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van Daalen

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[54] **HEAVE COMPENSATOR**

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[51] **Int. Cl.** **B66d 1/48**
[58] **Field of Search** 254/172, 173; 187/20, 23; 166/.5; 175/5–7

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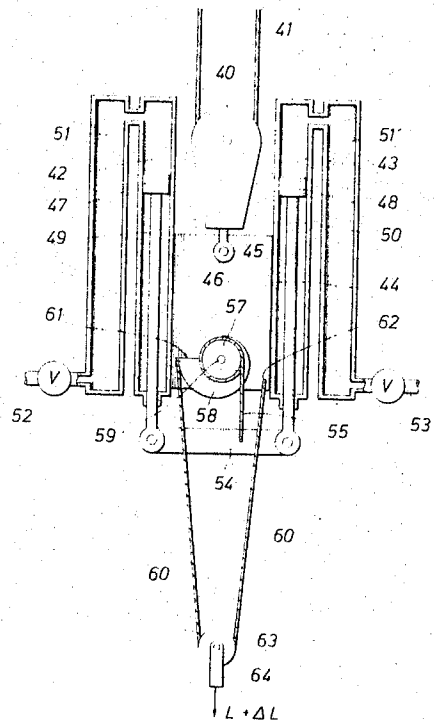
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[57] **ABSTRACT**

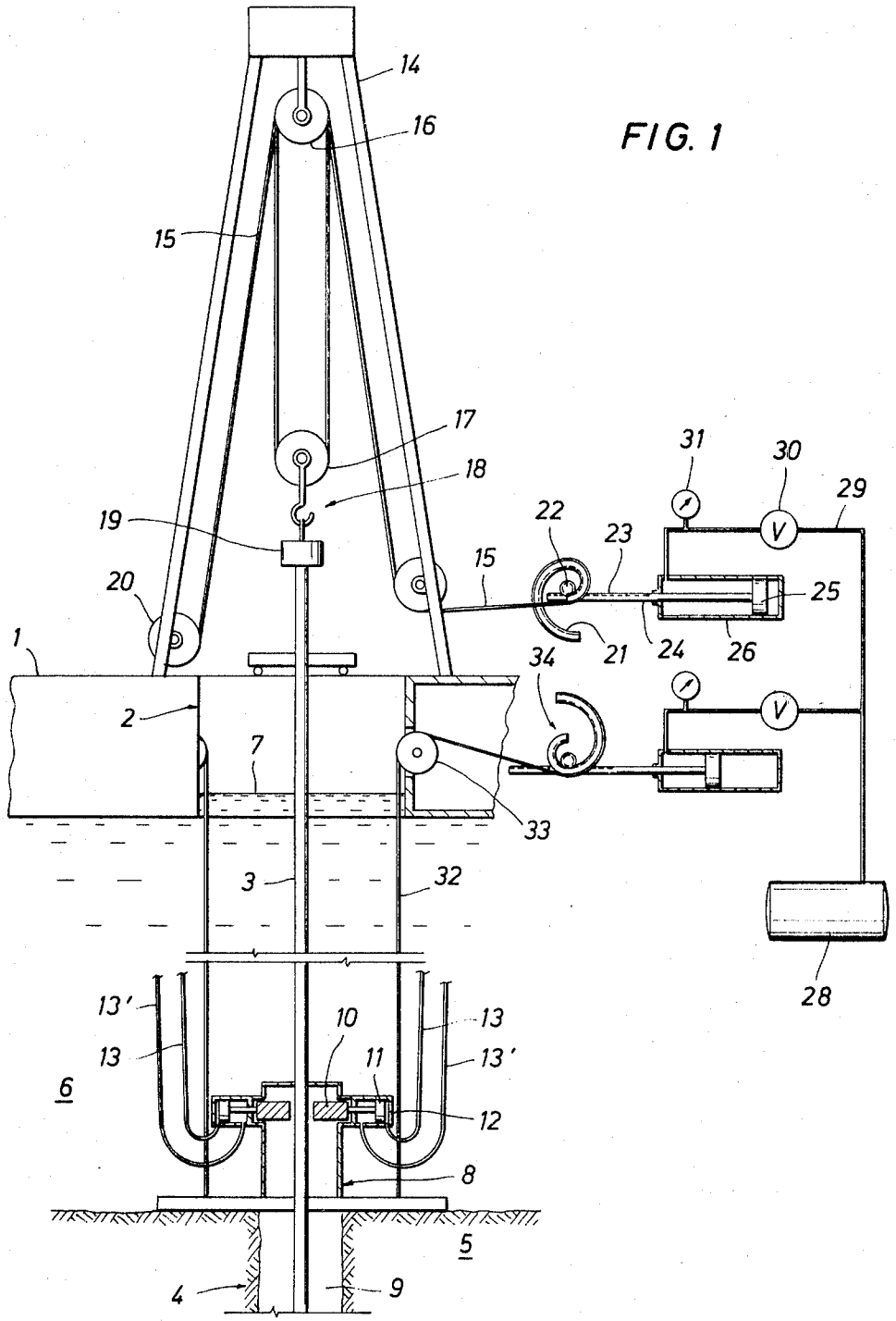
The dead end of a drilling cable is attached to a cable drum operably connected to a cylinder/piston assembly, the cable drum being spirally shaped to keep the tension in the drilling cable independent of the position of the piston.

