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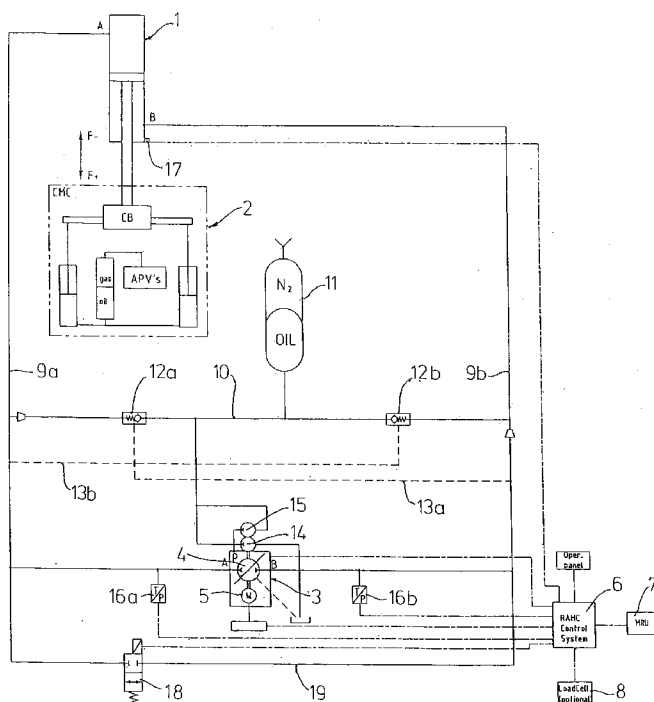
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(54) Title: A SYSTEM FOR ACTIVE HEAVE COMPENSATION AND USE THEREOF



(57) Abstract: A system for active heave compensation of the running block in a drilling derrick on board a floating off shore platform comprises a double-acting hydraulic cylinder (1) which is connected to a hydraulic power unit (3) for the supply of hydraulic pressure fluid to the hydraulic cylinder (1), a control unit (6) which regulates the supply conditions of the pressure fluid to the at any time active side (A, B) of the hydraulic cylinder, the hydraulic fluid concurrently being permitted to leave the passive side (B, A) of the hydraulic cylinder. The hydraulic power unit (3) comprises a pump unit (4) which via respective conduits (9a, 9b) are directly connected to the two sides (A, B) of the hydraulic cylinder (1) in order to form a generally closed hydraulic system therewith. The hydraulic fluid delivered by the pump unit (4) to the conduits (9a, 9b) to the active cylinder side is drawn from the conduit (9b, 9a) to the passive cylinder side, while the control unit regulates the output of the pump unit. The hydraulic system further comprises an accumulator (11) which equalizes the volumetric difference between the two sides of the hydraulic cylinder when it is a common double-acting cylinder. The system may also be provided with a hydraulic transformer (23) for regeneration of hydraulic

power during passive operation of the compensation system.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A SYSTEM FOR ACTIVE HEAVE COMPENSATION AND USE THEREOF

The present invention relates to a system for active heave compensation of a device in off shore arrangement, particularly on board a floating structure, comprising at least one double-acting hydraulic cylinder which is connected to the device which is to be heave compensated, a hydraulic power unit for providing hydraulic pressure fluid to the hydraulic cylinder, a control unit which regulates the supply conditions of the pressure fluid to be currently active side of the hydraulic cylinder, the hydraulic fluid concurrently being permitted to leave the passive side of the hydraulic cylinder, where in the hydraulic power unit comprises a pump unit which via respective conduits are connected to the two sides of the hydraulic cylinder for forming their there with a substantially closed hydraulic system, where in hydraulic fluid delivered by the pump unit to the conduit to the active cylinder side is drawn from the conduit to the passive cylinder side, the control unit regulating the output of the pump.

The system according to the invention is primarily intended as a supplement to a passive heave compensating system for use in drilling hydro carbon wells off shore or interventions in such wells. When drilling, landing equipment on the sea floor, or in other down hole operations from a floating drilling vessel or handling vessel, it is desirable that the drill string or wire is behaving as stabile as possible with respect to the sea floor, independent of the movements of the vessel due to the influence of waves, tide etc. An active heave compensating system in combination with a passive compensating system will increase the efficiency of the vessel, so that operations on the sea floor or down hole may be conduited without being disturbed by wave movements or other influence on the vessel. This will prevent damage to equipment and well formations and, further more, it will be possible to operate under more difficult weather conditions than would other wise be possible.

Active heave compensating systems or drill strings are all ready known. The most common systems are based on active double-acting cylinders of the three-chamber type or cylinders having a double-ended piston rod, e.g. as shown in GB-A-2053127. These are preferably arranged together with a passive compensating system for the crown block of drilling derrick, often called a CMC system (Crown-block Motion Compensation). A CMC system consists of passive compensating cylinders and accumulators coupled to a pressure controlled gas source, such as a compressor, and adjust the necessary tensile force. The three-chambered cylinder is a double-acting cylinder designed such that it has approximately the same acting area and displaced in both directions of movement of the cylinder rod. This permits simpler control and

approximate volumetric balance at passive CMC compensation when the active system is not in operation.

The hydraulic system usually consists of a high pressure hydraulic power unit placed at the level of the drill floor. The three-chambered double-acting cylinder is usually placed
5 in the top of the drilling derrick and is mechanically coupled to the passively compensated crown block. Typical capacity is plus/minus 25 mT, and this force is sufficient to overcome mechanical friction and hydraulic resistance in the passive system. The cylinder is controlled by a servo valve mounted on a proportional valve block placed on the cylinder.

10 The control of the active heave compensation system is based on an acceleration sensor, a so-called "Motion Reference Unit" (MRU), and cylinder position measurement which give input to a computer which sends signals to the servo valve, which in turn regulates the power and movements of the cylinder via the proportional valve block. In some
15 systems the control may also be based on input from pressure transmitters in the hydraulic circuit and from load cells and a lifting yoke, a lifting sheave block or a dead anchor.

A disadvantage of the existing systems is that they require advanced proportional servo valve control and strong hydraulic power units having a large tank volume. The systems also require much space and power since a high pressure loss is generated over the
20 various elements and the long supply pipes between the power unit at drill deck level and the cylinder in the top of the drilling derrick.

The commonly used three-chamber cylinders are expensive, heavy, complicated and require high pressures. Further more, they are vulnerable to internal leakages since they have three sealing interfaces. Besides, three-chamber cylinders do not have exactly the
25 same active area and displaced volume in both directions of movement. This may give rise to a jerking, uncontrolled face displaced active compensation at the restart following passive operation, and from time to time also during regular operation caused by an imbalance in the volumetric relationship.

