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AN UNDERWATER APPARATUS FOR OPERATING UNDERWATER
EQUIPMENT

The present invention relates to an underwater apparatus for operating underwater equipment, such as a
5 blowout preventer. The equipment preferably incorporates an accumulator.

Deepwater accumulators provide pressurized working fluid for the control and operation of equipment, for example for blowout preventer operators; gate valves for
10 the control of flow of oil or gas to the surface or to other subsea locations; hydraulically actuated connectors; and similar devices. The fluid to be pressurized is typically an oil based product or a water based product with added lubricity and corrosion
15 protection, for example, but not limited to hydraulic fluid.

Certain prior art accumulators are precharged with pressurized gas to a pressure at or slightly below an anticipated minimum pressure required to operate
20 equipment. Fluid can be added to the accumulator, increasing the pressure of the pressurized gas and the fluid. The fluid introduced into the accumulator is stored at a pressure at least as high as the precharge pressure and is available for doing hydraulic work.

25 Such prior art accumulators include: a bladder type with a bladder to separate the gas from the fluid; a piston type having a piston sliding up and down a seal bore to separate the fluid from the gas; and a float type with a float providing a partial separation of the fluid
30 from the gas and for closing a valve when the float approaches the bottom to prevent the escape of gas.

In one particular example, a prior art system has accumulators that provide typical 3000 psi (207 bars)

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working fluid to surface equipment has a 5000 psi (345 bars) working pressure and contain fluid which raises the precharge pressure from 3000 psi (207 bars) to 5000 psi (345 bars) The efficiency of accumulators is decreased in
5 deepwater; for example, 1000 feet (305m) of seawater the ambient pressure is approximately 465 psi (32 bars) and, for an accumulator to provide a 3000 psi (207 bars) differential at 1000 ft. (305m) depth, it is precharged to 3000 psi (207 bars) plus 465 psi (32 bars), or 3465
10 psi (239 bars) At slightly over 4000 ft. (1220m) water depth, the ambient pressure is almost 2000 psi (138 bars), so the precharge is required to be 3000 psi (207 bars) plus 2000 psi (138 bars), or 5000 psi (345 bars), i.e., the precharge equals the working pressure of the
15 accumulator. Any fluid introduced for storage causes the pressure to exceed the working pressure, rendering the accumulator non functional.

In the deepwater use of accumulators the ambient temperature can decrease to about 35 degrees F. (275K)
20 For an accumulator precharged to 5000 psi (345 bars) at a surface temperature of 80 degrees F. (300K) , about 416 psi (29 bars) precharge is lost simply because the temperature was reduced to 35 degrees F (275K) . The rapid discharge of fluids from accumulators and the
25 associated rapid expansion of the pressurizing gas causes a natural cooling of the gas so that an accumulator is quickly reduced in pressure from, for example, 5000 psi (345 bars) to 3000 psi (207 bars) without heat coming into the accumulator (adiabatic), experiences a pressure
30 drop to 2012 psi (139 bars).

U.S. Patents 7,108,006; 6,202,753; 4,777,800; 4,649,704; and 3,677,001 are illustrative of various prior art systems and are mentioned here not by way of

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limitation nor as exhaustive of the available prior art; and all said patents are incorporated fully herein for all purposes.

There has long been a need, recognized by the present inventor, for an effective accumulator systems and pressure compensation systems for underwater and subsea use. There has long been a need, recognized by the present inventor, for such systems which increase the amount of available pressurized gas to enhance the operation of subsea working fluid systems.

In accordance with the present invention, there is provided a underwater apparatus for operating underwater equipment, the underwater apparatus comprising a body, a fluid chamber within the body for selectively containing power fluid, a piston assembly movably disposed within the body, a gas chamber within the body for containing gas under pressure to move the piston assembly to move the power fluid out of the fluid chamber, a further chamber for containing gas at low pressure for the piston assembly to move within characterised in that the piston assembly comprises a cavity for containing gas under pressure for assisting in movement of the piston assembly, and the cavity in fluid communication with the gas chamber.

The underwater equipment may be activated by operation, such as activating rams of a blowout preventer. Preferably, the low pressure gas in the further chamber assists in moving power fluid from the power fluid chamber. The gas in the gas chamber and the low pressure gas in the further chamber are separated by a piston head acting as an accumulator.

Advantageously, the body has an opening to ambient water pressure and the piston assembly comprises a piston head

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having a face in fluid communication with the opening. The water pressure assists in movement of the piston assembly to move power fluid from the fluid chamber out of the body. Preferably, the opening comprises a plurality of small openings. Advantageously, the opening or plurality of openings lead into a water chamber within the body and outside the piston assembly for receiving water from outside the body, pressure of the water for assisting in moving the piston assembly to move power fluid from the power fluid chamber. Advantageously, the body comprises a cylinder having an end, the opening in the end. The cylinder may be of circular, oval, triangular, square, pentagonal or other sided section.

Preferably, the piston head is movable through the opening. Advantageously, the piston assembly further comprises a stem attached to the piston head the stem, a gland separating the fluid chamber from the gas chamber and a further piston attached to the stem separating the gas chamber from the further chamber. Preferably, the stem comprises a channel or hole advantageously, for allowing the passage of gas into the gas chamber. Advantageously, the cavity is at least partly located in the piston head.

