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(54) Title: SUBSEA PRESSURE CONTROL SYSTEM

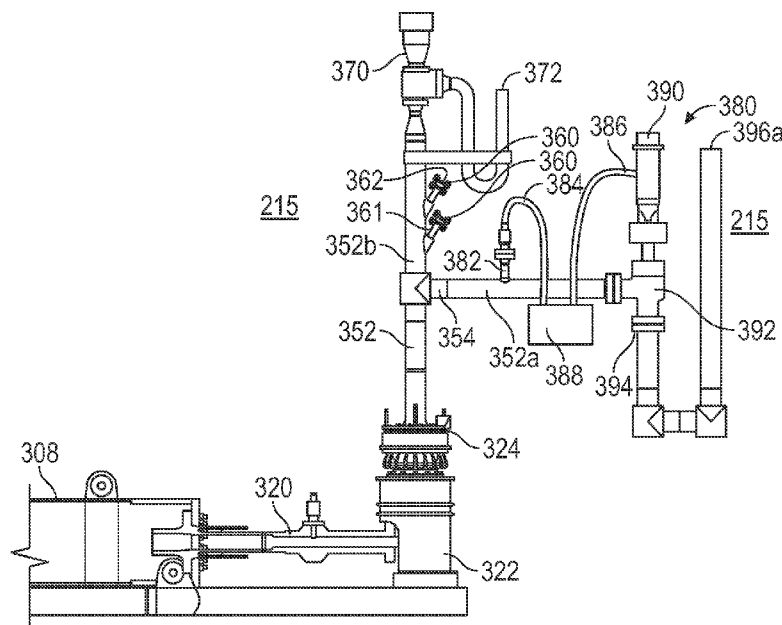


FIG. 3

(57) Abstract: The transfer of fluids from the wellhead to a receiving facility often involves communication from a high pressure system to a lower pressure system. In all such instances, it is important to prevent excessive pressure from building up in the inter-connecting flow lines. In order to relieve excess pressure when required a subsea pressure control system is arranged that includes an inlet flowline (352), a pressure sensor (382) coupled into the inlet flowline, a controller (388) coupled to the pressure sensor, an actuator (390) coupled to the controller, and a pressure relief valve (392) coupled to the actuator and a fluid outlet (396a).



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SUBSEA PRESSURE CONTROL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional patent application Serial No. 61/481,976 filed May 3, 2011, and entitled "Subsea Pressure Control System."

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

BACKGROUND

[0003] In producing oil and gas from offshore wells, a wellhead is employed at the seafloor and the hydrocarbons flow from the wellhead through tubular risers to the surface where the fluids are collected in a receiving facility located on a platform or other vessel. Normally, the flow of hydrocarbons is controlled via a series of valves installed on the wellhead, the risers, and in the receiving facility at the surface. At times, temporary flow lines from the wellhead to a receiving facility or other containment target, such as an existing reservoir, may be installed. The transfer of fluids from the wellhead to a receiving facility or other containment target often times involves communication from a high pressure system to a lower pressure system. In all such instances, it is important to prevent excessive pressure from building up in the interconnecting flow lines. Such excessive pressures could build up due to hydrate formation, sudden changes in pressure in the well bore, slugging flow, or excessive back pressure from valve closings or from other processes.

[0004] Water pressures could cause equipment failures at the sea floor, which may be 5,000 – 7,000 feet or more below the surface. At those depths, the water pressure exceeds 2,000 p.s.i. Because of the depth and pressures, effectuating repairs at such depths requires that equipment and tools be handled by deep diving, remotely operated vehicles (ROV's), which are essentially robots controlled by an operator in a surface vessel. Controlling the vehicles from such distances and using the ROV's to repair and/or replace equipment and components is a difficult and time consuming task. Consequently, a device is required to limit pressures in the subsea flow lines and other hydrocarbon-containing equipment to non-destructive levels, and to relieve excess pressure when required.

SUMMARY

[0005] Accordingly, there remains a need in the art for regulating fluid pressures between high pressure subsea systems and lower pressure subsea systems while in the subsea environment. Any pressure relief device installed at the sea bed must be capable of reliable operation at the pressures

that are encountered, and must withstand the corrosive environment of the sea. Further, it would be advantageous if the pressure setting at which the pressure relief device operates can be adjusted while the device is installed and in position subsea, rather than having to disconnect the device from a piping and/or containment system and then make the lengthy trip to the surface for adjustment. Still further, it would be advantageous if the pressure relief device operates only so long as to relieve enough pressure to bring the piping and/or containment system back to below the predetermined pressure setting, such that only the minimal amount of system fluids are released.

[0006] An embodiment of a subsea pressure control system includes an inlet and an inlet flowline, a pressure sensing device coupled into the inlet flowline and in fluid communication with the inlet flowline, a controller coupled to the pressure sensing device, an actuator coupled to the controller, and a valve coupled to the actuator and a fluid outlet. The controller may be responsive to the pressure sensing device. The controller may include a setpoint pressure and may be configured to compare the setpoint pressure to a measured pressure of the pressure sensing device. The actuator may be responsive to the controller. The valve may be responsive to the actuator. The actuator may be responsive to the controller based on a setpoint pressure to move the valve between a closed position isolating the inlet flowline from the fluid outlet and an open position exposing the inlet flowline to the fluid outlet. The valve may be movable to the open position if a measured pressure of the pressure sensing device exceeds the setpoint pressure, and to the closed position if the measured pressure is at or below the setpoint pressure. The actuator may be operably coupled to the valve to selectively expose the inlet flowline to the fluid outlet.

[0007] In some embodiments, the controller includes an electronic control module and the actuator comprises an electric actuator. The pressure sensing device and the controller may include a master hydraulic cylinder and a slave hydraulic cylinder. The actuator may include a hydraulic actuator. The valve may include a choke. The system may include a flowline coupled between the inlet and a subsea wellhead manifold. The system may include at least one backup pressure control subsystem coupled to the inlet.

[0008] In further embodiments, a subsea pressure control system includes a flowline configured for connection into a subsea fluid containment system, a controller configured to be responsive to a setpoint pressure in the flowline, and a valve configured to be responsive to a signal from the controller, wherein the signal is based on the setpoint pressure and actuates the valve from a closed position to an open position to expose the flowline to the sea or a container. The system may further include a pressure sensing device configured to be responsive to a measured pressure in the

flowline, wherein the signal is based on the measured pressure exceeding the setpoint pressure. The valve may be responsive to a second signal from the controller, wherein the second signal is based on the measured pressure equaling or falling below the setpoint pressure, and the second signal actuates the valve from the open position to the closed position to isolate the flowline from the sea. In some embodiments, the system includes at least one backup pressure control subsystem coupled to the flowline, wherein the backup pressure control subsystem is operable if the valve fails to actuate from the closed position to the open position.

[0009] In some embodiments, a method of controlling a pressure in a subsea fluid containment system includes determining a setpoint pressure for a subsea pressure control system, coupling the subsea pressure control system into the subsea fluid containment system, measuring a pressure of the subsea fluid containment system, comparing the measured pressure to the setpoint pressure, and exposing the subsea fluid containment system to the sea using the subsea pressure control system if the measured pressure exceeds the setpoint pressure. The method may further include isolating the subsea fluid containment system from the sea using the subsea pressure control system if the measured pressure falls below the setpoint pressure. The method may further include adjusting the setpoint pressure while subsea, modulating the measured pressure, and opening a backup subsystem to expose the subsea fluid containment system to the sea.

