

MODULAR BACKUP FLUID SUPPLY SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to provisional application no. 60/705,538.

TECHNICAL FIELD

[0001] The invention relates generally to a fluid supply system and apparatus and, more particularly, to a modular backup hydraulic fluid supply system and apparatus.

BACKGROUND OF THE INVENTION

[0002] Subsea drilling operations may experience a blow out, which is an uncontrolled flow of formation fluids into the drilling well. Blow outs are dangerous and costly. Blow outs can cause loss of life, pollution, damage to drilling equipment, and loss of well production. To prevent blowouts, blowout prevention (BOP) equipment is required. BOP equipment typically includes a series of functions capable of safely isolating and controlling the formation pressures and fluids at the drilling site. BOP functions include opening and closing hydraulically operated pipe rams, annular seals, shear rams designed to cut the pipe, a series of remote operated valves to allow controlled flow of drilling fluids, and well re-entry equipment. In addition, process and condition monitoring devices complete the BOP system. The drilling industry refers to the BOP system in total as the BOP Stack.

[0003] The well and BOP connect to the surface drilling vessel through a marine riser pipe, which carries formation fluids (e.g., oil, etc.) to the surface and circulates drilling fluids. The marine riser pipe connects to the BOP through the Lower Marine Riser Package ("LMRP"), which contains a device to connect to the BOP, an annular seal for well control, and flow control devices to supply hydraulic fluids for the operation of the BOP. The LMRP and the BOP are commonly referred to collectively as simply the BOP. Many BOP functions are hydraulically controlled, with piping attached to the riser supplying hydraulic fluids and other well control fluids. Typically, a central control unit allows an operator to monitor and control the BOP functions from the surface. The central control unit includes hydraulic control systems for controlling the various BOP functions, each of which has various flow control components upstream of it. An operator on the surface vessel typically operates the flow control components and the BOP functions via an electronic multiplex control system.

[0004] Certain drilling or environmental situations require an operator to disconnect the LMRP from the BOP and retrieve the riser and LMRP to the surface vessel. The BOP functions must contain the well when a LMRP is disconnected so that formation fluids do not escape into the environment. To increase the likelihood that a well will be contained in an upset or disconnect condition, companies typically include redundant systems designed to prevent loss of control if one control component fails. Usually, companies provide redundancy by installing two separate independent central control units to double all critical control units. The industry refers to the two central control units as a blue pod and a yellow pod. Only one pod is used at a time, with the other providing backup.

[0005] While the industry designed early versions of the pods to be retrievable in the event of component failure, later versions have increased in size and cannot be efficiently retrieved. Further, while prior art systems have dual redundancy, this redundancy is often only safety redundancy but not operational redundancy, meaning that a single component failure will require stopping drilling operations, making the well safe, and replacing the failed component. Stopping drilling to replace components often represents a major out of service period and significant revenue loss for drilling contractors and operators.

[0006] The industry needs a simple and cost effective method to provide added redundancy and prevent unplanned stack retrievals. The industry needs an easily retrievable system that allows continued safe operation during component down time and integrates easily and quickly into existing well control systems. The industry needs a simpler, economic, and effective method of controlling subsea well control equipment.

BRIEF SUMMARY OF THE INVENTION

[0006a] According to the first aspect of the present invention, there is provided a fluid supply apparatus, comprising: a primary fluid flow route that includes one or more primary flow control components, an intervention shuttle valve having a

primary inlet and a secondary inlet, and a destination; a secondary fluid flow route that bypasses the primary flow control components and includes a modular removable block of one or more secondary flow control components, the intervention shuttle valve, and a selectively removable hose connecting the modular removable block of secondary flow control components to the secondary inlet of the intervention shuttle valve; and the destination; wherein the modular removable block of one or more secondary flow control components further comprises at least one directional control valve, the number of directional control valves corresponding to the same number of blow out prevention (BOP) functions that the modular removable block may simultaneously serve.

[0006b] According to the second aspect of the present invention, there is provided a fluid supply apparatus, comprising: a plurality of primary fluid flow routes that include a corresponding plurality of primary flow control component sets, a corresponding plurality of intervention shuttle valves, and a corresponding plurality of destinations; a selectable secondary fluid flow route that bypasses a selected one of the primary flow control component sets, and includes a modular removable flow control component set, the intervention shuttle valve corresponding to the bypassed primary flow control component set, and a selectively attachable and removable hose connected to the secondary modular removable flow control component set and the intervention shuttle valve corresponding to the bypassed primary flow control component set; the destination corresponding to the bypassed primary flow control component set; and a remote operated vehicle that connects and removes the hose from the secondary modular removable flow control component set to the intervention shuttle valve; wherein the secondary modular removable flow control component set further comprises at least one directional control valve, the number of directional control valves corresponding to the same number of blow out prevention (BOP) functions that the secondary modular removable flow control component set may simultaneously serve.

[0006c] According to the third aspect of the present invention, there is provided a hydraulic fluid supply apparatus for use with an underwater BOP system,

comprising: a modular removable valve block having an inlet connected to a hydraulic fluid source and an outlet connected to a valve block stab connection; a plurality of intervention shuttle valves, each having a primary inlet hard piped to a hydraulic fluid supply line, a backup inlet connected to a backup inlet stab connection receiver, an outlet connected to a hydraulically operated BOP function, and a shuttle; a selectively engageable hose having a first end removably connectable to the valve block stab connection and a second end connectable to any one of the backup inlet stab connections; wherein the modular removable valve block further comprises: at least one directional control valve, the number of directional control valves corresponding to the same number of BOP functions that the modular valve block may simultaneously serve.

[0006d] According to the fourth aspect of the present invention, there is provided a method for providing a backup supply of hydraulic fluid to an underwater BOP function, comprising: providing a plurality of primary fluid control component sets and a modular valve block removably connected to a BOP stack, the modular valve block having an outlet connected to a valve block stab connection; providing a plurality of intervention shuttle valves, each having a primary inlet hard piped through a primary fluid control component set and to a hydraulic fluid supply, a backup inlet connected to a backup inlet stab connection, and an outlet hard piped to a hydraulically operated BOP function; and controlling a remote operated vehicle to connect via removable stab connections a first end of a hose to the valve block stab connection and a second end of the hose to one of the backup inlet stab connections; wherein the modular removable valve block further comprises: at least one directional control valve, the number of directional control valves corresponding to the same number of BOP functions that the modular valve block may simultaneously serve.

