AU9464196

(12) PATENT ABRIDGMENT (11) Document No. AU-B-64196/94
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 688311

(54) Title
PERCUSSION DRILLING IMPROVEMENTS
International Patent Classification(s)
(51)[5] E21B 004/14
(21) Application No. : 64196/94 (22) Application Date : 05.04.94
(87) PCT Publication Number : WO94/23171
(30) Priority Data
(31) Number (32) Date (33) Country
PL8157 05.04.93 AU AUSTRALIA
(43) Publication Date : 24.10.94
(44) Publication Date of Accepted Application : 12.03.98
(71) Applicant(s)
SDS PTY LTD
(72) Inventor(s)
MALCOLM BICKNELL MCINNES
(74) Attorney or Agent
MADDERNS , 1st Floor Wolf Blass House, 64 Hindmarsh Square, ADELAIDE SA 5000
(56) Prior Art Documents
WO 92/12323
WO 92/01138
US 4660658
(57) Claim

1. An hydraulically driven percussive hammer comprising

a hammer body having a piston bore,

a percussive drill bit at one end of said body,

a piston within said piston bore for reciprocating impact against said drill bit,

a plurality of piston driving areas comprising radially projecting surfaces, at least some of which have different surface areas, spaced along the outer surface of said piston arranged in two groups, a first group for driving said piston away from said drill bit, and a second group for driving said piston toward said drill bit, each said driving area having a bore sealing surface,

a plurality of piston sealing surfaces corresponding to each of said piston driving areas spaced along said piston bore engaged by said bore sealing surfaces,

fluid conduits for delivery of hydraulic fluid to said piston driving areas comprising a first conduit for delivery of said fluid at one end of said piston and a second conduit for delivery of said fluid at the other end of said piston, and

fluid control means to control flow to cause reciprocating movement of said piston,

. . ./2

said piston driving areas and said piston sealing surfaces arranged so that, in each said direction of travel of said piston, said fluid acts sequentially against said piston driving areas with each subsequent effective piston driving area being less than the last so that the flow rate of said fluid remains substantially constant.

OPI DATE 24/10/94 APPLN. ID 64196/94
AOJP DATE 08/12/94 PCT NUMBER PCT/AU94/00165

AU9464196

CT)

(51) International Patent Classification 5 : E21B 4/14

A1

(11) International Publication Number: WO 94/23171

(43) International Publication Date: 13 October 1994 (13.10.94)

(21) International Application Number: PCT/AU94/00165

(22) International Filing Date: 5 April 1994 (05.04.94)

(30) Priority Data:
PL 8157 5 April 1993 (05.04.93) AU

(71) Applicant *(for all designated States except US)*: SDS PTY. LTD. [AU/AU]; 136 Daws Road, Melrose Park, S.A. 5039 (AU).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: MCINNES, Malcolm, Bicknell [AU/AU]; 5 Chardonnay Court, Angle Vale, S.A. 5117 (AU).

(74) Agent: COLLISON & CO.; 117 King William Street, Adelaide, S.A. 5000 (AU).

(81) Designated States: AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KG, KP, KR, KZ, LK, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

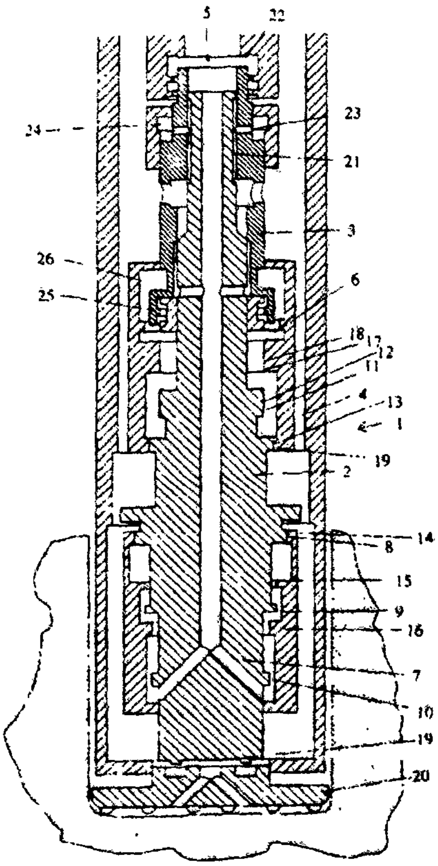
Published
With international search report.

