **325***h* adjacent the sealed gear case **325***c* may be open to seawater to accommodate the chain loops **325***l*. The chain loops **325***l* may be routed over sprockets or gears (not shown) within the housing **325***h*, rotating about the axis of the bearings assemblies **325***b*, and the chain loops may thus be guided by the bearing assemblies. A hydraulic or electric drive motor **325***m* may drive the chain loops. The drive motor may be in hydraulic/electric communication with the control relay **335** via a conduit/cable (not shown). The gear case **325***c* may house a plurality of gears (not shown) which may be driven by the drive motor **325***m* and which may drive the chain loops **325***l* via a drive shaft (not shown) sealably extending from the sealed gear case **325***c*.

[0042] The injector **325** may further include a lubricant reservoir **325***o*. The reservoir **325***o* may compensate pressure within the gear case **325***c*, each outboard bearing assembly **325***b*, and other components of the injector **325** that are sealed and sensitive to pressure differentials, such as the rollers **325***r*. The reservoir **325***o* may include a housing structurally separate from and attached to an outer housing of the gear case **325***c*. The reservoir housing may be divided into a compensator chamber and a lubricant chamber by a pressure compensator (not shown), such as a piston or diaphragm. The lubricant chamber maybe filled with a lubricant. A conduit **325***p* may be used to fluidly connect and pass lubricant between the reservoir **325***o* and the gear case **325***c*, the bearing assemblies **325***b*, the rollers **325***r*, and other sealed components. The compensator chamber may be in fluid communication with the sea by a port (not shown) formed through the reservoir housing. As the hydrostatic pressure surrounding the reservoir **325***o* increases, such as when the injector **325** is lowered into a subsea environment, the compensator may pressurize the lubricant, thereby equalizing or substantially equalizing the lubricant pressure and the hydrostatic seafloor pressure. The compensator may be biased so that the lubricant pressure is slightly greater than the seafloor pressure. Accordingly, the pressure differential that would otherwise exist between the seawater environment and the interior of the sealed components is reduced or eliminated.

[0043] FIG. **3**A illustrates deployment of the PCA **100** to the subsea production tree **50**. FIG. **3**B illustrates connection of the PCA **100** to the tree **50** and connection of the umbilical **450***u* to the PCA **100**. The support vessel **400** may be deployed to a location of the subsea tree **50**. The support vessel **400** may be a light or medium intervention vessel and include a dynamic positioning system to maintain position of the vessel **400** on the surface **1***s* over the tree **50** and a heave compensator (not shown) to account for vessel heave due to wave action of the sea **1**. Alternatively, the vessel **400** may be a MODU. The vessel **400** may further include a tower **411** located over a moonpool **405** and a winch **413**. The winch **413** may include a drum having wire rope **460***d* wrapped therearound and a motor for winding and unwinding the wire rope, thereby raising and lowering a distal end of the wire rope relative to the tower. Alternatively, a crane (not shown) may be used instead of the winch and tower. The vessel may further include umbilical drum **402**, coiled tubing drums **403** (only one shown), and wireline winch **413**.

[0044] The ROV **415** may be deployed into the sea **1** from the vessel **400**. The ROV **415** may be an unmanned, self-propelled submarine that includes a video camera, an articulating arm, a thruster, and other instruments for performing a variety of tasks. The ROV **415** may further include a chassis made from a light metal or alloy, such as aluminum, and a float made from a buoyant material, such as syntactic foam, located at a top of the chassis. The ROV **415** may be controlled and supplied with power from vessel **400**. The ROV **415** may be connected to support vessel **400** by an umbilical **416**. The umbilical **416** may provide electrical (power), hydraulic, and/or data communication between the ROV **415** and the support vessel **400**. An operator on the support vessel **400** may control the movement and operations of ROV **415**. The umbilical **416** may be wound or unwound from drum **417**.