[0007] In some embodiments, the present invention provides an improved method and apparatus to provide redundancy to fluid flow components via alternative flow routes. In some embodiments, the present invention allows for safe and efficient bypass of faulty components while allowing continued flow to functions or destinations. The present invention can be integrated into various existing flow systems or placed on entirely new flow systems to provide a layer of efficient redundancy. In other embodiments, the present invention relates to a stand alone control system for subsea blow out prevention (BOP) control functions. The present invention is particularly useful for hydraulically operated control systems and functions in water depths of 10,000 feet or more.

[0008] In some embodiments, a fluid supply apparatus comprises a primary fluid flow route that includes one or more primary flow control components, an intervention shuttle valve, and a destination and a secondary fluid flow route that bypasses the primary flow control components, and includes a modular removable block of one or more secondary flow control components, the intervention shuttle valve, a selectively removable hose that connects the modular removable block of secondary flow control components to the intervention shuttle valve, and the destination. A remotely operated vehicle (ROV) may deploy selectable hydraulic supply to a BOP function that has lost conventional control. In some embodiments, the intervention shuttle valve has an outlet that is hard piped to a BOP function and a secondary inlet that is hard piped from a receiver plate.

[0009] In some embodiments, the modular valve block is removable and includes a directional control valve. More directional control valves may be placed on modular valve block, with the number of directional control valves corresponding to the number of BOP functions that it may simultaneously serve. Modular valve block is generally retrievable by an ROV, thus making repair and exchange easy. Further, the modular nature of the valve block means that a replacement valve block may be stored and deployed when an existing valve block requires maintenance or service. Many other components may be placed on the modular valve block, including pilot valves, and pressure regulators accumulators. Pilot valves may be hydraulic pilots or solenoid operated.

[0010] In some embodiments, the modular valve block connects to the BOP stack via pressure balanced stab connections, and in embodiments requiring electrical connection, via electrical wet-make connection. In some embodiments, the modular valve block mounts onto a modular block receiver that is fixably attached to BOP stack. Preferably, the modular block receiver is universal so that many different modular valve blocks can connect to it. In some embodiments, either the modular valve block or the modular block receiver is connected to a temporary connector for receiving a hose to connect the modular valve block to an intervention shuttle valve.

[0011] In some embodiments, the intervention shuttle valve comprises a housing having a generally cylindrical cavity, a primary inlet entering the side of the housing, a secondary inlet entering an end of the housing, a spool-type shuttle having a detent means, and an outlet exiting a side of the housing. In some embodiments, the outlet is hard piped to a

destination, and the primary inlet is hard piped a primary fluid source. During normal flow, the shuttle is in the normal flow position and fluid enters the primary inlet and flows around the shuttle stem and out of the outlet. The shuttle design seals fluid from traveling into other areas. When backup flow is introduced into secondary inlet, the fluid forces the shuttle to the actuated position, isolating the primary inlet and allowing flow only from the secondary inlet.

[0012] In some embodiments a compound intervention shuttle valve comprises two intervention shuttle valves whose outlets are attached to the inlets of a gate shuttle valve. Thus, the compound intervention shuttle valve comprises two primary inlets, two secondary inlets, and an outlet. The gate shuttle valve is similar to the intervention shuttle valve in that it has a shuttle that shifts to allow flow from one inlet and to isolate flow from the other inlet, but generally has a different shuttle design.

[0013] In some embodiments, a BOP hydraulic control system includes a blue central control pod, a yellow central control pod, and at least one modular valve block associated with each pod to provide universal backup for all control pod components. The modular valve blocks have an outlet that attaches to a hose via a temporary connection, and the other end of the hose attaches to any one of a number of intervention shuttle valves, each associated with a BOP function. Thus, each modular valve block provides redundancy for at least one BOP function.

[0014] In another embodiment, the invention comprises a stand alone subsea control system, modular in construction and providing retrievable, local, and independent control of a plurality of hydraulic components commonly employed on subsea BOP systems. Such a system eliminates the need for separate control pods. Other embodiments allow independent ROV intervention using an emergency hydraulic line routed from the surface to an ISV in the case of catastrophic system control failure of all BOP functions.

[0015] Independent and/or redundant control over BOP functions reduces downtime and increases safety. Furthermore, a control system having easily retrievable components allows fast and easy maintenance and replacement. The present invention, in some embodiments is compatible with a multitude of established systems and provides inexpensive redundancy for BOP system components. In another embodiment of the invention, control over the modular block valves is transparently integrated into an existing multiplex control system, allowing an operator to control the modular valve block using the existing control system.

[0016] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0018] FIGURE 1 is a schematic diagram of a subsea control module representing one embodiment of the present invention;

[0019] FIGURE 2 is a schematic view of a deep sea drilling operation incorporating an embodiment of the present invention;

[0020] FIGURE 3 is a side view of a BOP apparatus incorporating an embodiment of the present invention;

[0021] FIGURES 4A is a schematic diagram of a modular valve block according to an embodiment of the present invention.

[0022] FIGURES 4B perspective view of a modular valve block according to an embodiment of the present invention.

[0023] FIGURES 5A and B are cross sectional side views of an intervention shuttle valve according to embodiments of the present invention.

[0024] FIGURES 6 is a cross sectional side view of a compound intervention shuttle valve according to an embodiment of the present invention.

[0025] FIGURE 7 is a schematic diagram of a BOP hydraulic control system incorporating an embodiment of the present invention.

[0026] FIGURE 8 is a schematic diagram of a BOP hydraulic control system incorporating an embodiment of the present invention.

[0027] FIGURES 9 A and B are flow charts showing embodiments of methods of using the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0028] As used herein, the use of the word “a” or “an” when used in conjunction with the term “comprising” (or the synonymous “having”) in the claims and/or the specification may mean “one,” but it is also consistent with the meaning of “one or more,” “at least one,” and “one or more than one.” In addition, as used herein, the phrase “connected to” means joined to or placed into communication with, either directly or through intermediate components.

