Nov. 24, 1964 A. W. KAMMERER 3,158,206

HYDRAULIC WEIGHT CONTROL AND COMPENSATING APPARATUS

Filed July 26, 1962 2 Sheets-Sheet 1

FIG. 1.

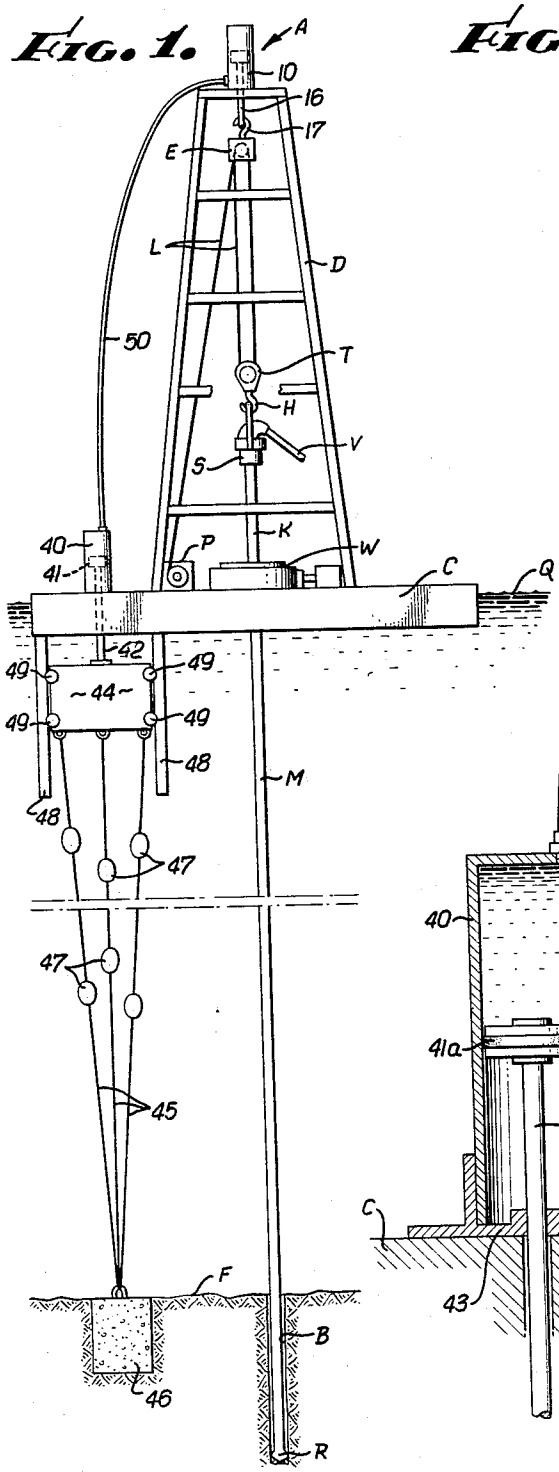
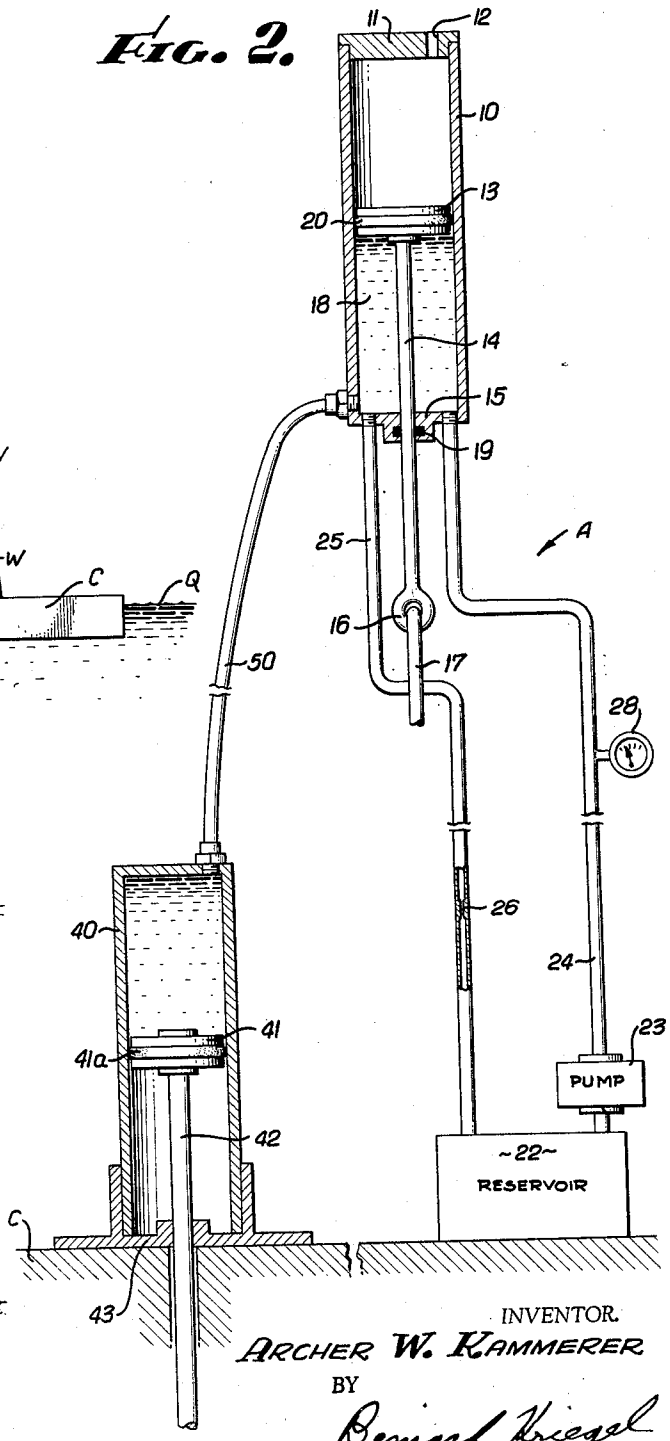


FIG. 2.



