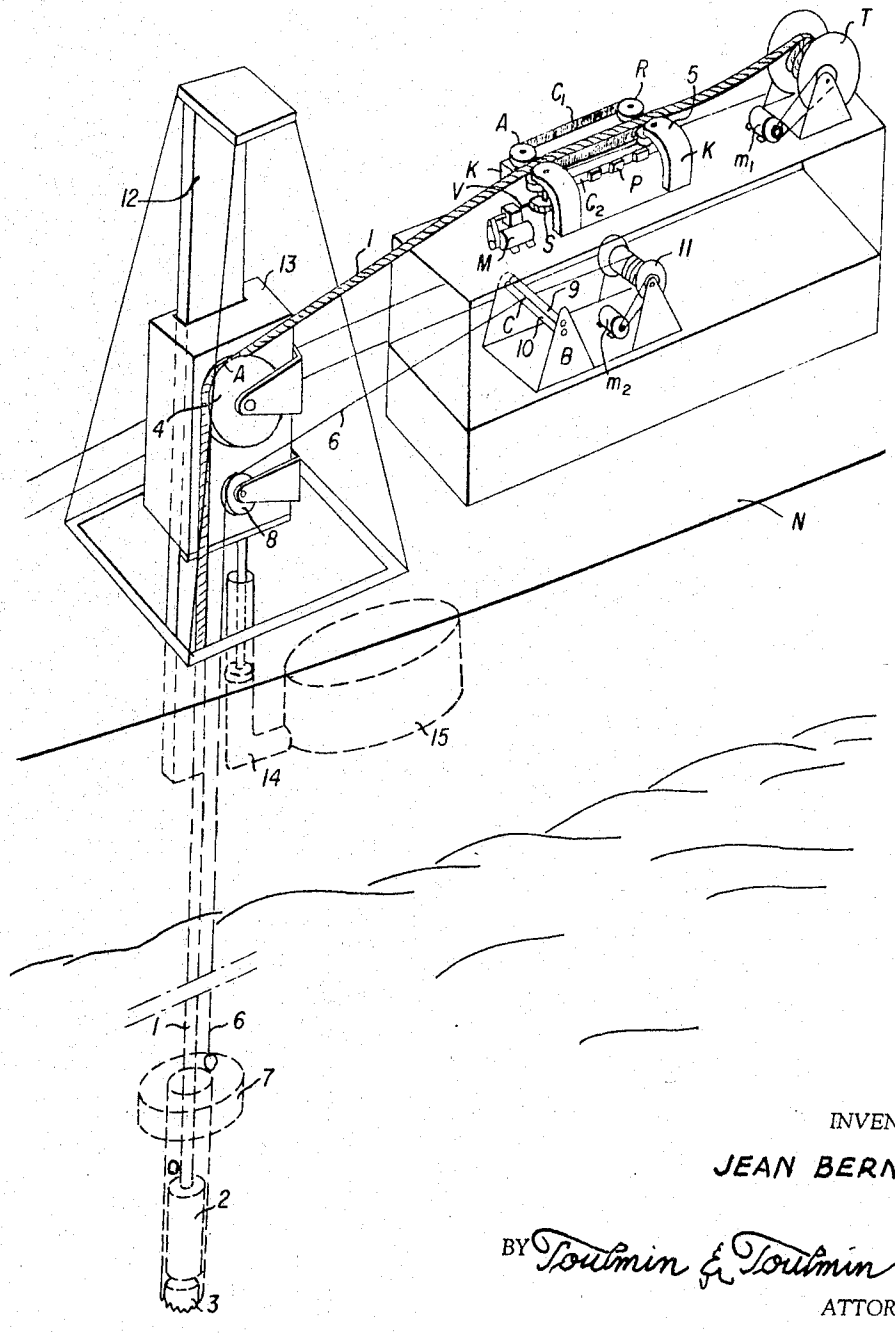
Oct. 4, 1966 J. BERNE 3,276,746

STABILIZING DEVICE

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FIG. 1



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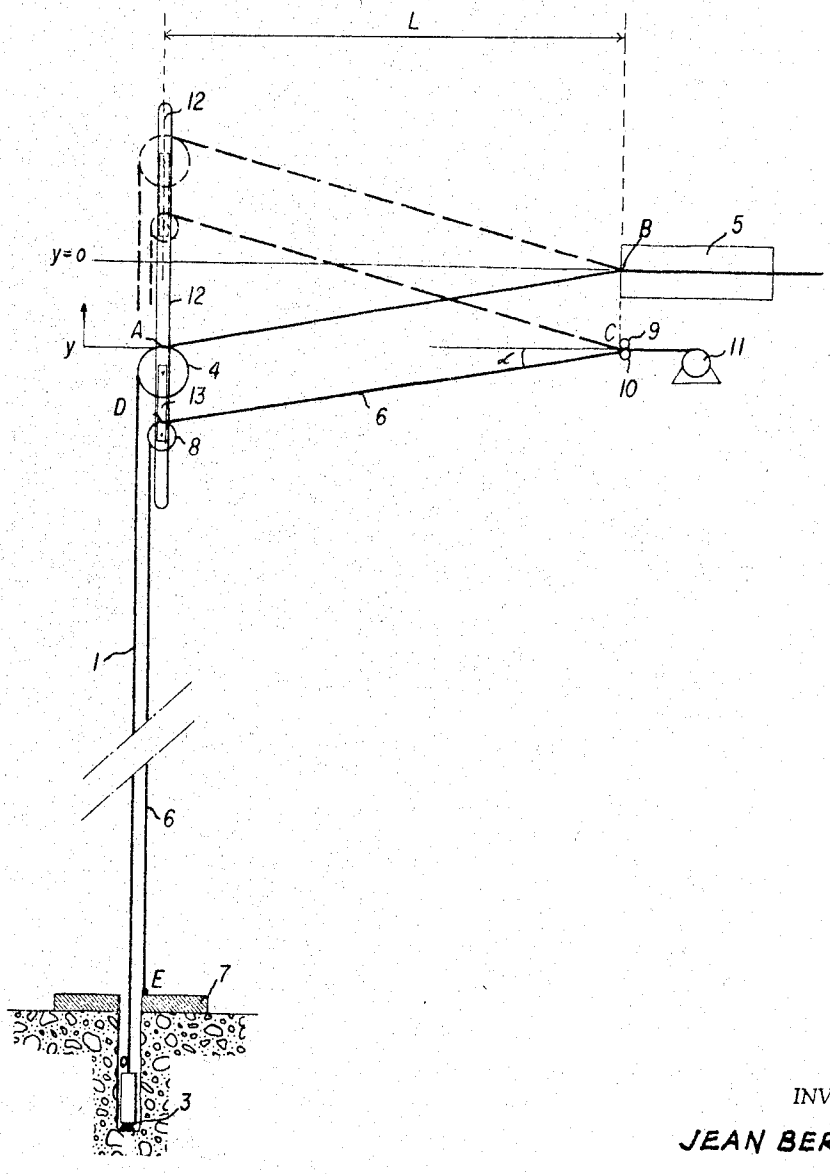