[0010] Thus, embodiments described herein comprise a combination of features and advantages intended to address various shortcomings associated with certain prior devices, systems, and methods. The various characteristics described above, as well as other features, will be readily apparent to those skilled in the art upon reading the following detailed description, and by referring to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a detailed description of exemplary embodiments of the invention, reference will now be made to the accompanying drawings in which:

[0012] Figure 1 is a schematic view of an exemplary subsea hydrocarbon recovery system employing a subsea manifold coupled to multiple hydrocarbon flow lines and containers;

[0013] Figure 2 is an elevation view of a subsea manifold coupled to a subsea pressure control system in accordance with embodiments and principles disclosed herein;

[0014] Figure 3 is a enlarged view of the subsea pressure control system of Figure 2;

[0015] Figure 4 is a perspective view of the primary pressure control subsystem of the subsea pressure control system of Figures 2 and 3;

[0016] Figure 5 is an elevation view of the subsea manifold coupled to an alternative pilot operated hydraulic embodiment of a subsea pressure control system in accordance with embodiments and principles disclosed herein;

[0017] Figure 6 is a schematic of the hydraulic sensor and controller for a pilot operated primary pressure control subsystem of the subsea pressure control system of Figure 6; and

[0018] Figure 7 is a flowchart illustrating an exemplary embodiment of a method for controlling a pressure in a subsea fluid containment system.

DETAILED DESCRIPTION

[0019] In the drawings and description that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. Certain terms are used throughout the description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function. The drawing figures are not necessarily to scale. Certain features and components 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. The present invention is susceptible to embodiments of different forms. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results.

[0020] The terms “including” and “comprising” are used in an open-ended fashion, and thus should be interpreted to mean “including, but not limited to... .” Unless otherwise specified, any use of any form of the terms “couple”, “attach”, “connect” 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. Thus, if a first device couples to a second device, that connection may be through a direct connection, or through an indirect connection via other devices, components, and connections.

[0021] A subsea pressure relief or control system for underwater applications is disclosed herein. The system may be employed in many underwater applications; however, it has particular application as a device to relieve overpressures that may develop in subsea flowlines, manifolds,

tanks, vessels and reservoirs containing and/or transporting hydrocarbons from the sea floor or between subsea containment systems. For convenience, the word “container” may be used herein to refer to all such hydrocarbon-containing lines, manifolds, tanks, vessels and reservoirs.

[0022] Referring to Figure 1, an exemplary embodiment of an offshore or subsea well control system 200 for recovering hydrocarbons from a subsea wellbore 201 is shown. In this embodiment, the system 200 includes a blowout preventer (BOP) 202 mounted to a wellhead 203 at the sea floor 204, and a capping stack 205 mounted atop the BOP 202. In certain embodiments of a well control system for producing from the well 201, hydrocarbons are allowed to flow through the BOP 202, through a lower marine riser package (not shown), and through risers 213 to a hydrocarbon-receiving vessel at the surface, such as a platform 211 floating on sea water 215. In this example, however, the capping stack 205 has been substituted for a lower marine riser package in a situation, for example, where hydrocarbon flow is not controlled via the normal path and is instead diverted and collected via an alternate collection system.

[0023] In other embodiments, the subsea system 200 includes, and the pressure control embodiments described below are compatible with, wellheads, BOP's, capping stacks, Christmas trees, flowlines, jumpers, manifolds, processing units, risers, pipeline end terminals (PLETs), flowline end terminations (FLETs), pipeline end manifolds (PLEMs), in-line tees (ILTs), and other subsea transportation systems.

[0024] The capping stack 205 includes at least one fluid outlet 206 controlled by a valve 207 for controlling the flow of hydrocarbons from the well to various destinations, including into a distribution manifold 208. In turn, one or more flowlines 209 are connected to valved outlets 210 in the manifold 208 and are employed to transport the hydrocarbons from the well to one or more hydrocarbon storage vessels at the surface, such as platform 211, or containers or reservoirs located subsea. For example, one or more of the flowlines 209 may coupled to a well and reservoir near the well 201. Furthermore, another source of hydrocarbons may be coupled into the network of flowlines 209 at another location. If such additional source of hydrocarbons provides a higher fluid pressure than the flowline network is generally capable of handling, the integrity of the flowline network can be jeopardized. A pressure relief device 10 may be coupled to the subsea manifold 208 such that it is in fluid communication with hydrocarbons contained in the manifold 208. When the valved outlet 210 interconnecting the flowline 209 and the manifold 208 is open, the pressure relief device 10 is likewise in fluid communication with the flowline 209. Exemplary

embodiments of a pressure relief device, or pressure control system, in accordance with principles disclosed herein are described in detail below.

[0025] Referring now to Figure 2, a subsea distribution manifold 308, similar to the distribution manifold 208 of Figure 1, includes outlets 310. It should be noted that the manifold 308 may be coupled between a well and a surface container, between two wells or reservoirs, between two subsea containers, or other combinations thereof in which two fluid systems are connected and there is the potential for communication of a higher pressure to a lower pressure fluid between the two fluid systems. The distribution manifold 308 also includes a fluid connection 320 to a base member 322. The base member 322 includes a fluid coupling 324 to an inlet flowline 352 of an embodiment of a subsea pressure control system 350. The inlet flowline 352 separates into two portions, a first portion flowline portion 352a leading to a primary pressure control subsystem 380, and a second flowline portion 352b leading to one or more backup pressure relief subsystems 360, 370 as described more fully below.

[0026] Additional reference can now be made to Figure 3 for an enlarged view of the subsea pressure control system 350 and the primary pressure control subsystem 380. The second flowline portion 352b includes the backup pressure relief subsystems 360 including one or more outlet tubes 361 each supporting a burst disc 362, or other rupturable or one way member for releasing fluid or exposing the second flowline portion 352b to the sea water 215. An upper end portion of the second flowline 352b includes a pressure relief valve 370 having an outlet 372 to the surrounding sea water 215 or another high pressure containment vessel. In some embodiments, the pressure relief valve 370 is a flow control valve adapted for subsea use. In certain embodiments, the pressure relief valve 370 includes a valve for onshore use modified for subsea use. For example, the valve outlet 372 may include a U-tube piping arrangement to prevent formation of hydrates when the hydrocarbons come into contact with seawater. In certain embodiments, the pressure relief valve 370 and the pressure relief subsystem 360 with burst disc 362 are backup subsystems to the primary pressure control subsystem 380. In some embodiments, the pressure relief valve 370 is a secondary pressure control subsystem that operates before the tertiary pressure control subsystem 360 including the burst disc 362. In other embodiments, the operation of the pressure relief valve 370 and the pressure relief subsystem 360 with burst disc 362 are switched in time to backup the primary pressure control subsystem 380; that is, the pressure relief subsystem 360 with burst disc 362 is the secondary pressure control subsystem and the pressure relief valve 370 is the tertiary pressure control subsystem.

