United States Patent

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[54] **WAVE MOTION COMPENSATING APPARATUS FOR USE WITH FLOATING HOISTING SYSTEMS**

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[52] **U.S. Cl.** **254/172,** 166/5, 175/5, 91/4, 254/189

[51] **Int. Cl.** **B66d 1/48**

[58] **Field of Search** 254/172, 173, 189; 187/26; 91/4; 166/5; 175/5

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[57] **ABSTRACT**

The dead end of the drilling line of the hoisting system of a floating drilling rig makes multiple passes between a stationary sheave assembly and a movable sheave assembly and then runs to a dead line anchor to which it is tied. A piston mechanism including a cylinder, piston, and piston rod is located on the floating rig structure and is coupled to the movable sheave assembly for controlling the spacing between the stationary and movable sheave assemblies. Fluid control apparatus communicates with the piston mechanism for controlling the fluid pressure therein for minimizing variations in the drilling line tension as the floating drilling rig or other type of floating structure rises and falls with the sea waves. The piston rod is subject to a pure tension load at all times, thereby enabling the rod to be of any suitable length to accommodate any wave height encountered.

4 Claims, 7 Drawing Figures

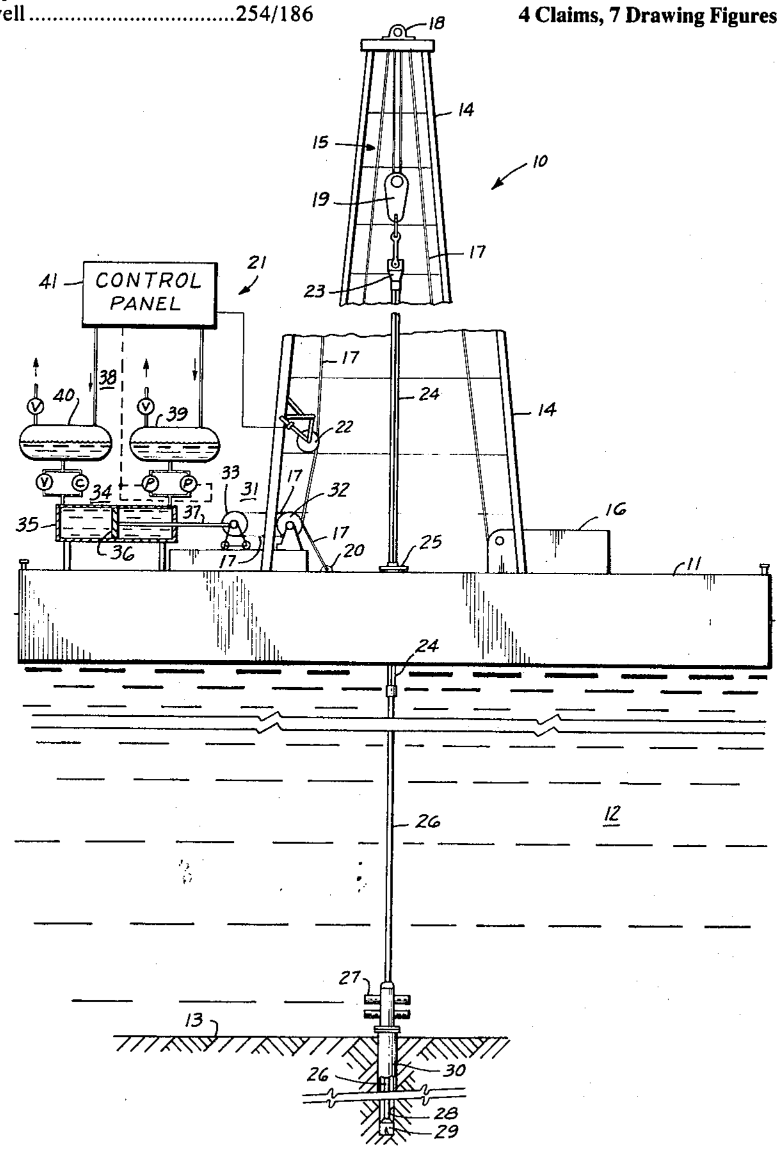
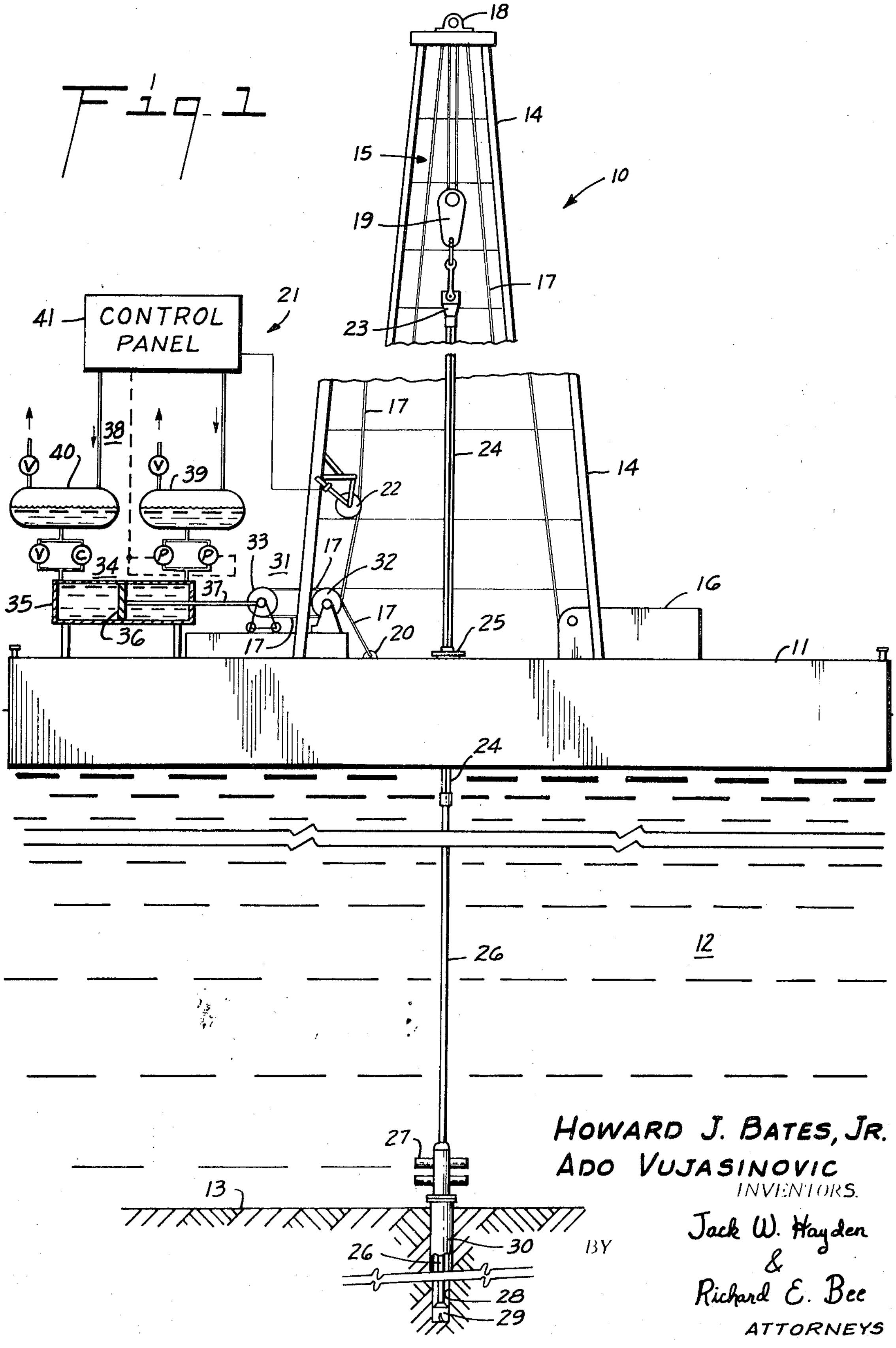