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STABILIZING DEVICE

Filed Oct. 9, 1964 3 Sheets-Sheet 2

FIG. 1a



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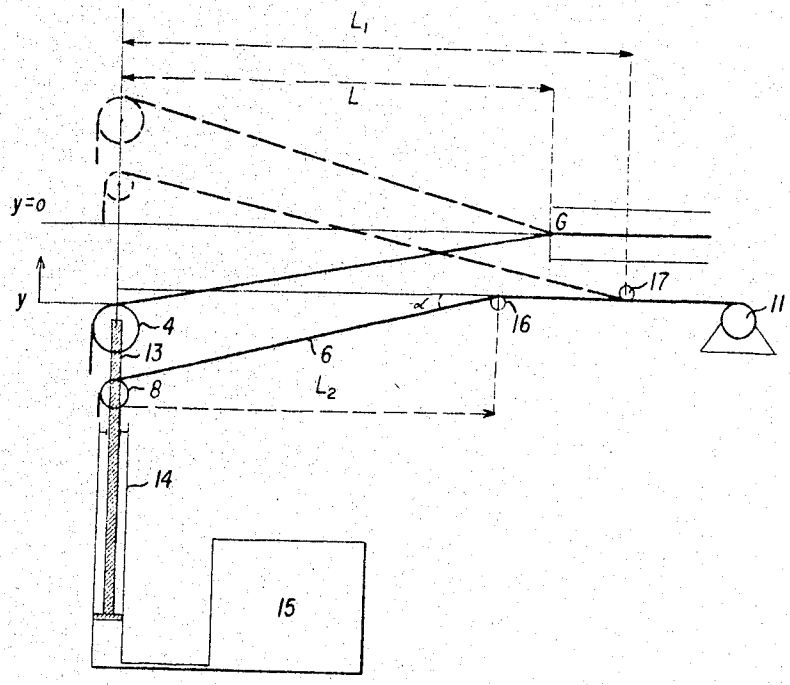
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STABILIZING DEVICE