9 Claims, 3 Drawing Figures



2 Sheets-Sheet 1

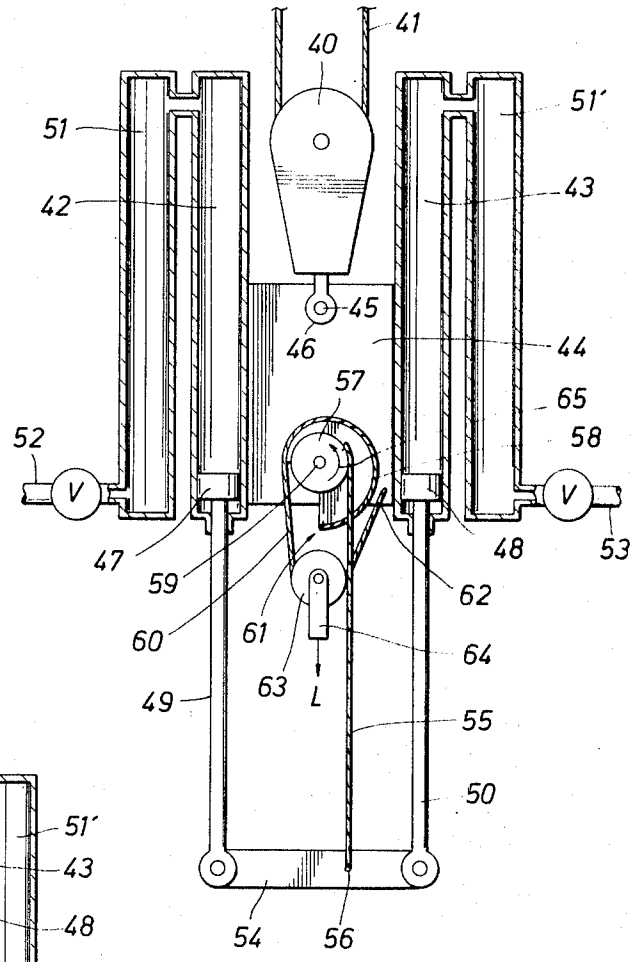
FIG. 1



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FIG. 2



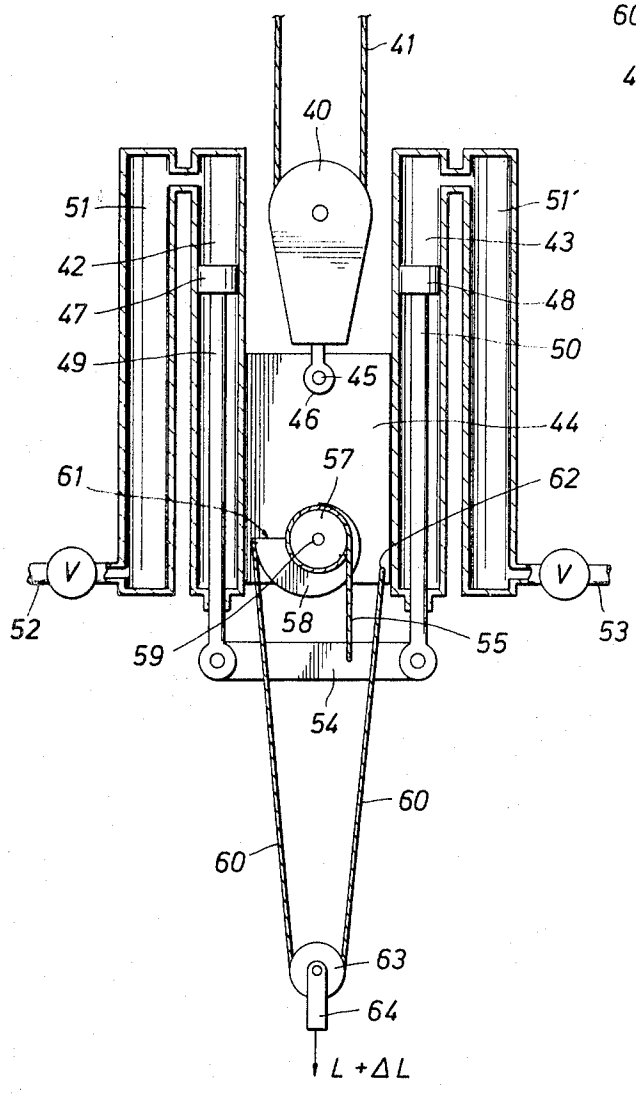


FIG. 3

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HEAVE COMPENSATOR

BACKGROUND OF THE INVENTION

The invention relates to an apparatus for maintaining a constant tension in or preventing overloading of a cable, chain or flexible conduit. In particular, the present invention relates to an apparatus for maintaining a constant tension in or preventing overloading of a cable, chain or flexible conduit having a load exerted thereon which varies as a result of variation in the distance between the ends of the cable, chain or flexible conduit or a variation in the distance between pulleys or sheaves over which the cable, chain or flexible conduit is guided.

Such apparatus may be of use in drilling boreholes in the sea bottom from a ship or other structure floating on the water. Due to the action of the waves and the vertical displacements of the drill ship resulting therefrom, the tension in the drilling cable and in the guidelines leading from the ship to the submerged wellhead varies and it is often necessary to control the magnitude of the load exerted on each cable or to make arrangements to prevent overloading of the cables.

To this end, use can be made of constant-tension winches which are provided with control equipment for measuring the load on the cable and controlling the operation of the winch as a result thereof. A disadvantage of such a system is that it needs a prime mover which has to stand by continuously. Moreover, the winches are provided with brakes which have to be engaged and disengaged each time a correction in the load is required, and as a result, they wear and require constant supervision.

