

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
13 February 2003 (13.02.2003)

PCT

(10) International Publication Number
WO 03/012242 A1

(51) International Patent Classification⁷: **E21B 4/02**

23 East Glebe, Stonehaven, Aberdeen AB3 2HW (GB).
GILLIES, Ian, Alexander [GB/GB]; 48 Mountskip Road,
Brechin, Angus DD9 6BY (GB).

(21) International Application Number: PCT/GB02/03483

(22) International Filing Date: 30 July 2002 (30.07.2002)

(74) Agents: **GOODENOUGH, Nigel**, et al.; A.A. Thomson &
Co., 235 High Holborn, London WC1V 7LE (GB).

(25) Filing Language: English

(26) Publication Language: English

(81) Designated States (*national*): CA, NO, US.

(30) Priority Data:
0118521.4 30 July 2001 (30.07.2001) GB
0124349.2 10 October 2001 (10.10.2001) GB

(84) Designated States (*regional*): European patent (AT, BE,
BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT,
LU, MC, NL, PT, SE, SK, TR).

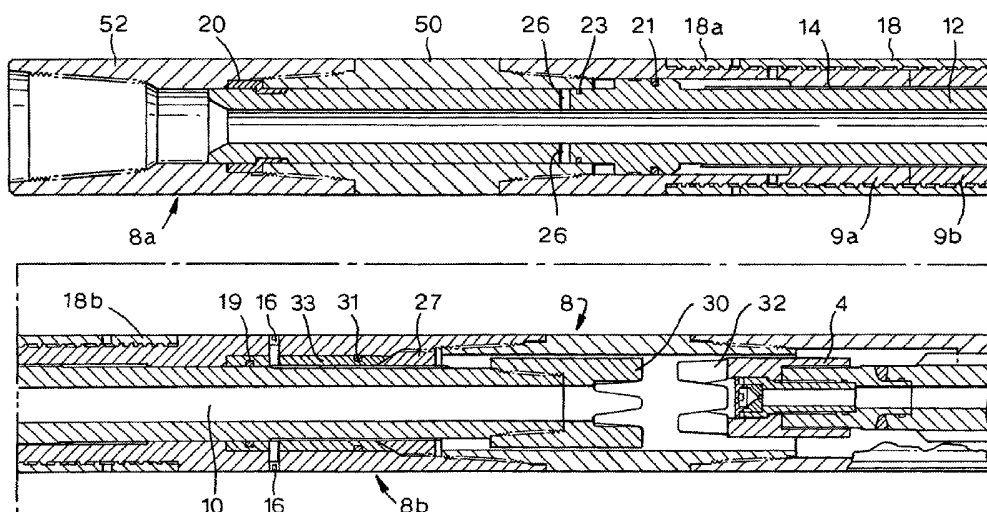
(71) Applicant (*for all designated States except US*): **SMITH
INTERNATIONAL, INC.** [US/US]; 16740 Hardy Street,
Houston, TX 77205-0068 (US).

Published:
— with international search report

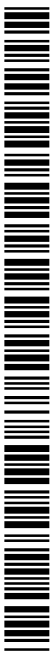
(71) Applicants and
(72) Inventors (*for US only*): **MCGARIAN, Bruce** [GB/GB];

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: DOWNHOLE MOTOR LOCK-UP TOOL



(57) Abstract: The present invention relates to downhole apparatus for limiting rotation of a rotor (4) relative to a stator (8) associated with said rotor (4). Apparatus according to the invention is provided with a locking member (12) movable from a first axial position to a second axial position by the application of a static fluid pressure to a differential area of said locking member (12). The apparatus is characterised by means for selectively applying static fluid pressure to said differential area of said locking member (12).



WO 03/012242 A1

- 1 -

DOWNHOLE MOTOR LOCK-UP TOOL

The present invention relates to downhole apparatus and particularly, but not exclusively, to downhole apparatus for use in releasing a stuck drill bit.

It is not uncommon for a drill bit to become stuck in hole during downhole oil and gas drilling operations. In order to allow retrieval of a downhole drill string when a drill bit becomes stuck, it is known to provide a drill string with an emergency release joint immediately uphole of the drill bit. During normal operation, the release joint transmits torque from a motor or string (from surface) to the drill bit. However, in the event that the drill bit becomes stuck to the extent that axial and rotational movement of the drill bit is not possible, the drill bit may be separated from the remainder of the drill string by virtue of the release joint. The remainder of the drill string may then be moved axially uphole so that specialist retrieving equipment may be run to the drill bit in a fishing operation.

Although the prior art release joints are effective in providing a system for releasing the drill bit from a wellbore, the steps of retrieving the drill string and subsequently running a fishing string is time consuming and expensive.

It is an object of the present invention to provide apparatus allowing a stuck drill bit to be conveniently, rapidly and inexpensively released from a wellbore.

Concept possibilities

1. Sprag-clutch in the motor output-shaft bearing assembly

(A) Advantages

A1) A sprag clutch assembly mounted at the lower end of the output shaft will give the strongest torque transmission design as the torque will be transmitted down through the motor casing threads, then through the bearing casing to the sprag assembly and then directly onto the motor output shaft bit box. This results in the torque not being limited by the torsional strength of the rotor end connection, universal joint (or flexible shaft) or end connections, or the output shaft/shaft coupling strength which will be much weaker than the casing threaded connections. It should

- 2 -

be feasible to design an assembly with a large number of long sprags to transmit high torque level required.

B) Disadvantages

B1) The sprag clutch should preferably be run in a sealed bearing assembly in an oil reservoir as the sprag would wear along with the shaft surface unless hard-faced with tungsten carbide or something similar.

B2) The sprag clutch may inadvertently jam if not run in an oil-reservoir sealed bearing assembly.

B3) The motor shaft bearing assembly would probably have to be re-designed to lengthen it to allow the incorporation of the sprag clutch assembly and there are still many motors without a sealed bearing assembly. No Drilex motors have sealed bearing shaft assemblies, although 6¼" and 3¼" assemblies were tested with only 50% success 13 and 9 years ago respectively. However, all National Oilwell motors (Trudrills and Vector models) have sealed bearing shaft assemblies. Most Canadian motor companies appear to have gone in the direction of sealed assemblies.

2. Burst disc in the universal assembly housing

A) Advantages

A1) The burst disc could be sized to rupture just below the pump pop-off valve pressure setting so that when the bit gets stuck and possibly the bit ports get blocked and stop flow, then the motor power section will not be able to have the mud passing through it and so the rotor/stator will not be able to produce the torque needed to free the bit. The pressure will build up rapidly even with a mud lubricated bearing assembly so that even with mud flowing down the bearing assembly, if this passage is not blocked at the bottom end, the pressure build-up would be quick resulting in the rupture of the burst disc. There will then be a flow path for the mud flow and hence an opportunity to re-establish a dynamic pressure drop across the power section and hence torque output to the bit.

B) Disadvantages

- 3 -

B1) The only disadvantage is that the disc could rupture when not required when drilling ahead and there would be no loss of power to the power section but there would be across the bit and hence an increased change of a drop in RPO due to inadequate cutter cleaning. The likelihood of this happening should be fairly small assuming also the disc is sealed correctly to prevent leakage.