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FIG. 3.

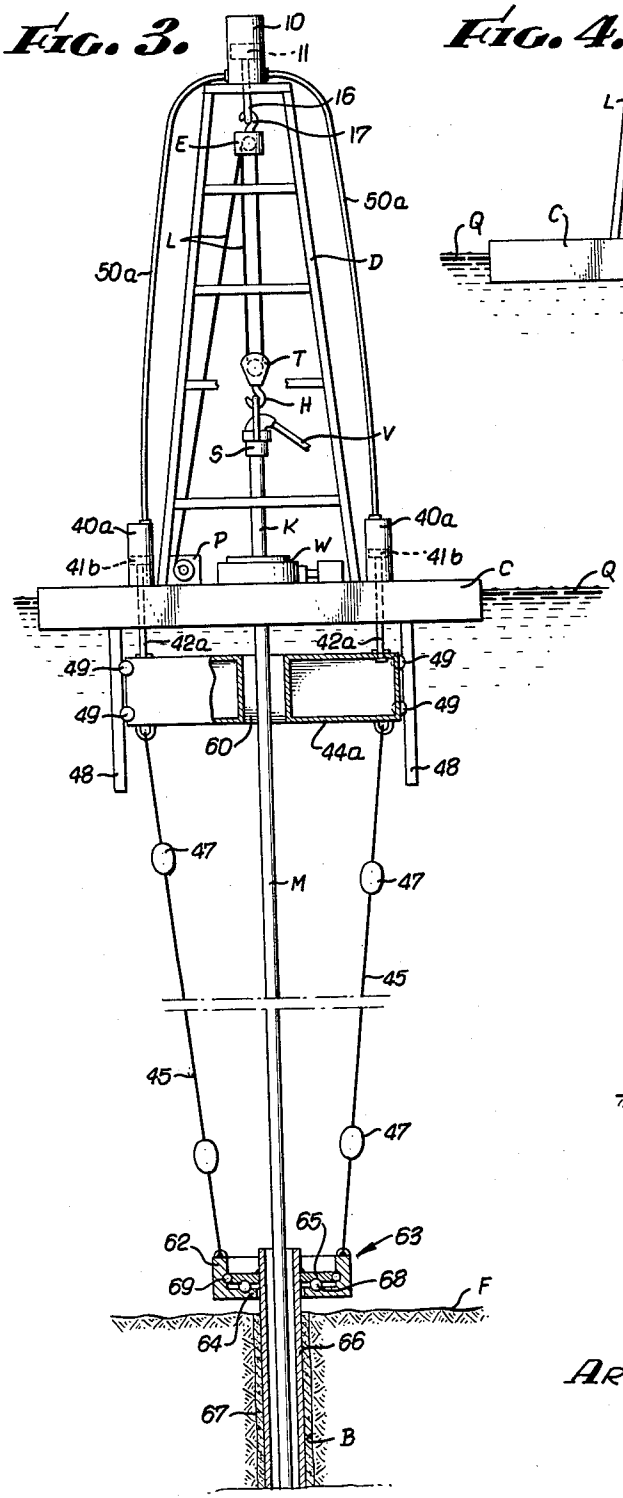
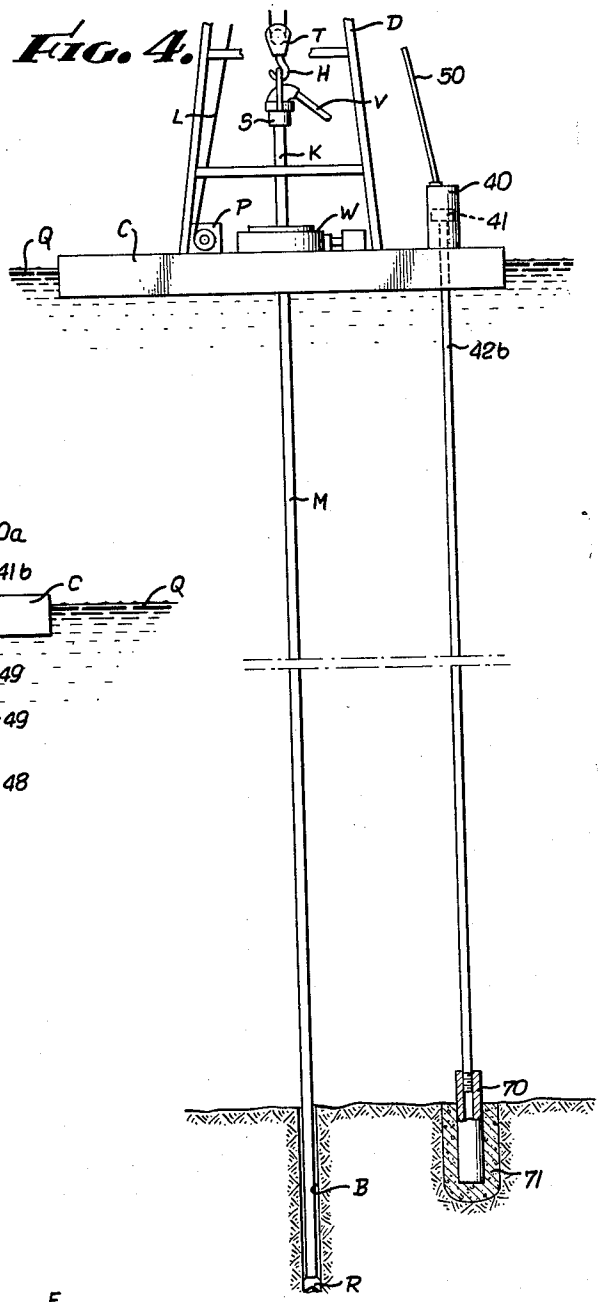


FIG. 4.



