

Sept. 7, 1965

J. BERNE
METHOD AND APPARATUS FOR SUBMARINE WELL
DRILLING, USING A FLEXIBLE
TUBING AS DRILL STRING

3,204,708

Filed July 18, 1963

4 Sheets-Sheet 1

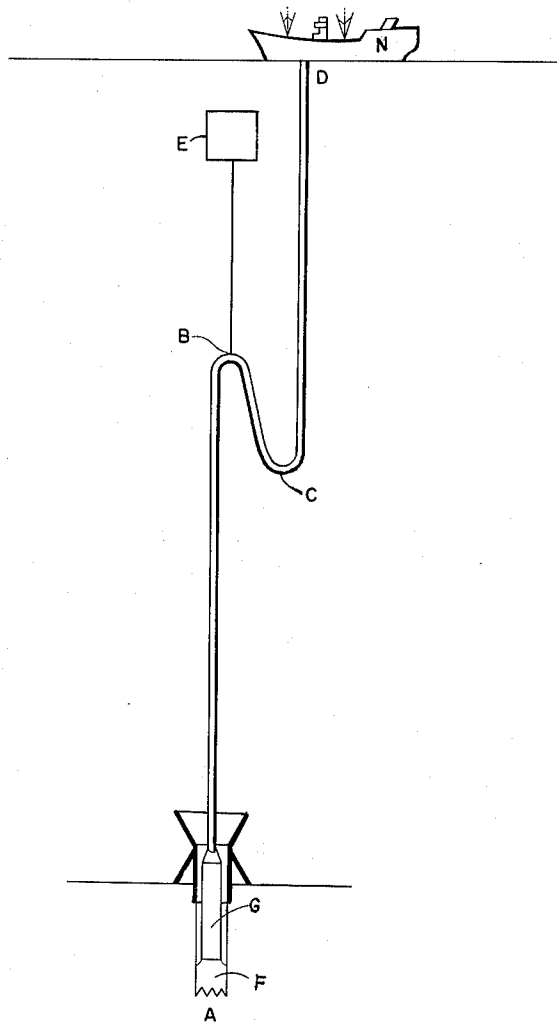


Fig. 1

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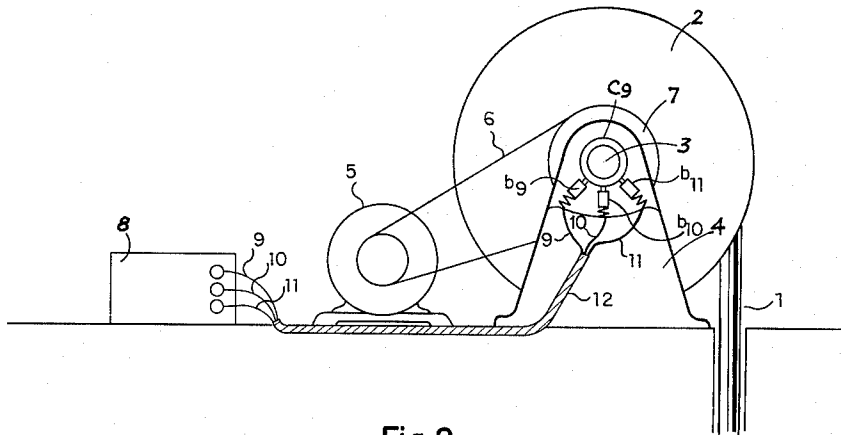


