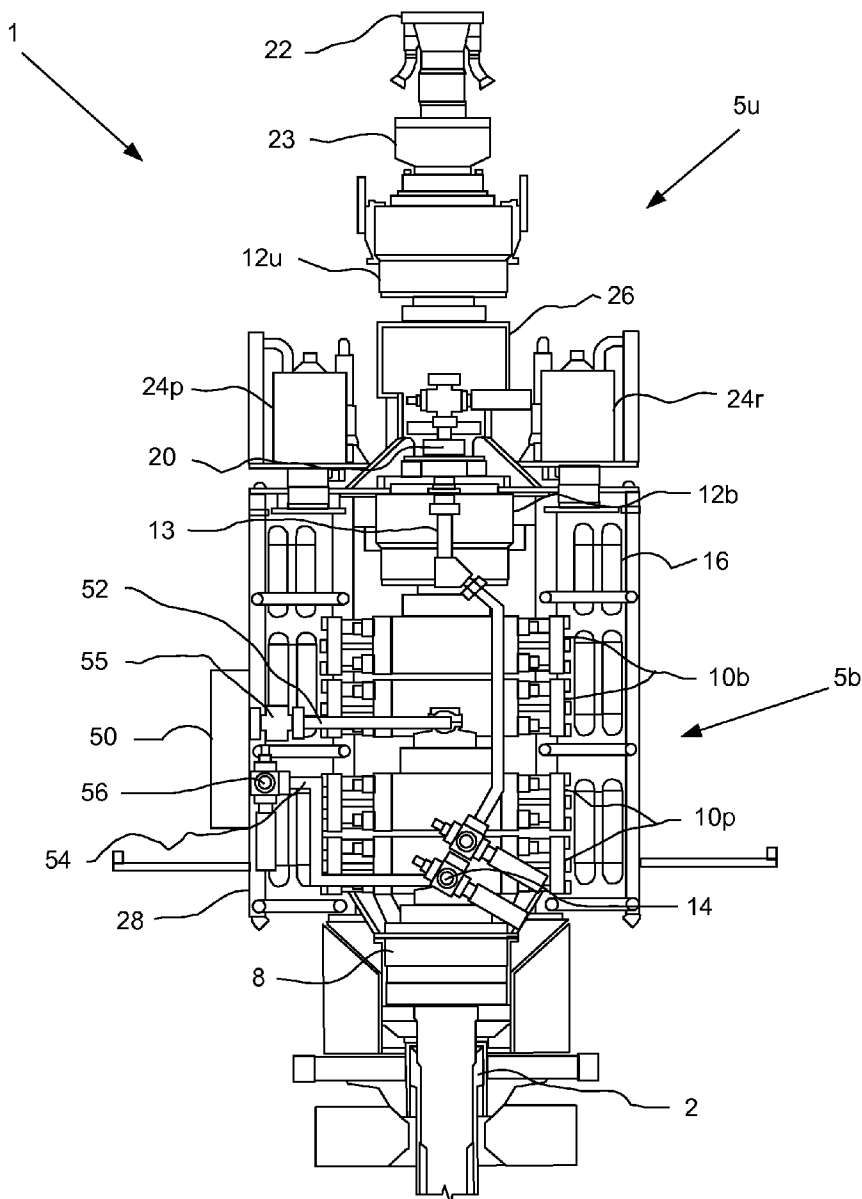


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