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FIG. 2



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United States Patent Office 3,276,746 Patented Oct. 4, 1966

3,276,746

STABILIZING DEVICE

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Filed Oct. 9, 1964, Ser. No. 402,742
Claims priority, application France, Oct. 10, 1963, 950,240
4 Claims. (Cl. 254—172)

The object of this invention is a device for stabilizing the weight on the drill bit in the case of underwater drilling carried out from a boat by means of a flexible tube from which is suspended the bit and a bottom motor driving it.

Up to the present, underwater drilling has generally been effected with a rigid drill pipe string running from the ship and held fairly vertically from the well head.

Such a system necessitates the use of a ship equipped with a drilling-machine and also has all the drawbacks inherent in the use of a rigid drill pipe string, mainly due to the numerous pipe connections necessary.

The use of a flexible tube formed by one sole length or by very long elements would remedy these drawbacks, but proves to be very difficult to employ as it necessitates the use of a bottom motor (generally electric) which is unable to take very big load variations.

But the movement of the ship, particularly due to swell, causes incessant displacement of the unit formed by the drilling tube, the bottom motor and the bit, and this results in considerable variations in the weight on the bit, making it practically impossible for the latter to work.

The object of this invention is to remedy that drawback by means enabling the weight on the bit to be kept substantially constant despite pounding or other movement to which the boat, from where the drilling is being done, may be subjected.

This can be done by rendering the tube substantially independent of the boat's movement, so that the group formed by the immersed tube (which is designated hereinafter by "flexible tubing"), the bottom motor and the drill bit (the latter two being fixed to the end of the tube) remain practically stationary when the boat is affected by swell, the sole displacements being those caused by the progress in drilling.

This is achieved by the stabilizing device according to this invention, which comprises in combination handling means such as a caterpillar drive on said floating base, flexible tube means for drilling, supported at one end thereof by said handling means, a jack arranged on the floating base, means for feeding said jack by fluid under pressure, a frame supported by the piston of said jack, a slide guide fixed on the floating base, first pulley means being carried by said frame, said flexible tube means passing over said first pulley means, said frame being substantially vertically movable upward and downward along said slide guide, said slide guide carrying second pulley means, a guide-rope, and a mooring mass, substantially at the well head, said guide-rope passing over said second pulley means, having one end fixed to said mooring-mass and the other end fastened to the floating base, for instance through a winding and unwinding device such as a winch and means for guiding the guide-rope length between the second pulley means and the fastening point of the guide-rope to the floating base, whereby only a part of said length is movable with said frame.

According to a first embodiment of the invention, said means for guiding the guide-rope comprise two rollers positioned opposite each other on either side of the guide-rope, in contact therewith and at the same distance from said slide guide as the end of the flexible tube supported by said handling means.

According to a second preferred embodiment of the invention said means for guiding the guide-rope comprise two rollers being in contact with said guide-rope and being placed above and below said guide-rope, respectively, and at different distances relative to said slide guide, the upper roller being the farther from the slide guide and the lower roller being the nearer to the slide guide, and the movable part of the guide-rope being limited by the upper roller when it moves upward and by the lower roller when it moves downward.