[0027] Still referring to Figure 3, an inlet coupling 354 couples the first flowline portion 352a and the rest of the primary pressure control subsystem 380 to the initial flowline 352. A sensor 382 is coupled into the first flowline portion 352a. In some embodiments, the sensor 382 is a pressure sensor or transducer. In other embodiments as described elsewhere herein, the sensor 382 can be another type of pressure sensing device. For ease of description, the following discussion will refer to the sensor 382 as the pressure sensor 382. The pressure sensor 382 is coupled into the first flowline portion 352a to communicate with fluid pressure therein, and then is also electrically coupled to an electronic control module 388, or controller, by electrical line 384. The controller 388 is electrically coupled to an actuator 390 by electrical line 386. The actuator 390 is coupled to a valve 392, which in some embodiments is a choke valve. The valve 392 includes a coupling 394 coupled to an outlet or exhaust pipe 396 (Figure 2), 396a (Figure 3) that communicates with the surrounding sea water 215 or another high pressure containment vessel. In some embodiments, the coupling 394 is a choke coupling.

[0028] Referring now to Figure 4, additional details of one embodiment of the primary pressure control subsystem 380 are shown. In the embodiment shown in Figure 4, the inlet coupling 354 is an inlet for coupling to the flowline 352 (not shown in Figure 4). The inlet 354 is mounted to a manifold 355 to which the pressure sensor 382 may also be coupled. The manifold 355 receives fluid flow from the inlet flowline 352 which is fluidly coupled to the manifold 308 and the hydrocarbon fluid flow network and container systems as described with respect to Figure 1. The controller 388 may be secured to a mount 389 adjacent the manifold 355 and the pressure sensor 382 or may be remote or set apart from the subsystem 380. The controller 388 may include a housing, a processor, a memory, a power source, and other features common to electronic controllers. As will be described more fully below, the processor and memory of the controller 388 may be configured for certain functions and processes.

[0029] The controller 388 is electrically coupled to the pressure sensor 382 via line 384, electrically coupled to the actuator 390 via the electrical line 386, and in some embodiments, includes an electrical line 385 to a power source. In some embodiments, the electrical line 385 is a flying lead to a battery box with subsea batteries on a mud mat or other nearby subsea equipment. In some embodiments, the actuator 390 is an electric choke actuator such as those manufactured by FMC Technologies. In other embodiments, as will be described more fully below, the actuator can take other forms. In certain embodiments, the valve 392 may be an FMC Technologies electric choke, a Master Flo Valve Inc. adjustable subsea choke, or a Cameron CC Series subsea choke.

Other choke valves are also possible and known to one having skill in the art. The choke coupling 394 leads into an outlet pipe 395 and the outlet 396 to the surrounding sea water 215.

[0030] Finally, the primary pressure control subsystem 380 may include lift eyes 398 for lifting and transporting the subsystem 380, and also an ROV panel 330 for operably coupling to and interacting with an ROV. The ROV panel 330 includes handles 334, a plug-in connection 336 and an operating connection 332.

[0031] Referring now to Figures 5 and 6, an alternative embodiment of a primary pressure control subsystem is shown, including hydraulic pressure sensing, control, and actuation of the choke actuator. The manifold 308 as previously described is coupled into a subsea pressure control system 550 in the same manner as already described, including inlet flowlines 552, 552a, 552b, and backup subsystems 560, 570, with subsystem 570 including an outlet 572. However, instead of an electronically based primary pressure control subsystem, a primary pressure control subsystem 580 is hydraulically based. A pressure sensing piston 582 and cylinder 583 arrangement is fluidly coupled into the first flowline portion 552a by tubing 585 and tubing 584. The cylinder 583 arrangement may also be referred to as a slave cylinder. The slave cylinder 583 includes an outlet tubing 586 ultimately coupled to an upper portion of an actuator 590, which in this embodiment is a hydraulic actuator. Tubing 585 also fluidly couples to a first cylinder 587 retaining a first end of a hydraulic piston 588. A second end of the hydraulic piston 588 is retained in a second cylinder 589. The hydraulic piston 588 and cylinders 587, 589 arrangement may also be referred to as a master cylinder 599. A tubing 591 fluidly couples the second cylinder 589 to a lower portion of the actuator 590. Also coupled between the tubings 586, 591 is a tubing 593, or flying lead, that fluidly couples to a hydraulic fluid supply or bladder 595 (Figure 6). As will be described in more detail below, the master cylinder 599 and slave cylinder 583 arrangement is a pressure sensing and control device wherein non-hydraulic pressure is converted to hydraulic pressure via the master cylinder-slave cylinder relationship.

[0032] Referring more specifically to Figure 6, the master cylinder 599 is a control device that converts the non-hydraulic pressure in the flowline 552a into hydraulic pressure in order to actuate the slave cylinder 583. As the pressure in the flowline 552a increases, the piston 588 moves in the cylinders 587, 589, and this movement is transferred through the hydraulic fluid to result in movement of the piston 582 in the slave cylinder 583 which actuates the actuator 590. By varying the comparative surface-area of the cylinders 587, 589 in the master cylinder 599 and the slave cylinder 583, the amount of force and displacement applied to the slave cylinder 583 is varied

relative to the amount of force and displacement that is applied to the master cylinder 599 and its components 587, 588, 589. The resulting hydraulic force is applied to the actuator 590 via the slave cylinder 583. Thus, the master cylinder 599, slave cylinder 583 arrangement is a pressure sensing and/or measuring device that is responsive to the pressure in the flowline 552a and reacts to the pressure to control the actuator 590. The actuator 590 is responsive to the master-slave cylinder 599, 583 to actuate a valve 592 (Figure 5), such as a hydraulic choke valve. The valve 592 is responsive to the actuator to selectively expose or isolate the flowline 552a relative to an outlet 596 and the surrounding sea 215. The outlet 596 is coupled to the valve 592 via the coupling 594 (Figure 5).

[0033] In certain embodiments, and with continued reference to Figures 5 and 6, the piston/cylinder 588, 587 is a pilot operated piston on the OPEN side of the circuit as shown in Figure 6. The assembly 582, 583, 585 is a pilot operated system which functions to apply pressure to one side of the cylinder 587, while the other side of the piston 588 is exposed to seawater hydrostatic pressure as shown in Figure 6. A control fluid is located in the volume on one side of the piston 588 in the cylinder 589 that is coupled to the line 591, which is coupled to the CLOSE side of the circuit and the actuator 590. As pressure builds in the high pressure source line 552a, the pilot lines 584, 585 pressure up the cylinder 582 and the OPEN side of the actuator 590 while simultaneously pressuring up the cylinder 587 to cause the cylinder 589 to pull fluid from the CLOSE side of the actuator 590. This creates a differential pressure that moves the actuator 590 in the open direction, thus evacuating the high pressure source line 552a through the valve 592 and the outlet 596. Conversely, as the pilot pressure drops in lines 552a, 584, 585, the seawater pushes back on the cylinder 589, increasing the control pressure in line 591 as well as to the CLOSE side of the actuator 590 while the cylinder 583 pulls fluid from the line 586 as well as on the OPEN side of the actuator 590. In some embodiments, pressure relief check valves are needed on both the OPEN and CLOSE control lines 586, 591 in order to keep the actuator 590 from being overpressurized during operation. The subsea bladder 595 of control fluid may replace any vented control fluid, and associated check valves may prevent the bladder 595 from being overpressurized during normal operation.