Fig. 2

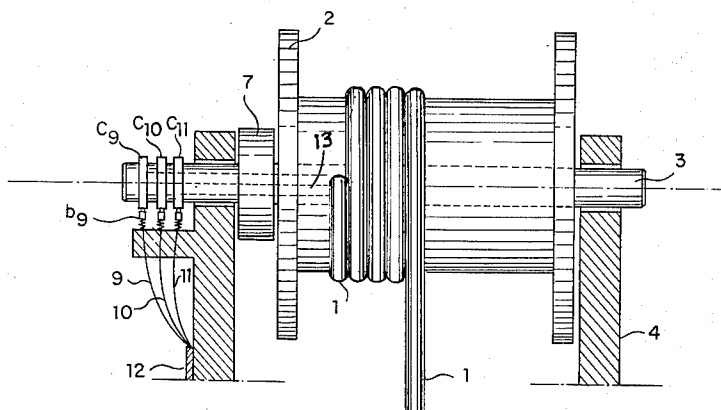


Fig. 3

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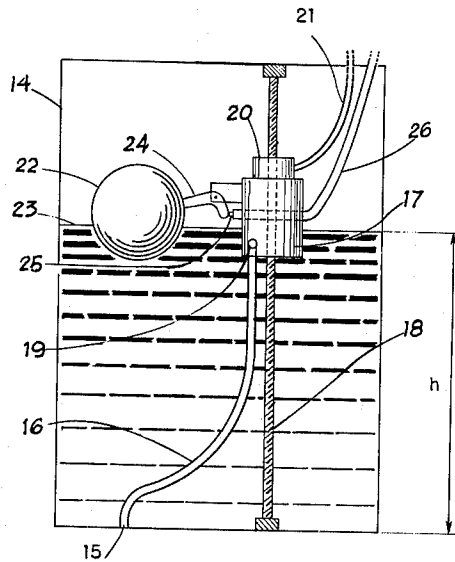


Fig. 4

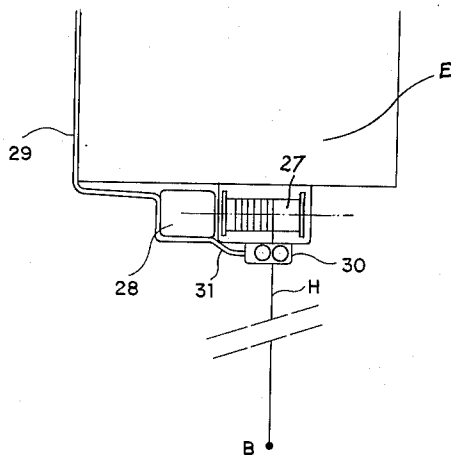


Fig. 5

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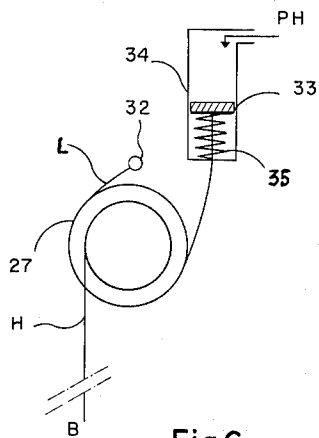


Fig. 6

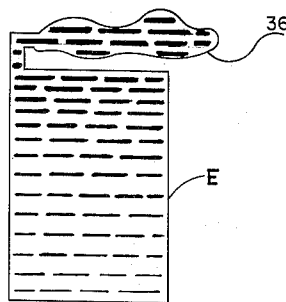


Fig. 7

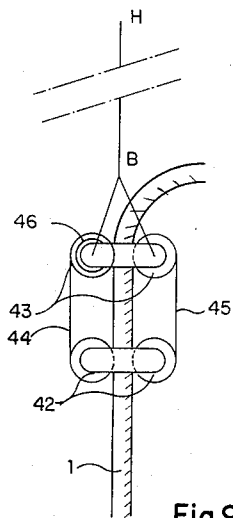


Fig. 9

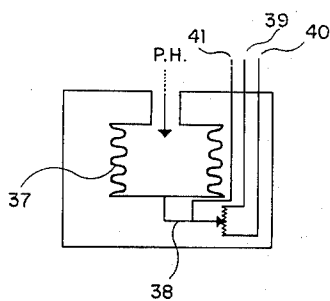


Fig. 8

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3,204,708

METHOD AND APPARATUS FOR SUBMARINE WELL DRILLING, USING A FLEXIBLE TUBING AS DRILL STRING

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Claims priority, application France, July 24, 1962, 904,975

9 Claims. (Cl. 175—6)

This invention relates to a method for carrying out submarine well drilling with a flexible tubing as drill string and an apparatus therefor.

Submarine well drilling at great depth is generally carried out with a drill string composed of a series of coupled rigid tube sections starting from a ship at the water surface and placed substantially in vertical alignment with the boring head.

Many problems arise, due to the presence of the waves, of undercurrents and/or climatic disturbances which tend on the one hand to move the ship away from its initial position and, on the other hand, to subject the ship to vertical displacements corresponding to the hollows or the peaks of the waves.

In these conditions, it is difficult to maintain the drill string in a substantially vertical alignment with the well boring head, and the permissible angle of the drill string with respect to said vertical alignment is relatively small. Furthermore, the movements of the ship make it difficult to adjust to the desired value the weight applied on the drill bit.