Preferably, the underwater apparatus further comprises at least one insert removably located within the cavity for reducing the gas-containing capacity of the cavity.

Advantageously, the further chamber is sealed. Alternatively, the further chamber could be open to a further chamber which may or may not have a fluid therein.

Preferably, the further chamber contains a gas at low pressure. Advantageously, the further chamber

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contains a vacuum.

Preferably, the body comprises a port through which power fluid can flow to operate the underwater equipment. Advantageously, the underwater equipment to be operated
5 is a blowout preventer operator. Preferably, the underwater apparatus further comprises a hydraulic power system located above the water, the hydraulic power system for providing the power fluid to the fluid chamber. This is preferably provided through the same
10 port through which power fluid can flow to operate the underwater equipment. Advantageously, the underwater apparatus further comprises valve apparatus for controlling flow of power fluid to the apparatus from the surface hydraulic power system and for directing power
15 fluid exhausted from the underwater equipment to a chosen line. Preferably, the chosen line can include any of a vent line or a line to a fluid recovery system.

The present invention also provides a method for operating underwater equipment, the method comprising
20 the steps of storing power fluid in an accumulator apparatus, the accumulator apparatus comprising a body, a fluid chamber within the body for selectively containing power fluid, a piston assembly movably disposed within the body, a gas chamber within the body for containing
25 gas under pressure to move the piston assembly to move the power fluid out of the fluid chamber, a further chamber for containing gas at low pressure for the piston assembly to move within characterised in that the piston assembly comprises a cavity for containing gas under
30 pressure for assisting in movement of the piston assembly, and the cavity in fluid communication with the gas chamber the method further comprising the steps of moving the piston assembly to move the power fluid out of

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the fluid chamber and to the underwater equipment, and operating the apparatus with the power fluid.

Preferably, the underwater equipment is a blowout preventer operator, the method further comprising the
5 step of operating the blowout preventer operator with the power fluid. Advantageously, the accumulator apparatus is located underwater, a hydraulic power system located at or above the surface of the water providing the power fluid to the fluid chamber of the body, the method
10 further comprising the step of providing power fluid to the fluid chamber of the accumulator system. Preferably, the accumulator apparatus includes valve apparatus for controlling flow of power fluid to the apparatus from the surface hydraulic power system and for directing power
15 fluid exhausted from the apparatus to a chosen line, the method further comprising the step of controlling with the valve apparatus flow of power fluid to the underwater equipment. Advantageously, the chosen line can include any of a vent line or a line to a fluid recovery system,
20 the method further comprising the step of directing with the valve apparatus power fluid exhausted from the apparatus to any of a vent line or a fluid recovery system.

The present invention also provides a subsea
25 apparatus comprising a frame a blow out preventer operator and an underwater apparatus for operating underwater equipment, the underwater apparatus comprising a body, a fluid chamber within the body for selectively containing power fluid, a piston assembly movably
30 disposed within the body, a gas chamber within the body for containing gas under pressure to move the piston assembly to move the power fluid out of the fluid chamber, a further chamber for containing gas at low

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pressure for the piston assembly to move within characterised in that the piston assembly comprises a cavity for containing gas under pressure for assisting in movement of the piston assembly, and the cavity in fluid communication with the gas chamber.

5 The present invention, in certain aspects, discloses an apparatus for operating underwater equipment one or more containers or "bottles" which have a primary gas-containing chamber for containing gas under pressure and, additionally, a secondary chamber or cavity for containing such gas, the secondary chamber in fluid communication with the primary chamber so that the total effective gas volume is increased to the extent of the volume of the secondary chamber. In one aspect, the secondary chamber is a cavity in part of a piston assembly.

The present invention, in certain aspects, discloses a pressure compensation system for subsea apparatus which has one or more hydraulic power units used in an hydraulic fluid system. In certain aspects, such subsea apparatus employs one or more hydraulic fluid reservoirs and/or accumulators which releasably hold operational amounts of hydraulic fluid at a pressure slightly greater than the pressure of water exterior to the reservoir for selectively operating subsea equipment and systems, for example BOP's, coiled tubing units, valves, and subsea wellhead connectors. The reservoir and/or accumulator(s) can require a substantial amount (for example 50, 100, 500 gallons or more) of hydraulic fluid which can entail the flow of this substantial amount of fluid from a reservoir to the accumulator(s). In certain systems in accordance with the present invention, a "seawater boost" is provided which includes exposing a piston end to the

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pressure of the seawater. This piston effectively boosts the force provided by another piston which is acted upon by compressed gas to move a power fluid out of the system. By using the seawater boost effect, the required
5 number of containers or bottles for compressed gas is reduced. The seawater boost can boost the pressure on contained hydraulic fluid in addition to the pressure of gas on the fluid, thus reducing the amount of pressurized gas required to achieve a certain pressure on the
10 hydraulic fluid.

In certain aspects, the reservoir is initially charged at a pressure slightly higher than the pressure of the water to be encountered at depth and the reservoir is pressure compensated so that at depth it is not
15 damaged or destroyed.

