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SUBSEA BOP CONTROL SYSTEM

FIELD OF THE INVENTION

The present invention relates to a subsea BOP control system for a hydraulic blowout preventer, and to a method of shifting a main valve in such a subsea BOP control system.

5

BACKGROUND TO THE INVENTION

BOP systems typically have one or more hydraulically powered BOP functions. A typical BOP system comprises a BOP control system involving a point of distribution (POD) comprising regulators and valves (SPM or DRG valves) to selectively expose BOP functions to a hydraulic operating pressure in a BOP function manifold or to a reservoir pressure ("atmosphere") which is lower than the hydraulic operating pressure. A common example of a subsea BOP control system can be found in a reference titled "Subsea BOP Control Systems" (last updated 18 April 2019) published on-line by Netwas Group Oil.

The hydraulic power unit is typically maintained at the sea surface, and particularly in deep water, activating and deactivating of a BOP function causes severe pressure peaks in the hydraulic fluid in the lines. This phenomenon is known as fluid hammer. Fluid hammer is traditionally addressed by control system component redesign, use of orifices in hydraulic lines, increasing of the hydraulic line sizes, installation of accumulators as fluid dampeners, reduction of the operating pressure or a combination of such options. Despite attempts to mitigate leaks and control system component failure resulting from fluid hammer, in practice operations still suffer from significant downtime as a consequence of fluid hammer.

25 SUMMARY OF THE INVENTION

In one aspect, there is provided a subsea BOP control system for a hydraulic blowout preventer, comprising:

- a BOP function manifold comprising a source side connectable to a hydraulic power unit for powering a BOP function;
- 30 - at least one main valve connected to said BOP function manifold on one side of the at least one main valve and on the other side of the at least one main valve

connectable to the BOP function, to selectively connect or isolate the BOP function from the BOP function manifold;

- a computer device functionally coupled to a main actuator of the at least one main valve and arranged to control activation and deactivation of the main actuator;

5 - an activatable choke assembly arranged at the source side of the BOP function manifold and upstream of the at least one main valve.

In another aspect, there is provided a method of shifting a main valve in a subsea BOP control system for a hydraulic blowout preventer, comprising:

- providing a BOP function manifold connected to a hydraulic power unit for powering a BOP function, and at least one main valve connected to said BOP function manifold on one side of the at least one main valve and on the other side of the at least one main valve connectable to the BOP function, to selectively connect or isolate the BOP function from the BOP function manifold;

- shifting the at least one main valve comprising activating or deactivating a main actuator of the at least one main valve, and activating a choke assembly, which is arranged at the source side of the BOP function manifold and upstream of the at least one main valve, prior to shifting the at least one main valve.

In still another aspect, there is provided a subsea BOP control system for a hydraulic blowout preventer, comprising:

- a hydraulic BOP function comprising a piston having a stroke;
- a BOP function manifold comprising a source side connectable to a hydraulic power unit for powering the BOP function;

- at least one main valve connected to said BOP function manifold on one side of the at least one main valve and on the other side of the at least one main valve connected to the BOP function, to selectively connect or isolate the BOP function from the BOP function manifold;

- an activatable choke assembly arranged at the source side of the BOP function manifold;

- a computer device functionally coupled to a choke actuator of the choke assembly, programmed to automatically activate the choke actuator prior to the piston of the BOP function reaching an end of its stroke.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawing figures depict one or more implementations in accord with the present teachings, by way of example only, not by way of limitation. In the figures, like reference numerals refer to the same or similar elements.

- 5 Fig. 1 schematically shows a hydraulic plan for a BOP control system including a choke assembly;
- Fig. 2 is a graph of pressure during operating a BOP function;
- Fig. 3 is shows a control sequence which optimizes the start of deceleration;
- 10 Fig. 4 schematically shows a hydraulic plan for a BOP control system including a choke assembly and an orifice.

DETAILED DESCRIPTION OF THE INVENTION

15 The person skilled in the art will readily understand that, while the detailed description of the invention will be illustrated making reference to one or more embodiments, each having specific combinations of features and measures, many of those features and measures can be equally or similarly applied independently in other embodiments or combinations.

20 Disclosed is a subsea BOP control system for a hydraulic blowout preventer, which comprises a BOP function manifold that at a source side thereof can be connected to a hydraulic power source. The BOP control system is equipped with an activatable choke assembly arranged at the source side of the BOP function manifold. The choke assembly can be activated before opening and closing of a valve in the control system, to spread acceleration and deceleration of the hydraulic fluid over time. The choke assembly preferably remains activated during the acceleration or deceleration phase of the hydraulic fluid. Accordingly, pressure peaks in the

25 hydraulic lines that normally result from shifting a valve will be lower or avoided. After acceleration/deceleration, the choke assembly can be deactivated to expose the full flow in the BOP function manifold.