In other known systems using a cylinder with a double-ended piston rod the cylinder
30 requires much space height wise due to the extending passive part of the piston rod.

The drawback mentioned above necessitates much maintenance work. The location of the various parts of the system makes replacements and service more difficult,

particularly during implement weather conditions when the need for the active systems is at its largest.

The purpose of the present invention is therefore to avoid, or at least to reduce the drawbacks of the prior art. This is obtained according to the invention by a system of the type mentioned by way of introduction, which is characterized in the hydraulic
5 system further comprises means which compensate for a volumetric difference between the two sides of the hydraulic cylinders, said means preferably being constructed such that the two conduits from the pump unit are connected to a source for hydraulic fluid in order to receive fluid from, or deliver fluid to, the passive cylinder side where this is
10 necessary in order to maintain fluid balance between the suction side and discharged side of the pump unit.

In this way the hydraulic power unit may be made less costly, smaller and with a minimum tank volume, such that in many cases it will be possible to place it at the same level at the hydraulic cylinder and thereby avoid the long connection conduits. Further
15 more, the jerking starting movement of the three-chambered cylinders may be eliminated and the use of simpler cylinder types may be made possible.

Thus, according to a preferred embodiment of the invention, it is suggested to use a hydraulic cylinder in the form of a common-acting cylinder, e.g. a differential cylinder. In this case the piston area and volume of the passive cylinder side will be much smaller
20 than on the active side. In order to accommodate the apparent imbalance this will cause in a closed system, the two conduits from the pump unit are connected to an accumulator for hydraulic fluid for receiving fluid from, or delivering fluid to, the passive cylinder side where this is necessary in order to maintain the fluid balance between the suction side and the discharged side of the pump unit. Where as can be
25 arranged between the conduits and the accumulator which act to close the accumulator against the instant cylinder side and open towards the passive cylinder side. These valves may be chosen from the group of pressure controlled check valves, electrically controlled valves, pneumatically controlled valves and pressure controlled over center valves.

30 The pump unit may comprise a step less variable positive displacement pump, or two variable positive displacement pumps which pumps to one side each of the hydraulic cylinder, possibly with indifferent capacity. It is also possible to use constant positive displacement pumps driven by rotational speed controlled power units, preferably frequency controlled alternating current motors.

In order for the system according to the invention to operate in shorter periods with higher compensating velocity the capacity of the hydraulic power unit would aloud, the pump unit may according to the invention be connected to a high pressure accumulator system for extra supply of hydraulic fluid to the hydraulic cylinder. This accumulator
5 system may be discharged during passive operation of the system through external force influence, such as from a connected passive compensation system. Similarly, it is possible to charge the high pressure accumulator system by means of the heave compensation system's own pump unit in situations where it has spear capacity. Further more, it will be possible to replace the pump unit by a hydraulic transformer unit, which
10 can act both as pump and motor, thereby permitting recovery and storage of energy bypassive and preferably also active operation of the system.

In situations where the active heave compensation system according to the invention is not used actively, e.g. because the connected passive compensation system is sufficient, the piston of the hydraulics cylinder will never the less move in step with the heave
15 movements of the vessel. This causes hydraulic oil to be pumped by the cylinder back and forth through the system, and if this does not take place via the pump unit for regenerating energy, a bypass conduit around the pump unit must be present. Such a bypass conduit may also be constituted by the conduits connecting the above-mentioned fluid balancing accumulator to the two piston sides, but in this case steps must be taken
20 for the valves in these conduits to open for the necessary fluid flow to and from the accumulator. However this will be within the normal capabilities of a skilled person.

An additional advantage of the compact form of the system according to the invention is that it may be put together of modules, preferably a first module comprising the pump unit with valves, the control unit and preferably a bypass conduit having a shut off valve
25 and pressure sensors, a second module comprising the accumulator and a third module comprising the hydraulic cylinder.

It will be understood that the system according to the invention may not only be used in addition to a passive heave compensation system for a crown block in a drilling derrick, but that it also will be suitable for heave compensation of a running block mounted drill
30 string, a winch, a crane, and A-frame or a sub-A-frame as recited in claim 16.

Further advantage features of the invention will be apparent from the deep ended claims and from the following description of exemplifying embodiments of the invention in connection with the appended drawings, where

figure 1 is a schematic flow diagram for a first embodiment of the system according to the invention,

figur 2 is a schematic flow diagram for a detail of a second embodiment of the system according to the invention,

5 figure 3 is a schematic flow diagram for a third embodiment of the system according to the invention,

figure 4 is a partial schematic flow diagram for a fourth embodiment of the system according to the invention,

10 figure 5 is a partial schematic flow diagram for a fifth embodiment of the system according to the invention,

figure 6 is a patial schematic flow diagram for a sixth embodiment of the system according to the invention,

figure 7 is a partial schematic flow diagram for a seventh embodiment of the system according to the invention,

15 figure 8 is a partial schematic flow diagram for an eight embodiment of the system according to the invention,

figure 9 is a partial schematic flow diagram for a ninth embodiment of the system according to the invention,

20 figure 10 is a parsal schematic flow diagram for a tenth embodiment of the system according to the invention,

figure 11- 15 illustrate schematically different use possibilities for the system according to the invention.

The exemplifying embodiment illustrated in figure 1 comprises a double-acting hydraulic cylinder 1 which is connected to a device 2 which is to be heave compensated, here shown in the form of a passive compensationsystem CMC for the crown block CB in e.g. a drilling derrick (not shown). The double-acting hydraulic cylinder 1 may be a differential cylinder, i.e. in area on the piston rod side B is equal to the piston area on

the plus side A. More over, ratios between the two sides are possible, provided that the buckling strength of the piston rod is sufficient for the current use.

5 The hydraulic cylinder is provided with hydraulic pressure fluid from a fluid power unit 3, the unit containing a pump 4 having variable positive displacement and is driven by a motor 5. The hydraulic power unit 3 is controlled by a control system 6, which receives input from an acceleration sensor or the like 7, also called "Motion Reference Unit" (MRU). The control system may also receive input from a load cell 8 in the device 2 to be heave compensated.