One way of overcoming these difficulties consists of adjusting the lowering or the rising, with respect to the ship's position, of the means for subjecting the drill string to a tensile strength, so that the load on the drill bit be kept substantially constant irrespective of the ship's displacements. However, the amplitude of the vertical displacement of the ship, depending on the sea condition and the type of the ship, may reach several meters.

The above method requires the use of a servo-mechanism capable of adjusting with a high accuracy (a few percent) the weight on the bit which may be as high as 20 to 30 metric tons.

Such a mechanism is very complex and also results in a considerable increase of the cost of the drilling equipment.

Furthermore, this method for adjusting the weight on the drill bit requires a very restricted margin of movement for the ship.

In the case of deep drilling, the drill string must be kept permanently within a cone having its peak at the well boring head and the ship must be so handled as to remain constantly inside the base of this cone. In this case, the margin for the angle of roll cannot be very large.

The method of drilling with the use of a flexible tubing avoids a part of the above-mentioned drawbacks due to the flexibility of the tube which results in a larger margin for handling the ship which may be moved inside a larger cone base.

However, due to the fact that the load on the bit must be small, it has to be adjusted with a greater accuracy, particularly in the case of deep drilling. It is thus necessary to make use of complex servomechanisms in order to maintain within the desired range the load on the bit and, accordingly, the traction strain on the flexible tubing.

It is therefore an object of this invention to carry out drilling operations with the use of a flexible tubing in such a manner as to avoid the above-mentioned drawbacks.

It is another object of this invention to provide means for adjusting with a satisfactory accuracy the load applied on the drill bit.

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It is still another object of this invention to considerably enlarge the margins for the ship displacements in submarine drilling operations.

These and other objects as may be apparent from the following specification and claims are achieved by means of the method and device according to this invention whereby the total traction strain exerted on the flexible drill string by traction means provided on the ship is replaced by two separate traction strains, each applying to a separate portion of the drill string; one of these traction strains, exerted on the lower portion of the drill string to which is suspended the drill bit, being maintained substantially constant whereas the other traction strain exerted from the ship on the upper portion of the drill string may be of variable magnitude.

The traction strain exerted on the upper portion of the drill string is only effective for balancing the weight of this tubing portion the length of which is variable. As a matter of fact, as the drilling progresses, new tubing lengths will be added to this upper portion of the tubing whereas the lower portion will remain unchanged.

Moreover the total tubing length immersed must be sufficient to provide for a sufficiently wide margin for handling the ship and avoiding surface disturbances (waves or the like) that have an effect on the adjustment of the traction strain exerted from the ship.

Accordingly, the upper portion of the drill string will be placed along a catenary curve whose end points are respectively the point of application of the constant traction strain exerted on the lower portion of the drill string, and the point of application of the traction strain exerted from the ship. The lower point of this catenary curve divides the upper portion of the tubing into two arcuate parts—the greater of which is supported from the ship, whereas the other, adjacent to the lower portion of the drill string is supported together with the latter by the constant traction strain.

Consequently, the weight on the drill bit will be equal to the difference between the weight of the assembly comprising the drill bit, the lower portion of the drill string having added thereto the adjacent arcuate part of the upper portion thereof and optionally drill collars if any, on the one hand, and the traction strain on the other hand.

This weight on the drill bit will be kept substantially constant inasmuch as the weight of the arcuate part of the upper portion of the drill string which is adjacent to the lower portion thereof may be considered negligible as compared to the weight of the latter.

An example of the method of the invention and of an embodiment of apparatus for carrying out the same is hereafter described with reference to the accompanying drawings in which:

FIGURE 1 represents schematically the entire system by which the method of this invention is put into practice;

FIGURE 2 shows the winding mechanism for unwinding the flexible cable;

FIGURE 3 shows the means for feeding electric current to the motor at the bottom;

FIGURE 4 shows the means for adjusting the tractive force on the drilling tool comprising a buoy whose buoyancy is regulated;

FIGURE 5 shows a mechanism for unwinding the cable that connects the buoy to the flexible tube;

FIGURE 6 shows an apparatus actuated by variations of hydrostatic pressure for controlling the unwinding of the cable;

FIGURE 7 shows a buoy having a deformable side;

FIGURE 8 shows an accumulator of hydrostatic pressure; and

FIGURE 9 shows an apparatus for moving the point

of attachment B of the tube to the cable which connects it to the buoy.