[0034] In some embodiments, the hydraulic primary pressure control subsystem 580 may require less to no power compared to that of the electrical primary pressure control subsystem 380. In the hydraulic primary pressure control subsystem 580, a fixed volume of hydraulic fluid is moved in the subsystem. Hydraulic power may be provided by the high pressure source from the reservoir in

some embodiments. In other embodiments, hydraulic power can be stored in a hydraulic accumulator. Such a hydraulic system reduces or minimizes the need to draw on subsea batteries or other electrical power sources.

[0035] In operation, the primary pressure control subsystems 380, 580 are autonomous pressure controllers that maintain pressure below an adjustable setpoint pressure or predetermined pressure by venting the minimum amount of fluid into the sea. At the surface, and before the deployment of the subsystems 380, 580 in the subsea pressure control systems 350, 550, the setpoint pressure is determined and implemented. For the electrical subsystem 380, the controller 388 is configured or programmed with the desired setpoint pressure. The setpoint pressure is the pressure below which the subsea well, flowline, manifold, container or similar system is in a normal range, and above which creates an overpressure situation. For the hydraulic subsystem 580, the master and slave cylinder arrangement 599, 583 is designed and dimensioned to react to the desired setpoint pressure.

[0036] Next, the subsea pressure control systems 350, 550 are deployed subsea including the primary pressure control subsystems 380, 580, respectively. The systems 350, 550 may be coupled into or between any of the various containers and systems already described herein, including any number of different subsea connectors such as a CVC hub, and can be serviced by ROV's. Consequently, the systems 350, 550 can connect anywhere in the flowline and containment system network as shown and described with reference to Figure 1.

[0037] Then, the pressure sensor 382 and the hydraulic master and slave cylinder arrangement 599, 583 of subsystem 550 are allowed to sense, measure, and monitor the pressure in the flowlines 352a, 552a and ultimately the subsea fluid containment system, while also comparing the measured pressure to the setpoint pressure. When the setpoint pressure is exceeded in the subsea fluid containment system, the controller 388 and the hydraulic master and slave cylinder arrangement 599, 583 respond and direct the actuators 390, 590 to actuate the valves 392, 592 to open and expose the subsystems 380, 580 and the subsea fluid containment system to the surrounding sea. Because of the dynamic and responsive nature of the controller 388 and hydraulic 599, 583 controllers of the subsystems 380, 580, the valves 392, 592 can be actuated closed when the measured pressure is detected to be at or below the setpoint pressure, thereby isolating the fluid containment system from the sea and releasing only the quantity of fluids necessary to bring the pressure below the setpoint pressure.

[0038] In some embodiments, the primary pressure control subsystems 380, 580 are designed to release the minimum amount of hydrocarbons possible into the sea, while protecting the subsea fluid containment system from an overpressure situation. The subsystems 380, 580 ensure minimal release of fluids to the sea by closing the valves 392, 592 immediately upon or soon after bringing the system pressure back below the setpoint pressure. Such controllability, sensitivity, and reaction time to the setpoint pressure is enabled by direct communication among and between the valve actuator 390, the controller 388, and the pressure sensor 382 for the electronic subsystem 380, and the similarly-functioning components of the hydraulic subsystem 580.

[0039] Furthermore, in at least the electronic subsystem 380, the setpoint pressure can be easily adjusted subsea by changing the program settings in the controller 388. A ROV may interact with the ROV panel 330 to re-program or re-configure the controller 388 to respond to a new setpoint pressure.

[0040] The controllability of the subsystems 380, 580 provides a gradual modulation of the system pressure, to avoid pressure spikes which could lead to an overpressure situation. As the valves 392, 592 are being operated in response to the comparison between the measured pressure and the setpoint pressure, the controllers 388, 599 and actuators 390, 590 are also operable to vary the positions of the valves 392, 592 between fully open and fully closed to modulate the flow rate therein.

[0041] Thus, the subsea pressure control systems 350, 550 can closely regulate the pressure of a subsea well, flowline, manifold, containment or similar subsea fluid system below a given setpoint using the primary pressure control subsystems 380, 580. The pressure sensors, controllers, actuators, and valves, or chokes, may work together to release fluid and relieve pressure from the subsea fluid containment system only until the pressure is reduced below the setpoint. In additional embodiments, the backup pressure relief subsystems 360, 370, 560, 570 as previously described may also be provided, in various combinations, to relieve pressure from the subsea fluid containment system in the event that the primary pressure control subsystems 380, 580 do not bring the measured pressure back below the setpoint pressure.

[0042] As previously described, the subsea pressure control systems 350, 550 and/or the primary pressure control subsystems 380, 580 may be coupled to and between various fluid containment or flowline systems. In addition, the subsea pressure control systems 350, 550 and/or the primary pressure control subsystems 380, 580, in various combinations, may be implemented in a device disposed as a transition point between a higher rated pressure system and the lower rated pressure

system and including a series of valves and sensors that will close and isolate the higher pressure system from the lower pressure system.

[0043] In an embodiment of a method 600 of controlling a pressure in a subsea fluid containment system, and with reference to the flowchart of Figure 7, the method starts at box 602 and includes determining a setpoint pressure for a subsea pressure control system at box 604. The method further includes deploying the subsea pressure control system at box 606, coupling the subsea pressure control system into a subsea fluid containment system at box 608, and measuring a pressure of the subsea fluid containment system at box 610. Then, the measured pressure is compared to the setpoint pressure to determine whether the measured pressure exceeds the setpoint pressure at box 612. If “No”, then the measured pressure continues to be monitored at box 610. If “Yes”, then the method includes opening a valve in the subsea pressure control system to expose the subsea fluid containment system to the sea at box 614, and closing the valve to isolate the subsea fluid containment system from the sea when the measured pressure falls below the setpoint pressure at box 616. As detailed herein, the responsiveness of the valve to the actuators described herein, which are responsive to the controllers described herein, which are responsive to the measured pressure, allows the closing of the valve and re-isolation of the subsea fluid containment system to be achieved while releasing only those fluids necessary to bring the measured pressure back below the setpoint pressure.

[0044] In alternative embodiments, and in various combinations, the method may include adjusting the setpoint pressure for the subsea pressure control system while subsea at box 618. The method may further include modulating the measured pressure of the subsea fluid containment system at box 620. The method may further include opening a backup subsystem to expose the subsea fluid containment system to the sea, at box 622, in the event the valve opening at box 614 is insufficient to lower the measured pressure to the setpoint pressure.

[0045] While specific embodiments have been shown and described, modifications can be made by one skilled in the art without departing from the scope or teachings herein. The embodiments as described are exemplary only and are not limiting. Many variations and modifications of the systems, apparatus, and processes described herein are possible and are within the scope of the disclosure. For example, the relative dimensions of various parts, the materials from which the various parts are made, and other parameters can be varied. Accordingly, the scope of protection is not limited to the embodiments described, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims.