[0029] Referring to FIGURE 1, one embodiment of the present invention comprises redundant fluid supply apparatus 10, comprising primary fluid flow route 11 and secondary fluid flow route 12. Primary fluid flow route 11 begins at fluid source 13 and continues through primary flow control components 14 and 15, through primary inlet 100 of intervention shuttle valve 16 and to destination 17. Secondary fluid flow route 12 begins at either fluid source 13 or alternate fluid source 102 and continues through modular valve block 18, through selectively removable hose 19, through secondary inlet 101 of intervention shuttle valve 16, and to destination 17.

[0030] Although FIGURE 1 shows two primary flow components 14 and 15, there may be any number of components. Primary flow components 14 and 15 may comprise any component in a fluid flow system, such as, but not limited to, valves, pipes, hoses, seals, connections, and instrumentation. Modular valve block 18 may comprise any modular,

removable flow control components, at least one of which should compensate for the bypassed fluid components 14 and 15. Although described in more detail below, intervention shuttle valve 16 accepts fluid through either primary inlet 100 secondary inlet 101. When flow is through secondary inlet 101, components upstream of primary inlet 100 are isolated and bypassed, but fluid continues to flow to destination 17 via secondary fluid flow route 12.

[0031] Hose 19 connects to modular valve block 18 via temporary connection 103 and to secondary inlet 101 of intervention shuttle valve 16 via temporary connection 104. In some embodiments, temporary connection 103 attaches directly to modular valve block 18, while in other embodiments piping and other equipment exists between them. Similarly, in some embodiments temporary connection 104 attaches directly to secondary inlet 101, while in other embodiments piping and other equipment exists between them.

[0032] Temporary connections 103 and 104 comprise commercially available stab connections, such as those having an external self-aligning hydraulic link that extends into a connection port and mates with its hydraulic circuit. Generally, a stab connection comprises a receiver or female portions and a stab or male portion, and either portion may be referred to generically as a stab connection. In one embodiment, secondary inlet 101 connects via piping to receiver plate 105 that houses temporary connection 104 and may house other temporary connections.

[0033] In some embodiments, fluid supply apparatus 10 comprises remote operated vehicle (ROV) 106 that deploys hose 19 and connects it to modular valve block 18 and secondary inlet 101 of intervention shuttle valve 16. ROV 106 may also disconnect hose 19 and connect and disconnect modular valve block 18. ROV 106 may be operated from the surface by a human operator, or it may be preprogrammed to perform specific connections or disconnections based on input from a multiplex control system.

[0034] In some embodiments, fluid supply apparatus 10 is used to supply hydraulic fluids to BOP components. Referring also to FIGURE 2, surface vessel 20 on water 21 connects to BOP stack 22 via marine riser pipe 23. Marine riser pipe 23 may carry a variety of supply lines and pipes, such as hydraulic supply lines, choke lines, kill lines, etc. In such embodiments, fluid source 13 is generally a main hydraulic supply line coming down marine riser pipe 23. Alternate fluid source 102 may include, but is not limited to, an accumulator, an auxiliary

hydraulic supply line, an auxiliary conduit on marine riser 23, or a hydraulic feed from control pod 24.

[0035] In one embodiment, control pod 24 attaches to BOP stack 22 and modular valve block 18 attaches to control pod 24. Hose 19 connects modular valve block 18 to BOP stack 22. Control pod 24 may be any system used to control various BOP functions, and may include various combinations of valves, gauges, piping, instrumentation, accumulators, regulators, etc. Traditionally, the industry refers to control pod 24 and its redundant counterpart control pod 25 as a blue pod and yellow pod. Failure or malfunction of any one of the components inside of control pod 24 that is not backed up according to the present invention may require stopping drilling and servicing the control pod, which costs a lot of money. However, one embodiment of the present invention, including ROV 106, hose 19, and modular valve block 18, allows redundancy for components inside of control pod 24 by bypassing and isolating a malfunctioning component and rerouting the fluid flow through modular valve block 18 and hose 19.

[0036] Referring to an embodiment of the present invention as demonstrated in FIGURE 3, control pod 24 (e.g., a blue pod) attaches to BOP stack 22 and modular valve block 18 attaches to control pod 24. In addition, a second control pod 25 (e.g., a yellow pod) attaches to BOP stack 22 and a second modular valve block 31 attaches to control pod 25. In these embodiments, the destinations of the hydraulic fluid are BOP functions. Control pods 24 and 25 provide control to the various BOP functions, some of which are referred to by numbers 301, 303, and 304. BOP control functions include, but are not limited to, the opening and closing of hydraulically operated pipe rams, annular seals, shear rams designed to cut the pipe, a series of remote operated valves to allow controlled flow of drilling fluids, a riser connector, and well re-entry equipment. Control pods 24 and 25 are hard piped to the various BOP functions, including BOP functions 301, 303, and 304, which means that if one component in control pod 24 or 25 fails and must be repaired, the whole control pod or the LMRP must be disconnected and the control pod's control over BOP functions cease or are limited. As used herein, "hard piped" or "hard piping" refers to piping and associated connections that are permanent or not easily removed by an ROV. In addition, for safety and regulatory reasons, a drilling operation cannot or will not operate with only one working control pod. Thus, a failure of one component of one pod forces a drilling operation to stop. One embodiment of the present invention overcomes this

problem in subsea drilling by providing modular and selectable backup control for many components in control modules 24 and/or 25.