30 Figure 1 shows a hydraulic plan for a BOP control system. It comprises a BOP function manifold 2, comprising a source side 7 which is connectable to a hydraulic power unit for powering a BOP function B1. The hydraulic power unit is represented by a series of surface accumulators A3. At least one main valve V1,V2 is connected to said BOP function manifold 2 on one side of the main valve(s). The other side of

the main valves V1,V2, is connectable to the BOP function B1. The valves can selectively connect or isolate the BOP function B1 from the BOP function manifold 2. Typically, when isolated from the BOP function manifold 2, the main valves connect the BOP function B1 to a hydraulic fluid reservoir (not shown). A computer logic device 8 is functionally coupled to main actuators of the main valve V1,V2. The main actuators are represented by solenoid valves S1,S2 but they also comprise the mechanisms to shift the main valves V1,V2. The computer device 8 is arranged to control activation and deactivation of the main actuator(s). The computer device 8 is programmed with computer logic which can control the system. Suitably, all or part of the computer logic may be embedded in a programmable logic controller (PLC). A system computer may be provided in addition thereof.

An activatable choke assembly 6 is arranged at the source side 7 of the BOP function manifold 2. It is positioned upstream of the main valve V1,V2. The chokes in choke assembly 6 are embedded in choke valves V3, and can selectively be positioned in the hydraulic flow path of the BOP function manifold 2 by activating the choke valves V3. Chokes of various sizes can be placed in series with each other to reduce the pressure drop over individual chokes. This extends their service life expectation and allows for running larger orifice sizes. Chokes are not required to seal. They can easily be changed out when they are of cartridge type.

Also shown in Fig. 1 are examples of a subsea manifold regulator 4 and a flow meter F1 all in line with the hydraulic flow path of the BOP function manifold 2. In this example, the subsea manifold regulator 4 comprises a pressure regulator R2 and a series of accumulators A4 upstream of the pressure regulator R2. In addition, or instead thereof, a second series of accumulators A5 may be provided downstream of the pressure regulator R2. Additional accumulator(s) A5, downstream of the pressure regulator R2, assist to further smoothen the response, and improve the supply-demand and reduce scattering.

In another example, the subsea manifold regulator 4 may comprise two or more pressure regulator stages in series with each other and each arranged to regulate over a limited pressure range. Accumulators may be positioned upstream, downstream, and/or between the various stages. The series of accumulators in Fig. 1 have been depicted by a single symbol of a piston accumulator. In reality there may be multiple,

such as four, per series. They may be pre-charged for various water depths to optimize the response of the regulator.

In the present example, the main valves V1,V2 and choke assembly 6 valve V3 are actuated by means of a pilot manifold 1. The pilot manifold may be operated at
5 for example a pressure in the range of 2500-3000 psi (17.2-20.7 MPa), regulated by a pilot manifold regulator 3. The details of the pilot manifold regulator 3 are not part of the present invention, but as shown in this example, the pilot manifold regulator 3 comprises a pressure regulator R1 and an accumulator A1 upstream of the pressure
10 regulator R1. In addition, or instead thereof, a second accumulator A2 may be provided downstream of the pressure regulator R1. Pilot manifolds for shifting the main valves are commonly used in BOP control systems. However the present invention can also work with other types of drivers for shifting the main valves, such as electric motors.

The choke assembly may comprise one or more activatable chokes in line with
15 the BOP function manifold 2. When not activated, the chokes are replaced by unrestricted flow channels (position as shown in Fig. 1). A choke actuator, here represented by a solenoid valve S3, is functionally coupled to the computer device 8 to control activation and deactivation of the choke actuator.

The computer device 8 is programmed to activate the choke actuator S3 prior
20 to shifting the main valves V1,V2 by activation of solenoid valves S1,S2. The computer device 8 may further be programmed to subsequently deactivate the choke actuator S3 to fully open the BOP function manifold 2 based on a criterion. The criterion is suitably one or more of the group consisting of: a pre-determined period of time; a flow rate acceleration crossing a predetermined threshold value; an
25 external trigger. To this end, the the flow meter F1 may for example be functionally coupled to the computer device 8, to provide flow data to the computer device 8. The flow data may then also be used in the computer logic to control the actuation and deactuation of choke assembly 6. For instance, the flow data may be used to anticipate on the BOP function B1 to reach the end of its stroke and activate the
30 chokes to slow down the shifting of the BOP function B1 before it reaches the end of the stroke. Information about how far the piston of the BOP function B1 is removed from the end of its stroke may also be generated in other ways, for example using position sensors on the BOP function B1 itself.