CLAIMS

What is claimed is:

1. A subsea pressure control system comprising:
an inlet and an inlet flowline;
a pressure sensing device coupled into the inlet flowline and in fluid communication with the inlet flowline;
a controller coupled to the pressure sensing device;
an actuator coupled to the controller; and
a valve coupled to the actuator and a fluid outlet.
2. The system of claim 1 wherein the controller is responsive to the pressure sensing device.
3. The system of claim 2 wherein the controller comprises a setpoint pressure and is configured to compare the setpoint pressure to a measured pressure of the pressure sensing device.
4. The system of claim 1 wherein the actuator is responsive to the controller.
5. The system of claim 4 wherein the valve is responsive to the actuator.
6. The system of claim 5 wherein the actuator is responsive to the controller based on a setpoint pressure to move the valve between a closed position isolating the inlet flowline from the fluid outlet and an open position exposing the inlet flowline to the fluid outlet.
7. The system of claim 6 wherein the valve is moved to the open position if a measured pressure of the pressure sensing device exceeds the setpoint pressure, and the valve is moved to the closed position if the measured pressure is at or below the setpoint pressure.
8. The system of claim 1 wherein the actuator is operably coupled to the valve to selectively expose the inlet flowline to the fluid outlet.
9. The system of claim 1 wherein the pressure sensing device measures a fluid pressure in the inlet flowline.
10. The system of claim 1 wherein the pressure sensing device comprises a pressure transducer.
11. The system of claim 1 wherein the controller comprises an electronic control module and the actuator comprises an electric actuator.
12. The system of claim 1 wherein the pressure sensing device and the controller comprise a master hydraulic cylinder and a slave hydraulic cylinder.
13. The system of claim 1 wherein the actuator comprises a hydraulic actuator.

14. The system of claim 1 wherein the valve comprises a choke.
15. The system of claim 1 further comprising a flowline coupled between the inlet and a subsea wellhead manifold.
16. The system of claim 1 further comprising at least one backup pressure control subsystem coupled to the inlet.
17. A subsea pressure control system comprising:
 - a flowline configured for connection into a subsea fluid containment system;
 - a controller configured to be responsive to a setpoint pressure in the flowline; and
 - a valve configured to be responsive to a signal from the controller, wherein the signal is based on the setpoint pressure and actuates the valve from a closed position to an open position to expose the flowline to the sea or a container.
18. The system of claim 17 further comprising a pressure sensing device configured to be responsive to a measured pressure in the flowline, wherein the signal is based on the measured pressure exceeding the setpoint pressure.
19. The system of claim 18 wherein the valve is responsive to a second signal from the controller, wherein the second signal is based on the measured pressure equaling or falling below the setpoint pressure, and the second signal actuates the valve from the open position to the closed position to isolate the flowline from the sea or the container.
20. The system of claim 17 further comprising at least one backup pressure control subsystem coupled to the flowline, wherein the backup pressure control subsystem is operable if the valve fails to actuate from the closed position to the open position.
21. A method of controlling a pressure in a subsea fluid containment system, comprising:
 - determining a setpoint pressure for a subsea pressure control system;
 - coupling the subsea pressure control system into the subsea fluid containment system;
 - measuring a pressure of the subsea fluid containment system;
 - comparing the measured pressure to the setpoint pressure; and
 - exposing the subsea fluid containment system to the sea or a container using the subsea pressure control system if the measured pressure exceeds the setpoint pressure.
22. The method of claim 21 further comprising isolating the subsea fluid containment system from the sea using the subsea pressure control system if the measured pressure falls below the setpoint pressure.
23. The method of claim 21 further comprising adjusting the setpoint pressure while subsea.

24. The method of claim 21 further comprising modulating the measured pressure.
25. The method of claim 21 further comprising opening a backup subsystem to expose the subsea fluid containment system to the sea.

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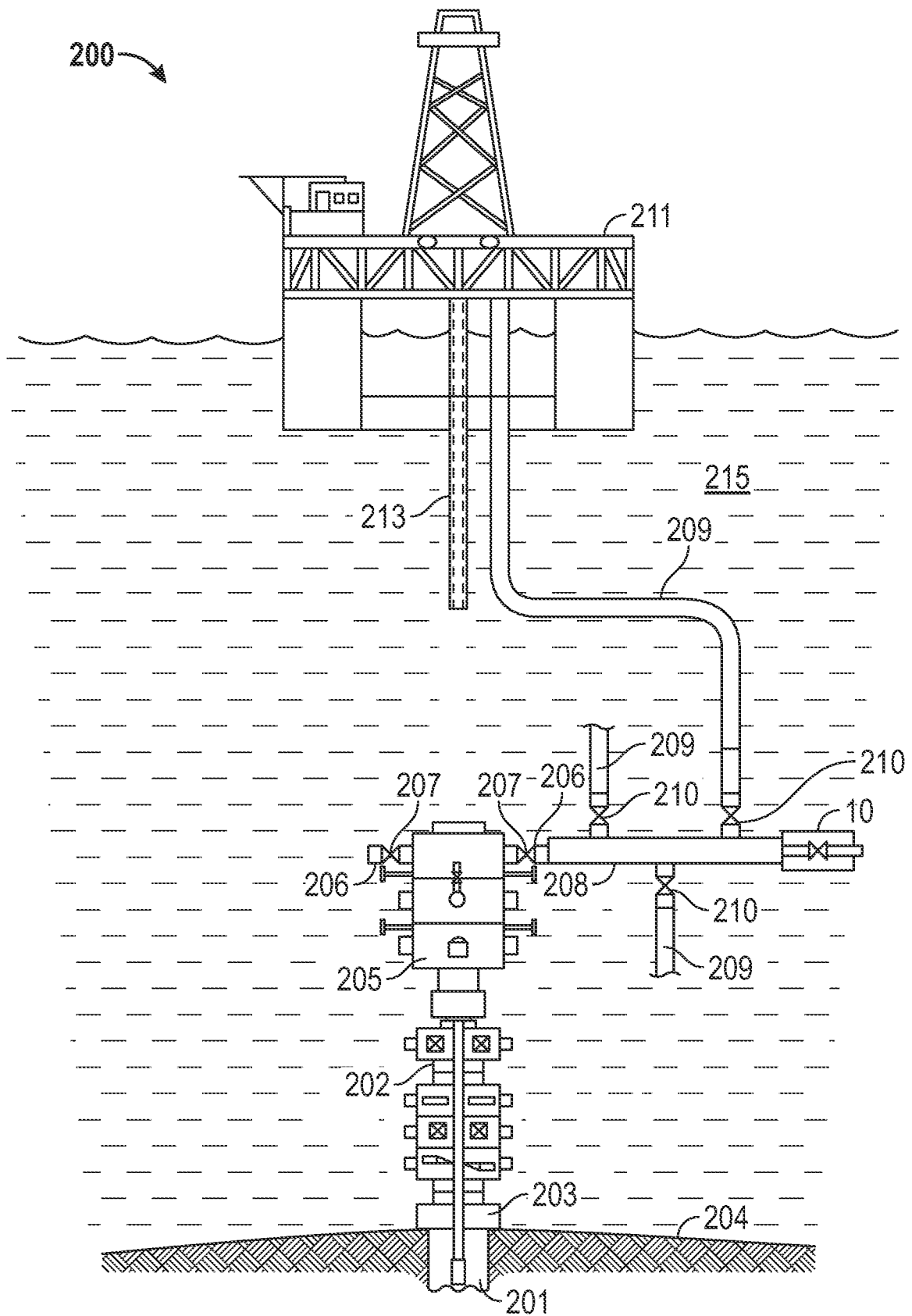