In this last mentioned embodiment the upper roller is placed at such a distance from the slide guide that when the frame rises above the alignment position of the top of the second pulley means with the two rollers, the movable part of the guide-rope included between the said pulley means and the said upper roller exceeds the movable part of the flexible tubing included between its holding point and the first pulley means by a length chosen so as to compensate for the shortening effect accompanying the reduction in tension of the flexible tube means resulting from the rising of the frame, and the lower roller is placed at such a distance from the slide guide that when the frame drops below the alignment position of the second pulley means with the two rollers the movable part of the flexible tube means included between its holding point and the first pulley means exceeds the movable part of the guide-rope included between the second pulley means and the said lower roller by a length chosen so as to compensate for the elongation effect accompanying the increase in the guide-rope tension resulting from the lowering of the frame.

The device according to the invention will be described in greater detail hereinafter, reference being made to the appended drawings in which like reference numerals refer to like parts throughout the several figures and wherein:

FIGURE 1 is an overall view of the device,

FIGURE 1*a* is a diagrammatic view of the device illustrated in FIG. 1,

FIGURE 2 illustrates the use of correcting devices for adjusting tension variations on the guide-rope so as to keep the tension of the flexible tubing substantially constant when the ship is subjected to vertical displacement.

FIGURES 1 and 1*a* should be referred to in connection with the explanation of the general operating principle of the device according to the invention.

A flexible drill string (tubing) **1**, from which is suspended at O an electric drilling motor **2** operating a tool **3**, passes over a reversing pulley **4** and is kept under tension by a caterpillar drive **5** used to free, as and when required, the tubing lengths required for the drilling advance.

The caterpillar drive is a standard one such as is used in cable-works for cable traction. It consists of two endless chains C_1 and C_2 with track-links P. These chains are placed facing each other and enclose the flexible tube **1** between their track-links. Each chain winds around two wheels R capable of revolving around a vertical spindle borne by frame K. Wheels R can be driven by cog-wheels S on an axle which is turned by horizontal endless screw V supported by a frame, the said screw being itself driven by a motor M (FIGURE 1).

Standard (e.g. hydraulic) means for compressing the two endless chains C_1 and C_2 against the portion of tube they enclose can advantageously be provided (not shown in the figure).

The flexible tube **1** is wound on a storage drum T which can be revolved by a motor m_1.

Drilling fluid is fed to the flexible tube **1** by an axial channel of the drum connected to the end of the tube **1**.

The electric conductors supplying the electric motor **2** are sunk in the core of the flexible tube and end in

collector rings on the drum axle. On these rings collectors rub against brushes at the current source feeding motor **2**.

A guide-rope **6** has its immersed end E fixed on the mooring-mass at the well head. It passes over a reversing pulley **8** to which an upward vertical force is applied by the piston of a jack **14**, then between two side-by-side rollers **9** and **10** before being wound by its other end on the barrel of a winch **11**, for instance. By having this winch driven by the motor m_2 it is possible to allow for the very slow variations in the height of the boat N due to the tide. In the following, however, it will be considered that the wound-out length of the guide-rope is adjusted periodically and it will be assumed that tidal influence during the unit drilling period is nil.

It can be seen from FIGURES 1 and 1*a* that the distance between the tops A and D of the pulleys **4** and **8** has been chosen equal to the distance between the caterpillar outlet B and the point of contact C of rollers **9** and **10**, the point through which the guide-rope passes.

The quadrilateral ABCD is, therefore, a parallelogram, from which it follows that the lengths AB and CD will remain equal whatever the pounding movement of the boat. The guide-rope is kept under tension by the upward force exerted on a frame **13** bearing the pulley **8**. In the following it will be assumed that the winch **11** and the caterpillar drive **5** remain locked, i.e. that the total lengths CDE and BAO of the guide-rope and the flexible tube remain substantially constant.

Lengths AB and CD remaining equal, it follows that the variations in lengths DE and AO during pounding movements of the boat will be substantially the same and, as a result of swell movements, will be expressed merely by a displacement of a slide guide **12** (being integral with the boat) in relation to the frame **13** sliding in the guide, the spindles of the pulleys **4** and **8** being fixed on the frame.

As can be seen from FIGURE 1*a*, the spot level of the pulley **4**, for instance, is not absolutely constant in relation to the sea bottom, since lengths AB and CD vary with the angle α of inclination of CD in relation to the horizontal at C, i.e. with the extent of the pounding movement of the boat.