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HYDRAULIC WEIGHT CONTROL AND COMPENSATING APPARATUS

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19 Claims. (Cl. 175—5)

The present invention relates to apparatus for supporting running-in strings, such as tubular strings of drill pipe, casing and tubing, in well bores.

A hydraulic weight control and compensating apparatus is disclosed in U.S. Patent No. 2,945,676 for maintaining the weight imposed by a drilling string on a drill bit constant while a bore hole is being drilled. Such apparatus is effective in maintaining bit drilling weight constant when the drilling apparatus is mounted on a barge floating in the ocean, or other body of water, below which the bore hole is being drilled, despite the up and down movements of the barge and equipment as a result of wave action, wind, and the like.

In the apparatus disclosed in the above patent, the vertical movement of the drilling barge may require a rapid delivery of substantial quantities of liquid by a pump to the apparatus and the maintenance of the liquid at a desired pressure. It may also require the rapid discharge of substantial quantities of liquid from the apparatus to a suitable reservoir while maintaining such liquid at the desired pressure. The supply and withdrwal of such quantities of liquid requires a pump of large capacity operated by a motor of substantial horsepower, and also may make it difficult to maintain the liquid pressure in the compensating apparatus at the desired constant value.

Accordingly, it is an object of the present invention to provide a hydraulic compensating apparatus for controlling the weight of the running-in string in a well bore, which minimizes the requirement for withdrawal of large liquid quantities under pressure from the system, and for the pump to supply large additional liquid quantities under pressure to the system, as a result of vertical movements of a drilling barge floating in a body of water and from which the running-in string is supported. Reduction of the need for the pump to supply large quantities of liquid under pressure greatly reduces the pump horsepower requirements of the system, since the pump need only supply liquid at a relatively small volumetric rate.

Another object of the invention is to reduce the rate at which a pump need supply liquid under pressure to a hydraulic weight control system used in connection with a well bore, thereby facilitating the maintenance of the liquid pressure in the system at a desired constant value, despite substantial vertical movements of a barge floating in a body of water and on which the apparatus embodying the system is carried.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURE 1 is a diagrammatic view of one form of the invention;

FIG. 2 is a diagrammatic view of the weight control and compensating apparatus;

FIG. 3 is a view similar to FIG. 1 of a modified form of apparatus;

FIG. 4 is a view similar to FIG. 1 of still another modified form of apparatus embodying the invention.

A weight control and compensating apparatus A is disclosed in the drawings as being operatively associated with a rig used for drilling a well bore B, such as a well bore underlying a body of water Q, the mouth of the well being at the floor F of the body of water. A floating barge or ship C supports the rig, this floating barge having a suitable derrick D mounted thereon in which is contained the usual crown block E over and through which passes a suitable member of cables or lines L that pass over the sheaves of a traveling block T, the hook H of which is connected to a swivel S secured to the upper kelly portion K of a string of drill pipe M extending through the body of water and into the bore hole B, the drill pipe having a suitable drill bit R on its lower end for drilling the hole. Suitable drilling fluid is pumped through a mud line V into the swivel S for downward passage through the drill pipe M and for discharge from the drill bit, the drilling fluid carrying the cuttings upwardly of the hole B and around the drill pipe to the floor of the ocean for suitable disposal. The string of drill pipe M and the bit R are rotated in the usual manner by a rotary table W through which the kelly K is slidably splined, the cables or lines L passing over the crown block E and to a suitable drawworks P mounted on the floating barge C.

The weight control and compensating apparatus A is preferably disposed completely out of the normal working area within the confines of a derrick D, being mounted on the upper end of the derrick. It includes a stationary cylinder **10** suitably fixed to and supported by the upper portion of the derrick, this cylinder having a suitable length, which may, for example, be about ten feet. It has an upper cylinder head **11** provided with a vent hole **12** to allow the upper portion of the cylinder to be at atmospheric pressure. A piston **13** is slidably mounted in this cylinder and has a piston rod **14** secured thereto passing through a lower cylinder head **15**. The piston rod **14** may have a length corresponding to the length of the cylinder **10** and is suitably connected to the crown block E, as by providing an eye **16** in the lower end of the piston rod which receives a hook **17** secured to the crown block.

The cylinder **10** below the piston **13** is adapted to contain a body of liquid **18**, such as oil, leakage of fluid downwardly from the cylinder along the piston rod **14** being prevented by a suitable rod packing **19** mounted in the lower cylinder head **15** and slidably and sealingly engaging the piston rod; whereas, leakage of fluid upwardly past the piston **13** is prevented by a suitable seal ring **20** mounted thereon and slidably and sealingly engaging the wall of the cylinder **10**.