Another way of keeping the load or tension in a cable constant is to connect one end of the cable to the piston rod of a piston/cylinder arrangement and maintain a constant pressure within the cylinder on one side of the piston by using a pressure detector and feeding the difference between the desired value and the measured value of the pressure in the cylinder to a controller for actuating a valve arranged in an air conduit leading from a pressure source to the cylinder and a valve arranged in a bleeding conduit connected to this cylinder. A disadvantage of this system is that rapidly occurring variations in the load of the cable cannot be quickly compensated; this being particularly true when it is required to compensate for an increase in load.

BRIEF SUMMARY OF THE INVENTION

Accordingly, this invention is directed to an apparatus suitable for maintaining a constant tension in, or preventing overloading of a cable (or chain or flexible conduit), the apparatus being inexpensive, simple in construction, reliable in operation and requiring minimum maintenance.

According to the invention, an apparatus for maintaining a constant tension in, or preventing overloading of a cable comprises a cylinder/piston arrangement having a piston connected to a cable drum through a transmission suitable to convert longitudinal displacements of the piston rod into rotation of the drum around its central axis, the drum having supporting surface for the cable, which supporting surface has a non-constant radius, one end of the cable being connected to the drum and the part of the cable adjacent to said end passing over the supporting surface.

The supporting surface for the cable may be in the shape of a conical screw or a spiral. A source of high pressure fluid is connected to the cylinder/piston arrangement. The combination of a spiral supporting surface and a cylinder/piston arrangement supplied with high pressure fluid produces a constant tension in the cable.

BRIEF DESCRIPTION OF THE DRAWING

The invention will now be described by way of example with reference to the drawing in which:

FIG. 1 shows a vertical section through part of a drill ship and drilling rig incorporating this invention;

FIG. 2 shows schematically a travelling block of a drilling rig combined with equipment according to the invention; and

FIG. 3 shows the combination of the equipment shown in FIG. 2, but with the equipment in another position.