FIG. 1

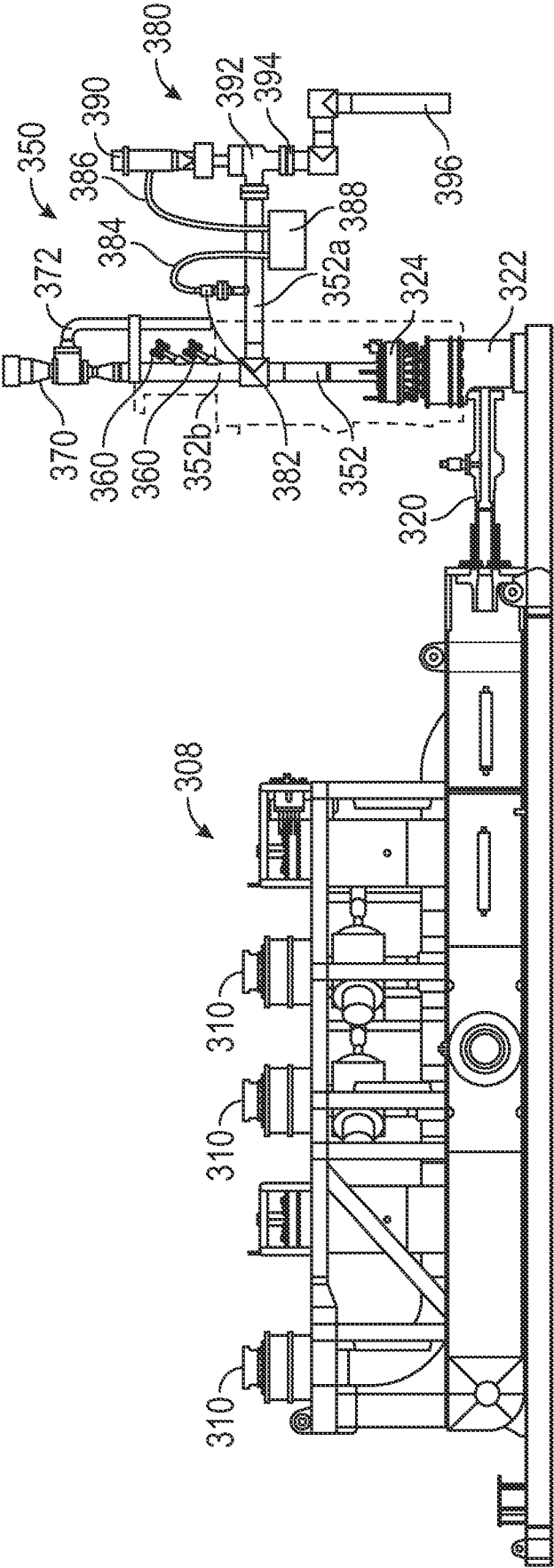


FIG. 2

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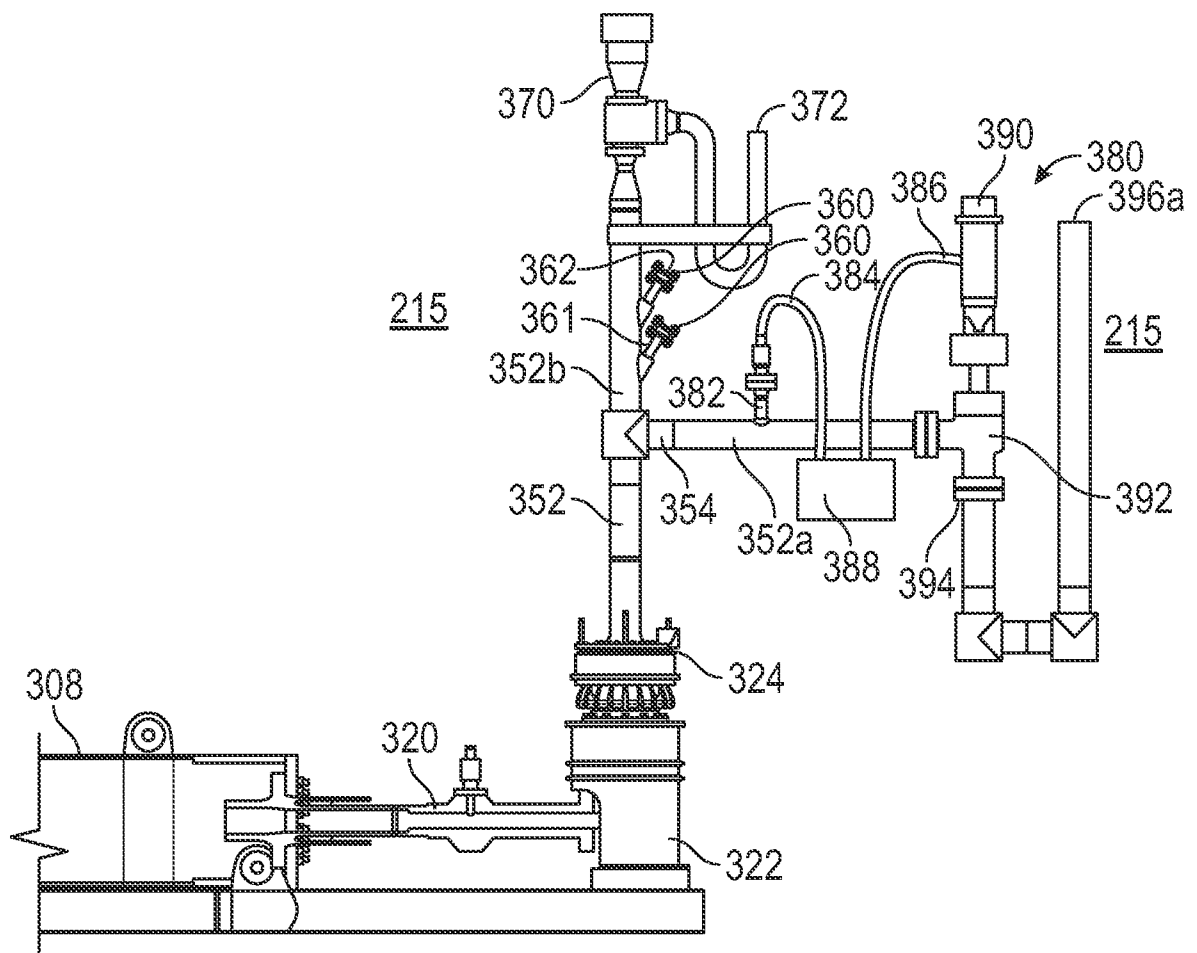