Fig. 1



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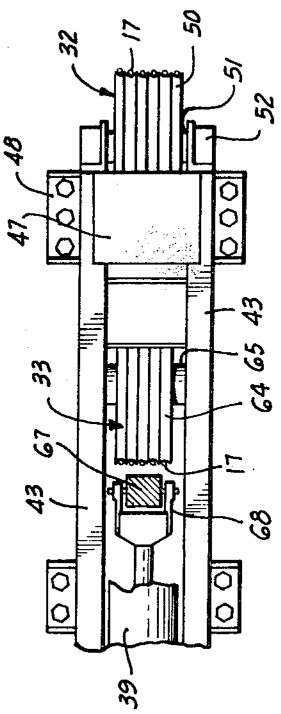

Fig. 4

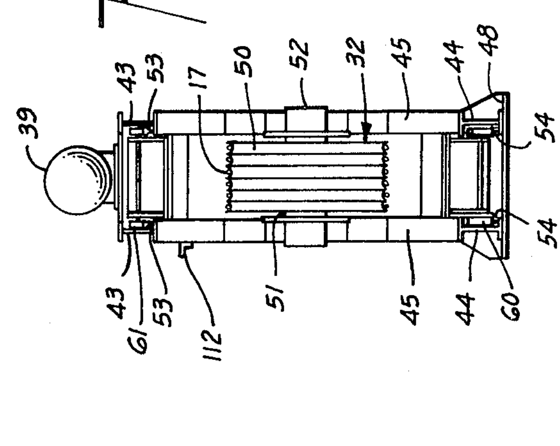

Fig. 3

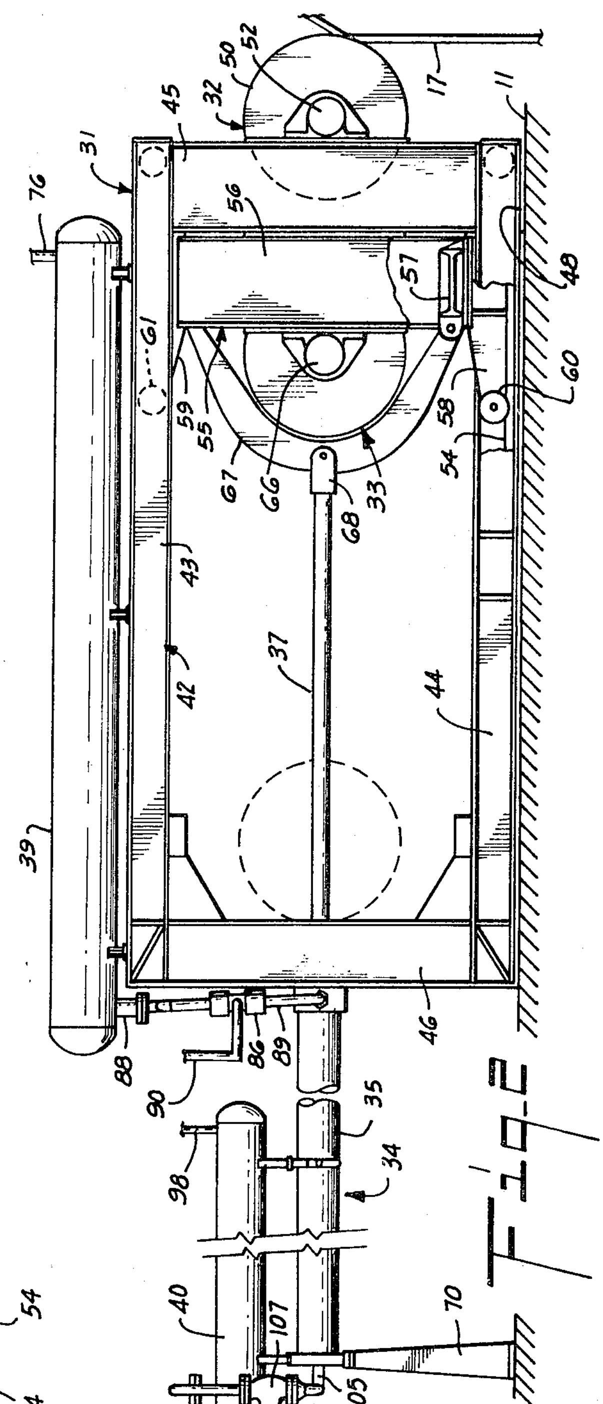

Fig. 2