688311

(54) Title: PERCUSSION DRILLING IMPROVEMENTS

(57) Abstract

A percussive hammer for use in-the-hole hammer percussive drilling using water pressure to drive the percussion hammer, the hammer having a piston cylinder combination which provides for multiple stages where there are successive effective piston areas of diminishing size for both return and impact directions which minimises peak pressures from water hammer effects. A dual piston arrangement with hydraulically linked pistons which are both driven by successive effective piston areas of diminishing size for both return and impact directions for each piston is also disclosed.



PERCUSSION DRILLING IMPROVEMENTS

BACKGROUND

This invention relates to percussion drilling improvements and in particular to drilling apparatus driven hydraulically.

It has previously been known to use down-the-hole reciprocating percussive motors which are driven pneumatically.

There are advantages in using liquid (usually water) instead of air but problems have been experienced in trials when a down-the-hole hydraulic percussive motor is used.

One of these problems to which this invention is directed relates to the problem conventionally known as hydraulic hammer (the mechanical shock resulting from the generation of high pressure peaks when the velocity of a long column of hydraulic fluid is rapidly changed). Such high pressure peaks can place great stress on seals and other constraining parts. A number of differing techniques have been tried in order to adequately reduce the pressure peaks which result if conventional equipment is used.

Previous trials have included a column of air to act as a buffer. Such arrangements have not worked successfully when trialed over an extended period of time. Other attempts have included the use of other buffering devices but again, where metal components have been used, metal fatigue has caused a high and early failure rate.

An object of this invention is to provide a different arrangement from those previously used which will achieve a reduction in pressure peaks.

SUMMARY OF THE INVENTION

In its broadest form, the invention is an hydraulically driven percussive hammer comprising a hammer body having a piston bore, a percussive drill bit at one end, of said body

a piston within said piston bore for reciprocating impact against said drill bit,

a plurality of piston driving areas comprising radially projecting surfaces, at least some of which have different surface areas, spaced along the outer surface of said piston arranged in two groups, a first group for driving said piston away from said drill bit, and a second group for driving said piston toward said drill bit, each said driving area having a bore sealing surface,

a plurality of piston sealing surfaces corresponding to each of said piston driving areas spaced along said piston bore engaged by said bore sealing surfaces,

fluid conduits for delivery of hydraulic fluid to said piston driving areas comprising a first conduit for delivery of said fluid at one end of said piston and a second conduit for delivery of said fluid at the other end of said piston, and

fluid control means to control flow to cause reciprocating movement of said piston,

said piston driving areas and said piston sealing surfaces arranged so that, in each said direction of travel of said piston, said fluid acts sequentially against said piston driving areas with each subsequent effective piston driving area being less than the last so that the flow rate of said fluid remains substantially constant.

The flow rate of supply fluid required to accelerate the piston during successive stages would be reduced if this piston started each new stage at rest. However, because the piston is increasing its speed, the smaller effective piston drive area will result in a more constant flow rate.

There will be achievable therefore an overall liquid flow rate which will be less subject to abrupt change and associated high pressure peaks.

The number of stages used may be increased above two both for the outward stroke and the inward movement of the piston.

Preferably, the hydraulic fluid used is water.

In preference, there is arranged to be met at the end of the return stroke of the piston a closed chamber filled with fluid to cause the piston to bounce or rebound due to the piston impacting the fluid in this closed chamber, thereby transferring a portion of the inward movement energy to the outward movement.

In an alternative aspect of the invention, there are provided two pistons within the same hammer body arranged to act in mutually opposing directions. One of the pistons has a tubular shape within which the second piston locates. The first piston has as a bore within which the second piston operates, and the combination of the first and second piston operate within a single bore with the hammer body.

