

Title:

Multi capacity riser tensioners

5 Technical field:

The invention relates generally to the field of floating offshore platforms or vessels for the exploitation of undersea deposits of petroleum and natural gas. More specifically, it relates to a system and apparatus for multi capacity riser tensioners that extend from a subsea wellhead or subsurface structure to a
10 floating platform or vessel.

Background of the invention

Offshore platforms for the exploitation of undersea petroleum and natural gas
15 deposits typically support production risers that extend to the platform from one or more wellheads or structures on the seabed. In deep water applications floating platforms (such as spars, tension leg platforms, extended draft platforms and semi-submersible platforms) are typically used. These platforms are subject to motion due to wind, waves and currents. Consequently, the risers employed with such
20 platforms must be tensioned so as to permit the platform to move relative to the risers. Also, riser tension must be maintained so that the riser does not buckle under its own weight. Accordingly, the tensioning mechanism must exert a substantially continuous tension force to the riser within a well-defined range.

25 Hydro-pneumatic tensioner systems are one form of riser tensioning mechanism typically used to support risers known as "Top Tensioned Risers" on various platforms. A plurality of passive hydraulic cylinders with pneumatic accumulators is connected between the platform and the riser to provide and maintain the necessary riser tension. Platform responses to the
30 above mentioned environmental conditions, mainly heave and horizontal motions, create changes in riser length relative to the platform, causing the tensioning cylinders to stroke in and out. The spring effect resulting from the gas compression or expansion during riser stroke partially isolates the riser from the low heave platform motions. For horizontal (or drift off) motions the
35 compression of gas causes a load variation on the tensioning cylinders that is similar to that of the heave motions.

Hydraulic cylinders constituting such hydro-pneumatic tensioning systems comprise pistons, in which the piston rods are at least indirectly connected to the riser, so that the pressure induced movements of the piston relative to its cylinder results in the desired riser tensioning.

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Such hydro-pneumatic tensioner systems are presently produced in a variety of dimensions / sizes, each corresponding to a certain load capacity (further detailed below). Examples of typical state of the art riser tensioner systems are disclosed in US 4'886, 397, US 3'902'319, GB 2'109'036 and US 5'846'028 A.

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However, common for these prior art tensioner systems is that they all constitute systems designed for a particular load capacity. Normally there is space for just one tensioning system size on a drilling rig / floating platform, hence setting a clear limitation of the available load capacity range. During the design of a rig the designer, having knowledge of these prior art systems, takes into account which type of operation the rig must perform, and the tensioning systems are chosen based on the maximum requirement for that particular rig. The criteria for choice of rig, and thereby tensioning size, may be sea depths, mud weight, riser type and task. The latter normally varies from e.g. wildcat drilling requiring large dimensional systems to e.g. workover or production testing requiring significantly less riser tensioning capacity. The need for riser tensioning may be as little as 10 % of maximum capacity of the installed riser tensioner. In these cases the largest and heaviest tensioner systems are in general unsuitable since the relatively large load variations introduce risks such as fatigue on wellhead and/or riser.

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Figures 2A and 2B show principal prior art drawings of two different cylinders presently used in the industry. The effective cross section of the cylinder piston 2, being composed of a piston rod 2' and a piston head 2'' and slidingly journaled within the cylinder 1, determines in addition to the net pressure difference across the piston head 2'' the total force ($F = pA$) exerted onto the cylinder piston 2 and thereby on the riser in question (not shown). A gas pressure source and a suitable high-pressure pneumatic accumulator 5 allow at least some control of the piston movement induced cylinder pressure.

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To ensure correct capacity for the various rig requirements during design, primarily two alternative arrangements have been chosen; single acting (figure 2A) and double acting (figure 2B).