3. Motor lock-up tool mounted in the motor universal housing assembly-lower end

A) Advantages

A1) A pull activated lock-up tool within a motor must be located within the rotor/stator or within the universal/flexible shaft assembly as the inners must have axial travel with respect to the outers, and within the motor bearing assembly the axial travel is not possible or at least only the play in the bearing pack is available and this is usually only 0 to 1/4" maximum, even on a worn assembly. It may be feasible to have a shear pinned slip joint as on a mechanical disconnect and after a given travel of 6-8" to have a female spline built into the outer universal housing, travel over a male spline on the motor output shaft coupling. This placement would be preferable with respect to the top end of the rotor which could result in a failure at the universal/flexible shafts or at the connections or taper drives at either end. Taper drives work well in a motor to transmit torque but are always accompanied by high rotor downthrust.

B) Disadvantages

B1) There is not much room in the area outside the output shaft coupling to install this type of design to produce a strong assembly.

4. Motor lock-up tool mounted at the top of the rotor

A) Advantages

A1) Easier to design compared to the installation of a unit over the shaft coupling and would perhaps be easier to install than a sprag clutch as most motors will have to have the shaft assembly redesigned i.e. lengthened to accommodate a sprag clutch. For this design, as with all options discussed here, the rotor should be solid or have a blank

nozzle fitted to attain maximum torque output with maximum flow rate so that there is more chance to free the bit if it gets stuck without the need for having to activate the lock-up tool.

B) Disadvantages

Weakest option from a torque transmission point of view as the rotor/universal/output shaft coupling and inter-connections would see all the transmitted string torque without hydraulic downthrust which could lead to taper drives turning also in motors which have this type of connection rather than threaded connections at either end of the universal. All Driflex motors used to have two or four 1:10 or 1:20 taper drives.

5. Fitting of a splined ring over the motor bit box

The fitting of an externally splined and internally splined ring in the lower housing of a motor may be feasible so that with some form of activation the ring travels down to engage over a male spline machined on the motor bit box. The means to activate the movement of this ring however may not be feasible as hydraulic communication is limited, as is the use of applying weight to activate its movement. If a design was feasible then this would perhaps be stronger than a sprag clutch design but the presence of cuttings may not allow the ring to move or engage fully. The same could be said if the bit got stuck by the hole collapsing.

The present invention provides downhole apparatus for limiting rotation of a rotor relative to a stator associated with the said rotor, the downhole apparatus comprising a body within a bore of which a locking member is located so as to be movable between a first axial position relative to the body, in which the locking member is disengaged from a rotor so as to allow rotation of said rotor relative to said locking member, and a second axial position relative to the body, in which the locking member is engaged with said rotor so as to limit rotation of said rotor relative to said locking member, the apparatus further comprising means for limiting rotational movement of the locking member relative to the body when said locking member is located in said second axial position, wherein said locking member is movable from said first axial position to said second axial position by the application of a static fluid

pressure to a differential area of said locking member, the apparatus being characterised by means for selectively applying static fluid pressure to said differential area of said locking member.

A further aspect of the present invention provides downhole apparatus for limiting rotation of a rotor relative to a stator associated with the said rotor, the downhole apparatus comprising a body within a bore of which a locking member is located so as to be movable between a first axial position relative to the body, in which the locking member is disengaged from a rotor so as to allow rotation of said rotor relative to said locking member, and a second axial position relative to the body, in which the locking member is engaged with said rotor so as to limit rotation of said rotor relative to said locking member, the apparatus further comprising means for limiting rotational movement of the locking member relative to the body when said locking member is located in said second axial position, wherein said locking member is selectively retained in the first axial position by retaining means.

Thus, the body of downhole apparatus according to the present invention may be secured to the stator of a motor so that, in use, torque transmitted from the motor to a drill bit may be reacted to the surface via the apparatus body. In the event that the drill bit becomes stuck in hole and the torque generated by the motor is insufficient to effect release, the selective retaining means may be activated so as to allow movement of the locking member from the first axial position into the second axial position wherein rotation of the locking member relative to both the rotor and the body is limited. In this way, the rotor is secured to the apparatus body in such a manner as to allow torque applied to the body at the surface to be transmitted to the rotor. In this way, rotational force over and above that generated by the motor itself can be applied to the drill bit in an attempt to release the bit from the well bore.

Embodiments of the present invention are shown in the accompanying drawings, in which:

Figure 1 shows a cross-sectional side view of an embodiment of the present invention wherein the locking member is arranged in a first axial position;

Figure 2 is a cross-sectional side view of the embodiment of Figure 1 wherein the locking member is arranged in an intermediate axial position;

Figure 3 is a cross-sectional side view of the embodiment wherein the locking member is arranged in a second axial position;

Figure 4 is a cross-sectional side view of a second embodiment;

Figure 5 is a cross-sectional side view of a third embodiment;

Figure 6 is a cross-sectional side view of a fourth embodiment wherein the locking member is arranged in a first axial position;

Figure 7 is an end view and a cross-sectional side view of a coupling of the fourth embodiment;

Figure 8 is a cross-sectional side view of the fourth embodiment wherein the locking member is arranged in an intermediate axial position; and

Figure 9 is a cross-sectional side view of the fourth embodiment wherein the locking member is arranged in a second axial position.

The accompanying drawings illustrate downhole apparatus 2 for limiting rotation of a rotor 4 relative to a stator 6 associated with said rotor 4.

The downhole apparatus 2 further comprises a body 8 within a bore 10 of which a locking member 12 is located so as to be movable between a first axial position (see Figure 1) and a second axial position (see Figure 3). In the first axial position relative to the body 8, the locking member 12 is disengaged from the rotor 4 so as to allow rotation of said rotor 4 relative to said locking member 12. In the second axial position relative to the body 8, the locking member 12 is engaged with the rotor 4 so as to limit rotation of said rotor 4 relative to said locking member 12. The apparatus 2 comprises means for limiting rotational movement of the locking member 12 relative to the body 8 when said locking member 12 is located in said second axial position. This limiting means comprises interlocking axially extending splines 14 defined on the body 8 and the locking member 12. Retaining means 16 is also provided for selectively retaining the locking member 12 in the first axial position. This retaining means comprises a shear pin secured to the body 8 and extending into an annular groove 17 defined in an outer surface of the locking member 12. Three O-ring seals 19,21,23 and a glyd ring 25 are located between the body 8 and the locking member 12.

The body 8 of the apparatus 2 comprises two portions 8a, 8b which are retained together by means of a loose fitting threaded coupling 18. The coupling 18

- 7 -

allows the two body portions 8a, 8b to move axially apart from one another into the intermediate configuration shown in Figure 2. In moving to said intermediate configuration, a shear ring 20 attaching the first body portion 8a to the locking member 12 fractures. In order to move the apparatus 2 into the intermediate configuration, the first body portion 8a is pulled uphole with sufficient force to fracture the shear ring and thereby separate the two body portions 8a, 8b. In moving to the intermediate position, the first body portion 8a defines an annular fluid chamber 22 with the locking member 12. Hydraulic lock in creating the chamber 22 is prevented by means of a one way vacuum release valve 24 located in the wall of the first body portion 8a. In the intermediate configuration, hydraulic transfer ports 26 defined in the locking member 12 provide fluid communication between a bore 28 extending through the locking member 12 with the chamber 22.

A locking ring 27 is retained between the locking member 12 and the second body portion 8b by means of a circlip 29. Ratchet teeth on the locking ring 27 engage ratchet teeth on the locking member 12. The arrangement is such as to permit movement of the locking member 12 towards the rotor 4 whilst opposing movement in the opposite direction.