In this alternative aspect of the invention, the pistons are hydraulically linked so that their motions are out of phase by 180 degrees resulting in counter oscillation. This hydraulic linking maybe achieved by providing a hydraulic chamber which is closed to external accesses and which is arranged so that each of the two pistons have portions which form chamber walls for fluid control so that as one wall is advanced into the substantially incompressible hydraulic fluid, the other will be forced out and vice versa.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of this invention it will now be described with reference to the preferred embodiments which shall be described with the assistance of drawings in which:-

Fig 1 is a schematic cross sectional view of a six stage (three per stroke) single piston percussion hammer according to a first embodiment incorporating a valve to effect reversal of flow;

Figs 1a-1g show the same schematic cross sectional view of a single piston percussion hammer as shown in Fig 1 at progressive stages during its inward and outward movements; and

Fig 2 is an arrangement according to a second embodiment showing schematically a dual piston percussive hammer with three stages per stroke.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings in detail there is shown in Fig 1 in a schematic arrangement, a percussive hammer 1 which includes a piston 2, a valve member 3, liner 4 with a piston bore, and a drill bit 20. The liner 4, piston 2 and drill bit 20 are located in a hammer body in accordance with normal practice.

The piston 2 has fluid conduits comprising a central passageway 5 with first and second conduits comprising outlets at 6 and 7 respectively for supply of water at substantial pressure.

The piston 2 is slidably located within the piston bore of the liner 4.

For ease of description, movements towards the bit 20 will be referred to as outward movement and movements back towards the drill string will be referred to as inward movement.

Piston 2 has piston drive areas 8, 9 and 10 at one end, arranged to engage with liner elements 14, 15 and 16 of liner 4 such that, when fluid is supplied via outlet 7, a force will act against the piston 2 to produce an inward movement. These piston drive areas 8, 9 and 10 will therefore be referred to as the inward acting piston areas. The bore sealing surface, in this embodiment a liner sealing surface, comprises the outer peripheral surface of each piston drive area 8, 9 and 10 which seal and slide against the piston sealing surfaces which comprise the outer peripheral surface of the liner elements 14, 15 and 16.

The piston 2 has piston drive areas 11 and 13 at its other end, arranged to slidably engage with liner elements 17 and 19 of cylinder 4 such that, when fluid is supplied via outlet 6, a force will act against the piston 2 to apply force to produce outward movement. These piston areas 11 and 13 will therefore be referred to as the outward acting piston areas. The liner sealing surface comprises the outer peripheral surface of each piston drive area 11 and 13 which seal and slide against the piston sealing surfaces which comprise the outer peripheral surface of the liner elements 17 and 19.

The piston 2 and the liner 4 are arranged such that the outward operating piston areas 11 and 13 and the inward operating piston areas 8, 9 and 10 can act simultaneously against each other creating additional effective piston areas. These effective piston areas are described below in relation to the outward movement of the piston 2.

In operation, the inward movement of piston 2 is caused by the action of

a first piston drive area comprising inward acting piston area 8 acting alone, followed by

a second piston drive area comprising inward acting piston area 9 acting alone, followed by

a third piston drive area comprising inward acting piston area 10 acting alone,

where the piston areas from first to third are progressively smaller.

In operation, the outward movement of piston member 2 is caused by the action of

a fourth (effective) piston drive area comprising outwards acting piston area 11 less inwards acting piston area 10, followed by

a fifth (effective) piston drive area comprising outwards acting piston area 11 less inwards acting piston area 9, followed by

a sixth (effective) piston drive area comprising outwards acting piston area 13 less inwards acting piston area 8,

where the effective piston areas from fourth to sixth are progressively smaller.

A fluid control means comprise a valve 3 arranged so that it can be controlled via pressure chamber 24 as follows. Referring to Fig 1, area A and area C are always exposed to supply pressure, whereas area B, within chamber 24 alternates between supply pressure and low return pressure. Areas A, B and C are sized such that when chamber 24 is exposed to supply pressure, the valve 3 moves outwards and when it is at low return pressure, valve 3 moves inwards.

