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Lackey

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[54] WEIGHT CONTROL SYSTEM

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[51] Int. Cl. E21b 19/08

[58] Field of Search ..... 173/4, 6, 9; 254/173 B; 91/1; 60/52 VS

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[57] ABSTRACT

A system for use in the drilling of oil wells, gas wells and the like which can be employed to maintain a relatively constant predetermined weight on the drilling tool. The system, which is preferably employed in connection with a drilling rig having a mast, a drill string supporting member which is vertically movable within the mast, and a hydraulic cylinder and piston assembly which is adapted to move the drill string supporting member within the mast, includes a transducer for converting the hydraulic pressure in the piston and cylinder assembly to an electrical signal. As the pressure in the piston and cylinder assembly is representative of the weight being supported by the mast and thus representative of the force being applied to the drill tool the signal may be compared with a second signal representing the desired weight to be applied to the drill tool and the difference used to remove hydraulic fluid from the piston and cylinder assembly through a relief valve when the weight being applied to the drilling tool is less than a desired weight. In a preferred embodiment the signal representing the difference between the actual weight being applied to the drill tool and the desired weight may be employed to control a reversible, variable displacement pump to move the drill string supporting member either upward or downward within the mast to increase or decrease the force being applied to the drill tool so that a predetermined weight is employed.