Accordingly, the present invention includes features and advantages which are believed to enable it to advance pressure accumulator system technology. Characteristics and advantages of the present invention described above
20 and additional features and benefits will be readily apparent to those skilled in the art upon consideration of the following detailed description of preferred embodiments and referring to the accompanying drawings.

Such systems for use with subsea blowout preventer
25 operators; and

Such systems which can effectively provide significantly large volumes of power fluid.

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For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a schematic view of a prior art pressure
5 compensated reservoir;

Figure 2 is a schematic view of a system in accordance with the present invention with accumulator containers in accordance with the present invention.

Figure 3 is a perspective view of a subsea blowout
10 preventer system in accordance with the present invention with a subsea pressure accumulator system in accordance with the present invention.

Figure 4 is a schematic view of a system in accordance with the present invention.

Figure 5A is a perspective view of a pressure
15 accumulator in accordance with the present invention.

Figure 5B is a cross-section view of the pressure accumulator of Figure 5A.

Figure 5C is a cutaway perspective view of the
20 pressure accumulator of Figure 5A.

Figure 6 is a cross-section view of a system in accordance with the present invention.

Figure 7A is a perspective cross-section view of a
25 system in accordance with the present invention as in Figure 5A.

Figure 7B is a front view of the system as shown in Figure 7A showing a step in a method in accordance with the present invention.

Figure 7C is a front view of the system of Figure 7B
30 showing a step in a method of operation of the system.

Figure 7D is a front view of the system of Figure 7B showing a step in a method of operation of the system.

Figure 7E is a front view of the system of Figure 7B

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showing a step in a method of operation of the system.

Figure 7F is a front view of the system of Figure 7B showing a step in a method of operation of the system.

Figure 8A is a perspective cross-section view of a
5 system in accordance with the present invention.

Figure 8B is a perspective cross-section view of the system of Figure 8A.

Figure 9A is a perspective cross-section view of a system in accordance with the present invention.

10 Figure 9B is a perspective cross-section view of the system of Figure 9A.

Figure 10A is a perspective cross-section view of a system in accordance with the present invention.

15 Figure 10B is a perspective cross-section view of the system of Figure 10A.

Figure 1 illustrates a pressure compensated reservoir as disclosed in U.S. Patent 3,677,001 which shows a submerged pipeline 10 on which is arranged a valve housing 11 which contains a valve member to open
20 and close pipeline 10 to control the flow of fluid therethrough. A valve stem housing is mounted on valve housing 11. A valve stem 13 extends through the valve stem housing and connects to a piston 14 arranged in an actuator cylinder 15. Piston 14 has fixed power and
25 exhaust strokes. The valve stem housing is provided with packing seals 17 which surround and seal off fluid flow around valve stem 13. A reduced internal diameter portion 20 of actuator cylinder 15 forms a cavity or chamber 21 and a seating shoulder 23. A mating shoulder
30 22 formed on piston 14 is adapted to engage shoulder 23. A static seal 24 which suitably may be an "O"-ring is arranged in a recess in shoulder 23 and seals off the space between shoulders 22 and 23 when piston 14 is at

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the end of its power stroke, as shown in Figure 1. A spring 25 is arranged in chamber 21 and functions to move piston 14 in its exhaust stroke. When the valve is fully open, piston 14 is at the end of its power stroke and
5 when the valve is fully closed the piston is at the end of its exhaust stroke. When the valve (or other equipment) to be operated is located at a remote offshore location, a hydraulic power fluid reservoir 30 is provided with a floating piston 31, compensated by sea
10 water pressure. A diaphragm could be substituted for piston 31. A conduit 34 supplies a pump 32 with hydraulic control fluid from reservoir 30. Pump 32 is operated by electrical power supplied from the water's surface through a conductor 33. An accumulator 35 is connected
15 to pump 32 to the exhaust stroke end of actuator cylinder 15 by means of a conduit 40. The purpose of the accumulator 35 is to provide a supply of power fluid available for immediate delivery to cylinder 15. A bypass conduit 41 connects conduit 40 to reservoir 30. A
20 solenoid operated valve 45 controlled by electrical power supplied from the water's surface through a conductor 46 is connected into conduit 41. Another solenoid operated valve 47 supplied with operating power from the water's surface through a conduit 48 is arranged between
25 accumulator 35 and the junction of conduits 40 and 41. An additional conduit 50 connects chamber 21 to reservoir 30.

Figure 2 shows a system 60 in accordance with the present invention in which power fluid from a hydraulic
30 power unit is provided to a subsea blowout preventer operator ("BOP OPERATOR"). Hydraulic power fluid is pumped from a reservoir ("TANK") by a pump ("PUMP") through a check valve ("CHECK VALVE") to a bank of

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accumulator containers at the surface ("ACCUMULATOR SYSTEM"). This fluid is then provided beneath a water level L through a check valve ("CHECK VALVE") to an accumulator system in accordance with the present invention with one or more depth compensated containers or bottles in accordance with the present invention ("DEPTH COMPENSATED ACCUMULATOR SYSTEM"). A control valve ("DIRECTIONAL CONTROL VALVE") selectively provides the power fluid from the depth compensated accumulator containers to operate a subsea device or apparatus, for example the BOP operator shown. Fluid exhausted from the BOP operator either flows into the water ("VENT") or to a fluid recovery system ("FLUID RECOVERY SYSTEM") from which it returns to the surface fluid reservoir ("TANK"). The containers of the depth compensated accumulator system may be any container or bottle in accordance with the present invention, including, but not limited to, any of those shown in Figures 5A to 9B.