[0045] The ROV **415** may be deployed to the tree **50**. The ROV **415** may transmit video to the operator on the vessel **400** for inspection of the tree **50**. The ROV **415** may remove the external cap **55** from the tree **50** and carry the cap to the vessel **400**. Alternatively, the winch **413** may be used to transport the external cap **55** to the waterline **1***w*. The ROV **115** may then inspect an internal profile of the tree **50**.

[0046] The wire rope **460***d* may then be used to lower the PCA **100** to the tree **50** through the moonpool **405** of the vessel **400**. The ROV **415** may guide landing of the PCA **100** on the tree **50**. The ROV **415** may then operate the adapter connector **105***d* to fasten the PCA **100** to the tree **50**. The ROV **415** may then deploy the umbilical **450***u* from the vessel **400** and connect the umbilical to the control pod **135**. The ROV **415** may then connect the jumper **451***t* to the tree control panel. The operator on the vessel may then close then close the tree valves **57***u,l,p* and the SSV **10***v* via the umbilical **450***u*. The ROV **415** may then deploy and connect the fluid conduits **450***f* to the manifold **140**.

[0047] FIG. **4**A illustrates deployment of the wireline module **200** to the tree **50**. FIG. **4**B illustrates connection of the wireline module **200** to the PCA **100**. FIG. **4**C illustrates deployment of the PRT **462** into the tree **50** and connection of the PRT with the upper crown plug **56***u*. FIG. **4**D illustrates retrieval of the PRT **462** and upper crown plug **56***u* into the tool housing **125**. FIG. **4**E illustrates retrieval of the wireline module **200** to the vessel **400**. FIG. **4**F illustrates the tree **50** ready for intervention.

[0048] The wireline **460***w* may be fed through the tower **411** and inserted through the wireline module **200** and connected to the PRT **462**. The PRT **462** may then be connected to the tool catcher **250**. The wireline module **200** may then be deployed through the moonpool **405** using the wireline winch **404** and landed on the tool housing **125**. The ROV **415** may operate the adapter connector, thereby fastening the wireline module **200** to the PCA **100**. The ROV **415** may then connect jumper **451***w* to the control pod **135** and control relay **235** and connect fluid conduit **452** to the manifold **140** and the junction box **240**. The vessel operator may then engage one or both of the stuffing boxes **220***u,l* with the wireline **460***w*. The vessel operator may then release the PRT **462** from the tool catcher **250** via the umbilical **450***u* and control relay **235**. The PRT **462** may be lowered to the upper crown plug **56***u* and operated to engage the upper crown plug by sending a signal through electrical conductors of the wireline **460***w*. The PRT **462** and upper crown plug **56***u* may then be raised until the PRT reengages the tool catcher **250**. The isolation valve **115** may then be closed. The PRT **462** and upper crown plug **56***u* may then be washed by injecting a hydrates inhibitor from the vessel **400**, through the fluid conduit **450***f*, the manifold, the conduit **451***w*, the junction plate, and into the port **210***p*. The spent inhibitor may be returned to the vessel **400** through the port **110***p*, the manifold, and the second fluid conduit (as discussed above, isolation valve **115** may allow downward flow when closed or the PCA **100** may include a bypass). Once washing is complete, the blind-shear preventer **120***b* may also be closed. The adapter connector may then be released by the ROV **415** and the wireline module **200** and upper crown plug **56***u* may be retrieved to the vessel **400**. The operation may then be repeated for the lower crown plug **56***l*.