The subsea BOP control system may be operated as follows. Just before the main valve is shifted, the choke assembly 6 is temporarily actuated to spread out the acceleration of the hydraulic fluid in the BOP function manifold. The choke assembly 6 can also be activated before ending the flow of hydraulic fluid in the BOP function manifold. This is schematically shown in Fig. 2, which shows the operating pressure as a function of time during BOP function operation. For example, the choke assembly may be activated during a period of Δt after t_0 . During the acceleration phase the operating pressure gradually increases until full flow is reached. At this point the choke assembly 6 is deactivated to fully open the BOP function manifold. The moment to deactivate the choke assembly 6 can be a fixed pre-determined time period after t_0 or it can be based on a dynamic criterion such as a flow rate acceleration crossing a predetermined threshold value or an external trigger.

At t_1 the choke assembly 6 is again activated to gradually slow down the flow of hydraulic fluid. The operating pressure forced to slowly decrease due to spread deceleration of the hydraulic fluid over a period of Δt . Suitable periods of time for Δt may be in the range of from 0.1 s to for example 1 s. The deceleration may use different value for Δt than the acceleration.

The choke assembly may be activated and deactivated automatically by means of the computer device 8. The computer logic programmed in the computer device 8 may use the flow meter F1 to measure the hydraulic fluid volume delivered to the BOP function B1, and it may control the fluid acceleration in the first Δt (e.g. approximately 500 ms) before the main valve is opened and it may control fluid deceleration of the flow at the end of the stroke of the BOP function (e.g. also during approximately 500 ms) before the main valve closes. By activation of the choke assembly 6 before opening and closing of the main valve, shifting pressure is decoupled from flow.

The fluid acceleration and deceleration can be selected such that the BOP function B1 to meet API 16D closing times while significantly reducing fluid inertia forces and valve seal erosion in the system. The hydraulic pressure can be kept within 110% of the rated working pressure (RWP) of the system.

The operation of the proposed BOP control system is illustrated by the following detailed example process sequences for three typical BOP function options: Block, Open, Close. Specific values for times are indicative examples only

and can be varied within API 16D or other applicable regulatory requirements.

Reference numbers refer to Fig. 1. Some or all of the tasks listed for the computer may be programmed in the main computer system if desired.

Block function

- 5 1. $t_0 = 0$: Press the block (usually orange) button on the BOP panel interface;
2. $t_0 + 20$ ms: computer activates solenoid valve S3;
3. $t_0 + 40$ ms: Choke assembly valves V3 are shifted to choke position;
4. $t_0 + 60$ ms : computer deactivates solenoid valve S1 and S2;
5. $t_0 + 80$ ms : Main valves V2 and V3 close;
- 10 6. $t_0 + 3$ s : BOP function B1 open and close pressure is vented to atmosphere;
7. $t_0 + 4$ s : computer deactivates solenoid valve S3;
8. $t_0 + 5$ s : Choke assembly valves V3 are fully open;
9. Flow meter F1 shows no flow;
10. Flow through pilot regulator R1 dampened by accumulators A1 and A2;
- 15 11. Accumulator A1 at surface charge pressure;
12. Accumulator A2 at regulator setpoint pressure;
13. Minimum flow through subsea manifold regulator;
14. Minimum interflow during valve shifting;
15. Accumulators A3 and A4 at surface charge pressure;
- 20 16. Accumulator A5 at regulator setpoint pressure.

Open function

1. $t_0 = 0$: Press the Open (usually green) button on the BOP panel interface;
2. $t_0 + 40$ ms : computer resets flow meter to zero;
3. $t_0 + 60$ ms: computer activates solenoid valve S3;
- 25 4. $t_0 + 80$ ms: Choke assembly valves V3 are shifted to choke position;
5. $t_0 + 100$ ms: computer deactivates solenoid valve S1;
6. $t_0 + 120$ ms: Main valve V1 closed and BOP function B1 close pressure vented;
7. $t_0 + 220$ ms: computer activates solenoid valve S2;
8. $t_0 + 240$ ms: Main valve V2 opens and BOP function B1 open is pressurized;
- 30 9. $t_0 + 260$ ms: computer records flow through flowmeter F1 to BOP function B1 open port;
10. $t_0 + 820$ ms: computer deactivates solenoid S3;
11. $t_0 + 840$ ms: Choke assembly valves V3 are shifted to open position;

12. t_1 : computer activates solenoid valve S3 just before end of function;
13. $t_1 + 20$ ms : Choke assembly valves V3 are shifted to choke position;
14. $t_1 + 520$ ms : BOP function B1 slowed down;
15. t_2 : computer confirms Flow meter F1 stopped and function in fully
5 open position;
16. $t_2 + 20$ ms : computer deactivates solenoid valve S3;
17. $t_2 + 40$ ms : Choke assembly valves V3 are shifted to open position;
18. Flow meter F1 shows open volume of the BOP function B1;
19. Flow through pilot regulator R1 dampened by accumulators A1 and A2;
- 10 20. Accumulator A1 at surface charge pressure;
21. Accumulator A2 at regulator setpoint pressure;
22. Flow through subsea manifold regulator R2 dampened by accumulators A4 and
A5;
23. Minimum interflow through subsea manifold regulator R2;
- 15 24. Minimum interflow during valve shifting;
25. Accumulators A3 and A4 at surface charge pressure;
26. Accumulator A5 at regulator setpoint pressure.