FIG. 3

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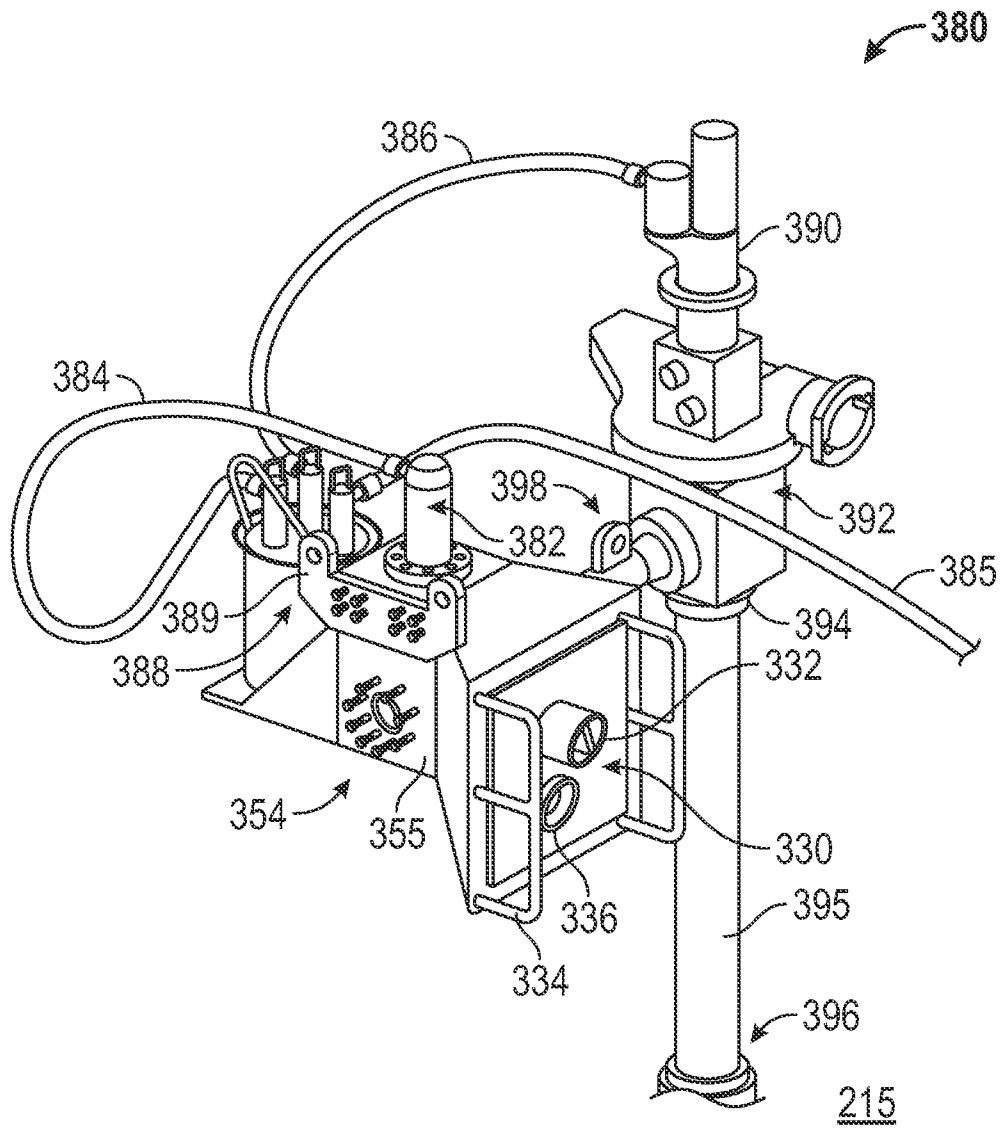
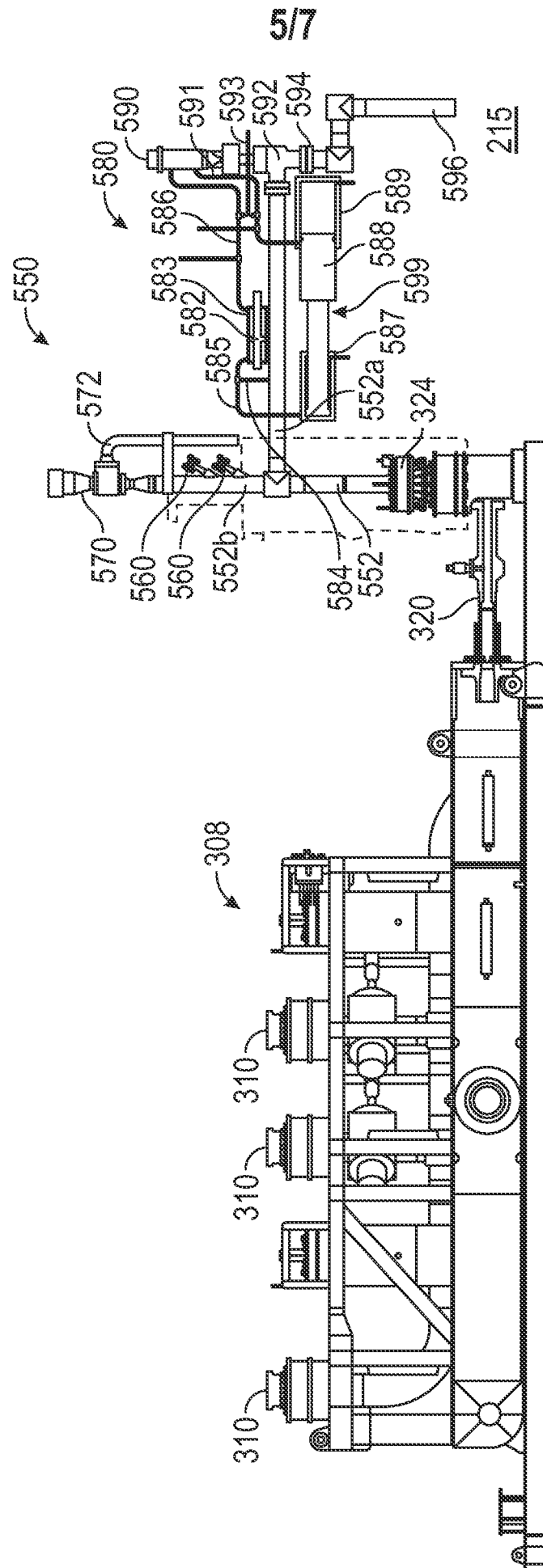