10 The pump 4 is connected to the two sides A, B of the hydraulic cylinder 1 by means of respective conduits 9a, 9b. The conduits 9a, 9b are connected to each other by means of a conduit 10, which is connected to a low pressure accumulator 11. On either side of the accumulator 11 the conduit 10 is provided with pilot operated (pressure controlled) check valves 12a, 12b, which in normal operating mood permit fluid flow from the accumulator 11 to the respective conduits 9a, 9b. The check valves 12a, 12 b are
15 provided with their own pilot pressure conduit 13a, 13b, which extend from the opposite conduit 9b, 9a, respectively. At a certain pressure in the pilot pressure conduit the connected check valve 12a, 12b is forced open so that it permits flow in both directions.

During operation of the active heave compensation system according to the invention the hydraulic unit 3 with the pump 4 will be the superior pressure source and control
20 unit for the work of the cylinder 1. At positive cylinder movement (F+, rod out) the pump 4 will pump at high pressure through the conduit 9a to the side A of the hydraulic cylinder 1. Concurrently, the pump will draw from the side B of the hydraulic cylinder through the conduit 9b, but since the displaced volume from the piston rod side B of the cylinder 1 is much less than the volume which has to be provided to the piston side A,
25 the pump 4 concurrently draws fluid from the low pressure accumulator 11 via the check valve 12b. When the cylinder 1 is driven in the opposite direction (F- rod in), the pump 4 delivers pressure fluid to the rod side B of the cylinder via the conduit 9b. However, concurrently a larger volume is displaced from the piston side A of the cylinder than the pump 4 draws in, and this surplus is supplied to the low pressure
30 accumulator via the conduit 10, and the check valve 12a. This is possible because the pressure in the conduit 9b has opened the check valve 12b via the signal conduit 13a for flow in both directions.

Leakage in the system is compensated for by a low pressure pump 14, which serves to maintain the volumetric balance in the system. A high pressure pilot pressure pump 15

provides a stabile pilot pressure to the control block of the variable positive displacement pump 4 in order to facilitate the necessary control response of the pump 4. Pressure transmitters 16a, 16b are mounted on either side of the pump 4 and send signals to the control system 6. This system is also provided with a signal from a position sensor 17 for the cylinder 1.

When the active heave compensation system according to the invention is inactive because the connected passive system 2 provides sufficient heave compensation, the cylinder 1 will, never the less, be forcibly driven by the movements of the passive system. In this case the pump 4 is disengaged and a bypass valve 18 in a bypass conduit 19 is opened in order to let the fluid flow between the two sides of the cylinder. At a positive cylinder stroke (rod out) the fluid flow will go from the rod side B to the piston side A, fluid concurrently being drawn from the accumulator 11 through the check valve 12a. At the opposite cylinder stroke a smaller pressure increase in the conduit system 9a, 9b will cause the check valves 12a, 12b to open and permit surplus fluid from the piston side A to flow to the accumulator. As an alternative to the bypass conduit 19 one may use the low pressure conduit 10 as a bypass conduit, but in this case one must take precautions for the check valves 12a, 12b to open as necessary. This may be done by installing a suitable valve between the pressure signal conduits 13a, 13b, e.g. an electrically operated double bypass valve, such that the valve 12a is connected to the conduit 13b and the valve 12 b is connected to the conduit 13a when the system is driven in inactive mood. In this case the check valve and the corresponding part of the valve 10 up to the accumulator 11 must be dimensioned for the entire fluid flow from the piston side A of the hydraulic cylinder.

As an example of the dimensioning of the system, the hydraulic cylinder 1 may have a stroke of 7.6 metres, in operating pressure 235 bar, a maximum force of 250 kN, and a stroke velocity of 1 m/sec. The low pressure accumulator may have a volume of 200 litres and function at a pressure of 4-8 bar. The system may also be provided with safety valves, both on the high pressure side and low pressure side, and a filter unit and a cooling system (not shown in figure 1).

Figure 2 shows an alternative embodiment of the check valves 12a and 12b. In this case the pressure signal via conduits 13a and 13b does not act directly on the check valve, but opens a bypass valve around the check valve.

Figure 3 shows a further variant where the check valves 12a, 12b are replaced by electrically controlled logical on/off valves.

An alternative embodiment of the hydraulic power unit 3 is shown in figure 4. Here the proportional over centre pump 4 is replaced by two variable positive displacement pumps 4a and 4b pumping to sides A and side B, respectively. These pumps may have different flow and pressure ratings. They may also be replaced by constant positive
5 displacement pumps being driven by frequency controlled alternating current motors (not shown).

In a further embodiment of the invention illustrated in figure 5 the proportional over centre pump 4 is replaced by a servo pump 20 which can act as a combined pump and motor in order for it to be driven by an electric motor or to drive a generator 21. By
10 passive operation of the system, the pump 20 may be used as a motor for driving the generator 21 and for generating electric power which may be stored, e.g. in batteries 22. This energy may later be used when the system is operated actively.

Figure 6 shows an embodiment where the proportional over centre pump is replaced by a hydraulic transformer 23 which can act as a combined motor and pump for
15 pressurizing a hydraulic/pneumatic accumulator 24 during passive compensator operation. The stored hydraulic energy can be applied for shorter periods during active compensation as a reinforcement in order to nearly double the stroke capacity of the hydraulic cylinder.

Figures 7-10 show further examples of how the hydraulic transformer is used for storing
20 hydraulic energy in accumulators. This high pressure regeneration of energy has led to the process according to invention often being referred to "Regenerative Active Heave Compensation" (RAHC).

It will be understood that the system according to the invention also can be used at an advantage for other services than active heave compensation of the crown block in a
25 drilling derrick. Examples of such alternative uses are illustrated in figures 11-13. Thus, figure 11 shows to different uses, i.e. heave compensation of a running block mounted drill string (DSC) and heave compensation of a jigger winch. Figure 12 illustrates heave compensation of a sub-A-frame, while figure 13 shows the system in relation to a nodding boom crane. Figures 14 and 15 indicate that the system according to the
30 invention also may be used with hydraulic cylinders of the three-chamber type 25 and cylinder 26 having a through-going piston rod.

It will be understood that the invention is not limited to the exemplifying embodiments described above, but may be varied and modified by a skilled person within the scope of

the following claims. It will also be understood that the invention has solved many of the problems typical of the prior art. Thus, the invention has made possible substantial reduction, e.g. in the area 25-40 % with respect to weight, price and power consumption.