DESCRIPTION OF A PREFERRED EMBODIMENT

The drill ship **1** which is only partly shown comprises an opening **2** through which the drill string **3** extends, which drill string is used for drilling the borehole **4** in the formation **5** below the body of water **6** having a level **7**.

The drill string **3** passes through wellhead equipment when entering the borehole **4**. For the sake of simplicity only the blow-out preventer **8** of this wellhead equipment has been shown.

This blow-out preventer **8** is used for closing the passage through the annular space **9** around the drill string **3** by means of rams **10** operated by pistons **11** arranged in cylinders **12**. The pistons are actuated by pressure fluid guided to the cylinder spaces by pressure conduits **13** and **13'** leading from the ship **1** to the cylinders **12**. Since various types of blow-out preventers are known by those skilled in the art, no further details of the blow-out preventer **8** are given. The drill string **3** is suspended from the derrick **14** on the ship **1** by means of the drilling cable **15** which is guided over the sheaves of the crown block **16** supported from the top of the derrick **14** and the sheaves of the travelling block **17** carrying the drilling hook **18**. The swivel **19** connected to the top of the drill string **3** is suspended from the hook **18**.

One end of the drilling cable **15** is attached to the hoisting drum **20** of drawworks (not shown). The other end of the cable **15** passes over the supporting surface of the cable drum **21**, mounted on a shaft (not shown) which is rotatably arranged with respect to the central axis thereof. The shaft carries a pinion **22** co-operating with a rack **23** connected to the piston rod **24**. Rod **24** is connected to the piston **25** suitably arranged in the cylinder **26** which is mounted stationary on the deck of the ship **1**.

The supporting surface of cable drum **21** has a non-constant radius and has the shape of a conical screw. A source **28** of pressure gas is further provided, this source communicating through a conduit **29** and valve **30** with one of the cylinder spaces. A pressure-indicator **31** suitable to measure and indicate the pressure in this cylinder space is mounted on the conduit **29** at a location between the valve **30** and the cylinder **26**.

Operation

The operation of the apparatus is as follows.

By opening the valve **30**, the gas pressure inside the left-hand side of the cylinder **26** is raised to value sufficiently high to keep the piston **25** in the position as shown in FIG. **1** against the force exerted on the piston rod **24** by the end of the drilling cable **15** by the cable drum **21**, the pinion **22** and the rack **23**. The valve **30** is closed when the desired pressure prevails in the left-hand side of the cylinder **26**.

In this situation, the end of drilling cable **15** attached to the cable drum **21** is kept stationary, even when the hoisting drum **20** of the drawworks having the other end of this cable **15** connected thereto, is operated to displace the drill string **3** in vertical direction. Vertical displacement of the ship as a result of wave action will not displace the piston **25** relative to the cylinder **26**, provided that the pressure as exerted in the left-hand compartment of the cylinder **26** has been chosen sufficiently high. When it is desired to close the blow-out preventer **8** for safety reasons, a high pressure is exerted on the fluid in the conduits **13** for displacing the rams **10**, which rams on closing clamp the drill string **3** therebetween. Upward movement of the ship after closing of the blow-out preventer **8** will increase the load on the drilling cable **15** until the load in the end thereof attached to the cable drum **21** is sufficiently high to move the piston **25** to the left against the gas pressure prevailing in the left side cylinder space. By this displacement of the piston, the pressure inside the cylinder space will increase owing to the decrease in volume of this space. At the same time, however, the longitudinal movement of the piston rod **24** will, as this rod is connected to the cable drum **21** via a rack and pinion system **22, 23**, rotate the cable drum **21**, thereby partly unwinding the cable **15** from the drum **21**. At the same time the radius at which the cable **15** contacts the drum **21**, is increased. With a suitable choice of the shape of the supporting surface of the cable drum **21** the increase in radius will compensate the increase in pressure in the cylinder space in such a way that the load exerted on the end of the drilling cable **15** remains substantially constant.