[0049] The wireline module **200** and PRT **462** may then be deployed again with a tree saver **490**. The tree saver **490** may include a sleeve with a metal seal on its outer surface. The metal seal may be a depending lip that engages a tapered inner surface of the internal tree cap **54**. Alternatively, the tree saver may be engage the tubing hanger instead of the tree cap. The sleeve may have a plurality of windows which allow fasteners, such as dogs, to extend and retract. The dogs may be pushed outward by an actuator, such as a central cam. The cam may have a profile on its upper end. The cam may move between a lower locked position and an upper position freeing dogs to retract. A retainer may secure to the upper end of body to retain the cam. The tree saver **490** may further include one or more seals **490***u,l*. The seals **490***u,l* may each be made from a polymer, such as an elastomer. The sleeve may have a length sufficient to extend past the production passage and the lower seal **490***l* may engage an inner surface of the tubing hanger **53**, thereby isolating the production passage from any harmful fluids used during the intervention operation, such as cement or fracing fluid. Alternatively, the sleeve may extend into the production tubing **10***p* and the lower seal **490***l* may engage an inner surface of the production tubing. The sleeve may also extend upward to the tree adapter **105** and the upper seal may engage an inner surface of the adapter sleeve **105***s*. Alternatively, the sleeve portion extending from the dogs to the tree connector and the upper seal **490***u* may be omitted.

[0050] Alternatively, the coiled tubing module **300** may be used to deploy the PRT **462** instead of the wireline module **200**.

[0051] FIG. **5**A illustrates deployment of the coiled tubing module **300**. FIG. **5**B connection of the coiled tubing module **300** to the PCA **100**. FIG. **5**C illustrates slacking of the coiled tubing **460***t* and movement of the vessel **400** away from the tree **50**. FIG. **5**D illustrates deployment of the BHA **464** into the wellbore **10**. The vessel **400** may further include a coiled tubing injector **410**. The vessel injector **410** may include a head for driving the coiled tubing **460***t*, controls, and a power unit. The power unit may be electric or hydraulic. The coiled tubing **460***t* may be inserted through the coiled tubing module **300** and connected to the BHA **464**. The BHA **464** may include one or more tools operable to perform an intervention or abandonment operation in the wellbore **10**. The BHA **464** may then be connected to the tool catcher **350**. The injector head may be deployed over the moon pool **405** and the coiled tubing module **300** may be lowered to the tree **50** using the vessel injector **410** and the coiled tubing **460**t.

[0052] Once the CT adapter **305** has landed onto the PCA **100**, the ROV **415** may operate the adapter connector, thereby fastening the coiled tubing module **300** to the PCA **100**. The ROV **415** may then connect jumper **451***w* to the control pod **135** and control relay **335** and connect fluid conduit **452** to the manifold **140** and the junction box **340**. Once fastened, the vessel injector **410** may feed the coiled tubing toward the tree **50**, thereby creating slack **470** in the coiled tubing **460***t*. The vessel **400** may then (or simultaneously) be moved a distance from the tree **50** ensuring safety of the vessel **400** should a blowout occur during the intervention operation. The slack **470** may also serve to compensate for heave of the vessel **400**.

[0053] The stripper **320** may be engaged with the coiled tubing **460***t* by the vessel operator and then the isolation valve **115**, blind-shear BOP **120***b*, and SSV **10***v* may be opened. The vessel operator may then release the BHA **464** from the tool catcher **350** via the umbilical **450***u* and control relay **335**. The subsea drive motor **325***m* may then be operated by the vessel operator, thereby advancing the BHA **464** toward the tree **50**. The slack **470** may be maintained through synchronization of the vessel injector **410** with the subsea injector **325** by communication with the surface controller. The coiled tubing **460***t* may continue be advanced (while maintaining the slack **470** via synchronous operation of the vessel injector **410**) into the wellbore **10** by the subsea injector **325** until the BHA **464** reaches a desired depth in the wellbore. The intervention or abandonment operation may then be conducted using the coiled tubing **460***t* and the BHA **464**. To facilitate the intervention or abandonment operation, fluid may be pumped through the coiled tubing **460***t* and the BHA **464** and returned to the vessel via the port **110***p*. Further, fluid may be pumped into the wellbore **10** before or after deployment of the BHA **464** through the port **110***p* with the isolation valve **115** closed, thereby protecting the BOP stack **120** from the fluid.