CLAIMS

1. A system for active heave compensation of a device in off shore arrangement, particularly on board a floating structure, comprising at least one double-acting hydraulic cylinder (1) which is connected to the device (2) which is to be heave compensated, a hydraulic power unit (3) for providing hydraulic pressure fluid to the hydraulic cylinder (1), a control unit (6) which regulates the supply conditions of the pressure fluid to be currently active side (A, B) of the hydraulic cylinder (1), the hydraulic fluid concurrently being permitted to leave the passive side (B, A) of the hydraulic cylinder, where in the hydraulic power unit (3) comprises a pump unit (4) which via respective conduits (9a, 9b) are connected to the two sides (A, B) of the hydraulic cylinder (1) for forming their there with a substantially closed hydraulic system, where in hydraulic fluid delivered by the pump unit (4) to the conduit (9a, 9b) to the active cylinder side is drawn from the conduit (9b, 9a) to the passive cylinder side, the control unit (6) regulating the output of the pump (4),
- 15 c h a r a c t e r I z e d i n t h a t the hydraulic system further comprises means (11, 12a, 12b) which compensate for a volumetric difference between the two sides (A, B) of the hydraulic cylinders (1), said means preferably being constructed such that the two conduits (9a, 9b) from the pump unit (4) are connected to a source (11) for hydraulic fluid in order to receive fluid from, or deliver fluid to, the passive cylinder side where this is necessary in order to maintain fluid balance between the suction side and discharged side of the pump unit (4).
- 20
2. A system according to claim 1, wherein said source is an accumulator (11).
3. A system according to claim 2, wherein valves (12a, 12b) are arranged between the conduits (9a, 9b) and the accumulator (11) acting to close the accumulator (11) against the at any time active cylinder side (A, B) and open towards the passive side (B, A)
- 25
4. A system according to claim 3, wherein said valves (12a, 12b) are chosen from the group of pressure controlled check valves (12a, 12b) electrically controlled valves, pneumatically controlled valves and pressure controlled over centre valves.
- 30
5. A system according to anyone of the preceding claims, wherein the pump unit comprises a continuously variable positive displacement group (4)

6. A system according to anyone of claims 1-4, wherein the pump unit comprises two variable positive displacement pumps (4a, 4b) pumping to either side (A, B) of the hydraulic cylinder (1), possibly at different capacities.
7. A system according to anyone of claims 1-4, wherein the pump unit comprises
5 constant positive displacement pumps which pump to either side of the hydraulic cylinder (1) and are driven by rotational speed controlled power units, preferably frequency controlled alternating current motors.
8. A system according to anyone of the preceding claims, wherein the hydraulic cylinder is a differential cylinder (1).
- 10 9. A system according to anyone of the preceding claims 2-8, wherein the pump unit comprises a low pressure pump (14) feeding the accumulator (11) in order to compensate for leakage from the system.
- 15 10. A system according to claim 5, where the pump unit comprises the control pressure pump (15) which supplies the control block of the positive displacement pump (4) with a stabile pressure.
11. A system according to anyone of the preceding claims, wherein the pump unit (32) is connected to a high pressure accumulator system (24) for extra supply of hydraulic fluid to the hydraulic cylinder (1) during need for higher compensation velocity.
- 20 12. The system according to claim 11, wherein the high pressure accumulating system (24) is charged by passive operation of the system during external force influence, such as from a connected passive compensation system.
13. A system according to anyone of the preceding claims, wherein the hydraulic system comprises a bypass conduit (14) provided with a shut off valve (18), said bypass
25 conduit being arranged between the conduits (12a, 12b) to the hydraulic cylinder (1) for opening when the system operates in passive mood.
14. A system according to anyone of the preceding claims 2-13, wherein the system is assembled from modules, preferably with a first module comprising the pump unit (4) with valves (12a, 12b), the control unit (6) and preferably a bypass conduit (19) with

shut off valve (18) and pressure sensors (9) a second module comprising the accumulator (11), and a third module comprising the hydraulic cylinder (1).

15. A system according to anyone of the preceding claims, wherein the pump unit is replaced by a hydraulic transformer unit (23), said transformer unit being connected to a device (24) for storing energy recovered during passive and preferably also active operation of the system.

16. The use of a system according to anyone of the preceding claims as an addition to a passive heave compensation system for a crown block in a drilling derrick, or for heave compensation of a running block mounted drill string, a winch, a crane, and a – frame, or a sub-A-frame.