If

c = total length of stroke of the piston in the cylinder,

s = displacement of piston from its end position,

p_o = pressure in cylinder space in end position of piston,

p_s = pressure in cylinder when piston has been displaced over a distance "s,"

F_o = force exerted by gas pressure on piston in end position thereof,

F_s = force exerted by gas pressure on piston when piston has been displaced over distance "s,"

L = load exerted on cable end,

a = radius of pinion,

r_o = radius at which cable contacts cable drum when piston is in its end position,

r_s = radius at which cable contacts cable drum when piston has been displaced over a distance "s,"

ϕ = angle of rotation of pinion when piston is displaced over a distance "s," and

assuming that the gas in the cylinder can be described using the Ideal Gas Law (isothermal case), then

$$F_o c = F_s (c-s) \quad (1)$$

$$F_s/F_o = 1/(1-s/c) \quad (2)$$

$$L \cdot r_s = F_s \cdot a \quad (3)$$

$$L = Fo/(1-s/c) \cdot a/r_s \quad (4)$$

By choosing

$$R_s = r_o/(1-s/c) \text{ or } r_0/1-(a\phi/c) \quad (5)$$

the load on the cable

$$L = f_o \cdot a/r_o \quad (6)$$

remains constant independent of the position of the piston **25** within the cylinder **26**.

It will be appreciated that the shape of the supporting surface of the cable drum **21** is not limited to the one indicated by formula (5). Deviations may be introduced e.g., for compensating friction variations occurring during the stroke of the piston, or for compensating the variation in the angle under which the cable is fed to the cable drum.

A suitable way of designing the shape of the surface of cable drum **21** is by replacing the cable drum **21** by a drum having a constant radius and measuring the load on cable **15** in the various positions of the piston **25** within the cylinder **26**. By the load/displacement diagram thus obtained, the exact shape of the drum **21** can be calculated, wherein the particular circumstances under which the gas is compressed, and the dynamic behavior of the system have been taken into account.

In the example as shown, there is incorporated an apparatus according to the invention for maintaining a constant load on the guideline **32** extending between the ship **1** and the wellhead comprising the blow-out preventer. Since such a guideline is known to those skilled in the art, it is not described here in detail.

The upper part of the guideline **32** is passed over a sheave **33** and the end thereof is connected to a cable drum **34** having a supporting surface with a non-constant radius. This surface may be in the form of a conical screw or if only part of the surface as shown is used, have the shape of a spiral. The arrangement comprising a rack and pinion and a cylinder/piston system is similar to the one described hereinabove.

It will be appreciated that the application of the present invention is not limited to apparatuses using rack and pinion as a means for converting longitudinal displacements of the piston into rotation of the cable drum. Any other type of transmission suitable for the purpose may be applied as well. Such transmission may be formed by a roller chain connected at one end thereof to the piston **25** (or the piston rod **24**) and guided over a sprocket wheel mounted on the shaft of the cable drum. Suitable guide wheels are provided to press the chain to the sprocket wheel. If desired, at least two roller chains may be used parallel to each other.

Further, the application of the apparatus according to the present invention is not limited to keeping the load on the cable constant or preventing overloading of such a cable. The apparatus may also be used for maintaining a constant load on or preventing overloading of a chain or flexible conduit.

If the length of cable which is to be wound and unwound from the cable drum is relatively short, the supporting surface of the cable drum need not be in the shape of a conical screw, but may be shaped as a spiral. As the cable part passing over the spirally shaped sup-

porting surface is in a flat plane, the cable may be replaced by a flexible member which can be bent in one direction only, e.g., a roller chain.

The cylinder **26** may be filled with liquid instead of gas, and communicate with a high pressure vessel which is partially filled with liquid.

Instead of the piston, the cylinder of the piston cylinder arrangement may be connected to the cable drum, whereas the piston is connected via the piston rod to a fixed point of the ship.

FIGS. 2 and 3 of the drawing show an application of the apparatus according to the invention in combination with a travelling block of a drilling rig.

The travelling block **40** is suspended from the drilling cable **41**, which in its turn is suspended from a fixed block (not shown) of a drilling rig (also now shown). Pneumatic cylinders **42** and **43** are connected to each other by means of connecting plates (only one of which indicated by reference numeral **44** being shown in the drawing), and to the travelling block **40** by a pin **45** passing through openings between the plates **44** and an eye piece **46** of the travelling block **40**.

The cylinders **42** and **43** have pistons **47** and **48** respectively slidably arranged therein, these pistons being coupled to piston rods **49** and **50** respectively.

The cylinders **42** and **43** are in fluid communication with reservoirs **51** and **51'** respectively, which can be filled with high-pressure gas via valve-controlled conduits **52** and **53** respectively.