10 Claims, 2 Drawing Figures

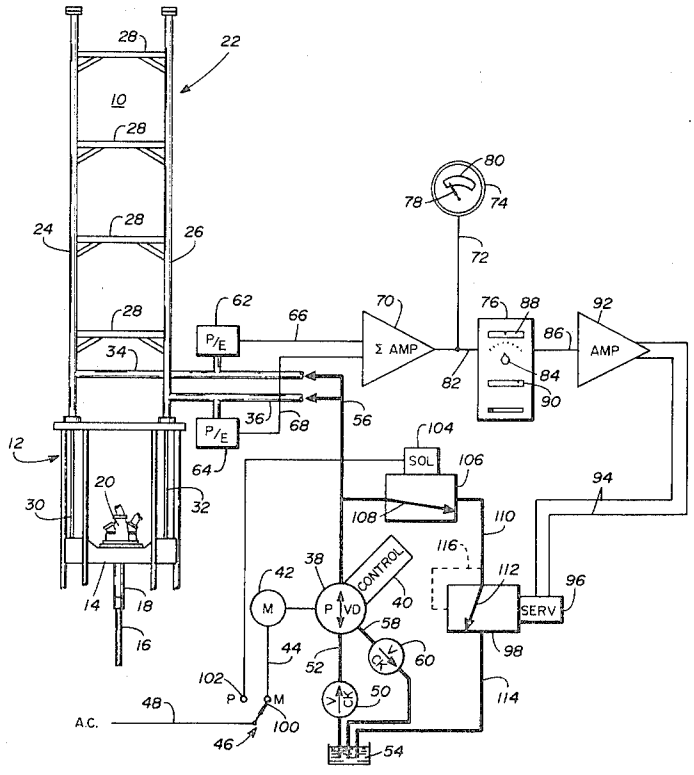
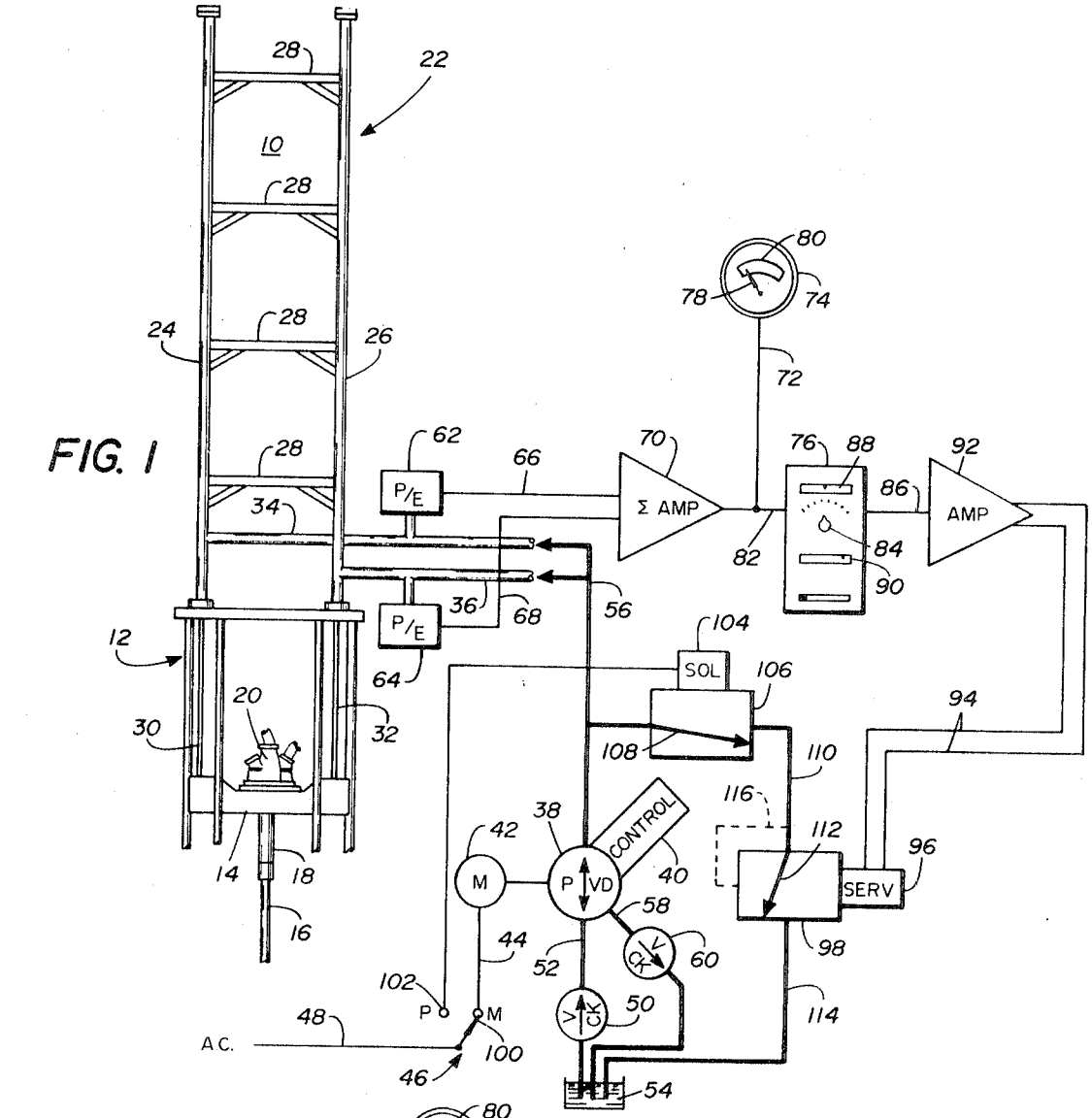