[0037] Referring to FIGURE 3, BOP functions 301, 303, and 304 connect via hard piping to intervention shuttle valves 16, 300, and 302, respectively. In this embodiment, intervention shuttle valve 16 is hard piped to temporary connection 104 on receiver plate 105 via hard piping 32. Intervention shuttle valves 300 and 302 also connect to other temporary connection receivers on receiver plate 105 via hard piping. In addition, control pod 24 connects to intervention shuttle valve 16 via hard piping 33. Although not shown, control pod 24 also connects to intervention shuttle valves 300 and 302. When a control component in control pod 24 malfunctions, the BOP function to which the control component corresponds will not respond to normal commands (for instance, an annular will not shut). After it is determined that a BOP component is not working, ROV 106 may be directed to connect hose 19 at the connection receiver on receiver plate 105 that is hard piped to the nonresponsive function. In FIGURE 3, ROV 106 has connected hose 19 to temporary connection 104, one of several temporary connections on receiver plate 105. ROV 106 also connects hose 19 to modular valve block 18 at temporary connection 103. In other embodiments, ROV 106 connects hose 19 to modular valve block 18 first and then to intervention shuttle valve 16. In either scenario, the malfunctioning control component of control pod 24 is bypassed, and hydraulic fluid flows through a secondary route that includes modular valve block 18, hose 19, and intervention shuttle valve 16. The BOP function will now work properly, avoiding downtime.

[0038] In some embodiments, modular valve block 18 is designed to be robust in that it is capable of servicing several different BOP functions, each of which is selected by plugging hose 19 into the particular intervention shuttle valve associated with the BOP function experiencing control problems. The components on modular valve block 18, described in detail below, may provide redundancy for numerous components in control pod 24 and/or 25, making modular valve block generally universal and monetarily efficient. Even before a component failure arises, hose 19 may be connected to modular valve block 18 and a particular connection on receiver plate 105 to anticipate a malfunction of a particular component. Of course, if at a later time a different component fails than the one anticipated, ROV 106 can disconnect hose 19 from the first connection on receiver plate 105 and connect it to a different connection (the one corresponding to the malfunctioning BOP function) to allow backup control.

MODULAR VALVE BLOCK

[0039] FIGURES 4A and B demonstrate one embodiment of modular valve block 18, which includes directional control valves 40 and 42 and pilot valves 41 and 43. Although two sets of valves and pilot valves are shown, any number of valves may be placed on the modular valve block 18. The number of directional control valves corresponds to the number of BOP functions that modular valve block 18 may simultaneously serve. However, modular valve block 18 in most cases is small enough to be retrievable by ROV 106. In some embodiments, modular valve block 18 comprises manifold pressure regulator 45 to control the hydraulic fluid supply pressure to systems components downstream of directional control valves 40 and 42, and pilot pressure regulator 46 to control pressure available to the pilot system. In some embodiments, pilot pressure regulator 46 is configured to also provide back feed hydraulic pressure to control pod 24.

[0040] In some embodiments, modular valve block 18 comprises pressure accumulator 44 to avoid any pressure loss when shifting pilot valves 41 and 43, and accumulator dump valve 47 to allow venting of accumulator 44 as required during normal operations. In some embodiments, pilot valves 41 and 43, pressure accumulator 44, manifold pressure regulator 45, and pilot pressure regulator 46 are not housed on modular valve block 18, but rather are placed upstream or are not required. While many BOP components require hydraulic fluid at the same pressure, in embodiments where modular valve block 18 is to be generically able to supply hydraulic fluid to different BOP components at different pressures (such as an annular compared to a shear ram), manifold pressure regulator 45 is advantageous. Various combinations of valves, pilots, regulators, accumulators, and other control components are possible, and in some embodiments, pilot valves 41 and 43 are solenoid operated pilot valves, while in other embodiments, they are hydraulic pilot valves. In addition, in some embodiments, BOP stack 22 is connected to a plurality of modular valve blocks, each of which may provide backup for one or more control component.

[0041] Modular valve block 18 further comprises connections 400, 401, 402, and 403 to connect to BOP stack 22. In some embodiments, connections 400, 401, 402, and 403 are pressure balanced stab connections that allow for removal and reinstallation via ROV 106. In embodiments requiring electrical connection, connection 410 is an electrical wet make connection to allow making and breaking of electrical connections underwater. Referring to

FIGURE 4B, modular valve block 18 mounts onto modular block receiver 48 in some embodiments. Modular block receiver 48 is fixably attached to BOP stack 22 and a hydraulic fluid supply is hard piped to it. According to the embodiment in FIGURE 4B, modular block receiver 48 includes receptacles 404, 405, 406, and 407 to receive connections 400, 401, 402, and 403. Receptacles 404, 405, 406, and 407 and connections 400, 401, 402, and 403 are preferably universal so that the present invention can be installed on any number of BOP stacks and different modular valve blocks can attach to modular block receiver 48.

[0042] Hydraulic supply connections 408 and 409 supply hydraulic fluid and pilot hydraulic fluid to modular valve block 18. Any suitable source may supply hydraulic supply connections 408 and 409, such as, but not limited to, the main hydraulic supply, an accumulator, an auxiliary hydraulic supply line, an auxiliary conduit on marine riser 23, or a hydraulic feed from control pod 24. While temporary connection 103 may be housed on modular valve block 18 directly, it may also be housed on modular block receiver 48. In addition, one or more additional temporary connections 411 may be included. The number of temporary connections connected to modular valve block 18 generally will correspond to the number of directional control valves on modular valve block 18 and will also generally dictate how many BOP functions may be simultaneously served. Although temporary connection 103 is shown as exiting the side of modular block receiver 48, it may also exit at other locations on modular block receiver 48, such as on a bottom portion, pointing vertically in relation to the sea floor, for easy disconnect during emergency stack pulls.

INTERVENTION SHUTTLE VALVE

[0043] Referring to FIGURES 5A and B, intervention shuttle valve 16 comprises housing 58, generally cylindrical cavity 500, primary inlet 100, secondary inlet 101, generally cylindrical spool-type shuttle 51, and outlet 50. Cavity 500 comprises a top generally circular area 501, bottom generally circular area 502, and a side cylindrical area 503. Housing 58 has lip 52 above top generally circular area 503. In some embodiments, shuttle 51 comprises first region 504 nearest to secondary inlet 101 and having a radius substantially similar to that of cavity 500, second region 505 further from secondary inlet 101 and having a radius smaller than that of first region 504, third region 506 further still from secondary inlet 101 and having a radius substantially similar to that of cavity 500, fourth region 507 furthest from secondary inlet 101 and having a radius smaller than that of third region 506, and transition surface 56 between first

region 504 and second region 505. Transition surface 56 may gradually slope between the radii of first region 504 and second region 505, or it may be an immediate change from the radius of first region 504 to that of second region 505 (in which case transition surface 56 is a flat surface normal to the cylindrical side of second region 505). In some embodiments, outlet 50 is hard piped to a destination, such as a BOP function, primary inlet 100 is hard piped to control pod 24, and secondary inlet 101 is hard piped to receiver plate 105. During normal flow, which corresponds to flow along primary fluid flow route 11 of FIGURE 1, shuttle 51 is in the normal flow position and fluid enters primary inlet 100, flows around second region 505, and out outlet 50. Fluid does not flow to other areas because sealing areas 54 and 53, corresponding to first region 504 and third region 506, respectively, prevent fluid from leaking or flowing past them. Fluid flowing through primary inlet 100 applies a force against transition region 56 to keep shuttle 51 balanced. Accordingly, the shuttle valve remains in the normal position.