Figure 3 shows a subsea blowout preventer system 80 in accordance with the present invention with multiple accumulator systems 82 in accordance with the present invention.

Figures 5A, 5B and 5C illustrate a system 100 in accordance with the present invention. Figure 4 shows schematically the system 100 as used to operate a BOP operator. Fluid from a surface hydraulic power system HP is stored in the system 100 for use through a directional control valve DV to a BOP operator BO. Fluid exhausted from the BOP operator either flows to a vent V or to a fluid recovery system FR for return to the surface. The systems of Figures 6, 7A, 8A, 9A and 10A may be used in the scheme shown in Figure 4 instead of or in addition to a system 100.

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The system 100 has an outer housing 102 within which is movably mounted a piston assembly 110 which has a piston rod 112 with a first end 114 and a second end 116. A piston end 120 with an interior cavity 122 is secured
5 to the first end 114 of the rod 112. A piston end 130 is secured to the second end 116 of the rod 112.

The piston rod 112 moves in a hole 142 in a gland 140 that divides a first chamber 160 (for example a chamber for hydraulic fluid) from a second chamber 170
10 (for example a chamber for gas under pressure, for example nitrogen). A third chamber 180 (for example, a vacuum chamber) is formed between the piston end 130 and an end cap 190. Optionally, these chambers are interchanged with chamber 160 being a vacuum chamber and
15 chamber 180 containing power fluid.

An end cap 126 secured in an opening 124 seals off the interior cavity 122. A valve 128 permits gas under pressure, for example nitrogen, to be pumped into and through the cavity 122, through a channel 118 extending
20 through the length of the piston rod 112, out through a channel 119, and into the second chamber 170 to provide pressurized gas force against the piston end 130. A recess 132 is provided in the piston end 130 so that the gas can flow into the second chamber 130. Appropriate
25 seals S1-S6 seal the indicated structural interfaces.

The cavity 122 in the piston end 120 effectively increases the total amount of pressurized gas within the piston assembly 110 by the volume of the cavity 122.

In one embodiment, the end cap 126 and the end
30 surface of the piston end 120 are exposed to the pressure of water, for example, sea water, when the system 100 is underwater. The force of this water pressure is additive with the force of the pressurized gas in the second

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chamber 170 and in the interior cavity 122.

Power fluid, for example hydraulic fluid, is pumped from the first chamber 160 through a port 162, for example, to operate a BOP operator on a BOP.

5 Optionally, one, two, three, four or more (two shown) inserts 146 (solid or hollow, one solid shown, one hollow shown) may be placed within the interior cavity 122 to reduce the effective gas-containing volume of the cavity 122; for example to optimize the minimum pressure
10 (in terms of adiabatic discharge).

Figure 6 illustrates a system 300 in accordance with the present invention which has a movable piston with an inner member with a gas-containing cavity within the piston. This cavity is in fluid communication with a
15 gas-containing chamber so that the effective total volume of gas is increased (as compared to having a gas-containing chamber alone) and, thus, the effective total volume of available gas is increased and, correspondingly, the available volume of power fluid is
20 increased.

A piston 302 movable in a body 304 has an inner chamber 306. An inner member 310 is secured to the body 304 with a beam or rod 308. The inner member 310 is immobile and has a hollow part 312 with an inner cavity
25 314 that is in fluid communication with the chamber 306 via a channel 318. Both the inner chamber 306 and the cavity 314 can contain gas under pressure. A cavity 322 can be evacuated so that a vacuum (or a very lower pressure is present or, alternatively, it can contain
30 power fluid). A chamber 320 can contain power fluid, for example hydraulic fluid (or, alternatively, it can be evacuated so that a vacuum or a very low pressure is present). The pressure of water outside the body 304 can

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act on an outer surface 324 of the piston 302 and an outer surface 328 of the inner member 310. Appropriate seals S101 - S104 seal the indicated interfaces.

As illustrated in Figure 6, power fluid may exit
5 through a port 330 (like the port 162, Figure 5A) to a control valve and on to an apparatus to be operated by the fluid. In this embodiment, there is a vacuum or very low pressure in the cavity 322. Alternatively the power fluid may be in the cavity 322 and exit for use through a
10 port 340 (shown in dotted lines) with a vacuum or very low pressure in the inner chamber 306.

Figures 7A - 7F illustrate steps in a method of operation of a system like that of Figure 5A in accordance with the present invention.