[0054] Once the intervention or abandonment operation has concluded, the BHA **464** and coiled tubing **460***t* may be retrieved from the wellbore **10** by reversing the subsea drive motor **325***m* (while maintaining the slack **470** via synchronous operation of the surface injector **410**) until the BHA **464** engages the tool catcher **350**. The isolation valve **115** and SSV **351** may then be closed by the vessel operator. The BHA **464** may then be washed as discussed above for the upper crown plug **56***u*. The blind-shear preventer **120***b* may then be closed. The vessel **400** may return to the position over the tree **50**. The slack **470** may be removed from the coiled tubing by the vessel injector (after or simultaneously with vessel movement). The ROV **415** may disconnect the adapter connector and the coiled tubing module **300** may be retrieved from the tree **50** using the vessel injector. If an intervention operation was conducted, the tree saver **490** may be removed and the crown plugs **56***u,l* reinstalled using the wireline module **200** and PRT **462**. The PCA **100** may then be retrieved and the well returned to production.

[0055] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

1. A method for riserless intervention of a subsea well, comprising:

connecting an intervention assembly to a bottom hole assembly (BHA), wherein the BHA is connected to coiled tubing;

lowering the intervention assembly to a blowout preventer (BOP) fastened to a subsea production tree using an injector of a support vessel engaged with the coiled tubing;

fastening the intervention assembly to the BOP;
slacking the coiled tubing using the vessel injector;
engaging a stripper of the intervention assembly with the coiled tubing; and
driving the BHA through the tree and into a wellbore using a subsea injector of the intervention assembly while synchronizing both injectors to maintain the slack in the coiled tubing.

2. The method of claim **1**, further comprising releasing the BHA from the intervention assembly.

3. The method of claim **1**, wherein:
the BOP is part of a pressure control assembly (PCA), and
the BHA is disposed in a tool housing of the PCA after fastening the intervention assembly to the BOP.

4. The method of claim **3**, further comprising opening an isolation valve of the PCA before driving the BHA.

5. The method of claim **3**, further comprising washing the BHA after driving the BHA.

6. The method of claim **1**, further comprising:
injecting fluid through the coiled tubing and into the wellbore; and
returning fluid from the wellbore to the vessel.

7. The method of claim **1**, further comprising performing an intervention operation in the wellbore using the BHA.

8. The method of claim **1**, further comprising moving the vessel a safe distance from the tree.

9. A coiled tubing module for a riserless subsea intervention system, comprising:
a stripper operable to seal against coiled tubing;
a subsea injector having:
opposed chain loops having grippers operable to grip the coiled tubing and longitudinally move the coiled tubing;
outboard bearing assemblies operable to guide the chain loops;
a motor and sealed gear case operable to drive the chain loops, the gear case having lubricant; and
a pressure compensator operable to pressurize the lubricant to a pressure equal to or substantially equal to subsea pressure; and
a controller operable to synchronize an injector of a support vessel engaged with the coiled tubing with the subsea injector to maintain slack in the coiled tubing.

10. The module of claim **9**, further comprising a tool catcher operable to connect a bottom hole assembly connected to the coil tubing with the module.

11. The module of claim **9**, further comprising an isolation valve operable to prevent flow from a subsea wellbore through a bore of the module in a closed position.

12. The module of claim **9**, wherein the isolation valve is further operable to cut the coiled tubing or the module further comprises a coiled tubing cutter.

13. The module of claim **9**, further comprising an adapter having a connector operable by a remotely operated vehicle (ROV) for fastening the module to a pressure control assembly fastened to a subsea production tree.

14. The module of claim **13**, further comprising:
a control relay in communication with the stripper and the motor; and
a frame fastened to the adapter and the control relay,
wherein the control relay is operable to receive a subsea jumper providing communication with the controller.

15. The module of claim **14**, further comprising a fluid sub having a port in communication with a bore of the module.

16. The module of claim **15**, further comprising a junction plate for providing fluid communication between the fluid sub and a fluid conduit extending from a support vessel.

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