1,164,214

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

The Inventors of this invention in the sense of being the actual devisers thereof within the meaning of Section 16 of the Patents Act 1949 are:—JIMMY RAY COLE of 1800 North Ash, and PAUL LEON BULLER, of 2305 Drake Lane, both of Ponca City, Oklahoma, United States of America and both citizens of the United States of America.

Depth Controller for a Subaqueous Seismic Detector Cable

We, CONTINENTAL OIL COMPANY, a corporation organized under the laws of the State of Delaware, United States of America, of Ponca City, State of Oklahoma, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a depth controller, which may be in the form of a water kite, for maintaining an elongate member being towed through water at a predetermined depth. The invention is chiefly, but not solely, concerned with maintaining a seismic detector-cable at a predetermined depth while being towed during marine seismic-prospecting operations.

The detectors or hydrophones used in marine seismic-prospecting operations are normally towed through the water by, and form a part of, a seismic detector cable constructed substantially as disclosed in the United States Patent Specification No. 2,465,696. The problem with such a cable with which this invention is concerned is the maintenance of the cable at a selected, predetermined depth in the water while the cable is being towed by the surveying vessel. It is not unusual for a marine seismic detector cable to be a mile or even two miles long, and the efficiency of the seismic survey is affected to a large degree by the ability to maintain the various detectors or hydrophones along the length of the cable at the same, predetermined depth in the water. As a practical matter, it has been found impossible to control the specific gravity of the cable sufficiently to maintain the entire cable at a predetermined depth.

Probably the most popular technique heretofore used in an effort to maintain the seismic detector cable at a predetermined depth is by using a plurality of weights tied to the cable at spaced intervals to make the cable negatively buoyant. Floats are then also tied to the cable at spaced intervals, the plan being that the floats would ride on the surface of the water and support the cable at the desired depth. However, the floats are flung about by wave action and surveys simply can not be made in rough water. Also, the specific gravity of the water will frequently vary along the length of the cable and the floats will submerge to varying degrees. Further, it has been found that surveys can be conducted when using this technique normally only during daylight hours, primarily because of the navigational hazard provided by the many floats which are normally used. Finally, it is believed that the noise received by the detectors in the cable is generated to a large degree by the floats crashing through waves on the surface of the water, such that an increase in the number of floats merely increases the noise problem.

Various other techniques have been tried for maintaining a seismic detector cable at a predetermined depth in water, but none have proven satisfactory. For example, a boom is sometimes lowered into the water at the stern of the towing vessel to hold the leading end of the detector cable at the desired depth, but the major portion of the cable will vary in depth as the survey is being conducted. The use of a water kite tied to the trailing end of a detector cable and having automatic depth control capabilities has also been disclosed, but such a water kite will be subject to twisting motions of the detector cable and will not effectively maintain even the trailing end of the cable at the desired depth.

According to the invention there is provided

[*Price 4s. 6d.*]

SEE ERRATA SLIP ATTACHED

a depth controller for an elongate member, such as a seismic detector-cable, which member is adapted to be towed substantially horizontally through water, said depth controller serving to maintain said member at a predetermined depth and comprising an elongate housing having an axial bore extending along at least a part of its length, said bore being of a size to receive a portion of said member and to allow rotation of said member about its longitudinal axis without rotation of said housing, a bearing for rotatably securing the housing to said member, means for preventing lengthwise movement of said housing relative to said member, depth controlling means carried by the housing for maintaining the depth controller at a predetermined depth in the water as the depth controller is moved through the water by the member, and means for counter-acting rotational forces imposed on the housing by the member and/or the water.

The invention also contemplates the combination of a seismic detector cable to be towed through the water and a plurality of depth controllers journalled on the cable at spaced intervals for maintaining the entire length of the cable at the desired depth in water.

The preferred embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:—

Figure 1 is a schematic illustration of a seismic surveying system, including a detector cable being maintained at a predetermined depth in a body of water by a plurality of depth controllers constructed in accordance with this invention.

Figure 2 is a plan view of a first embodiment of the depth controller mounted on the detector cable.

Figure 3 is a vertical sectional view taken along the longitudinal axis of the preferred depth controller, with a portion of the detector cable being shown in cross-section.

Figure 4 is a sectional view taken along lines 4—4 of Figure 3.

Figure 5 is a sectional view taken along lines 5—5 of Figure 3.

Figure 6 is a sectional view taken along lines 6—6 of Figure 3.

Figure 7 is a schematic end view of a modification of the first embodiment of the depth controller mounted on a seismic detector cable.

Figure 8 is a side view, partially in section, of a second embodiment of the depth controller mounted on a seismic detector cable.

Figure 9 is a schematic cross-sectional view of a third embodiment of the depth controller mounted on a detector cable.

Figure 10 is a schematic cross-sectional view taken along lines 10—10 of Figure 9, and

Figure 11 is a side view, partially in section, of a fourth embodiment of the depth controller according to the invention mounted on a seismic detector cable.