Single acting: The simplest way of arranging the hydraulic cylinder in riser tensioning systems is as a so-called single acting cylinder, hereinafter referred to as a plunger. In a plunger the piston head 2'' is normally seal free and comprises several piston perforations 6 perforating the head 2'', thereby equalizing the pressure (P) above and below the piston head 2. When the piston 2 is displaced within the cylinder 1 the cylinder fluid located therein flows through the perforations 6. Consequently, the effective cross section (A) of the piston 2 is equal to the effective radial cross section of the piston rod 2'. The required fluid pressure within the cylinder 1 is ensured by a single high pressure accumulator 5 being in fluid communication with the cylinder 1 via a high pressure conduit 8. Further, the accumulator 5 is typically divided into a high pressure gas end 5' and a high pressure fluid end 5'' by a floating piston 7, where the high pressure conduit 8 is connected to the high pressure fluid end 5''. To provide the necessary pressure on the high pressure gas end 5', and thereby causing the desired compression of the fluid in the high pressure fluid end 5'' by the resulting translational movement of the floating piston 7, a gas bank (not shown) is connected in fluid communication via a high pressure gas conduit 9 to the high pressure gas end 5'.

Dual acting: Figure 2B shows an alternative hydraulic cylinder in a prior art riser tensioning system; a dual acting cylinder. As for the plunger the dual acting system comprises a compressed cylinder 1 with a piston 2,2',2'', a high pressure accumulator 5,5',5'', a floating piston 7, a high pressure conduit 8 and a high pressure gas conduit 9. However, in contrast to the plunger arrangement the piston head 2'' in a dual acting cylinder forms a fluid tight separation with the inside walls of the cylinder 1, hence effectively dividing the cylinder 1 into two mutually fluid tight chambers; a first cylinder chamber 1' and a second cylinder chamber 1''. The separation may be achieved by arranging one or more piston seals between the inner wall of the cylinder and the circumference of the piston head 2''. To be able to control the pressure in the first cylinder chamber 1', i.e. on the piston rod 2' side, a pressure source such as a low pressure accumulator 10 is connected in fluid communication with the first cylinder chamber 1' via a low pressure conduit 11. In figure 2B this low pressure accumulator 10 is illustrated as a partly fluid filled container into which an open end of a low pressure fluid conduit 11 is inserted. The pressure formed in the first cylinder chamber 1' must be low enough to avoid that the pressure force set up in the second cylinder chamber 1'' due to the above mentioned high pressure accumulator 5,5',5'' is not

significantly counteracted. For further details about dual acting systems, see for example US 2008/0304916 A1.

5 Tensioning systems applying these two types of hydraulic cylinders provide
tensioning of risers that covers the two capacity requirements mentioned
above. More specifically, the plunger type and the dual acting type may
successfully be applied for low capacity requirements such as workover or
production testing and high capacity requirements such as wildcat drilling.
10 However, as indicated previously there is a need for a riser tensioner system
which may handle the above mentioned variations of the drilling rig
requirements without introducing any significant operational risks such as fatigue
on wellhead and/or riser.

15 Various tensioner systems have been disclosed which are able to handle
capacity variations. One example may be found in US 4'362'438 which
discloses a tensioner system having at least two hydraulic cylinders connected
to the riser in question. The purpose of the solution disclosed in US
4'362'438 is to redistribute total pressure among any remaining functional
20 hydraulic cylinders in order to maintain constant riser tensioning in case of
undesired pressure changes such as failure in one or more cylinders. Hence, it
does not provide a system that would allow a change between a large, high
capacity, system and a small, low capacity system. Another example is
publication US 4351261 A disclosing a heave compensation system that
25 adjusts to various operations with different requirements for load equalization
by means of switching between several high pressure accumulators. However,
also this solution does not allow a change between a large system having high
capacity and a small system having low capacity. Hence, all the above
mentioned publications disclose solutions to problems which differs
30 significantly from the problem of the present invention, i.e. to handle large
capacity variations due to predictable changes in drilling rig requirements.

It is therefore an object of the present invention to provide a cylinder
assembly for connection to a riser tensioning system that overcomes the
above mentioned disadvantage, that is, to provide a stable and easy
35 operational tensioning assembly that may enable switching between two fully
functional systems, each exhibiting tensioning capacities covering different
ends of the pre-calculated capacity range, for example from below 10 % and

up to 100 % of the riser tensioning capacity requirement expected throughout the rigs estimated lifetime.