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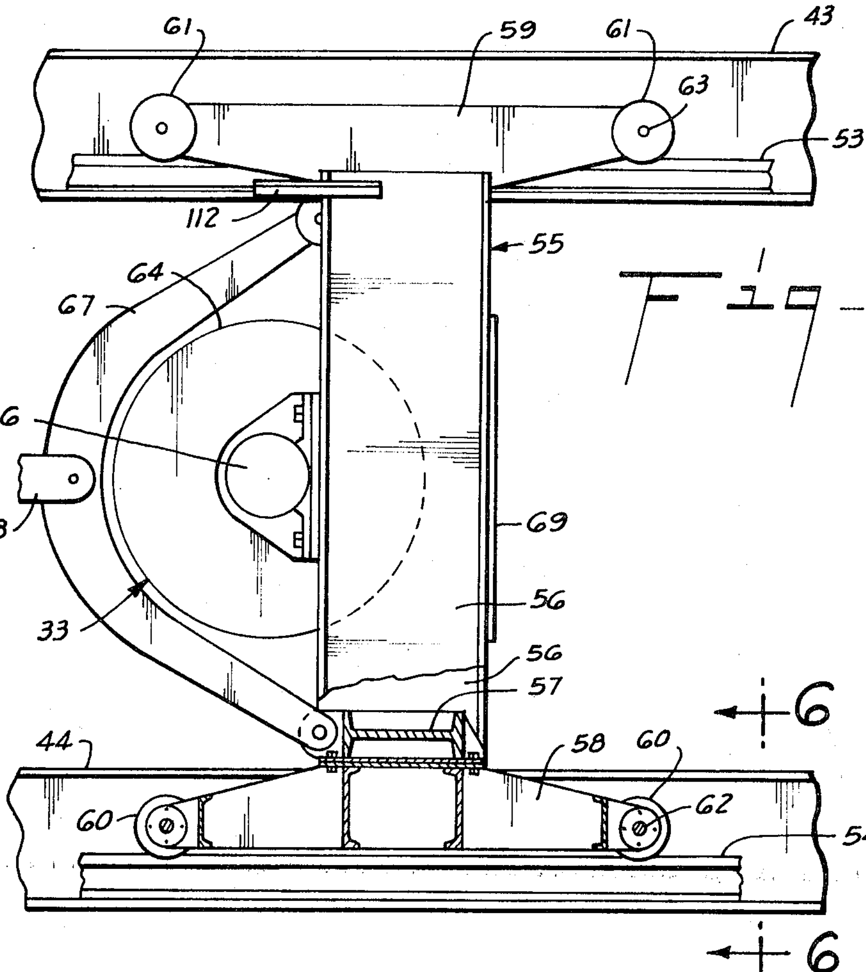

Fig. 5

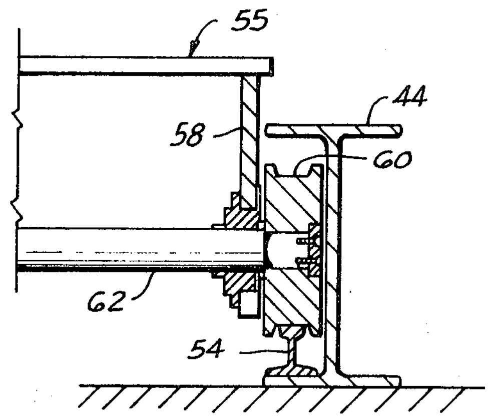

Fig. 6

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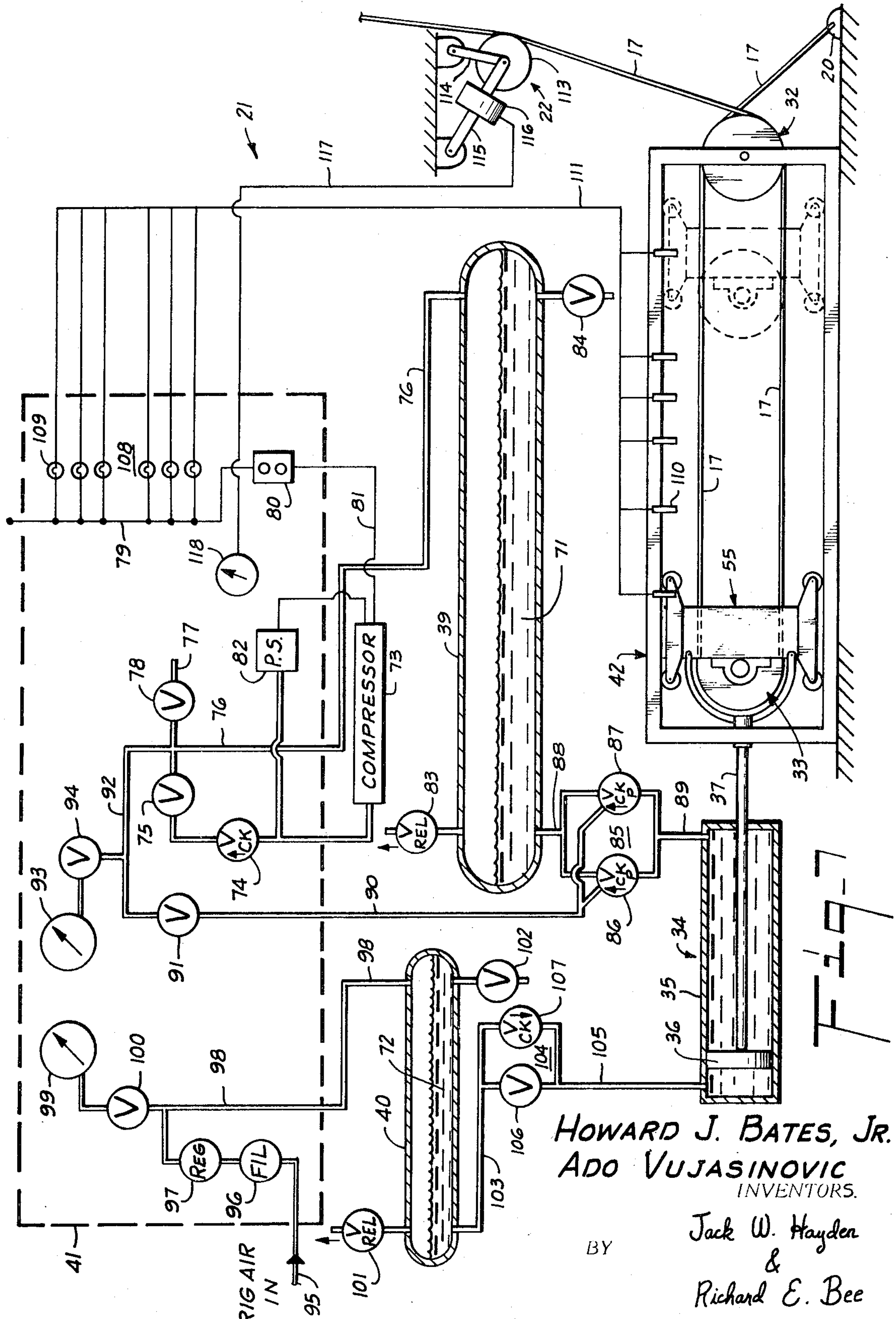