[0044] When it is desired to switch from normal flow to backup flow, fluid is introduced to secondary inlet 101, which applies pressure to broad face 55 of shuttle 51. Because the surface area of broad face 55 is greater than the surface area of transition zone 56, a flow of fluid in secondary inlet 101 at equal pressure to a fluid entering through primary inlet 100 will force shuttle 51 into the actuated position. FIGURE 5B depicts an embodiment of intervention shuttle valve 16 with shuttle 51 in the actuated position. During flow in the actuated position, which corresponds to flow along secondary flow route 12 of FIGURE 1, fluid enters secondary inlet 101 and out outlet 50. Fluid does not flow beyond shuttle 51 because sealing area 54 prevents flow. In addition, third region 506 hits lip 52, which prevents shuttle 51 from actuating any further. Thus, when shuttle 51 is in the actuated position, primary inlet 100 and components upstream of it are isolated and bypassed. Shuttle 51 may be reset at any time by supplying a fluid into bleed port 57 and forcing shuttle in the normal position.

[0045] Referring to FIGURE 6, in some embodiments, intervention shuttle valve 16 is combined with other valves to form compound intervention shuttle valve 60. In some embodiments, compound intervention shuttle valve 60 comprises two intervention shuttle valves 16 and 61, gate intervention shuttle valve 62, primary inlets 100 and 600, secondary inlets 101 and 601, gate shuttle 64, and outlet 65. Connector 63 connects compound intervention shuttle valve 60 to a BOP function. The term "gate shuttle" is not meant to be limiting to any particular type of shuttle or valve, but is only used to distinguish it from intervention shuttle valve 16. Gate

intervention shuttle valve 62 can be any shuttle valve that will shift to accept flow from only one side and isolate the other side.

[0046] Tracing one possible flow route in FIGURE 6, flow enters through secondary inlet 101 of shuttle valve 16, forcing shuttle 51 into the actuated position. Flow continues out intervention shuttle valve 16 and into gate intervention shuttle valve 62, forcing gate shuttle 64 to the left and allowing flow out outlet 65 and isolating intervention shuttle valve 61. If flow through intervention shuttle valve 16 ceased and flow was introduced into shuttle valve 61, gate shuttle 64 would be forced to the right, isolating shuttle valve 16. In some embodiments, compound intervention shuttle valve 60 may be used to provide normal flow of hydraulic fluid from either the blue pod or yellow pod (e.g., control pods 24 and 25 of FIGURE 3) and alternative flow from modular valve block 18 or 31 of FIGURE 3. In such embodiments, compound intervention shuttle valve 60 will be capable of routing hydraulic fluid from four different sources to an outlet that leads to a BOP function. In some embodiments, the housings of intervention shuttle valves 16, 61, and 62 are made from a unitary piece of material, while in other embodiments the housings are made from distinct components and intervention shuttle valves 16, 61, and 62 are fixably attached to each other such that the outlets of intervention shuttle valves 16 and 61 flow into inlets 602 and 603 of gate intervention shuttle valve 62.

SCHEMATIC FLOW DIAGRAMS

[0047] FIGURE 7 is a schematic including BOP pipe ram 700 and associated hydraulic feed systems. Fluid source 13 comprises a main hydraulic inlet and flows through valve 70 to either control pod 24 or control pod 25. In one possible flow route, valve 70 routes flow to control pod 24 and valve 703 routes flow through control components 14 and 15 to compound intervention shuttle valve 60. Referring FIGURES 6 and 7, in one embodiment compound intervention shuttle valve 60 has primary inlet 100 downstream of control pod 24, primary inlet 600 downstream of control pod 25, secondary inlet 101 downstream of temporary connection 104, and secondary inlet 601 downstream of temporary connection 74. Gate shuttle 64 isolates the inactive side of compound intervention shuttle valve 60 to allow flow through connector 63 to a BOP function. In this example, intervention shuttle valve 16 is in the actuated position to allow flow from secondary inlet 101, and gate shuttle 64 isolates intervention shuttle valve 61 and allows flow through intervention shuttle valve 16.

[0048] Although the destination of the hydraulic fluid can include any BOP function, FIGURE 7 depicts an embodiment including two complementary destinations: the first function, “pipe ram close” 701, is associated with compound intervention shuttle valve 60 and opens pipe ram 700, and the second function, “pipe ram open” 702, is associated with compound intervention shuttle valve 78 and closes pipe ram 700. In this example, hose 19 connects temporary connection 103 and temporary connection 104 to route backup hydraulic flow to intervention shuttle valve 16 of compound intervention shuttle valve 60. Thus, control components 14 and 15 of control pod 24 that normally direct fluid to the function “pipe ram close” 701 have been isolated and bypassed, and fluid flow is routed through modular valve block 18, hose 19, and intervention shuttle valve 16 of compound intervention shuttle valve 60.