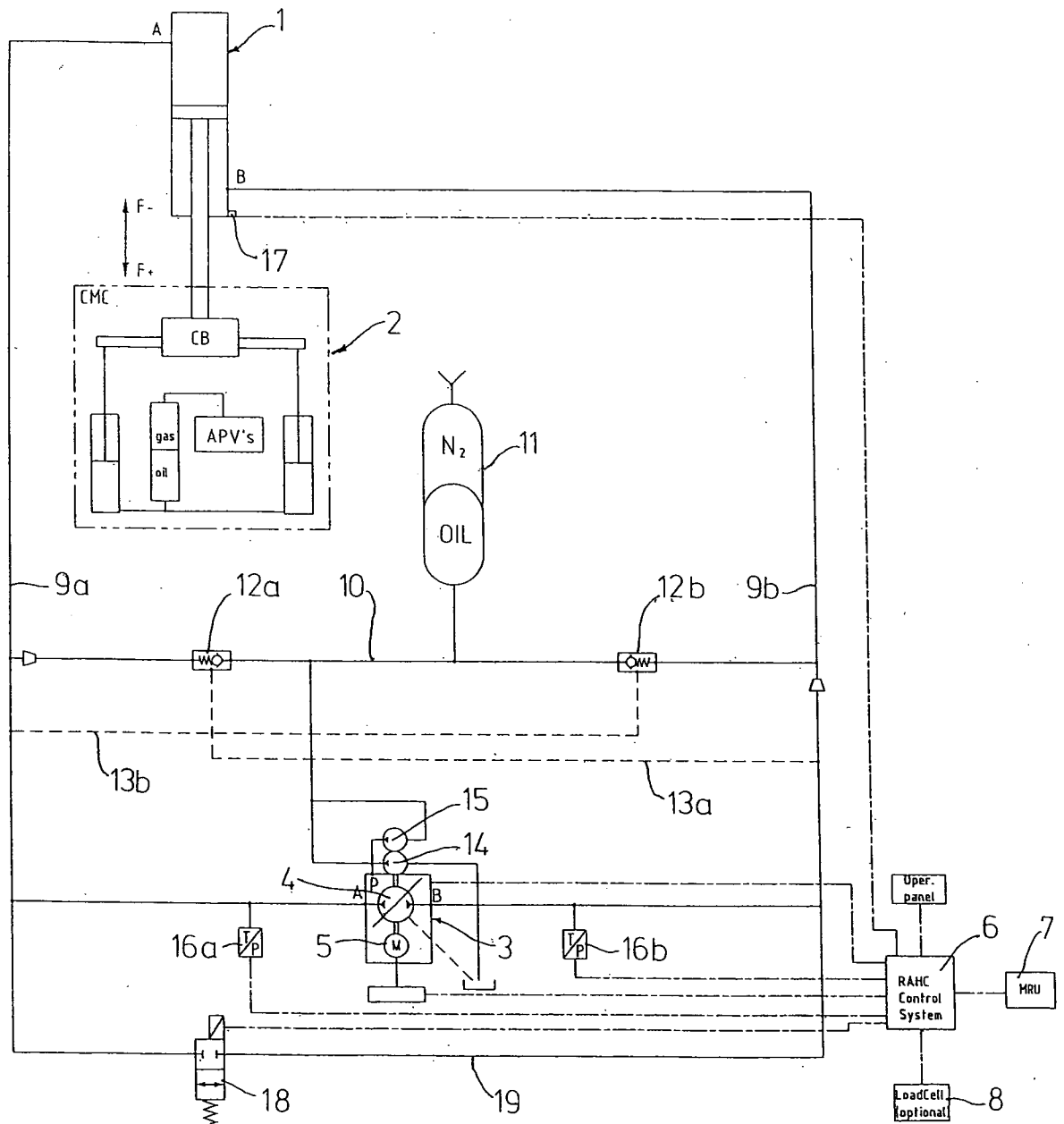


Fig. 1

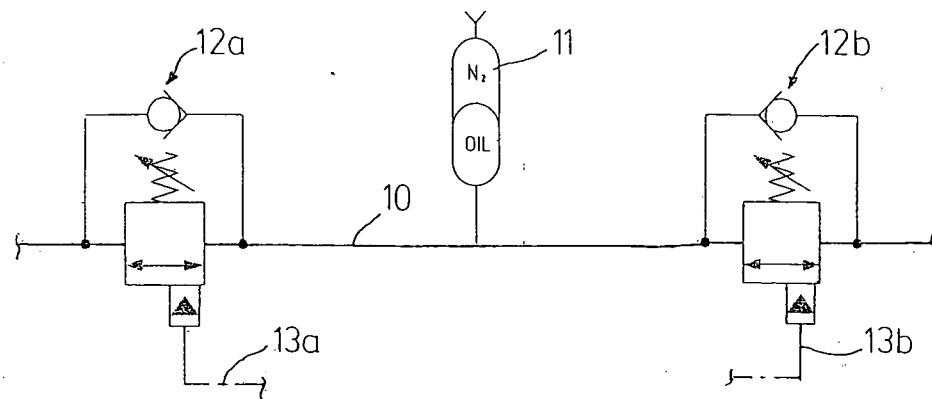


Fig. 2

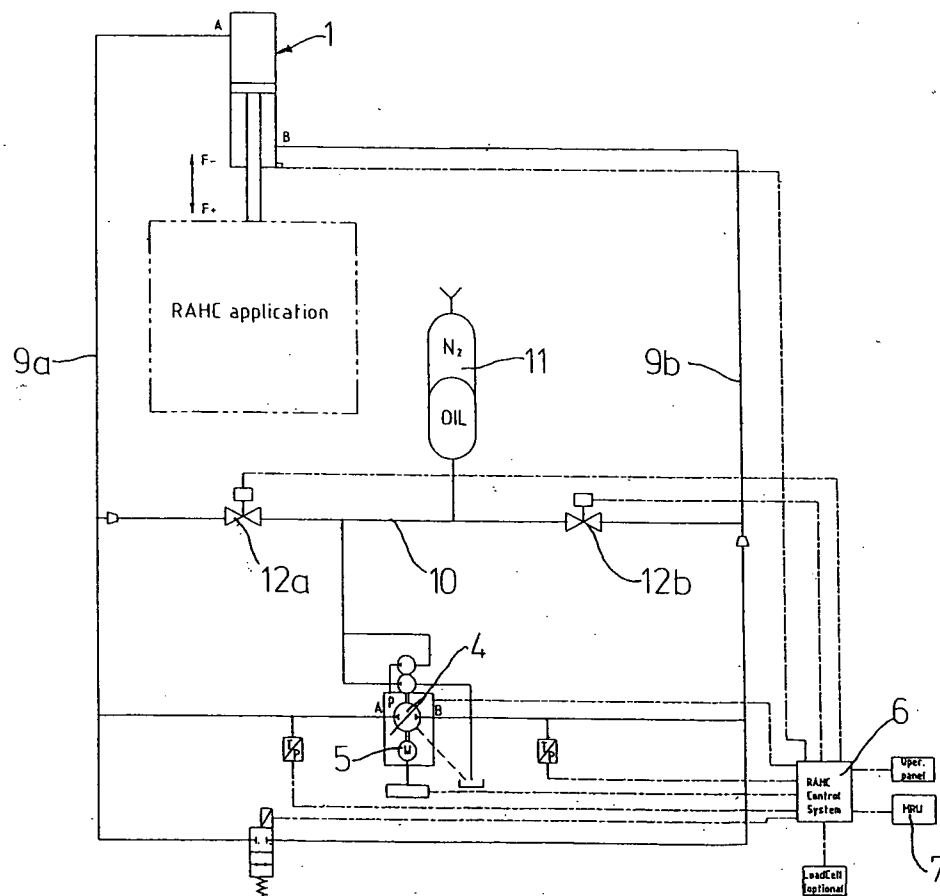


Fig. 3

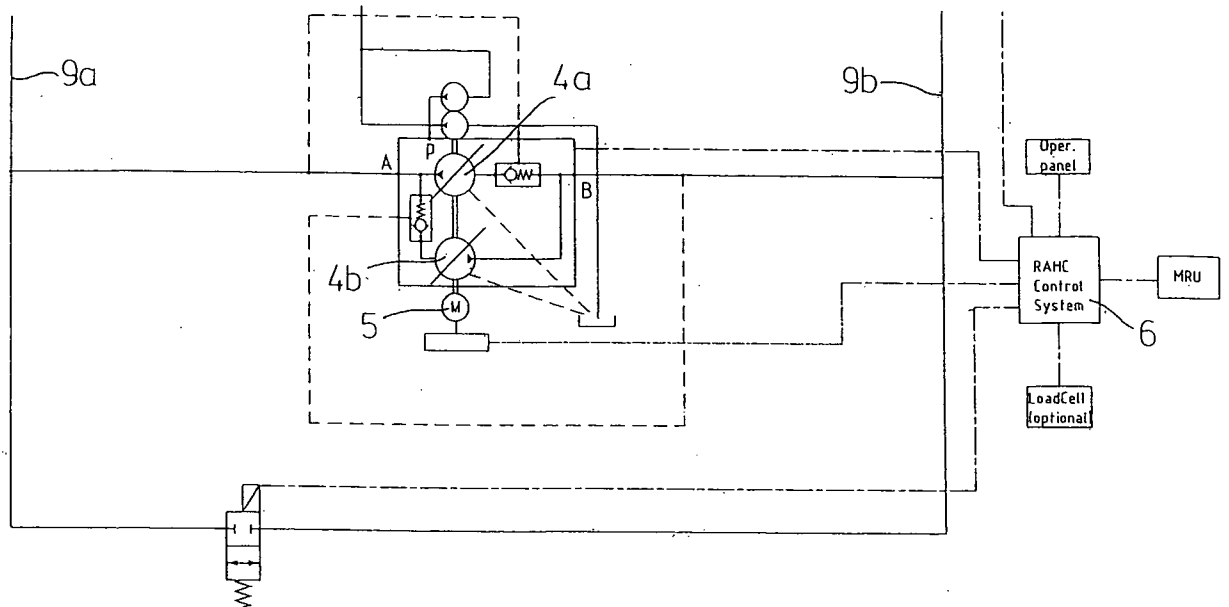


Fig. 4

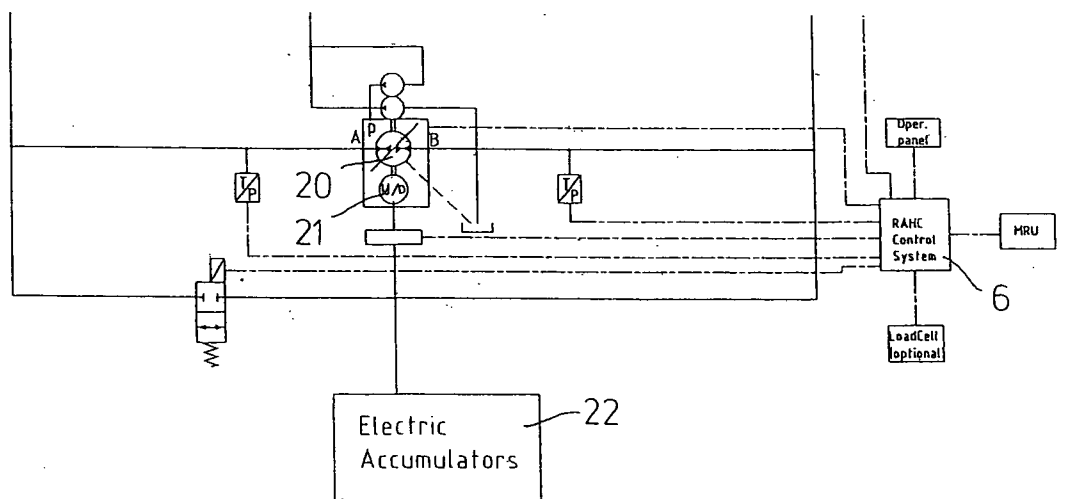


Fig. 5

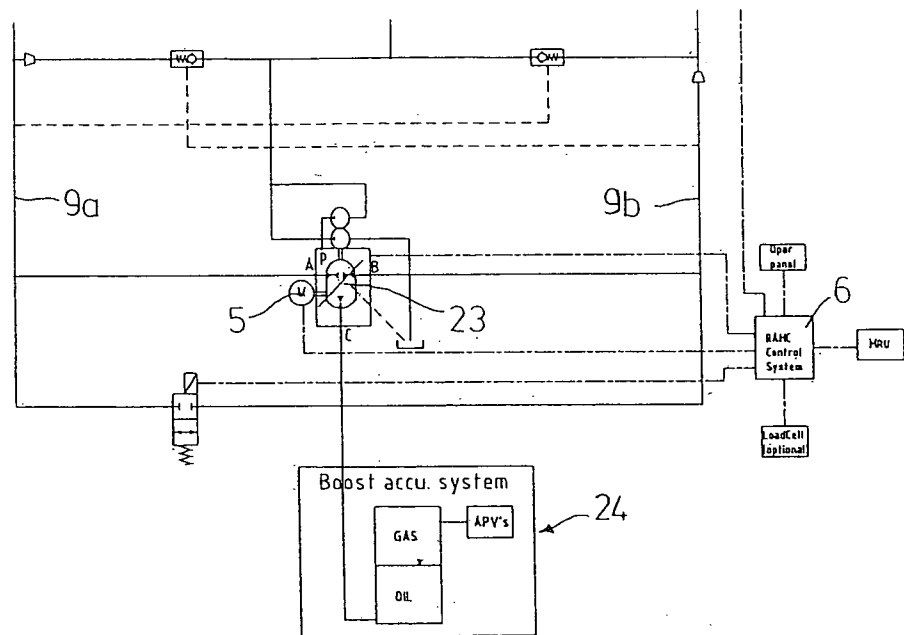


Fig. 6

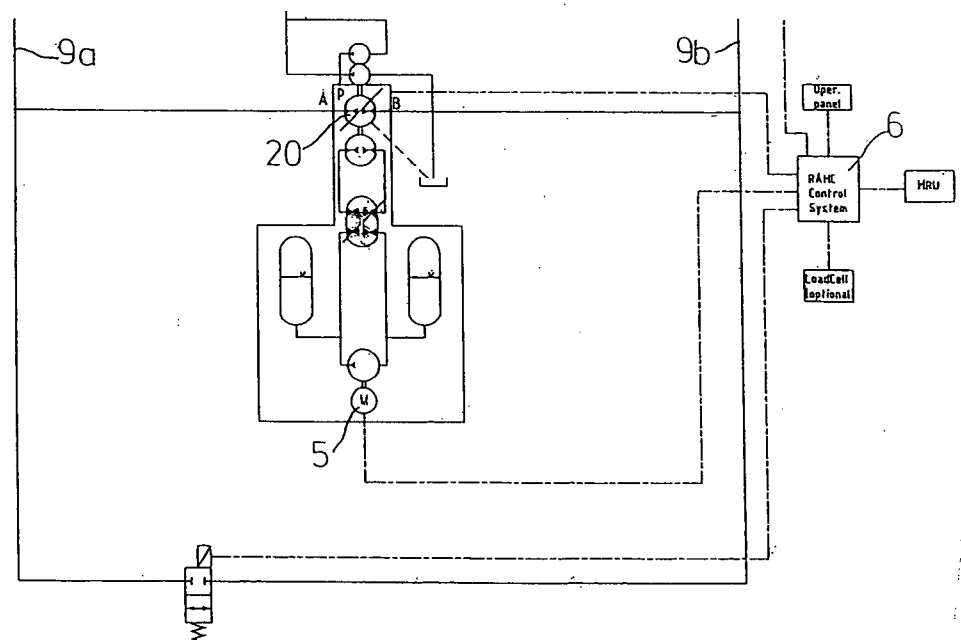


Fig. 7

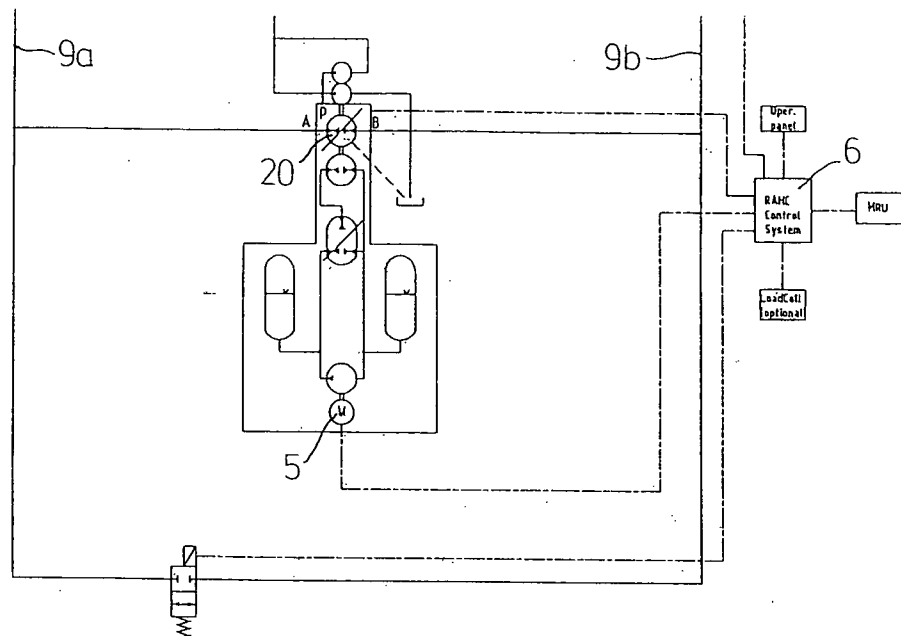


Fig. 8

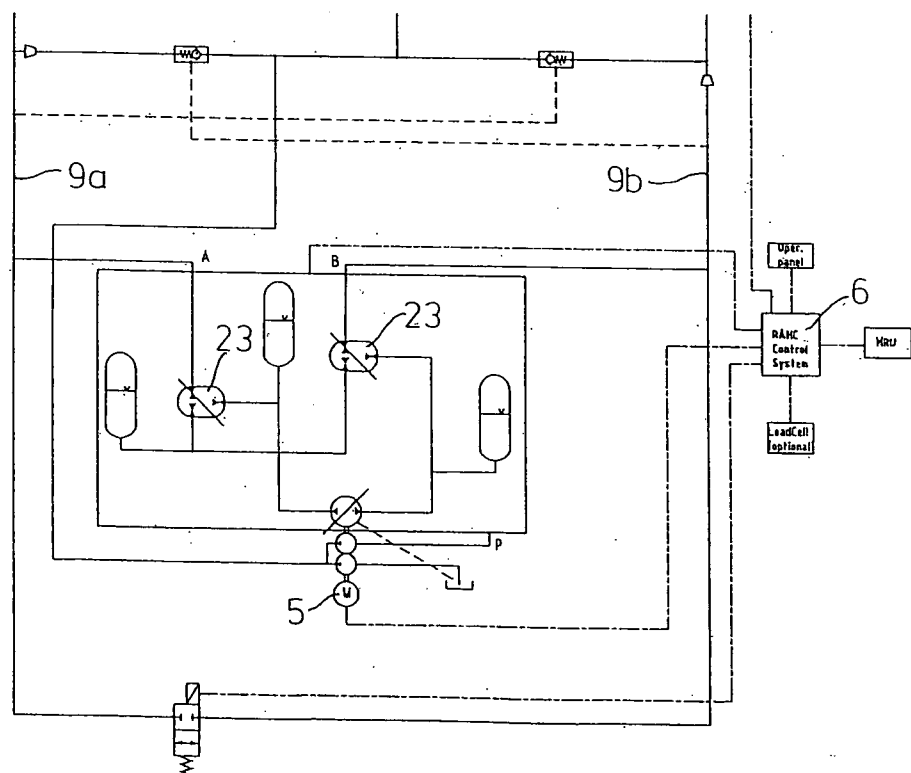


Fig. 9

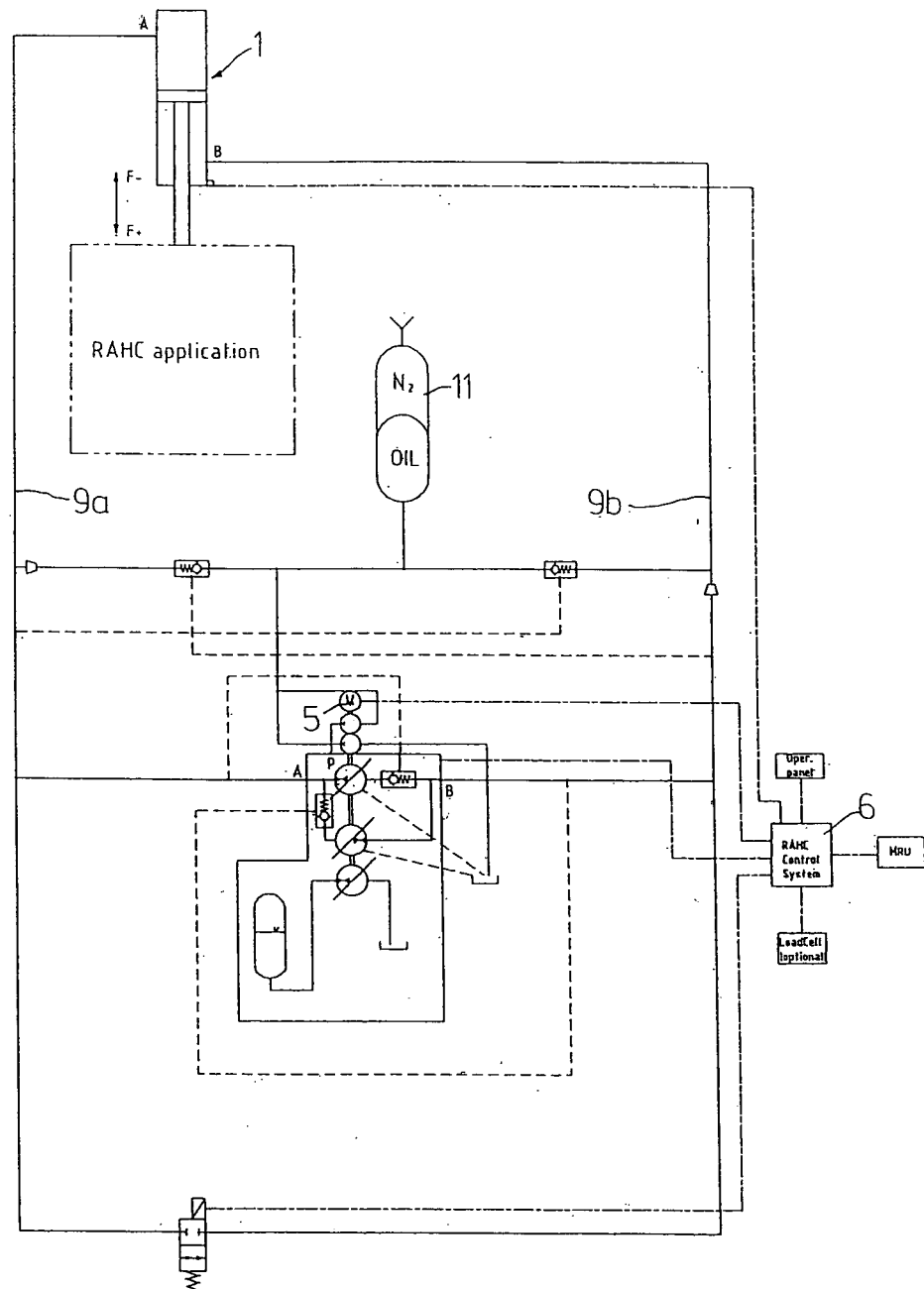


Fig. 10

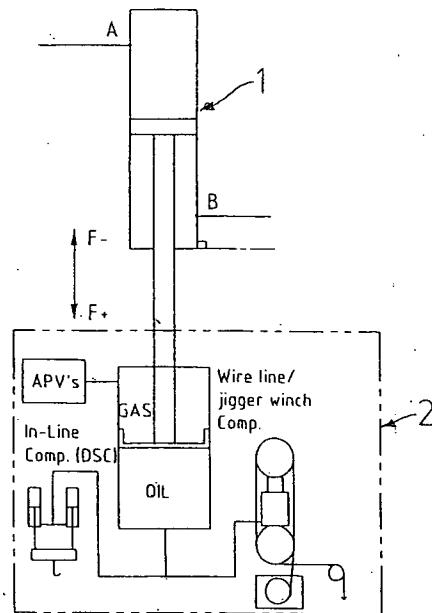


Fig. 11

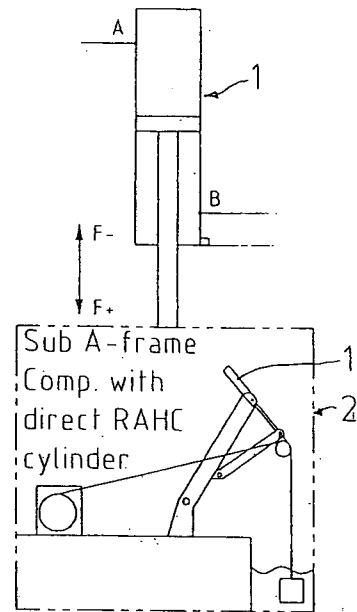


Fig. 12

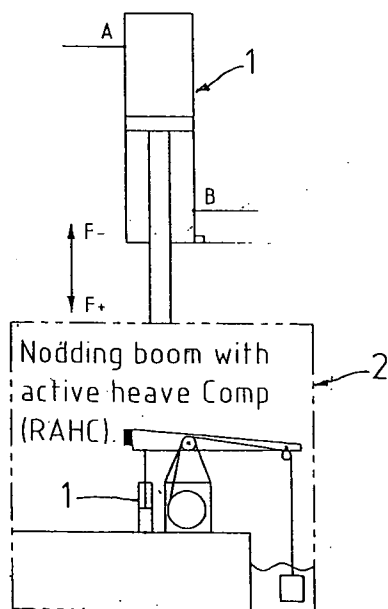


Fig. 13

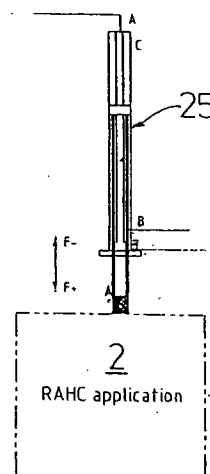


Fig. 14

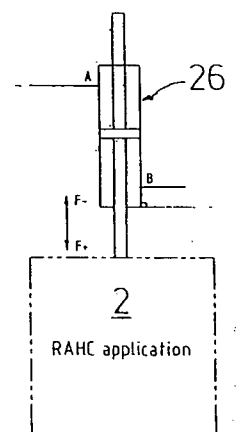


Fig. 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2007/000190

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B63B

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4121806 A (IATO ET AL), 24 October 1978 (24.10.1978), column 4, line 27 - line 35; column 4, line 62 - line 68; column 5, line 10 - line 34, figures 4,6,7, abstract --	1-13
X	GB 2053127 A (GEC MECHANICAL HANDLING LIMITED), 4 February 1981 (04.02.1981), page 1, line 119 - page 2, line 14, abstract, fig. --	1-13
A	US 4382361 A (BLANCHET), 10 May 1983 (10.05.1983), column 5, line 25 - line 60, figure 4, abstract --	1-16

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2007/000190

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 3948486 A (JOURDAN ET AL), 6 April 1976 (06.04.1976), column 5, line 10 - line 30, figure 7, abstract -- -----	1-16

International patent classification (IPC)**B63B 39/00** (2006.01)**E21B 19/09** (2006.01)**B63B 35/44** (2006.01)**Download your patent documents at www.prv.se**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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International application No.

PCT/NO2007/000190

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