Close function

1. $t_0 = 0$: Press the close (usually red) button on the BOP panel interface;
- 20 2. $t_0 + 40$ ms : computer resets flow meter to zero;
3. $t_0 + 60$ ms : computer activates solenoid valve S3;
4. $t_0 + 80$ ms : Choke assembly valves V3 are shifted to choke position;
5. $t_0 + 100$ ms: computer deactivates solenoid valve S2;
6. $t_0 + 120$ ms : Main valve V2 closed and BOP function B1 open pressure vented;
- 25 7. $t_0 + 220$ ms: computer activates solenoid valve S1;
8. $t_0 + 240$ ms: Main valve V1 opens and BOP function B1 close is pressurized;
9. $t_0 + 260$ ms: computer records flow through flowmeter F1 to BOP function B1
close port;
10. $t_0 + 820$ ms: computer deactivates solenoid S3;
- 30 11. $t_0 + 840$ ms: Choke assembly valves V3 are shifted to open position;
12. t_1 : computer activates solenoid valve S3 just before end of function;
13. $t_1 + 20$ ms : Choke assembly valves V3 are shifted to choke position;
14. $t_1 + 520$ ms: BOP function B1 slowed down;

15. t2 : computer confirms Flow meter F1 stopped and function in fully close position;
16. t2 + 20 ms : computer deactivates solenoid valve S3;
17. t2 + 40 ms : Choke assembly valves V3 are shifted to open position;
- 5 18. Flow meter F1 shows close volume of the function;
19. Flow through pilot regulator R1 dampened by accumulators A1 and A2;
20. Accumulator A1 at surface charge pressure;
21. Accumulator A2 at regulator setpoint pressure;
22. Flow through subsea manifold regulator R2 dampened by accumulators A4 and
- 10 A5;
23. Minimum interflow through subsea manifold regulator;
24. Minimum interflow during valve shifting;
25. Accumulators A3 and A4 at surface charge pressure;
26. Accumulator A5 at regulator setpoint pressure.
- 15 Control of the start of fluid deceleration in the fuction operation is directed at letting BOP fuction operate within the regulatory specifications (e.g. API 16D) without creating fluid hammer (or at least reducing fluid hammer). The computer logic embedded in the PLC or main computer system may preferably be self-learning. The computer logic may use the measured hydraulic fluid volume and time,
- 20 and compare this against values from the last operation to determine when to start the deceleration of the fluid in the system. The PLC or the control system computer will self-learn and continue to optimize the system. Fig. 3 illustrates an example of the logic for the self-learning that can be programmed in the PLC or in the main computer system. The self-learning system will allow continuous optimizion of the
- 25 the system response set to meeting certain parameters, including but not limited to: maximum fluid velocity, measured volume to the function, maximum and minimum operating time.

Even though the volume of hydraulic fluid that passes the pilot manifold 1 is relatively small compared to the BOP function manifold 2, also the pilot manifold 1

30 may suffer from fluid hammer. This may be mitigated by providing a flow restriction C1 (e.g. an orifice and/or a choke) in the pilot manifold 1 downstream of the pilot manifold regulator 3, such as illustrated in Fig. 4. The flow restriction C1 may be activatable, similar to the chokes in choke assembly 6, but it is expected this is not

necessary in the pilot manifold 1. Accumulator(s) A2 downstream of the pressure regulator R1 will reduce pressure spikes. The additional flow restriction C1 in the pilot manifold 1 reduce the pressure spikes in the pilot system so that they can adequately be absorbed by the accumulator(s) A2 placed between the pressure regulator R1 and the flow restriction C1. An additional advantage of slowing down the flow in the pilot manifold 1 by the flow restriction C1 is that cross flow through valves V1 and V2 is prevented as a result of slower shifting of solenoid valves S1 and S2 as the choke assembly 3 is activated at that time. The magnitude of the flow restriction C1 (e.g. the size of the orifice) is suitably selected so that the pressure drop over the flow restriction C1 does not jeopardize the activation pressure of other valves, activated by hydraulically powered solenoids.

An advantage of the presently proposed modification of subsea BOP control systems is that it can be retrofitted on pre-existing BOP control systems. A choke assembly can be placed before each point of distribution (POD) in the BOP control system. The choke assembly can easily be added to a pre-existing BOP control system which did not have such a choke assembly. The computer device can either be replaced, or a pre-existing computer device can be reprogrammed.

The person skilled in the art will understand that the present invention can be carried out in many various ways without departing from the scope of the appended claims.