The liquid **18** in the cylinder is maintained at substantially a constant pressure, this liquid being derived from a suitable reservoir **22**, which may be located outside the working area within the derrick, a motor driven

pump 23 drawing the oil from the reservoir 22 and discharging it through an inlet line 24 into the lower end of the cylinder 10. The liquid in the cylinder can pass outwardly therefrom through an outlet line 25 and back to the reservoir 22, flowing through a suitable choke orifice 26 in the outlet line. The motor driven pump 23 may be a centrifugal pump capable of developing comparatively high pressures, this pump constantly rotating during the operation of the apparatus and constantly delivering liquid into the cylinder 10 below the piston 13, the liquid constantly flowing through the outlet line 25 and the choke orifice 26 back to the reservoir 22. Because of the choke orifice 26, a back pressure is built up in the cylinder 10 and inlet line 24, and in that portion of the outlet line 25 upstream of the choke orifice 26, which pressure acts upon the underside of the piston 13 and exerts an upward force thereon, which upward force is transmitted through the piston rod 14 to the movable crown block E, and through the lines L passing over the crown block to the traveling block T and the swivel S, which is connected to the drill pipe M.

The weight of the string of drill pipe M and of the mechanism connected thereto is known by securing an indication on a suitable weight indicator (not shown). This weight is counteracted by the pressure of the liquid acting upwardly over the effective cross-sectional area of the piston 13 outwardly of the piston rod. The weight of the mechanism suspended from the piston 13, including the string of drill pipe M, less the total force of liquid acting upwardly on the piston, will provide the net downweight acting on the drill bit R and forcing it against the bottom of the bore hole B. By changing the pressure of the liquid 18, the drilling weight on the bit can be changed correspondingly. The pressure of the liquid is known to the operator, as by observing a suitable pressure gauge 28 connected to the inlet line 24.

The apparatus A disclosed automatically maintains the drilling weight on the drill bit R. By virtue of the pump 23 rotating at a desired speed, and because of the choke orifice 26, a substantially constant unit pressure of the liquid 18 in the cylinder results, this pressure acting over the effective area of the piston 13 and urging it upwardly, thereby relieving the bit R of a portion of the total weight of the drill string M and the mechanisms S, H, T, L, E between the drill string and the piston rod 14. With substantially constant pressure of the liquid 18, the weight on the drill bit R remains constant, despite lowering of the drill string M as the result of the making of hole by the bit, the piston 13 merely moving downwardly in the cylinder. Assuming the floating barge C and derrick D do not move vertically, it is not even necessary for the driller to allow any line L to feed from the drawworks P for the purpose of lowering the drill string M as drilling proceeds, until the piston 13 is near the lower end 15 of the cylinder or the lower end of its stroke. When this occurs, a suitable amount of line L may be allowed to feed off the drawworks P, which will tend to reduce the tension in the line L extending between the crown block E and the traveling block T. Since the pressure of the liquid is acting upwardly on the piston, any tendency for this line tension to reduce will immediately result in an upward movement of the piston 13 and the piston rod 14 in the cylinder 10 to prevent such reduction in tension, the piston and piston rod merely moving upwardly in the cylinder as additional line is fed from the drawworks until the piston 13 is adjacent to the upper end 11 of the cylinder, at which time the feeding off of line from the drawworks P may be discontinued. The drill pipe M is rotated and the drilling action continues, the piston 13 and piston rod 14 again feeding downwardly as drilling proceeds, allowing the crown block E, lines L, traveling block T and swivel S to travel downwardly with the string of drill pipe M and as the kelly K slides through the rotary table W, until the piston 13 again nears the lower end of its

stroke, whereupon additional line can again be fed off the drawworks P.

Regardless of the upward or downward movement of the piston 13, so long as the pressure of the liquid 18 in the cylinder 10 on the underside of the piston is maintained constant, the upward supporting force of the piston on the drill pipe string M remains constant, resulting in a constant drilling weight being imposed on the drill bit R, forcing it against the bottom of the well bore B.

By virtue of the mechanism disclosed and described, the drilling weight on the bit can be maintained constant. Such constant weight is also maintained in the event the floating barge C and derrick D tend to move upwardly or downwardly as the result of the action of waves on the body of water Q in which the barge is floating. Assuming the floating barge and derrick were to rise as the result of wave action, the cylinder 10 will be carried upwardly with the derrick, but the piston 13 will remain in essentially the same position with the liquid 18 remaining at substantially the same pressure, inasmuch as the liquid is merely forced through the outlet line 25 and the choke orifice 26 back to the reservoir 22. Similarly, assuming that the barge C descends as the result of wave action, the derrick D and cylinder 10 are carried downwardly with it, effectively increasing the cylinder volume below the piston 13. However, the pump maintains the cylinder filled below the piston as its volume is increasing and produces substantially the same liquid pressure. Thus, during upward and downward movement of the floating barge C, derrick D and cylinder 10, the piston 13 and piston rod 14 and the mechanism suspended from the rod 14 remain in substantially the same position, the cylinder 10 merely telescoping upwardly and downwardly along the piston. The length of the cylinder is chosen such that the floating barge C and derrick D can rise and fall well beyond the maximum distance resulting from the action of waves without the piston engaging either the lower cylinder head 15 or the upper cylinder head 11. The cylinder 10 is always free to telescope or slide along the piston 13. During the up and down, or undulating, movements of the floating barge, derrick and cylinder, the piston 13 can still shift downwardly as the drill bit R increases the depth of the well bore B.

During the upward and downward movement of the floating barge, derrick and cylinder, as the result of water wave action, the fact that the drawworks P is connected to the line L and will also move upwardly and downwardly with the floating barge C does not interfere with the automatic compensating action of the hydraulic piston and cylinder mechanism. The piston 13 is always exerting a constant upward force on the lines L between the crown block E and the traveling block T and will maintain this constant force regardless of the movement of the drawworks P vertically toward the crown block E or vertically away from the crown block, depending upon the rise or fall of the floating barge on which the drawworks is mounted. Assuming the barge to move upwardly, the cylinder 10 and drawworks P also move upwardly, the drawworks tending to put a slack in the drilling line L. However, this slack is instantly taken up by the fact that the pressure on the underside of the piston 13 will move the piston and the crown block E upwardly to maintain a constant tension in the lines L. In effect, as the drawworks moves up simultaneously with the rise of the floating barge, derrick and cylinder, the piston 13 follows this upward movement to a fractional extent to maintain the tension in the lines L constant.

