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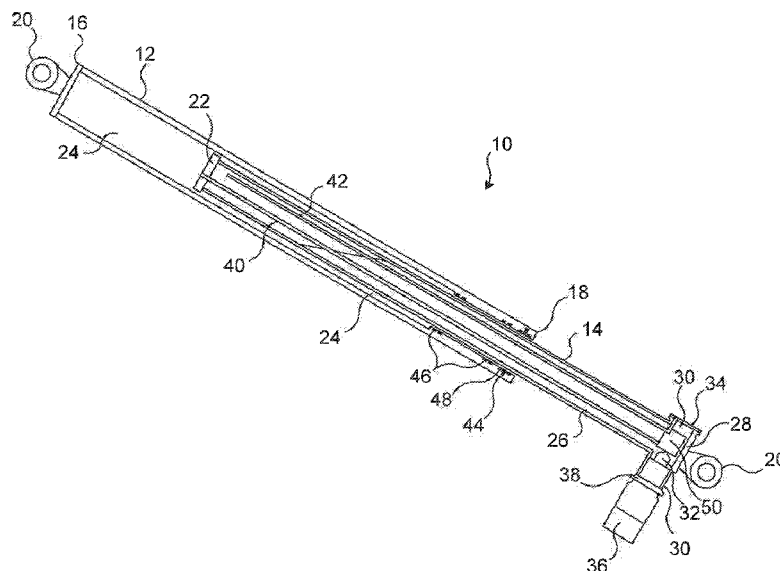


Fig. 1

(57) Abstract: A hydraulic actuator with an internal hydraulic reservoir and hydraulic conduits comprising a stationary piston rod containing the hydraulic reservoir. A motor-pump assembly is mounted to the base of the actuator and a cylinder is extended when fed with hydraulic oil through the stationary piston rod.

## HYDRAULIC ACTUATOR

### Technical Field

The present disclosure generally relates to hydraulic actuators. In particular, a hydraulic actuator with a reservoir within the rod and a crane comprising the hydraulic actuator are described.

### Background

Cranes are commonly used on vessels and offshore installations for lifting and lowering loads. One type of crane for offshore use is a knuckle boom crane. Such crane often includes a hydraulic actuator for controlling movement of the main jib relative to the king and a hydraulic actuator for controlling movement of the knuckle jib relative to the main jib.

The conventional hydraulic actuators typically employ external piping to supply and receive hydraulic fluid to and from a working chamber of the actuator. External piping is generally undesirable, for example due to installation limitations and for safety reasons.

EP 2868932 A1 discloses an electro-hydraulic linear actuator device allegedly eliminating any work fluid reservoir. The device is however rather complicated. For example, there are three sliding surfaces in the device that need to be hard chromed. Moreover, an external compensation chamber is used.

EP 0949423 A1 discloses a hydraulic cylinder with a reservoir formed within the piston rod. The piston-side oil chamber is brought into communication selectively with a pump or a tank through an external change-over valve and through oil paths formed in the bottom of the cylinder. In other words, external piping needs to be provided at the cylinder bottom.

WO 9641764 A1 discloses a hydraulic unit where the piston rod is hollow by comprising a tubular portion that confines a cavity. The piston side chamber is

selectively connectable to a pump or tank through a main conduit. Thus, external piping needs to be provided to the hydraulic unit.

## Summary

Accordingly, one object of the present disclosure is to provide a hydraulic actuator with a simple and cheap structure suitable for use in a crane.

According to one aspect, a hydraulic actuator is provided, wherein the hydraulic actuator comprises a tubular body with a cap and a head; a rod slidably received through the head of the tubular body; a push chamber; a reservoir within the rod for accommodating a hydraulic fluid; and a cap conduit extending at least partly within the rod and through a wall of the rod, or through a piston, for delivering the hydraulic fluid after being pressurized into the push chamber to extend the hydraulic actuator; wherein the hydraulic actuator is configured to feed the hydraulic fluid from the push chamber to the reservoir through the wall of the rod, or through a piston, when the hydraulic actuator is retracted.

The tubular body may be a cylinder. The cap and head of the tubular body may alternatively be referred to as the base and gland, respectively. The hydraulic fluid used is typically oil.

The hydraulic actuator may be either single acting or double acting. In case the hydraulic actuator is made single acting, pressurized hydraulic fluid is only delivered to and from the push chamber. The hydraulic actuator may then be retracted by the gravity of the carried weight or by an external force. The outer diameter of the rod may be slightly smaller than the inner diameter of the tubular body. The single acting hydraulic actuator may be a plunger cylinder where the plunge is constituted by the rod.

The rod may be formed from a pipe. Hydraulic piping may be provided within the rod.

A rod sealing arrangement may be provided between the rod and the head of the tubular body. Lugs, forks or similar mounting devices may be provided at the ends of the hydraulic actuator for attachment between relatively movable parts.

The cap conduit may extend along substantially the entire length of the rod. The cap conduit may alternatively be referred to as a push chamber conduit. In case a plunger cylinder is used, the cap conduit may extend through a top wall or top portion of the rod (i.e. the plunge) and into the push chamber. The top portion of the rod or plunge is the portion facing the cap of the tubular body. Alternatively, or

in addition, the cap conduit may extend through a side wall of the rod and into the push chamber between the rod and the tubular body.

If the hydraulic actuator comprises a piston (both single acting and double acting actuators may comprise a piston), the cap conduit may extend through the piston for delivering the hydraulic fluid after being pressurized into the push chamber to extend the hydraulic actuator. In this case, the hydraulic fluid may also be fed from the push chamber to the reservoir through the piston when the hydraulic actuator is retracted. When a piston is used, the push chamber is formed between the piston and the tubular body (including the cap) and may thus be referred to as a piston-side chamber. Thus, the wall of the rod may be constituted by the piston.

The hydraulic actuator may be configured to feed the hydraulic fluid through the cap conduit when hydraulic actuator is retracted. In this variant, the hydraulic actuator may comprise only one fluid connection to and from the push chamber.

Alternatively, the hydraulic fluid in the push chamber may be fed back to the reservoir through a further conduit provided in a wall of the rod or through a piston. Thus, more than one cap conduit may be provided in a wall of the rod, or in a piston, to deliver hydraulic fluid both to and from the push chamber. One or more of the cap conduits may be provided with one-way valves. According to one realization, the pressurized hydraulic fluid is delivered to the push chamber in a first cap conduit with a one-way valve through the top portion of the rod, or through a piston, and delivered from the push chamber in a second cap conduit with a one-way valve. Each cap conduit may extend entirely within the rod and through the top portion of the rod, or through a piston. The hydraulic actuator may comprise a valve arrangement configured to selectively close and open the cap conduit to the reservoir.

The hydraulic actuator may further comprise an air conduit for communicating air between the reservoir and the atmosphere. The air conduit, also referred to as a breathing tube, may end adjacent to the top portion of the rod or a piston. The opposite end of the air conduit may be arranged adjacent to the exposed end of the rod (exposed when the hydraulic actuator is in an extended state). Thus, the air conduit may extend along substantially the entire length of the rod. The hydraulic actuator according to this variant may operate with the cap above the base.

The hydraulic actuator may further comprise a piston and a head conduit extending at least partly within the rod for delivering the hydraulic fluid after being

pressurized into a pull chamber formed between the rod, the piston and the tubular body to retract the hydraulic actuator. The hydraulic actuator according to this variant is double acting. The head conduit may comprise one or several orifices into the pull chamber. The pull chamber may also be referred to as a rod-side chamber.

5 According to one variant, the head conduit comprises at least one orifice at a laterally outer portion of the piston. Alternatively, or in addition, the head conduit comprises at least one orifice at a laterally outer portion of the rod. The head conduit may extend entirely within the rod and the piston or entirely within the rod. The head conduit may alternatively be referred to as a pull chamber conduit.

10 The hydraulic actuator may comprise a valve arrangement for selectively connecting the cap conduit and the head conduit to a source of pressurized hydraulic fluid. The source of pressurized fluid may be a pump. Alternatively, dedicated sources of pressurized hydraulic fluid may be employed to supply pressurized hydraulic fluid to the cap conduit and the head conduit. Such separate  
15 sources may be constituted by two reversible pumps mechanically connected to each other. Thereby, hydraulic power may be collected and/or used both when extending and retracting the hydraulic actuator.

In case the hydraulic actuator is single acting, a valve arrangement may be provided for closing the cap conduit and for opening the cap conduit to the  
20 reservoir, optionally through the pump. Both valve arrangements may be constituted by a hydraulic block (manifold) comprising passive or active cartridge valves. The valve arrangement may for example be hydraulically powered by the pump and electrically controlled by the electric motor.

The reservoir may have a volume at least equal to the difference between the  
25 volume of the push chamber and the volume of the pull chamber. In other words, the volume of the reservoir within the rod is sufficient for the operation of the hydraulic actuator. Thus, an external reservoir may be avoided.

The hydraulic actuator may further comprise a pump for pressurizing hydraulic fluid from the reservoir. The pump may be a variable displacement hydraulic pump.  
30 Alternatively, the pump may be configured to deliver a fixed flow of pressurized hydraulic fluid. The pump may be mechanically attached to the rod, either on the outside or within the rod.

The rod may comprise a T-coupling for receiving the pump from two alternative sides prior to being mounted within the rod. The T-coupling thus comprises two

pipes extending laterally from the rod. The outlets of the T-coupling may be provided with openable lids such that either one of the two pipes can be selected for pump installation after the hydraulic actuator has been installed. The reservoir may be provided both in the rod and in the T-coupling.

5 The hydraulic actuator may further comprise an electric motor for electrically powering the pump. The electric motor may be mechanically connected to the rod. In case the T-coupling is used, the electric motor may be attached in the opening of one of the two pipes. The electric motor, the pump and the rod may thus form an integral unit, requiring merely electrical power.

10 According to a further aspect, there is provided a crane for an offshore installation comprising a hydraulic actuator according to the present disclosure. The crane may be a knuckle boom crane. The crane may further comprise a king and a main jib, wherein the hydraulic actuator is connected between the king and the main jib.

### **Brief Description of the Drawings**

15 Further details, advantages and aspects of the present disclosure will become apparent from the following embodiments taken in conjunction with the drawings, wherein:

Fig. 1: shows a cross-sectional side view of a single acting hydraulic actuator; and

20 Fig. 2: shows a cross-sectional side view of a double acting hydraulic actuator.

### **Detailed Description**

In the following, a hydraulic actuator and a crane comprising the hydraulic actuator will be described. The same reference numerals will be used to denote the same or similar structural features.

25 Fig. 1 shows a cross-sectional side view of a single acting hydraulic actuator 10. The hydraulic actuator 10 is a plunger cylinder. In Fig. 1, the hydraulic actuator 10 is in a substantially neutral state, i.e. in a position from which the hydraulic actuator 10 may be both extended and retracted. The hydraulic actuator 10 comprises a tubular body 12, here implemented as a cylinder, and a rod 14. The  
30 rod 14 is formed from a pipe and hydraulic piping is provided within the rod 14.

The tubular body 12 comprises a cap 16 at one end and a head 18 at the opposite end. The cap 16 may alternatively be referred to as a base and the head 18 may alternatively be referred to as a gland.

5 Mounting devices 20 in the form of lugs are provided at opposite ends of the hydraulic actuator 10, one at the cap 16 of the tubular body 12 and one at the exposed end of the rod 14. The rod 14 extends through the head 18 of the tubular body 12. The rod 14 is substantially cylindrical and has an outer diameter slightly smaller than the inner diameter of the tubular body 12. A few millimetres' play, such as 2 to 3 mm, is established between a top portion 22 of the rod 14 and the  
10 tubular body 12 allowing the hydraulic fluid to bypass the top portion 22. A push chamber 24 is formed between the tubular body 12 and the exterior profile of the rod 14 within the tubular body 12.

The hydraulic actuator 10 further comprises a reservoir 26 accommodating hydraulic fluid. The reservoir 26 is arranged within the rod 14. As can be seen in  
15 Fig. 1, the reservoir 26 is constituted by the cavity within the hollow rod 14. The volume of the reservoir 26 is larger than the volume of the push chamber 24 when the hydraulic actuator 10 adopts the most extended state.

A T-coupling 28 is provided at the exposed end of the rod 14, i.e. at the end of the rod 14 next to the mounting device 20. In Fig. 1, the T-coupling 28 is integrally  
20 formed with the rod 14, i.e. made from the same piece of material. The T-coupling 28 comprises two lateral pipes 30 extending substantially perpendicular to a longitudinal axis of the rod 14.

A pump 32 is mounted within the rod 14. The pump 32 is positioned adjacent to the exposed end of the rod 14 and is substantially centrally positioned within the rod  
25 14. The inlet of the pump 32 is thereby in fluid connection with the reservoir 26. The pump 32 may be inserted into the rod 14 through either of the two pipes 30 of the T-coupling 28 by removing or opening a lid 34 (only one shown in Fig. 1).

As can be seen in Fig. 1, an electric motor 36 is mechanically connected to the rod 14. More specifically, the electric motor 36 is connected to one of the pipes 30 of  
30 the T-coupling 28 by a flange connection 38. The electric motor 36 is used to power the pump 32. The electric motor 36, the pump 32 and the rod 14 form an integral unit. By opening the lid 34 of the T-coupling 28 opposite to the electric motor 36, access to the interior of the rod 14, e.g. for service, is made possible.

A cap conduit 40 is provided within the rod 14. The cap conduit 40 extends from the pump 32 (or from a position close to the pump 32), along the rod 14 and through the top portion 22 of the rod 14 where it opens into the push chamber 24. Thus, the cap conduit 40 extends along substantially the entire length of the rod 14. In Fig. 1, the cap conduit 40 is substantially coaxial with the longitudinal axis of the rod 14.

Fig. 1 further shows that an air conduit 42 is provided within the rod 14. The air conduit 42 serves to communicate air between the reservoir 26 and the atmosphere. Thus, the hydraulic actuator 10 in Fig. 1 represents an open system and the hydraulic fluid within the reservoir 26 is at atmospheric pressure. The air conduit 42 extends along substantially the entire length of the rod 14. In Fig. 1, the air conduit 42 is arranged parallel with the cap conduit 40, i.e. substantially coaxial with the longitudinal axis of the rod 14.

One end of the air conduit 42 is positioned within the rod 14 adjacent to the top portion 22. The opposite end of the air conduit 42 is positioned at the exposed end of the rod 14. More specifically, in Fig. 1, the air conduit 42 extends from a position within the rod 14 adjacent to the top portion 22, along substantially the entire length of the rod 14, through the pipe 30 of the T-coupling 28 and finally through the lid 34 where it opens to the atmosphere.

The hydraulic actuator 10 in Fig. 1 comprises only one sealing 44 around the rod 14 or plunge. Thus, only the exterior surface of the rod 14 needs to be hard chromed. The tubular body 12 comprises two guide rings 46 for keeping the tubular body 12 straight. The distance between these guide rings 46 may be about 700 mm. The push chamber 24 extends into a volume between the guide rings 46 and down to the sealing 44. A scraper 48 is also visible in Fig. 1, adjacent to the head 18 of the tubular body 12.

The guide rings 46, the sealing 44 and the scraper 48 are provided on an interior surface of the tubular body 12 of slightly smaller diameter than the remainder of the interior surface of the tubular body 12. Thus, a step is formed between these surfaces. When the hydraulic actuator 10 adopts the most extended state, the top portion 22 contacts this step and thus works as an end stop.

In order to extend the hydraulic actuator 10, the electric motor 36 powers the pump 32 so that the pump 32 sucks unpressurized hydraulic fluid from the reservoir 26. Pressurized hydraulic fluid is delivered from the pump 32, through the

cap conduit 40, which also extends through the top portion 22, and into the push chamber 24. When a sufficiently high pressure is reached within the push chamber 24 (the limit depends for example on the gravital load imposed on the hydraulic actuator 10), the pressure forces the rod 14 to move away from the cap 16 and the hydraulic actuator 10 is extended. The effective area for this pressurization is the area of the outer diameter of the rod 14.

Since hydraulic fluid is drawn from the reservoir 26 and delivered into the push chamber 24, the amount of hydraulic fluid within the reservoir 26 decreases as the hydraulic actuator 10 is extended. In order to avoid a vacuum being created in the reservoir 26, air from the atmosphere is delivered into the reservoir 26 through the air conduit 42 as the hydraulic actuator 10 is extended. When a target extension of the hydraulic actuator 10 is reached, the push chamber 24 may be closed to maintain the hydraulic actuator 10 in this state. This may for example be realized with a valve arrangement 50 in the form of a hydraulic block (manifold) on the cap conduit 40 adjacent to the pump 32.

The hydraulic block 50 is screwed directly to the ports of the pump 32. The hydraulic piping within the rod 14 (e.g. the cap conduit 40 and the air conduit 42) is held by the hydraulic block 50. The hydraulic block 50 comprises cartridge valves (not shown) for holding the load when the pump 32 is not driven. One or more safety valves (not shown) are also provided in the hydraulic block 50.

In order to retract the hydraulic actuator 10, a fluid connection from the push chamber 24, through the top portion 22 and to the reservoir 26 is opened. This may for example be realized by opening the valve arrangement 50 on the cap conduit 40 adjacent to the exposed end of the rod 14. Hydraulic fluid is then delivered from the push chamber 24, through at least a part of the cap conduit 40 (including the top portion 22) and into the reservoir 26. The valve arrangement 50 may in this case direct the returning hydraulic fluid directly from the cap conduit 40 to the reservoir 26.

Alternatively, the returning hydraulic fluid may be directed from the push chamber 24, through the cap conduit 40 (including the top portion 22), through the pump 32 and into the reservoir 26. In this case, the pump 32 may be reversible. Thus, electric energy may be stored when retracting the hydraulic actuator 10.

As the hydraulic actuator 10 is retracted, the reservoir 26 is filled with hydraulic fluid. Thus, the air pressure within the reservoir 26 adjacent to the top portion 22

increases and air is forced from the reservoir 26, through the air conduit 42 and to the atmosphere.

Since the hydraulic actuator 10 in Fig. 1 is a single acting plunger cylinder, pressurized hydraulic fluid is only delivered to and from the the push chamber 24.

5 The hydraulic actuator 10 in Fig. 1 operates with the cap 16 above the head 18. The hydraulic actuator 10 may for example be used in a knuckle boom crane for controlling the movement of a main jib relative to the king and/or for controlling the movement of the knuckle jib relative to the main jib. Thus, the gravity force from the main jib and/or the knuckle jib, respectively, constitutes a force for  
10 retracting the hydraulic actuator 10.

The hydraulic actuator 10, the pump 32 and the electric motor 36 constitutes a hydraulic system. The installed power in the hydraulic system may be 60-70 kW, such as 65-68 kW, such as 67 kW. The nominal pressure of the pump 32 may be 300-400 bar, such as 315 bar. The diameter of the tubular body 12 may above 300  
15 mm, such as 400-500 mm, such as 420 mm. The stroke may be 5000-6000 mm, such as 5500 mm.

Reference is now made to Fig. 2 which shows a double acting hydraulic actuator 10. Mainly differences with respect to Fig. 1 will be described.

20 Instead of a top portion 22, the hydraulic actuator 10 in Fig. 2 comprises a piston 52 connected to the rod 14. The rod 14 in Fig. 2 is a piston rod. The piston 52 is slidably arranged within the tubular body 12. A sealing 54 and guide rings 56 are provided on the piston 52. In Fig. 2, the exterior surface of the rod 14 and the interior surface of the tubular body 12 are hard chromed.

25 In the hydraulic actuator 10 in Fig. 2, the push chamber 24 is formed between the piston 52 and the portion of the tubular body 12 where the cap 16 is provided. The cap conduit 40 extends from the pump 32 (or from a position close to the pump 32), along the rod 14 and through the piston 52 where it opens into the push chamber 24.

30 The hydraulic actuator 10 further comprises a head conduit 58 extending within the rod 14. More specifically, the head conduit 58 is connected to a valve arrangement 50 adjacent to the pump 32. The head conduit 58 is substantially concentrically arranged within the rod 14 and extends between the valve arrangement 50 and the piston 52, i.e. along substantially the entire length of the rod 14.

At the piston 52, the head conduit 58 transitions into a lateral conduit 60, below the sealing 54 and guide rings 56 on the piston 52. The lateral conduit 60 of the head conduit 58 ends with an orifice for delivering pressurized fluid into a pull chamber 62. The pull chamber 62 is formed between the tubular body 12, the piston 52 and the rod 14.

The valve arrangement 50 selectively connects the pump 32 to either the cap conduit 40 or the head conduit 58. Thereby, pressurized hydraulic fluid can be delivered either to the push chamber 24 or to the pull chamber 62.

When extending the double acting hydraulic actuator 10 in Fig. 2, the electric motor 36 powers the pump 32 so that the pump 32 sucks unpressurized hydraulic fluid from the reservoir 26. The valve arrangement 50 is then placed in an operational position such that pressurized hydraulic fluid is delivered from the pump 32, through the cap conduit 40, which also extends through the piston 52, and into the push chamber 24 to extend the hydraulic actuator 10.

Also in the double acting hydraulic actuator 10, hydraulic fluid is drawn from the reservoir 26 and delivered into the push chamber 24 such that the amount of hydraulic fluid within the reservoir 26 decreases as the hydraulic actuator 10 is extended. As the hydraulic fluid is drawn from the reservoir 26, air from the atmosphere is delivered into the reservoir 26 through the air conduit 42. The push chamber 24 may be closed when a target extension of the hydraulic actuator 10 is reached, for example by means of the valve arrangement 50.

In order to retract the double acting hydraulic actuator 10 in Fig. 2, pressurized hydraulic fluid is delivered into the pull chamber 62. More specifically, the valve arrangement 50 is brought into an operational position such that pressurized hydraulic fluid is fed from the pump 32 into the head conduit 58. The head conduit 58 in turn leads the pressurized hydraulic fluid through the rod 14, laterally out from the piston 52 via the lateral conduit 60 and to the orifice where the head conduit 58 opens into the pull chamber 62.

At the same time as pressurized hydraulic fluid is fed into the pull chamber 62, the cap conduit 40 opens to the reservoir 26, for example via the valve arrangement 50. The hydraulic fluid within the push chamber 24 is thereby led through the piston 52, through the cap conduit 40 and to the reservoir 26. The pressure of the pressurized hydraulic fluid within the pull chamber 62 acting on the piston 52 serves to retract the hydraulic actuator 10.

As the hydraulic actuator 10 is retracted, the amount of hydraulic fluid within the reservoir 26 increases. As a consequence, air trapped within the reservoir 26 is pressurized and thereby forced out to the atmosphere through the air conduit 42.

5 The hydraulic actuator 10 in Fig. 2 may operate in any orientation, i.e. regardless of whether the piston side is positioned above the rod side. Also the hydraulic actuator 10 in Fig. 2 may be used in a crane, such as a knuckle boom crane, for controlling relative movement between jibs.

As can be seen in the figures, the hydraulic actuator 10 merely requires an electrical connection for its operation. Thereby, an external reservoir or tank and  
10 external piping can be avoided. For example, no external piping is required to supply pressurized hydraulic fluid into the push chamber 24.

According to the present disclosure, electricity may only be needed when extending the hydraulic actuator 10. Furthermore, in case the hydraulic actuator 10 is employed in a knuckle boom crane to drive a main jib relative to the king, no  
15 hydraulic power unit (HPU) is needed in the king.

With a single acting hydraulic actuator 10 according to the present disclosure, only the exterior surface of the rod 14 needs to be hard chromed. With a double acting hydraulic actuator 10, only the exterior surface of the rod 14 and the interior surface of the tubular body 12 need to be hard chromed. Additionally, the hydraulic  
20 actuator 10 according to the present disclosure merely includes one sealing with a potential leakage hazard.

While the present disclosure has been described with reference to exemplary embodiments, it will be appreciated that the present invention is not limited to what has been described above. Accordingly, it is intended that the present invention  
25 may be limited only by the scope of the claims appended hereto.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence  
30 of a plurality of such elements. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

## C l a i m s

1. Hydraulic actuator (10) comprising:
  - a tubular body (12) with a cap (16) and a head (18);
  - a rod (14) slidably received through the head (18) of the tubular body (12);
  - 5       - a push chamber (24);
  - a reservoir (26) within the rod (14) for accommodating a hydraulic fluid;
  - and
  - a cap conduit (40) extending at least partly within the rod (14) and through a wall of the rod (14), or through a piston (52), for delivering the hydraulic
  - 10       fluid after being pressurized into the push chamber (24) to extend the hydraulic actuator (10); wherein the hydraulic actuator (10) is configured to feed the hydraulic fluid from the push chamber (24) to the reservoir (26) through the wall of the rod (14), or through a piston (52), when the hydraulic actuator (10) is retracted.
- 15       2. The hydraulic actuator (10) according to claim 1, wherein the cap conduit (40) extends along substantially the entire length of the rod (14).
3. The hydraulic actuator (10) according to claim 1 or 2, wherein the hydraulic actuator (10) is configured to feed the hydraulic fluid through the cap conduit (40) when hydraulic actuator (10) is retracted.
- 20       4. The hydraulic actuator (10) according to any of the preceding claims, further comprising an air conduit (42) for communicating air between the reservoir (26) and atmosphere.
5. The hydraulic actuator (10) according to claim 4, wherein the air conduit (42) extends along substantially the entire length of the rod (14).
- 25       6. The hydraulic actuator (10) according to any of the preceding claims, further comprising a valve arrangement (50) configured to selectively close and open the cap conduit (40) to the reservoir (26).
7. The hydraulic actuator (10) according to any of the preceding claims, further comprising a piston (52) and a head conduit (58) extending at least partly
- 30       within the rod (14) for delivering the hydraulic fluid after being pressurized into a pull chamber (62) formed between the rod (14), the piston (52) and the tubular body (12) to retract the hydraulic actuator (10).

8. The hydraulic actuator (10) according to claim 7, wherein the head conduit (58) comprises at least one orifice at a laterally outer portion of the piston (52).
- 5 9. The hydraulic actuator (10) according to claim 7 or 8, further comprising a valve arrangement (50) for selectively connecting the cap conduit (40) and the head conduit (58) to a source of pressurized hydraulic fluid.
10. The hydraulic actuator (10) according to any of claims 7 to 9, wherein the reservoir (26) has a volume at least equal to the difference between the volume of the push chamber (24) and the volume of the pull chamber (62).
- 10 11. The hydraulic actuator (10) according to any of the preceding claims, further comprising a pump (32) for pressurizing hydraulic fluid from the reservoir (26).
12. The hydraulic actuator (10) according to claim 11, wherein the rod (14) comprises a T-coupling (28) for receiving the pump (32) from two alternative  
15 sides prior to being mounted within the rod (14).
13. The hydraulic actuator (10) according to claim 11 or 12, further comprising an electric motor (36) mechanically connected to the rod (14) for electrically powering the pump (32).
14. Crane for an offshore installation comprising a hydraulic actuator (10)  
20 according to any of the preceding claims.
15. The crane according to claim 14, further comprising a king and a main jib, wherein the hydraulic actuator (10) is connected between the king and the main jib.

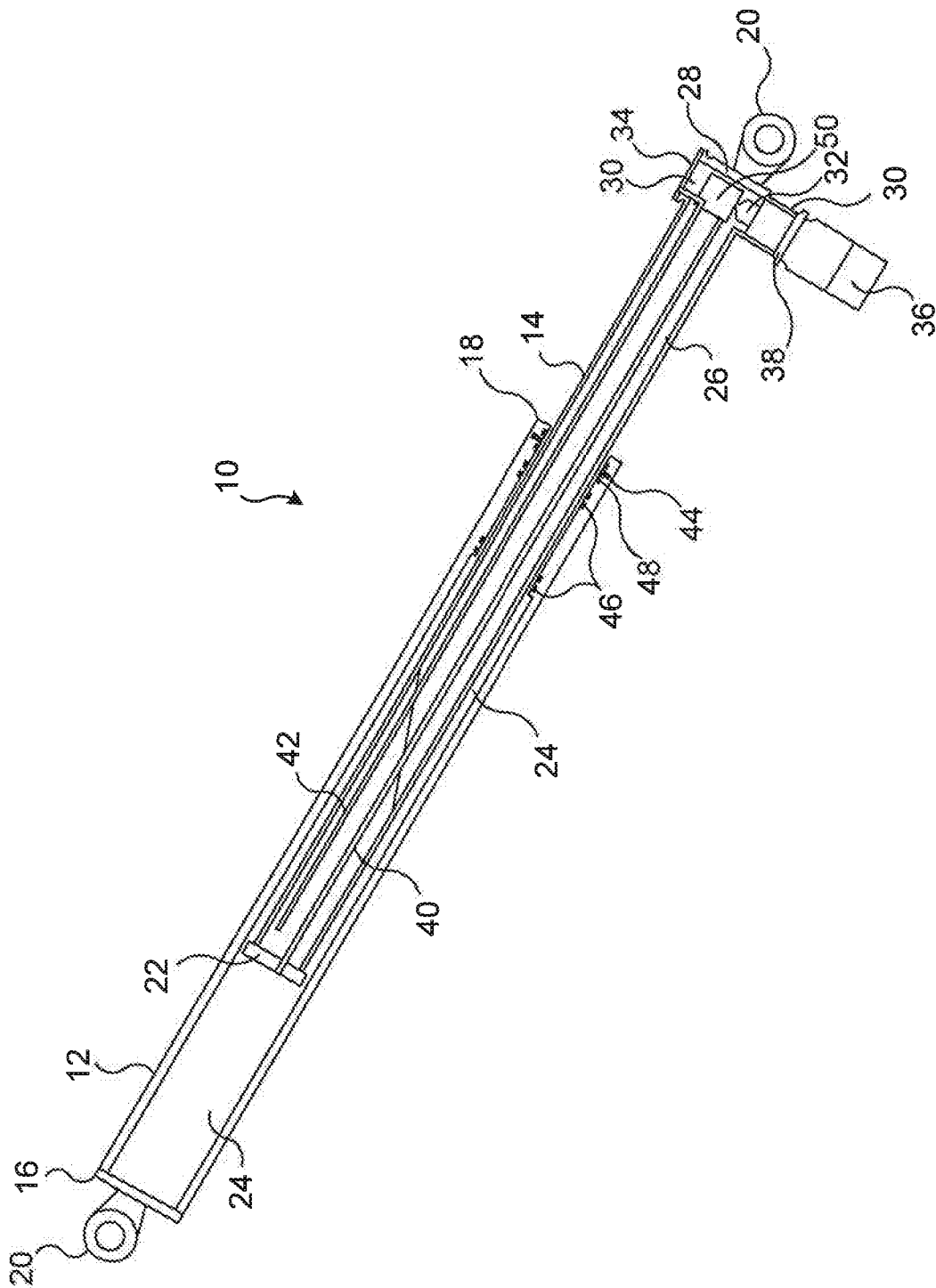


Fig. 1

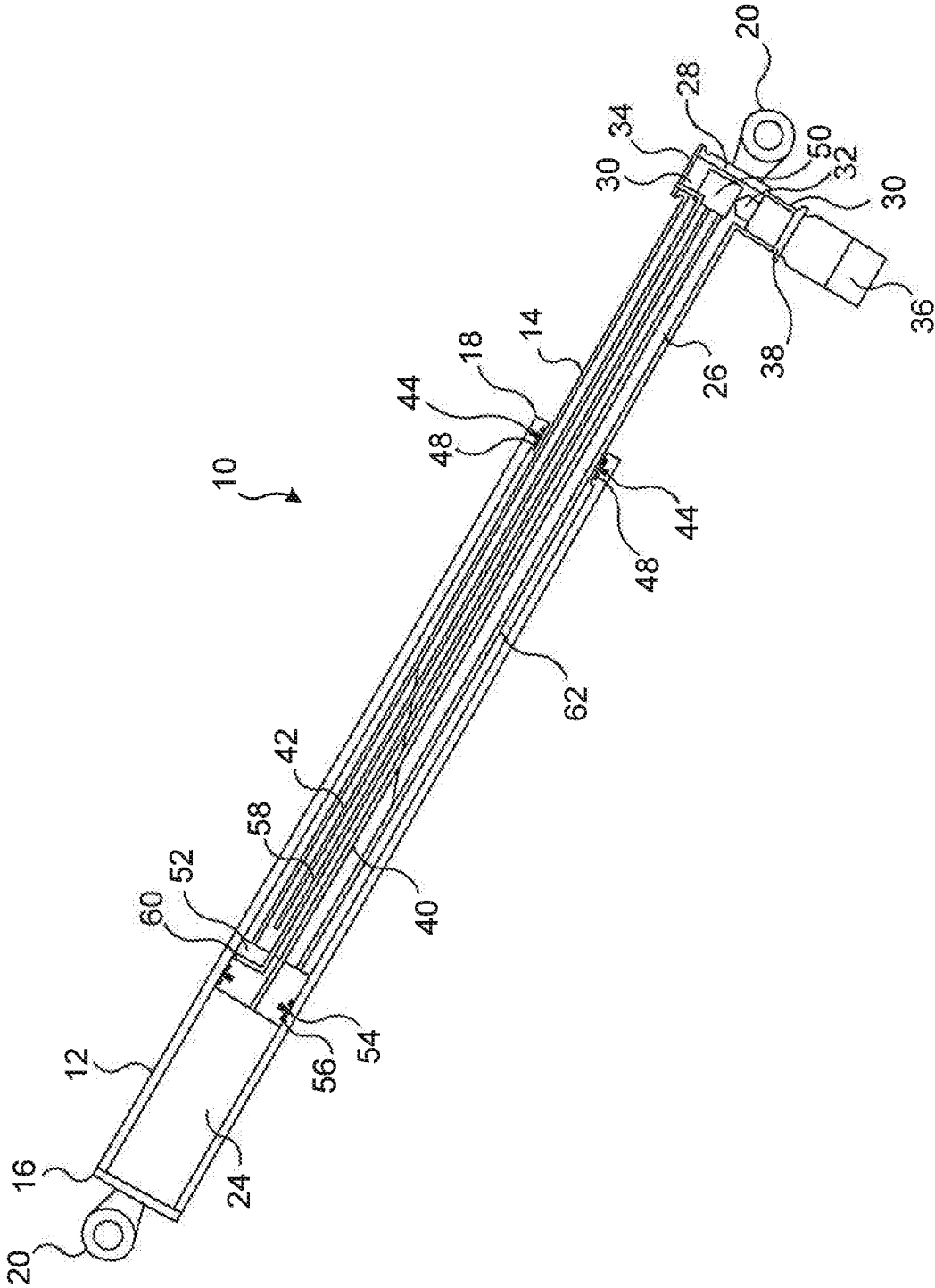


Fig. 2

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/NO2016/050143

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br>F15B 15/18 (2006.01)<br>According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                      |                                                                     |
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| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br>F15B<br><br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>DK, NO, SE, FI: Classes as above.<br><br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>EPODOC, WPI, FULL TEXT: ENGLISH, GERMAN, FRENCH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                      |                                                                     |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                      |                                                                     |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Citation of document, with indication, where appropriate, of the relevant passages                                   | Relevant to claim No.                                               |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2939284 A (DONALD G.) 1960.06.07.<br>Claim 1, 8, column 1 lines 21-32, col 3 line 59 – col 4 line 16 and figure 1 | 1-15                                                                |
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| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                      |                                                                     |
| * Special categories of cited documents:<br>“A” document defining the general state of the art which is not considered to be of particular relevance<br>“E” earlier application or patent but published on or after the international filing date<br>“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>“O” document referring to an oral disclosure, use, exhibition or other means<br>“P” document published prior to the international filing date but later than the priority date claimed<br><br>“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<br>“&” document member of the same patent family |                                                                                                                      |                                                                     |
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