FIG. 4



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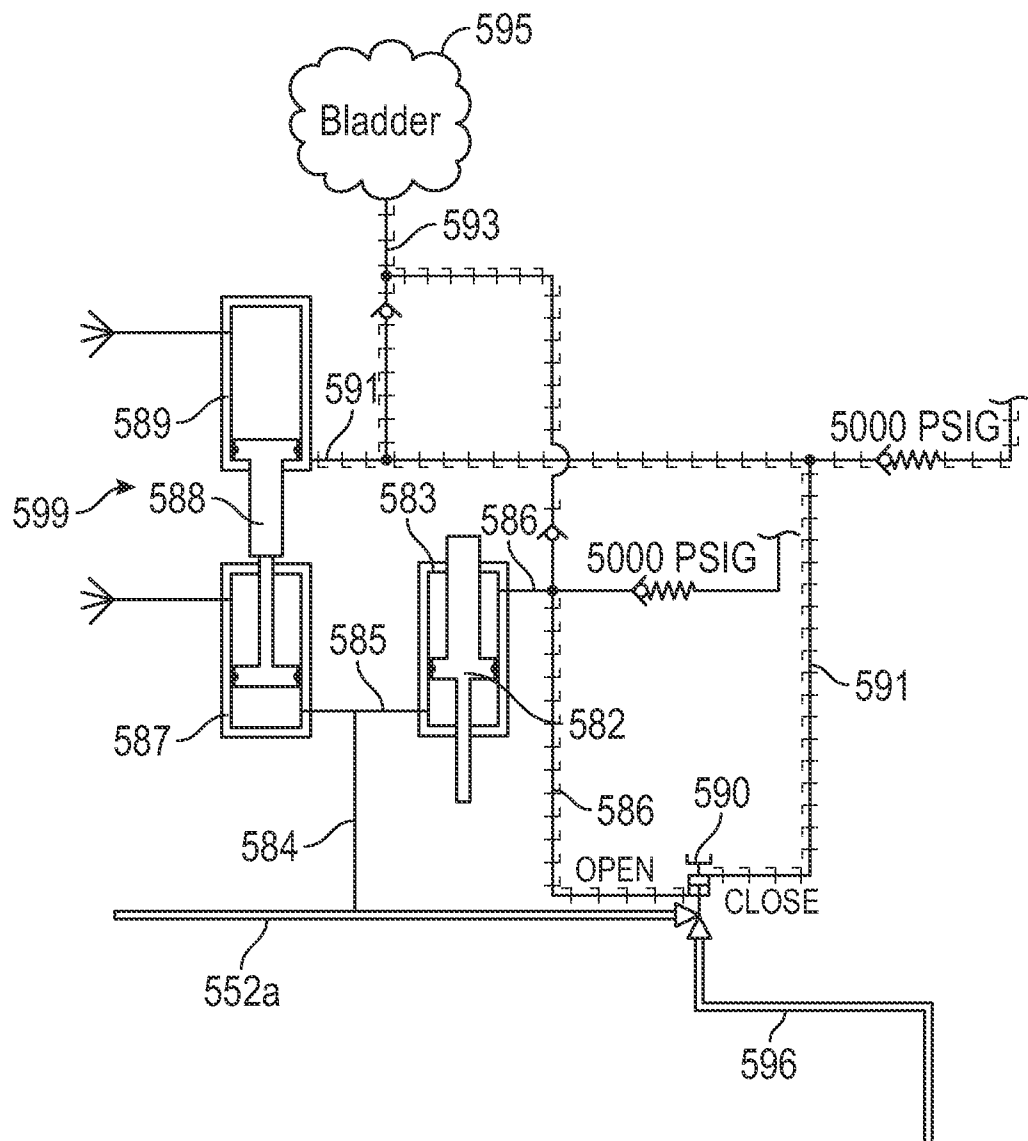


FIG. 6

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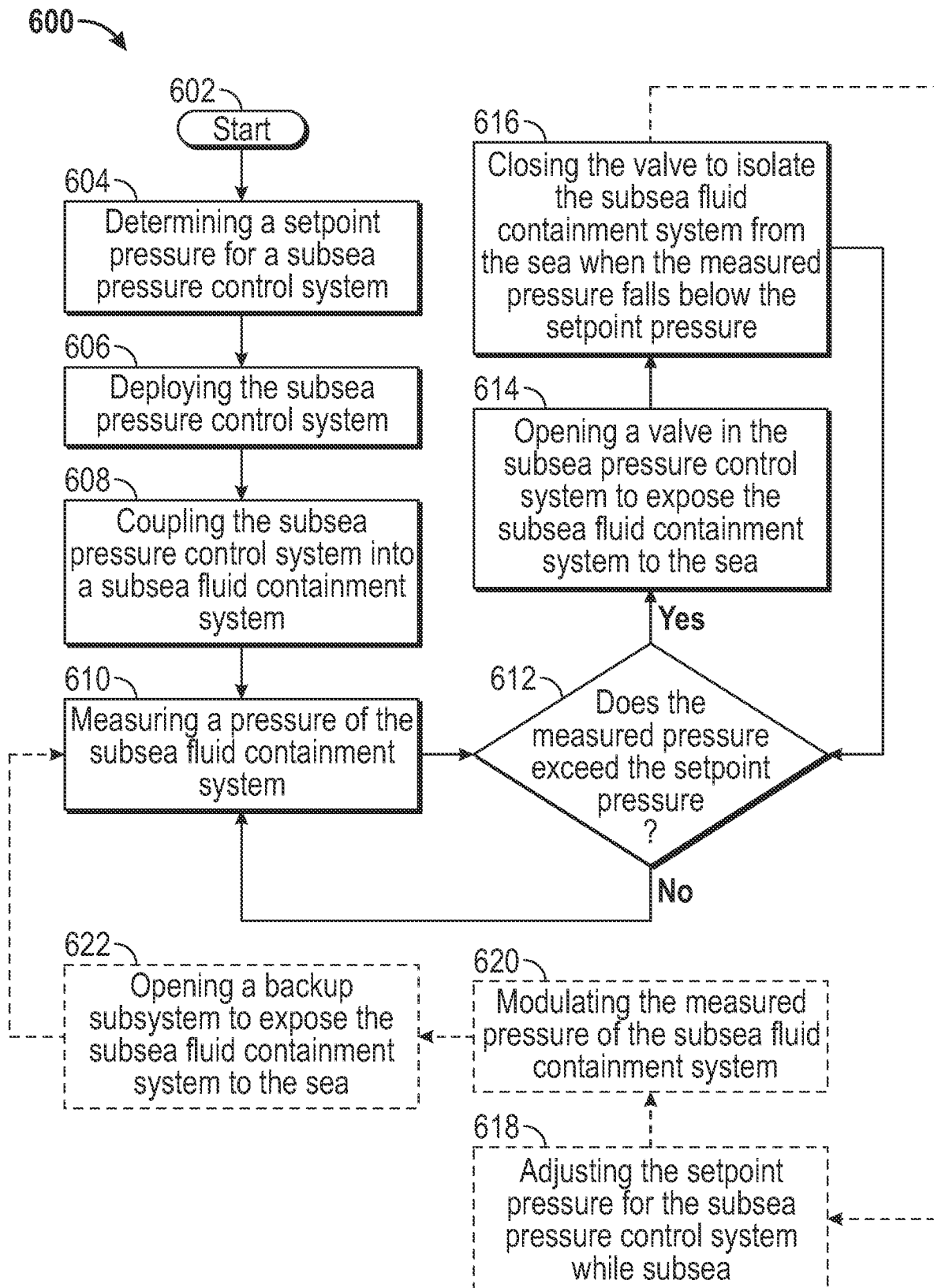


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2012/035298

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/01
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B G05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

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X	GB 2 393 494 A (ULTRONISC LTD.) 31 March 2004 (2004-03-31)	1,2,4,5, 8-10,14
Y	page 6, line 11 - line 19 page 8, line 14 - line 19 page 9, line 6 - line 12 -----	3,6,7, 13,24
X	WO 00/36482 A1 (CHROMPACK INT. BV) 22 June 2000 (2000-06-22)	16-22,25
Y	page 15, line 8 - line 24 -----	3,6,7,24
Y	US 2008/023662 A1 (REINICKE ET AL.) 31 January 2008 (2008-01-31) paragraphs [0027], [0028] -----	3,6,7
Y	US 2008/265190 A1 (FLEISCHER ET AL.) 30 October 2008 (2008-10-30) paragraph [0023] -----	3,6,7
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

4 September 2012

Date of mailing of the international search report

19/09/2012

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Rampelmann, Klaus

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2012/035298

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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International application No

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