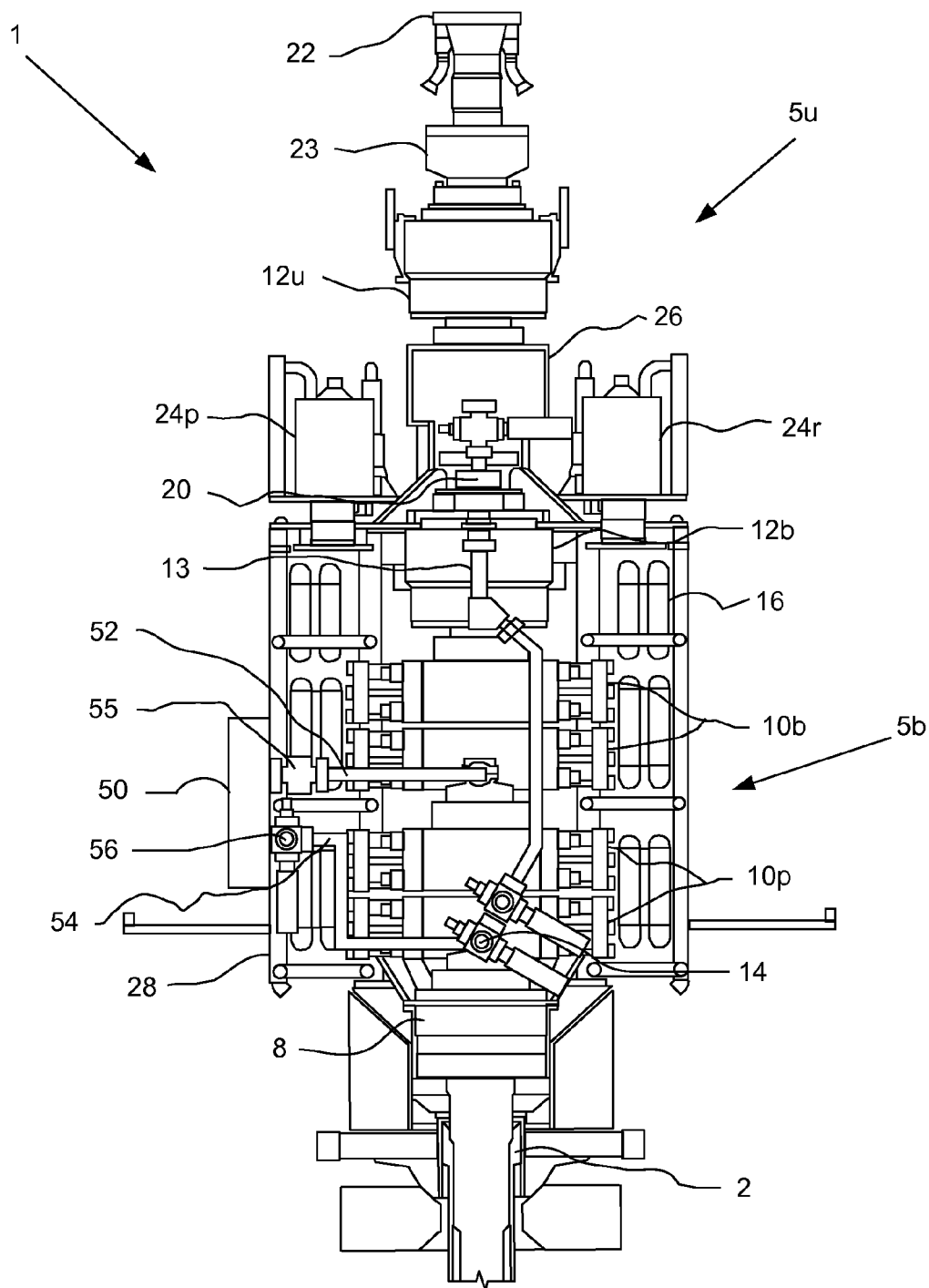
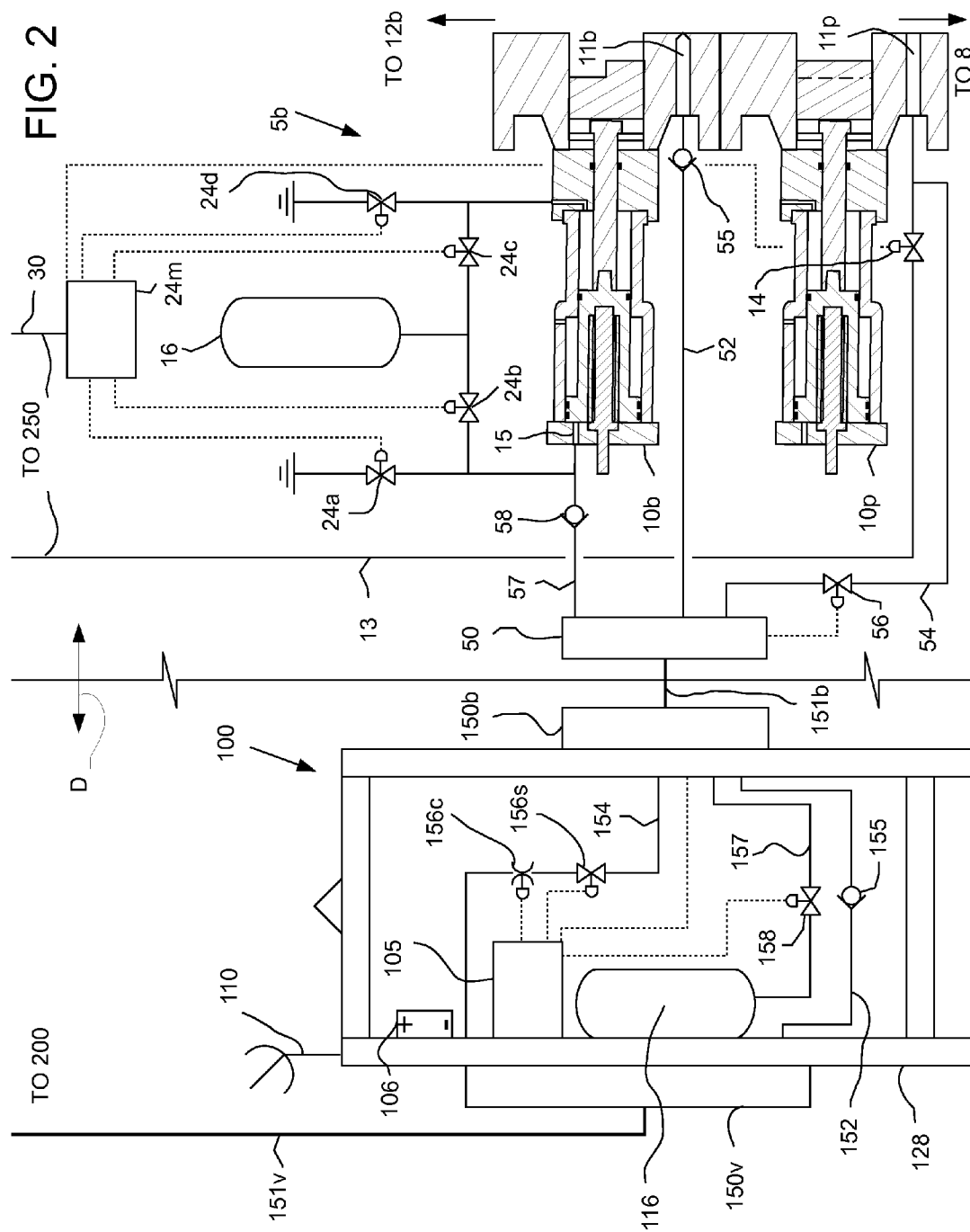