Actually, with length EDC remaining constant, if the letter L stands for the distance from point C to the vertical passing through the axles of the pulleys **4** and **8** and the letter y stands for the displacement of the frame **13** in relation to its reference position corresponding to $\alpha=0$ (A and D then being respectively in horizontal alignment with B and C), it can be said:

$$DC=\sqrt{L^2+y^2}$$

The maximum DC variation is therefore:

$$\sqrt{L^2+y_m{}^2}-L\doteq\frac{1}{2}y_m{}^2/L$$

where y_m represents maximum pounding.

Length EDC being constant, it follows that ED, which represents the elevation of the pulley **8** above the sea bottom, will vary by

$$-\frac{1}{2}y_m{}^2/L$$

However, as the pulley **4** is connected to the pulley **8** by the frame **13** and as ABCD forms a parallelogram, there will be no relative variation in length between the flexible tubing and the guide-rope.

As an object of the invention is to maintain the weight on the tool fairly constant, an upward force F should be exerted on the frame so as to keep the latter up.

This force F which, according to the invention, is supplied by a jack **14** (FIGURES 1 and 2), must be substantially constant. In practice it would be costly to use means of compression to ensure rigorous constancy of the

pressure in the jack, and the simplest solution is to feed the jack from a tank of fluid under pressure (tank **15**, FIGURES 1 and 2) such as an oleo-pneumatic accumulator of sufficient capacity for the pressure variations resulting from the piston displacement to remain moderate.

If v_0 designates the volume of the tank for $y=0$, the force F developed by the jack, taking the volume variations as polytropic, will be:

$$\text{(I)}\qquad F=Sp=Sp_0\left(1+\frac{Sy}{v_0}\right)^{-\gamma}\doteq Sp_0\left(1-\gamma\frac{Sy}{v_0}\right)$$

in which:

S represents the section of the piston of the jack, being integral with the frame **13**,

p the pressure exerted on the piston,

p_0 the initial pressure of the fluid in the tank communicating with the jack for $y=0$, and

γ the polytropic coefficient, at the limit equal to 1.4, for the air.

All the vertical forces taken together that are applied downward on the frame **13** are equal to:

$$\text{(II)}\qquad F_v=P+T(1+\sin\alpha)+t(1+\sin\alpha)$$

in which:

P represents the weight of the frame **13**,

T the tension of the flexible tubing,

t the tension of the guide-rope.

By equalizing the expressions of F and F_v, there results:

$$\text{(III)}\qquad Sp_0\left(1-\gamma\frac{Sy}{v_0}\right)=P+T(1+\sin\alpha)+t(1+\sin\alpha)\doteq P+(T+t)\left(1+\frac{y}{L}\right)$$

The tension t of the guide-rope is linked with the length x of the latter by an equation of the form:

$$\text{(IV)}\qquad t=t_0+k(x-x_0)$$

k being the coefficient of rigidity of the guide-rope and t_0 the tension for the initial length x_0 of the guide-rope (corresponding to $y=0$).

Similarly, the tension T of the flexible tubing is linked with the length z thereof by the equation:

$$\text{(V)}\qquad T=T_0+K(z-z_0)$$

K being the coefficient of rigidity of the flexible tube and T_0 its initial tension for the length z_0, corresponding to $y=0$.

Elongations $x-x_0$ and $z-z_0$ of the guide-rope and the flexible tubing are equal and from their equality the following equation is derived:

$$\text{(VI)}\qquad t=\frac{k}{K}(T-T_0)+t_0$$

Taking this Equation VI into account, Equation III then becomes:

$$T+\frac{k}{K}(T-T_0)+t_0=\frac{1}{1+\frac{y}{L}}\left(Sp_0\left(1-\gamma\frac{Sy}{v_0}\right)-P\right)$$

or

$$\text{(VII)}\qquad T=\frac{K}{k+K}\left[\frac{Sp_0\left(1-\gamma\frac{Sy}{v_0}\right)-P}{1+\frac{y}{L}}+\frac{k}{K}T_0-t_0\right]$$

As an example, application of this formula shows that for a weight $P=3000$ kg. of the frame, an initial tension (for $y=0$) of $T_0=7{,}000$ kg. on the flexible tubing, an initial tension (for $y=0$) of $t_0=3{,}000$ kg. on the guide-

rope, i.e. for $Sp_0=7,000+3,000+3,000=13,000$ kg., and coefficient of rigidity values of:

$$K=120 \text{ kg./mm.}$$
$$k=80 \text{ kg./mm.}$$

taking $L=7$ m. and using, in addition, a value of $\gamma S/v_0$ equal to 0.05 m.²/m.³, we find that the tension T on the flexible tubing varies between 5,800 kg. for $y=+1$ meter and 8,600 kg. for $y=-1$ meter.