The lower ends of the piston rods **49** and **50** are mutually connected by a bridge piece **54**, to which one end of the cable **55** is connected at point **56** thereof. The other end of this cable **55** is wound on a circular drum or sheave **57** and connected thereto.

A curved drum or sheave **58** is coupled to the circular sheave **57**, the combination of these two sheaves being rotatably mounted on a shaft **59**, which is carried at the ends thereof by the connecting plates **44**. The sheave **58** has a spiral-shaped surface and has one end of a cable **60** connected thereto at the point **61**. The other end of the cable **60** is connected to a point **62** of one of the connecting plates **44**.

A sheave **63** provided with means **64** suitable to carry a load L is carried by the cable **60**.

The operation of the embodiment of the invention shown in FIGS. **2** and **3** will not be described.

When the sheave **63** is loaded by a load L, the position of the pistons **47, 48** will be as shown in FIG. **2**. In this case the gas pressure prevailing in the cylinders **42, 43** is sufficient to maintain the pistons **47, 48** in their lowest position relative to the cylinders **42, 43** against the force exerted in the cable **55** under influence of the load L exerted on the sheave **63**.

However, an increase of this load L by Δ L will increase the force in the cable **55** sufficiently to become slightly larger than the sum of the forces exerted by the gas on the pistons **47** and **48**. The pistons will then be lifted and the sheave **63** will descend. Since the spiral-shaped sheave **58** over which one end of the cable **60** passes will then be rotated in the direction indicated by the arrow **65** in FIG. **2**, the momentum exerted on the sheave **58** by the cable **60** will increase with the increase of the radius of the sheave **58** at the point thereof where the cable **60** is tangential to this sheave. As, however, the sheave **57** which is rotated simultaneously with the sheave **58** since being coupled thereto, has a constant radius, the force exerted in the cable **55** will increase as a result of this rotation of the sheave **58**.

The spiral shape of the supporting surface of the sheave **58** is chosen such that the increase of the force exerted in the cable **55** when being wound on the sheave **57** is sufficient to compensate the increase of the force exerted by the gas on the pistons **47, 48** when these pistons are lifted in the cylinders **42, 43** by the cable **55** which is being wound onto the sheave **57**.

Thus, the force exerted in the cable **60** by the load L $+ \Delta$ L will always be in equilibrium with the sum of the forces exerted by the gas on the pistons **47, 48**, provided that these pistons **47, 48** are not in one of their end positions in the cylinders **42, 43**.

The equipment according to FIGS. **2** and **3** can be used for maintaining a constant weight on bit when drilling a hole into the earth's surface. The drill string is then suspended from the sheave **63** by means **64**. During drilling the travelling block is lowered at a rate sufficient to maintain the pistons **47, 48** somewhere between their end-positions relative to the cylinders **42, 43**. The load suspended from the sheave **63** will then be constant and equal to L $+ \Delta$ L, as long as the pistons **47, 48** are not in one of their end-positions.

When drilling is carried out from a ship by means of the equipment according to FIG. **2**, displacements of the ship in a vertical sense as a result of wave action will not influence the weight on bit. Further, if a blow-out preventer situated on the wellhead of the hole which is being drilled, is closed, and the drill string is clamped between the rams of this blow-out preventer, no overload of the drill string can take place as a result of the wave action displacing the ship in a vertical sense, since the load on the drill string cannot increase above the value $+ \Delta$ L as long as the pistons **47, 48** are not in one of their end positions.

It will be understood that the equipment according to the invention and shown in FIGS. **2** and **3** can also be applied for maintaining a constant weight on the bit when drilling a hole on land. By lowering the travelling block at a rate sufficient to maintain the pistons somewhere between their end positions in the cylinders the load on the sheave **63** will remain constant.

Variations in resistance met by the drill, which result in variations in the drilling rate when the bit passes through the various layers of the underground formations will not influence the weight exerted on the bit, as long as the pistons **47, 48** are not in one of their end positions.

It will be appreciated that several amendments may be introduced in the schematic design of the embodiment of the invention as shown in FIGS. **2** and **3**. The spiral-shaped sheave **58** may be replaced by a cable drum having a supporting surface for the cable **60**, which surface has the form of a conical screw. Also, sheave **57** may be replaced by a cable drum around which more than one loop of cable **55** can be wound. Two (or even more than two) systems, each consisting of the sheaves **57, 58**, the cables **55, 60** and the sheave **63**, may be used. The sheaves **63** are then combined to form a travelling block with common means **64** to suspend a load therefrom. By applying two (or any other even number) of these systems, the unbalance of the system as shown in FIG. **2** resulting from the asymmetric location of the points **56** and **62** with respect to the central axis of the block **40**, can easily be compensated by locating the corresponding points of the other system at the other side of the central axis of the block **40**.