FIG. 1



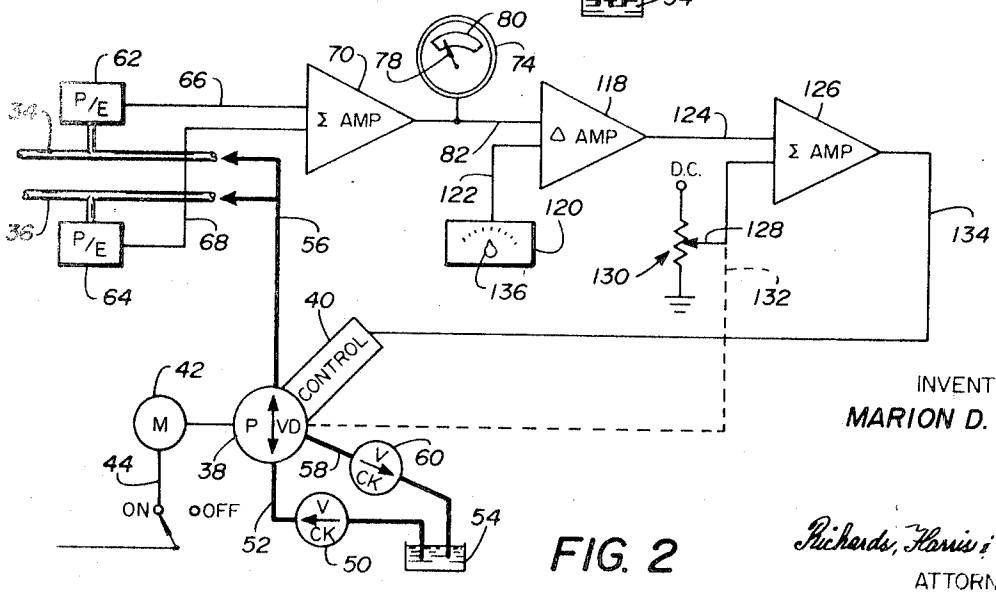


FIG. 2

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WEIGHT CONTROL SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to earth-boring machines, and more particularly to systems for maintaining a constant weight on the drilling tool employed by the earth-boring machine to penetrate the earth's crust in order to achieve a maximum penetration rate consistent with the type of formation being penetrated.

In the drilling of oil wells, gas wells and the like it has been known that the optimum penetration rate of a particular drilling tool may be obtained by controlling, among other variables, the weight being applied to the drilling tool. The amount of weight applied to the drilling tool will vary with the type of formation which is being penetrated. One method of determining the weight applied to the drilling tool consists of adding to the drill string a number of "drill collars" which are positioned proximate the bottom of the drill string and are quite heavy, compared to conventional drill pipe. By varying the number of drill collars affixed to the drill string, the weight of the drill string may be varied and thus the weight applied to the drilling tool may be regulated. However, during the life of any one drilling tool, such as a three-cone rotary bit, a drag bit or the like, the bit may encounter several different types of formations. In all likelihood maximum penetration rate through one of the formations may be achieved by applying a weight to the drill bit which is less or greater than the actual weight which is being applied. As it is impractical to retrieve the drill string from the hole upon encountering different formations to vary the number of drill collars, operators have had to settle for less than optimum penetration rate, or use means to adjust the force in cables supporting a traveling block responsive to indications of weight change.

While it is possible for an operator to observe a weight indicator and manually increase or lessen the weight being applied to the drill bit by manual operation of the draw works used with conventional drilling rigs having a traveling block, the position of which may be regulated by the draw works, this system is not feasible to perform manually. More particularly, as the drill bit will continuously be advancing through the formations, the traveling block must continuously be lowered if a constant force is to be maintained upon the bit for the particular formation being encountered. Thus, constant supervision by an operator would be required. As a result, systems have been designed which will mechanically release the brake of the draw works to maintain a fairly constant weight on a drilling tool. However, these systems are incapable of relieving weight on the drilling tool if the weight momentarily increases during drilling.

The present invention provides a system which may be employed to maintain a predetermined weight on the drilling bit and which may be additionally employed to vary the weight both up and down to achieve maximum penetration rate while encountering different formations without the need for retrieving the bit and drill string from the hole to vary the number of drill collars attached to the drill string.

SUMMARY OF THE INVENTION

The invention may be generally described as a system for use with a drilling rig having a mast, a drill string supporting member vertically movable within the mast, and means for moving the drill string supporting member up and down within the mast, which system is for maintaining a predetermined weight on a drilling tool attached to the end of the drill string. The system includes first means for generating a first signal which is representative of the weight acting upon the drill tool, second means for generating a signal which is representative of the desired weight to be exerted on the drilling tool, third means which are operatively associated with the first and second means for comparing the magnitude of the two signals and generating an output signal related to the first and second signals and fourth means responsive to the output signal from the third means for actuating the means for moving the drilling string supporting member in a direction to cause the weight exerted upon the drilling tool to equal the desired weight.