Summary of the invention

5 The above-identified objects are achieved by applying the principal idea of switching between a system through which a relatively small amount of fluids flow, resulting in a correspondingly small gas compression, and a system through which a relatively large amount of fluids flow, resulting in a correspondingly large fluid compression.

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The inventive principal idea is achieved by a hydraulic cylinder unit in accordance with claim 1 when connected to a wire line riser tensioning system. The invention also concerns a method for switching a hydraulic cylinder unit between a hydraulic cylinder unit with low tension capabilities and a hydraulic cylinder unit with high tension capabilities in accordance with claim 10 and a wire line riser tensioning system for a riser connected to a floating platform in accordance with claim 11. Further beneficial features are defined in the remaining dependent claims.

20 In particular, the invention concerns a hydraulic cylinder unit for connection to a wire line riser tensioner system, comprising

- a hydraulic cylinder being separated in a first cylinder chamber and a second cylinder chamber by at least one cylinder piston comprising a piston rod and a piston head,
- 25 - a low pressure tank having a desired pressure,
- at least one first conduit arranged to provide fluid communication means between the low pressure tank and the first cylinder chamber, wherein the low pressure tank is a closed cylinder into which the first conduit is inserted,
- a high pressure fluid reservoir, and
- 30 - at least one second conduit being arranged to provide fluid communication means between the high pressure fluid reservoir and the second cylinder chamber.

The inventive cylinder unit further comprises

- 35 - at least one feedback conduit being arranged to provide direct fluid communication between the first cylinder chamber and the second cylinder chamber, and

- valve means comprising at least one valve, the valve means being in fluid communication with the at least one second conduit and the at least one feedback conduit, and arranged to provide reversible switching between the following alternative configurations:

- 5 - fluid obstruction between the low pressure tank and the first cylinder chamber, and fluid communication between the first cylinder chamber and the second cylinder chamber via the at least one feedback conduit, and
- 10 - fluid obstruction between the first cylinder chamber and the second cylinder chamber, and fluid communication between the low pressure tank and the first cylinder chamber via the at least one first conduit.

At least one of the valves constituting the valve means is preferably arranged in the at least one first conduit and may be either a three-way valve or at least
15 two two-way valves, or a combination thereof. In the case of two-way valves, at least one valve may be arranged in fluid communication on the at least one first conduit and at least one valve may be arranged in fluid communication on the at least one feedback conduit.

20 Note that there are no restrictions on the length of the above mentioned conduits. Consequently, the invention also covers the embodiment in which the cylinder / tank / reservoir are arranged in immediate proximity to each other to allow the desired fluid communication.

25 Furthermore, the piston rod may in one preferred embodiment be arranged in the first cylinder chamber.

For the receival of a riser tensioning cable that is intended to be connected to one end of a riser during use, at least one first sheave or upper sheave is
30 advantageously arranged at one of the two axial sides of the piston cylinder, in addition to at least one second sheave or lower sheave arranged at the other of the two axial sides of the piston cylinder. In a preferred embodiment of the invention at least two first sheaves and at least two second sheaves are arranged at the two axial sides of the piston cylinder.

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In another embodiment of the invention the high pressure fluid reservoir is being separated in a high pressure gas end and a high pressure fluid end by a

reservoir piston, and said at least one second conduit or high pressure conduit provides fluid communication means between the high pressure fluid end and the second cylinder chamber. This reservoir piston may be a floating piston.

- 5 The present invention also concerns a method for switching a hydraulic cylinder unit between a hydraulic cylinder unit having properties that facilitate tensioning of risers with low tension requirements, for example workover or production testing, and a hydraulic cylinder unit having properties that facilitate tensioning of risers with high tension requirements, for example
10 wildcat drilling. It should be obvious for a skilled person what is considered low tension requirements and high tension requirements as soon as the drilling task has been defined.