Alternatively, two systems, each comprising a set of sheaves **57, 58** and a cable **55** may be used. A single sheave **63** is then applied, carried by a cable which is at one end thereof connected to the spiral-shaped sheave **58** of the one system, and at its other end to the spiral-shaped sheave of the other system. The two spiral-shaped sheaves may be rotatably mounted on a common shaft to move in opposite directions when the pistons **47, 48** are displaced relative to the cylinders **42, 43.**

If desired, the sheave **57** may be replaced by a sheave having a non-constant radius, whereas the sheave **58** may be replaced by a sheave with a constant radius. By a suitable choice of the non-constant radius, the same effect can be reached as with the embodiment as shown in FIGS. **2** and **3.**

It will further even be possible to provide the sheave **57** as well as the sheave **58** with a non-constant radius. The cable-supporting surfaces of these sheaves are then designed such that when the radius of the point where cable **60** is tangential to the sheave **58** increases on rotation of the sheaves **57, 58** in one direction, the radius of the point where the cable **55** is tangential to the sheave **57** will decrease at the same time.

The cables **60** and **65** may be replaced b chains. If desired, the sheaves **57** and **58** may be replaced by sprocket wheels. If necessary, suitable guide wheels may be used for pressing the chains to the sprocket wheels.

It will be understood that the apparatus according to the invention may also be used for suspending the fixed block of a drilling cable therefrom. The apparatus shown in FIG. **2,** with the exception of the travelling block **40,** may then be placed on the water table of a derrick by connecting the cylinders **42, 43** to this water table. The fixed block of the drilling cable system is then suspended from the sheave **63,** and the travelling block is provided with a hook for supporting the drill string or other equipment used in the drilling operation.

I claim as my invention:

1. An apparatus for maintaining a constant tension in a cable, said apparatus comprising:

a cylinder/piston assembly supplied with energy from an external source;

a cable drum, said drum being mounted for rotation about a central axis and having a supporting surface for the cable, said surface having a non-constant radius, one end of the cable being connected to the drum and the part of the cable adjacent to said end passing over the supporting surface of the drum; and

a transmission means connecting said piston to the cable drum, said transmission means being suitable to convert longitudinal displacements of the piston into rotation of the cable drum about its central axis.

2. The apparatus of claim **1** wherein the supporting surface is in the shape of a spiral.

3. The apparatus of claim **1** wherein the energy source is high pressure gas.

4. The apparatus of claim **1** wherein said apparatus is mounted on a floating structure that moves vertically in response to wave action and said cable extends from said floating structure to a position that does not move in response to wave action.

5. An apparatus for maintaining a constant tension in a cable, said apparatus comprising:

a first drum having suitable means for connecting one end of the cable thereto, said first drum having a cable supporting surface having a non-constant radius;

a cylinder/piston assembly supplied with energy from an external source;

a transmission means connecting the first drum and piston of said cylinder/piston assembly, said transmission means comprising a second drum coupled to the first drum to rotate in combination therewith; and

a cable coupled between the piston and the second drum to rotate said second drum when said piston moves.

6. The apparatus of claim **5** wherein the supporting surface is in the shape of a spiral.

7. The apparatus of claim **5** wherein the energy source is high pressure gas.

8. An apparatus for maintaining a constant tension in a cable, said apparatus comprising:

a travelling block;

a pair of cylinder/piston assemblies suitably connected by a bridge piece, said assemblies moving in unison with each other through said bridge piece, said assemblies being supplied with energy from an external source;

a pair of connecting members for connecting said travelling block to said cylinder/piston assemblies;

a first drum, said drum being mounted for rotation on said pair of connecting members, said first drum having suitable means for connecting one end of the cable thereto, and said first drum having a cable supporting surface having a non-constant radius; and

a transmission means connecting the first drum to said bridge piece, said transmission means including a second drum coupled to the first drum to rotate in combination therewith and a cable coupled between the bridge piece and the second drum to rotate said second drum when said pistons move.

9. The apparatus of claim **8** wherein the supporting surface is in the shape of a spiral.

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