Referring to the drawings in detail, and particularly Fig. 1, reference character 20 designates a seismic detector cable being towed through a body of water 22 by a survey vessel 24. The survey vessel 24 also tows a seismic energy source 26 through the water 22. The source 26 either continuously or periodically generates sound waves which enter the subsurface 28 below the water 22 as seismic signals and are reflected back upwardly as indicated by the various arrows. The reflected signals are detected by a plurality of detectors or geophones (not shown) carried in the cable 20 and are converted to electrical signals which are in turn conducted through the cable 20 to suitable recording equipment on the survey vessel 24. In accordance with the present invention, the cable 20 is maintained at a predetermined depth in the water 22 by a plurality of depth controllers or water kites 30 secured in spaced relation along the length of the cable.

As shown in Fig. 2, the first depth controller 30 comprises an elongated housing 32 having vertical and horizontal, fixed, stabilizing fins 34 secured around the rearward end 36 thereof, and having hydroplanes, or so-called diving planes or vanes 38 supported by shafts 40 on the opposite sides thereof, as will be more fully set forth below. Also, projections or guards 42 are preferably provided on the opposite sides of the housing 32 immediately forward of the inner edges of the diving planes 38 to minimize the possibility of weeds or the like becoming entangled between the diving planes 38 and outer surface of the housing 32.

The housing 32 is substantially hollow and is preferably formed of a light-weight material, such as a material commonly designated as a plastics material. For example, the housing 32 may be molded "Teflon" (Registered Trade Mark) or nylon and suitably reinforced if desired. An inner tubular wall 44 (Fig. 3) extends throughout the length of the housing 32 and forms an axial bore 46 extending throughout the length of the housing having a diameter of a size to loosely receive the seismic detector cable 20. Further, and as shown most clearly in Figs. 4 and 6, the housing 32 is formed in an upper section 48 and a lower section 50 of equal size. That is, the juncture 52 between the upper and lower housing sections 48 and 50 is substantially at the center line of the axial bore 46 extending through the housing, and the exposed surfaces of the housing 32 above and below the center line of the axial bore 46 are of equal area to minimize the tendency of the housing 32 to be turned by cross water currents, as will be set forth more fully below. The upper and lower housing sections 48 and 50 are secured in assembled relation around the cable 20 by a plurality of metal straps 54 suitably secured to the lower housing section 50 and in turn secured at their upper ends to the upper housing section 48 by

suitable fasteners 56. The fasteners 56 may be of any desired construction which will enable them to be readily removed for assembly and disassembly of the complete housing 32 around the cable 20. It will also be observed in Fig. 6 that the inner tubular wall 44 of the housing 32 is split at the juncture 52 between the upper and lower housing sections 48 and 50, and the respective halves of the tubular wall 44 are secured to the outer shell of the housing 32 by webs 58. It should further be noted at this point that the tubular wall 44 is cut away throughout a section 60 in the central portion of the housing 32, as shown in Fig. 3, in order that water in the axial bore 46 around the cable 20 will have access to a pressure sensing device generally designed by reference character 62 in Fig. 3. The pressure sensing device 62 will be described in detail below.

The housing 32 is journaled on the cable 20 by a main bearing 64, which is capable of opposing axial thrust, adjacent the forward end 66 of the housing 32, and a secondary bearing 68 adjacent the rearward end 36 of the housing. The secondary bearing 68 may merely comprise a split ring of plastics material suitably bonded to the tubular wall 44 to rather loosely surround the cable 20 and simply tend to retain the rearward end 36 of the housing 32 substantially centered around the cable 20.

As shown in Figs. 3 and 6, the main or thrust bearing 64 comprises an inner bush, or so-called race, 70 and an outer bush, or so-called race, 72. The inner race 70 is in the form of a split ring having the half sections thereof rigidly secured around the outer surface of the cable 20 by bolts or screws 73. It should also be noted that a reinforcing ring 76 is preferably embedded in the cable 20 inwardly of the race 70 to reinforce the cable at this point and permit the race 70 to be firmly secured to the cable. The inner race 70 is provided with a circumferential groove 78 in the outer surface thereof of a size to loosely receive the outer race 72. The outer race 72 is in the form of a split ring rigidly secured to the adjacent portion of the tubular wall 44 by suitable fasteners 80. In a preferred construction, the inner race 70 is in the form of a light weight metal, such as an aluminium alloy, and the outer race 72 is in the form of a plastics material which may be the same as the material of construction of the housing 32 to provide good cooperating bearing surfaces between the inner and outer races.

As indicated above, the outer race 72 fits loosely in the groove 78 in the inner race 70 to provide complete freedom of turning of the outer race 72 on the inner race 70, and yet prevent any appreciable length-wise movement of the housing 32 on the cable 20. It may also be observed in Fig. 3, that the tubular wall 44 of the housing 32 may be bulged outwardly at 81 around the thrust bearing 64 to accommodate the structure of the bearing if necessary. It should further be noted at this point that both the thrust bearing 64 and the secondary bearing 68 provide sufficient clearance that the pressure of the water in which the depth controller 30 is immersed will be transmitted lengthwise through the housing 32 into the cut-away section 60 of the tubular wall 44 during operation of the paravane.