15 In Figure 7A and 7B, no hydraulic power fluid has yet entered the system. The pressure of the seawater is applied to a piston top 126 of a piston assembly (that includes items 130, 142, 120 and 126) and the pressure of gas in chambers 122 and 170 (in this case, nitrogen,
20 "N2") is applied to the piston end 130. As shown in Figure 7C, fluid PE from a surface hydraulic power unit flows from the port 162 into the chamber 160 moving the piston assembly and compressing the gas in the chambers 122 and 170. This hydraulic power fluid enters the
25 chamber 160 at a pressure sufficient to overcome the pressure of the seawater and the pressure of the gas.

As shown in Figure 7D, the piston assembly has moved to the extent of its travel, and the chamber 160 is full of hydraulic fluid and fluid from port 162 ceases. A
30 vacuum (or very low pressure, for example 1 bar (14.7 psi)) exists in the chamber 180. In one particular example, the seawater pressure is 369 bars (5348 psi); the gas pressure is 88 bars (1272 psi); and the power

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fluid is at a pressure of 704 bars (10211 psi). This hydraulic power fluid is now available to be moved from the system to power a device (for example, but not limited to, a BOP operator).

5 Figure 7E illustrates the beginning of the provision of the power fluid from the chamber 160 to an external apparatus or control system. Power fluid flows from the chamber 160 through the port 162. The force of the seawater and of the compressed gas, and the vacuum's
10 force move the power fluid.

Figure 7F illustrates the discharge of the power fluid from the system. The system is now ready to again receive power fluid from the surface.

Figures 8A and 8B show a system 200 in accordance
15 with the present invention like the systems of Figure 5A and Figure 7A, but with an interior chamber for water, for example seawater. As with the system shown in Figure 5A, the system 200 is generally cylindrical, but only half is shown in Figures 8A and 8B.

20 A piston 210, movably positioned on a housing 208, has a gas chamber 214 for gas under pressure. The housing 208 may be two pieces secured together as shown (or a single piece). The piston 210 is mounted around and moves on a piston guide 216 which has an interior
25 chamber 218 for additional gas under pressure. Hydraulic power fluid flows through a port 232 into a power fluid chamber 230 which is defined by part of an interior wall of the housing 208 and part of an exterior wall of the piston 210. An interior vacuum chamber 240 (or chamber
30 of relatively low pressure) is located at one end of the housing 208. The lower end of the chamber 218 of the guide 216 is open to the chamber 214.

Gas under pressure, for example nitrogen, is charged

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into the chambers 214, 218 through a port 250. Water from outside the system 200 flows into a chamber 260 through openings 262. The pressure of the water acts on an end 211 of the piston 210. The gas under pressure in
5 the chambers 214, 218 acts on an end 213 of the piston 210. Seals SL seal various interfaces in the system.

Hydraulic power fluid at a pressure greater than the combined pressure of the gas in chambers 214, 218 and the water in chamber 260 and the force of the vacuum in
10 chamber 240 is introduced through the port 232 into the chamber 230 (for example for storage until it is used for a function, for example to operate a BOP operator). This moves the piston 210 (upwardly as shown in Figures 8A, 8B). With the valve 232 shut, the power fluid remains in
15 the chamber 230. Upon opening of the valve 232 by a control system (not shown), the power fluid flows out from the chamber 230 (due to the vacuum, force of gas, and force of water).

Figures 9A and 9B show a system 400 in accordance
20 with the present invention like the systems of Figure 5A, Figure 7A, but with an interior chamber for water, for example seawater and with a "tub" piston assembly movable within the housing. As with the system shown in Figure 5A, the system 400 is generally cylindrical, but only
25 half is shown in Figures 9A and 9B.

A piston 410, movably positioned in a housing 408, has a gas chamber 414 for gas under pressure. The piston 410 is a "tub" piston with exterior walls and an internal fluid containing space for containing power
30 fluid and gas. The housing 408 may be two pieces secured together, or as shown a single piece. The piston 410 is mounted around and moves on a piston guide 416 and guide rod 418. The guide rod 418 projects through an opening

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417 in the piston 410 and through a top plate 409 of the housing 408. Hydraulic power fluid (for example from a surface source) flows through a port 439, through a channel 433 and through a port 432 into a power fluid
5 chamber 430 which is defined by part of an interior wall of the piston 410 and part of an exterior wall of the guide rod 418 and top of the piston guide 416. An interior vacuum chamber 440 (or chamber of relatively low pressure) is located at one end of the housing 408.

10 Gas under pressure, for example nitrogen, is charged into the chamber 414 through a port 450. Water from outside the system 400 flows into a chamber 460 through openings 462. The pressure of the water acts on an end 411 of the piston 410. The gas under pressure in the
15 chamber 414 acts on an end 413 of the piston 410. Seals SE seal various interfaces in the system.

Hydraulic power fluid at a pressure greater than the pressure of the gas in chamber 414 and the water in chamber 460 and the force of the vacuum in chamber 440,
20 is introduced through the port 432 into the chamber 430. This moves the piston 410 (upwardly as shown in Figures 9A, 9B). With no flow through the port 432, the power fluid remains in the chamber 430 until it is used. Upon fluid flow from the port 432, the power fluid flows out
25 from the chamber 430 (due to the vacuum force, force of gas, and force of water). The systems 200, 300 and 400 provide the water "boost" feature discussed above.