It will be understood from reference to Figure 2 that, when in the intermediate configuration, the locking member 12 remains spaced from the rotor 4. In order to engage the locking member 12 with the rotor 4, fluid pressure within the bore 28 of the locking member 12 is increased. Dynamic pressure caused by a fluid flow through the apparatus 2 will allow a force to be generated which presses the locking member 12 towards the rotor 4. Also, the geometry of the locking member 12 is such that a differential in area of locking member 12 exposed to wellbore fluid exists. This area differential is generated by virtue of the annular chamber 22. Thus, once the apparatus is in the intermediate configuration, static pressure within the bore 28 tends to press the locking member 12 into engagement with the rotor 4.

Once the biasing force applied to the locking member 12 is sufficient to overcome the retaining force of the shear pin 16, the shear pin 16 shears and the locking member 12 moves downhole into engagement with the rotor 4. The locking member 12 and rotor 4 are provided with interlocking teeth members 30,32 respectively which, when engaged with one another, prevent relative rotation between

- 8 -

the locking member 12 and the rotor 4. Relative rotation between the body 8 and the rotor 4 is thereby prevented.

The present invention is not limited to the specific embodiment described above. Alternative arrangements will be apparent to the reader skilled in the art. Two further embodiments are shown in Figures 4 and 5 of the accompanying drawings. These two embodiments are similar to the embodiment of Figures 1 to 3 but comprise a number of modifications as described below. Corresponding parts of the embodiments are identified with like reference numerals.

In the further two embodiments the two shoulders at either end of the outer casing 18,18a,18b are pre-loaded by the applied make-up torque through added threaded portions 18a,18b at each end which do not have one of the thread starts removed. Also, the shear ring mounted at the top of the central (locking) shaft 12 on the first embodiment is replaced by shear pins 16 at the lower end of the shaft.

The central shaft 12 has three diametrical seals 19,21,23 working on it. The first two 21,23 are at the top (left-hand) end while the third is at the lower (right-hand) end. The uppermost seal, plus the one at the bottom, act on the same effective diameter. The third seal is sealing on a larger diameter. The purpose of the two smaller seals acting on the same diameter is to ensure that the shaft does not have a load acting on it (up or down) with internal pressure until the assembly has been activated by an axial pull. The shaft has a castellated adapter screwed onto it which has a profile facing downwards to mate with a special castellated adapter attached to the top end of a downhole motor rotor. The castellations 30,32 are designed to mesh when the tool has been activated and thereby torsionally lock the rotor with respect to the outer casings so that torque from surface (or at least from above the assembly) can be applied down through the rotor to the stuck bit. The central shaft 12 is held in the assembled position by both shear pins 16 and a serrated split collar 27 below the shear pins.

The outer casings 18,18a,18b in the middle of each tool are designed with a unique design of threaded joint. As shown in Figures 4 and 5, the thread is a two-start thread which has been machined as a female box style thread from end to end on the outer casing. The inner section 18 approx. 3-4" from each end (i.e. between the illustrated undercuts) has one of the threads removed thereafter by

machining. The pins 9a,9b of the casings 18a,18b either side of the central casing 18, which are linked by the central casing 18, also have one of the thread starts removed. The upper and lower pins 9a,9b are held together by the outer casing 18m18am18b screw threads at either end of the outer casing. The connections are torqued up right hand conventionally and so, with left hand torque from the motor stator, the right hand threads will tighten when the motor is working and so will not unscrew. The threads removed from the pins 9a,9b and box between the outer casing undercuts allow axial travel between the top and bottom of the tool when an overpull is applied (which overpull is at least equal to the load required to shear the outer casing in the area of the undercuts). The 4 3/4" version of the tool shown in Figures 4 and 5 is designed to shear at 80,000 lbs pull. The bending stiffness of the assembly is enhanced in the assembly of Figure 5 by the overlap of the two threaded pins 9a,9b by the spigot engagement in the wall section between the internal splines 14 and the external two start thread.

The axial pull will also result in the tool stroking open by the total available movement from the removal of the threads in the central area of the outer casing 18,18a,18b. When this happens, the uppermost seal 23 will be removed from the bore of the top sub 8a. When internal hydraulic pressure is applied as the rig pumps are turned on and the pressure between the inside and outside of the tool reaches a certain level, the shear pins 16 will shear and the central shaft 12 will be moved downwards. When the shaft moves down the castellations 30,32 of the two adapters will engage and torque can then be applied directly down the centre of the internal motor drive assembly from the surface via the splines 14 meshing the internal centre shaft and the external casings. The centre shaft 12 cannot move back up due to the serrations on the split collar 27 locating around the centre shaft at the lower end. The circlip 29 in the lowermost casing bore acts as a stop shoulder to prevent the split stop collar 27 moving down.

It is to be noted that the area around the splines and the double start threads are at the external lower pressure and hence the sealing of the inside of the tool is completed by the seal 31 on the outside of the sleeve 33 through which the shear pins are located. 10 of the centre shaft and through the castellated adapter screwed onto the centre shaft. The castellations may or may not be designed to seal

off the flow to the outside of the adapters when the two sets mesh together. If they are designed to seal off the flow into the rotor-stator profile, it would be beneficial to have a nozzle fitted in the top of the rotor so that a flow path is available down the centre of the rotor and then either simply down to the bit as in a conventional motor or out through a nozzle fitted in the universal housing of the motor. A nozzle fitted in the side of the motor would be beneficial in some circumstances as circulation would still be possible if the formation collapsed around the bit and blocked off the flow path around the outside of the bit.

A yet further embodiment of the present invention is shown in Figures 6 to 9 of the accompanying drawings. This further embodiment is again similar to the embodiment of Figures 1 to 3 and corresponding parts are identified with like reference numerals. The further embodiment principally differs from the first embodiment in that the single shear pin of the first embodiment is placed with a pair of shear pins 16 which pass through a sleeve 33 as in the second and third embodiments of Figures 4 and 5. Also, as described in relation to the second and third embodiments, the third embodiment shown in Figures 6 to 9 comprises a seal 31 provided on the outside of the sleeve 33. The further embodiment also retains the shear ring 20 and the hydraulic transfer ports 26. The further embodiment also differs from the first embodiment in that the threaded coupling is provided in three discrete portions. A central portion 18 (as shown in Figure 7) spans the first and second body portions 8a,8b. The second portion 18a of the coupling is screw threaded to the first body portion 8a whilst the third coupling portion 18b is screw threaded to the second body portion 8b. As for the previous embodiments, the coupling engages a two-start thread on the body 8 wherein one of the threads is removed. Similarly, the central portion 18 of the coupling has a two-start thread wherein one thread is removed. However, the remaining coupling portions 18a,18b have an unmodified two-start thread which allows said portions to be locked against respective shoulders of the first and second body portions 8a,8b. The ends of the second and third coupling portions 18a,18b distal to said respective shoulders are provided with castellations for engagement with castellations provided on the ends of the central coupling portion 18. With the castellations of the three portions 18,18a,18b engaged with one another, a torque may be transmitted through the coupling and the arrangement assists in

- 11 -

assembly of the tool. In other respects, and in operation, the tool is the same as described in relation to the first embodiment. Indeed, Figures 8 and 9 show the locking member 12 of the further embodiment in intermediate and second axial positions respectively. It will be seen from each of these Figures that the castellations of the coupling allow the three coupling portions to move axially away from one another.

The fourth embodiment shown in Figures 6 to 9 is assembled under the following procedure:

Step 1 - make up second coupling portion 18a (upper lock ring) to first body portion 8a (upper body).