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WAVE MOTION COMPENSATING APPARATUS FOR USE WITH FLOATING HOISTING SYSTEMS

BACKGROUND OF THE INVENTION

This invention relates to wave motion compensating apparatus for use with floating hoisting systems such as those used on floating drilling rigs.

In the drilling of offshore oil and gas wells, an attempt is usually made to commence the drilling operation when the sea is relatively calm. Since several days or weeks may be required to drill the well, it sometimes happens that the sea will become quite rough before the well is completed. The rising and falling of the floating drilling rig under rough sea conditions presents problems. For example, it would be desirable to leave the drill string in the well bore so that drilling could be quickly resumed after the sea has calmed down again. If this is done, however, the rising and falling of the drill pipe during the rough sea conditions would tend to swab the well bore and could lead to an undesired blowout of the well. This can be prevented by activating the blow out preventer included in the wellhead equipment located on the ocean floor. When activated, the blowout preventer firmly engages and seals off around the drill pipe and allows only a very limited upward or downward movement thereof. This, however, causes problems aboard the floating drilling rig. In particular, since the drill string is now anchored to the ocean floor, the rising and falling of the rig places a considerable strain on the rig hoisting system and could, in fact, break the hoisting line. In addition, the upper part of the drill pipe might jam itself into the rig structure and damage the rig structure or the drill pipe or both.

These undesirable consequences could be avoided by providing some form of wave motion compensating device on board the drilling rig for maintaining a positive tension on the upper end of the drill pipe as the rig rises and falls and, at the same time, preventing such tension from exceeding the limits of the hoisting system. The use of such a device would enable the drill string to be left in the well bore so that drilling could again be commenced in fairly short order after the sea again becomes calm.

Various wave motion compensating arrangements have been heretofore proposed for use aboard a floating drilling rig. Some propose the use of rather involved systems of auxiliary sheave blocks and lines for connecting the customary travelling block to the drilling rig in a manner such that the travelling block will not rise and fall with the wave movement. Other prior proposals make use of special hydraulic piston mechanisms connected between the travelling block and the load or between the crown block and the top of the rig derrick for providing the wave motion compensation.

In general, these prior proposals tend to complicate the layout of the drilling rig hoisting system. They frequently require a substantial modification of the conventional hoisting system and sometimes require a modification of the derrick structure itself. In addition, many of the previously proposed devices are limited to use where the wave movements are relatively small, such as on the order of a few feet or less. They are not readily capable of accommodating wave movements on the order of 10 or 15 feet or more.

A further form of device which is pertinent to the present discussion is the hydropneumatic cable tensioner described in U.S. Pat. No. 3,314,657, granted to Messrs. Prud'homme and Reynolds on Apr. 18, 1967. This device employs a movable sheave block, a stationary sheave block and a piston mechanism located therebetween for purposes of controlling the tension in a cable or rope reeved between the two sheave blocks. While of general utility, this device has not heretofore been adapted for use in solving the particular problem presently being considered.

SUMMARY OF THE INVENTION

It is an object of the invention, therefore, to provide new and improved wave motion compensating systems and apparatus for use with floating hoisting systems and which substantially avoid one or more of the foregoing limitations of the arrangements heretofore proposed.

It is another object of the invention to provide new and improved hoisting system wave motion compensating apparatus for use with a floating drilling rig and which requires very little modification of the conventional drilling rig hoisting system.

It is a further object of the invention to provide new and improved hoisting system wave motion compensating apparatus for use with a floating drilling rig and which can be used when the drill string extending from the underwater well bore is clamped by the water bottom blowout preventer.

In accordance with the invention, wave motion compensating apparatus for controlling the tension in the hoisting line of a hoisting system located on a floating structure comprises sheave structure for location on the floating structure adjacent the hoisting system. In accordance with one feature of the invention, this sheave structure includes a frame structure adapted to be mounted on the deck of the floating structure, a first sheave assembly mounted at one end of the frame structure, track means carried by the frame structure, carriage means adapted for movement on the track means and a second sheave assembly carried by the carriage means. The first and second sheave assemblies are adapted to receive the dead end of the hoisting line and to pass same back and forth therebetween before passing it to a dead line anchor. The apparatus also includes a piston mechanism coupled to the movable or carriage mounted sheave assembly for controlling the position thereof. The apparatus further includes fluid control means for passing pressurized fluid to and from the piston mechanism for controlling the tension in the hoisting line. In accordance with another feature of this invention, the fluid control means includes fluid reservoir means for passing pressurized fluid to and from the piston mechanism and valve means for controlling the movement of such fluid between the reservoir means and the piston mechanism.