The inventive method comprises two steps:

- 15 - operating the valve means in a hydraulic cylinder unit in accordance with the specification given above to allow fluid communication between the first cylinder chamber and the second cylinder chamber via the at least one feedback conduit and simultaneously to prohibit fluid communication between the first cylinder chamber and the low pressure tank, and
20 - operating the valve means in a hydraulic cylinder unit in accordance with the specification given above to prohibit fluid communication between the first cylinder chamber and the second cylinder chamber, and simultaneously to allow fluid communication between the first cylinder chamber and the low pressure tank. In the former step and the latter step the hydraulic cylinder unit
25 is configured as a unit with low tension capabilities (plunger) and high tension capabilities (dual acting), respectively.

- The invention also concerns a wire line riser tensioning system for a riser connected to a floating platform. The inventive system comprises a multiple
30 of individually operated hydraulic cylinder assemblies comprising at least one hydraulic cylinder unit in accordance with the specification given above. During use, the multiple of assemblies is connectable to a riser by at least one suitable riser tensioning cable, for example made of wire or fibre rope. The pressure supplied to the second cylinder chamber via the high pressure fluid
35 reservoir is automatically adjusted as a response to the riser induced force on the cylinder piston caused by the movement of the floating platform, thereby ensuring an approximately geostationary riser positioning. At least one of the individually operated hydraulic cylinder assemblies preferably comprises at

least two hydraulic cylinder units in accordance with the specification given above.

In the following description, numerous specific details are introduced to provide a thorough understanding of embodiments of the claimed apparatus and method. One skilled in the relevant art, however, will recognize that these embodiments can be practiced without one or more of the specific details, or with other components, systems, etc. In other instances, well-known structures or operations are not shown, or are not described in detail, to avoid obscuring aspects of the disclosed embodiments.

Brief description of the drawings

Figure 1 shows a perspective view of a wire line riser tensioning system comprising a multiple of hydraulic cylinder assemblies in accordance with the prior art,

Figure 2A and 2B show sectional views of hydraulic cylinder units of type plunger and dual acting, respectively, in accordance with the prior art,

Figure 3 shows a sectional view of a hydraulic cylinder unit with multi capacity properties in accordance with the invention, and

Figure 4 shows a sectional view of an inventive hydraulic cylinder unit of the type illustrated in figure 3 with attached sheaves for receiving riser tensioning cables.

Detailed description of the drawings

Figure 1 shows a perspective view of a wire line riser tensioning system 30 in accordance with the prior art, comprising in total eight hydraulic cylinder assemblies 200 or tensioner units (corresponding to at total of sixteen hydraulic cylinder units) providing radial symmetric tension to a marine riser 40. In this particular embodiment each of the assemblies 200 has two hydraulic cylinder units 100 arranged between two pairs of sheaves 3,4 through which a set of riser tensioning cables 15 (wire cable or other flexible tensioning line) having properties suitable for the particular application is guided in order to improved force and length exchange within the system as well as to provide reliable cable guiding means. In the figure the set of cables 15 is introduced at the upper pair of sheave 3 and is exited at the lower pair of

sheaves 4. In addition, to each set of cables 15 there is arranged one or more third sheaves or turndown sheaves 41 in order to further improve the force exchange, as well as to reorientate the cables 15 in a direction towards a riser tensioning ring 45 secured around the riser 40 in question, onto which ring 45 the cables 15 are connected. During use, any movements of the floating platform (not shown) at which the riser tensioning system 30 is mounted creates a force on the riser 40 which (via the attached riser tensioning ring 45) results in a cable tension that corresponds to the force on the cylinder piston 2 in the pressurized hydraulic cylinder 1. For example, if the platform or vessel heaves upwardly, the tension in the set of riser tensioning cables 15 forces the cylinder piston 2 downwardly which, in turn, forces the high pressure hydraulic fluid out of the lower end 1'' of the hydraulic cylinder 1 and into the high-pressure accumulator 5 (see figure 2-4). Conversely, if the platform or vessel heaves downwardly, the high-pressure accumulator 5 forces additional hydraulic fluid into the lower end 1'' of the hydraulic cylinder 1, thereby forcing the cylinder piston 2 upwardly to maintain tension in the set of riser tensioning cables 15. The result is a close to geostationary riser positioning of the riser 40. The formulation "close to" signifies any movement of the riser considered to be within an acceptable range for continuous operation.

Nowadays these types of wire line riser tensioning systems are manufactured for a large range of engineering loads. Typical capacities for each hydraulic cylinder assembly are 100 kip, 125 kip, 160 kip, 200 kip, 225 kip, 250 kip and 285 kip, corresponding to 445 kN, 556 kN, 712 kN, 890 kN, 1001 kN, 1112 kN and 1268 kN expressed in SI units, and typical number of hydraulic cylinder assemblies in a tensioning system is eight, twelve or sixteen.

In principle, in order to allow a particular tension to a riser a system constituting a number of assemblies having a certain engineering load (for example eight assemblies times 100 kip (445 kN)) may be combined with another wire line tensioning system having a different configuration (for example eight times 250 kips (1112 kN)). In practice however, such a combination of systems is never implemented.

In general, the size and the number are chosen based on the maximum design requirement. For example, if one chooses a system having sixteen times 225 kips (1001 kN) the user is in effect restricted to the resulting capacity of that

particular size throughout the system's entire lifetime. To reduce the number of applied cylinders has proven to be impractical since it would necessitate entering the moonpool in open sea in order to disconnect riser tensioning cables. In addition to be both being time-consuming and costly, a solution
5 which involves letting some of the cables be suspended unsupported inside the moonpool is considered highly undesirable due to the increased risk of damaging the surrounding equipments and the actual cables.

In figures 2A and B sectional views of a hydraulic cylinder unit 100 forming
10 part of the above mentioned hydraulic cylinder assembly 200 are shown for the plunger type and the dual acting type, respectively. More specifically, the cylinder or barrel 1 illustrated in figure 2 is set in fluid communication at its lower end (piston head side) with a high-pressure accumulator 5, which in turn is pressurized by a suitable gas bank (not shown). Further, the high-
15 pressure accumulator 5 comprises in this particular embodiment a floating piston 7 slidably journaled within the accumulator 5, hence dividing the accumulator 5 into a high pressure gas end 5' and high pressure fluid end 5''. A relatively high pressure gas (e.g., nitrogen or dry air between 2000-2500 psi) is supplied from the gas bank to the high pressure gas end 5' of the
20 accumulator 5 via a high pressure gas conduit 9, thereby driving the hydraulic fluid situated in the high pressure fluid end 5'' towards the lower end or piston head side 1'' of the cylinder 1. As a result the cylinder piston 2 is pushed upwardly in the cylinder 1, thus providing the desired tensioning of the riser in question 40. To render the translational movement of the piston 2
25 possible, it is in the particular prior art arrangement illustrated in figure 2A essential that fluids arranged on each side of the piston head 2'' can flow freely between the two cylinder chambers 1', 1''. The piston head 2'' should therefore be composed of one or more through-going perforations 6 to ensure the desired fluid communication and thus pressure equalization, indicated in
30 figure 2A with the letter *P*.

The hydraulic cylinder unit shown in figure 2B (dual acting) is configured in a similar way as that shown in figure 2A (plunger). However, the principle configuration of dual acting compared to plunger differs in two essential
35 ways:

- there is no fluid communication between the first cylinder chamber (piston rod side) 1' and the second cylinder chamber (piston head side) 1'', and

- in addition to the fluid communicating high-pressure accumulator 5 attached on the cylinders 1 lower end (piston head side 1''), the upper end (piston rod side 1') is set in fluid communication with a low pressure tank 10 via a first conduit or low pressure fluid conduit 11.

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The consequence of the former differing feature is inter alia that, since there are no possibilities for pressure equalization across the piston head 2'', a low pressure zone and high pressure zone is established within the first cylinder chamber 1' and second cylinder chamber 1'', respectively. Further, the consequence of the latter differing feature is that a pressure in the first cylinder chamber 1' equals the prevailing pressure in the low pressure tank 10, or in the part of the low pressure tank 10, that is in direct fluid communication with the chamber 1'. In figure 2B the low pressure tank 10 is illustrated as a cylinder partly filled with a tank fluid 12, into which the free end of the low pressure fluid conduit 11 is inserted. Also illustrated in figure 2B are piston seals 20 arranged on the circumference of the piston head 2'' to allow fluid tight translational movements along the inner walls of the cylinder 1. There is normally no need for internal lubrication of the piston head 2'' since the hydraulic fluid filling the cylinder 1 allows adequate lubrication. However, other embodiments including dedicated piston lubrication may be envisaged.