Figures 10 and 10B show a system 500 in accordance with the present invention which has five interior
30 chambers 510, 520, 530, 540 and 550. The system 500 is generally cylindrical, but only half is shown in Figure 10A. The chamber 510 is a vacuum chamber (or chamber of very low pressure). The chamber 520 contains gas under

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pressure, for example nitrogen. The chambers 530 and 540 contain power fluid. The chamber 550 contains water, for example sea water.

Water enters the chamber 550 through holes 552 in a top plate 501 of a first housing 502. Power fluid enters the chamber 530 through a port 532 and flows into the chamber 540 through a port 542. Gas flows through a port 522 and through a channel 524 in a rod 526 to the chamber 520. Seals 503 - 509 seal the interfaces where they are located.

The rod 526 is connected to or formed integrally with an end 528. Part of the rod 526 and the end 528 are within a hollow member 511 in which are the chambers 520 and 540 (which, like other chambers in other embodiments herein, vary in volume depending on the position of other elements). The hollow member 511 is movable within a first housing 502 and a second housing 513.

Connected to the first housing 502, the second housing 513 contains part of the movable member 511 is in the second housing 513. The seal 505 prevents water from impacting the exterior of the member 511 around the chamber 520 and thus the chamber 520 is always maintained with a positive internal pressure. The chamber 510 has a negative internal pressure. For this reason, the wall thickness of the second housing is relatively thicker than the wall thickness of the first housing. The first housing 502 includes the chambers 530, 540, and 550 in all of which a positive internal pressure is maintained. Adding the chamber 530 results in a relatively larger volume of available power fluid (as compared to a system in which there is no chamber 530) and which provides the correct piston surface area ratios for operation.

The present invention, therefore, in at least some,

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but not necessarily all embodiments, provides an accumulator system, the accumulator system for subwater use, the accumulator system including: a body; a fluid chamber within the body for selectively containing power
5 fluid; a piston assembly movably disposed within the body; a gas chamber within the body for containing gas under pressure to move the piston assembly to move the power fluid out of the fluid chamber of the body; the piston assembly including a cavity therein for containing
10 gas under pressure for assisting in movement of the piston assembly; and the cavity in fluid communication with the gas chamber. Such a system may have one or some (in any possible combination) of the following: the piston assembly having a first piston end exposed
15 exteriorly of the body for action thereupon of water pressure of water exterior to the body, said water pressure assisting in movement of the piston assembly to move power fluid from the fluid chamber out of the body; at least one insert removably located within the cavity
20 for reducing the gas-containing capacity of the cavity; an apparatus to be operated by the power fluid, the fluid chamber having an exit port in fluid communication with the apparatus to be operated by the power fluid moved from the fluid chamber; the apparatus to be operated by
25 the power fluid being a blowout preventer operator; the accumulator system located beneath water, a surface hydraulic power system at a surface above the water, the surface hydraulic power system for providing the power fluid to the fluid chamber of the body; the accumulator
30 system located beneath water, a surface hydraulic power system at a surface above the water, the surface hydraulic power system for providing the power fluid to the fluid chamber of the body, and valve apparatus for

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controlling flow of power fluid to the apparatus from the surface hydraulic power system and for directing power fluid exhausted from the apparatus to a chosen line; the chosen line including any of a vent line or a line to a fluid recovery system; and/or a body having three interior chambers, including the fluid chamber, the gas chamber, and a third chamber, the body having a first body end with a first opening in the body, and a second body end with a second opening in the body, an amount of operational power fluid in the fluid chamber, an amount of pressurized gas in the gas chamber, a lower pressure in the third chamber, the piston assembly movably and sealingly mounted within the body, in the piston assembly a first piston end closing off the first opening and preventing hydraulic fluid from exiting through the first opening from the first chamber, the first piston end having an outer surface and an inner surface, the operational power fluid applying a first pressure against the first piston end's inner surface, water exterior to the accumulator system above to contact and to apply pressure to the outer surface of the first piston end to move the piston assembly in a direction toward the second body end, a piston rod with a first rod end and a second rod end, the first rod end connected to the first piston end, the second rod end connected to the second piston end, the piston assembly having a second piston end movably located in the second chamber, the second rod end connected to the second piston end, gas in the second chamber able to act on the second piston end to move the piston assembly in a direction away from the first opening, a channel through the piston rod and in fluid communication with the cavity and with the second chamber so that the gas within the cavity is flowable into the

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second chamber.

The present invention, therefore, in at least some, but not necessarily all embodiments, provides an accumulator system, the accumulator system for subwater
5 use, the accumulator system including: a body; a fluid chamber within the body for selectively containing power fluid; a piston assembly movably disposed within the body; a gas chamber within the body for containing gas under pressure to move the piston assembly to move the
10 power fluid out of the fluid chamber of the body; the piston assembly including a first piston end with a cavity therein for containing gas under pressure for assisting in movement of the piston assembly; the cavity in fluid communication with the gas chamber; the first
15 piston end exposed exteriorly of the body for action thereupon of water pressure of water exterior to the body, said water pressure assisting in movement of the piston assembly to move power fluid from the fluid chamber out of the body; an apparatus to be operated by
20 the power fluid; the fluid chamber having an exit port in fluid communication with the apparatus to be operated by the power fluid moved from the fluid chamber; the accumulator system located beneath water; a surface hydraulic power system at a surface above the water, the
25 surface hydraulic power system for providing the power fluid to the fluid chamber of the body; the accumulator system located beneath water; a surface hydraulic power system at a surface above the water, the surface hydraulic power system for providing the power fluid to
30 the fluid chamber of the body; valve apparatus for controlling flow of power fluid to the apparatus from the surface hydraulic power system and for directing power fluid exhausted from the apparatus to a chosen line; and

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wherein the chosen line can include any of a vent line or a line to a fluid recovery system.