A flexible tubing ABCD ending with the drill bit F actuated for instance by means of an electromotor G and located at point A at the beginning of the drilling operation, is suspended from the ship at point D. A buoy E immersed at a sufficient depth to avoid the effect of the surface disturbances (a depth of the order of 30 meters for instance) and so located as to be sheltered from undercurrents and in substantially vertical alignment with the boring head, exerts a constant traction strain on the portion AB of the flexible tubing, through the intermediary of a traction cable EB secured on the flexible tubing at a pre-determined point B thereof. The upper portion of the flexible tubing between B and D (on the ship) must have a length slightly greater than the distance BD so that the tubing portion BCD takes on the shape of a catenary curve. When this is the case, and as it can be seen on the drawing, the ship supports the weight of the portion DC of the drill string, whereas the traction force exerted at point B by the buoy balances the weight of the lower part AB of the drill string together with the electromotor and the drill bit as well as the weight of the tubing portion BC.

The feeding rate of the flexible tubing is adjusted so as to be substantially equal to the depth drilled, whereby the tubing length BC is kept substantially constant.

Means for feeding the flexible tubing are illustrated by way of example, in FIGURE 2. This figure shows the flexible tubing 1 wound on a reel 2 rotatably mounted on a horizontal shaft 3 supported on a frame structure 4.

This reel is driven by the motor 5 by means of belt or chain 6 passing over a pulley or sprocket wheel 7.

The feeding of electric current to the motor at the bottom is accomplished by means of an electric generator 8.

The three conductors 9, 10 and 11 forming the cable 12 are connected to the brushes b_9 , b_{10} and b_{11} which are pressed against slip-rings c_9 , c_{10} and c_{11} respectively by springs carried by supports 4 (FIG. 3), the slip-rings being mounted on the axis 3 of the reel and are insulated from the axis and from one another.

Three insulated conductors are connected to these slip-rings and as shown in dotted lines, pass along the hollow axis to be connected at 13 to the end of a flexible three-strand conductor whose opposite end is connected to the motor G at the bottom. Such a flexible conductor is described in U.S. application Ser. No. 246,898 filed December 26, 1962.

Since the tubing length AB is invariable, the weight on the drill bit is kept constant inasmuch as the tubing length BC is also constant.

However, under the action of high amplitude waves, the point D may be moved vertically by several meters from its mean position. The tubing length corresponding to this amplitude variation is distributed by half over the two arcuate tubing lengths BC and DC.

The variation of the traction strain at point B is therefore equal to one half of the weight of the tubing length corresponding to the difference between BCD and distance BD, i.e. to the product of this length difference expressed in meters for instance, by the weight per meter of the flexible tubing. Since the tubing length AB is constant, this variation will also be that of the weight applied to the drill bit, which variation is very small with respect to the amplitude of the ship displacement. When the drill bit is in operation, the tubing length AB remains constant and the point B moves downwardly towards the sea-bottom in proportion to the progression of the drill bit in the bore-hole. As the load on the bit depends on the length BC, it is convenient to keep this length substantially constant by feeding the flexible tubing at an average rate equal to the speed of advance of the drill bit.

However, it may be more convenient, in the case for instance where the speed of advance of the drill bit is

low, to feed the flexible tubing in a discontinuous manner, in conformity with a time schedule, for instance every hour or half hour.

At each time, the adjustment is made by calculating the maximal tubing length to be fed as a function of the maximum bearable load variation on the bit.

The maximal load variation may be of $\pm 5\%$ under very limitative conditions, which corresponds, in the case of a total load of 500 kgs. for instance, to a load variation on the bit of ± 25 kgs. If the weight of the flexible tubing used is, for instance, of 10 kgs. per meter, a length variation of 5 meters of the portion BC of the tubing length will be acceptable, this variation corresponding to a 10 meter variation of the total tubing length.

Of these 10 meters of maximal variation of the total tubing length, 2 to 3 meters will be kept free for instance in order to compensate for the vertical movement imparted to the ship, 2 meters for the lateral displacements which, in the case where the hanging point of the lower portion of the tubing to the buoy is for instance at a depth of about 2000 meters, corresponds to the possibility for the ship to move within a circle having a radius of the order of a hundred meters. Of the 10 meters, 5 to 6 are thus available for a periodical feeding of the tube from the ship, which may correspond, when drilling in hard formations, to a drilling period of the order of from one half hour to one hour.