Similarly, assuming the barge to move downwardly, which will carry the derrick, cylinder and drawworks P downwardly with it, the descent of the drawworks relative to the crown block E would tend to increase the tension in the line L. Inasmuch as the unit pressure of the liquid 18 acting on the underside of the piston 13 is exerting a constant upward force on the latter, an in-

crease in tension of the line results in immediate downward shifting of the piston 13 in the cylinder 10, forcing liquid from the cylinder and through the choke orifice 26 back to the reservoir 22, the piston moving downwardly partially in the cylinder to maintain the tension in the lines L constant. Again the piston will move relatively downwardly in the cylinder to a fractional extent of the downward movement of the cylinder and of the drawworks.

The fractional follow-up of the piston 13 in the cylinder 10 is due to the fact that there are usually a substantial number of lengths of lines running between the crown block E and the traveling block T. Thus, if there are ten lines extending between the crown block and the traveling block, a feeding of a certain length of line from or back onto the drawworks P will result in a travel of the crown block E with respect to the traveling block T of only one-tenth the amount of the feed from or to the drawworks. Under the example given, the drawworks P actually is not rotating for the purpose of feeding line L from its drum (not shown) or feeding line back onto its drum, but it is the upward movement of the drawworks or its downward movement which is equivalent to allowing a line to pass over the crown block and traveling block, or a pulling line from the traveling block and crown block. In the example given of ten lines between the crown block and traveling block, for each unit of vertical movement of the drawworks P and of the floating barge C, derrick D and cylinder 10 under wave action, the piston 13 would only follow up one-tenth of that distance within the cylinder 10 and would still maintain the tension in the line L constant, and, consequently, the weight on the drilling bit R constant.

During the vertical movement of the floating barge or ship structure C in the body of water Q, as a result of wave action and the like, the compensating piston 13 that carries the drill string M remains substantially fixed; whereas, the compensating cylinder 10 at the upper end of the derrick moves up and down, all of which requires a discharge of liquid 18 from the compensating cylinder 10 below the piston 13 during the upward movement of the barge and derrick, and the necessity for supplying a large quantity of liquid 18 to the cylinder 10 on the high pressure side of the piston during descent of the floating barge and derrick. Heretofore, as in the system disclosed in United States Patent No. 2,945,676, the excess liquid in the cylinder was required to discharge through the choke orifice 26 back to the reservoir 22, and any deficiency in liquid was supplied by the pump 23 in a rapid manner in the event that the pressure of the liquid were to be maintained at a desired constant value, in order to appropriately support the desired portion of the weight of the mechanism suspended from the piston 13, including the string of drill pipe M. The requirement for supplying large quantities of liquid 18 at a rapid rate would necessitate the use of a large capacity pump, and corresponding motor of large horsepower.

In the present instance, the pump 23 need not supply any substantial quantities of liquid 18, the liquid still being permitted to leave the cylinder 10 rapidly, and reenter the cylinder rapidly, while its pressure is being maintained. As shown in FIGS. 1 and 2, a vertical compensating or expansion cylinder 40 is mounted on the drilling barge C. Slidable vertically in this cylinder is a piston 41 having a piston rod 42 secured thereto which extends downwardly through a lower cylinder head 43, the rod being firmly secured to a partially or fully submerged hollow float structure 44 which tends to move upwardly in the body of water Q, but which is anchored against such upward movement by a plurality of cables 45 secured thereto and appropriately secured to the floor F of the body of water, as, for example, by being anchored to a concrete anchor block 46 buried in the formation. The hollow float structure 44 is buoyed by the water and tends to move upwardly, but such upward movement is resisted by the anchored cables 45. Where a well is being drilled through very deep water, which may be several thousand feet deep, and, in fact, 15,000 to 20,000 feet deep, the weight of the cables 45 would tend to counteract the buoyancy of the hollow float structure 44, pulling it downwardly, as well as the piston 41 secured thereto. The weight of the cables can be offset by attaching suitable floats 47 thereto, which may be hollow, which will tend to buoy the cables and maintain them in tension throughout their length.

The hollow float structure 44 will remain in a fixed position, which is also true of the rod 42 and stationary piston 41 secured thereto, the barge C being guided in its vertical movement along the hollow float structure 44 by vertical guide members 48 secured to the barge and extending downwardly therefrom, being freely movable vertically along the hollow float structure 44, as by providing suitable rollers 49 on the float structure, or on the guides, that rollably engage the other member.