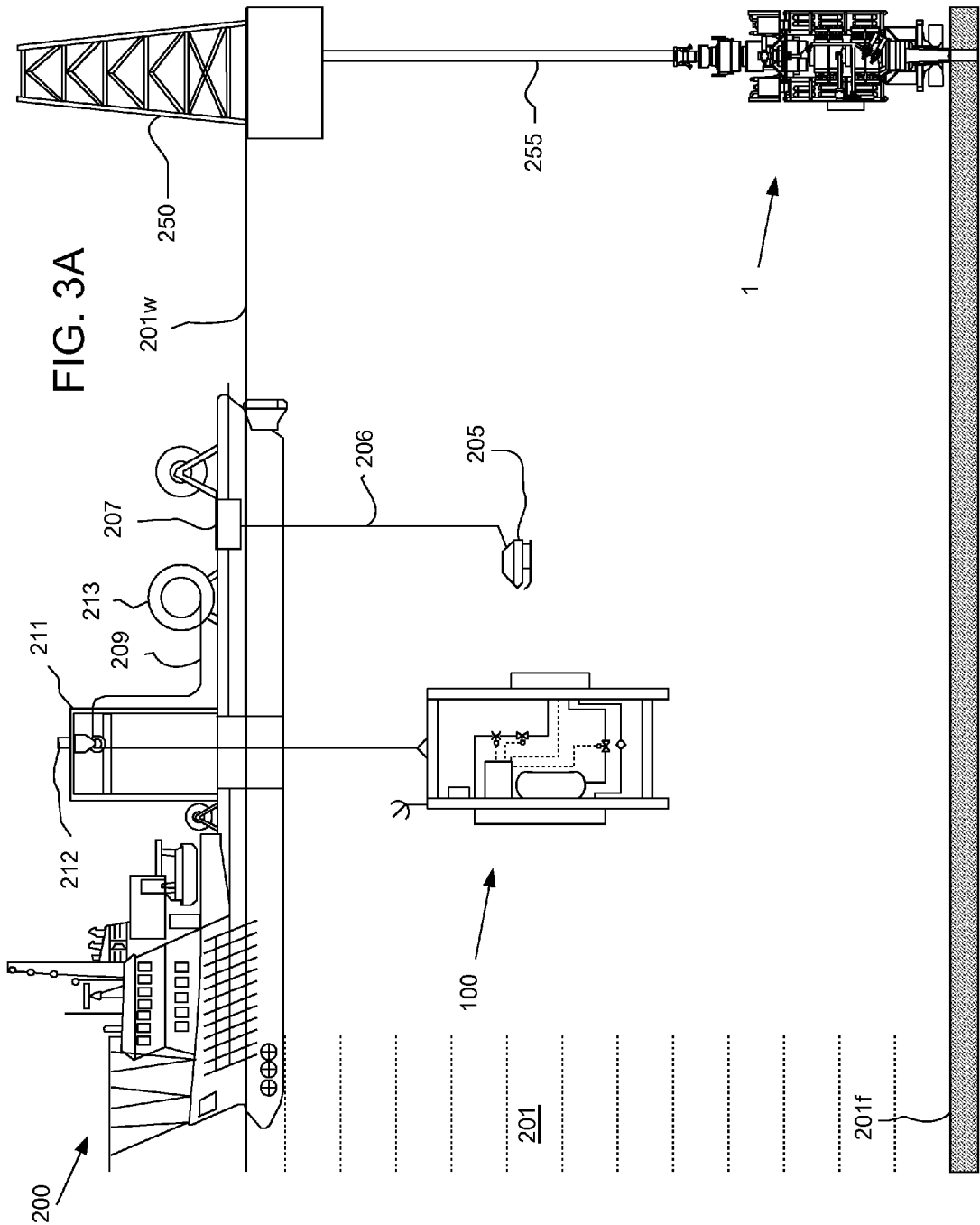
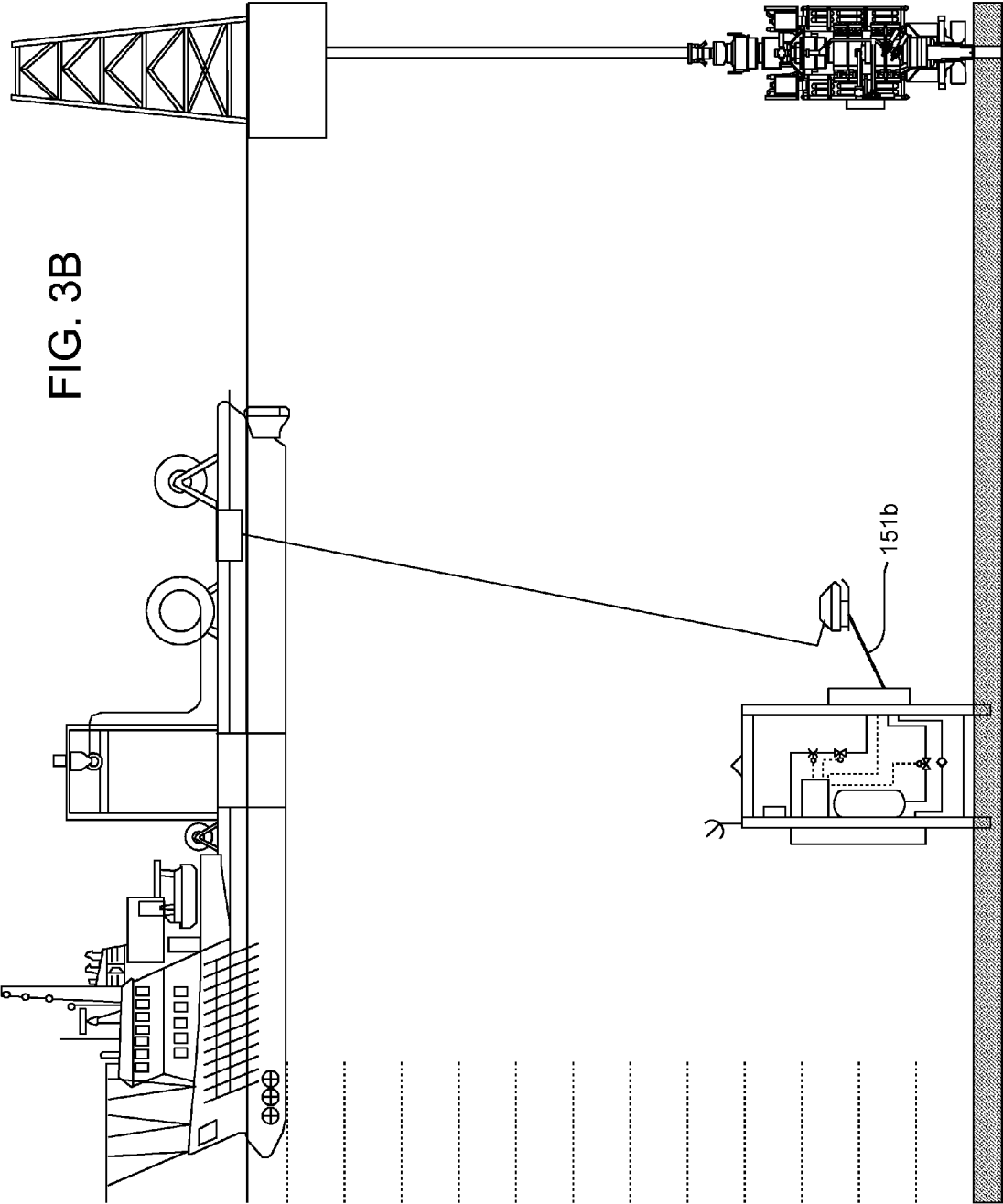