Figure 3 shows the hydraulic cylinder unit 100 in accordance with the invention in which the principles of the hydraulic cylinder unit illustrated in figure 2A and the principles of the hydraulic cylinder unit illustrated in figure 2B have been combined. The cylinder or barrel 1 shown in figure 3 is, in a similar way as for solution seen in both figure 2A and 2B, set in fluid communication at its lower end 1'' (piston head side) with a high-pressure accumulator 5 by the use of a second conduit or high pressure fluid conduit 8. The accumulator 5 is pressurized by a suitable gas bank (not shown), normally by an additional high pressure gas conduit 9 arranged at the opposite axial end of the accumulator 5 relative to the high pressure fluid conduit 8. Further, as for the solution seen in figure 2B, the upper end (piston rod side) 1' of the cylinder 1 is set in fluid communication with a low pressure tank 10 by the use of a first conduit or low pressure fluid conduit 11.

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The high-pressure accumulator 5 comprises in this particular embodiment a floating piston 7 slidingly journaled therein, dividing the accumulator 5 into a

high pressure gas end 5' and high pressure fluid end 5''. A gas, for example nitrogen or dry air, is applied at a relatively high pressure (e.g. between 2000-2500 psi) from the gas bank to the high pressure gas end 5' of the accumulator 5, thereby driving the hydraulic fluid arranged in the high pressure fluid end 5'' through the high pressure fluid conduit 8 and towards the piston head side of the piston 2. The result is an upward movement of the piston 2 within the cylinder 1, providing the desired tensioning of the riser 40 via the corresponding riser tensioning cable 15. Note that the pressure from the gas bank may vary significantly from the above indicated range. Nowadays, an typical upper load range of riser tensioning systems is about 3000 psi. However, higher load ranges of for example 4000-5000 psi are envisaged. Likewise, the minimum pressure may be a few hundred psi, for example 200 psi.

The piston head 2'', dividing the cylinder chamber 1 into the first cylinder chamber (piston rod side) 1' and the second cylinder chamber (piston head side) 1'', is designed to sustain a fluid tight separation between the two chambers 1', 1'', preferably by arranging one or more seals 20 on the circumference of the piston head 2'' to allow continued contact with the inner wall of the cylinder 1 during piston sliding.

The upper end (piston rod side) 1' is set in fluid communication with the low pressure tank 10 by the low pressure fluid conduit 11. In figure 3 the low pressure tank 10 is illustrated as a cylinder partly filled with a tank fluid 12, into which the free end of the low pressure fluid conduit 11 is inserted. However, a skilled person would understand that any low pressure tank having the desired (or the ability to establish the desired) pressure may be used.

The configuration of the assembly in figure 3 differs from the hydraulic cylinder units shown in figure 2A and 2B in two principle ways:

- a feedback conduit 13 is arranged to provide fluid communication means between the first cylinder chamber 1' (here via the low pressure fluid conduit 11) and the second cylinder chamber 1'', and
- one or more valves 14 are arranged in the feedback conduit 13 (here situated between the feedback conduit 13 and the low pressure fluid conduit 11) to render reversible switching between the following alternative modes possible:

- to allow fluid flow from the low pressure tank 10 to the first cylinder chamber 1' (here via the low pressure fluid conduit 11) while preventing fluid flow from the first cylinder chamber 1' to the second cylinder chamber 1'' and
- 5 - to allow fluid flow from the first cylinder chamber 1' to the second cylinder chamber 1'' via the feedback conduit 13 while preventing fluid flow from the low pressure tank 10 to the first cylinder chamber 1'.

10 Reversible switching between the two intrinsic capacity potentials of the two individual systems plunger (figure 2 A) and dual acting (figure 2 B) is thus achieved.

The application of pressure from the high pressure accumulator 5, as well as fluid pressure from the low pressure tank 10, may be controlled by
15 conventional control mechanisms such as valves (not shown) operated from a platform / vessel deck situated control panel. Likewise, over-pressure relief for the high pressure accumulator 5 and the low pressure tank 10 may be provided by conventional "pop-off" pressure relief valves (not shown), as is well-known in the art.

20 In a system of riser tensioners the two longitudinal ends of each cylinder 1 are both typically equipped with assemblies of sheaves 3,4. In the particular embodiment shown in figure 4 and 1 two pair of sheaves are applied, resulting in a transmission ratio of 1:4 relative to the wire force, and a 4:1 transmission ratio of
25 the wire length. A typical dimension used in the industry is a cylinder of length 3.8 meter, having ca. 15 meter wire travel length.

In the preceding description, various aspects of the apparatus according to the invention have been described with reference to the illustrative embodiment.
30 For purposes of explanation, specific numbers, systems and configurations are set forth in order to provide a thorough understanding of the apparatus and its workings. However, this description is not intended to be construed in a limiting sense. Various modifications and variations of the illustrative embodiment, as well as other embodiments of the apparatus, which are
35 apparent to persons skilled in the art to which the disclosed subject matter pertains, are deemed to lie within the scope of the present invention.

Reference list:

- 1 Hydraulic cylinder / barrel
- 1' First cylinder chamber / piston rod side / upper end
- 1'' Second cylinder chamber / piston head side / lower end
- 2 Cylinder piston
- 2' Piston rod
- 2'' Piston head
- 3 First sheave / upper sheave
- 4 Second sheave / lower sheave
- 5 High-pressure accumulator / high-pressure fluid reservoir
- 5' High pressure gas end
- 5'' High pressure fluid end
- 6 Piston perforation / through perforation
- 7 Reservoir piston / floating piston
- 8 Second conduit / high pressure conduit
- 9 High pressure gas conduit
- 10 Low pressure tank
- 11 First conduit / low pressure conduit
- 12 Tank fluid
- 13 Feedback conduit
- 14 Valve / valve means
- 15 Riser tensioning cable
- 20 Piston seals
- 30 Wire line riser tensioning system
- 40 Riser
- 41 Third sheave / turndown sheave
- 45 Riser tensioning ring
- 100 Hydraulic cylinder unit
- 200 Hydraulic cylinder assembly

PATENT CLAIMS

1. Hydraulic cylinder unit (100) for connection to a wire line riser tensioner system (30), comprising

- 5 - a hydraulic cylinder (1) being separated in a first cylinder chamber (1') and a second cylinder chamber (1'') by at least one cylinder piston (2) comprising a piston rod (2') and a piston head (2''),
- a low pressure tank (10) having a desired pressure,
- at least one first conduit (11) arranged to provide fluid communication means between the low pressure tank (10) and the first cylinder chamber (1'),
- 10 wherein the low pressure tank (10) is a closed cylinder into which the first conduit (11) is inserted,
- a high pressure fluid reservoir (5), and
- at least one second conduit (8) being arranged to provide fluid communication means between the high pressure fluid reservoir (5) and the
- 15 second cylinder chamber (1''),

characterized in that the cylinder unit (100) further comprises

- at least one feedback conduit (13) being arranged to provide direct fluid communication between the first cylinder chamber (1') and the second cylinder chamber (1''), and
- 20 - valve means (14) comprising at least one valve; the valve means (14) being in fluid communication with the at least one second conduit (11) and the at least one feedback conduit (13), and arranged to provide reversible switching between the following alternative configurations:
 - fluid obstruction between the low pressure tank (10) and the first
 - 25 cylinder chamber (1'), and fluid communication between the first cylinder chamber (1') and the second cylinder chamber (1'') via the at least one feedback conduit (13), and
 - fluid obstruction between the first cylinder chamber (1') and the second cylinder chamber (1''), and fluid communication between the low
 - 30 pressure tank (10) and the first cylinder chamber (1') via the at least one first conduit (11).

2. Hydraulic cylinder unit (100) according to claim 1, **characterized in that**
- 35 at least one of the valves constituting the valve means (14) is arranged in the at least one first conduit (11).

3. Hydraulic cylinder unit (100) according to one of the preceding claims, **characterized in that** at the valve means (14) comprises a three-way valve.

4. Hydraulic cylinder unit (100) according to one of the preceding claims, **characterized in that** at the valve means (14) comprises

at least one valve (14) being arranged in fluid communication on the at least one first conduit (11) and

at least one valve (14) being arranged in fluid communication on the at least one feedback conduit (13).

5. Hydraulic cylinder unit (100) according to one of the preceding claims, **characterized in that** said piston rod (2') is arranged in the first cylinder chamber (1').

6. Hydraulic cylinder unit (100) according to one of the preceding claims, **characterized in that** the cylinder unit (100) further comprises

at least one first sheave (3) being arranged at one of the two axial sides of the first cylinder chamber (1), and

at least one second sheave (4) being arranged at the other of the two axial side of the first cylinder chamber (1),

the sheaves (3,4) being configured to receive a riser tensioning cable (15) connectable to one end of a riser (40) during use.

7. Hydraulic cylinder unit (100) according to one of the claims 1-5, **characterized in that** the cylinder unit (100) further comprises

at least two first sheaves (3) being arranged at one of the two axial sides of the first cylinder chamber (1), and

at least two second sheaves (4) being arranged at the other of the two axial side of the first cylinder chamber (1),

the sheaves (3,4) being configured to receive a riser tensioning cable (15) connectable to one end of a riser (40) during use.

8. Hydraulic cylinder unit (100) according to one of the preceding claims, **characterized in that** the high pressure fluid reservoir (5) is being separated in a high pressure gas end (5') and a high pressure fluid end (5'') by a reservoir piston (7),

the high pressure fluid end (5'') being arranged in fluid communication with the second cylinder chamber (1'') by the at least one second conduit (8).

9. Hydraulic cylinder unit (100) according to claim 8, **characterized in that** the reservoir piston (7) is of type floating piston (7).

5 10. Method for switching a hydraulic cylinder unit (100) between a hydraulic cylinder unit with low tension capabilities and a hydraulic cylinder unit with high tension capabilities,

characterized by

10 - operating the valve means (14) in a hydraulic cylinder unit (100) in accordance with one of claims 1-9 to allow fluid communication between the first cylinder chamber (1') and the second cylinder chamber (1'') via the at least one feedback conduit (13), and simultaneously to prohibit fluid communication between the first cylinder chamber (1') and the low pressure tank (10), to provide a hydraulic cylinder unit (100) with low tension capabilities, and

15 - operating the valve means (14) in a hydraulic cylinder unit (100) in accordance with one of claims 1-9 to prohibit fluid communication between the first cylinder chamber (1') and the second cylinder chamber (1''), and simultaneously to allow fluid communication between the first cylinder chamber (1') and the low pressure tank (10) to provide a hydraulic cylinder unit (100) with high tension capabilities.

11. Wire line riser tensioning system (30) for a riser (40) connected to a floating platform, **characterized in that** the system (30) comprises

25 a multiple of individually operated hydraulic cylinder assemblies (200) composed of at least one hydraulic cylinder unit (100) in accordance with one of the claims 1-9,

said multiple of assemblies (200) being connected to a riser (40) by at least one riser tensioning cable (15) during use,

30 wherein the pressure supplied to the second cylinder chamber (1'') via the high pressure fluid reservoir (5) is automatically adjusted as a response to the riser induced force on the cylinder piston (1) caused by the movement of the floating platform, thereby ensuring an approximately geostationary riser positioning.

35 12. Riser tensioner system in accordance with claim 11, **characterized in that** at least one of the individually operated hydraulic cylinder assemblies (200) comprises at least two hydraulic cylinder units (100) in accordance with

one of claims 1-9.