[0049] In the embodiment of FIGURE 7, both pipe ram open 702 and pipe ram close 701 can be backed up for flow around control pod 24 and control pod 25. Thus, complete redundancy of control components are provided for both control pod 24 and control pod 25. Modular block valve 18 includes an additional outlet for temporary connection 411, and modular valve block 77 includes temporary connections 75 and 76. Similarly, receiver plate 105 includes additional ports for temporary connections 72, 73, and 74. As depicted, none of temporary connections 411, 75, 76, 72, 73, or 74 has a hose attached to it, but ROV 106 could attach a hose to those connections as needed. In some embodiments, due to the universal nature of modular block valves 18 and 77, ROV can attach hoses to any or all temporary connections 103, 411, 75, and 76 and route the hoses to any number of temporary connections that lead to other BOP functions (not shown). In some embodiments, BOP functions such as pipe ram open 702 and pipe ram close 701 can vent hydraulic fluid using backward flow through compound intervention shuttle valves 60 and 78 to vent lines (not shown).

[0050] It is also possible for the intervention shuttle valve 16 to provide emergency backup hotline flow to a BOP function in event of total loss of hydraulic control. In such embodiments, ROV 106 carries an emergency hydraulic supply line from the surface and connects it directly to temporary connection 104, which is connected to secondary inlet 101 of intervention shuttle valve 16, thus supplying hydraulic fluid in the event of other hydraulic fluid supply failure. In this manner, hydraulic fluid can be progressively supplied to any number of BOP functions in the event of catastrophic system failure.

[0051] In some embodiments, an electronic multiplex control system ("MUX") and an operator on the surface control and/or monitor BOP functions and hydraulic supply. In a simple sense, the MUX allows an operator to control BOP functions by the push of buttons or the like. For example the operator closes an annular by pressing a button or inputting an electronic command to signal the hydraulic system to close the annular. In some embodiments, the present invention is integrated into an existing multiplex system such that the initiation of backup hydraulic supply can be commanded by the push of a button. In addition, software can allow the switch between normal flow and backup flow to be transparent in that the operator pushes the same button to control a particular function whether normal or backup flow used.

[0052] In another embodiment of the present invention, shown in FIGURE 8, central control pods (such as control pods 24 and 25 of FIGURE 7) are entirely removed from the BOP hydraulic supply system. In place of central control pods, a plurality of primary, dedicated modular valve blocks and associated intervention shuttle valves are hard piped to the various BOP functions. By way of non-limiting example, primary modular valve blocks 80 and 81 are typically hard piped to compound intervention shuttle valves 60' and 78', respectively, but may be connected via temporary connections. Primary modular valve blocks 80 and 81 typically retrievably mount to modular receiver plates, but may mount directly on the BOP stack. Having a plurality of primary modular valve blocks makes repairing a malfunctioning primary control component easier and more cost efficient because an ROV can retrieve the particular malfunctioning primary modular valve block instead of retrieving an entire central control pod. In some embodiments, primary modular valve blocks are backed up with a one or more secondary modular valve blocks, such as secondary modular valve blocks 18' and 77', that connect to intervention shuttle valves via one or more hoses 19'. Thus, total hydraulic control is redundantly supplied via easily retrievable modular valve blocks. In addition to being easily retrievable, the plurality of modular valve blocks save money through economy of scale because they can be mass produced.

FLOW DIAGRAMS

[0053] Referring to FIGURE 9A, in one embodiment a method provides backup fluid flow to a destination. In some embodiments, referring to box 91, an operator initiates an alternate fluid flow route, such as when he detects a malfunctioning function and/or he needs to route flow around a control component. In some embodiments, the fluid is hydraulic fluid and

the destination is a BOP function. Referring to boxes 92 and 93, a ROV is deployed to connect a hose to a modular valve block and a secondary inlet of an intervention shuttle valve. After the hose is connected, flow is sent through the modular valve block, hose, and secondary inlet of the intervention shuttle valve and to the destination as shown in box 94. In some embodiments, as shown in box 95, multiplex control of the hydraulic flow to the function is transparently switched such that operator can control the BOP function via the modular valve block using the same button or input means that controlled the malfunctioning control component.

[0054] FIGURE 9B shows an embodiment of the present invention involving blue and yellow central control pods to supply hydraulic fluids to one or more BOP functions. In one embodiment, hydraulic fluid is supplied by the blue pod, but a control component malfunction is detected as shown in box 902. In some embodiments, as shown in box 903, hydraulic supply switches from the blue pod to the yellow pod, the switch resulting from either operator input or automatic computer initiation. Of course, in another embodiment, control could remain in the blue pod while backup flow is initiated. Referring to box 904, an ROV is deployed and connects a hose to modular valve block and to the compound intervention shuttle valve associated with the proper BOP function. In some embodiments, as shown in box 905, multiplex control of the hydraulic flow to the function is transparently switched such that an operator can control the BOP function via the modular valve block using the same button or input means that controlled the now-malfunctioning control component. Referring to box 906, hydraulic supply may be switched back to the blue pod, and hydraulic fluid flows around the malfunctioning control component, through the modular valve block, and to the BOP function, restoring hydraulic control of the BOP function through the blue pod.

[0055] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention.

Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

CLAIMS

What is claimed is:

1. A fluid supply apparatus, comprising:

a primary fluid flow route that includes

one or more primary flow control components,

an intervention shuttle valve having a primary inlet and a secondary inlet,

and

a destination;

a secondary fluid flow route that bypasses the primary flow control components

and includes

a modular removable block of one or more secondary flow control

components,

the intervention shuttle valve, and

a selectively removable hose connecting the modular removable block of secondary flow control components to the secondary inlet of the intervention shuttle valve; and the destination; wherein the modular removable block of one or more secondary flow control components further comprises

at least one directional control valve, the number of directional control valves corresponding to the same number of blow out prevention (BOP) functions that the modular removable block may simultaneously serve.

2. The apparatus of claim 1, wherein the modular removable block of one or more secondary flow control components further comprises:

at least one pilot valve operatively coupled to the at least one directional control valve;

a manifold pressure regulator operatively coupled to the at least one pilot valve, the manifold pressure regulator controls the supply pressure to components downstream of the at least one directional control valve; and

a pilot pressure regulator operatively coupled to the at least one pilot valve.

3. The apparatus of claim 1 or 2, further comprising a remote operated vehicle that connects and removes the hose from the modular removable block of secondary flow control components to the secondary inlet of the intervention shuttle valve.

4. The apparatus of any one of the preceding claims , wherein the modular removable block of secondary flow control components further comprises components selected from the group consisting of a manifold pressure regulator, an accumulator, a pilot valve, a pilot pressure regulator, and any combination thereof.