The present invention, therefore, in at least some, but not necessarily all embodiments, provides a method
5 for operating an apparatus located beneath water with power fluid, the method including storing power fluid in an accumulator system, the accumulator system as any in accordance with the present invention, moving a piston assembly of the accumulator system to move power fluid
10 out of a fluid chamber and to an apparatus, and powering the apparatus with the power fluid. Such a system may have one or some (in any possible combination) of the following: wherein the apparatus to be operated by the power fluid is a blowout preventer operator, the method
15 including: operating the blowout preventer operator with the power fluid; wherein the accumulator system is located beneath water, a surface hydraulic power system at a surface above the water, the surface hydraulic power system for providing the power fluid to the fluid chamber
20 of the body, the method including providing power fluid to the fluid chamber of the accumulator system; wherein the accumulator system includes valve apparatus for controlling flow of power fluid to the apparatus from the surface hydraulic power system and for directing power
25 fluid exhausted from the apparatus to a chosen line, the method including controlling with the valve apparatus flow of power fluid to the apparatus; and/or wherein the chosen line can include any of a vent line or a line to a fluid recovery system, the method including: directing
30 with the valve apparatus power fluid exhausted from the apparatus to any of a vent line or a fluid recovery system.

The present invention, therefore, in at least some,

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but not necessarily all embodiments, provides an accumulator system, the accumulator system for subwater use, the accumulator system including: a body; a piston assembly movably disposed within the body, the piston
5 assembly having an interior; a rod member passing through the body and extending into the interior of the piston assembly; a rod member end on an end of the rod member, the rod member end disposed within the interior of the piston assembly, the rod member end having a first side
10 and a second side; power fluid chamber in the interior of the piston assembly, the power fluid chamber adjacent the first side of the rod member; a gas chamber in the interior of the piston assembly, the gas chamber adjacent the second side of the rod member; and the piston
15 assembly movable by gas in the chamber to move power fluid out of the power fluid chamber. Such a system may have one or some (in any possible combination) of the following: a low pressure chamber within the body and outside of the piston assembly, low pressure (for example
20 but not limited to, a vacuum) within the low pressure chamber for assisting in moving power fluid from the power fluid chamber; a water chamber within the body and outside the piston assembly for receiving water from outside the body, pressure of said water for assisting in
25 moving the piston assembly to move power fluid from the power fluid chamber; an apparatus to be operated by the power fluid; the power fluid chamber having an exit port in fluid communication with the apparatus to be operated by the power fluid moved from the fluid chamber1 and/or
30 wherein the apparatus to be operated by the power fluid is a blowout preventer operator.

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CLAIMS:

1. An underwater apparatus for operating underwater equipment, the underwater apparatus comprising a body (102;208;304;408;513), a fluid chamber (160;230;320;430;530;540) within the body (102;208;304;408;513) for selectively containing power fluid, a piston assembly (130,112,120;210;310;411;511) movably disposed within the body (102;208;304;408;513), a gas chamber (170;214;306;414;520) within the body (102;208;304;408;513) for containing gas under pressure to move the piston assembly (130,112,120;210;310;411;511) to move the power fluid out of the fluid chamber (160;230;320;430;530;540), a further chamber (180;240;322;440;510) for containing gas at low pressure for the piston assembly (130,112,120;210;310;411;511) to move within characterised in that said piston assembly (130,112,120;210;310;411;511) comprises a cavity (122,218;314;414;540) for containing gas under pressure for assisting in movement of said piston assembly (130,112,120;210;310;411;511), and the cavity (122,218;314;414;540) in fluid communication with said gas chamber.
2. An underwater apparatus as claimed in Claim 1, wherein the body (102;208;304;408;513) has an opening (S1;S103;262;462;552) to ambient water pressure and the piston assembly (130,112,120;210) comprises a piston head (120;211;310;410) having a face (126,211;328;411) in fluid communication with said opening (262;462;552).
3. An underwater apparatus as claimed in Claim 2, wherein said opening (262;462;552) comprises a plurality of small openings.
4. An underwater apparatus as claimed in Claim 2 or 3, wherein said opening (262;462;552) leads into a water

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chamber (260;460;550) within the body (208;408;513) and outside the piston assembly (211;411;511) for receiving water from outside the body (208;408;513), pressure of said water for assisting in moving the piston assembly
5 (211;411;511) to move power fluid from the power fluid chamber (230;.

5. An underwater apparatus as claimed in Claim 2 or 3, wherein said body (102;304) comprises a cylinder having an end, the opening (S1;S103) in said end.