The expansion or compensating cylinder 40 above the piston 41 is filled with the liquid 18 prevented from leaking past the piston by a suitable piston ring 41*a*. A suitable interconnecting pipe or line 50 is connected to the upper cylinder head 51, the line also being connected with the lower portion of the derrick mounting cylinder 10 adjacent to its lower cylinder head 15. The cylinder 10 below the piston 13, the interconnecting pipe or line 50, and the expansion cylinder 40 above the piston 41 are all filled with the liquid 18. The cross-sectional area of the expansion cylinder 40 is equal to the cross-sectional area of the compensating cylinder 10, and the length of stroke of the expansion cylinder 40 along the stationary piston 41 is at least the same as the length of stroke of the compensating cylinder 10 along its piston 13. In effect, the stationary piston 41 and the piston 13 supporting the drilling mechanism suspended therefrom may be both considered to be stationary members; whereas, the expansion cylinder 40 and the compensating cylinder 10 move vertically jointly as the barge C moves vertically. Thus, as the barge C moves upwardly, the expansion cylinder volume above its piston 41 increases; whereas, the volume of the compensating cylinder 10 below its piston 13 decreases, the increased volume of the expansion cylinder equaling the decreased volume of the compensating cylinder. The liquid 18 can transfer freely through the inter connecting pipe or line 50 between these two cylinders. As a result, there is no need for any liquid 18 to be exhausted from the compensating cylinder 10 back to the reservoir 22, or additional liquid to be supplied by the pump 23 from the reservoir to the compensating cylinder below the piston, as the barge C rises and falls, causing a corresponding rise and fall in the compensating cylinder 10. The pump 23 need merely supply liquid 18 to the cylinder 10 at a sufficient rate to maintain the back pressure therewithin created by the flow of fluid through the choke orifice 26 before such liquid returns to the reservoir 22.

The stationary piston 41 within the expansion cylinder 40 has the pressure of the liquid acting upon its upper surface, which tends to force it downwardly. Such downward force is resisted by the buoyant action of the hollow float structure 44, which has a total lifting tendency that exceeds the maximum total force that might be imposed by the liquid 18 acting over the area of the stationary piston 41. In other words, the hollow float structure 44 will exert an upward force on the stationary piston 41 which is substantially greater than the weight of the longest length of drill pipe M, or other running-in string, in the well bore B, the longest length of pipe being present when it extends to the bottom of the well bore after the latter has been drilled to final depth. If, for example, the pressure of the liquid in the compensating and expansion cylinders 10, 40 is sufficiently high as to act on the compensating piston 13 and exert an

upward force thereon of 500 tons, then the upward thrust imposed by the hollow float structure 44 on the piston 41 will be such as to exceed 500 tons, such upward thrust being resisted by the anchored cables 45. It is only a downward thrust on the piston 41 in the expansion cylinder 40 exceeding the total buoyancy force exerted by the hollow float structure 44 that would tend to depress the stationary piston. However, the apparatus is so designed that the hollow float structure always exerts an upward thrust which is substantially greater than the anticipated maximum load to be supported by the piston 13 in the compensating cylinder 10 mounted at the top of the derrick D.

As described above, the pump 23 need only deliver fluid 18 at a sufficient rate to build up the desired back pressure in the liquid, so as to support the appropriate desired weight of the mechanism suspended from the piston rod 14 and including the drill pipe M, thereby maintaining the required drilling weight on the drill bit R. Upward movement of the barge C will cause the liquid 18 to flow from the compensating cylinder 10 into the expansion cylinder 40; whereas, downward movement of the barge will cause the liquid to be forced from the expansion cylinder 40 through the interconnecting line 50 back into the compensating cylinder 10, the pressure of the liquid at all times being maintained constant merely by the operation of the pump 23, which need only pump liquid through the system and the choke orifice 26 at a sufficient rate to maintain the required back pressure in the liquid 18. Such back pressure and rate of flow supplied by the pump 23 is independent of the upward and downward movement of the floating barge C and the drilling equipment mounted thereon.

In the form of apparatus illustrated in FIG. 3, essentially the same system is used as shown in FIG. 1, except that the hollow float structure 44*a* encompasses the string of drill pipe M, the latter passing through a large opening 60 in the structure 44*a*. In lieu of a single expansion cylinder, a plurality, such as a pair, of expansion cylinders 40*a* are mounted on the barge C, each cylinder having a stationary piston 41*b* therein with the piston rod 42*a* extending down through the barge C and being suitably connected to the hollow float structure 44*a*. As in the other form of the invention, the barge C will move vertically along the hollow float structure 44*a*, being guided in such movement by vertical guide members 48 attached to the barge and extending therebelow, and being contacted by rollers 49, or the like, suitably mounted on the float structure and rollably engaging the guide members.

The hollow float structure 44*a* tends to rise in the body of water Q and exerts a considerable upward buoyant force. Such upward movement is prevented by a plurality of cables 45, the upper ends of which are suitably secured to the float structure, and the lower ends of which are secured to the outer annular member 62 of a swivel device 63. This outer member has an inwardly directed flange or disc portion 64 disposed under a plate 65 secured, as by welding, to a surface pipe 66 extending into the well bore B and anchored therewithin by a surrounding annulus of cement 67. To permit some limited arcuate movement between the float structure 44*a* and the surface pipe 66, while holding the float structure anchored against upward movement, suitable axial thrust ball bearing elements 68 may be provided between the inwardly directed flange member 64 and the plate 65, and suitable radial thrust ball bearing elements 69 may be provided between the periphery of the plate 65 and the cylindrical skirt of the outer member 62.

As illustrated, in very deep wells, the weight of the anchoring cables 45 tending to offset the buoyancy of the float 44*a* may be compensated for by attaching floats 47 at suitable intervals to the cable, which will tend to support the cables in a taut condition, and which will not detract from the upward floating tendency of the buoyant structure 44*a*.