Step 2 - make up third coupling portion 18b (lower lock ring) to second body portion 8b (lower body) and assemble seal sleeve 33 complete with seals. Hold in position with a slave screw (not shown).

Step 3 - thread first and second body portions 8a,8b to central coupling portion 18 while maintaining sufficient axial tension force to ensure maximum separation of the body pins 9a,9b. When made up, the castellations of the coupling portions 18,18a,18b will be aligned. Compress the sub-assembly axially so as to engage castellations.

Step 4 - hold body assembly in torque unit and apply sufficient torque to align internal splines 14. Do not exceed make up torque.

Step 5 - slide over cross-over sub 50 of first body portion 8a onto the locking member 12 (complete with seals).

Step 6 - slide locking member 12 through the body assembly to engage fully with aligned internal splines 14. Make up cross-over sub 50 to first body portion pin 9a (hand tight).

Step 7 - insert shear ring segments 20 and push locking member 12 down to locate fully. In order to displace trapped air, slightly back off the cross-over sub 50.

Step 8 - make up top sub 52 of the first body portion 8a and tighten to recommended make up torque.

Step 9 - assemble shear pins 16 and associated plugs.

Step 10 - assemble locking ring 27 and, with specialist tool, make up to recommended torque.

- 12 -

Step 11 - connect castellated adapter to locking member 12 and, with specialist tool, make up to recommended torque.

Step 12 - assemble bottom sub and make up to recommended torque.

In assembling any of the embodiments described herein, it will be appreciated that the locking ring 27 is ideally made up to a torque sufficient to place the two body portions 8a,8b in abutment with one another and under compression. Although the first embodiment (see Figure 1) is provided with a gap between said portions 8a,8b of the body, it is preferable for these portions to abut one another as in the second, third and fourth embodiments. In this way, the tool may be placed in compression so as to provide rigidity.

Yet further alternative arrangements will be apparent to the reader skilled in the art.

CLAIMS:

1. Downhole apparatus for limiting rotation of a rotor relative to a stator associated with the said rotor, the downhole apparatus comprising a body within a bore of which a locking member is located so as to be movable between a first axial position relative to the body, in which the locking member is disengaged from a rotor so as to allow rotation of said rotor relative to said locking member, and a second axial position relative to the body, in which the locking member is engaged with said rotor so as to limit rotation of said rotor relative to said locking member, the apparatus further comprising means for limiting rotational movement of the locking member relative to the body when said locking member is located in said second axial position, wherein said locking member is movable from said first axial position to said second axial position by the application of a static fluid pressure to a differential area of said locking member, the apparatus being characterised by means for selectively applying static fluid pressure to said differential area of said locking member.
2. Downhole apparatus as claimed in claim 1, wherein said selective means for applying static fluid pressure comprises means for permitting intermediate movement of said locking member from said first axial position to an intermediate position relative to the body wherein the area of locking member exposed to said static fluid pressure is different to that exposed to said static fluid pressure when said locking member is located in said first axial position.
3. Downhole apparatus as claimed in claim 2, wherein said body comprises two portions movable relative to one another so as to permit said intermediate movement of said locking member relative to one of said body portions.
4. Downhole apparatus as claimed in claim 3, wherein said body portions are axially movable relative to one another.
5. Downhole apparatus as claimed in claim 3 or 4, wherein said locking member is selectively retained in said first axial position relative to said one body portion by frangible means.

6. Downhole apparatus as claimed in any of claims 3 to 5, wherein said locking member is selectively retained in said first axial position and said intermediate position relative to the other one of said body portions.
7. Downhole apparatus as claimed in any of claims 3 to 6, wherein said two body portions are screw threadedly connected to one another.
8. Downhole apparatus as claimed in claim 7, wherein the screw threaded connection between said two body portions is sufficiently loose to permit said relative intermediate movement between said locking member and said one body portion.
9. Downhole apparatus as claimed in claim 8, wherein said screw threaded connection comprises a two-start thread with one of the two threads thereof removed.
10. Downhole apparatus as claimed in claim 9, wherein said screw threaded connection comprises a thread collar spanning said two body portions.

Fig.1.

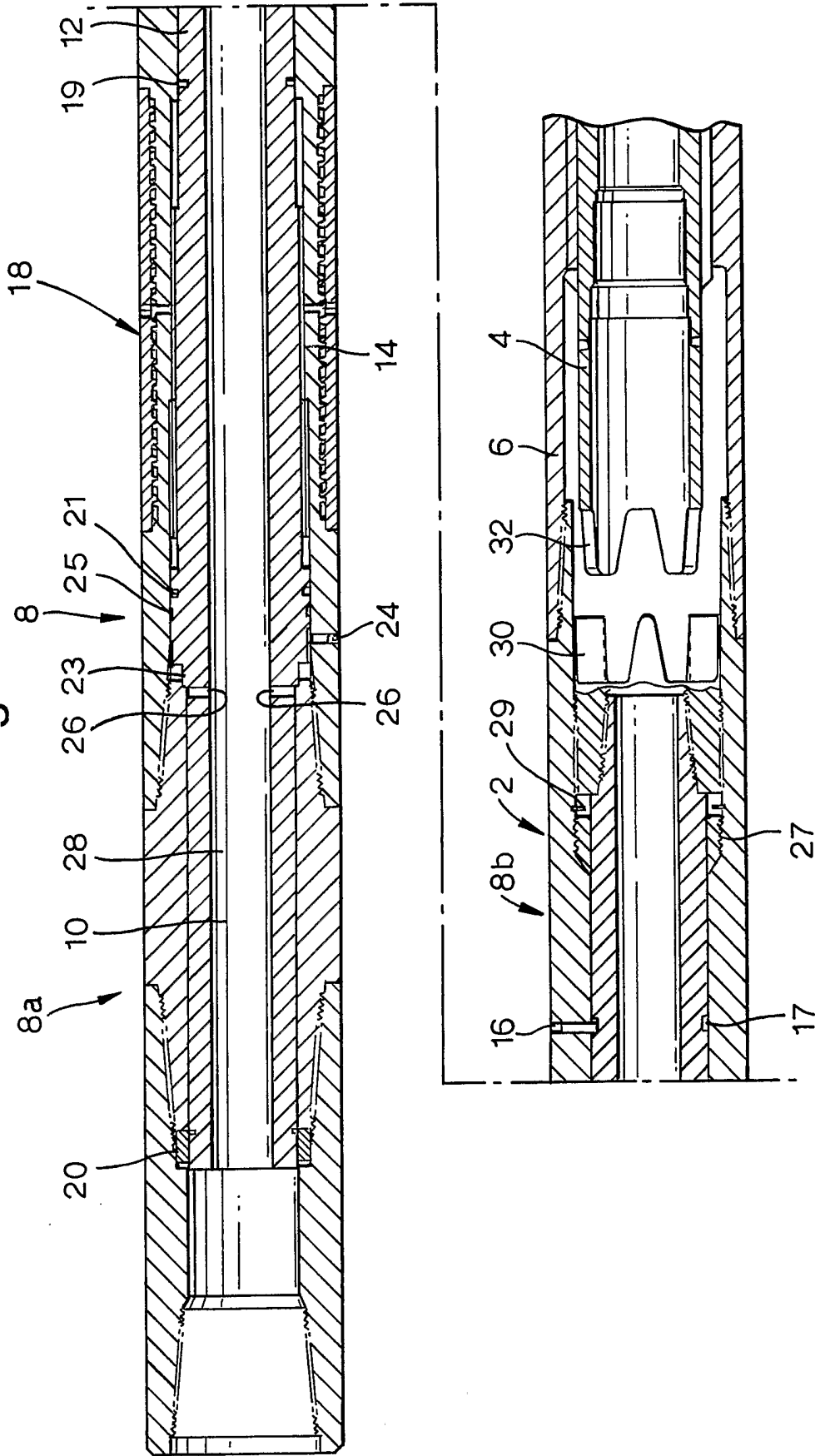


Fig.2.

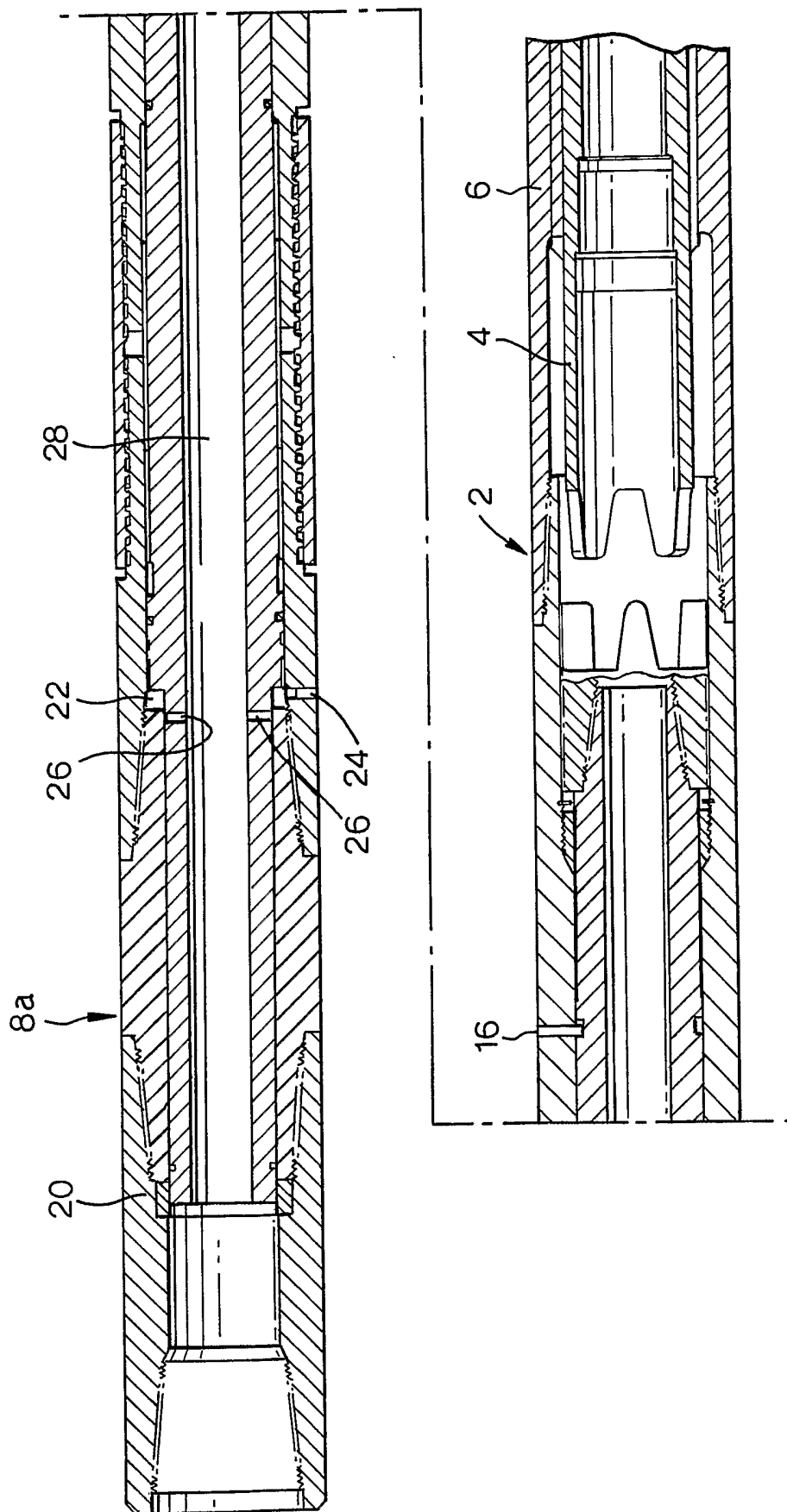


Fig.3.

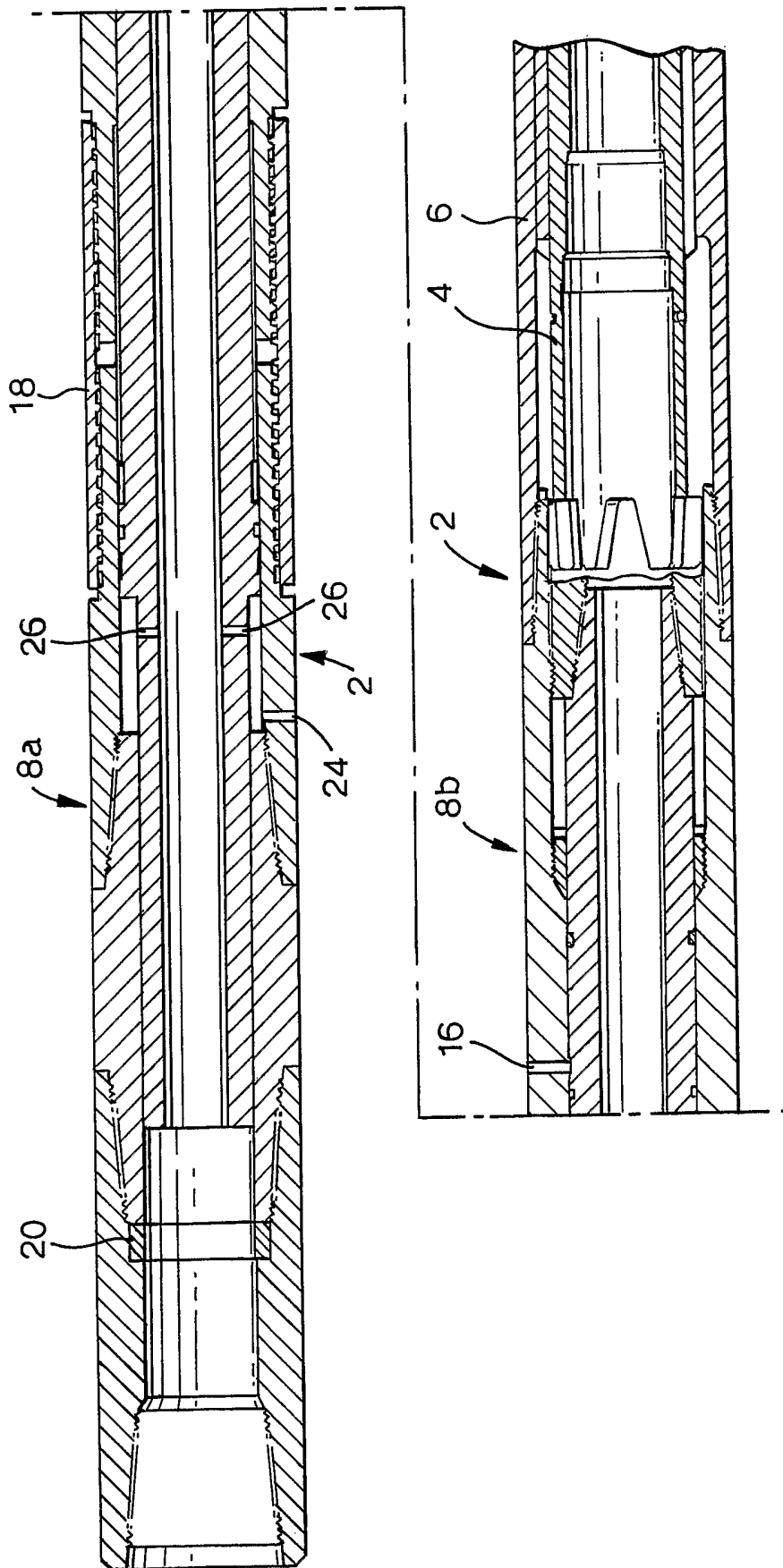


Fig.4.

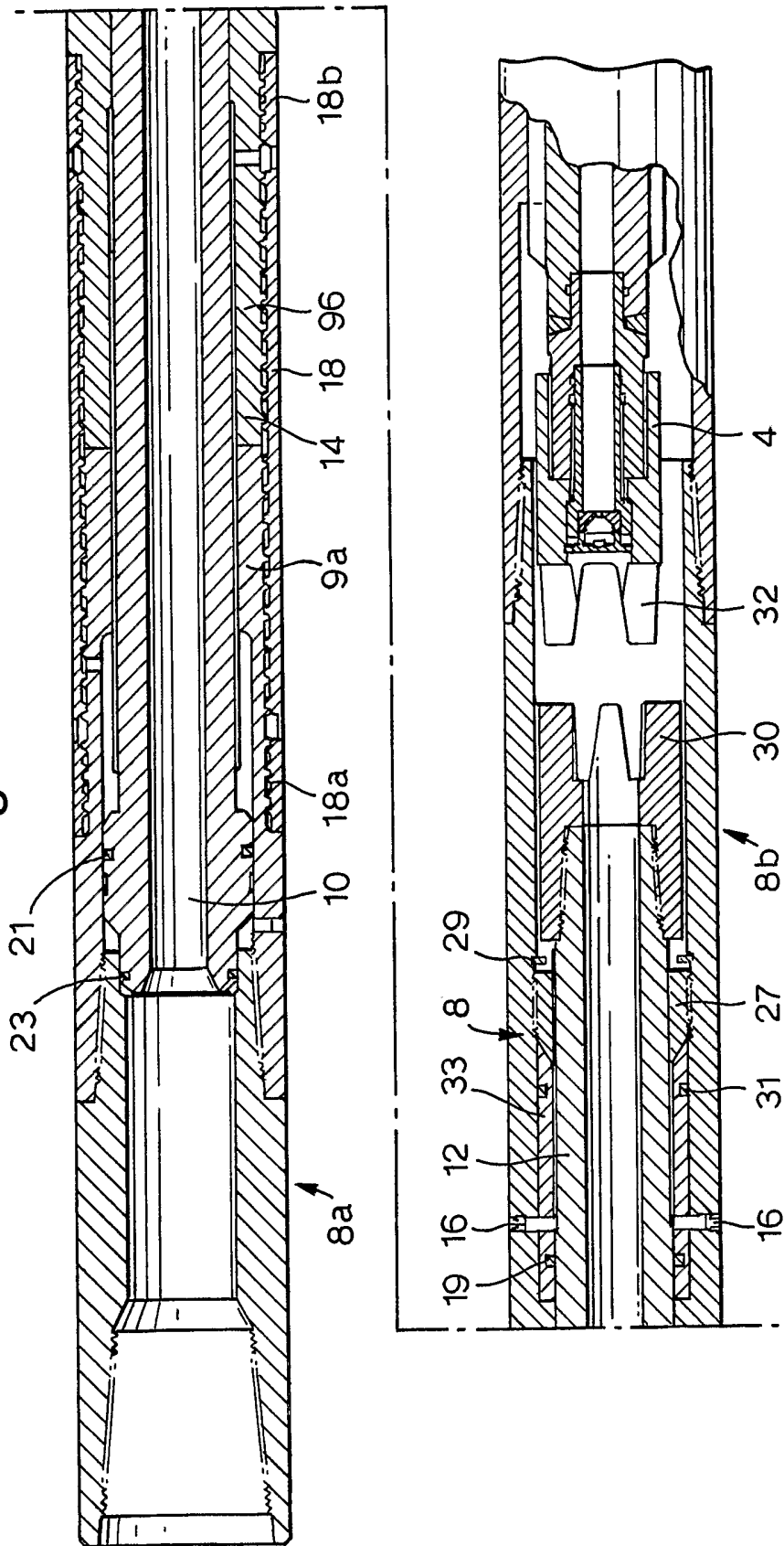
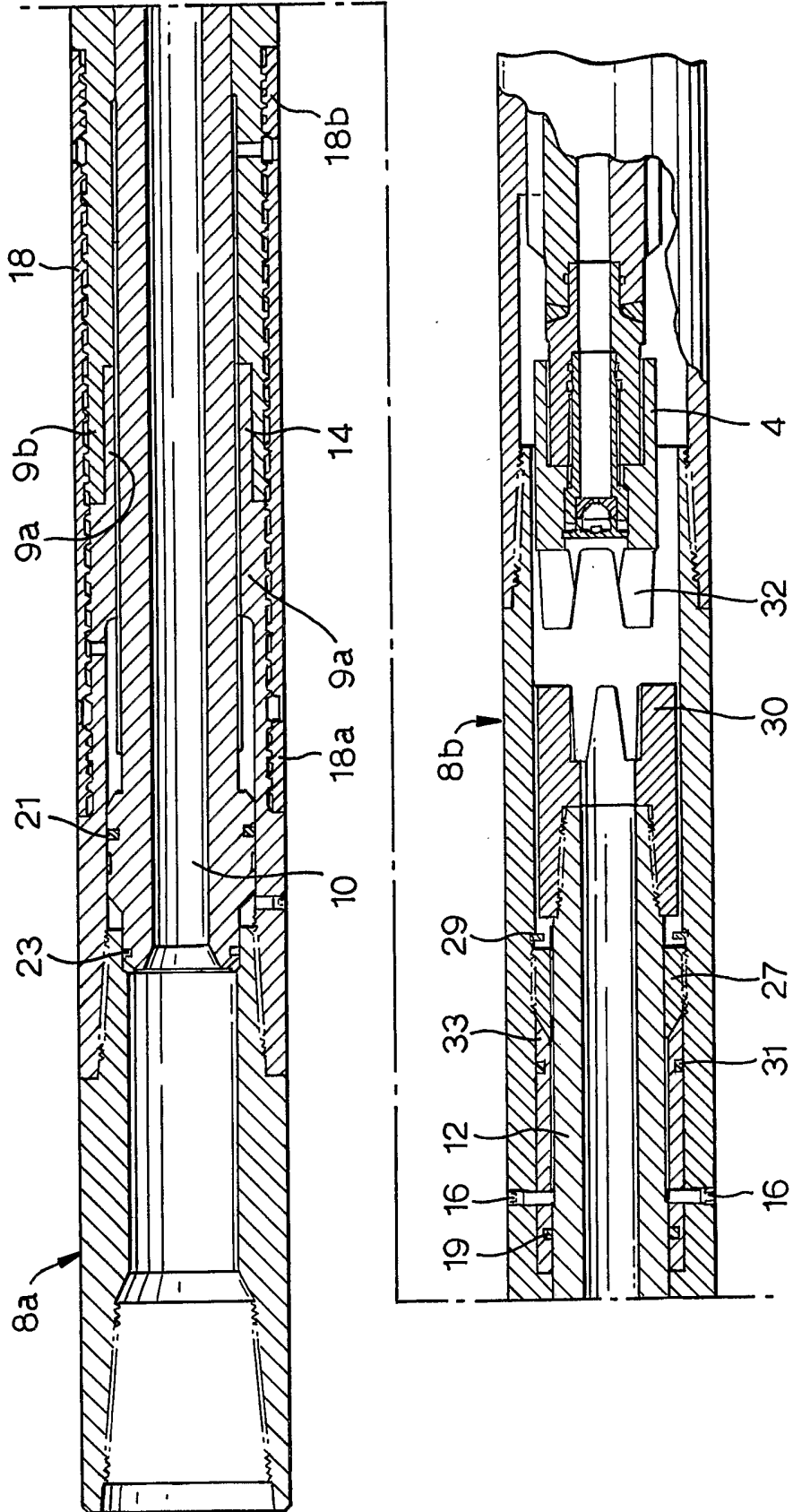


Fig. 5.



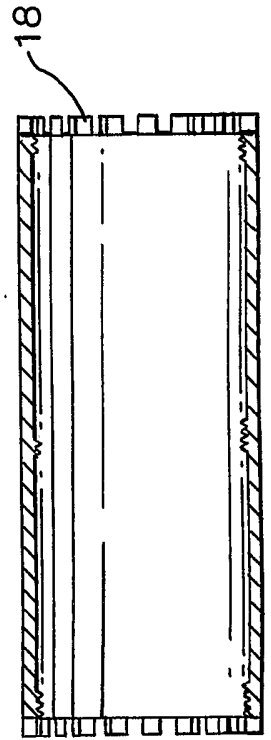
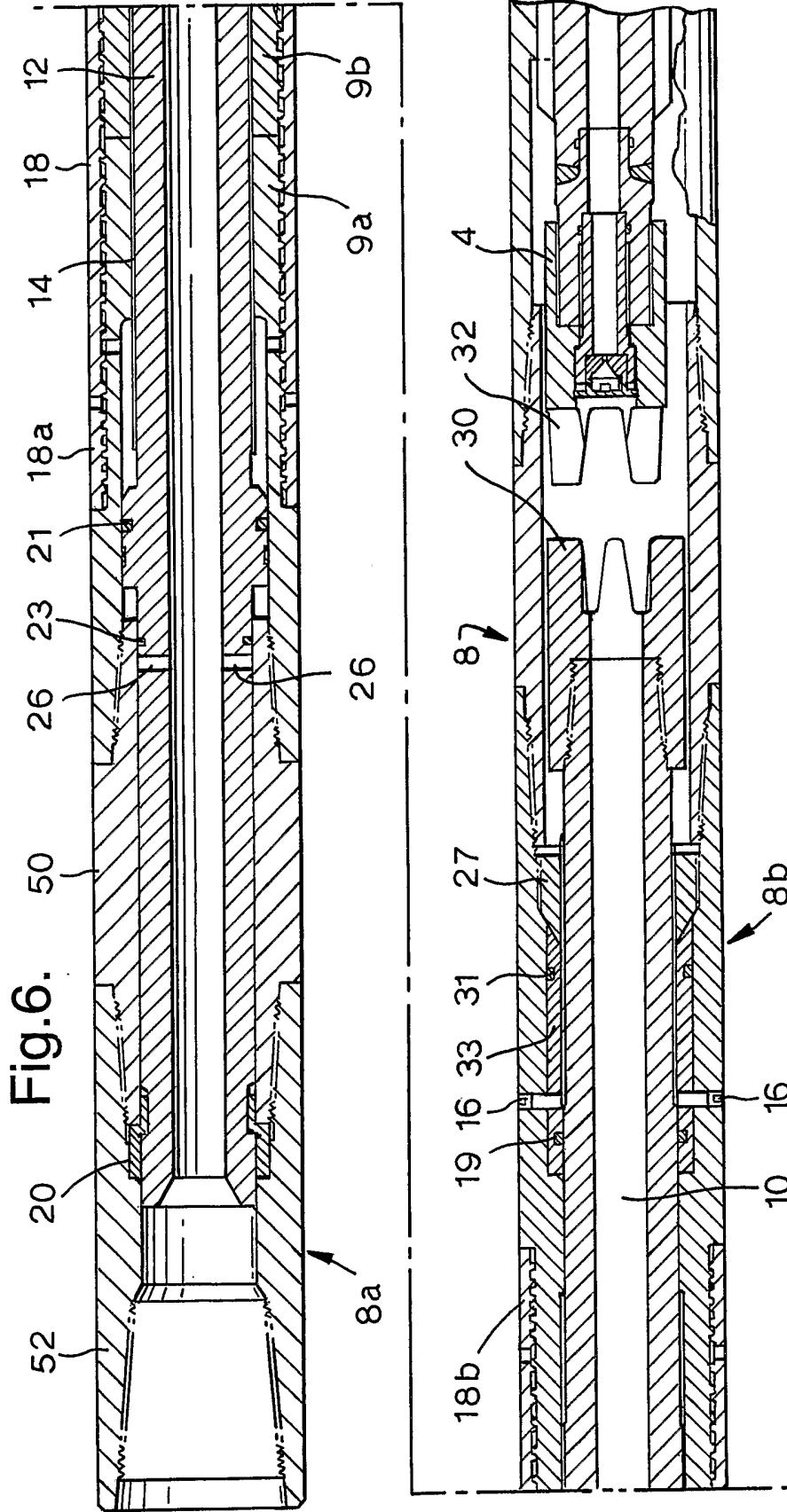


Fig. 7 b.

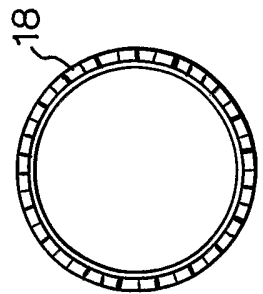


Fig. 7 a.

Fig.8.

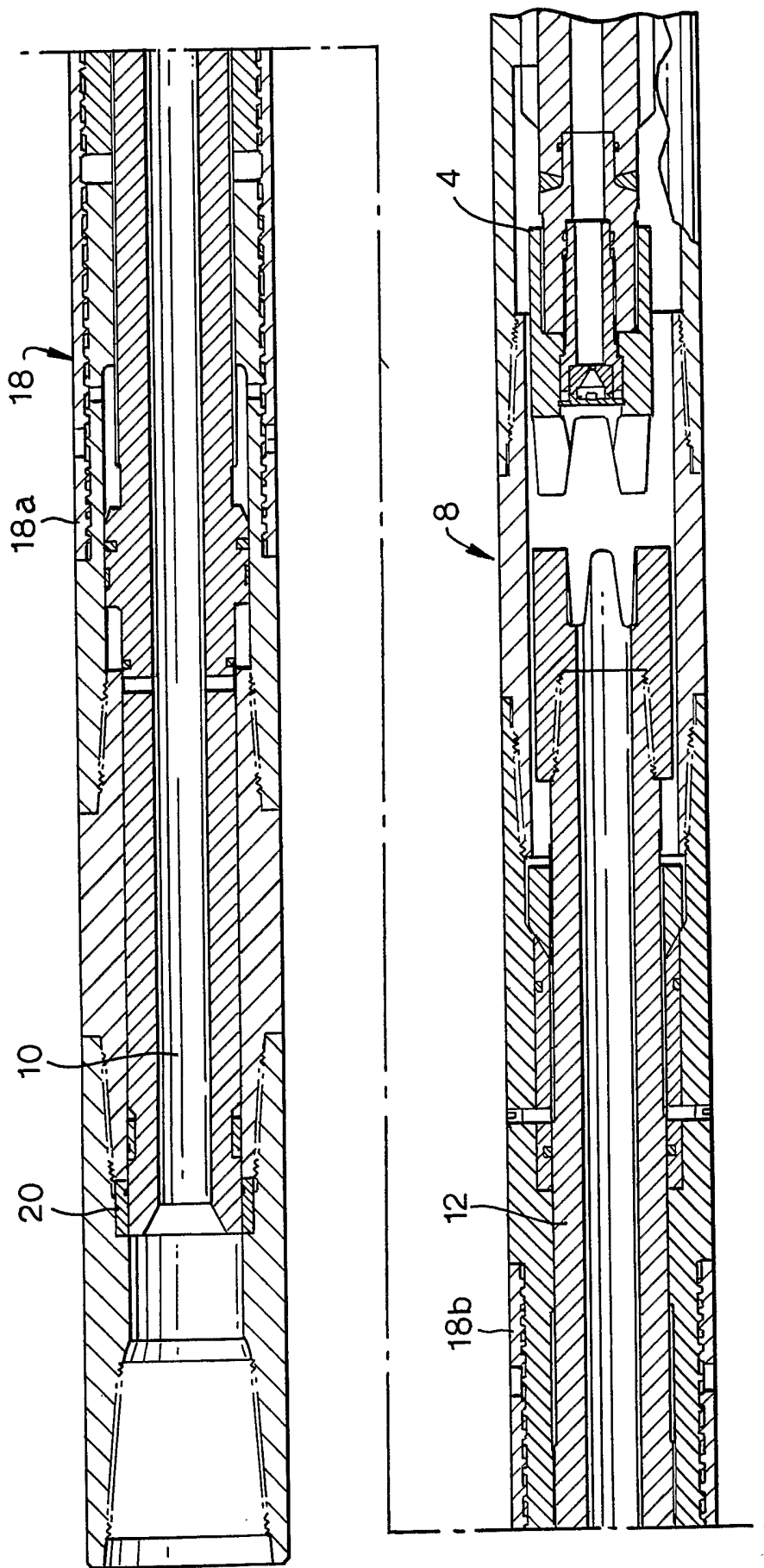
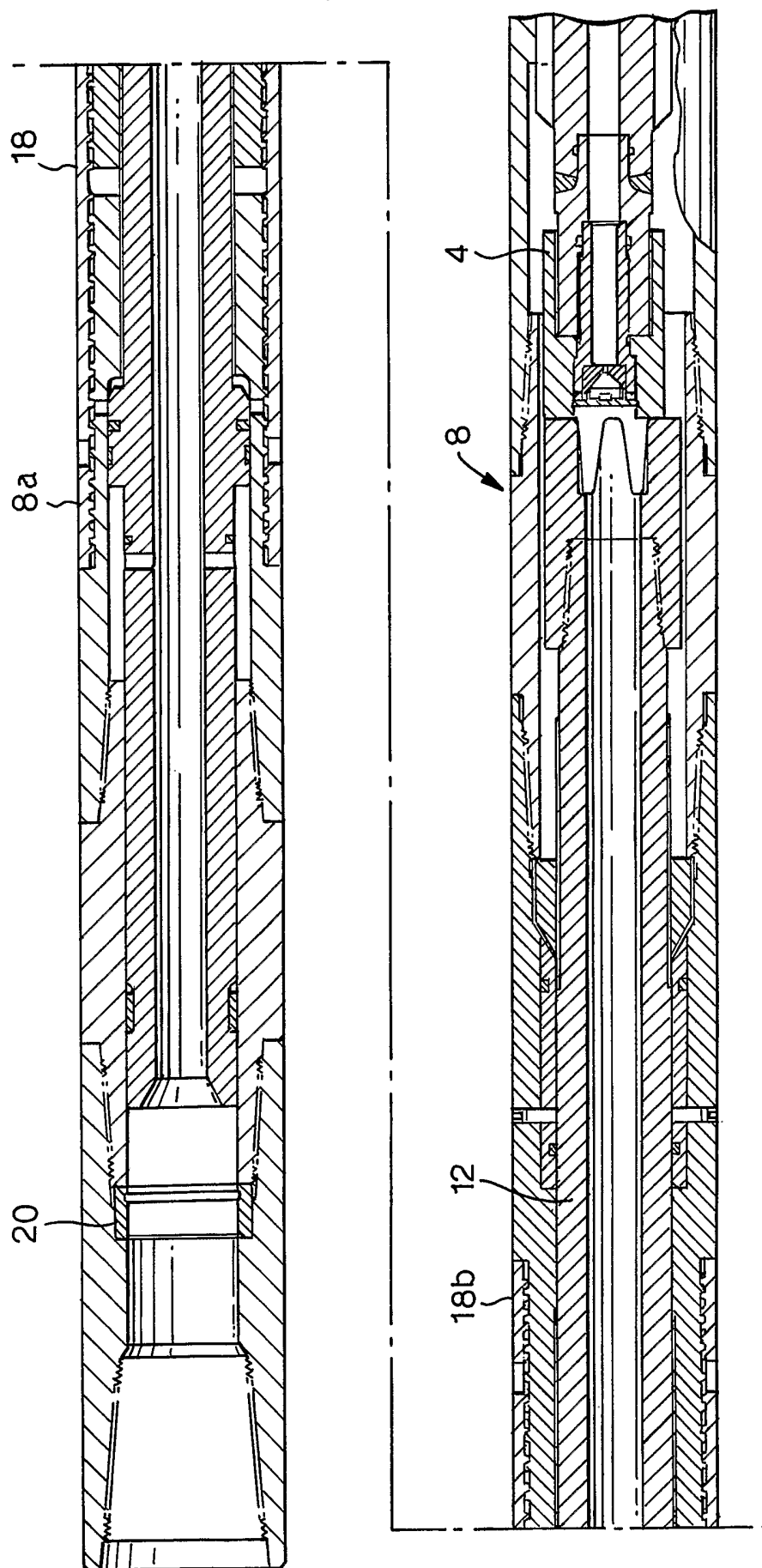


Fig.9.



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/03483

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B4/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B F03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 705 117 A (WARREN TOMMY M ET AL) 10 November 1987 (1987-11-10) abstract ---	1
A	WO 01 07749 A (CRUICKSHANK BRIAN ;MCGARIAN BRUCE (GB); BOYCE JOHN PATRICK (GB); C) 1 February 2001 (2001-02-01) abstract ---	1
A	US 4 678 044 A (LUKE ROBERT R ET AL) 7 July 1987 (1987-07-07) column 4, line 30 - line 40 -----	1

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

° Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- * & * document member of the same patent family

Date of the actual completion of the international search

30 September 2002

Date of mailing of the international search report

15/10/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Bellingacci, F

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/03483

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4705117	A	10-11-1987	NONE	
WO 0107749	A	01-02-2001	EP 1198654 A1 WO 0107749 A1 GB 2353332 A NO 20020240 A	24-04-2002 01-02-2001 21-02-2001 14-03-2002
US 4678044	A	07-07-1987	NONE	