For a better understanding of the present invention, together with other and further objects and features thereof, reference is had to the following description taken in connection with the accompanying drawings, the scope of the invention being pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the drawings:

FIG. 1 shows a floating drilling rig including a simplified diagrammatic representation of wave motion compensating apparatus constructed in accordance with the present invention;

FIG. 2 is an elevational view showing in greater detail the major mechanical structures of the wave motion compensating apparatus shown diagrammatically in **FIG. 1**;

FIG. 3 is an elevational view looking from the right-hand end of the apparatus of **FIG. 2**;

FIG. 4 is a partial plan view of the **FIG. 2** apparatus with some of the structure removed to show some of the underlying structure;

FIG. 5 is an enlarged partially cross-sectional view of a portion of the **FIG. 2** apparatus;

FIG. 6 is a cross-sectional view of a portion of the **FIG. 5** apparatus taken along section line **6—6** thereof; and

FIG. 7 is a schematic diagram showing in greater detail the pneumatic, hydraulic and electrical systems used with the wave motion compensating apparatus of **FIG. 2**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the diagrammatic illustration of **FIG. 1**, there is shown a drilling rig **10** located on a floating structure **11** floating at the surface of a body of water **12**. The submerged land mass underlying the body of water **12** is indicated at **13**. The drilling rig **10** includes a derrick structure **14** for supporting a hoisting system designated generally at **15**. The hoisting system **15** includes drawworks **16**, a drilling line **17**, a crown block **18**, a travelling block **19** and a dead line anchor **20**. The drilling line **17** passes from the winch drum of the drawworks **16**, upwardly to the crown block **18** and then makes multiple loops back and forth between the crown block **18** and the travelling block **19**. The drilling line **17** then runs downwardly from the crown block **18**, through a sheave portion of wave motion compensating apparatus **21** and to the dead line anchor **20**, to which it is tied or otherwise secured. In its downward journey from the crown block **18**, the drilling line **17** passes over a weight indicator **22** which provides an indication of the tension in the drilling line **17**.

Operation of the winch mechanism of drawworks **16** serves to reel in or pay out the drilling line **17**, depending on the direction of operation thereof, thus causing a raising or lowering of the travelling block **19**.

Hung from the hook of the travelling block **19** is a swivel mechanism **23** which is connected to the top end of a drilling kelly **24**. Kelly **24** passes downwardly through a rotary table **25** and is connected to the top end of a string of drill pipe **26**. Drill pipe **26** extends downwardly through the water **12**, passes through a blowout preventer **27** and into a borehole **28** being drilled into the subbottom soil material **13**. A drill bit **29** is attached to the bottom end of the drill pipe **26**. The upper portion of the borehole **28** is lined with a protective pipe **30** and the blowout preventer **27** is mounted on the upper end of such pipe **30**. It is noted that the showing of the wellhead equipment located at the bottom of the body of water **12** has, for sake of simplicity, been considerably simplified. Among other things, the control lines running from the floating structure **11** to the blowout preventer **27** have been omitted.

The wave motion compensating apparatus **21** includes sheave structure **31** located on the deck of the floating structure **11** to one side of the derrick **14**. Major components of this sheave structure **31** include a stationary sheave assembly **32** and a movable sheave assembly **33**, between which the hoisting line **17** makes multiple loops back and forth before it passes to the dead line anchor **20**. The wave motion compensating apparatus **21** also includes a piston mechanism **34** coupled to the movable sheave assembly **33** for controlling the position thereof with respect to the stationary sheave assembly **32**. This piston mechanism **34** includes a piston cylinder **35**, a piston **36** and a piston rod **37** for coupling the piston **36** to the movable sheave assembly **33**. The wave motion compensating apparatus **21** further includes fluid control apparatus **38** for passing pressurized fluid to and from the piston mechanism **34**. Major components of this fluid control apparatus include a high pressure fluid reservoir **39** communicating with the rod side of the piston cylinder **35**, a low pressure fluid reservoir **40** communicating with the opposite or nonrod side of the piston cylinder **35** and a control panel **41** for controlling and monitoring the operation of the fluid reservoirs **39** and **40**.

Referring now to FIGS. **2–6**, there will be considered in detail a preferred form of construction for the sheave structure **31**. As indicated in FIG. **2**, the sheave structure **31** includes a frame structure **42** which is bolted to the deck of the floating structure **11**. This frame structure **42** includes an upper pair of longitudinal beams **43**, a lower pair of longitudinal beams **44** and forward and rearward pairs of vertical connecting beams **45** and **46**. The two resulting side frames are tied together by periodic tie plates, an upper one being indicated at **47** in FIG. **4** and a lower one being indicated at **48** in FIGS. **3** and **4**. As indicated in FIG. **4**, the lower plate **48** is adapted to be bolted to the deck of the floating structure **11**. This construction provides a narrow elongated box-like form of frame structure.

As indicated in FIGS. **3** and **4**, the fixed or stationary sheave assembly **32** includes a set of six side-by-side sheaves **50** rotatably mounted on a common shaft or axle **51**. Sheaves **50** rotate independently of one another. The axle **51** is journaled in a pair of bearing blocks **52** which are secured to the vertical front end beams **45**. If desired, the sheave assembly **32** can take the form of a conventional crown block type of sheave assembly.

Secured to and extending along the inner sides of the longitudinal beams **43** and **44** are upper and lower pairs of carriage tracks **53** and **54** which are, perhaps, best seen in FIG. **5**. In FIG. **5**, the nearer two of the beams **43** and **44** have been omitted. As indicated in the cross-sectional view of FIG. **6** for the lower rear carriage track **54**, each of the carriage tracks is mounted on the upper side of the lower interior flange portion of its longitudinal beam. These carriage tracks **53** and **54** extend the length of the longitudinal beams **43** and **44**.

As indicated in FIGS. **2** and **5**, the sheave structure **31** further includes a wheeled carriage **55** which is adapted for movement on the carriage tracks **53** and **54**. Carriage **55** includes a box-like center structure formed by vertical beams **56** and horizontal beams **57**. A lower wheel truck **58** is secured to the underside of the box-like central structure, while an upper wheel truck **59** is secured to the upper side of such structure. Wheels **60** and **61**, located at the four corners of the wheel trucks **58** and **59**, respectively, ride on the carriage tracks **53** and **54**, the lower wheels **60** riding on the lower tracks **54** and the upper wheels **61** riding on the upper tracks **53**. Wheels **60** are mounted on axles **62**, while wheels **61** are mounted on axles **63**. These axles extend laterally across the respective wheel trucks **58** and **59** and are rotatably supported by such wheel trucks **58** and **59**.

