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AUSTRALIA CONVENTION STANDARD PATENT APPLICATION FORM

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CONVENTION APPLICATION FOR STANDARD PATENT OR A STANDARD PATENT OF ADDITION

Full name(s) of Applicant(s)

~~I~~/We Eastman Christensen Company

Address(es) of Applicant(s)

of 1937 South 300 West, Salt Lake City, Utah 84115, United States of America

hereby apply for the grant of a standard patent ~~patent of addition~~

for an invention entitled

Title of Invention

Tool for Optional Straight Hole Drilling in Underground Rock Formations

which is described in the accompanying complete specification.

DETAILS OF BASIC APPLICATION(~~S~~)

Number(~~s~~) of Basic Application(~~s~~)

P3804493.5

Name(~~s~~) of Convention Country(~~ies~~) in which Basic Application(~~s~~) was/were filed

Federal Republic of Germany

(~~respectively~~)

Date(~~s~~) of Basic Application(~~s~~)

12 February, 1988 (~~respectively~~)

~~My~~/Our address for service is:

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Dated this TENTH day of MAY 1989

Eastman Christensen Company

By: [signature]

Registered Patent Attorney

To: The Commissioner of Patents

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Australia

Patents Act 1990

NOTICE OF ENTITLEMENT

I, Nancy B. Allen, of Eastman Christensen Company (Applicant/ Nominated Person), 1937 South 300 West, Salt Lake City, UT 84115, USA being authorised by the Applicant/Nominated Person in respect of Application No 29564/89 state the following:-

The Applicant/Nominated Person has entitlement from the actual inventor(s) as follows:-

The Applicant/Nominated Person is the assignee of the actual inventor(s).

The Applicant/Nominated Person is the applicant of the basic application(s) listed on the Patent Request. The basic application listed on the application form is the application first made in a Convention Country in respect of the invention.

DATED this 5th day of August 1991

Nancy B. Allen
(Signature)

Nancy B. Allen, Secretary
(Name & Title)

IRN: 85250:JGH:JPA INSTR CODE: 63105

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(54) Title
TOOL FOR OPTIONAL STRAIGHT HOLE DRILLING IN UNDERGROUND ROCK FORMATIONS

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(56) Prior Art Documents
US 4465147
US 4739842

(57) Claim

1. An apparatus for drilling a borehole with an optionally rectilinear or an arcuate center line into underground rock formations, with a rotary drilling tool which can be connected to a drill string, including means for driving the drill string in a slow autorotational movement for straight hole drilling and for orienting and holding the drill string free from autorotation for directional drilling operations; with the rotary drilling tool having a casing in which a deep-hole motor is arranged and in which a bit shaft is located, which is connected to the rotor of the deep-hole motor and which supports on its end protruding from the casing a rotary drilling bit with the rotary drilling tool having a first stabilization point proximate the rotary drilling bit and with a minimum of a second stabilization point being located at a fixed distance from the first stabilization point; and with the rotation axis of the bit shaft and an imaginary lower extension of that part of the principal axis of the drilling tool located at the level of the second stabilization point, forming an angle of deflection (α) which opens up toward the rotary drilling bit when operating the rotary drilling tool while drilling a borehole with an arcuate center line, comprising at least one bend in the rotary drilling tool, said bend of a dimension to form a clearance angle between the rotational axis of the bit shaft and an imaginary connecting line between the arc center and the base of the arcuate center line of the borehole to be drilled, said clearance angle (β) having 90° as its lower limit.

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COMPLETE SPECIFICATION

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Complete Specification for the invention entitled:

Tool for Optional Straight Hole Drilling in Underground Rock Formations

The following statement is a full description of this invention, including the best method of performing it known to me/us

SBR:ALB:5W

BACKGROUND OF THE INVENTION

The present invention provides a method and apparatus for drilling a borehole with an optionally rectilinear or arcuate center line into earth formations.

Tools of this type, which are used for navigational drilling without tool change, are known to be available in various designs.

In order to create an angle of deflection--which at the same time determines the build--up rate to be achieved--for the rotation axis of the drill bit shaft during directional drilling, the first and the second stabilizer of a first well-known tool (U.S. Patent No. 4,465,147) are arranged eccentrically on the casing--which has the shape of a straight tube--of the rotary drilling tool. In directional drilling operations, such a design imparts a deflection, which determines the angle of deflection, to the casing.

In a second well-known tool (U.S. Patent No. 4,739,842), the stabilizers are concentrically arranged on the casing of the rotary drilling tool, and the casing is provided with sections deflected relative to the principal axis of the tool, which define two bends which face in opposite directions and which in combination with each other determine the angle of deflection. According to a further development of this tool, as also disclosed in U.S. Patent No. 4,739,842, the deflection of the casing regions can be designed in such a way that only one single bend between the two stabilizers determines the angle of deflection.

Instead of one or two bends in the region of the casing between the first and the second stabilizer, a third well-known tool of the type mentioned in the introduction provides for a bend between the rotary drilling bit and the first stabilizer (U.S. Patent No. 4,492,276). This bend is formed in such a way that the bit shaft is carried in the lower area of the casing--which has the form of a straight tube--at an angle relative to the axis of this casing and exits at a slant from the end of the casing.

In a fourth well-known tool (U.S. Patent No. 4,485,879), the bit shaft is carried in the casing of the rotary drilling tool, with its rotation axis being laterally and parallelly offset with respect to the axis of the casing.

The present invention provides a method and apparatus which has a higher accuracy of tracking and a higher penetration rate during directional drilling while at the same time reducing its wear.

STA/1568W

SUMMARY OF THE INVENTION

Methods and apparatus in accordance with the present invention utilize a downhole drilling tool which includes a drill bit, a downhole motor, a deflection member imparting an angle of deflection of the drill bit relative to the axis of the drill string above the drilling tool assembly, and at least first and seconds stabilization points, which may or may not be of a dimension greater than the remainder of the drilling tool. When the drilling tool is to be utilized for generally straight ("rectilinear") hole drilling, the entire drill string will be rotated to affect the drilling. When arcuate (or "navigational") drilling is desired, the drill string will be fixed in a position such that the deflection member orients the bit in the desired direction of travel, and rotation of the bit (and thus drilling) will be accomplished through use of the downhole motor. With methods and apparatus in accordance with the present invention, the axis of the bit shaft will be oriented generally tangentially (for example, $90-91^{o}$), to the radius of the arc of the intended borehole path. Particular preferred embodiments of the invention may utilize one or more bends to achieve the above relation of the bit axis to the radius of the arcuate borehole path.

With use of an apparatus according to this invention, the resulting component forces exerted on the guiding direction of the rotary drilling bit are considerably reduced during directional drilling as a result of the special orientation of the axis of the bit shaft of the rotary drilling bit, which is responsible for a more wear-resistant operation and a higher penetration rate. This applies particularly to a design of the rotary drilling tool for a build-up rate of 2^{o}/30 meters and more. At the same time, a much greater tracking accuracy for the rotary drilling bit is achieved during directional drilling not only in uniform rock formations but also in successively different rock formations.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts a truncated schematic view, partially in vertical section, of a tool for optional straight hole drilling and directional drilling with a rotary drilling tool according to this invention during directional drilling operations.

Figure 2 depicts a schematic representation of a first embodiment of a rotary drilling tool in accordance with the present invention in a drilling hole produced by means of directional drilling and having an arcuate center line.

Figure 3 depicts a schematic cross-sectional view of the upper portion of the rotary drilling tool according to Figure 2.

Figure 4 depicts a schematic cross-sectional view of the lower portion of the rotary drilling tool according to Figure 2, with this lower portion being a continuation of the corresponding upper portion of the representation according to Figure 3.

Figures 5 to 11 are schematic representations similar to those shown in Figure 2 to further illustrate seven alternative embodiments of a rotary drilling tool in accordance with the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The tool shown as a schematic diagram in Figure 1 consists of a rotary drilling tool 2 which is located in a borehole 1 and whose casing 3 is connected at its upper end to drill string 4. Drill string 4 is clamped into a rotary table 5 of a drilling rig 6. Rotary table 5 is fitted with a driving and blocking device 7 by means of which the chuck of rotary table 5, and thus of drill string 4, can be put into continuous rotation or can be aligned by means of a limited rotary movement and subsequently be secured into position so as to not be able to turn..

The embodiment of a rotary drilling tool 2 illustrated in Figures 1 to 4 has a casing or housing 3 which consists of several components or sections 8, 9, 10, 11, 12 which are screw-jointed to each other. Along one section of its length, casing section 10 is designed as a stator 13 of a deep-hole motor with rotor 14. In the practical example shown in Figures 3 and 4, deep-hole motor 13, 14 is a displacement motor operating according to the Moineau principle; however, it may also be a turbine or a motor of any suitable construction.

Rotor 14 is connected to the upper end of a bit shaft 16 by means of a propeller shaft 15 which is located in casing section 11. This bit shaft 16 rotates in bearings 17, 18 of casing section 12 which forms a bearing block. In the embodiment of the rotary drilling tool according to Figures 1 to 4, the bit shaft has a rotation axis 19 which is at a small angle relative to the surrounding casing axis 20 of casing section 12. In correspondence with this slanted bearing, bit shaft 16 whose outer end is fitted with a rotary drilling bit 21 exits at a slant from the lower end of casing 3.

In its lower section, near rotary drilling bit 21, rotary drilling tool 2 is fitted with a first stabilization point 22 in the form of a stabilizer 24 which is attached to casing section 12 and which has a number of stabilizer blades or ribs that are distributed throughout its circumference. At a certain distance from and above this first stabilization point 22, rotary drilling tool 2 has a second stabilization point 25 which is also formed by a conventional stabilizer 24 which is located on casing section 8. The imaginary central points of these stabilization points 22, 25, in combination with an imaginary central point of the rotary drilling bit 19a, define the course of an imaginary center line for borehole 1, which in the areas of borehole 1 drilled in the course of directional drilling takes an arcuate course.

The center line (not shown in the drawing for reasons of clarity) of the area of borehole 1, which in Figures 2 and 5 to 11 is shown to be curvilinear, has its base at point 26 and has an arc center which is substantially removed in distance.

The distance of the arc center from the arcuate center line of an area of borehole 1 produced by means of directional drilling is measured on the basis of the build-up rate (BUR = $2\alpha/D$ in °/meter) for which the rotary drilling tool is designed. α denotes the angle--opening up into the direction of rotary drilling bit 21--between the imaginary connecting line of the central point 19a (which coincides with base 26) of rotary drilling bit 21 with the imaginary central point of the borehole at the level of the first stabilization point 22 and an imaginary lower extension of the rectilinear connecting line of the imaginary central points of borehole 1 at the level of the first and the second stabilization 22, 25. D denotes the distance between the imaginary central point of the second stabilization point 25 and the mentioned central point 19a of rotary drilling bit 21. The build-up rate is preferably a minimum of approximately 2°|20 meter, corresponding to a distance from the arc center to the center line of the borehole of approximately 850 meters.

As all other modifications of this invention, illustrated or imaginable, rotary drilling tool 2 is designed in such a way that in directional drilling operations, rotation axis 19 of bit shaft 16 has an orientation relative to an imaginary rectilinear connecting line 28 between the arc center and base 26 of the arcuate center line of borehole 1--which can be drilled with the rotary drilling tool--with a clearance angle β of approximately 90° as a lower limit. The "clearance angle" is the angle between the bit axis and the radius of the curve to be drilled at the position of the bit in the borehole. Thus, in effect, angle β of 90° represents the bit axis being tangential to the arcuate part of the borehole.

Thus, this type of orientation establishes the rotational axis 19 of bit shaft 16 as a tangent to the arcuate center line of borehole 1 at the level of base 26, with the result that the resulting component forces exerted upon rotary drilling bit 21 are reduced to a minimum. In the conventionally known tools discussed earlier herein, these component forces are considerably greater since in these tools, the rotation axis 19 of bit shaft 16 forms a second to the arcuate center line of a borehole drilled by means of directional drilling, with intersections with the center line, which are located above base 26.

Clearance angle ß may also be slightly larger than 90^{O}, and thus may range between approximately 90^{O} and 91^{O}. This "lead" makes it possible to compensate for bending strains which a rotary drilling tool may be subjected to as it is introduced into a partially drilled borehole, e.g., in the course of a round trip.

Between the first and the second stabilization points 22, 25, rotary drilling tool 2 has a bend 29, and in the area between rotary drilling bit 21 and the first stabilization point 22, there is a second bend 30. Preferably, both bends 29, 30 (in the principal axis defined by several individual sections connected to each other) are located in the integral casing section 12, in which the lower stabilization point 22 is to be found, and both bends 29, 30 face into the same direction, namely toward the arc center.

In rotary drilling tool 2, bend 29 is formed by a cocked upper threaded pipe connection 31 of casing section 12, and the second bend 30 is formed by the inclined bearing 17, 18 of bit shaft 16 in casing section 12. The sum of the values of both angles of bend corresponds to the value of the angle of deflection α, and the build-up rate is calculated on the basis of the angles of bend. In the presence of several bends, it is, however, possible to assign different values to the angles, thus making it possible to take special structural arrangements into consideration. Preferably, it is bend 29 which is used to determine the build-up rate while bend 30 is mainly responsible for the desired clearance angle ß. Thus, for example, the angle of bend of bend 29 may measure 1.5^{O} and more, while the angle of bend of bend 30 may, for example, amount to 0.6^{O} or less.

The location of both bends within one single casing section 12, as suggested for rotary drilling tool 2, simplifies the structural design singe all other casing sections 8 to 11 located higher up can consist of straight-line pipes.

Figure 5 illustrates an alternative embodiment of a rotary drilling tool 102 in which, in addition to bend 29, a further bend 32 is provided between the first stabilization point 22 and the second stabilization point 25. Both bends 29, 30 may face into the same direction of bend or may, as shown in Figure 5, face in opposite directions, with bend 32 facing away from the arc center of the arcuate center line of borehole 1 and with bend 29 having a direction of bend facing this borehole center. This type of arrangement of the directions of bend reduces and eliminates an eccentricity of the imaginary center point of rotary drilling bit 21 relative to an imaginary rectilinear lower extension of the upper section 27 of the principal axis of the tool. Furthermore, this type of arrangement of the directions of bend is to be preferred for drilling operations in which rotary drilling bits 21 with a small diameter and a low clearance are used.

Otherwise, the embodiment of the tool according to Figure 5 corresponds largely to that according to Figure 4; therefore, corresponding reference numbers are used customarily for corresponding structural components. Both bends 29, 32 are located within one casing section 11 which may be molded in the form of one integral section, or casing section 11 may consist of three separated sections with cocked threaded pipe connections.

Figure 6 illustrates another embodiment of a rotary drilling tool 202 which differs from rotary drilling tool 2 in that instead of bend 29, it has a different bend 33 which is located between the rotary drilling bit 21 and the first stabilization point 22. Like bend 30, this other bend 33 may be structurally designed identically to bends 29, 30 (Figure 2). Again, both bends 30, 33 are located within casing section 12; however, the first stabilization point 22 is to be found in casing section 11.

Figure 7 illustrates another alternative embodiment of a rotary drilling tool 302 which is essentially the same as that shown in Figure 6, with the exception that bend 33 faces into a direction of bend opposite to that of bend 30. Bend 33 has a direction of bend facing away from the arc center, and the lower bend 30 has a direction of bend facing the arc center.

Figure 8 shows an embodiment of a rotary drilling tool 402 which has only one bend 29, which corresponds to bend 29 of rotary drilling tool 2, between stabilization points 22, 25. As an additional measure, the lower stabilization point 22 is formed by stabilizer 424 which is undersized compared to a stabilizer which, relative to a given rotary drilling bit 21, is designed in standard size. Furthermore, rotary drilling tool 402 as shown in the embodiment of Figure 8 is fitted with a bit shaft 16 which is seated coaxially in casing section 12.

Another alternative embodiment of rotary drilling tool 502 is depicted in Figure 9 and is similar to that shown in Figure 8, with the difference that the lower stabilization point 22 is formed by stabilizer 524 which is eccentrically arranged on casing section 12.

Yet another alternative embodiment of rotary drilling tool 602 is illustrated in Figure 10. Rotary drilling tool 602 is designed in such a way that the first stabilization point 22 is located on rotary drilling bit 21 and forms an integral part thereof, e.g., by inserting a stabilization component after the cutting element and molding it to the bit. Otherwise, rotary drilling tool 602 has one single bend 29 between the two stabilization points 22, 25; this single bend 29 may correspond in its construction to bend 29 as shown in Figure 4.

Figure 11 finally shows another alternative embodiment of a rotary drilling bit 702 in which the upper stabilization point 25 is not formed by a stabilizer of conventional form or shape but by a stabilization region of casing 3 or its casing section 8. At the same time, this stabilizer is undersized compared to the standard stabilizer. In a borderline case, as illustrated, the diameter of this stabilizer may correspond to the diameter of casing 3. As is the case for rotary drilling tool 2 according to Figure 2, rotary drilling tool 702 has a bend 29 in the region between stabilization points 22, 25 and a bend between rotary drilling bit 21 and the first stabilization point 22 whose structural form may be identical to that of rotary drilling tool 4.

Instead of bends which define a predetermined angle of bend, such as is the case if bit shaft 16 is carried in slanted bearing 17, 18 or if the threaded pipe connections 31 are cocked, it is also possible to provide bends which are formed only in the course of the directional drilling operation. These bends form under stress in special casing sections to which the formation of the bends is restricted due to the fact that these particular sections are provided with a special flexibility.

The claims defining the invention are as follows:

1. An apparatus for drilling a borehole with an optionally rectilinear or an arcuate center line into underground rock formations, with a rotary drilling tool which can be connected to a drill string, including means for driving the drill string in a slow autorotational movement for straight hole drilling and for orienting and holding the drill string free from autorotation for directional drilling operations: with the rotary drilling tool having a casing in which a deep-hole motor is arranged and in which a bit shaft is located, which is connected to the rotor of the deep-hole motor and which supports on its end protruding from the casing a rotary drilling bit with the rotary drilling tool having a first stabilization point proximate the rotary drilling bit and with a minimum of a second stabilization point being located at a fixed distance from the first stabilization point; and with the rotation axis of the bit shaft and an imaginary lower extension of that part of the principal axis of the drilling tool located at the level of the second stabilization point, forming an angle of deflection (α) which opens up toward the rotary drilling bit when operating the rotary drilling tool while drilling a borehole with an arcuate center line, comprising at least one bend in the rotary drilling tool, said bend of a dimension to form a clearance angle between the rotational axis of the bit shaft and an imaginary connecting line between the arc center and the base of the arcuate center line of the borehole to be drilled, said clearance angle (β) having 90° as its lower limit.

2. An apparatus in accordance with Claim 1, wherein the clearance angle (β) is within a range of from 90° to about 91°.

3. An apparatus in accordance with Claim 1, wherein the rotary drilling tool is designed for a build-up rate of a minimum of $2^\circ/30$ meter.

4. An apparatus in accordance with Claim 1, wherein said rotary drilling tool comprises a bend between the first and the second stabilization points.

5. An apparatus in accordance with Claim 4, wherein said rotary drilling tool comprises a bend in the section between the first stabilization point and the rotary drilling bit.

6. An apparatus in accordance with Claim 5, wherein both bends are located on an integral casing section which includes the lower stabilization point.

7. A apparatus in accordance with Claim 6, wherein the bend located between the rotary drilling bit and the first stabilization point is formed

by a slanted bearing of the bit shaft and that the bend located between the first and the second stabilization point is formed by a cocked upper threaded pipe connection of the integral casing section.

8. An apparatus in accordance with Claim 1, wherein two bends are located between the first and the second stabilization point inside the casing of the rotary drilling tool.

9. An apparatus in accordance with Claim 1, wherein two bends are located between the first stabilization point and the rotary drilling bit.

10. An apparatus in accordance with Claim 8, wherein the directions of bend of the bend located between the first and the second stabilization point and the bend located between the first stabilization point and the rotary drilling bit are the same.

11. An apparatus in accordance with Claim 8, wherein the directions of bend of the bend located between the first and the second stabilization point and the bend located between the first stabilization point and the rotary drilling bit ~~face~~ are in opposite directions.

12. An apparatus in accordance with Claim 11, wherein the upper bend faces away from the arc center of the arcuate center line of a borehole to be drilled and wherein the lower bend faces into the direction of the arc center.

13. An apparatus in accordance with Claim 1, wherein at least one of the first and the second stabilization points is formed by a stabilizer located on the casing of the rotary drilling tool.

14. An apparatus in accordance with Claim 13, wherein the first stabilizaton point is formed by a surface which is undersized compared to a stabilizer which, relative to a given rotary drilling bit is ~~desinged~~ designed in standard size.

15. An apparatus in accordance with Claim 14, wherein the second stabilization point is formed by a surface of a dimension which corresponds to the diameter of the drill casing.

16. An apparatus in accordance with Claim 1, wherein the first stabilization point is an integral part of the rotary drilling bit.

17. An apparatus in accordance with Claim 1, wherein the stabilizer section which forms the first stabilization point is eccentrically arranged on the casing.

18. An apparatus in accordance with Claim 1, wherein the bit shaft is carried in the casing with a lateral parallel shift of its rotational axis relative to the axis of the casing.

DATED this SECOND day of FEBRUARY 1989
Eastman Christensen Company

Patent Attorneys for the Applicant
SPRUSON & FERGUSON

29564/89

Fig-1

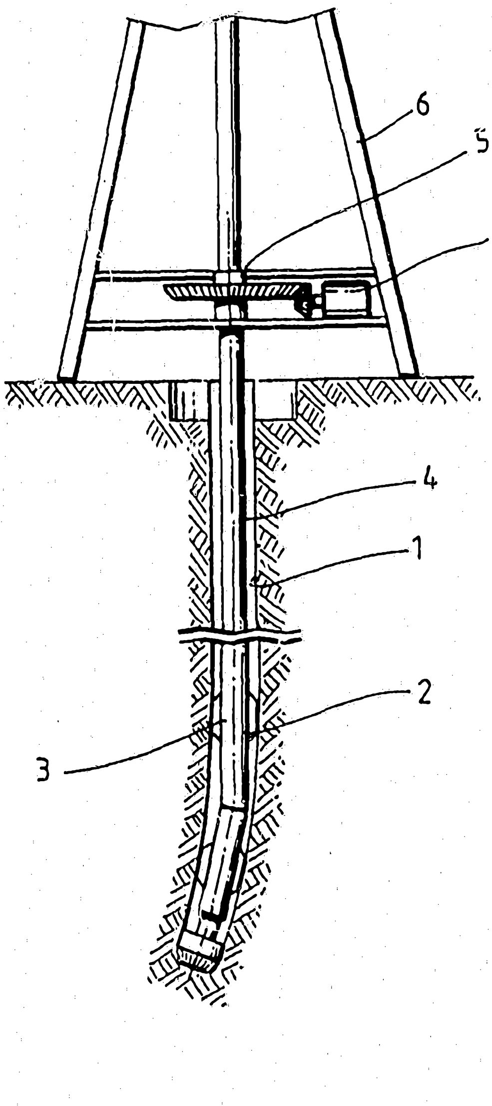

Fig-2

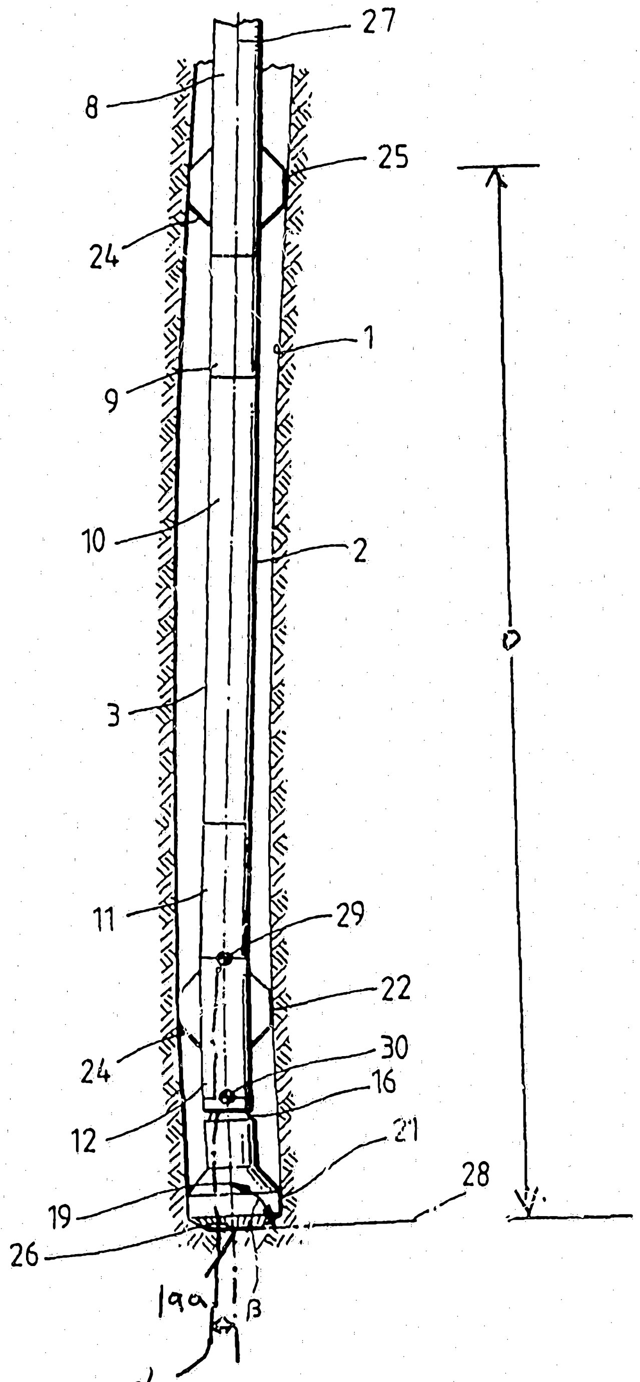

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Fig. 3

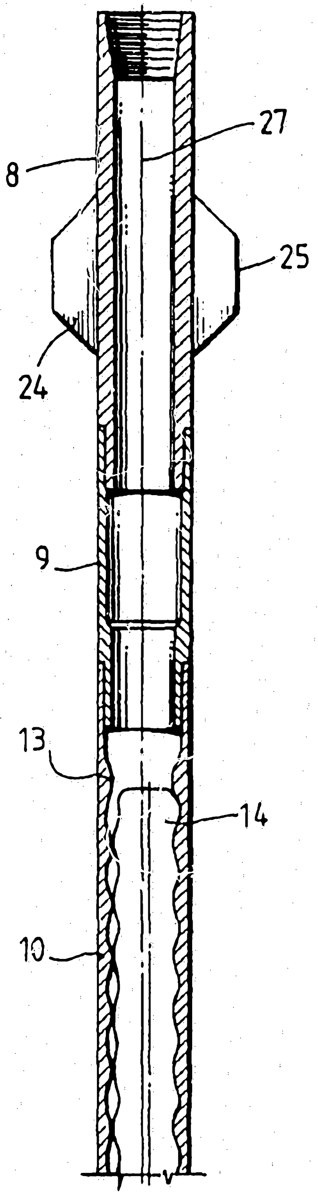

Fig. 4

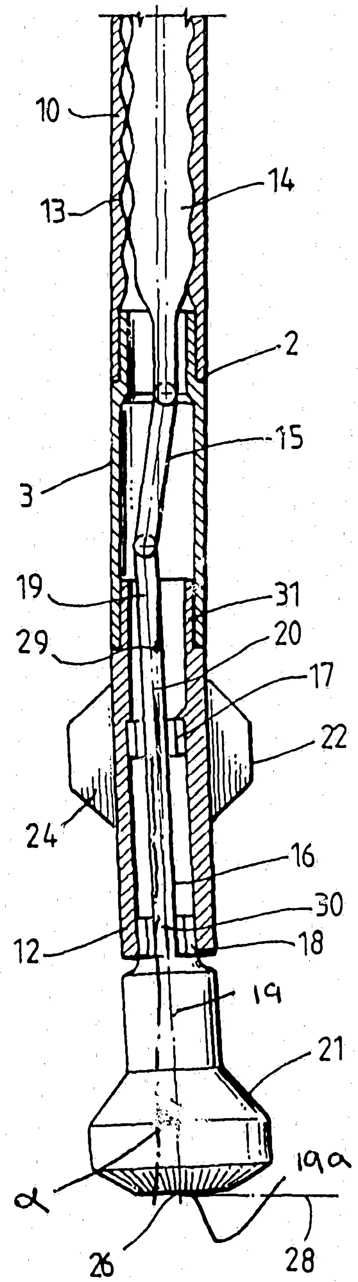

Fig. 5

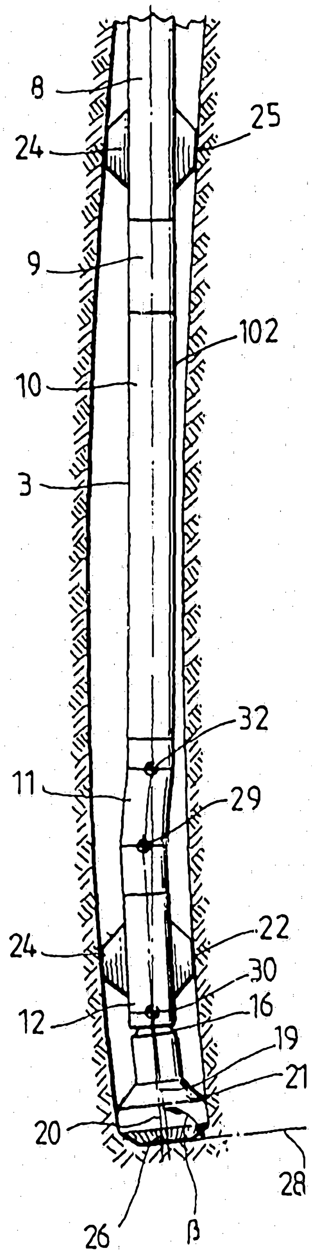

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Fig.6

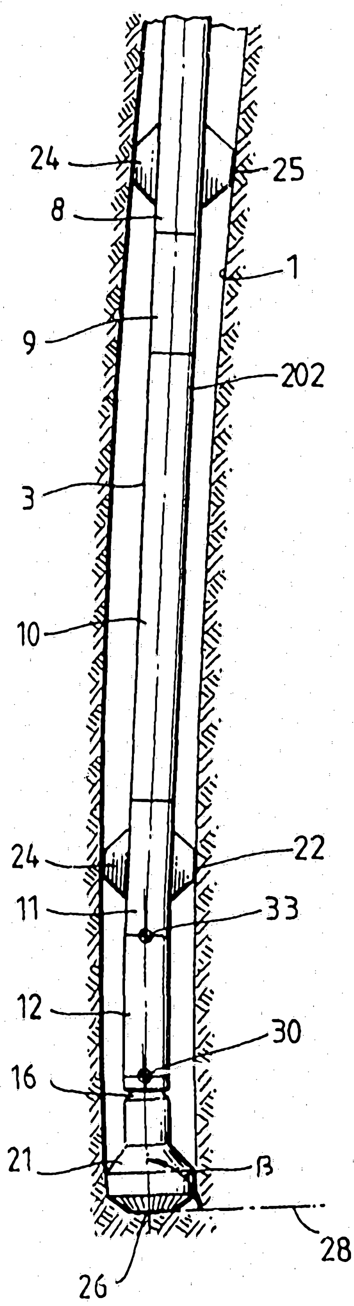

Fig.7

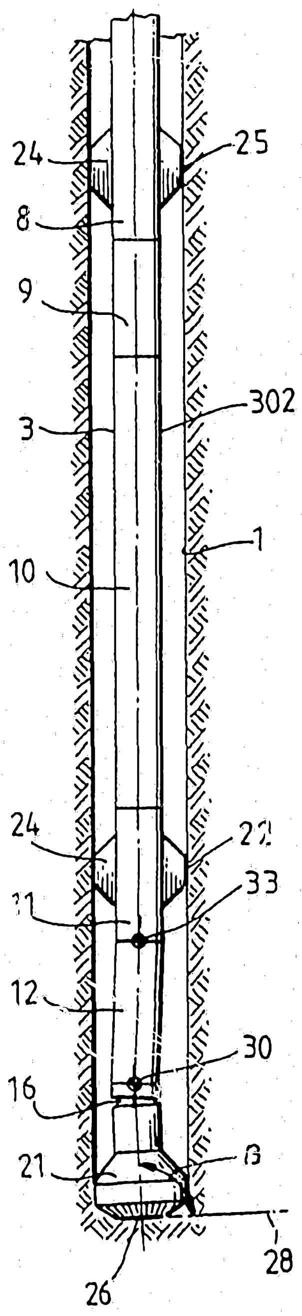

Fig.8

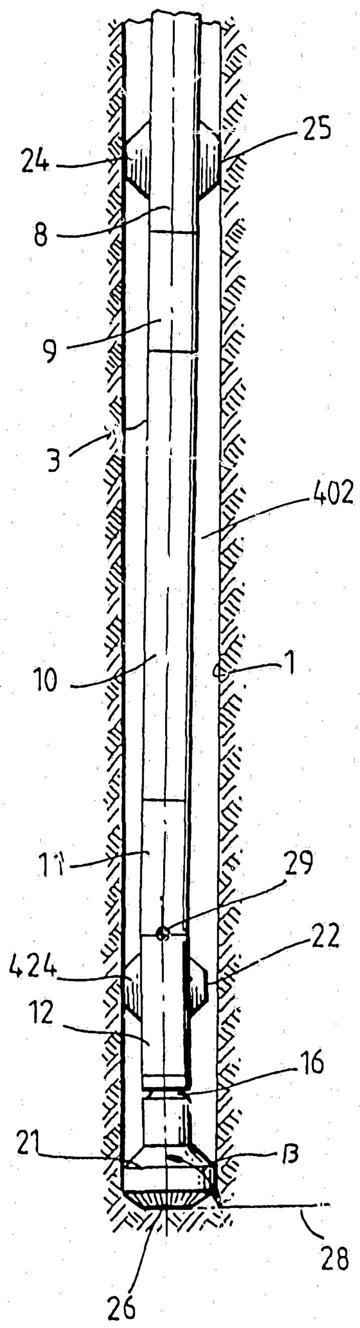

Fig.9

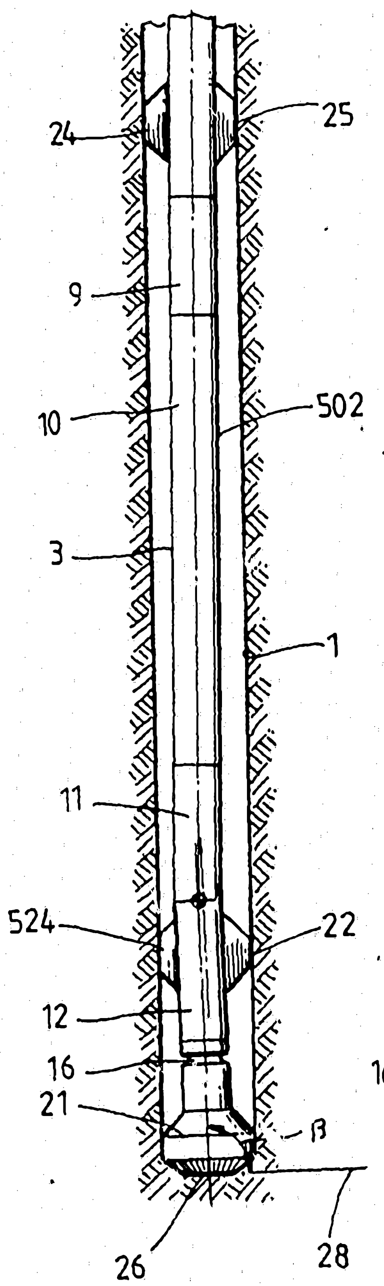

Fig.10

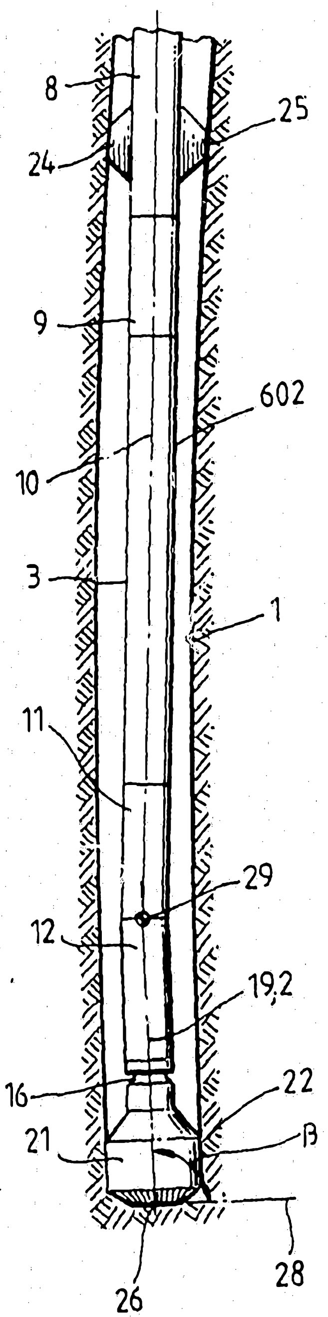

Fig.11