Being more specific, reference is made to the drawings described below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic of a simplified hydraulic and electrical circuit which embodies the present invention; and

FIG. 2 is a simplified schematic of a hydraulic and electrical system representing an alternative embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown an application of the present invention to an automatic hydraulic drilling rig of the type described in U.S. Pat. No. 3,158,213. The drilling rig 10, only a portion of which is illustrated, includes a mast 12 within which is slidably carried a vertically movable drill string supporting member 14. Drill head assembly 14 supports a drill string 16, only a portion of which has been illustrated. Drill string 16 may be several thousand feet in length and is attached at the upper end thereof to a spindle 18 which extends downwardly from drill string supporting member 14 and is rotatably journaled within a power swivel assembly 20 which may be utilized to rotate spindle 18 and thus drill string 16 which is attached thereto. Movement of drill string supporting member 14 within mast 12 is accomplished by use of a suitably braced tower 22 affixed to the top of mast 12. The tower 22 includes cylinders 24 and 26 which are braced by struts 28. While only two cylinders are illustrated, more may be employed, if necessary, to support the weight of drill string 16. Reciprocally mounted within cylinders 24 and 26 are rods 30 and 32, respectively, which are attached to pistons within the cylinders 24 and 26 so that the drill string supporting member 14 may be vertically moved within mast 12 by introduction and withdrawal of hydraulic fluid to cylinders 24 and 26 through lines 34 and 36, respectively. By introducing fluid into cylinders 24 and 26 the force being exerted on the drill bit attached to the bottom of drill string 16 may be lessened as the introduction of hydraulic fluid into cylinders 24 and 26 will cause rods 30 and 32 to move upwardly thus relieving the weight which serves to exert the force on the drill bit. Conversely, by withdrawing hydraulic fluid from cylinders 24 and 26, the force acting upon the drill bit attached to drill string may be increased up to a maximum force at which point there will be no fluid pressure in cylinders 24 or 26 as the entire weight of any drill collars attached to drill string 16 including the weight of drill string 16 above the collars will act upon the drilling tool.

Thus, by control of the pressure of the hydraulic fluid within cylinders 24 and 26 the force acting upon the drill tool may be varied between zero force and the force representing the entire weight of the drill string. The hydraulic fluid may be admitted to or withdrawn from cylinders 24 and 26 by use of a reversible, variable displacement pump 38 which may be, for example, a bent-axis, variable-displacement yoke type pump. The direction of the volume of flow through the pump 38 is determined by a controller 40 which positions the yoke of the pump in either direction from a center position, the direction from the center position controlling the direction of flow through the pump and the distance at which the yoke is displaced from the center position determining the flow rate through the pump, as the pump is powered by a constant speed motor 42. Motor 42 derives its power through conductor 44, which communicates through switch 46 with a source of alternating current of suitable voltage supplied through conductor 48 to switch 46. Operation of controller 40 may be controlled manually or in any other conventional manner. Pump 38 derives its hydraulic fluid through hydraulic line 52 which communicates with a reservoir 54 and has a check valve 50 interposed therein. Pump 52 discharges fluid through hydraulic line 56 to lines 34 and 36 which, as explained be-

fore, communicate with cylinders 24 and 26. Check valve 50 is provided to assure that fluid is maintained in pump 38 when the yoke is at its center position to prevent draining of the fluid into the reservoir and starving of the pump 38. In order to elevate the drill string supporting member 14, controller 40 is operated to move the yoke of pump 38 in a direction to cause pump 38 to withdraw hydraulic fluid from reservoir 54 and introduce it through lines 34 and 36 to cylinders 24 and 26. To lower drill pipe supporting member, controller 40 is operated to move the yoke of pump 38 in the opposite direction past the center position to withdraw hydraulic fluid through lines 34 and 36 and discharge fluid withdrawn therefrom through hydraulic line 58 and check valve 60 back to the reservoir 54.

In order to determine the actual weight being exerted on the drilling tool, transducers 62 and 64 sense the hydraulic pressure in lines 34 and 36, respectively, and convert the pressure to electrical signals which are communicated through conductors 66 and 68 to a summing amplifier 70 the output of which is coupled through conductor 72 to a weight indicator gauge 74 and a controller 76. The weight indicator 74 converts the electrical signal in conductor 72, which represents the total signal from transducers 62 and 64, into a representation of the weight being supported by member 14. As indicator 74 reflects the weight being supported by rods 30 and 32, it thus represents the weight being exerted on the drill bit as the weight exerted on the bit is the weight of the drill string 16 less the weight supported by rods 30 and 32. The latter weight is determined by viewing the position of needle 78 on dial 80 of indicator 74. The controller 76, which for example is a model 61 or 62 "Foxboro" controller such as manufactured by The Foxboro Company, Foxboro, Massachusetts, receives the signal from summation amplifier 70 through conductor 82 and compares it with a signal which represents the desired weight to be applied to the bit which has been set into the instrument by manipulation of knob 84. The signal generated by movement of knob 84 is actually directly related to the weight to be supported by rods 30 and 32, and is thereby representative of the weight to be placed on the drilling tool. If the two signals are unequal, controller 76 generates an output signal in conductor 86 representative of the difference. The difference is also indicated in window 88 of controller 76 while the output signal magnitude is indicated in window 90 of controller 86. The output signal in conductor 86, which is proportional to the error between the signal set by manipulation of knob 84 in the signal and conductor 82 is amplified by amplifier 92 to drive through conductor 94 a floating voltage coil in servo 96. Servo 96 controls the position of spool 112 in a pressure relief valve 98, which is normally closed. Valve 86 may be placed in communication with the hydraulic fluid in lines 34 and 36 by movement of arm 100 of switch 46 to communicate the AC power source with contact 102 thus energizing solenoid 104 of two-way valve 106 to move the spool 108 thereof to permit flow from hydraulic line 56 through valve 106 to hydraulic line 110 which communicates with valve 98. Once solenoid 104 is actuated to communicate fluid in lines 34 and 36 with valve 98, the operation of servo 96 will either maintain valve 98 closed, as illustrated in FIG. 1, or when driven by an output from amplifier 92, move spool 112 of valve 98 to admit fluid in hydraulic line 110 into reservoir 54. While the spool 112 of valve 98 may be controlled by servo 96, it is also capable of being self-relieved under conditions where excess pressures may be generated, as indicated by dotted control line 116. In operation the embodiment illustrated in FIG. 1, the drill string supporting member 14 is moved to position where the weight acting on the bit attached to drill string 16 is approximately equal to the desired weight as indicated by gauge 74 by moving switch 46 to the position indicated in FIG. 1 to energize motor 42 and thus drive pump 38, the direction and quantity of flow through which may then be manually controlled by external means (not illustrated) through controller 40. Once the approximate loading on the drill bit is reached, switch 46 is moved to place arm 100 in contact with contact 102 after the yoke of the pump has been moved to center position, at which position fluid has neither discharged from or admitted to lines 34 and 36. Upon movement of arm 100 into engagement with contact 102, solenoid 104 will be energized placing the fluid in lines 34 and 36 and thus the fluid in cylinders 24 and 26 into communication with relief valve 98. Knob 84 of controller 76 is then adjusted to generate a signal within controller 76 which is representative of the weight to be supported by rods 30 and 32 and thus of the desired weight to be exerted on the drill bit. As the drill bit is rotated by rotation of power swivel 20, the bit will cut away that portion of the formation in which it is drilling and cause the pressure in cylinders 24 and 26 to increase as less weight of the drill string will be supported by the formation. The increased pressure in cylinders 24 and 26 will be sensed by transducers 62 and 64 which are attached to pipes 34 and 36 causing the output of summation amplifier 70 to increase producing a deviation between that signal and the signal generated within controller 76 by setting of knob 84. This deviation will be noted in window 88 and will cause an output signal in conductor 86, proportional to the amount of the deviation, which output signal will be reflected in window 90. The output signal will be coupled to amplifier 92 by conductor 86 causing amplifier 92 to drive floating voltage coil of servo 96 through conductor 94 and partially open relief valve 98 to permit discharge of a portion of the hydraulic fluid in cylinders 24 and 26 through lines 34 and 36, hydraulic line 56, valve 106 and hydraulic lines 110 and 114 into reservoir 54. As the pressure in cylinders 24 and 26 lessens, the decrease will be sensed by transducers 62 and 64 causing the output of summation amplifier to drop and the deviation in controller 76 to lessen. As the deviation reaches zero, amplifier 92 will eventually reach a quiescent state permitting servo 96 to close spool 102 when the desired pressure in cylinders 24 and 26 is reached.

Thus, the embodiment of FIG. 1 permits automatic control of the weight or force being applied to the drill bit, which later force may be noted by inspection of indicator 74 and which may be increased or decreased by manipulation of knob 84 of controller 76.

An alternative embodiment of this invention is illustrated in FIG. 2. In this embodiment the output of summation amplifier 70 which, as before, is coupled to a weight indicator 74 having a needle 78 and a dial 80 is coupled by conductor 82 to a differential amplifier 118 which compares the signal from summation amplifier 70 with a signal derived from a manually adjustable signal generator 120 through conductor 122. Any deviation between the output signal from signal generator 120 and that from summation amplifier 70 will cause the output of differential amplifier 118 to deviate above or below a quiescent output voltage, which output is coupled through conductor 124 to a second summation amplifier 126. Summation amplifier 126 also receives a signal from the center arm 128 of a pot 130 which is mechanically coupled, as indicated by dotted line 132, to the yoke of the reversible, variable displacement pump 38. Summation amplifier 126 drives, through conductor 134, the controller 40 of variable displacement pump 38.

If the output of differential amplifier 118 is above the quiescent condition output, and therefore greater than the voltage received from pot 130 with arm 128 in the center position, which will be the position of arm 128 when the yoke of variable displacement pump 38 is centered, summation amplifier through conductor 134 will cause controller 40 to move the yoke of variable displacement pump 38 in one direction, whereas the drop in voltage of conductor 124 below its normal output at its quiescent state will cause summation amplifier 126 to drive controller 40 for moving the yoke in the opposite direction. The direction which summation amplifier 126, through controller 40, drives the yoke of variable displacement pump 38 will depend upon the pressure within lines 34 and 36. More particularly, assuming, as in the discussion in connection with the embodiment of FIG. 1, that a drill string supporting member 14 has been moved to position within

mast 12 at which approximately the desired weight to be placed on the drilling tool is reached, which may be determined by inspection of indicator 74 before and after the bottom of the hole is reached. Any increase in the pressure of fluid in lines 34 and 36, caused by the tendency of the drill bit to move downward as the drill tool drills away the formation will be sensed by transducers 62 and 64 as noted before. The increased pressure in lines 34 and 36 will cause the output of summation amplifier 70 to increase creating a difference between the signal in conductor 82 and that in conductor 122 which had been preset by manipulation of knob 136 to generate a signal representative of the desired weight to be placed on the bit. The output of differential amplifier 118 will increase upon increase of the pressure in lines 34 and 36 creating an output from summation amplifier 126 which through controller 40 moves the yoke of pump 38 in direction from the center position which will be required to remove fluid from lines 34 and 36 through hydraulic line 58 and check valve 60 into reservoir 54. As the yoke of pump 38 is moved by controller 40, arm 128 will also be moved, downwardly as viewed in FIG. 2 causing the voltage input to summation amplifier 126 from pot 130 to increase approach a voltage which will null that in conductor 124 causing the output of summation amplifier 126 to cease movement of the yoke of pump 38 as the voltages from pot 130 and voltage in conductor 124 reach the same level. Pump 38, on movement of the yoke, will discharge fluid from lines 34 and 36, as explained above relieving the pressure in lines 34 and 36 and thus lessening the output of transducers 62 and 64 and summation amplifier 70. When the desired force to be exerted on the drill bit is reached, the output of summation amplifier 70 and that of manually adjustable voltage source 120 will be equal causing the output of differential amplifier 118 to reach its quiescent operating condition. If the arm 128 of pot 130 is not at its center position when the desired force is exerted on the drill bit, the magnitude of the signal from pot 130 will be less than that in conductor 124 causing the summation amplifier 126 to drive the yoke of pump 38 through controller 40 in the reverse direction until the voltages in conductor 124 and the output from pot 130 are equal. If, because the drill bit has entered a different formation, the force on the drill bit is to be lessened, the output of voltage source 120 may be increased causing the differential amplifier 118 to decrease, thus the output of summation amplifier 126 to move the yoke of pump 38, through controller 40 in a direction to admit fluid to lines 34 and 36. Movement of yoke 38, as explained before will cause the center arm 128 of pot 130 to move upward, lessening the voltage differential between the signal in conductor 128 and that admitted to summation amplifier 126 from pot 130 till they reach equality at which point the yoke of pump 38 will be in the desired position.

Any drift of the yoke of pump 38 from the desired position will be sensed by the movement of arm 128 of pot 130 causing an imbalance of voltage input to summation amplifier 126 and to the output of summation amplifier 126 will cause the movement of the yoke back to the proper position to maintain the desired weight on the drill bit which is determined by manipulation of knob 136.

The embodiment of the invention illustrated in FIG. 2 is useful in those situations where positive and negative control of the force exerted on the drill bit is required, while embodiment illustrated in FIG. 1 is useful in those applications where positive control of the weight on the drill bit is necessary.

The weight control system illustrated above is also useful in the controlling of the drill string supporting member 14 as the drill string is retrieved from the hole. More particularly as a joint of drill pipe is lifted from the hole, slips, or the like, will be actuated to engage the top of the second joint of pipe to support the drill string during removal of the joint attached to spindle 18. Spindle 18 cannot, however, be disengaged from the top joint without relieving the pressure in cylinders 24 and 26 as too much tension is being exerted on the threads. Nor will the complete venting of lines 34 and 36 permit easy removal of the top joint as complete venting will permit the entire weight of the drill string supporting member 14 to act on the threads of spindle 18 and the top joint.

By use of the present invention, however, the threads may be easily disengaged by setting the knob 88 of controller 76 or the knob 136 of voltage source 120 to set the hydraulic circuit to maintain a pressure in cylinders 24 and 26 which is sufficient to support the weight of the drill string supporting member only. Then, as the weight of the drill string supporting member 14 is being supported in rods 30 and 32 and the drill string, from the second joint down is being supported by the slips, spindle 18 may be disengaged from the top joint. The embodiment of FIG. 2 is preferred, for spindle 18 backs out of the top joint, any increase in pressure in cylinders 24 and 26 will be sensed and pump 38 utilized to lift the assembly 14 slightly to minimize thread wear.

While various embodiments of the invention have been illustrated and described, and rather specific language used in their description, such is neither intended nor should be construed as limitation upon the invention as defined by the following claims.

What is claimed is:

1. A system for use with a drilling rig having a mast, a drill string supporting member vertically movable within the mast and means for moving the drill string supporting member up and down within the mast, which system is for maintaining a predetermined vertical weight force on a drilling tool attached to the end of the drill string and comprises:

first means for generating a first signal which is representative of the weight acting on the tool;

second means for generating a second signal which is representative of the desired weight to be exerted on the drilling tool;

third means operatively associated with the first and second means for comparing the magnitude of the two signals and generating an output signal related to the first and second signals; and

fourth means responsive to the output signal from the third means for moving the drill string supporting member down when the force acting on the drilling tool is less than the desired force and for terminating the downward movement when the desired force is reached, and

for moving the drill string supporting member up when the force acting on the drilling tool is greater than the desired force and terminating the upward movement when the desired force is reached.

2. The system of claim 1 wherein the drill string supporting member is supported through a cylinder and piston assembly and means are provided for introducing and withdrawing hydraulic fluid to and from said cylinder and piston assembly, and said first means comprises:

transducers for converting the hydraulic pressure in said cylinder and piston assembly to an electrical signal which is representative of the vertical force acting on the drilling tool.

3. The system of claim 2 wherein said fourth means comprises:

a pressure relief valve in fluid communication with the cylinder and piston assembly;

a servo mechanism attached to said pressure relief valve for controlling the position of the pressure relief valve;

means communicating the output signal from said third means to said servo mechanism to cause said mechanism to open said valve for lowering of the drill string supporting member and to close the valve to terminate vertical downward movement of the drill string supporting member.

4. The system of claim 3 wherein said means for introducing fluid to and withdrawing fluid from the cylinder and piston assembly comprises a reversible pump having a controller which may, responsive to an input signal, be employed to control the direction and volume of flow through said pump, and the system includes:

means communicating the output signal from the third means with the controller for the pump to thereby render the direction of flow and volume of flow through the pump responsible to the output signal of the third means.

5. The device of claim 4, including:

fifth means responsive to operation of the controller for generating an output signal related to the operation of said controller; and

means utilizing the signal from said fifth means to cancel the output signal from said third means upon energizing of the controller.

6. A system for use with a drilling rig having a mast, a drill string supporting member vertically movable within the mast and a cylinder and piston assembly for supporting the drill string supporting member and for moving the drill string supporting member up and down within the mast, which system is for maintaining a predetermined weight on the cylinder and piston assembly and comprises:

first means for generating a first signal which is representative of the weight to be supported by the cylinder and piston assembly;

second means for generating a second signal which is representative of the desired weight to be supported by the cylinder and piston assembly;

third means operatively associated with the first and second means for comparing the magnitude of the two signals and generating an output signal related to the first and second signals; and

fourth means responsive to the output signal from the third means for moving the drill string supporting member upwardly when the weight supported by the cylinder and piston assembly is less than the desired weight and downwardly when the weight is greater than the desired weight.

7. The system of claim 6 wherein means are provided for introducing and withdrawing hydraulic fluid to and from said cylinder and piston assembly, and said first means comprises:

transducers for converting the hydraulic pressure in said cylinder and piston assembly to an electrical signal which is representative of the vertical force acting on the cylinder and piston assembly.

8. The system of claim 7 wherein said fourth means comprises:

a pressure relief valve in fluid communication with the cylinder and piston assembly;

a servo mechanism attached to said pressure relief valve for controlling the position of the pressure relief valve;

means communicating the output signal from said third means to said servo mechanism to cause said mechanism to open said valve for lowering of the drill string supporting member and to close the valve to terminate vertical downward movement of the drill string supporting member.

9. The system of claim 8 wherein said means for introducing fluid to and withdrawing fluid from the cylinder and piston assembly comprises a reversible pump having a controller which may, responsive to an input signal, be employed to control the direction and volume of flow through said pump, and the system includes:

means communicating the output signal from the third means with the controller for the pump to thereby render the direction of flow and volume of flow through the pump responsible to the output signal of the third means.

10. The device of claim 9, including:

fifth means responsive to operation of the controller for generating an output signal related to the operation of said controller; and

means utilizing the signal from said fifth means to cancel the output signal from said third means upon energizing of the controller.

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