Such a variation, of more than 2,800 kg., in the tension of the flexible tubing, i.e. in the weight on the tool, is, in practice, too much in many cases.

According to the system of the invention, the length of guide-rope **6** would be acted upon to keep the tension on the flexible tubing constant.

This can be effected, in practice, by using two tension correcting rollers **16** and **17** placed at distances L_2 and L_1 respectively from the vertical passing through the axle of the pulleys **4** and **8**, as shown in the diagram, FIG. 2.

According to whether α is positive or negative these correcting rollers make it possible to lengthen or shorten the effective length of the guide-rope. This results in a compensating variation in the tension on the latter.

When the elevation y of the frame **13** above its reference position increases, the tension T on the rope decreases, since from Formula VII it follows at once that T is a decreasing function of y.

This reduction in the tension T is accompanied by a reduction Δt in the tension t on the guide-rope since, according to Equation VI, T and t have variations in the same direction.

Reduction in tension Δt is associated with a reduction in the length Δx of this guide-rope, such that:

$$\Delta x=\frac{\Delta t}{k}$$

The correcting roller mechanism illustrated in FIGURE 2 will, in that case, make it possible to increase the apparent length of the guide-rope by a length dx given by the formula:

$$dx=\frac{y^2}{2L}-\frac{y^2}{2L_1}=\frac{y^2}{2}\left(\frac{1}{L}-\frac{1}{L_1}\right)=\frac{y^2}{2}\frac{(L_1-L)}{LL_1}$$

By suitably choosing the position of correcting roller **17** (which determines the length L_1) one can, for a given value and, for instance, for the maximum value y_m of y, obtain a value of dx exactly equal to $\Delta t/k$, k being the coefficient of rigidity of the guide-rope. The excess of apparent length of this rope over the corresponding length according to the embodiment illustrated in FIGURE 1, exactly compensates for the shortening of the rope under the effect of the reduction Δt in its tension.

Conversely, when y becomes negative, the force applied by the jack on the frame **13** increases and the weight borne by the latter decreases. Tensions T and t will tend to rise, which will increase the length x of the guide-rope **6**. To keep the length constant, the apparent length of this guide-rope **6** must be reduced, which is done, according to the invention, by means of a correcting roller **16** placed at a distance L_2 from the vertical passing through the axis of the pulleys **4** and **8**, which distance L_2 is so selected that for a certain deviation for instance for the greatest downward deviation (y_m negative), the reduction in the elongation thereof under the effect of the increased tension to which it is subjected.

The consequence of compensation for variations in the length of the guide-rope is a compensation for variations in the tension on the flexible tubing.

It should be noted that this compensation is exact only for a given positive deviation and a given negative deviation, for example for the maximum deviations $\pm y_m$ (y maximum in absolute value), as assumed in the following computation.

As, for a zero value of y, the weight on the tool is fixed at the desired value, a certain variation in the weight on the tool will remain, caused by insufficient correction for y values between $-y_m$ and 0 and between 0 and $+y_m$.

This variation in the weight on the tool is, however, considerably less than it would be if there were no correcting rollers.

This is shown, for instance, by the following calculations made for the values below:

$$L=7 \text{ meters}$$
$$y_m=\pm 0.7 \text{ meter}$$

Two 60-meter guide-ropes (corresponding to the depth of water) with a coefficient of rigidity $k=80$ kg./mm.

A flexible drilling rod with a coefficient of rigidity $K=120$ kg./mm., 40 meters long and weighing 15 kg./m.

Weight of the rigid part of the boring set (tool, bottom motor and drill collars): 2,500 kg.

Initial tension of the flexible tubing $T_0=40\times 15+2,500=3,100$ kg.

Weight of frame P: 3,000 kg.

Initial tension (for $y=0$) on the guide-ropes $t_0=2,000$ kg.

One takes $\gamma S/V_0=0.05$ m.²/m³.

The force developed by the jack for $y=0$ will be:

$$Sp_0=3,100+3,000+2,000=8,100 \text{ kg.}$$

Variations in the flexible rod tension ($T-T_0=\Delta T$) in terms of y are determined from the Formula VII giving the value of T from which the value $T_0=3,100$ kg. is subtracted, i.e.:

$$\Delta T=0.6\left[\frac{8,100(-0.07y)-3,000}{1+\frac{y}{7}}+\frac{2}{3}\times 3,100-2,000\right]-3,100$$

$$\Delta T=0.6\left[\frac{5,100-560y}{1+\frac{y}{7}}+66\right]-3,100$$

For the values of y varying between -0.7 m. and $+0.7$ m. the following table is obtained:

TABLE 1

y	−0.7	−0.6	−0.5	−0.4	−0.3	−0.2	−0.1	0
ΔT	600	510	415	330	240	160	78	0
y	+0.7	+0.6	+0.5	+0.4	+0.3	+0.2	+0.1	0
ΔT	−490	−430	−360	−290	−250	−150	−76	0

The position of the correcting rollers according to the invention will be determined by the distances L_1 and L_2 such as:

(1) For $y>0$

$$dx=\frac{|\Delta t_m|}{k}=\frac{|\Delta T_m|}{K}=\frac{y_m^2(L_1-L)}{2LL_1}$$

$$\frac{490}{120,000}=\frac{0.49L_1-3.43}{14L_1}$$

of which one deducts:

$$14L_1=120\ L_1-840$$

and $L_1\doteqdot 7.924$ meters

(2) for $y<0$

$$dx=\frac{y_m^2(L-L_2)}{2LL_2}=\frac{\Delta t_m}{k}=\frac{\Delta T_m}{K}$$

i.e.:

$$\frac{600}{120,000}=\frac{3.43-0.49L_2}{14L_2}$$

of which one deducts:

$$14L_2=686-98\ L_2$$

and $L_2\doteqdot 6.125$ meters.

For the values of y comprised between 0 and $+y_m$ and

between 0 and $-y_m$, the variations Δf of force on the guide-ropes are given by the formulas:

For $y > 0$

$$\Delta f = \Delta t + \frac{ky^2(L_1 - L)}{2LL_1}$$

$$= \Delta t + \frac{80{,}000 \times 0.924}{14 \times 7.924} y^2$$

$$\doteq \Delta t + 667y^2$$

and for $y < 0$

$$\Delta f = \Delta t - \frac{80{,}000 \times 0.875}{14 \times 6.125} y^2$$

$$\doteq \Delta t - 816y^2$$

The values of Δt in these formulas being taken from Table 1 by the relation:

$$\Delta t = \frac{k}{K} \Delta T = \frac{2}{3} \Delta T$$

The corresponding tension on the flexible rod ΔT will be given by the formula:

$$\Delta T = \frac{K \Delta f}{K + k} = \frac{120}{120 + 80} \Delta f = 0.6 \Delta f$$

The following table shows for different values of y the variations of Δf and ΔT.

TABLE 2

y	−0.7	−0.6	−0.5	−0.4	−0.3	−0.2	−0.1	0
Δf	0	+46	+72	+90	+86	+74	+44	0
ΔT	0	+28	+43	+54	+52	+45	+27	0
y	+0.7	+0.6	+0.5	+0.4	+0.3	+0.2	+0.1	0
Δf	0	−48	−73	−87	−87	−73	−44	0
ΔT	0	−29	−44	−52	−52	−44	−26	0

A comparative examination of Tables 1 and 2 above shows that the use of correcting rollers, according to the invention, makes it possible to reduce tension variations of the flexible tubing and, consequently, the weight variations on the tool from a maximum of 1,090 kg. to a maximum of 106 kg. in the case envisaged. Adjustment of the position of the corrector rollers in the above example, by cancelling out tension variations on the flexible tubing for $y = \pm 0.7$ meter, allows pounding divergences of more than 0.7 meter without increasing the difference between the maximum and minimum values of the tension to which the flexible tubing is subjected.

Actually, for $y = +0.8$ meter, the variation in the flexible tubing tension is only +34 kg. i.e. far less than the maximum positive variation recorded between −0.7 and +0.7 meter (+54 kg.).

Similarly, for $y = -0.8$ meter, the variation in the flexible tubing tension is only −33 kg., which is also far less than the maximum negative variation recorded between −0.7 and +0.7 meter (−52 kg.).

It can be seen, therefore, that the y value for which it is desired to cancel out the variation in tension on the flexible tubing in relation to the nominal tension may very well be chosen slightly less than the maximum anticipated pounding value (y_m).

This value of y, on which is based the adjustment of the correcting rollers, may also be selected of a different absolute value according to whether y is positive or negative.

In addition, the straight alignment line of the rollers may, if so desired, be not horizontal, in which case the deviations $\pm y$ will be represented by the divergence between the top of the pulley on which passes the guide-rope and the point of intersection of the straight alignment line of the correcting rollers (straight line tangent to the under side of the upper roller and tangent to the upper side of the lower roller) with the vertical passing through the top of the pulley. The roller correcting mechanism will then operate in the same way, but the nominal tension on the flexible rod will be chosen for a frame position such that the top of the pulley on which the guide-rope passes will be in alignment with the rollers.

However, in the case already examined as an example, it can be seen that the value of ±0.7 meter leads to maximum variations in the tension of the same order when y is negative as when it is positive (52 and 54 kg., respectively). In that case, therefore, there is no need to provide far an adjustment based on different absolute values of y according to whether it is positive or negative.

It will be understood that this invention is susceptible to modification in order to adapt it to different usages and conditions, and, accordingly, it is desired to comprehend such modifications within this invention as may fall within the scope of the appended claims.

What is claimed is:

1. In an apparatus for underwater drilling having a tool and operating from a floating base, a device for stabilizing the weight on said tool, comprising, in combination, handling means on said floating base, flexible tube means for drilling, held at one end thereof by said handling means, a jack arranged on the floating base, means for feeding said jack by fluid under pressure, a frame supported by the piston of said jack, a slide guide fixed on the floating base, first pulley means being carried by said frame, said flexible tube means passing over said first pulley means, said frame being substantially vertically movable upward and downward, along said slide guide which slide guide carries second pulley means, a guide-rope, and a mooring-mass, said guide-rope passing over said second pulley means, having one end fixed to said mooring-mass and the other end fastened to the floating base, and means for guiding the guide-rope length between the second pulley means and the fastening point of the guide-rope to the floating base, whereby only a part of said length is movable with said frame.

2. A stabilizing device as claimed in claim **1** wherein the said means for guiding the guide-rope comprise two rollers positioned opposite each other on either side of the guide-rope and being in contact therewith, said means for guiding the guide-rope being placed substantially at the same distance from said slide guide as the end of the flexible tube supported by said handling means.

3. A stabilizing device as claimed in claim **1** wherein the said means for guiding the guide-rope comprise two rollers being in contact with said guide-rope and being placed above and below said guide-rope, respectively, and at different distances relative to said slide guide, the upper roller being the farther from the slide guide and the lower roller being the nearer to the slide guide and the movable part of the guide-rope limited by the upper roller when it moves upward and by the lower roller when it moves downward.

4. A stabilizing device as claimed in claim **3**, wherein the upper roller is placed at such a distance from the slide guide that when the frame rises above the alignment position of the top of the second pulley means with the two rollers, the movable part of the guide-rope included between the said pulley means and the said upper roller exceeds the movable part of the flexible tubing included between its holding point and the first pulley means by a length chosen so as to compensate for the shortening effect accompanying the reduction in tension of the flexible tube means resulting from the rising of the frame, and in which the lower roller is placed at such a distance from the slide guide that when the frame drops below the alignment position of the second pulley means with the two rollers the movable part of the flexible tube means included between its holding point and the first pulley means exceeds the movable part of the guide-rope included between the second pulley means and the said lower roller by a length chosen so as to compensate for the elongation effect accompanying the increase in the

guide-rope tension resulting from the lowering of the frame.

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