5. The apparatus of claim 4, wherein the pilot valve is a secondary solenoid pilot valve or a secondary hydraulic pilot valve.

6. The apparatus of claim 1, wherein the destination comprises a hydraulic inlet to a BOP function selected from the group of consisting of a shear ram open, a shear ram close, a pipe ram open, a pipe ram close, an annular seal open, an annular seal close, a riser connector open, a riser connector close, a fluid control valve open, a fluid control valve close, a well reentry open, and a well reentry close.

7. The apparatus of claim 1, wherein the hose connects to the intervention shuttle valve and the modular removable block of secondary flow control components via a stab type connection.

8. The apparatus of claim 7, wherein the secondary inlet of the intervention shuttle valve is hard piped to a stab type connection receiver.

9. The apparatus of claim 1, further comprising a plurality of destinations, and a corresponding plurality of intervention shuttle valves; wherein the hose connects from the modular removable block of secondary flow control components to any one of the plurality of intervention shuttle valves.

10. The apparatus of claim 9, wherein the one or more primary flow control components is connected to a first central control pod comprising a plurality of primary flow control components routed to a plurality of destinations.

11. The apparatus of claim 9, wherein the one or more primary flow control components is connected to a modular removable block and a plurality of other primary flow control components are connected to a corresponding plurality of modular removable blocks, and each modular removable block comprising primary flow control components is hard piped to one of a corresponding plurality of intervention shuttle valves and destinations.

12. The apparatus of claim 10, further comprising a second central control pod that provides redundancy to the first central control pod; and
at least one additional modular removable block of secondary flow control components associated with the second central control pod.

13. The apparatus of claim 7, wherein the modular removable block of secondary flow control components removably attaches to a modular block receiver that houses a stab type receiver connection for connection with the hose; and

the modular removable block of secondary flow control components is removable from the modular block receiver without interrupting the primary flow route.

14. The apparatus of claim 13, wherein the stab type receiver connection on the modular block receiver for connection with the hose is oriented in a vertical direction in relation to a sea floor.

15. The apparatus of claim 1, further comprising an electronic multiplex control system.

16. The apparatus of claim 15, wherein the electronic multiplex control system transparently integrates the primary fluid flow route and the secondary fluid flow route.

17. A fluid supply apparatus, comprising:

a plurality of primary fluid flow routes that include a corresponding plurality of primary flow control component sets, a corresponding plurality of intervention shuttle valves, and a corresponding plurality of destinations;

a selectable secondary fluid flow route that bypasses a selected one of the primary flow control component sets, and includes

a modular removable flow control component set,

the intervention shuttle valve corresponding to the bypassed primary flow control component set, and

a selectively attachable and removable hose connected to the secondary modular removable flow control component set and the intervention shuttle valve corresponding to the bypassed primary flow control component set;

the destination corresponding to the bypassed primary flow control component set; and

a remote operated vehicle that connects and removes the hose from the secondary modular removable flow control component set to the intervention shuttle valve; wherein the secondary modular removable flow control component set further comprises at least one directional control valve, the number of directional control valves corresponding to the same number of blow out prevention (BOP) functions that the secondary modular removable flow control component set may simultaneously serve.

18. The apparatus of claim 17, wherein the secondary modular removable flow control component set further comprises:

at least one pilot valve operatively coupled to the at least one directional control valve;

a manifold pressure regulator operatively coupled to the at least one pilot valve, the manifold pressure regulator controls the supply pressure to components downstream of the at least one directional control valve; and

a pilot pressure regulator operatively coupled to the at least one pilot valve.

19. The apparatus of claim 17 or 18, wherein the intervention shuttle valve comprises a primary inlet, a secondary inlet and a shuttle.

20. The apparatus of any one of claims 17 to 19, wherein the secondary modular removable flow control component set further comprises components selected from the group consisting of a manifold pressure regulator, an accumulator, a pilot valve, a pilot pressure regulator, and any combination thereof.

21. The apparatus of claim 20, wherein the pilot valve is a secondary solenoid pilot valve or a secondary hydraulic pilot valve.

22. The apparatus of claim 17, wherein the destination comprises a hydraulic inlet to a BOP function selected from the group of consisting of: a shear ram open, a shear ram close, a pipe ram open, a pipe ram close, an annular seal open, an annular seal close, a riser connector open, a riser connector close, a fluid control valve open, a fluid control valve close, a well reentry open, and a well reentry close.

23. The apparatus of claim 18, wherein the hose connects to the secondary inlet of the intervention shuttle valve and the secondary modular removable flow control component set via a stab type connection.

24. The apparatus of claim 23, wherein the secondary inlet of the intervention shuttle valve is hard piped to a stab type connection receiver.

25. The apparatus of claim 17, wherein the plurality of primary flow control component sets are connected to a first central control pod.

26. The apparatus of claim 17, wherein each of the plurality of primary flow control component sets is connected to one of a corresponding plurality of modular removable blocks, and each modular removable block is connected to a corresponding intervention shuttle valve and destination.

27. The apparatus of claim 25, further comprising a second central control pod that provides redundant sets of primary flow control components to the primary flow control component of the first central control pod; and

at least one additional secondary modular removable flow control component set associated with the second central control pod.

28. The apparatus of claim 27, wherein one or more of the intervention shuttle valves are compound intervention shuttle valves each comprising a first primary inlet, a second primary inlet, a first secondary inlet, a second secondary inlet, a first shuttle, a second shuttle, a gate shuttle, and an outlet to a BOP function.

29. The apparatus of claim 23, wherein the secondary modular removable flow control component set removably attaches to a modular block receiver that houses at least one stab type receiver connection for connection with the hose; and

the secondary modular removable flow control component set is removable from the modular block receiver without interrupting the primary flow route.

30. The apparatus of claim 29, wherein the stab type receiver connection on the modular block receiver for connection with the hose is oriented in a vertical direction in relation to a sea floor.

31. The apparatus of claim 17, further comprising an electronic multiplex control system.

32. The apparatus of claim 31, wherein the electronic multiplex control system transparently integrates the primary fluid flow route and the secondary fluid flow route.

33. A hydraulic fluid supply apparatus for use with an underwater BOP system, comprising:

a modular removable valve block having an inlet connected to a hydraulic fluid source and an outlet connected to a valve block stab connection;

a plurality of intervention shuttle valves, each having a primary inlet hard piped to a hydraulic fluid supply line, a backup inlet connected to a backup inlet stab connection receiver, an outlet connected to a hydraulically operated BOP function, and a shuttle;

a selectively engageable hose having a first end removably connectable to the valve block stab connection and a second end connectable to any one of the backup inlet stab connections;

wherein the modular removable valve block further comprises: at least one directional control valve, the number of directional control valves

corresponding to the same number of BOP functions that the modular valve block may simultaneously serve.

34. The apparatus of claim 33, wherein the modular removable valve block further comprises:

at least one pilot valve operatively coupled to the at least one directional control valve;

at least one pilot valve, the manifold pressure regulator controls the supply pressure to components downstream of the at least one directional control valve; and

a pilot pressure regulator operatively coupled to the at least one pilot valve.

35. The apparatus of claim 33 or 34, wherein the modular removable valve block further comprises components selected from the group consisting of a manifold pressure regulator, an accumulator, a pilot valve, a pilot pressure regulator, and any combination thereof.

36. The apparatus of claim 35, wherein the pilot valve is a solenoid pilot valve or a hydraulic pilot valve.

37. The apparatus of claim 33, wherein backup inlet stab connections are housed on a receiver plate and are hard piped to the backup inlet of the intervention shuttle valves.

38. The apparatus of claim 33, further comprising an emergency hydraulic source that is selectively and removably attached to one of the backup inlet stab connections.

39. The apparatus of claim 33, wherein the BOP system comprises a plurality of primary flow control component sets connected to a first central control pod.

40. The apparatus of claim 33, wherein the BOP system comprises a plurality of primary flow control component sets, each connected to a one of a corresponding plurality of primary modular removable blocks, wherein each primary modular removable block is connected to a corresponding intervention shuttle valve and destination.

41. The apparatus of claim 39, further comprising a second central control pod that provides redundant sets of primary flow control components to the primary flow control

components of the first central control pod;

and at least one additional modular removable valve block associated with the second central control pod.

42. The apparatus of claim 41 wherein one or more of the intervention shuttle valves are compound intervention shuttle valves each comprising a first primary inlet, a second primary inlet, a first secondary inlet, a second secondary inlet, a first shuttle, a second shuttle, a gate shuttle, and an outlet to a BOP function.

43. The apparatus of claim 42, wherein the modular removable valve blocks each attach to a separate modular block receiver that houses at least one stab type receiver connection for connection with the hose; and

the modular removable valve blocks are removable from the modular block receiver without interrupting a flow through the first central control pod or the second central control pod.

44. The apparatus of claim 43, wherein the stab type receiver connections of the modular block receiver for connection with the hose are oriented in a vertical direction in relation to a sea floor.

45. The apparatus of claim 43, wherein the modular removable valve blocks attach the separate modular block receivers via pressure balanced stab connections and an electrical wet-make connection.

46. The apparatus of claim 33, further comprising an electronic multiplex control system.

47. The apparatus of claim 46, wherein the electronic multiplex control system transparently integrates with operation of the modular removable valve block.

48. A method for providing a backup supply of hydraulic fluid to an underwater BOP function, comprising:

providing a plurality of primary fluid control component sets and a modular valve block removably connected to a BOP stack, the modular valve block having an outlet connected to a valve block stab connection;

providing a plurality of intervention shuttle valves, each having a primary inlet hard piped through a primary fluid control component set and to a hydraulic fluid supply, a backup inlet connected to a backup inlet stab connection, and an outlet hard piped to a hydraulically operated BOP function; and

controlling a remote operated vehicle to connect via removable stab connections a first end of a hose to the valve block stab connection and a second end of the hose to one of the backup inlet stab connections; wherein the modular removable valve block further comprises: at least one directional control valve, the number of directional control valves corresponding to the same number of BOP functions that the modular valve block may simultaneously serve.

49. The method of claim 48, wherein the modular removable valve block further comprises:

at least one pilot valve operatively coupled to the at least one directional control valve;

at least one pilot valve, the manifold pressure regulator controls the supply pressure to components downstream of the at least one directional control valve; and

a pilot pressure regulator operatively coupled to the at least one pilot valve.

50. The method of claim 48, further comprising the step of selecting which intervention shuttle valve to connect the hose to based on a signal from an operator or an electronic monitoring system.

51. The method of claim 48, further comprising providing electronic surface control of the modular valve block; and

integrating the electronic surface control of the modular valve block into an electronic multiplex control system.

52. The method of claim 48, further comprising routing a fluid into the backup inlet stab connection of one of the intervention shuttle valves and through the intervention shuttle valve to the BOP function, wherein the flow through the intervention shuttle valve forces a shuttle to actuate and isolate the primary inlet of the and the primary fluid control component set upstream of it.

53. The method of claim 48, further comprising the step of establishing hydraulic supply to the modular valve block before the step of controlling a remote operated vehicle to connect the hose.

54. The method of claim 48, further comprising the steps of mounting the backup inlet stab connection to a receiver plate; and

hard piping the backup inlet stab connection to the backup inlet of the intervention shuttle valve.

55. The method of claim 48, further comprising the steps of attaching the plurality of primary fluid control component sets to a first central control pod;

providing a second central control pod that provides a redundant set of primary

fluid control components; and

providing at least one additional modular valve block with the second pod.

56. The method of claim 55, further comprising the step of providing the plurality of intervention shuttle valves with a second primary inlet, a second backup inlet, a first shuttle, a second shuttle, and a gate shuttle.

57. The method of Claim 56, further comprising the steps of receiving an indication that a BOP function is malfunctioning while hydraulic fluid is being supplied from the

first central control pod; and

switching hydraulic flow to the second central control pod.

58. The method of any one of claims 48-57, further comprising the step of providing the modular removable valve block with components selected from the group consisting of a manifold pressure regulator, an accumulator, a pilot valve, a pilot pressure regulator, and any combination thereof.