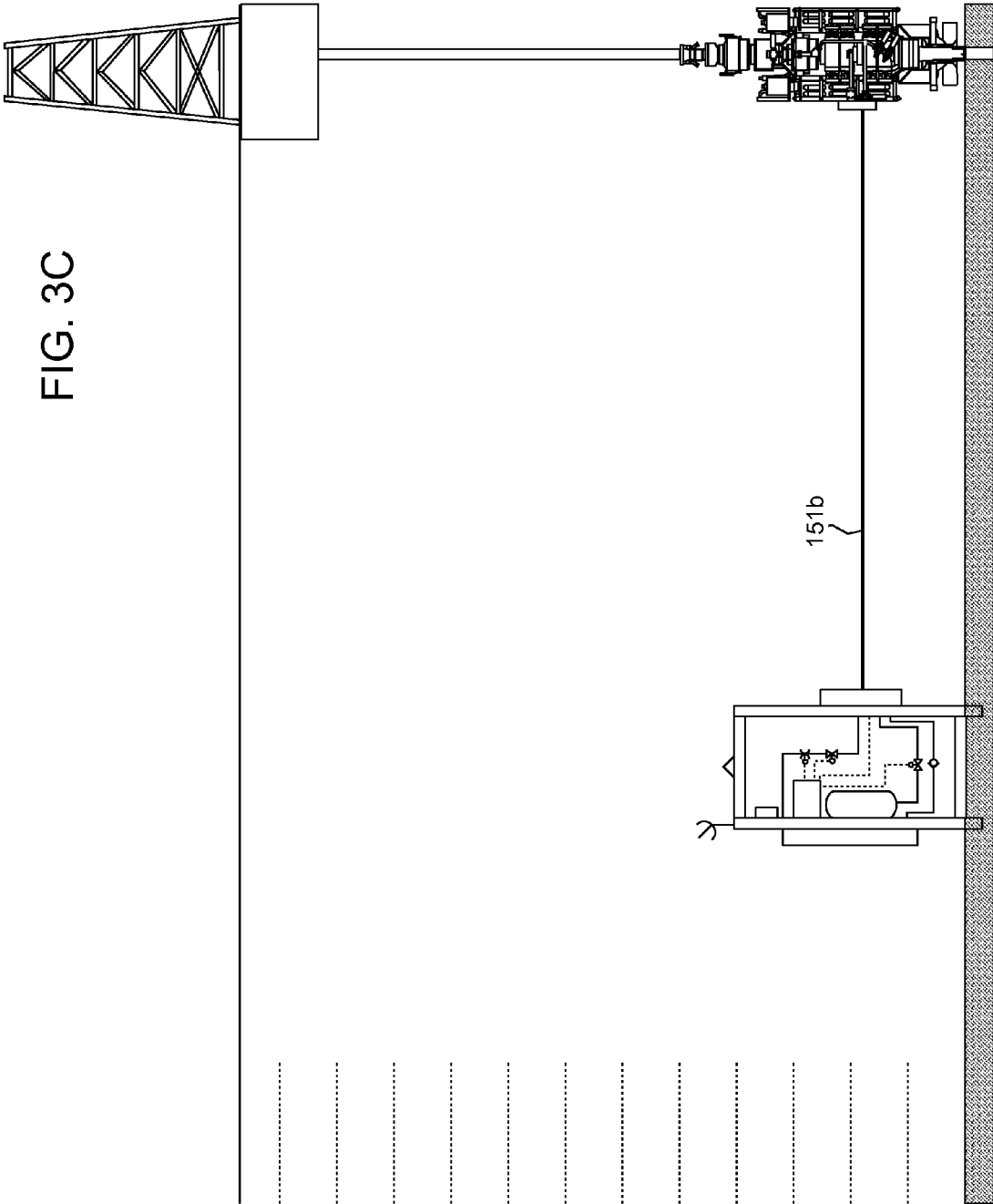
FIG. 1

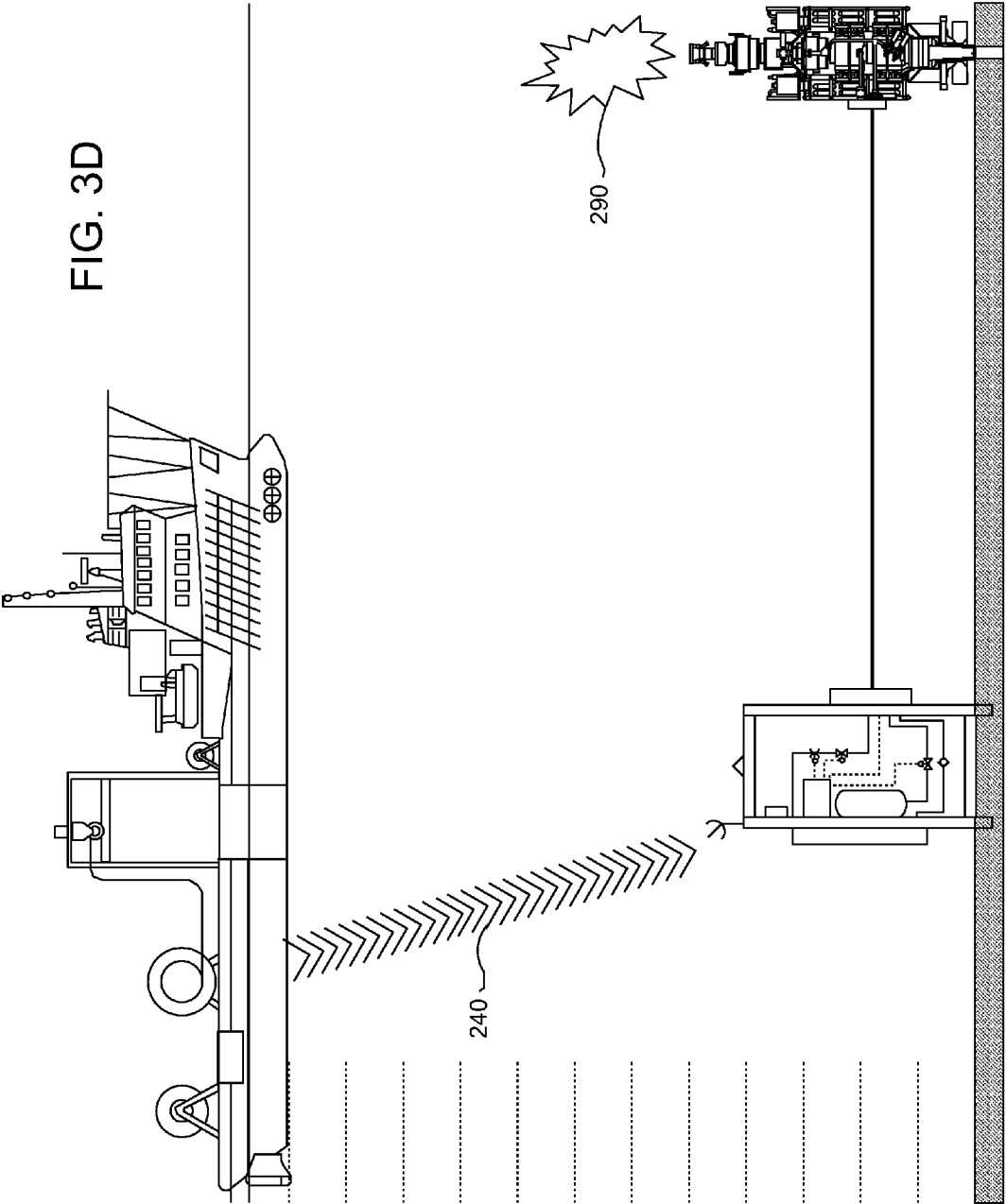
FIG. 2

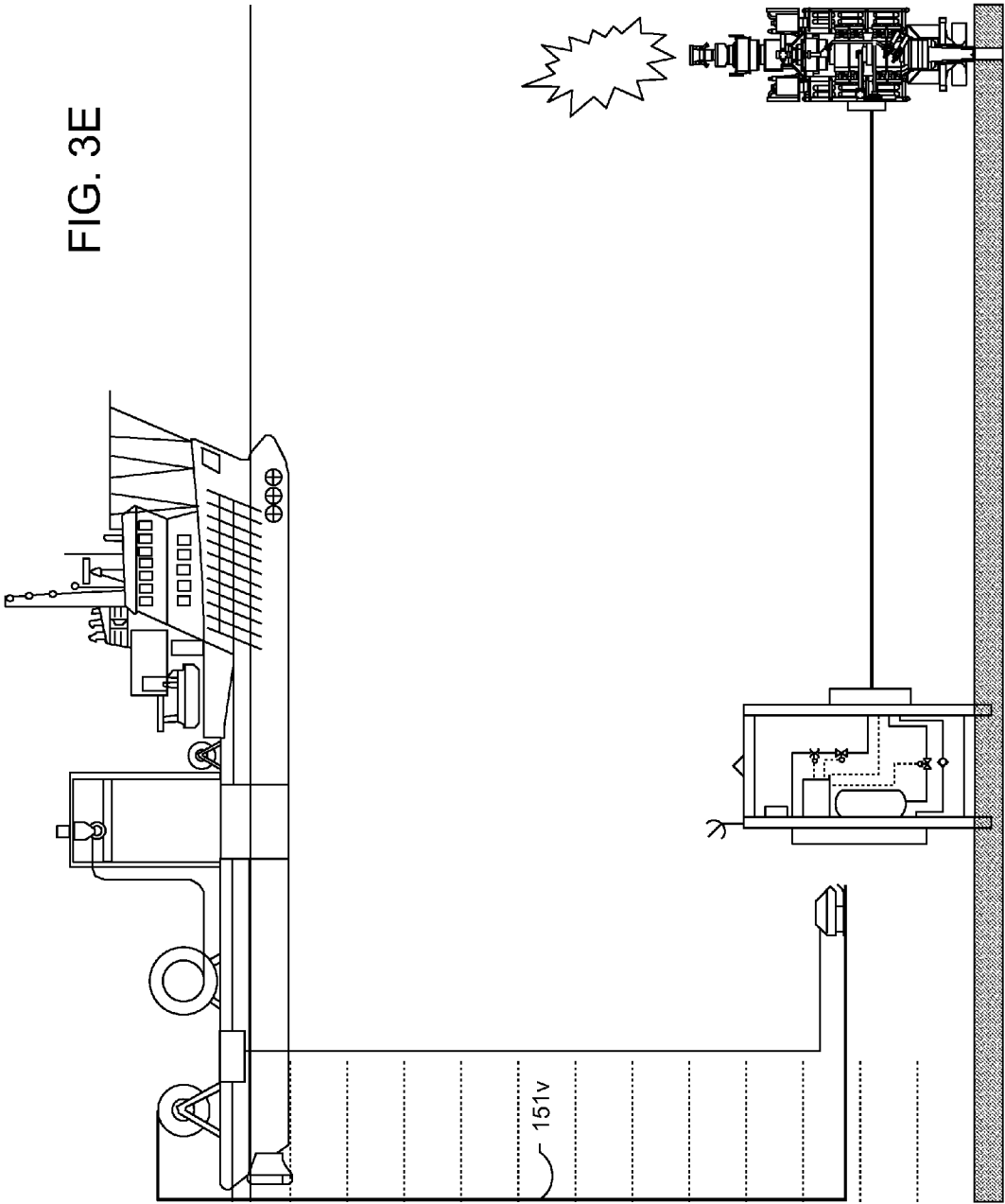


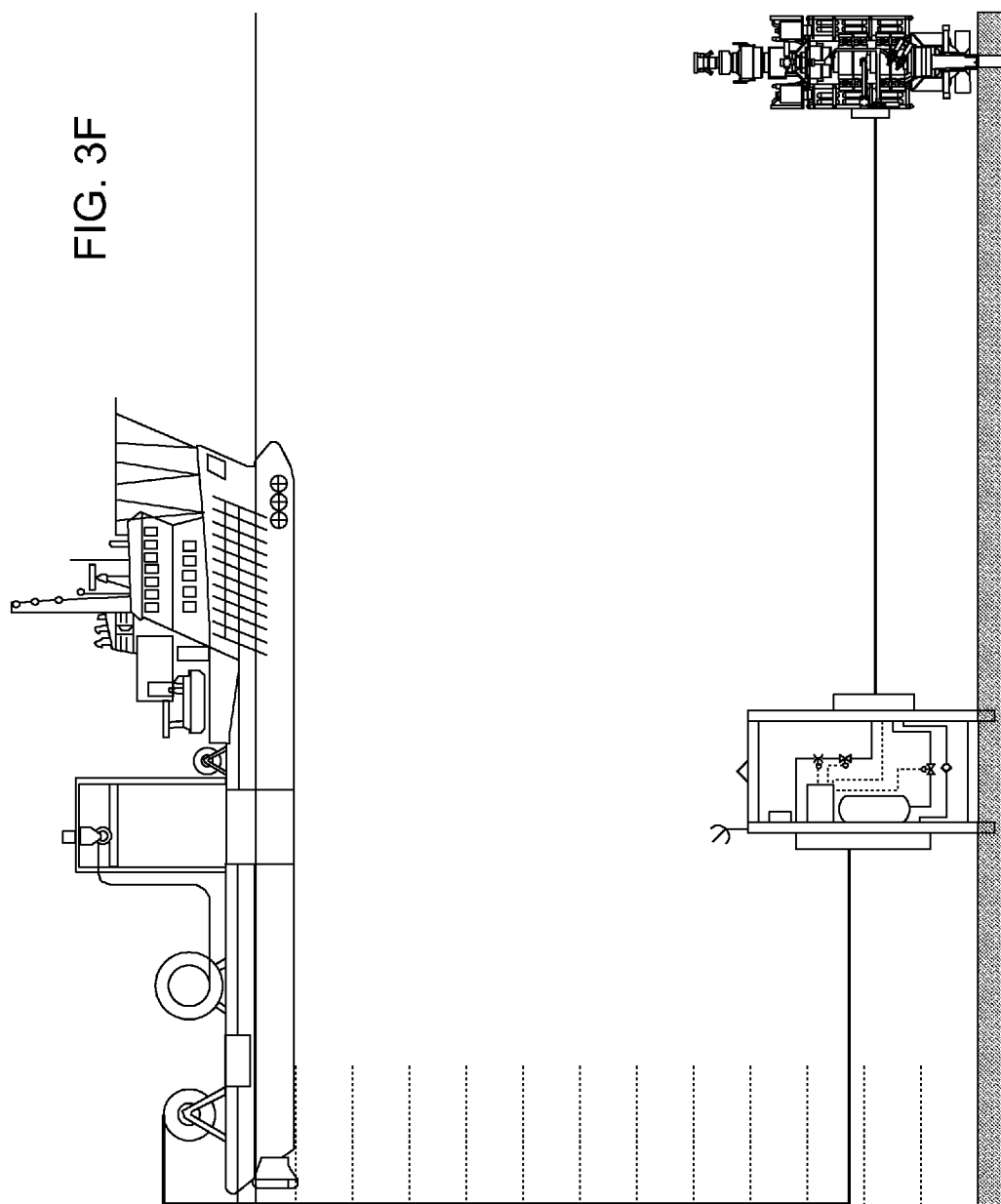












EMERGENCY CONTROL SYSTEM FOR SUBSEA BLOWOUT PREVENTER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of U.S. Provisional App. No. 61/411,666 (Atty. Dock. No. WWC1/0017USL), filed Nov. 9, 2010, which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] Embodiments of the present invention generally relate to an emergency control system for a subsea blowout preventer.

[0004] 2. Description of the Related Art

[0005] Bringing an underwater well blowout under control is difficult since it is usually accompanied by hydrocarbons and/or fire at the surface and damage to the subsea equipment connector. This uncontrolled flow of oil and gas is not only a waste of energy but also can be a source of water and beach pollution. Control of the well flow from a blowout and collection of oil spills therefrom have been handled separately. Control of well flow is attempted by drilling separate wells to feed heavy mud into the flowing well to kill the flow.