As best seen in FIG. **4**, the movable sheave assembly **33** includes a set of five side-by-side sheaves **64** rotatably mounted on a common axle **65**. Sheaves **64** rotate independently of one another. Axle **65** is journaled in a pair of bearing blocks **66** which are mounted on the rearward side of the movable carriage **55**, the closer one of these bearing blocks **66** being visible in FIGS. **2** and **5**. If desired, such sheave assembly **33** may take the form of a conventional crown block type of sheave assembly.

As indicated in FIG. **2**, the carriage **55** is coupled to the piston rod **37** by means of a yoke **67** and a clevis **68**, the legs of the yoke **67** being pinned to the central structure of the carriage **55** and the clevis **68** being mounted on the end of the piston rod **37** and pinned to the yoke **67**. As best seen in FIG. **5**, a bumper plate **69** is mounted on the forward end of the central structure of the carriage **55**. This bumper plate **69** limits the forward movement of the carriage **55** by butting against the rearward sides of the vertical front end beams **45** of the frame structure **42**. A cooperating stationary bumper plate may be mounted on and extend across between the rearward sides of such vertical front end beams **45**.

Considering now the piston mechanism **34**, such mechanism **34** is located adjacent the rearward end of the frame structure **42**, as indicated in FIG. **2**. The longitudinal center axis of the elongated piston cylinder **35** is in approximate alignment with the longitudinal center axis of the frame structure **42**. The forward end of the cylinder **35** is secured to the rearward end of the frame structure **42** and the rearward end of the cylinder **35** is supported by a support member **70**. As further indicated in FIG. **2**, the high pressure fluid reservoir **39** is in the form of an elongated cylindrical tank and is mounted on top of the frame structure **42**. The low pressure fluid reservoir **40**, on the other hand, is in the form of a cylindrical tank mounted on top of the piston mechanism **34**.

Referring now to FIG. **7**, there is shown in greater detail the pneumatic, hydraulic and electrical systems associated with the wave motion compensating apparatus **21**. It is initially noted that both sides of the piston cylinder **35** and the lower portions of the fluid reservoirs **39** and **40** are filled with oil. The oil in reservoir **39** is indicated at **71**, while the oil in reservoir **40** is indicated at **72**. The remainder of the high pressure reservoir **39** is filled with high pressure air. This high pressure air is obtained from an air compressor **73** which is connected to the reservoir **39** by way of a compressor air check valve **74**, an air shutoff valve **75** and an air conduit **76**. A vent pipe **77** is connected to the conduit **76** by way of a vent pipe shutoff valve **78**. The free end of vent pipe **77** is open to the atmosphere. The air compressor **73** includes an electrical motor which is energized by electricity supplied thereto by an electrical supply line **79**, a start-stop switch **80** and an electrical line **81**. The electrical supply line **79** is connected to the normal electrical system of the drilling rig. Associated with the air compressor **73** is a pressure switch **82** which senses the pressure on the output line of the compressor **73** and turns the compressor **73** on and off, as necessary, to keep this pressure constant. Compressor **73** is capable of providing pressurized air at a pressure of, for example, 2,500 pounds per square inch.

Coupled to the high pressure reservoir **39** is a pneumatic relief valve **83** for releasing air from the reservoir **39** when the pressure in such reservoir **39** exceeds a predetermined limit established by the release mechanism in the valve **83**. This release limit may be set at a value of, for example, 2,000 pounds per square inch. Relief valve **83** sets the maximum desired system pressure. The high pressure reservoir **39** is also provided with a normally closed drain valve **84**.

The high pressure reservoir **39** is fluidly coupled to the rod side of the piston cylinder **35** by means of a remote controlled valve mechanism **85**. This valve mechanism **85** includes a pair of pilot operated check valves **86** and **87** connected in parallel with one another. The flow lines above the check valves **86** and **87** are designated by the reference numeral **88**, while those below the check valves **86** and **87** are designated by the reference numeral **89**. The pilot mechanisms in the check valves **86** and **87** are pneumatically controlled by high pressure air which is selectively supplied thereto by way of an air line **90**, an on-off control valve **91** and an air line **92**, the latter being connected to the high pressure air line **76**. When the control valve **91** is closed, no air pressure actuating signal is supplied to the pilot mechanisms in the check valves **86** and **87**. In the absence of such an actuating signal, the check valves **86** and **87** function as check valves to only allow the passage of fluid from the piston cylinder **35** to the reservoir **39** and not vice versa. When the control valve **91** is set to its open position, the air pressure actuating signal is supplied to the valves **86** and **87** and functions to keep the check mechanisms in such valves **86** and **87** in a continuously open condition. This enables fluid to flow in either direction through the valves **86** and **87**. As will be more fully appreciated hereinafter, valve mechanism **85** provides means for quickly activating the wave motion compensating apparatus **21**.

A pressure gauge **93** is located in the control panel **41** and is connected to the high pressure line **92** by way of a gauge shutoff valve **94**. Pressure gauge **93** monitors the fluid pressure in the reservoir **39**.

Considering now the low pressure reservoir **40**, the remainder of such reservoir **40** is filled with low pressure air. This low pressure air is obtained from the drilling rig air supply system and is supplied to the reservoir **40** by way of an air supply line **95**, an air filter **96**, an air pressure regulator **97** and an air line **98**. A pressure gauge **99** is connected to the air line **98** by way of a gauge shutoff valve **100**. Gauge **99** monitors the fluid pressure in the low pressure reservoir **40**. The air pressure provided by the rig air supply may be on the order of, for example, 250 pounds per square inch. A pneumatic relief valve **101** is coupled to the low pressure reservoir **40** for releasing air from such reservoir **40** when the pressure therein exceeds a predetermined limit set by the release mechanism in the relief valve **101**. Such release limit may be set at, for example, 200 pounds per square inch. Reservoir **40** is also provided with a normally closed drain valve **102**.

The low pressure reservoir **40** is fluidly coupled to the opposite or nonrod side of the piston cylinder **35** by means of a fluid conduit **103**, a valve mechanism **104** and a fluid conduit **105**. Valve mechanism **104** includes a flow control valve **106** and a check valve **107** connected in parallel therewith. Check valve **107** enables fluid flow therethrough from the reservoir **40** to the piston cylinder **35** but does not allow fluid flow in the reverse direction. Valve **106** is set or sized to restrict the rate of flow of the oil from the piston cylinder **35** to the reservoir **40** when the piston rod **37** is being retracted. This limits the rate of retraction of such piston rod **37** and serves to prevent damage to the piston mechanism **34** in the event of a sudden decrease in the tension in the drilling line **17**. Check valve **107** together with the flow valve **106**, on the other hand, cooperate to enable a much greater rate of flow when the piston rod **37** is being extended.

The wave motion compensating apparatus **21** further includes an electrical indicator system for remotely monitoring the position of the movable sheave assembly **33** within the frame structure **42**. This indicator or position monitoring system includes a position indicator display **108** located on the control panel **41** and comprised of a series of electrical lamps **109**, each of which denotes a different position of the carriage **55** within the frame structure **42**. The position monitoring system further includes carriage position sensing means represented by a series of spaced apart microswitches **110** which are mounted on the frame structure **42**. These microswitches **110** are connected by different sets of conductors in an electrical cable **111** to different ones of the indicator lamps **109** on the control panel **41**. The microswitches **110** are tripped, one at a time, by a trip bar **112** (FIGS. **3** and **5**) which is mounted on and extends from the side of the carriage **55**. When one of the microswitches **110** is tripped, it causes a particular one of the electrical lamps **109** to be lighted, the remainder of the lamps **109** remaining unlit. The length of the trip bar **112**, together with the spacing of the microswitches **110**, is preferably selected so that one of the lamps **109** will always be lit to reveal the present position of the carriage **55**.

The weight indicator **22** which measures the tension in the drilling line **17** includes a roller **113** rotatably mounted on pivoted arms **114** and **115** for engaging the drilling line **17**. A strain gauge transducer **116** is mounted on the arm **115** for sensing the stress in such arm **115** and producing an electrical signal proportional thereto. The stress in arm **115** increases as the tension in cable **17** increases. The electrical signal generated by the transducer **116** is carried by an electrical line **117** to an electrical gauge or meter **118** which may, for convenience, be located on the control panel **41**. Meter **118** provides a visual indication proportional to the tension in drilling line **17**.

OPERATION OF THE PREFERRED EMBODIMENT

A principal use of the wave motion compensating apparatus **21** described above is as a safety device to prevent damage to the structure of the drilling rig **10** or to the drill string **26** when the blowout preventer **27** is activated to clamp the drill pipe **26** and, thus, to anchor it to the ocean floor **13**. In such case, it need not be used when the sea is relatively calm and the normal drilling of the borehole **28** is being performed. Assuming this to be the desired manner of usage, the wave motion compensating apparatus **21** may be deactivated during the normal drilling operation by setting the air compressor shutoff valve **75** to its closed to and opening the vent pipe shutoff valve **78**. This releases the pressure from the high pressure reservoir **39**. This causes the piston **36** to move to the right so as to completely extend the piston rod **37**. In this condition, the movable sheave carriage **55** abuts against the vertical front end beams **45** (FIG. **2**) at the right-hand end of the frame structure **42**. In this position, the compensating apparatus **21** has no effect on the performance of the drilling operation.

Once the piston rod **37** is completely extended for purposes of deactivating the compensating apparatus **21**, it is then desired to preset or cock the compensating apparatus **21** so that it can be quickly reactivated if conditions should warrant. This is accomplished by closing the pilot control valve **91** and the vent pipe shutoff valve **78**. After this is done, the compressor shutoff valve **75** is reopened to again pressurize the interior of the high pressure reservoir **39**. It is assumed, of course, that the air compressor **73** is turned on and is operative for supplying the high pressure air. At this time, the valves **86** and **87** function as check valves to prevent the oil **71** in the reservoir **39** from flowing back into the piston cylinder **35**.

Assume now that sea conditions become so rough that it becomes desirable to discontinue the drilling operation and to activate the blowout preventer **27** to clamp the drill pipe **26**. Before the blowout preventer **27** is activated, the wave motion compensating apparatus **21** is activated to bring it into operation. This is quickly accomplished by simply opening the pilot control valve **91**. This supplies the actuating pressure to the pilot mechanism in the valves **86** and **87** for purposes of opening the valves **86** and **87** so as to enable fluid flow in both directions therethrough. This enables the pressurized oil in the high pressure reservoir **39** to flow into the rod side of the piston cylinder **35** and to move the piston **36** toward the left. This moves the movable sheave carriage **55** away from the stationary sheave assembly **32**. When the carriage **55** reaches approximately its mid-position and the drilling rig floating structure **11** is about midway between a wave peak and a wave trough, the blowout preventer **27** is activated to clamp the drill pipe **26**. Thereafter, the compensating apparatus **21** performs its wave motion compensating function.

Considering now such wave compensating function, when the drilling rig floating structure **11** falls during the trough of a sea wave, the tension in the drilling line **17** tends to decrease. The pressure in the high pressure reservoir **39** thereupon forces more oil into the piston cylinder **35**, thus forcing the piston **36** and hence the movable sheave carriage **55** toward the left. This movement takes up the slack in the drilling line **17** in a manner which offsets the decrease in tension which would otherwise be caused by the falling of the floating structure **11**. As a consequence, the tension in the drilling line **17** remains very nearly constant.

When, on the other hand, the drilling rig floating structure **11** rises with the crest of a sea wave, the tension in the drilling line **17** tends to increase. This causes a movement of the movable sheave carriage **55** back toward the right. This, in turn, moves the piston **36** to the right and forces oil back into the high pressure reservoir **39**. If this movement should cause the pressure in the reservoir **39** to exceed the limit set back by the relief valve **83**, then such relief valve **83** releases sufficient air from the reservoir **39** to maintain the pressure therein at this limit. The movement of the movable sheave carriage **55** toward the right decreases the tension in the drilling line **17** in a manner which offsets the increase caused by the upward movement of the floating structure **11**, the net change in tension being approximately zero.