The process of the invention thus provides for a large margin of movement of the ship together with a small variation of the load on the drill bit. The latter may be determined with a high accuracy by adjusting the positive buoyancy of the buoy in accordance with the length of the lower portion of the tubing. FIGURE 4 shows a conventional apparatus for varying the actual floatability of the buoy E, or for keeping it constant at a definite value.

This apparatus is formed of a caisson 14 having in its lower portion a single opening 15 connected by a flexible tube 16 to a sliding member 17 which can be moved along a threaded column 18 and with which the upper open end of the tube is connected at 19. An electric motor 20 controlled from the surface through a cable 21 permits remote control of the vertical displacement of the sliding member along the guide rod 18.

A float 22 rests upon the level 23 of the water introduced through 19 into the buoy. When the buoy moves down with the downward movement of the drill, the level 23 of the water in the buoy rises, lifting the float 22 which acts through the pivoted lever 24 to open the valve 25 for admitting compressed air that was sent from the surface through conduit 26.

The functioning is as follows: the sliding member 17 being in a fixed position on the guide rod 18, the height of the water h in the buoy takes a value such that the float 22 would have a position corresponding to the opening limit of the valve and would remain in that position.

In fact, if the height h tends to increase beyond the value defined above, in consequence of the lowering of the buoy, the float 22 will rise and open the valve 25 to admit compressed air into the buoy until the height h returns to its initial value. If, on the contrary, the buoy rises again, the water level in it is lowered and uncovers the opening 19 of the tube 16 through which air then escapes, which, by lowering the pressure of the air, brings the water level to its original initial value.

In order to regulate from the surface the position of the sliding member 17, the equilibrium height h in the buoy is regulated, and thereby the actual floatability of the buoy which corresponds to this height.

The pressure under which the air is introduced through conduit 26 should be at least equal to the hydrostatic pressure existing at the level to which the buoy is lowered. The surface equipment required therefor is simpler than that used in conventional earth boring—the accurate and continuous adjustment of the load on the bit being no

longer necessary. The adjustment of the load on the bit is thus effected in a simpler manner than it is when drilling from the earth surface since in this latter case, much more complicated means would be required for adjusting with the same degree of accuracy the weight applied on the drill bit.

In proportion to the drilling advance, the buoy sinks to greater depths. This is not an inconvenience, provided that the mechanical strength of the buoy is sufficient. If, on the contrary, the buoy cannot withstand high pressures, it must be immersed only at the depth at which the hydrostatic pressure is lower than the maximal pressure that the buoy may sustain.

In this case, as the drilling electromotor progresses into the bore hole, which results in the lowering of point B, the cable length BE will be lengthened so as to maintain the buoy at a depth which is compatible with the maximal pressure that it may sustain.

This may be achieved by providing the buoy with a cable unreeling system controlled by the variations of the hydrostatic pressure exerted on the buoy. An automatic control of this type may be effected by means for instance of a pressure gauge capsule. When the buoy depth is maintained substantially constant by means of such an automatic control system, the depth of point B may be determined at any time by measuring the unreeled cable length. An approximate value of this depth may also be deduced from the tubing length fed from the surface equipment on the ship.

FIGURE 5 shows a device for increasing from the surface the length of the portion BH of the cable and for measuring that portion.

This device comprises a windlass 27 with a substantially horizontal axis situated at the lower end of the buoy.

The windlass is actuated, e.g. by an electric motor 28 controlled from the surface through conductors in a sheath 29. A conventional revolution-counter transmits its impulses to the surface through an electric cable 31 contained in the same sheath 29.

The control of the unwinding of the cable BH can also be effected automatically by hydrostatic pressure by replacing the motor 28 by a known apparatus shown schematically in FIGURE 6. In the latter, the rotation of the windlass 27 is controlled by a brake band L wrapped around the rim of the drum and of which one end is connected to a fixed point 32. The other end of this band is connected to a piston 33 movable in a cylinder 34. One side of this piston is acted upon by a hydrostatic pressure PH while a calibrated spring 35 presses against the other side.

It can be easily seen that with this simple arrangement any increase of hydrostatic pressure over the calibrated equilibrium pressure of the apparatus, which is caused by a lowering of the buoy E, will result in a relaxation of the drag of the brake L on the drum 27 and a consequent unwinding of the cable BH until the corresponding upward movement of the buoy brings the hydrostatic pressure back to its initial value which equilibrates the force of the calibrated spring 35.

According to another operating method, the cable length BE is not changed and the buoy is allowed to lower by a depth corresponding to the drilling advance. In this case, the buoy must be capable to sustain high pressures. A simple and economical type of structure for such a buoy would consist of a deformable casing filled up with a liquid having a lower density than that of water. Such a deformable casing would not be subjected to pressure strains in view of its deformability.

FIGURE 7 shows schematically a buoy E having a deformable wall 36 and filled with a liquid less dense than water.

However, such a type of buoy suffers from the drawback of being more voluminous than a buoy of the preceding type providing for the same upward force.

In this case, the depth of point B may be accurately

determined by measuring the hydrostatic pressure exerted on the buoy.

The telemetering of the hydrostatic pressure exercised on the buoy can be accomplished by means of a captive manometric device of the kind shown schematically in FIGURE 8 in which a bellows 37 becomes deformed under hydrostatic pressure PH, which actuates a contact arm 38 of a potentiometer whose ends are connected to conductors 39 and 40 under a constant potential difference. The potential at a point on the surface of the potentiometer between the conductors 39 and 40 will then be a function of the hydrostatic pressure. This potential is transmitted to the ship through conductor 41.

It must be noticed furthermore that, in view to avoid too numerous withdrawals of the flexible drill string and the associated equipment, it may be convenient to provide means for displacing the point B of the tubing at which the same is hanged to the cable of the floating element or buoy.

This displacement of point B may be effected during the drilling operation for instance by means of a clamping device controlled by electromagnetic means or by the hydrostatic pressure, or by use of a capstan supported from the buoy and having the flexible tubing wound thereon. The operation of this capstan may be adjusted, either continuously or in a discontinuous manner, in proportion to the drilling advance, for instance by control thereof from the floating element.

A displacement of the point B can be effected for example by means of the apparatus shown in FIGURE 9 in which the conduit 1 is squeezed between two pairs of rollers 42 and 43 respectively, over which belts 44 and 45 pass. At least one of these rollers is connected coaxially to an electric motor 46 energized by a conductor which can be included in the cable BH. By controlling the current to the motor, the junction B can be moved along the flexible tube any desired distance.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions. Consequently, such changes and modifications are properly, equitably described and intended to be within the full range of equivalence of the following claims:

What is claimed as this invention is:

1. A method for submarine well drilling, comprising the step of suspending a motor and a bit driven thereby from the lower end of a flexible tubing having an upper end at floating surface equipment, driving in the submarine soil said drill bit actuated by said motor, applying two traction strains separately to two portions of said tubing—one of the said strains, which is applied to the upper end of a lower portion of invariable length of the tubing, ending with the drill bit, being maintained substantially constant, and the other strain, applied to an upper portion of variable length of the tubing, from a surface equipment, balances the weight of said upper portion.

2. A device for submarine well drilling by means of a drill bit suspended from a flexible tubing used as drill string, comprising a power source, a bottom motor adapted to drive said bit, means for transmitting energy from said power source to said bottom motor, a floating element immersed at a given depth and a cable suspending a lower portion of said flexible tubing of invariable length, ending with the drill bit, from said floating element, and means for so adjusting the buoyancy thereof as to support only a portion of the weight of the lower portion of the tubing, whereby a substantially constant upward force is applied to the upper end of said lower portion of the tubing.

3. A device according to claim 2 further comprising means for varying the length of said cable so as to main-

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tain said given depth within limits compatible with the mechanical strength of said floating element.

4. A device, according to claim 2, wherein said cable is of invariable length so that the depth of the floating element varies in proportion to the drilling advance.

5. A device according to claim 3, wherein said means includes means for varying the cable length in proportion to the depth drilled, whereby the floating element is maintained at a substantially constant depth.

6. A device, according to claim 5, wherein said means for varying the cable length are controlled by the variations of the hydrostatic pressure exerted on the walls of the floating element, and hydrostatic pressure responsive means for controlling the means for varying the cable length when said pressure exceeds a predetermined value.

7. A device, according to claim 5, wherein to said means for varying the cable length are associated measuring means of the resulting length variations.

8. A device, according to claim 4, wherein the walls of the floating element are of a sufficient mechanical strength to sustain the variations of the hydrostatic pressure exerted thereon.

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9. A device according to claim 4, wherein the floating element is provided with deformable walls and further comprising a liquid having a density lower than that of water, filling up said floating element.

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CHARLES E. O'CONNELL, *Primary Examiner.*