A symmetrical system is illustrated in FIG. 3, in which turning or arcuate shifting of the barge C and the mechanism associated therewith can occur without interference from the anchored float structure 44*a*, since the lower anchor portion 62 can swivel with respect to the surface pipe 66 cemented in the well bore. During the vertical movement of the barge C and the expansion cylinders 40*a* mounted thereon, as well as of the compensating cylinder 10 at the top of the derrick D, the liquid 18 can transfer readily between the expansion cylinders 40*a*, on the one hand, and the compensating cylinder 10, on the other hand, through the interconnecting pipes or lines 50*a* in the same fashion as described in connection with the other embodiment of the invention. Although not illustrated in FIG. 3, the same reservoir 22, pump 23, inlet line 24, outlet line 25, and choke orifice 26 are provided in connection with the compensating cylinder 10, this mechanism operating in the same manner as described above in connection with FIGS. 1 and 2. However, since a pair of expansion cylinders 40*a* are provided, each one of them only has one-half the cross-sectional area of the compensating cylinder 10. As a result, the joint up and down movement of the compensating cylinder 10 and the expansion cylinders 40*a* will result in the exact changes in volume of the compensating cylinder and in the two expansion cylinders. That is to say, during lowering of the barge C, lowering of the compensating cylinder will cause the required volume of liquid to be discharged from the expansion cylinders 40*a* through the inter-connecting lines 50*a* into the compensating cylinder 10. Similarly, raising of the barge in the water will result in the two expansion cylinders increasing in volume exactly equal to the decrease in volume in the compensating cylinder 10 below its piston 13.

In the form of invention disclosed in FIG. 4, the hollow float structure is not used. The hydraulic system is essentially the same as disclosed in FIGS. 1 and 2 with the exception that the stationary piston 41 in the expansion cylinder 40 is connected to a rod 42*b* extending through a relatively shallow body of water Q, the lower end of the rod being fixed to a casing 70 anchored in the formation through the agency of a suitable body of hardened cement 71. The piston 41 cannot move downwardly because of the intervening rod 42*b*. In all respects, however, it functions in conjunction with the expansion cylinder 40, in which it is relatively movable, in the same manner as the piston device 41 illustrated in FIGS. 1 and 2.

I claim:

1. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: cylinder means; piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and having fluid therein at substantially the same pressure as said cylinder means and fluid to said second means and to the rig; and an expansion chamber in fluid communication with said cylinder means to allow fluid under pressure to transfer between said cylinder means and chamber as the rig and barge move vertically in the body of water.

2. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in

string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being adapted for movement with the rig and barge as the rig and barge move vertically in the body of water; and means for preventing vertical movement of the other of said expansion means, whereby vertical movement of said rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means.

3. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being adapted for movement with the rig and barge as the rig and barge move vertically in the body of water; and means adapted to be disposed in the body of water and connected to the other of said expansion means to prevent vertical movement of said other of said expansion means, whereby vertical movement of the rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means.

4. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being adapted for movement with the rig and barge as the rig and barge move vertically in the body of water; and means in the body of water secured against vertical movement therein and connected to the other of said expansion means to prevent vertical movement of said other of said expansion means, whereby vertical movement of the rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means.

5. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being adapted for movement with the rig and barge as the rig and barge move vertically in the body of water; and means buoyant in the body of water secured therein against upward movement and connected to the other of said expansion means to prevent vertical movement of said other of said expansion means, whereby vertical movement of the rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means.

6. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being adapted for movement with the rig and barge as the rig and barge move vertically in the body of water; means for preventing vertical movement of the other of said expansion means, whereby vertical movement of said rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means; the cross-sectional areas of said expansion cylinder means and compensating cylinder means being substantially equal.

7. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being adapted for movement with the rig and barge as the rig and barge move vertically in the body of water; a hollow structure buoyant in the body of water connected to the other of said expansion means to prevent downward movement of said other of said expansion means; cable means secured to and depending from said structure; and means securing said cable means to the formation underlying the body of water; whereby vertical movement of the rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means.

8. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying

a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being adapted for movement with the rig and barge as the rig and barge move vertically in the body of water; a hollow structure buoyant in the body of water connected to the other of said expansion means to prevent downward movement of said other of said expansion means; cable means secured to and depending from said structure; means securing said cable means to the formation underlying the body of water; whereby vertical movement of the rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means; and float means attached to said cable means to support at least a portion of the weight of said cable means.

9. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being adapted for movement with the rig and barge as the rig and barge move vertically in the body of water; and means anchored in the formation underlying the body of water and connected to the other of said expansion means to prevent downward movement of said other of said expansion means, whereby vertical movement of the rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means.

10. In a combination for use with a running-in string: a ship structure adapted to float in a body of water above a well bore; a rig on said ship structure; cylinder means; piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string adapted to be disposed in the well bore; a second of said means being supported by the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; and an expansion chamber carried by said ship structure and being in fluid communication with said cylinder means and having fluid therein at substantially the same pressure as said cylinder means to allow fluid under pressure to transfer between said cylinder means and chamber as the rig and ship structure move vertically in the body of water.

11. In a combination for use with a running-in string: a ship structure adapted to float in a body of water above a well bore; a rig on said ship structure; compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string adapted to be disposed in the well bore; a second of said means being supported by the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being carried by said ship structure and being movable therewith as the ship structure moves vertically in the body of water; a hollow structure buoyant in the body of water connected to the other of said expansion means to prevent downward movement of said other of said expansion means; cable means secured to and depending from said hollow structure; means securing said cable means to the formation underlying the body of water; whereby vertical movement of the rig and ship structure effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means; and guide means extending from said ship structure and slidable vertically along said hollow structure.

12. In a combination for use with a running-in string: a well bore underlying a body of water and having a pipe secured therein; a ship structure adapted to float in the body of water above the well bore; a rig on said ship structure; compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string adapted to be disposed in the well bore; a second of said means being carried by the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being carried by the ship structure to move vertically therewith as the rig and ship structure move vertically in the body of water; a hollow structure buoyant in the body of water and connected to the other of said expansion means to prevent downward movement of the other of said expansion means; cable means secured to and depending from said hollow structure and attached to said pipe to anchor said hollow structure against upward movement in the body of water; and guide means extending from said ship structure and slidable vertically along said hollow structure.