SUMMARY OF THE INVENTION

[0006] Embodiments of the present invention generally relate to an emergency control system for a subsea blowout preventer. In one embodiment, an emergency control system (ECS) for a subsea blowout preventer (BOP) includes a frame having a mud mat for engaging a seafloor; an ECS accumulator connected to the frame; a BOP interface connected to the frame and operable to connect to a stack interface of a BOP stack; a valve connected to the frame and operable to supply hydraulic fluid from the ECS accumulator to the interface; an acoustic receiver; and a controller operable to receive an instruction signal from the acoustic receiver and open the valve.

[0007] In another embodiment, a method of safeguarding a subsea drilling operation includes: lowering an emergency control system (ECS) to a seafloor, the ECS comprising: an ECS accumulator, a BOP interface, a hydraulic line extending from the ECS accumulator to the BOP interface, and a valve disposed in the hydraulic line; and operating a remotely operated vehicle (ROV) to connect the BOP interface to a stack interface of a subsea blowout preventer (BOP) stack, wherein the ECS is located at a substantial distance from the BOP stack.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] 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.

[0009] FIG. 1 illustrates a subsea blowout preventer (BOP) stack, according to one embodiment of the present invention.

[0010] FIG. 2 is a flow diagram of an emergency control system (ECS) connected to the BOP stack.

[0011] FIG. 3A-3F are operational diagrams illustrating installation and use of the ECS.

DETAILED DESCRIPTION

[0012] FIG. 1 illustrates a subsea blowout preventer (BOP) stack 1, according to one embodiment of the present invention. FIG. 2 is a flow diagram of an emergency control system (ECS) 100 connected to the BOP stack 1. The BOP Stack 1 may be employed to control the well during drilling operations in the event of erratic formation pressure causing loss of pressure control, i.e., a kick, which may otherwise lead to a blowout 290 (FIG. 3D). The BOP stack 1 may also be used to secure and disconnect a marine riser 255 (see FIG. 3A) from a wellhead 2 in the event of a mobile offshore drilling unit (MODU) 250 losing position due to automatic station keeping failure, weather, sea state, or mooring failure.

[0013] The BOP Stack 1 may be arranged in two sections, including an upper section (aka Lower Marine Riser Package (LMRP)) 5u which may interface with the riser 255 via a riser adapter 22 located at a top thereof. The LMRP 5u may further include a flex joint 23 which may accommodate angular movement to compensate for MODU offset. The flex joint 23 may interface with an upper single or dual element hydraulically operated upper annular BOP 12u for the stripping of drill pipe or tubulars which are run in and out of a wellbore (not shown). The LMRP 5u may further include a hydraulically operated connector 26 for connection to a mandrel at a top of the BOP stack lower section 5b.

[0014] The BOP stack lower section 5b may include one or more hydraulically operated ram preventers 10b,p, such as a blind-shear preventer 10b and a pipe preventer 10p, connected together via bolted flanges. Each ram preventer 10b,p 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 or dual pistons (dual piston shown in FIG. 1, single piston shown in FIG. 2).

[0015] Each of the rams may be equipped with seals that engage and prohibit flow through the bore when the rams are closed. The pipe preventer 10p may include pipe rams operable to engage and seal against an outer surface of drill pipe, thereby closing the annulus. The blind-shear preventer 10b may include blind-shear rams operable to cut through drill pipe and seal the well. The upper portion of the severed drill string may be freed from the ram while the lower drill string portion may remain in the wellbore. Alternatively, the BOP stack may include a separate blind preventer and a separate shear preventer which may act together to perform the function of the blind-shear preventer. Additionally, the lower section 5b may include additional pipe preventers (not shown).

for engaging and sealing against an outer surface of other tubulars, such as casing (not shown), and/or a redundant drill pipe preventer.

[0016] The BOP stack lower section **5b** may further include a lower annular BOP **12b**. The BOP stack lower section **5b** may further include a hydraulically latched wellhead connector **8** connected to a bottom ram preventer via a flange. The wellhead connector **8** may connect to the wellhead **2**. The wellhead **2** may lead to the wellbore.

[0017] The LMRP **5u** may further include one or more control pods, such as a primary pod **24p** and a backup pod **24r**. Each pod **24p,r** may be in electrical or hydraulic communication with the MODU via a control line **30**. Each pod **24p,r** may include one or more control valves **24a-d** and a controller **24m**. Each valve **24a-d** may be in electric or hydraulic communication with the controller **24m** via an electric or hydraulic control line (unnumbered dashed lines). The BOP stack lower section **5b** may further include one or more accumulators **16** for storing pressurized hydraulic fluid. The BOP stack lower section **5b** may further include a frame **28** for supporting the accumulators **16**. The accumulators **16** may be in fluid communication with one or more of the control valves **24a-d** for operating the various functions of the BOP stack **1**, such as the annular **12u,b** and ram preventers **10b,p** (only blind-shear preventer **10b** shown connected to the pod **24**). A hydraulic fluid charge line (not shown) may extend from the accumulators **16** to the MODU **250** for charging the accumulators. Although shown as shutoff valves, the control valves **24a-d** may alternatively be directional control valves, thereby combining functionality of two valves into one valve. The controller **24m** may receive instruction signals from the MODU **250** via the control line **30** and operate the appropriate valves **24a-d** in response to the instruction signals. Each control pod **24p,r** may also include a dead-man's switch (not shown) for closing the preventers **10b,p,12u,b** in response to a loss of communication with the MODU **250**. Each pod **24p,r** may be hydraulically latched to the BOP stack **1** to facilitate maintenance of the pods.

[0018] A choke and/or kill line **13** may also extend between the MODU **250** and a port **11p** formed through a body of the pipe preventer **10p**. The choke/kill line **13** line may connect to the stack lower section **5b** at connector **20**. A shutoff valve **14** may be disposed at the preventer port **11p**. The shutoff valve **14** may be operated by the pods **24p,r** via an electric or hydraulic control line. Although one line **13** is shown, a separate choke line and a separate kill line may extend between the MODU **250** and respective ports **11p** formed through the pipe preventer body. Alternatively, the choke/kill line **13** may connect to a separate spool (not shown) of the stack lower section **5b**. As discussed above, the LMRP **5u** may further include additional pipe ram preventers (not shown) and each pipe ram preventer may have port(s) to receive the choke/kill line to allow circulation through the BOP Stack column depending on which individual preventer is closed. The choke/kill line **13** may be used to bypass the riser **255** during a well control event, such as a kick. A choke valve (not shown) on the MODU **250** may then be operated to exert backpressure on the annulus while circulating mud through the drill string. Alternatively, the choke/kill line **13** may be used to bullhead the wellbore.

[0019] To facilitate connection of the ECS **100**, the lower stack section **5b** may further include an interface, such as a junction plate **50**. A choke/kill tie-in line **54** may extend from the stack junction plate **50** to the choke/kill line **13** at a lower

section of the choke/kill line **13** between the valve **14** and the port **11p**. A shutoff valve **56** may be disposed in the choke/kill tie-in **54**. The shutoff valve **56** may have an electric or hydraulic actuator in communication with the stack junction plate **50** so that the valve **56** may be operated from the ECS **100**. Alternatively or additionally, the valve **56** may be operated manually by a remotely operated vehicle (ROV) **205** (FIG. 3A) at the stack junction plate **50**. An injection line **52** may extend from the stack junction plate **50** to a port **11b** formed through a body of the blind-shear preventer **10b**. A check valve **55** may be disposed in the injection line **52** and operable to allow flow from the junction plate **50** to the preventer port **11b** and prevent reverse flow therethrough. A hydraulic tie-in line **57** (shown in FIG. 2 only) may extend from the stack junction plate **50** to an extension actuation port **15** of the blind-shear actuator. A check valve **58** may be disposed in the injection line **52** and operable to allow flow from the stack junction plate **50** to the actuator port **15** and prevent reverse flow therethrough.

[0020] The ECS **100** may include a skid frame **128**, a controller **105**, a battery **106**, a receiver **110**, an accumulator **116**, one or more interfaces, such as junction plates **150b,v**, an injection line **152**, a hydraulic line **157**, and a choke/kill line **154**. Each of the ECS components may be connected to the skid frame **128** and the skid frame may include retractable legs and a mud mat for supporting and stabilizing the ECS **100** from a floor **201f** of the sea **201** (FIG. 3A). The ECS accumulator **116** may store sufficient fluid energy to extend the blind-shear preventer **10b** one or more times, such as twice. The hydraulic line **157** may provide fluid communication between the accumulator **116** and the BOP junction plate **150b**. A shutoff valve **158** may be disposed in the hydraulic line **157** and have an actuator in hydraulic or electrical communication with the controller **105** via a control line.

[0021] A support vessel, such as a light or medium intervention vessel **200** (FIG. 3A), may connect to the vessel junction plate **150v** via a vessel umbilical **151v**. The vessel umbilical **151v** may include one or more fluid conduits and an electrical cable. The junction plate **150v** may connect the electrical cable to the controller **105** for providing electricity from the vessel **200** to the controller and providing data communication between the vessel and the controller. One of the vessel umbilical conduits may connect to the choke/kill line **154** via the vessel junction plate **150v**. The choke/kill line **154** may provide fluid communication between the vessel junction plate **150v** and the BOP junction plate **150b**. A shutoff valve **156s** and choke valve **156c** may be disposed in the hydraulic line **157** and each have an actuator in hydraulic or electrical communication with the controller **105** via a control line. Leads (not shown) may connect the battery **106** and the receiver **110** to the controller **105**. The battery **106** may provide electricity to the ECS controller **105** before connection of the vessel umbilical **151v** and the receiver **110** may allow an instruction signal to be sent wirelessly from the vessel **200** before connection of the vessel umbilical **151v**. A second of the vessel umbilical conduits may connect to the injection line **152** via the vessel junction plate **150v**. The injection line **152** may provide fluid communication between the vessel junction plate **150v** and the BOP junction plate **150b**. A check valve **155** may be disposed in the injection line **152** and allow fluid flow from the vessel junction plate **150v** to the BOP junction plate **150b** and prevent reverse flow therethrough.

[0022] A BOP umbilical **151b** may connect the junction plates **50, 150b**. The BOP umbilical **151b** may have a substantial length **D**, such as greater than or equal two-hundred fifty, five-hundred, or one-thousand feet, such that the vessel **200** may connect to the ECS **100** while being clear from the BOP stack **1** during the blowout **290**. The BOP umbilical **151b** may have a first conduit connected to the hydraulic line **157** via the BOP junction plate **150b**, a second conduit connected to the choke/kill line **154** via the BOP junction plate **150b**, a third conduit in communication with the injection line **152** via the BOP junction plate **150b**, and a control conduit/cable in communication with the controller **105** via the BOP junction plate **150b**. The junction plate **50** may connect the first BOP umbilical conduit to the hydraulic tie-in **57**, the second BOP umbilical conduit to the choke/kill tie-in **54**, the third BOP umbilical conduit to the injection line **52**, and the BOP umbilical control conduit/cable to the actuator of valve **56**.

[0023] Each of the shutoff valves **56, 156s**, and **158** and choke valve **156c** may be fail-closed and may include an ROV operable override. The choke valve **156c** may also include a visual position indicator for viewing by the ROV **205**. Alternatively, each conduit/cable of the umbilicals **151b,v** may be run as separate lines or only some of the lines may be grouped together in an umbilical. Alternatively, the choke valve **156c** may be arranged in a bypass spool of choke/kill line **154** (having shutoff valves straddling the choke valve **156c**) or the ECS **100** may further include separate choke and kill lines (corresponding to separate choke and kill lines of the BOP stack **1**).

[0024] FIG. 3A-3F are operational diagrams illustrating installation and use of the ECS **100**.

[0025] The vessel **200** may be deployed during an early stage of a drilling operation, such as after the MODU **250** has cemented the conductor pipe and connected the BOP stack **1** to the wellhead **2**. The vessel **200** may include a dynamic positioning system to maintain position of the vessel **200** on the waterline **201w** and a heave compensator to account for vessel heave due to wave action of the sea **201**. The vessel **200** may further include a tower **211** having an injector **212** for deployment cable **209**. The injector **212** may wind or unwind the deployment cable **209** from drum **213**.

[0026] The ROV **205** may be deployed into the sea **201** from the vessel **200**. The ROV **205** 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 **205** 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 **205** may be controlled and supplied with electricity from the vessel **200**. The ROV **205** may be connected to the support vessel **200** by a tether **206**. The tether **206** may provide electrical, hydraulic, and/or data communication between the ROV **206** and the vessel **200**. An operator on the vessel **200** may control the movement and operations of ROV **205**. The tether **206** may be wound or unwound from drum **207**.

[0027] The injector **212** and deployment line **209** may then be used to lower the ECS **100** to the seafloor **201f** through the moonpool of the vessel **200**. The ROV **205** may guide landing of the ECS **100**. The ROV **205** may then operate the skid frame legs until the mud mat has engaged the seafloor **201f**. Once the ECS **100** has landed on the seafloor **201f**, the ROV **205** may then deploy the umbilical **151b** and connect the umbilical to the junction plates **150b, 50**. The umbilical **151b**

may connect to the junction plates **150b, 50** using hot stabs or hydraulic connectors. Once the umbilical **151b** is connected to the junction plates **150b, 50**, the vessel **200** may leave and drilling operations may continue. The drilling operation may or may not be halted during installation of the ECS **100**. Alternatively, the ECS **100** may be deployed by the MODU **250** or any other vessel having an ROV and a hoist.

[0028] In the event of the blowout **290** (failure of the BOP stack **1**), the vessel **200** may be re-deployed to the ECS site. An acoustic signal **240** may be transmitted from the vessel **200** to the ECS **100** instructing the ECS to open the valve **158**. The ECS controller **105** may receive the signal via the receiver **110** and operate the actuator of the valve **158**. The accumulator **116** may then inject hydraulic fluid through the hydraulic line **157**, junction plate **150b**, the respective conduit of the umbilical **151b**, junction plate **50**, hydraulic tie-in **57**, and check valve **58** to the blind-shear preventer extension port **15**. The fluid path of the hydraulic fluid may bypass the control pods **24p,r**, thereby operating the preventer actuator notwithstanding malfunction of the control pods **24p,r**. Assuming the MODU **250** is burning, the vessel **200** may be deployed and the blind-shear preventer closed before the MODU sinks, thereby reducing the chance sinking debris may obstruct closure of the blind-shear preventer **10b**. If the blind-shear preventer **10b** is successfully closed and damage to the MODU **250** is minimal, then the BOP stack **1** and the MODU **250** may be repaired or replaced and drilling operations may resume or the wellbore may be plugged and abandoned through the BOP stack. If damage to the MODU **250** is extensive (i.e., sunk to the seafloor), then the vessel **200** may remain in place while a relief well is drilled using a new MODU (not shown).

[0029] If closure of the blind-shear preventer **10b** fails or is only partially successful, then the ROV **205** may be used to deploy and connect the vessel umbilical **151v** to the vessel junction plate **150v**. Once connected, the vessel **200** may instruct the ECS controller **105** via the electrical cable of the vessel umbilical **151v** to open the choke **156c** and shutoff **156s** valves and the shutoff valve **56**. The vessel **200** may then pump heavy mud (aka kill fluid) through the respective conduit of vessel umbilical **151v**, vessel junction plate **150v**, the choke/kill line **154**, BOP junction plate **150b**, respective conduit of BOP umbilical **151b**, stack junction plate **50**, and choke/kill tie in **54** to the pipe preventer port **11p** in an attempt to bullhead the wellbore. If the bullhead operation fails, then dispersant may be injected through the respective conduit of vessel umbilical **151v**, junction plate **150v**, the injection line **152**, junction plate **150b**, respective conduit of BOP umbilical **151b**, and injection line **52** to the blind-shear preventer port while a new MODU drills a relief well.

[0030] Alternatively or in response to failure of the bullhead operation, the production fluid from the blowing wellbore may be allowed to flow to production facilities (not shown) located on board the vessel **200** via the choke/kill line **154**. If capacity of the production facilities is greater than or equal to the production (blowout) rate of the wellbore, the choke valve **156c** may be controlled to maintain a positive pressure differential in the BOP stack **1** (relative to ambient pressure at the seafloor **201f**), such as greater than or equal to one psig. Production fluid may flow to the vessel through the umbilical and to the production facilities where the production fluid may be separated into crude oil, natural gas, and (produced) water. The crude oil may be stored onboard the vessel or transferred to a tanker or supertanker (not shown).

The gas may be flared. The water may be stored for later treatment or treated and pumped into the sea. The BOP stack **1** and/or the ECS **100** may further include a pressure sensor (not shown) in fluid communication with the respective choke/kill line/tie-in **54**, **154** and in data communication with the ECS controller **105**. As the wellbore is produced, the pressure may be monitored to ensure that the pressure differential is maintained. A hydrates inhibitor, such as methanol, ethylene glycol, or propylene glycol, or dispersant may be injected into the blind-shear preventer port **11b** via the injection lines **52**, **152**. Alternatively, the ROV **205** may visually monitor the BOP stack **1** for leakage to ensure that the pressure differential is being maintained.

[0031] If production capacity is less than the production rate of the wellbore, then the choke **156c** may be kept fully open and the excess production fluid may leak into the sea **201** and, as discussed above, dispersant may be injected into the blind-shear preventer port via the injection lines **52**, **152**.

[0032] Alternatively, the ECS **100** may be operated by the MODU **250**, the new MODU, or any other vessel having acoustic transmission capability, an ROV, and/or fluid handling capability. Alternatively, the acoustic signal **240** may be sent by any vehicle having acoustic transmission capability, such as a helicopter dropping an acoustic transmission buoy.

[0033] Alternatively, the ECS **100** may not be deployed until after the blowout occurs. The step of sending the acoustic signal may be omitted as the ECS **100** may be lowered with the vessel umbilical **151v** already connected and the ROV may connect the BOP umbilical **151b** or the ROV may connect both umbilicals **151b,v**.

[0034] 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. An emergency control system (ECS) for a subsea blowout preventer (BOP), comprising:

- a frame having a mud mat for engaging a seafloor;
- an ECS accumulator connected to the frame;
- a BOP interface connected to the frame and operable to connect to a stack interface of a BOP stack;
- a valve connected to the frame and operable to supply hydraulic fluid from the ECS accumulator to the stack interface;
- an acoustic receiver; and
- a controller operable to receive an instruction signal from the acoustic receiver and open the valve.

2. The ECS of claim 1, further comprising a vessel interface in communication with the controller and operable to receive an umbilical from a support vessel.

3. The ECS of claim 2, further comprising a choke/kill line connected to the BOP and vessel interfaces.

4. The ECS of claim 3, further comprising a choke valve disposed in the choke/kill line.

5. The ECS of claim 2, further comprising an injection line connected to the BOP and vessel interfaces and having a check valve disposed therein.

6. The ECS of claim 1, further comprising a battery in communication with the controller.

7. A blowout preventer (BOP) system, comprising:
the ECS of claim 1;

a BOP stack, comprising:

- a shear and/or blind ram preventer;
- a BOP accumulator;
- a wellhead connector;
- a lower marine riser package having a control pod for selectively providing fluid communication between the BOP accumulator and the ram preventer;
- the stack interface;
- a hydraulic line extending from the stack interface to an actuator of the ram preventer.

8. The BOP system of claim 7, wherein the hydraulic line has a length greater than or equal to two hundred and fifty feet.

9. The ECS of claim 1, wherein the frame is a skid frame and further has retractable legs for engaging the seafloor.

10. A method of safeguarding a subsea drilling operation, comprising:

- lowering an emergency control system (ECS) to a seafloor, the ECS comprising:

an ECS accumulator, a BOP interface, a hydraulic line extending from the ECS accumulator to the BOP interface, and a valve disposed in the hydraulic line; and

- operating a remotely operated vehicle (ROV) to connect the BOP interface to a stack interface of a subsea blowout preventer (BOP) stack, wherein the ECS is located at a substantial distance from the BOP stack.

11. The method of claim 10, wherein:

the ECS further comprises an acoustic receiver and a controller, and

the method further comprises sending an acoustic instruction signal to the ECS in response to a blowout, wherein the controller opens the valve in response to receiving the instruction signal, thereby providing hydraulic fluid to the stack interface.

12. The method of claim 11, wherein:

the ECS further comprises a vessel interface, and the method further comprises connecting an umbilical from a support vessel to the ECS interface.

13. The method of claim 12, wherein:

the ECS further comprises a choke/kill line connected to the BOP and vessel interfaces, and the method further comprises pumping kill fluid from the vessel to the stack interface via the ECS.

14. The method of claim 13, wherein:

the ECS further comprises a choke valve disposed in the choke/kill line, and the method further comprises flowing production fluid from the stack interface to the vessel via the ECS.

15. The method of claim 12, wherein:

the ECS further comprises an injection line connected to the BOP and vessel interfaces, and the method further comprises pumping dispersant or hydrates inhibitor from the vessel to the stack interface via the ECS.

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