As thus seen, the wave motion compensating apparatus **21** serves to keep the tension in the drilling line **17** substantially constant. This means that a positive tension will always be maintained on the travelling block **19** and the drill string **26** connected thereto. It further means that the hoisting system **15** will not be subjected to an excessive stress when the floating structure **11** rises with the crest of a sea wave.

In a rough or approximate sense, the wave motion compensating apparatus **21** is like a large spring connected between the end of the drilling line **17** and the dead line anchor **20**. Such "spring" serves to expand and contract with the rise and fall of the sea waves to keep the drilling line **17** taut without breaking it.

After the sea has died down sufficiently to allow drilling to be resumed, the wave motion compensating apparatus **21** can again be disabled by closing the compressor shutoff valve **75** and opening the vent pipe shutoff valve **78**.

From the foregoing, it is seen that the rod end of the piston cylinder **35** is the working chamber of such cylinder **35**. The high pressure fluid in such chamber is the principal load bearing and tension controlling medium.

The presence of the oil on both sides of the piston cylinder **35** provides continuous lubrication for the inner wall of the piston cylinder **35**. The presence of the oil on the nonrod side of the piston **36**, together with the use of the low pressure reservoir **40**, provides a dampening of the movement of the piston **36** to prevent any sustained high frequency back and forth oscillations of the piston **36** following an abrupt change in drilling line tension. The use of the direction sensitive valve mechanism **104** intermediate the piston cylinder **35** and the low pressure reservoir **40** to limit the rate of movement of oil from the cylinder **35** to the reservoir **40** serves to prevent damage to the piston mechanism **34** in the event of a sudden decrease in the drilling line tension. The use of the pilot-operated check valves **86** and **87** also provides a further safety feature. In particular, if the pilot control valve **91** should be shut off without the piston rod **37** being completely extended, the check valves **86** and **87** nevertheless allow oil to move from the cylinder **35** to the reservoir **39** in the event of the occurrence of an increase in drilling line tension, which occurrence produces an extending force on the piston rod **37** if it is not completely extended.

The maximum peak-to-trough amplitude of sea wave movement which can be accommodated by the wave motion compensating apparatus **21** is determined by the length of the piston cylinder **35** (or the length of the frame structure **42**, if less) and the number of loops made by the drilling line **17** between the stationary sheave assembly **32** and the movable sheave assembly **33**. If, for example, the drilling line **17** makes the same number of loops between the sheave assemblies **32** and **33** as it does between the crown block **18** and the travelling block **19**, then there is a 1-to-1 ratio between the movement of the travelling block **19** and the movement of the movable sheave assembly **33**. In this case, a piston cylinder having an effective operating length or, more accurately, a rod stroke of 15 feet would enable the wave compensating apparatus **21** to provide compensation for sea waves as large as 15 feet in height.

The present invention is constructed so that the high pressure is exerted on the piston rod **37** to apply and maintain a pure tension force on the rod. Since there is no compression loading of the rod **37**, the problem of buckling of the rod is eliminated and therefore its length can be increased to accommodate the highest sea waves.

While there has been described what is at present considered to be a preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, intended to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. Wave motion compensating apparatus for controlling the tension in the hoisting line of a hoisting system in response to upward and downward movement of a floating structure on which the hoisting system is located comprising:

a. a frame structure for location on the deck of the floating structure adjacent the hoisting system;

b. a first sheave assembly mounted at one end of said frame structure;

c. track means carried by said frame structure;

d. carriage means adapted for movement on said track means;

e. a second sheave assembly carried by said carriage means;

f. said first and second sheave assemblies being adapted to receive the dead end of the hoisting line and to pass same back and forth therebetween before passing it to a dead line anchor;

g. a piston mechanism coupled to said carriage means for controlling the position thereof on said track means, said piston mechanism including:

1. a piston cylinder for location on the deck of the floating structure adjacent said frame structure;
2. a piston movable within said cylinder;
3. and a piston rod for coupling said piston to said carriage means;

h. and fluid control means for passing pressurized fluid to and from the piston mechanism for controlling the tension in the hoisting line in response to upward and downward movement of the floating structure with the waves, said fluid control means including:

1. high pressure fluid reservoir means communicating with the rod side of said piston cylinder;

2. fluid supply means for supplying high pressure fluid to said high pressure reservoir means;
3. low pressure fluid reservoir means communicating with the piston side of said piston cylinder;
4. fluid supply means for supplying low pressure fluid to the piston side of said piston cylinder;
5. relief valve means communicating with said high pressure reservoir means for releasing fluid therefrom when the pressure therein exceeds a predetermined limit;
6. remote controlled valve means for controlling the movement of fluid between said high pressure reservoir means and said piston cylinder on the rod side thereof;
7. and means for selectively supplying an actuating signal to said remote controlled valve means, said remote controlled valve means being comprised of pilot operated check valve means and the actuating signal is in the form of a fluid pressure signal, the check valve means, when not actuated, functioning as a check valve and, when actuated, functioning to allow passage of fluid in both directions between said high pressure reservoir means and said piston cylinder on the rod side thereof.

2. Apparatus in accordance with claim **1** wherein both sides of the piston cylinder and the lower portions of both of the reservoir means are filled with oil and the two fluid supply means supply pressurized air for filling the remainder of their respective reservoir means.

3. Apparatus in accordance with claim **1** wherein said fluid control means further includes valve means for regulating the movement of fluid between the low pressure fluid reservoir means and said piston cylinder, such valve means including means for providing a greater restriction on the flow of fluid in one direction than in the other.

4. Apparatus in accordance with claim **1** wherein said fluid control means further includes valve means for regulating the movement of fluid between the low pressure fluid reservoir means and the piston cylinder, such valve means including means for passing fluid in both directions and check valve means connected in parallel therewith for providing a second flow path only for fluid flowing from the low pressure fluid reservoir means to said piston cylinder.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,653,635 Dated April 4, 1972

Inventor(s) HOWARD J. BATES, JR. et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 55, remove "to" after "closed" and insert --position--.

Signed and sealed this 18th day of July 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents