United States Patent

[11] 3,563,323

[72] Inventor **Howard Trethewen Edgecombe**
Filton, England

[21] Appl. No. **791,913**
[22] Filed **Jan. 17, 1969**
[45] Patented **Feb. 16, 1971**

[73] Assignee **Rolls-Royce Limited**
Derby, England
a British Company

[32] Priority **Jan. 19, 1968**
[33] **Great Britain**
[31] **2915/68**

---

[54] **APPARATUS FOR BOREHOLE DRILLING**
4 Claims, 1 Drawing Fig.

[52] **U.S. Cl.** **175/76,** 175/107
[51] **Int. Cl.** **E21b 7/06**
[50] **Field of Search** 175/73, 75, 76, 325, 107

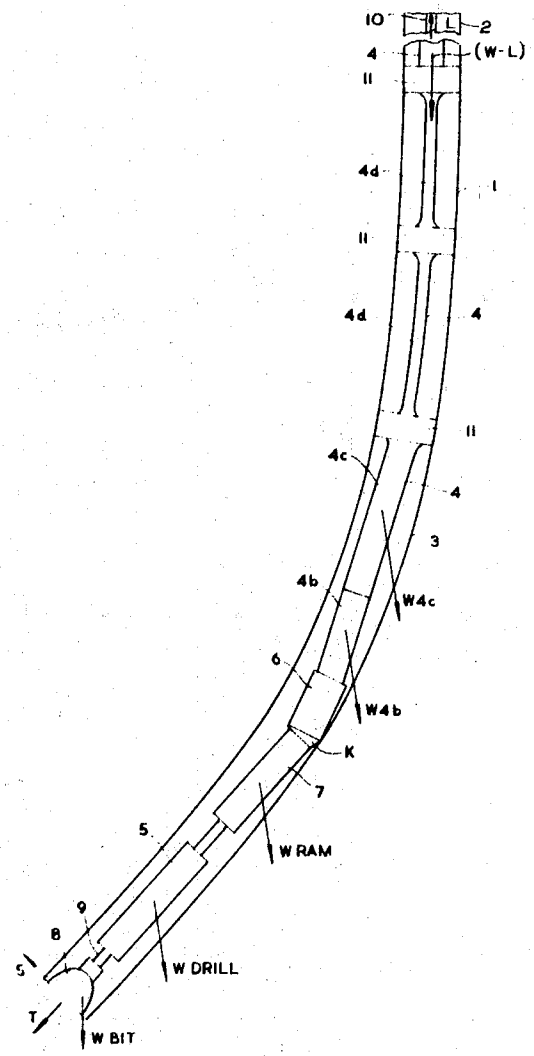
[56] **References Cited**

UNITED STATES PATENTS

2,336,338	12/1943	Zublin	175/75
2,500,267	3/1950	Zublin	175/75
2,565,794	8/1951	Young	175/75X
2,805,840	9/1957	Thompson	175/76
2,829,864	4/1958	Knapp	175/325
3,380,543	4/1968	Vincent	175/73
3,476,196	11/1969	Whittle et al.	175/325

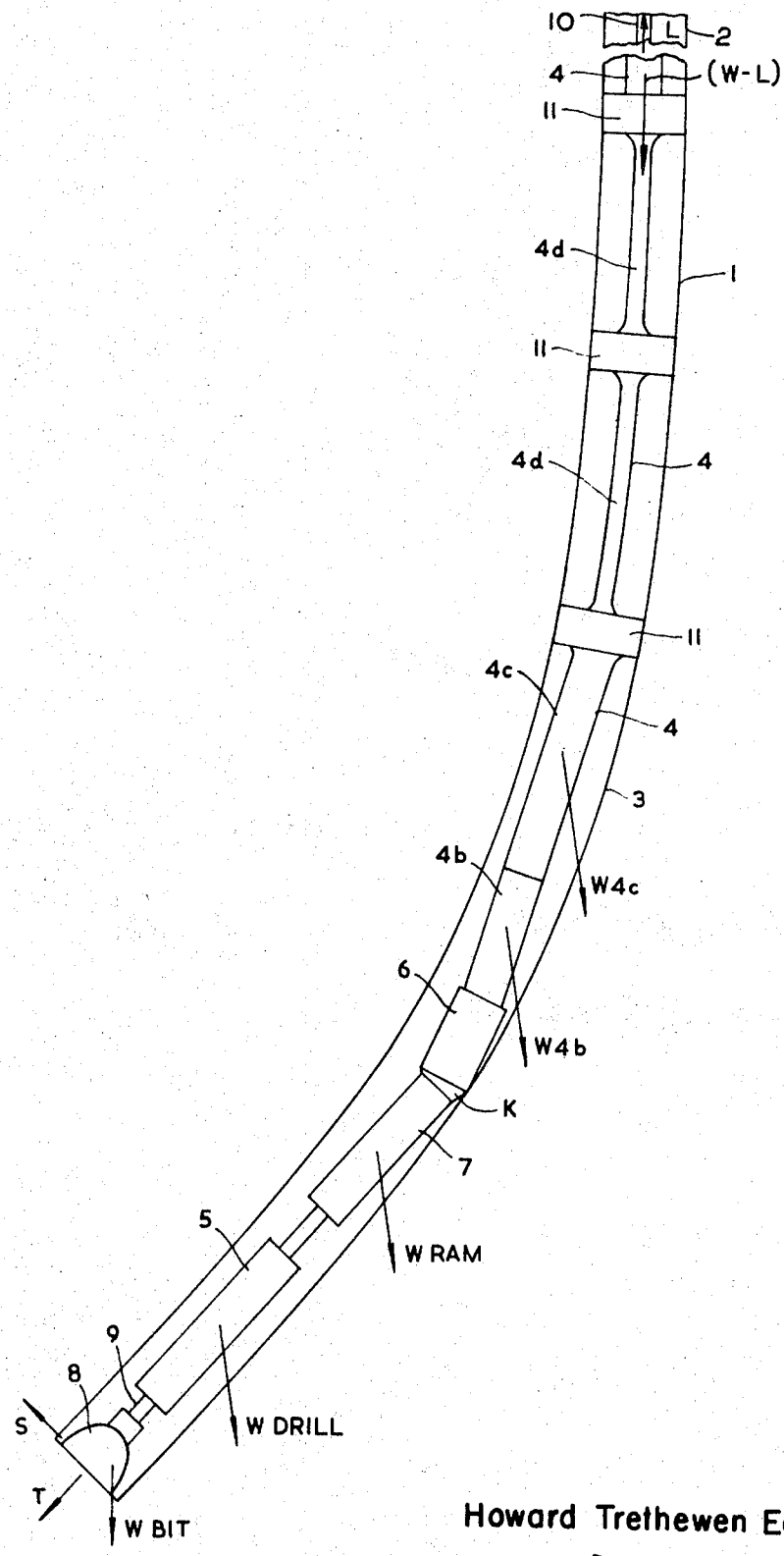
Primary Examiner—Marvin A. Champion
Assistant Examiner—Richard E. Favreau
Attorney—Mawhinney & Mawhinney

ABSTRACT: In deviation borehole drilling with a down-hole motor a plurality of flexible collars is disposed in the drill string between the main stand of weight collars and the deviation assembly. In this way the bending moments of the main stand of weight collars are not transmitted to the down-hole motor and better control of deviation is achieved.



PATENTED FEB 16 1971

3,563,323



INVENTOR

Howard Trethewen Edgecombe

BY Mawhinney & Mawhinney

ATTORNEYS

APPARATUS FOR BOREHOLE DRILLING

The present invention relates to apparatus for use in drilling a borehole which deviates from one path to another. The drilling of boreholes of this type is referred to herein as deviation drilling.

The invention is more particularly concerned with apparatus for use in drilling that section of the borehole which deviates from the said one path, and which will be referred to hereinafter as the inclined section of the borehole. The invention is also particularly, though not exclusively, concerned with a turbodrilling method.

In deviation drilling, (especially wherein the borehole inclination deviates from the vertical by 30° to 40° or more), the axial component of the weight of the drill collars which produces the bit thrust is reduced, and that part of the axial load on the drill bit which is due to the weight of the collars in the more vertical part of the drill string, is dissipated by friction due to those parts of the drill and drill string which rub on the more inclined part of the hole. Thus the load actually applied to the bit, varies in an indeterminate fashion due to the friction at the inclined part of the hole.

Further, in a drill string with a downhole motor, such as a turbodrill, and which has a bent sub to cause deviation, those parts of the drill string which lie above the bent sub, between the bent sub and the more vertical section of the borehole apply to those parts of the drill string which lie below the bent sub, weight bending moment which increases as the deviation from the vertical increases. Since there are usually relatively few parts of the drill string below the bent sub, the weight bending moment produced above the bent sub, opposing that produced below the bent sub, becomes sufficiently great to make control of the side loads on the drill bit, and of the rate of deviation difficult, and there is a possibility of exceeding the limit of bending moment of the turbodrill.

According to the present invention in deviation borehole drilling with a down-hole motor, a drill string comprises a deviation assembly, as hereinbefore defined, at least one flexible collar connected above the deviation assembly, and a second collar assembly connected above the flexible collar or collars, the flexible collar or collars being sufficiently flexible to substantially prevent the second collar assembly from exerting a bending moment on the deviation assembly, but at the same time being capable of transmitting axial loads from the second collar assembly to the deviation assembly.

Preferably the flexible collar or collars are provided at their ends with stabilizers.

Also in a preferred embodiment of the invention a ram is provided in the deviation assembly above the down-hole motor for providing an axial thrust on the drill bit.

According to an embodiment of the present invention, the deviation assembly comprises, from the bottom of the borehole the drill bit, the down-hole motor, a bent sub and a plurality of drill collars which provide the necessary bending moment about the bent sub to produce a side load on the drill bit for deviation.

Use of the flexible collar or collars enables the main stand of weight collars to be moved to the less inclined section of the borehole and thus has an added advantage of allowing more of the weight of the main stand of weight collars to act along the axis of the borehole.

The invention will now be described in more detail, merely by way of example, with reference to the accompanying drawing which shows a vertical section through a partly drilled borehole together with a drill string assembly of the present invention.

Referring now to the drawing a borehole **1** being drilled, has a straight vertical portion **2**, and a curved portion **3** in which the hole deviates from the vertical. The curvature may be, for example 3° per 100 ft. length and the total deviation may be 30° to 40°. The curved portion of the borehole is shown in the figure with an exaggerated curvature for the purposes of illustration, the actual length being 1000 ft. to 1400 ft.

In the borehole **1** is a drill string assembly which comprises a plurality of hollow drill collars **4** which are attached to a downhole motor, in the form of a turbodrill **5**, by means of a bent sub **6** and a ram **7**.

The bent sub **6** is a deviation control device and comprises a hollow cylindrical member having an angled end face which provides control of the azimuth direction of the drill bit together with the included angle between the drill axis and that of the drill collars above it. At the bottom of the borehole **1** is the drill bit **8** which is attached to and driven by the turbodrill **5**. Above the collars **4** is the drill-pipe **10**.

The turbodrill **5** is of known type and comprises a turbine (not shown) which is driven by a mud flush which is pumped down from the surface inside the drill string, and comes out at the drill bit after passing through the turbine. The mud flush then passes back up the borehole **1** to the surface passing over the outside of the drill string. The drill bit is driven by the turbine via a shaft **9**.

In operation the bent sub contacts the side of the curved portion **3** of the borehole at a point K, known as the knee, and those parts of the drill string which are in the curved portion of the hole produce bending moments about K which govern the side load on the drill bit.

The ram **7**, is of a kind similar to those described in British Patent Specification No. 755207. The interior of the ram comprises a hollow central tube and the mud flush is passed therethrough on its way to the drill turbine. A cylinder surrounds the hollow central tube and a piston is mounted on the tube for cooperation with the cylinder walls. The hollow central tube is moveable axially of the ram relative to the cylinder. The mud flush passing through the hollow central tube is allowed to communicate through the tube with the cylinder on one side of the piston, and the mud flush in the borehole returning to the surface communicates through the cylinder wall with the opposite side of the piston. Thus a pressure differential is applied to the piston which is substantially equal to the pressure drop of the mud flush in passing through the drill turbine and the drill bit. This thrust will always act axially of the ram whatever the inclination of the ram is to the vertical. The ram may however be hydraulically operated.

Above the bent sub are collars **4*b***, **4*c*** and **4*d***. Collar **4*b*** is a nonmagnetic survey collar which contains instruments to detect the borehole heading and inclination. Collars **4*c*** are heavy collars to provide bending moment about the knee, known as weight collars, and collars **4*d*** are relatively lightweight flexible collars. The collars **4*d*** are provided at their ends with stabilizers **11**. Above the flexible collars is the main stand of drill collars **4** which comprise, for example, 400 feet of weight collars and which provide an axial load on the drill bit, and above the weight collars is the drill pipe **10**. The term "deviation assembly" is applied to those parts of the drill string, including the deviation device, which provide the forces which govern the side load on the drill bit for controlling deviation. In the above-described described example the collars **4*c*** with a stabilizer **11**, the collar **4*b***, the bent sub and the drill string below the bent sub collectively form the deviation assembly.

In a turbodrill string assembly without a ram, the drill relies principally on the weight W of the drill collars above it, minus the lift tension L in the drill pipe, for axial thrust T on the bit. This is the indicated bit weight at the surface. In deviation drilling, as more and more of the drill collars pass into the curved section of the borehole their axial thrust on the drill decreases for two reasons, (a) less of the weight W of the drill collars acts along their axes as thrust, and (b) more of the collar thrust is dissipated in friction between the collars and the side of the borehole.

The ram, pushing against the weight of the collars above it and the frictional resistance of the collars and the bent sub to sliding in the borehole, provides a force on the drill bit which, by placing the ram immediately above the turbodrill, acts axially of the borehole regardless of the inclination of the borehole. The force provided on the drill bit by the ram is thus greater than W–L because of the wall friction.

As the deviation of the borehole from the vertical increases the advantages of the ram become greater. However, by placing the ram below the bent sub, the ram becomes exposed to the bending moments produced by the drill collars above the bent sub and care must be taken not to exceed the limit of bending moment of the ram. The ram is particularly useful at large deviations when the axial component of the weight of the collars is much reduced. The ram is also particularly useful in that section of the borehole below the curved portion where the bending moment problem is less severe.

The bending moment problem is overcome by the use of the relatively lightweight flexible collars **4***d* these collars are stabilized at their ends by stabilizers **11** which reduce lateral movements of the ends of the collars **4***d*. The collars **4***d* must be sufficiently flexible to prevent substantial transmission of bending moment but must at the same time be capable of transmitting the axial thrust from the main stand of drill collars. The collars **4***d* are of reduced diameter and hence are relatively lightweight so that the bending moment on the drill is substantially only that produced by the collars **4***b* and **4***c* and is thus readily controlled.

The flexible collars also have the advantage that with their use, the main stand of weight collars can be kept in the more vertical portion of the hole so that more of their weight acts axially and their tendency to foul on the sides of the borehole is diminished.

The forces acting on the drill bit are the axial thrust T and the side load S. As above, the thrust T is the ram thrust and it is only a little more than the indicated bit weight (W–L). The side load S is produced by the bending moments acting around K the contact point of the bent sub.

Without the interposed flexible collars the weight bending moment above the bent sub increases as the inclined portion of the hole gets longer and more of the drill collars become inclined to the vertical. Deviation control is a difficult process under such conditions, and the bending moments may be sufficiently large to damage the drill or the ram. Use of the stabilized flexible collars avoids transmission of large bending moment from the collars **4** to the deviation assembly and so the deviation bending moment is derived from the clockwise moment of the collars **4***b* and **4***c* above the bent sub, and the anticlockwise moment of the ram, the turbodrill and the bit below the bent sub, i.e. the deviation assembly. This will be variably affected to a lesser degree by the stabilized lightweight collars **4***d*. The ram has to be stiff in order to transmit bending moment and thus a short stroke is preferred.

It will be appreciated that the position of the components of the deviation assembly may be changed, for example, the ram and the collar **4***b* and may be interchanged. This would place the survey collar nearer the drill bit, which is preferable, but would cause the ram thrust to be produced above the bent sub so that the ram thrust would be partially dissipated by friction on the wall and would act at an angle to the drill which would be a disadvantage. The main criterion when a ram is used is that the ram should be disposed as close to the drill as possible.

This embodiment has shown a deviation assembly in which the deviation control device is a bent sub, but it is not meant to be limited to such a device, since the side load on the bit may be produced by other means.

I claim:

1. A drill string for use in deviation drilling with a down-hole motor comprising a deviation assembly, at least one flexible collar connected above the deviation assembly, a second collar connected above said at least one flexible collar, said at least one flexible collar being sufficiently flexible to substantially prevent the second collar from exerting a bending moment on the deviation assembly, but at the same time being capable of transmitting axial loads from the second collar to the deviation assembly, the deviation assembly further comprising, from its lower end, a drill bit, a down-hole motor, a bent sub, and a plurality of drill collars, which are sufficient to provide the necessary bending moment about the bent sub to produce the required side load on the drill bit for deviation thereof.

2. A drill string according to claim **1** and in which a ram is provided in the deviation assembly for providing an axial load on the drill bit.

3. A drill string as claimed in claim **1** and in which a ram is disposed in the deviation assembly between the down-hole motor and the bent sub.

4. A drill string as claimed in claim **1** and in which the down-hole motor is a turbodrill.