13. In a combination for use with a running-in string: a well bore underlying a body of water and having a pipe secured therein; a ship structure adapted to float in the body of water above the well bore; a rig on said ship structure; compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string adapted to be disposed in the well bore; a second of said means being carried by the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being carried by the ship structure to move vertically therewith as the rig and ship structure move vertically in the body of water; a hollow structure buoyant in the body of water and connected to the other of said expansion means to prevent downward movement of the other of said expansion means; cable means secured to and depending from said hollow structure; swivel means connecting the lower por-

tion of said cable means to said pipe to prevent upward movement of said hollow structure in the body of water; whereby vertical movement of the rig and ship structure effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means; and guide means extending from said ship structure and slidable vertically along said hollow structure.

14. In apparatus for maintaining a predetermined stress in a running-in string disposed in a well bore underlying a body of water and which is supported by a rig mounted on a barge, or the like, floating in the body of water: compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string and a second of said means being adapted for operative connection with the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and to the rig; expansion cylinder means adapted to be secured to the barge to move vertically therewith and in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; and means for preventing vertical movement of said expansion piston means, whereby vertical movement of the rig and barge effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means.

15. In a combination for use with a running-in string: a ship structure adapted to float in a body of water above a well bore; a rig on said ship structure; compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string adapted to be disposed in the well bore; a second of said means being supported by the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being carried by said ship structure and being movable therewith as the ship structure moves vertically in the body of water; a hollow structure buoyant in the body of water connected to the other of said expansion means to prevent downward movement of said other of said expansion means, said hollow structure having an opening therethrough through which the running-in string can pass; cable means secured to and depending from said hollow structure; means securing said cable means to the formation underlying the body of water; whereby vertical movement of the rig and ship structure effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means; and guide means extending from said ship structure and slidable vertically along said hollow structure.

16. In a combination for use with a running-in string: a well bore underlying a body of water and having a pipe secured therein; a ship structure adapted to float in the body of water above the well bore; a rig on said ship structure; compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string adapted to be disposed in the well bore; a second of said means being carried by the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being carried by the ship structure to move vertically therewith as the rig and ship structure move vertically in the body of water; a hollow structure buoyant in the body of water and connected to the other of said expansion means to prevent downward movement of the other of said expansion means, said hollow structure having a vertical opening therethrough through which the running-in string can pass; cable means secured to and depending from said hollow structure and attached to said pipe to anchor said hollow structure against upward movement in the body of water; and guide means extending from said ship structure and slidable vertically along said hollow structure.

17. In a combination for use with a running-in string: a well bore underlying a body of water and having a pipe secured therein; a ship structure adapted to float in the body of water above the well bore; a rig on said ship structure; compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted for operative connection to the running-in string adapted to be disposed in the well bore; a second of said means being carried by the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; expansion cylinder means in fluid communication with said compensating cylinder means; expansion piston means slidable in said expansion cylinder means; one of said expansion means being carried by the ship structure to move vertically therewith as the rig and ship structure move vertically in the body of water; a hollow structure buoyant in the body of water and connected to the other of said expansion means to prevent downward movement of the other of said expansion means, said hollow structure having a vertical opening therethrough through which the running-in string can pass; cable means secured to and depending from said hollow structure; swivel means connecting the lower portion of said cable means to said pipe to prevent upward movement of said hollow structure in the body of water; whereby vertical movement of the rig and ship structure effects transfer of fluid under pressure between said compensating cylinder means and expansion cylinder means; and guide means extending from said ship structure and slidable vertically along said hollow structure.

18. In a combination for use with a running-in string: a ship structure adapted to float in a body of water above a well bore; a rig on said ship structure; compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted to be connected to the running-in string extending into the well bore and a second of said means being connected to the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; a plurality of expansion cylinders mounted on said ship structure and in fluid communication with said compensating cylinder means; a plurality of expansion pistons slidable in said expansion cylinders; a hollow structure buoyant in the body of water connected to said expansion pistons to prevent downward movement of said expansion pistons; cable means secured to and depending from said hollow structure; and means securing said cable means to the formation underlying the body of water; whereby vertical movement of the rig and ship structure effects transfer of fluid under pressure between said compensating cylinder means and said expansion cylinders.

19. In a combination for use with a running-in string: a ship structure adapted to float in a body of water above a well bore; a rig on said ship structure; compensating cylinder means; compensating piston means slidable in said cylinder means; a first of said means being adapted to be connected to the running-in string extending into the well bore and a second of said means being connected to the rig; means for maintaining fluid under pressure in said cylinder means as said piston means and cylinder means move longitudinally relative to each other, whereby the stress in the running-in string is transferred through said first means and fluid to said second means and rig; a plurality of expansion cylinders mounted on said ship structure and in fluid communication with said compensating cylinder means; a plurality of expansion pistons slidable in said expansion cylinders; a hollow structure buoyant in the body of water connected to said expansion pistons to prevent downward movement of said

expansion pistons; cable means secured to and depending from said hollow structure; and means securing said cable means to the formation underlying the body of water; whereby vertical movement of the rig and ship structure effects transfer of fluid under pressure between said compensating cylinder means and said expansion cylinders; the combined cross-sectional areas of said expansion cylinders being substantially equal to the cross-sectional area of said compensating cylinder means.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,158,206 November 24, 1964

Archer W. Kammerer

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, lines 62 and 63, strike out "and having fluid therein at substantially the same pressure as said cylinder means" and insert the same after "means" in line 65, same column 8.

Signed and sealed this 27th day of April 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents