(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 298 537 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **88201228.9**

(22) Date of filing: **15.06.88**

(51) Int. Cl.4: **E21B 7/28 , E21B 10/32 , E21B 10/60 , E21B 10/46 , E21B 4/02 , E21B 44/00 , E21B 4/18**

The title of the invention has been amended (Guidelines for Examination in the EPO, A-III, 7.3).

(30) Priority: **25.06.87 GB 8714921**

(43) Date of publication of application: **11.01.89 Bulletin 89/02**

(84) Designated Contracting States: **DE GB NL**

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(54) Device and method for underreaming a borehole.

(57) A borehole underreamer device comprises a downhole motor having a rotor part which carries by means of a pivot (2) an elongate clapper body (1) in which a series of abrasive teeth (8) are embedded. In use the device is pulled in upward direction through the borehole while the clapper body describes an orbital motion inside the borehole thereby forcing the teeth to penetrate into the surrounding side wall of the borehole so as to underream the hole.

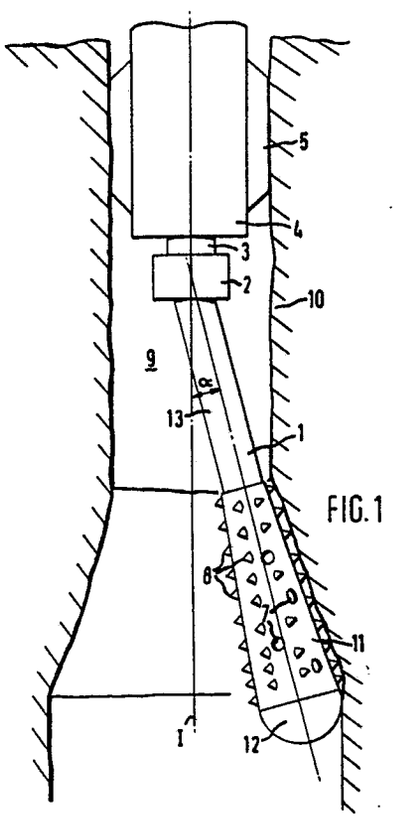

FIG.1

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BOREHOLE UNDERREAMER DEVICE

The invention relates to a device and a method for underreaming a borehole penetrating through subsurface earth formations.

Borehole underreamers are used to increase the diameter of a borehole, for example prior to setting a casing inside the borehole or to install a gravel packing in the production zone of an oil production well. Currently known underreamer devices generally comprise cutters mounted on arms which can be hinged to an expanded position whereupon the device is rotated while moving it in axial direction through the borehole so as to underream the borehole to an enlarged diameter.

It is also known, for example from U.S. patent 1,954,166, to utilize an underreamer comprising a bearing sleeve which is mounted eccentrically on a mandrel and a rolling cutter carried in a tilted orientation by the mandrel. In use the mandrel is rotated while the bearing sleeve and rolling cutter engage opposite sides of the hole thereby inducing the cutter to underream the hole.

A disadvantage of the known underreamer devices is that only a limited diameter increase of the borehole can be accomplished and that they can easily get stuck in the borehole during operation and retrieval.

It is therefore an object of the present invention to provide an underreamer device which is able to underream the borehole to a larger diameter ratio than conventional devices without the risk of stalling of the device.

It is a further object of the invention to provide an underreamer device which can be used for scaling out production liners without causing damage to the liner itself.

The underreamer device according to the invention comprises a downhole motor having a rotor part which can be rotated relative to a stator part. The rotor part carries by means of a privot means a clapper body, in which a series of abrasive teeth are embedded, which teeth are in use induced to penetrate into the surrounding side-wall of the borehole when the clapper body is induced by centrifugal force to describe an orbital motion inside the borehole.

In accordance with the invention there is further provided a method of underreaming a borehole. The method comprises the steps of

- lowering into a borehole a borehole underreamer device comprising a downhole motor having a rotor part which carries by means of a pivot means a clapper body in which a series of abrassive teeth are embedded, and

- pulling the underreamer device in upward direction through the borehole while rotating said rotor part relative to a stator part of the motor, thereby inducing the clapper body to describe an orbital motion inside the borehole and causing the teeth to penetrate into the boreholewall.

Preferably the underreamer device according to the invention comprises a hydraulic motor of the Moineau type, which is in use suspended from a pipe string through which drilling fluid is injected. The speed of pulling the device through the borehole during underreaming operations may be adjusted in response to variations in the fluid pressure of the injected drirring fluid as there is a clear relation between the hole size and the power consumption of the rotating clapper at a given rotary speed.

The invention will now be explained in more detail with reference to the accompanying drawings, in which

Fig. 1 is an elevational view of a lower part of an underreamer device according to the invention,

Fig. 2 is a partly elevational and partly vertical-sectional view of the lower part of another underreamer device according to the invention, and

Fig. 3 shows the underreamer of Fig. 2 with expanded stabilizer blades.

Referring to Fig. 1 there is shown an underreamer device comprising a clapper body 1 which is carried via a universal joint 2 by an output shaft 3 of a hydraulically driven downhole motor. The motor comprises a housing 4 which is stabilized in a borehole 5 by stabilizer blades 6. The motor housing 4 is connected at the upper end thereof to a pipe string (not shown) which carries the underreamer device and through which a driving fluid is pumped into the motor housing 4 thereby inducing a rotor mounted inside the housing to rotate the output shaft 3 and clapper body 1. The output shaft 3, universal joint 2 and clapper body 1 comprise an axial fluid passage (not shown) and the driving fluid is discharged from the housing via said fluid passage and a series of nozzles 7 into the borehole so as to cool the abrasive teeth 8 mounted the clapper body and to remove drill cuttings therefrom.

When after lowering the underreamer device into a pilot hole 9 the output shaft 3 of the motor is rotated the clapper body 1 starts orbiting in the pilot hole. This orbiting motion generates a centrifugal force as a result of which the teeth 8 penetrate the side wall 10 of the pilot hole 9 in lateral direction. The teeth 8 are distributed circumpherentially on a frustoconical section 11 of the clapper body 1. Said frustoconical section 11 is located between a hard faced noze section 12 and a tubular section 13 of the clapper which latter sections

serve to ensure that during operations the clapper 1 is oriented at a selected angle α relative to a central axis I of the borehole 9 and to avoid that the borehole would be underreamed to an undesired large extend. The underreaming process can be monitored at the surface by measuring the pressure of the driving fluid which is injected via a standpipe into the pipestring carrying the underreamer device. Since at a given rotary speed of the clapper 1 there is a clear relation between the standpipe pressure and power consumption of the clapper 1 and since there is a clear relationship between the power consumption of the clapper and the hole size, the measured standpipe pressure can be used to control the speed of pulling the underreamer device through the borehole during operation thereof.

If desired the universal joint 2 may comprise a fluid passage which restricts the amount of fluid flow into the clapper body 1 with a progressing tilt angle α. In that case standpipe pressure changes generated as a result of the varying flow restriction in the universal joint may be used as a means for controlling the pulling speed of the device through the borehole during underreaming operations. Alternatively the universal joint 2 may be provided with a by-pass valve (not shown) having a fluid passage which is controlled by the tilt angle α of the clapper body 1.

It will be understood that during underreaming operations the pipe string and motor housing 4 may be rotated or be kept non-rotating and that if the device is lowered into or retrieved from the pilot hole 9 the whole assembly is kept non-rotating so as to ensure that the clapper body 1 is kept in a longitudinal orientation in the pilot hole.

In Figs. 2 and 3 there is shown the lower part of an underreamer device provided with hingeable stabilizer blades 20 which can be expanded so as to centralize the underreamer device in boreholes of various widths. A device of this type is able to make more passes to ream the hole to the ultimate diameter.

In Fig. 2 the device is shown in a small diameter pilot hole 21 with the stabilizer blades 20 in the contracted position, whereas in Fig. 3 the device is shown in a widened hole 22 in which the stabilizer blades 20 are located in an expanded thereof.

As can be seen both in Fig. 2 and 3 the underreamer device comprises a motor housing 23 which carries near the lower end thereof the stabilizer blades 20. The motor comprises a hollow output shaft 25 which carries a clapper body 26 via a universal joint 27. The motor is a hydraulic motor, such as a Moineau motor which is driven by a driving fluid which is injected into the motor via a pipe string (not shown) which is connected to the upper end of the motor housing 23. The driving fluid is discharged (see arrows II) from the motor housing 23 into the hollow output shaft 25 via orifices 28 at the upper end of said shaft 25. The driving fluid subsequently flows via the interior of the output shaft 25, universal joint 27 and clapper body towards a series of nozzles 29 which are circumpherentially distributed on a frustoconical section 30 of the clapper body 26.

At the lower end of the motor housing there is mounted an annular piston 31 which is slidably arranged in an annular-shaped piston housing 32. The piston housing 32 is coupled in fluid communication with the interior 34 of the motor housing 23 via an axial fluid passage 33. In this manner the pressure of the driving fluid inside the motor housing 34 exerts a downward force to the piston 31 thereby inducing a smoothly curved noze section 36 of the piston to push away in lateral direction inwardly curved lower portions 37 of the stabilizer blades 20, thereby forcing the stabilizer blades 20 towards an expanded position thereof.

The piston 31 may be forced back into the retracted position by spring means (not shown) if no driving fluid is pumped through the motor so as to enable axial movement of the device through the borehole during insertion and retrieval while the stabilizer blades are kept in a retracted position.

The clapper body 26 of the device shown in Figs. 2 and 3 is provided with hard faced cylindrical section 39 located above the frustoconical section 30 in which the abrassive teeth 40 are inserted. The cylindrical section 39 serves to limit the hole diameter increase per pass. The final borehole diameter is limited by the arrangement of a smooth hard faced noze section 41 at the lower end of the clapper body 26.

The underreamer device according to the invention may be used for any conventional underreaming operation such as for underreaming of boreholes, for example prior to setting a casing or prior to setting a gravel packing. The underreamer device according to the invention is furthermore particularly suitable for scaling out of at least partly plugged production liners. The smooth nose section of the clapper body prevents damage to the liner itself and the underreamer is able to operate properly in liner sections with various degrees of scaling.

During operation of the underreamer device according to the invention there is no risk of stalling of the downhole motor driving the clapper body because the cutting action of said body becomes less pronounced with decreasing rotary speed. It will be understood that the orbital movement of the clapper in the borehole generates a centrifugal force as a result of which the teeth penetrate into the borehole wall in lateral direction and that the

teeth will generally simultaneously have a tangential speed relative to the borehole wall as a result of which the teeth will scrape the rock from the wall. As the lateral force exerted to the teeth and the tangential speed thereof relative to the boreholewall may vary along the length of the clapper body the size, the orientation and distribution of teeth may also vary along the length of the clapper. If it is desired that the teeth have no tangential speed relative to the borehole wall during operation of the device, then the frustoconical section may be shaped such that the top of a mathematical cone enveloping the frustoconical section is located in the pivot centre of the universal joint. Alternatively the teeth may also be embedded in a spherical section of the clapper body. If desired part of the spherical surface of said section may be oriented tangential to a mathematical cone having its top located at the pivot centre of the universal joint. In that case at least some of the teeth have no tangential movement relative to the borehole wall during operation of the device.

The abrasive teeth may be made of any wear resistant material such as diamond, tungsten carbide or sintered diamond or boron nitrite particles which are secured to a tungsten carbide substratum. The teeth may further have a triangular, disk, or any other suitable shape.

It will further be understood that, if desired, the universal joint which interconnects in the examples shown in the drawings the output shaft of the motor and the clapper body may be replaced by any suitable other type of pivot means, such as a pivot having a single pivot axis or a flexible conduit section.

Once the principle of the present invention is understood various other modifications will also become apparent to those skilled in the art. Accordingly it is to be clearly understood that the apparatus and method hereinbefore depicted and described with reference to the accompanying drawings are illustrative only.

Claims

1. Borehole underreamer device, the device comprising a downhole motor having a rotor part which can be rotated relative to a stator part, the rotor part carrying pivot means, said pivot means carrying a clapper body in which a series of abrasive teeth are embedded, said pivot means allowing the clapper body to describe in use an orbital motion inside the borehole, thereby inducing the abrasive teeth to penetrate into the surrounding borehole wall.

2. The underreamer device of claim 1, wherein the motor is a hydraulically driven motor and comprises a motor housing which forms the stator part of the motor and which is suitable to be connected to the lower end of a pipe string through which a driving fluid can be injected into the motor, the motor further comprising a rotor part comprising a hydraulically driven rotor and an output shaft protruding from the lower end of the motor and being connected at the upper end thereof to said rotor and at the lower end thereof to said pivot means carrying the clapper body.

3. The underreamer device of claim 2, wherein the motor is of the Moineau type.

4. The underreamer device of claim 2, wherein the clapper body comprises a tubular section which is connected via said pivot means to said output shaft and a frustoconical section in which said abrasive teeth are embedded, said frustoconical section having an outer diameter which increases in a direction away from said universal joint, the clapper body further comprising a nose section located at the lower end of the frustoconical section.

5. The underreamer device of claim 4, wherein said output shaft and clapper body comprise a fluid passage via which driving fluid can flow from the motor housing into a series of fluid nozzles which are arranged in the frustoconical section of the clapper body.

6. The underreamer device of claim 2, wherein the motor housing comprises expandable stabilizer means for centralizing the motor housing inside the borehole, which stabilizer means can be adjusted to various borehole widths.

7. The underreamer device of claim 6, wherein the expandable stabilizer means comprise a series of stabilizer blades which are pivotably connected to the motor housing at a location near the lower end thereof and which have each a lower part having a thickness which increases in downward direction, said lower parts cooperating with an annular piston which can be pushed out of the housing by fluid pressure of the driving fluid thereby moving the stabilizer blades towards an expanded position thereof.

8. The underreamer device of claim 4, wherein said fluid passage in the output shaft and clapper body comprises flow restriction means which impose an increasing flow restriction to the fluid flow through said passage in response to an increasing tilt angle of the clapper body relative to the output shaft.

9. The method of claim 1, wherein the pivot means consists of a universal joint.

10. A method of underreaming a borehole, the method comprising

- lowering into a borehole a borehole

underreamer device comprising a downhole motor having a rotor part which carries by means of pivot means a clapper body in which a series of abrasive teeth are embedded, and

- pulling the underreamer device in upward direction through the borehole while rotating said rotor part relative to a stator part of the motor, thereby inducing the clapper body to describe an orbital motion inside the borehole and causing the teeth to penetrate into the boreholewall.

11. The method of claim 10, wherein the motor is a hydraulic motor driven by a driving fluid which is pumped through a pipe string carrying at the lower end thereof said stator part of the motor and wherein the speed of pulling the underreamer device is adjusted in response to variations in the fluid pressure of the driving fluid.

12. The method of claim 10 wherein the steps of lowering the underreamer device into the borehole and underreaming the borehole while pulling the device in upward direction therethrough are repeatedly carried out until the hole has been underreamed to a desired diameter.

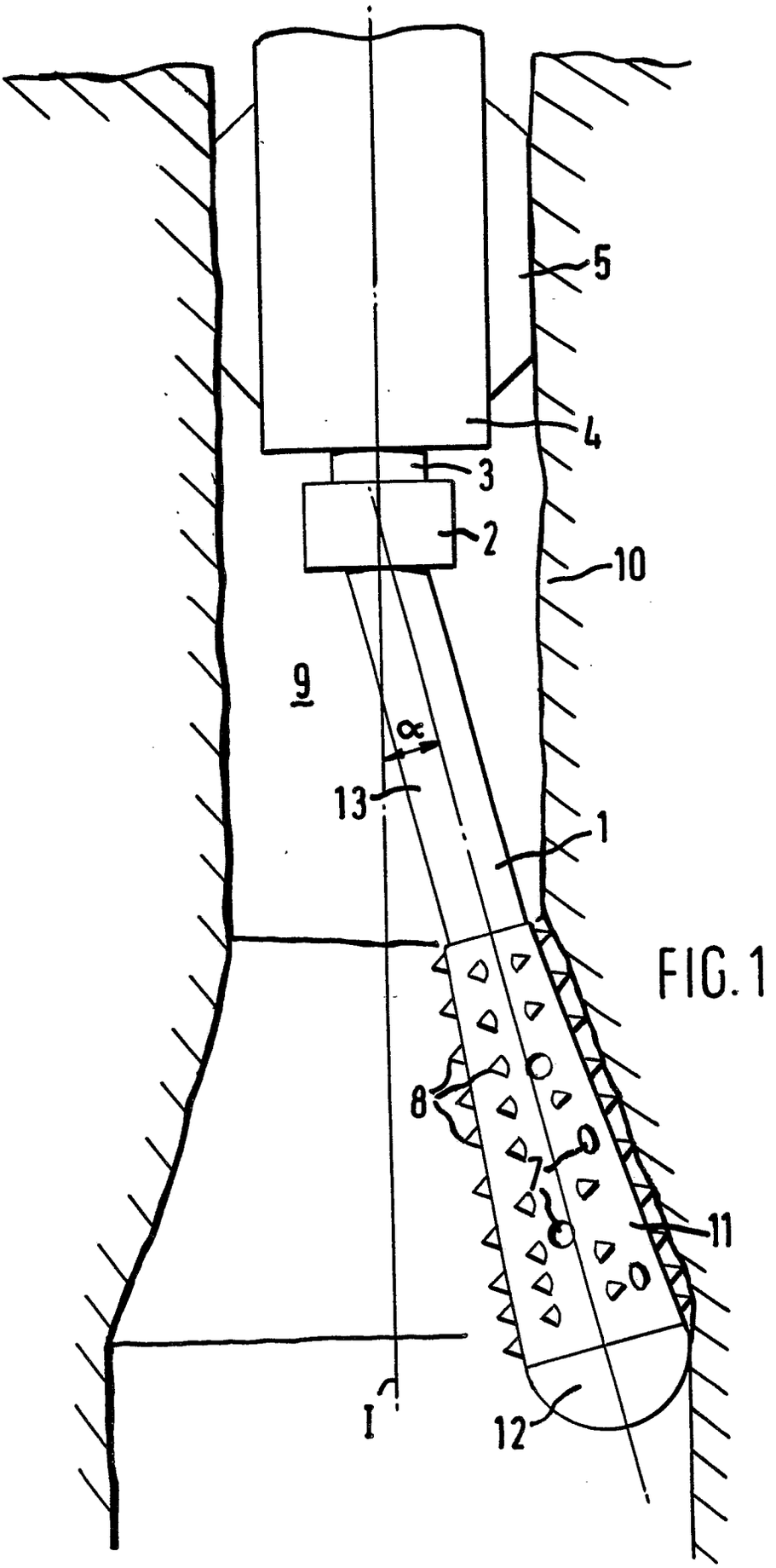

FIG.1

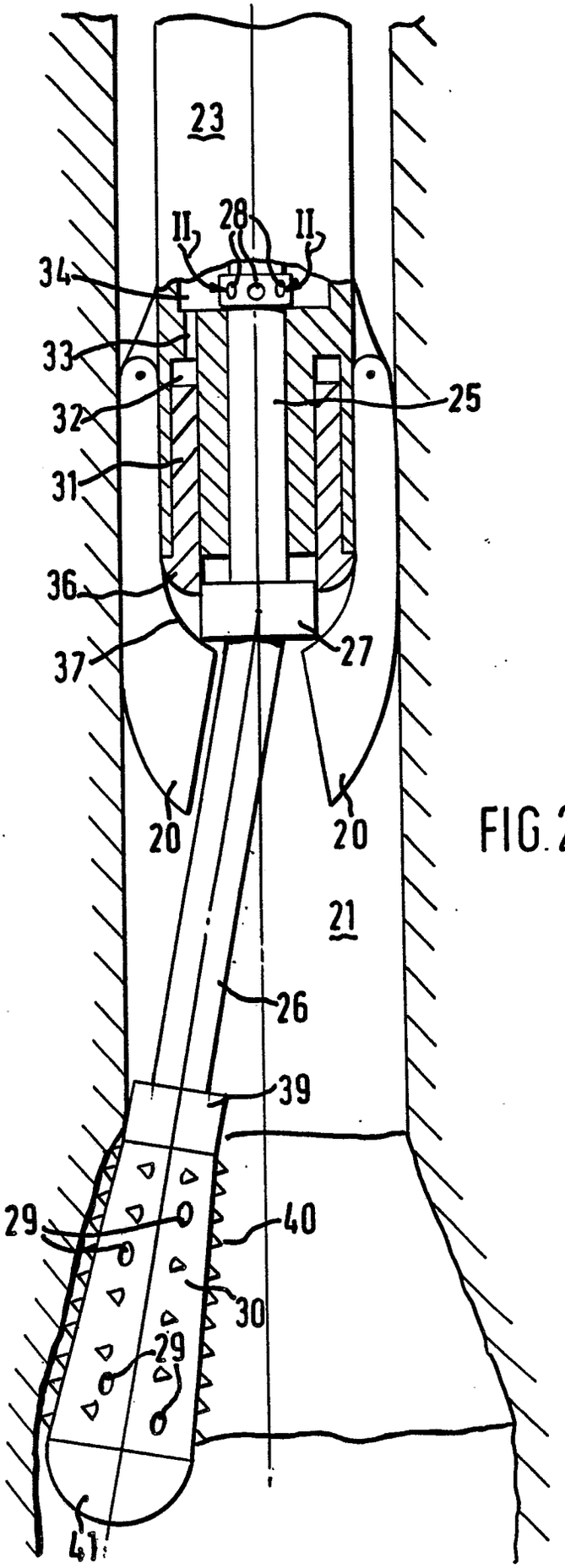

FIG.2

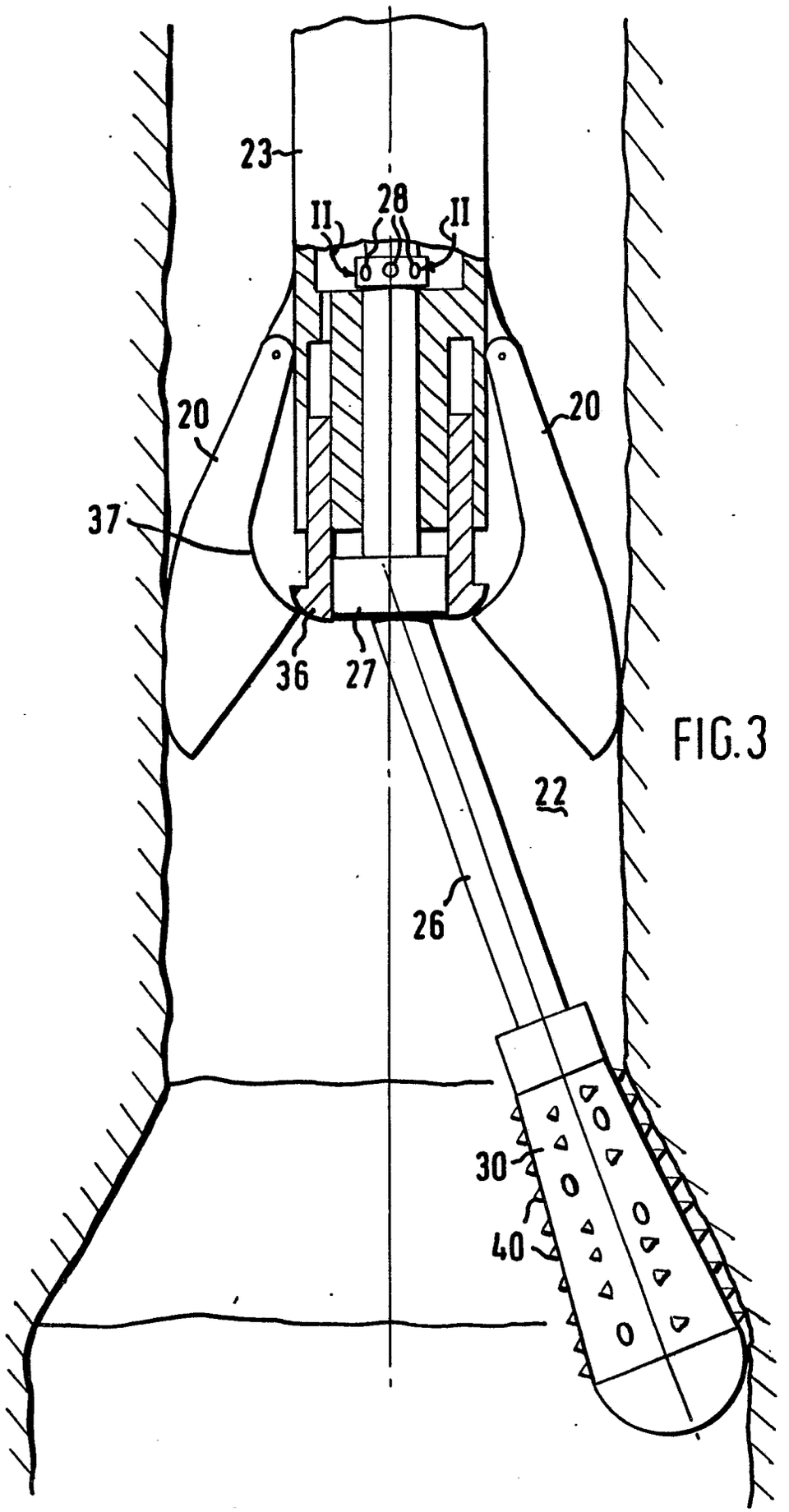

FIG.3