CLAIMS

1. A subsea BOP control system for a hydraulic blowout preventer, comprising:
 - a BOP function manifold comprising a source side connectable to a hydraulic power unit for powering a BOP function;
 - at least one main valve connected to said BOP function manifold on one side
 - 5 of the at least one main valve and on the other side of the at least one main valve connectable to the BOP function, to selectively connect or isolate the BOP function from the BOP function manifold;
 - a computer device functionally coupled to a main actuator of the at least one main valve and arranged to control activation and deactivation of the main actuator;
 - 10 - an activatable choke assembly arranged at the source side of the BOP function manifold and upstream of the main valve.
2. The subsea control system of claim 1, wherein the choke assembly comprises choke actuator functionally coupled to the computer device to control activation and deactivation of the choke actuator.
- 15 3. The subsea control system of claim 1 or 2, wherein the computer device is programmed to activate the choke actuator prior to shifting the main acuator.
4. The subsea control system of claim 3, wherein the computer device is programmed to subsequently deactivate the choke actuator to fully open the BOP function manifold based on a criterion.
- 20 5. The subsea control system of any one of the preceding claims, further comprising a flow meter configured in the BOP function manifold.
6. The subsea control system of claim 6, wherein the flow meter is functionally coupled to the computer device to provide flow data to the computer device, and wherein said flow data is used in the computer logic to control activation and
- 25 deactivation of the choke actuator.
7. The subsea control system of any one of the preceding claims, wherein the computer device is programmed with self-learning logic to regulate activation and deactivation of the activatable choke assembly.
8. A method of shifting a main valve in a subsea BOP control system for a
- 30 hydraulic blowout preventer, comprising:

- providing a BOP function manifold connected to a hydraulic power unit for powering a BOP function, and at least one main valve connected to said BOP function manifold on one side of the at least one main valve and on the other side of the at least one main valve connectable to the BOP function, to selectively connect or isolate the BOP function from the BOP function manifold;
- shifting the at least one main valve comprising activating or deactivating a main actuator of the main valve, and activating a choke assembly, which is arranged at the source side of the BOP function manifold and upstream of the at least one main valve, prior to shifting the at least one main valve.
9. The method of claim 8, further comprising deactivating the choke assembly to fully open the BOP function manifold based on a criterion.
10. The method of claim 8 or 9, wherein the choke assembly is activated and deactivated automatically by means of a computer device functionally coupled to a choke actuator.
11. The method of any one of claims 8 to 10, further comprising retrofitting the choke assembly on a pre-existing BOP control system after the pre-existing BOP control system has been operated devoid of said choke assembly.
12. A subsea BOP control system for a hydraulic blowout preventer, comprising:
- a hydraulic BOP function comprising a piston having a stroke;
 - a BOP function manifold comprising a source side connectable to a hydraulic power unit for powering the BOP function;
 - at least one main valve connected to said BOP function manifold on one side of the at least one main valve and on the other side of the at least one main valve connected to the BOP function, to selectively connect or isolate the BOP function from the BOP function manifold;
 - an activatable choke assembly arranged at the source side of the BOP function manifold;
 - a computer device functionally coupled to a choke actuator of the choke assembly, programmed to automatically activate the choke actuator prior to the piston of the BOP function reaching an end of its stroke.
13. The subsea control system of claim 12, further comprising a sensor functionally coupled to the computer device to provide information to the computer device about how far the piston is removed from the end of its stroke, and

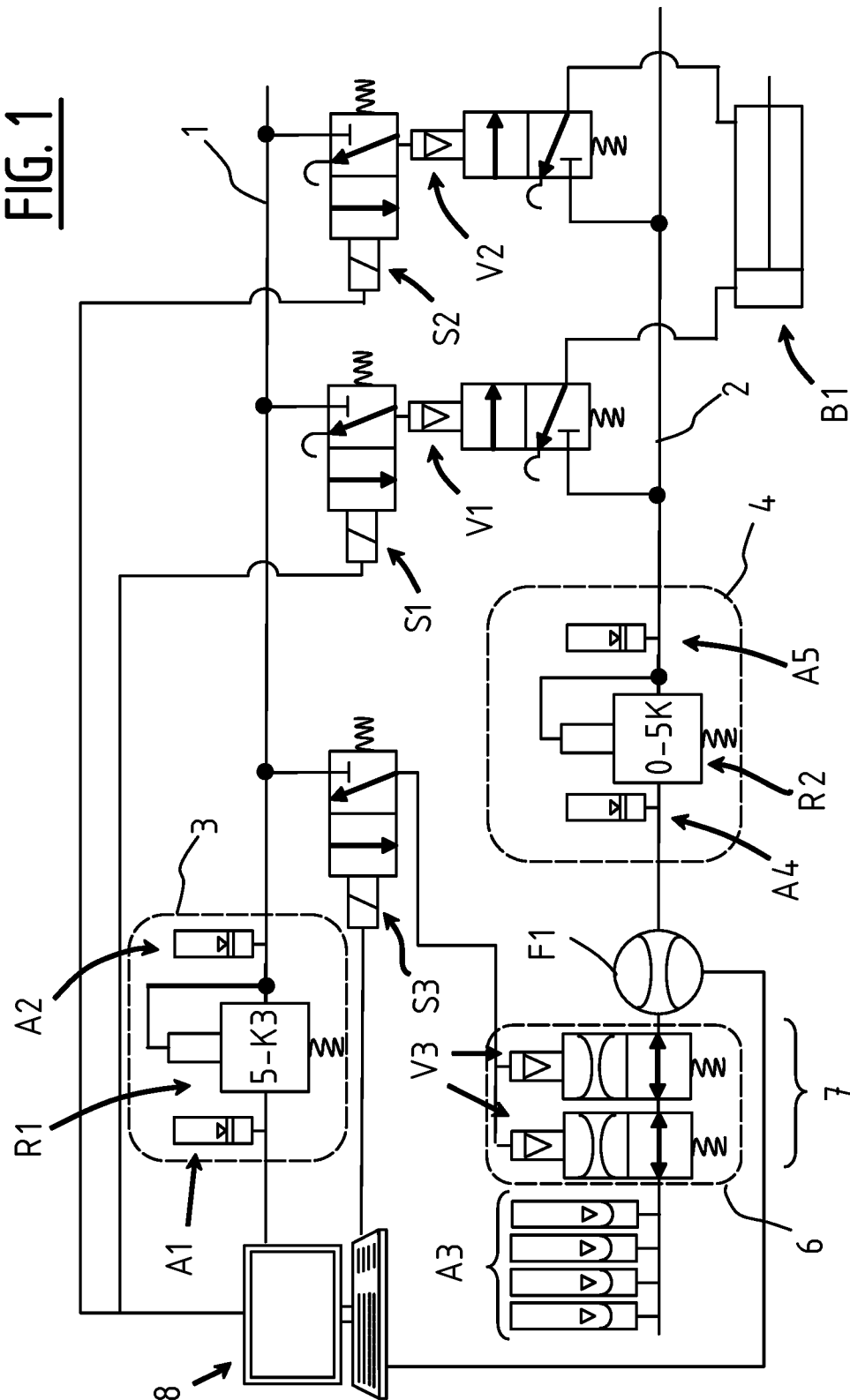
wherein the LC device is programmed to activate the choke assembly based on the information.

14. The subsea control system of claim 14, and wherein said sensor comprises a flow meter configured in the BOP function manifold, said flow data is used in the computer logic to estimate how far the piston is removed from the end of its stroke.

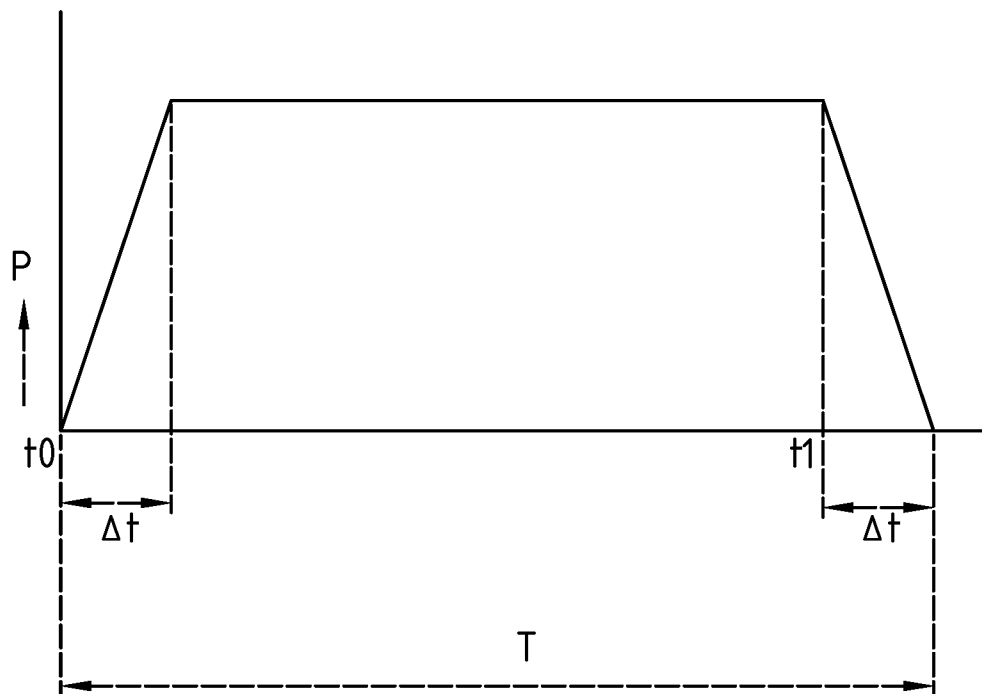
15. The subsea control system of any one claims 12 to 14, wherein the computer device is programmed with self-learning logic to regulate activation and deactivation of the activatable choke assembly.

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FIG. 1



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FIG. 2

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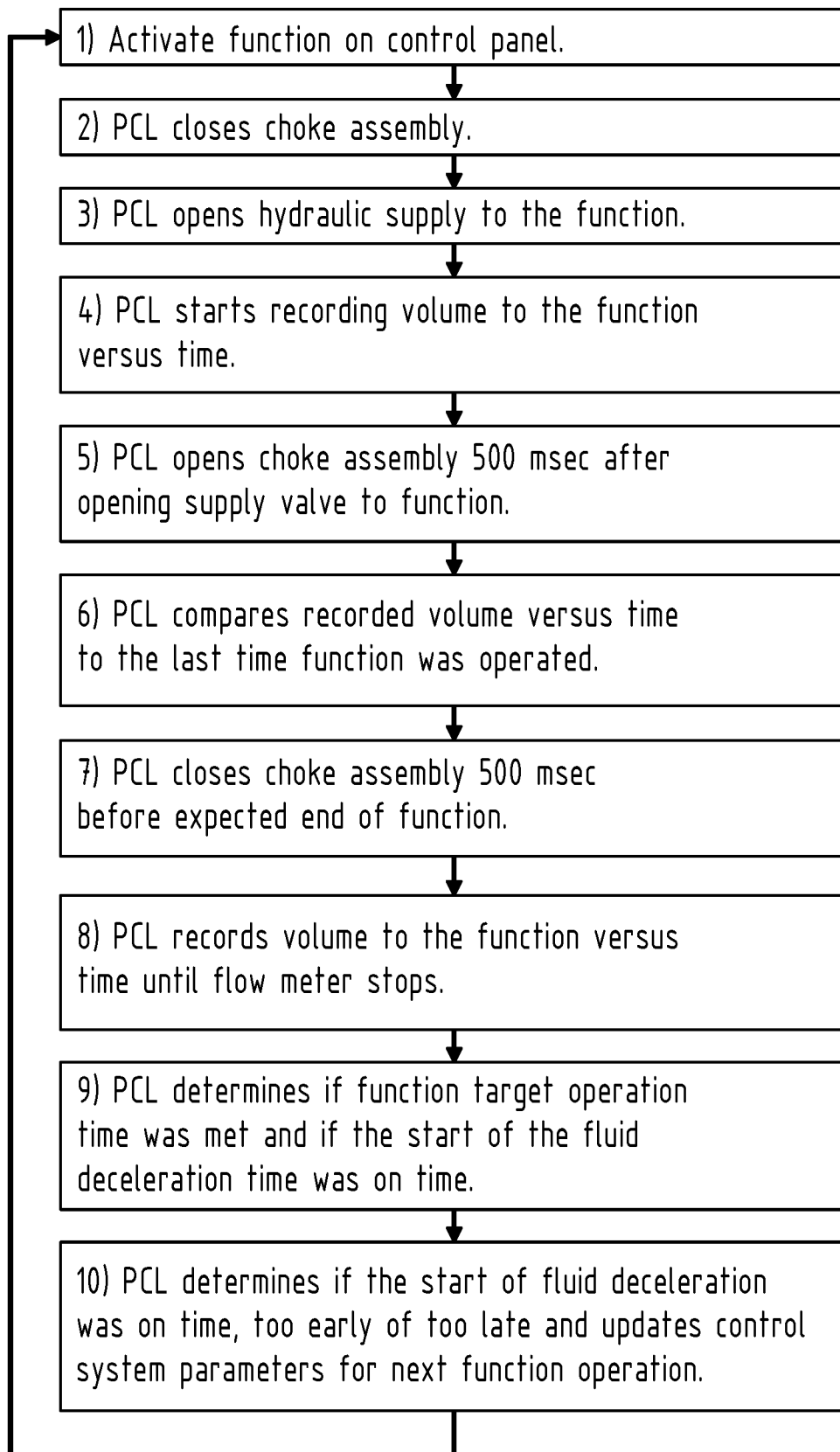
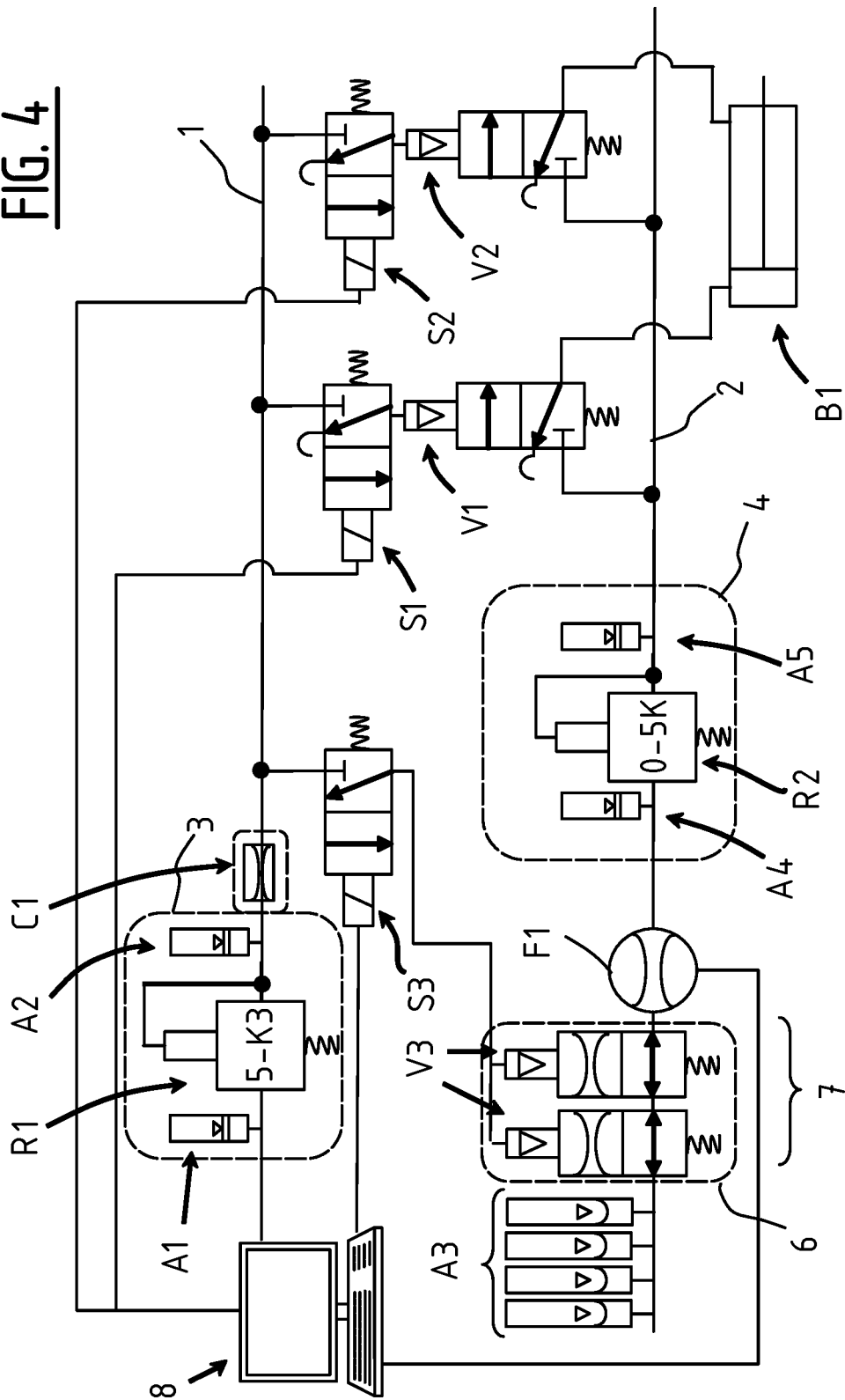
FIG. 3

FIG. 4



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/064447

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B34/16
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018/283138 A1 (PEYREGNE JOEY [US] ET AL) 4 October 2018 (2018-10-04) page 1, paragraph 17 - page 5, paragraph 43; figure 1 -----	1,8,12
A	US 2017/159394 A1 (KALINEC CHRISTOPHER LANCE [US]) 8 June 2017 (2017-06-08) page 3, paragraph 36 - paragraph 38; figure 4 -----	1,8,12
A	US 2019/078426 A1 (ZHENG SHUNFENG [US] ET AL) 14 March 2019 (2019-03-14) the whole document -----	1,8,12
A	US 2010/193245 A1 (GLOMSRUD JON ARNE [NO] ET AL) 5 August 2010 (2010-08-05) the whole document ----- -/-	1,8,12



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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22/09/2020

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/064447

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005/092523 A1 (MCCASKILL JOHN W [US] ET AL) 5 May 2005 (2005-05-05) the whole document -----	1,8,12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/064447

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2018283138 A1	04-10-2018	CA 2996153 A1 CN 108691528 A RU 2018111421 A US 2018283138 A1	30-09-2018 23-10-2018 30-09-2019 04-10-2018
US 2017159394 A1	08-06-2017	BR 112018011075 A2 CN 108474244 A KR 20180088726 A US 2017159394 A1 WO 2017093794 A1	21-11-2018 31-08-2018 06-08-2018 08-06-2017 08-06-2017
US 2019078426 A1	14-03-2019	US 2019078426 A1 WO 2019055240 A1	14-03-2019 21-03-2019
US 2010193245 A1	05-08-2010	BR PI0810037 A2 CN 101711304 A KR 20100031663 A NO 326572 B1 US 2010193245 A1 WO 2008127125 A2	14-10-2014 19-05-2010 24-03-2010 12-01-2009 05-08-2010 23-10-2008
US 2005092523 A1	05-05-2005	NONE	