As shown best in Figs. 3 and 4, the pressure sensing device 62 comprises a tank or chamber 82 for containing air under pressure, and the air pressure is adjusted by means of a suitable valve 84 which may be, for example, of a construction similar to that used in pneumatic tires. An opening 86 is formed in the top of the tank 82 and is covered by a flexible and elastic diaphragm 88. The diaphragm 88 may be formed of, for example, neoprene, and the edges thereof are suitably secured in an air-tight relationship with the adjacent portions of the top of the tank 82, as by bonding. Upper and lower reinforcing plates 90 are secured to the top and bottom, respectively, of the central portion of the diaphragm 88 and form therewith a pressure responsive member continually urged upwardly by the air pressure in the tank 82 and constantly urged downwardly by the water pressure in the housing 32. A rod 92 extends downwardly from the reinforcing plates 90 through an aperture 94 in the upper end of a bracket 96. The bracket 96 is rigidly secured to the bottom wall of the tank 82 and a limit pin 98 extends transversely through the lower end of the rod 92 to engage the upper end of the bracket 96 and limit the upward movement of the reinforcing plates 90.

A U-shaped yoke 100 has its lower, closed end 102, rigidly secured to the upper reinforcing plate 90, and the legs 104 of the yoke extend upwardly from the reinforcing plates 90 on opposite sides of the axial bore 46. It will be observed in Fig. 4 that the legs 104 of the yoke 100 are spaced sufficiently apart to not engage the cable 20 when the yoke is moved up and down with the movement of the reinforcing plates 90. The upper end of each of the yoke legs 104 is pinned to an arm 106 which extends substantially horizontally when the reinforcing plates 90 are in their neutral positions as illustrated in Figs. 3 and 4. The forward end of each arm 106 is rigidly secured to a respective diving plane shaft 40 at the respective side of the housing 32. As shown in Fig. 5, each diving plane shaft 40 is journaled in a suitable bearing 108 in the respective side of the housing 32 with the center lines of the shafts 40 being aligned with the center line of the axial bore 46. Therefore, when the reinforcing plates 90 are moved either up or down, the arms 106 will be pivoted to turn the diving plane shafts 40 equal amounts and in the same directions to adjust the settings of the diving planes 38.

In this preferred embodiment, a U-shaped brace 110 (see Fig. 5) has its free ends rigidly

secured to the diving plane shafts 40 and extends downwardly around the axial bore 46 out of interference with the cable 20. The brace 110 further assures simultaneous and equal movements of the diving planes, as in the event wear may develop in the connection of the yoke 100 to the arms 106. Further, a spring 112 is preferably anchored to the lower end portion of the brace 110 and an adjacent portion of the tank 82 to urge the diving planes 38 in directions for automatically raising the depth controller 30 in the event of failure of the diaphragm 88. Also, the spring 112 prevents or minimizes an hysteresis effect in the diaphragm 88 by maintaining the diaphragm 88 in a known position and assures that a given change in the pressure differential across the diaphragm provides a given movement of the reinforcing plates 90. The pressure sensing device 62 including the spring 112 forms the subject matter of our co-pending application No. 4,781/68 (Serial No. 1,164,218).

Ballast, in the form of a lead weight 114 or the like, is secured in the lower portion of the housing 32 to further assure that the depth controller will not turn or spin during movement through the water and that the diving plane shafts 40 will remain extended horizontally.

A suitable floatation material 116 preferably fills the housing 32, except for that portion 118 of the housing around the cutaway portion 60 of the tubular wall 44. The floatation material 116 may be of any desired type which will prevent the housing 32 from being filled with water, and, thus, ensure the buoyancy of the depth controller. However, the depth controller will normally be slightly negatively buoyant.

Operation of the First Embodiment

As previously indicated, a plurality of depth controllers 30 are used on the cable 20. Thus, before the cable 20 is placed in the water 22, the air pressure in the tank 82 of each depth controller to be used is adjusted for the desired running depth of the depth controller and, hence, the desired depth of operation of the cable 20. As previously indicated, this air pressure may be easily adjusted by means of the valve 84 in each depth controller. It may also be pointed out that when each tank 82 is pressurized to the desired degree, the diving planes 38 of the respective depth controller will be turned into a diving attitude, since the air pressure in the tank will be opposed only by atmospheric pressure on the top of the respective diaphragm 88 and reinforcing plates 90. However, the stop pin 98 connected to the reinforcing plates in each depth controller will prevent the respective diaphragm 88 from being over stressed when the depth controller is out of the water.

In use, the depth controllers 30 are secured around the cable 20 as the cable 20 is paid out from the survey vessel 24. Each depth controller is easily installed around the cable 20 by placing the upper and lower housing sections 48 and 50 around the cable with the outer bearing race 72 fitting in the inner bearing race 70 secured around the cable 20, and then attaching the fasteners 56. In this connection it may be noted that the inner bearing races are normally left intact on the cable 20 when the depth controllers 30 are removed, although these inner bearing races can be removed in the event the cable needs repair.

As each depth controller 30 is dropped into the water 22 with the cable 20, the diving planes 38 will be in their diving attitudes, such that the depth controller will start trying to dive to the predetermined depth as regulated by the pressure in the air tank 82. When each depth controller 30 is first placed in the water 22 behind the survey vessel 24, the wake provided by the survey vessel will sometimes make the depth controller unstable and the depth controller will tend to spin on the cable 20 for a short period of time. However, by virtue of the depth controller being journaled on the cable 20, spinning of the depth controller for a short period of time does not twist the cable. As soon as the depth controller is moved rearwardly out of the wake provided by the survey vessel through a continued paying out of the cable 20, the depth controller becomes stable in the water and oriented with diving plane shafts 40 extending horizontally. The diving planes 38 are then effective to urge the depth controller downwardly to the predetermined depth of operation.

When the cable 20 has been paid out to the desired length with the depth controller 30 secured thereto, the pressure of the water surrounding each depth controller will act on diaphragm 88 and on the upper reinforcing plate 90 and will force the reinforcing plates 90 to a neutral position when the pressure on the opposite sides of the diaphragm 88 becomes equal. At this point, the diving planes 38 will be extended horizontally, providing the diving plane shafts 40 are aligned with the center line of the cable 20 and the center line of the axial bore 46.

In the event a depth controller 30 moves below the predetermined depth, as by action of water currents, the hydrostatic pressure of the water will become greater than the pressure in the tank 82; whereupon the reinforcing plates 90 will be moved downwardly and act through the yoke 100 and arms 106 to turn the diving planes 38 to elevating positions. The depth controller 30 will therefore be moved upwardly by the reaction of the water 22 on the diving planes 38 until the depth controller 30 reaches the desired depth, at which time the diving planes 38 will be returned to neutral positions. Conversely, in the event the depth controller 30 moves upwardly above the predetermined operating depth, the pressure in the tank 82 will be greater than the hydro-

static pressure of the water 22 acting on diaphragm 88 and on the upper reinforcing plate 90, and the diving planes 38 will return to diving positions to return the depth controller 30 to the desired operating depth.

The diaphragm 88 may be sized to control the operating depth of the depth controller 30 to a plus or minus variation which will not affect the efficiency of the seismic survey being conducted. A two foot change in depth of the water 22 provides approximately a one pound per square inch variation in hydrostatic pressure. Thus, the area of the diaphragm 88 exposed to the hydrostatic pressure of the water 22 and to the pressure in the tank 82 will control the operating force available for application to adjust the diving planes 38. In one construction of depth controller 30, a diaphragm 88 having an exposed area of seven square inches has been used, and with this size of diaphragm, the depth controller will be maintained within plus or minus two feet of the desired operating depth in a surveying operation.

It will be understood that when each depth controller 30 is maintained at a predetermined operating depth, the adjacent portion of the cable 20 will likewise be maintained at the desired depth, since any vertical movement of the depth controller 30 will be reflected in the adjacent portion of cable 20, and vice versa. On the other hand, any twisting of the cable 20 will not effect the orientation of the depth controller 30, since the cable 20 may twist and turn in the axial bore 46 of the depth controller and will simply move the inner bearing race 70 with respect to the outer bearing race 72 and not turn the depth controller. The depth controller 30 will be virtually unaffected by currents, except when the depth controller is in the wake of the survey vessel as referred to above, such that the depth controller will remain oriented with the diving plane shafts 40 extending horizontally, and the diving planes 38 will effectively control the depth of operation of the depth controller.

Since the cable 20 will be maintained at the desired operating depth by the depth controller 30, the cable 20 may be maintained out of danger from being cut or damaged by another vessel cutting across astern of the survey vessel 24, and the cable 20 may be left in the water 22 throughout the night, with the seismic surveying operation being continued if desired. Further, since the cable 20 is maintained below surface turbulence, the noise picked up by the detectors in the cable is maintained at a minimum. In fact, in one test, a cable held at a predetermined depth by depth controllers 30 experienced a 10 : 1 signal-to-noise reduction over a similar operation of the cable when the cable was supported by floats from the surface of the water.

Modification of Fig. 7

A slightly modified depth controller 120 is schematically illustrated in Fig. 7. The depth controller 120 is constructed in the same manner as the depth controller 30 previously described, except that the ballast 122 for the depth controller 120 is carried below the housing 32 by a web or support 124, rather than being in the housing as in the previous embodiment.

Placing the ballast farther below the cable 20, as in Fig. 7, tends to stabilize the orientation of the depth controller which may tend to be upset by twisting of the cable 20, and is therefore desirable under some operating conditions. On the other hand, the exposed surfaces of the depth controller 120 are greater below the center line of the cable 20 than above the center line of the cable 20, such that the depth controller 20 is more subject to disorientation in response to cross currents than is the depth controller structure disclosed in Figs. 1 through 6.

Embodiment of Fig. 8

A second embodiment of the depth controller according to the invention is schematically illustrated in Fig. 8. This depth controller 130 comprises a generally oval-shaped housing 132 secured symetrically on the cable 20 by front and rear bearings 134. Each bearing 134 comprises an outer bearing bush or race 136 rigidly secured to the inner surface of a tubular wall 138 of the housing 132, and an inner bush or race 140 rigidly secured around the cable 20. The inner bearing race 140 has a circumferential groove 142 in the outer surface thereof loosely receiving the outer bearing race 136 in a manner similar to that previously described to effectively journal the housing 132 on the cable 20 and yet prevent lengthwise movement of the housing 132 along the cable.

The housing 132 is substantially hollow and includes an upper tubular arm 144 and a lower tubular arm 146. A cylinder 148 is suitably secured in the upper arm 144 in a fixed position and contains a piston 150 slidingly movable therein. The piston 150 is continually urged in one direction by a spring 152, the compression of which may be adjusted by an adjusting screw 154 threadedly secured in one end 156 of the cylinder 148. The opposite end of the piston 150 is exposed to the hydrostatic pressure of the water in which the paravane is immersed, since the water communicates with this face of the piston 150 through ports 158 formed in the walls of the arm 144. It may also be pointed out that the setting of the adjusting screw 154 may be controlled through an opening 168 in the housing arm 144 which is normally covered by a removable plate 170.

A rod 172 projects from the piston 150 and has its free end 174 pinned to an arm 176. The arm 176 is in turn rigidly secured to a shaft 178 which carries hydroplanes, or so-called diving planes or vanes, 180 positioned on opposite sides of the housing arm 144.

The lower arm 146 of the housing 132 contains ballast 182 in the form of a lead weight or the like which tends to maintain the housing 132 oriented as shown in Fig. 8 with the diving plane shaft 178 maintained horizontally. It will also be apparent that the housing 132 may be formed in upper and lower sections for ease of assembly and disassembly of the paravane 130 on the cable 20 in a manner similar to that disclosed in Figs. 1—6.

Before the depth controller 130 is placed in water with the cable 20, the spring 152 is adjusted by the screw 154 for the desired operating depth. Since the force exerted by the spring 152 will be virtually unopposed when the depth controller 130 is out of the water, the piston 150 will be moved the maximum extent by the spring 152 to turn the diving planes 180 into a diving attitude when the depth controller 130 is first placed in the water. Therefore, the depth controller will quickly dive.

As the depth controller 130 dives, the hydrostatic pressure imposed on the piston 150 through the ports 158 will increase to move the piston 150 against the spring 152 and gradually decrease the diving attitude of the diving planes 180. This movement of the piston 150 increases the spring compression and also the air pressure in the cylinder as piston 150 is sealed against leakage of air around its periphery. When the depth controller 130 reaches the desired operating depth, the hydrostatic pressure of the water on the piston 150 will equalize the force provided by the spring 152 and the increased air pressure to place the piston 150 in what may be considered a neutral position and position the diving planes 180 in positions such that the depth controller 130 will remain at said depth.

In the event the depth of operation of the depth controller 130 is increased, as by forces imposed on the cable 120, the hydrostatic pressure in the water will increase to force the piston in a direction to further compress the spring 152 and adjust the diving planes 180 into positions for raising the depth controller. Conversely, in the event the depth controller 130 is inadvertently moved upwardly in the water, the hydrostatic pressure will decrease and the spring 152 will move the piston 150 in a direction to place the diving planes 180 into diving positions and thereby lower the depth controller back to the desired operating depth.

The bearings 134 prohibit a twisting motion of the cable 20 from being transmitted to spin or turn the housing 132, such that the depth controller 130 will remain oriented in the water with the diving plane shaft 178 extending horizontally, and the diving planes 180 will remain in the proper positions for controlling the depth of operation of the depth controller. On the other hand, any vertical forces imposed on the cable 20 will tend to raise or lower the depth controller 130, and vice versa, such that the depth controller 130 will maintain the adjacent portion of the cable 20 at the desired operating depth.

Embodiment of Figs. 9 and 10

A third embodiment of the depth controller according to the invention is schematically illustrated in Figs. 9 and 10. This depth controller 200 comprises a hollow housing 202 which may be formed in sections joined along a line 204 for easy placement around the cable 20. The housing 202 is journaled on the cable 20 by bearing portions schematically illustrated at 206 in the forward and rear ends of the housing.

In this embodiment of the invention, a ring gear 208 is rigidly secured around the cable 20 within the housing 202 and is engaged by a plurality of equally, circumferentially spaced pinions 210. Each pinion 210 is provided with flanges 214 on the opposite ends thereof of a size to overlap the respective ends of the ring gear 208 and prevent the housing 202 from moving lengthwise along the cable 20. Each pinion 210 is rigidly mounted on a shaft 216 having its opposite ends journaled in bearings 218. Each bearing 218 is in turn held in the desired position in the housing 202 by a plate 220 extending inwardly from the outer walls of the housing in any desired manner. The shaft 216 of one of the pinions 210 is connected by a belt drive 222 to the output shaft of a reversible electric motor 224. The motor 224 is rigidly secured in the housing 202 in any desired manner.

A pendulum 226 is suitably journaled on a shaft 228 supported in a horizontal position in the housing 202 by a pair of bearings 230 and supports 232, such that the pendulum 226 will tend to swing transversely with respect to the cable 20 at any time the angular orientation of the housing 202 is changed. As schematically illustrated in Fig. 10, the pendulum 226 is connected to a source of electrical energy 234, such as a battery. Also, opposed contacts 236 and 238 are positioned on opposite sides of the pendulum 226 and are connected to the forward and reverse inputs 240 and 242, respectively, of the motor 224.

The complete depth controller 200 also includes hydroplanes or so-called diving planes and a pressure responsive device therein similar to the depth controller previously described in connection with Figures 1—6, or 8 to control the operating depth of the depth controller.

In operation of the depth controller 200, the pendulum 226 will remain in a vertical position as long as the housing 202 is properly oriented, that is, as long as the housing 202 is not turned on the cable 20. If the housing 202 starts turning in one direction, the pendulum 226 will contact one of the contacts 236 or 238 to energize the motor 224 in one direction. The motor 224 will in turn drive the pinion 210 connected thereto in a given direction.

The respective pinion 210 will in turn engage the ring gear 208 and return the housing 202 to the proper angular orientation. In the event the housing 202 starts turning in the opposite direction the pendulum 226 will contact the opposite contacts 236 or 238 and energize the motor 224 in an opposite direction to return the housing 202 to the desired position through the driving engagement of the pinion 210 connected to the motor 224. The remaining pinions 210 act as idlers and equalize the forces imposed on the ring gear 208.

Embodiment of Fig. 11

A fourth embodiment of the depth controller according to the invention is schematically illustrated in Fig. 11. This depth controller 300 comprises an upper housing section 302 and a lower housing section 304 interconnected by forward and rear tubular portions 306. The tubular portions 306 are journaled around the cable 20, as by bearings of the type shown in Fig. 8. The lower housing section 304 contains a suitable ballast 308 which will retain the lower housing section 304 extending downwardly below the cable 20 and will retain the upper housing section 302 extending upwardly above the cable 20.

The upper housing section 302 contains walls forming an inlet passageway 310 communicating with the forward end 312 of the housing; a rearwardly and upwardly extending arcuate passageway 314 communicating with the passageway 310 and the outer surface of the housing section 302; and a downwardly and rearwardly extending arcuate passageway 316 communicating with the inlet passageway 310 and the outer surface of the housing section 302. A vane 318 is rotatably secured in the housing section 302 by a shaft 320 in a position to selectively at least partially close off the passageways 314 and 316 from the inlet passageway 310. In other words, referring to Fig. 11, when the vane 318 is turned counterclockwise, the passageway 314 will be at least partially closed off, and when the vane 318 is turned clockwise, the passageway 316 will at least be partially closed from the inlet passageway 310. The shaft 320 is suitably connected to a pressure sensing device as of the type shown in either Fig. 3 or Fig. 8, such that the vane 318 will be turned by variations in the hydrostatic pressure of the water in which the depth controller 300 is operating.

In operation of the depth controller 300, the pressure sensing device will turn the shaft 320 to turn the vane 318 into a position partially closing off the passageway 316 from the inlet 310 when the depth controller 300 is first placed in the water. Thus, as the depth controller 300 is towed through the water, the water flowing through the inlet passageway 310 and then upwardly and rearwardly through the passageway 314 will by centrifugal action cause the depth controller to dive toward the predetermined depth of operation. When the predetermined depth is reached, the vane 318 will have been moved to a neutral position as illustrated in Fig. 11. In the event the depth controller 300 is lowered from the desired operating depth, the vane 318 will be turned by the pressure sensing device to partially close off the passageway 314 from the inlet passageway 310. The water then flowing through the inlet passageway 310 will be directed downwardly by the passageway 316 and the centrifugal action thereof raises the depth controller 300 back to the desired operating depth.

From the foregoing it will be apparent that the present invention will effectively maintain a marine seismic detector cable at a predetermined depth in water as the cable is being towed through the water. The noise received by the detectors in the cable will be substantially reduced over previous operating techniques and the cable can be left in the water during the night and, in fact, the seismic surveying operations may be continued throughout the night if desired. The depth controller provided by this invention will not be affected by twisting of the cable, as when the direction of the surveying vessel is changed, such that the means for controlling the depth of the depth controller will remain oriented in the proper position and remain effective for controlling the depth, even as the cable is turned.

WHAT WE CLAIM IS:—

1. A depth controller for an elongate member, such as a seismic detector-cable, which member is adapted to be towed substantially horizontally through water, said depth controller serving to maintain said member at a pre-determined depth and comprising an elongate housing having an axial bore extending along at least a part of its length, said bore being of a size to receive a portion of said member and to allow rotation of said member about its longitudinal axis without rotation of said housing, a bearing for rotatably securing the housing to said member, means for preventing lengthwise movement of said housing relative to said member, depth controlling means carried by the housing for maintaining the depth controller at a predetermined depth in the water as the depth controller is moved through the water by the member, and means for counteracting rotational forces imposed on the housing by the member and/or the water.

2. A depth controller as claimed in claim 1, wherein the second said means includes stabilising means carried by the housing below the member to counteract the rotational forces imposed on the housing, and the depth controlling means includes depth sensing means carried by the housing, said diving means engaging the water and being connected to the depth sensing means so as to vary the depth of immersion of the depth controller in response to operation of the depth sensing means.

3. A depth controller as claimed in claim 2, wherein the means for counteracting rotational

forces also includes vertical and horizontal fixed fins secured to the exterior of the housing.

4. A depth controller as claimed in claim 2 or 3, wherein said diving means comprises diving planes rotatably secured to the opposite sides of the housing, and means interconnecting the diving planes for uniform adjustment of the diving planes in response to the depth sensing means.

5. A depth controller as claimed in claim 2 or 3, wherein said diving means comprises walls in the housing forming an inlet passageway for ambient water at the forward end of the housing, a rearward and upwardly extending passageway communicating with the inlet passageway and the exterior of the housing, and a rearward and downwardly extending passageway communicating with the inlet passageway and the exterior of the housing, and a vane connected to the depth sensing means and pivotably secured in the housing in a position to selectively at least partially close off said upwardly and downwardly extending passageways to control the flow of water therethrough as the housing is moved through the water.

6. A depth controller as claimed in any preceding claim in which the means for preventing lengthwise movement of the housing relative to the member is constituted by said bearing which is located in said bore.

7. A depth controller as claimed in claim 6, wherein said housing comprises an upper section, a lower section, and fasteners securing the upper and lower sections around the member.

8. A depth controller as claimed in claim 6 or 7, wherein said bearing comprises an inner bush rigidly secured around the member, and an outer bush journalled on the inner bush and rigidly secured to the housing within said bore.

9. A depth controller as claimed in claim 8, wherein said inner bush is secured in said bore adjacent the forward end of the housing.

10. A depth controller as claimed in claim 8 or 9, wherein said inner bush comprises a ring having a circumferential groove in the outer periphery thereof, and said outer bush comprises a ring of a material different from the inner bush ring and sized to slidably fit in said circumferential groove.

11. A depth controller as claimed in claim 10 as appendant to claim 7, wherein said outer bush ring is formed in two sections, one section being secured to the upper housing section and the other section being secured to the lower housing section.

12. A depth controller as claimed in any of claims 9 to 11, wherein a secondary bearing is secured in the bore loosely around the member adjacent the rearward end of the housing.

13. A depth controller as claimed in claim 2 or any claim appendant thereto, wherein said stabilizing means includes ballast carried by the lower portion of the housing below the member.

14. A depth controller as claimed in claim 13, wherein the ballast is secured in the lower portion of the housing and wherein the area of the surfaces of the housing below the centre line of said bore exposed to the water are equal to the area of the surfaces of the housing above the centre line of said bore exposed to the water.

15. A depth controller as claimed in claim 13, wherein said ballast is positioned below the housing.

16. A depth controller as claimed in claim 1, wherein said depth controlling means includes horizontally extending shafts journalled in the opposite sides of the housing, a diving plane rigidly secured on each shaft, a pressure responsive member reciprocally carried by the housing having one end thereof exposed to the water through which the depth controller is towed, an adjustable spring engaging the pressure-responsive member whereby the pressure-responsive member will move in response to changes in depth of the depth controller above and below a predetermined depth, and a linkage system connecting the pressure-responsive member to said shafts for turning said shafts and controlling the settings of the diving planes.

17. A depth controller as claimed in claim 16, wherein said pressure-responsive member is supported in the housing for vertical movement with said one end thereof exposed to said bore, and wherein the diameter of said bore is larger than the diameter of the member, whereby the water through which the depth controller is moving contacts said one end of the pressure responsive member.

18. A depth controller as claimed in claim 16, wherein said shafts are aligned with the center line of said bore, and wherein said linkage system includes a U-shaped yoke having its free ends extending upwardly and being sized to move vertically without interference with the member, means for connecting the closed end of the yoke to the pressure-responsive member to effect vertical movement of the yoke with the pressure-responsive member, and an arm pivotably secured to each of the free ends of the yoke and rigidly secured to the shaft on the respective side of the member for turning the shafts upon movement of the pressure-responsive member.

19. A depth controller as claimed in claim 18, further including a semi-circular shaped brace loosely encircling one-half of the member and having its ends rigidly secured to the shafts to assure equal movement of the diving planes.

20. A depth controller as claimed in claim 1, wherein said housing is hollow and includes buoyant material filling the available space in the housing not required for said bearing, and depth controlling means.

21. A depth controller as claimed in claim 1, wherein the means for counteracting rotational forces includes a ring gear rigidly secured

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The respective pinion 210 will in turn engage the ring gear 208 and return the housing 202 to the proper angular orientation. In the event the housing 202 starts turning in the opposite direction the pendulum 226 will contact the opposite contacts 236 or 238 and energize the motor 224 in an opposite direction to return the housing 202 to the desired position through the driving engagement of the pinion 210 connected to the motor 224. The remaining pinions 210 act as idlers and equalize the forces imposed on the ring gear 208.

Embodiment of Fig. 11

A fourth embodiment of the depth controller according to the invention is schematically illustrated in Fig. 11. This depth controller 300 comprises an upper housing section 302 and a lower housing section 304 interconnected by forward and rear tubular portions 306. The tubular portions 306 are journaled around the cable 20, as by bearings of the type shown in Fig. 8. The lower housing section 304 contains a suitable ballast 308 which will retain the lower housing section 304 extending downwardly below the cable 20 and will retain the upper housing section 302 extending upwardly above the cable 20.

The upper housing section 302 contains walls forming an inlet passageway 310 communicating with the forward end 312 of the housing; a rearwardly and upwardly extending arcuate passageway 314 communicating with the passageway 310 and the outer surface of the housing section 302; and a downwardly and rearwardly extending arcuate passageway 316 communicating with the inlet passageway 310 and the outer surface of the housing section 302. A vane 318 is rotatably secured in the housing section 302 by a shaft 320 in a position to selectively at least partially close off the passageways 314 and 316 from the inlet passageway 310. In other words, referring to Fig. 11, when the vane 318 is turned counterclockwise, the passageway 314 will be at least partially closed off, and when the vane 318 is turned clockwise, the passageway 316 will at least be partially closed from the inlet passageway 310. The shaft 320 is suitably connected to a pressure sensing device as of the type shown in either Fig. 3 or Fig. 8, such that the vane 318 will be turned by variations in the hydrostatic pressure of the water in which the depth controller 300 is operating.

In operation of the depth controller 300, the pressure sensing device will turn the shaft 320 to turn the vane 318 into a position partially closing off the passageway 316 from the inlet 310 when the depth controller 300 is first placed in the water. Thus, as the depth controller 300 is towed through the water, the water flowing through the inlet passageway 310 and then upwardly and rearwardly through the passageway 314 will by centrifugal action cause the depth controller to dive toward the predetermined depth of operation. When the predetermined depth is reached, the vane 318 will have been moved to a neutral position as illustrated in Fig. 11. In the event the depth controller 300 is lowered from the desired operating depth, the vane 318 will be turned by the pressure sensing device to partially close off the passageway 314 from the inlet passageway 310. The water then flowing through the inlet passageway 310 will be directed downwardly by the passageway 316 and the centrifugal action thereof raises the depth controller 300 back to the desired operating depth.

From the foregoing it will be apparent that the present invention will effectively maintain a marine seismic detector cable at a predetermined depth in water as the cable is being towed through the water. The noise received by the detectors in the cable will be substantially reduced over previous operating techniques and the cable can be left in the water during the night and, in fact, the seismic surveying operations may be continued throughout the night if desired. The depth controller provided by this invention will not be affected by twisting of the cable, as when the direction of the surveying vessel is changed, such that the means for controlling the depth of the depth controller will remain oriented in the proper position and remain effective for controlling the depth, even as the cable is turned.

WHAT WE CLAIM IS:—

1. A depth controller for an elongate member, such as a seismic detector-cable, which member is adapted to be towed substantially horizontally through water, said depth controller serving to maintain said member at a pre-determined depth and comprising an elongate housing having an axial bore extending along at least a part of its length, said bore being of a size to receive a portion of said member and to allow rotation of said member about its longitudinal axis without rotation of said housing, a bearing for rotatably securing the housing to said member, means for preventing lengthwise movement of said housing relative to said member, depth controlling means carried by the housing for maintaining the depth controller at a predetermined depth in the water as the depth controller is moved through the water by the member, and means for counteracting rotational forces imposed on the housing by the member and/or the water.

2. A depth controller as claimed in claim 1, wherein the second said means includes stabilising means carried by the housing below the member to counteract the rotational forces imposed on the housing, and the depth controlling means includes depth sensing means carried by the housing, said diving means engaging the water and being connected to the depth sensing means so as to vary the depth of immersion of the depth controller in response to operation of the depth sensing means.

3. A depth controller as claimed in claim 2, wherein the means for counteracting rotational

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around the member, at least one pinion journalled in the housing in a position to engage the ring gear and turn the housing around the member, a reversible electric motor in the housing drivingly connected to said pinion, a source of electrical energy for said motor, a pendulum secured in the housing so as to remain vertical when the housing turns on the member and being connected to the source of electrical energy, and switch-contacts in the housing on the opposite sides thereof and positioned to be selectively engaged by the pendulum upon turning of the housing on the member, said contacts being connected to the forward and reverse electrical input-connections of the motor so as to maintain the housing in a predetermined angular orientation upon twisting of the member about its own axis.

22. A depth controller for a seismic detector-cable adapted to be towed substantially horizontally through water substantially as described hereinbefore with reference to and as shown in Figures 2 to 6, Figures 2 to 6 as modified in accordance with Figure 7, Figure 8, Figures 9 and 10, or Figure 11 of the accompanying drawings.

23. Apparatus for maintaining a seismic detector-cable at a predetermined depth as the cable is being towed through water, said apparatus comprising a plurality of depth controllers each in accordance with any preceding claim and secured in spaced relation along the cable for maintaining the adjacent portion of the cable at said predetermined depth.

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