10 6. An underwater apparatus as claimed in Claim 5, wherein said piston head (120;211;310;410) is movable through said opening (S1,S103).

7. An underwater apparatus as claimed in any one of Claims 2 to 5, wherein the piston assembly (130) further
15 comprises a stem (112) attached to said piston head (120) said stem (112), a gland (140) separating the fluid chamber (160) from the gas chamber (170) and a further piston (130) attached to said stem (118) separating said gas chamber (170) from said further chamber (180).

20 8. An underwater apparatus as claimed in Claim 7, wherein said stem (118) comprises a channel or hole (118)

9. An underwater apparatus as claimed in Claim 7 or 8, wherein said cavity (122) is at least partly located in said piston head (120).

25 10. An underwater apparatus as claimed in any preceding claim, further comprising at least one insert removably located within said cavity (122) for reducing the gas-containing capacity of the cavity.

11. An underwater apparatus as claimed in any preceding
30 claim, wherein said further chamber is sealed.

12. An underwater apparatus as claimed in any preceding claim, wherein said further chamber contains a gas at low pressure.

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13. An underwater apparatus as claimed in any preceding claim, wherein said further chamber contains a vacuum.

14. An underwater apparatus as claimed in any preceding claim, wherein said body (102) comprises a port (162) through which power fluid can flow to operate said underwater equipment.

15. An underwater apparatus as claimed in any preceding claim, wherein said underwater equipment to be operated is a blowout preventer operator.

16. An underwater apparatus as claimed in any preceding claim, further comprising a hydraulic power system located above the water, the hydraulic power system for providing the power fluid to the fluid chamber .

17. An underwater apparatus as claimed in Claim 16, further comprising valve apparatus for controlling flow of power fluid to the apparatus from the surface hydraulic power system and for directing power fluid exhausted from the underwater equipment to a chosen line.

18. An underwater apparatus as claimed in Claim 17, wherein the chosen line can include any of a vent line or a line to a fluid recovery system.

19. A method for operating underwater equipment, the method comprising the steps of storing power fluid in an accumulator apparatus, the accumulator apparatus comprising a body (102;208;304;408;513) , a fluid chamber (160;230;320;) within the body (102;208;304;408;513) for selectively containing power fluid, a piston assembly (130,112,120;210;310;411;511) movably disposed within the body (102;208;304;408;513), a gas chamber (170;214;306;414;520) within the body (102;208;304;408;513) for containing gas under pressure to move the piston assembly (130,112,120;210;310;411;511) to move the power fluid out of the fluid chamber (160;230), a further chamber for

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containing gas at low pressure for the piston assembly (130,112,120;210;310;411;511) to move within characterised in that the piston assembly (130,112,120;210;310;411;511) comprises a cavity (122,218;314;414;540) for containing gas under pressure for assisting in movement of the piston assembly (130,112,120;210;310;411;511), and the cavity (122,218;314;414;540) in fluid communication with the gas chamber the method further comprising the steps of moving the piston assembly to move the power fluid out of the fluid chamber and to the underwater equipment, and operating the apparatus with the power fluid.

20. A method in accordance with Claim 19, wherein the underwater equipment is a blowout preventer operator, the method further comprising the step of operating the blowout preventer operator with the power fluid.

21. A method in accordance with Claim 19 or 20, wherein the accumulator apparatus is located underwater, a hydraulic power system located at or above the surface of the water providing the power fluid to the fluid chamber of the body, the method further comprising the step of providing power fluid to the fluid chamber of the accumulator system.

22. A method in accordance with Claim 21, wherein the accumulator apparatus includes valve apparatus for controlling flow of power fluid to the apparatus from the surface hydraulic power system and for directing power fluid exhausted from the apparatus to a chosen line, the method further comprising the step of controlling with the valve apparatus flow of power fluid to the underwater equipment.

23. A method in accordance with Claim 21, wherein the chosen line can include any of a vent line or a line to a

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fluid recovery system, the method further comprising the step of directing with the valve apparatus power fluid exhausted from the apparatus to any of a vent line or a fluid recovery system.

- 5 24. A subsea apparatus comprising a frame (80) a blow out preventer operator and a plurality of underwater apparatus for operating underwater equipment, each underwater apparatus comprising a body (102;208;304;408;513), a fluid chamber (160;230;320;430;530;540) within the body (102;208;304;408;513) for selectively containing power fluid, a piston assembly (130,112,120;210;310;411;511) movably disposed within the body (102;208;304;408;513), a gas chamber (170;214;306;414;520) within the body (102;208;304;408;513) for containing gas under pressure to move the piston assembly (130,112,120;210;310;411;511) to move the power fluid out of the fluid chamber (160;230;320;430;530;540), a further chamber (180;240;322;440;510) for containing gas at low pressure for the piston assembly (130,112,120;210;310;411;511) to move within characterised in that said piston assembly (130,112,120;210;310;411;511) comprises a cavity (122,218;314;414;540) for containing gas under pressure for assisting in movement of said piston assembly (130,112,120;210;310;411;511), and the cavity (122,218;314;414;540) in fluid communication with said gas chamber.