The automatic motion of the piston will now be explained with reference to Fig 1 and Fig 1a to 1g. Fig 1 shows the piston impacting at the completion of the outward stroke. Pressure in valve chamber 24 is relieved through exhaust port 21a via channels 23 and 21. This causes valve 3 to move inwards, as shown in Fig 1a, closing supply port 26a and at the same time opening exhaust port 21b thereby relieving pressure in chamber 26. At this point there is no pressure acting on piston 2 in an outward direction and so pressure against a first and largest piston drive area, inward acting piston area 8, causes piston 2 to accelerate inwards. During inward acceleration high pressure water is supplied through conduit 5 and outlets 7. Fig 1b shows the smaller second piston drive area, comprising inwards acting piston area 9, coming into engagement with liner element 15. Fig 1c shows the smaller again third piston drive area, comprising inwards acting piston area 10, coming into engagement with liner element 16. During this three-stage inward stroke the swept area of the piston progressively decreases but this is offset by the increasing speed of the piston. Accordingly, the rate of change of water flow through the stages of the full stroke of the piston is reduced substantially.

Towards the end of the inward stroke, the piston 2 brings into coincidence channel 21 between the source of high pressure fluid at 22 and channel 23 in the valve member 3 as shown in Fig 1c. This accordingly pressurises chamber 24 which has the result of causing the valve member 3 to move outwardly as shown progressively in Fig 1d and Fig 1e. Fig 1d shows exhaust port 21b closed and since this closure occurs just prior to the piston 2 reaching the end of its inwards stroke, the piston is "bounced" on a trapped volume of water within chamber 26. This "bouncing" effect results in a transfer of energy between the piston's 2 inward motion and its outward motion. Fig

1e shows valve member 3 in its outward position in which supply port 26a has opened causing a supply of pressure fluid into chamber 26. With chamber 26 now pressurised, the fourth (effective) piston drive area is formed comprising outwards acting piston area 11 acting against inwards acting piston area 10. This causes acceleration of piston 2 outwards. Fig 1f shows the creation of the fifth (effective) piston drive area. Inward acting piston area 10 disengages from cylinder element 16 allowing high pressure water to act upon inward acting piston area 9 which then works against outwards acting piston area 11. Finally in Fig 1g the creation of the sixth (effective) piston drive area is shown. Inward acting piston area 9 disengages from liner element 15 allowing high pressure water to act upon inward acting piston area 8 which then works against outwards acting piston area 13.

With the piston now back at the impact position, valve chamber 24 is relieved through exhaust port 21a via channels 23 and 21. This causes valve 3 to move inwards starting another cycle.

In the embodiment described above, the distance between the respective piston drive areas and their location for engaging liner elements will be such that as a first piston drive area comes out of engagement, the next liner element is located so that there is effectively a seamless transfer. Therefore minimal sudden abrupt stopping or starting of full flow of the liquid at pressure (and associated water hammer) occurs.

In the embodiment described above, the six (effective) piston drive areas are formed by only five actual piston areas (two inwards acting and three outwards acting). Alternative embodiments have three inwards acting piston drive areas and three outward acting piston drive areas. These embodiments however have the disadvantage of additional tool length.

The above description is in relation to a schematic layout with the purpose of illustrating the principle by which succeeding effective piston drive areas can be arranged to achieve the result required.

A second embodiment of the invention, being a dual piston percussive hammer, will now be described.

Fig 2 shows in schematic detail this second embodiment.

In this embodiment there are provided two pistons 43 and 44. The two pistons are kept in relative association with each other by having respective parts shown at 45 in the case of the outer piston and at 50 in the case of the inner piston 43 such that there is confined in chamber area 46 a quantity of water which will not vary. A further chamber 47 located close to the outer end A also locks the pistons together.

This hydraulically couples the two pistons 43 and 44 together and causes them to act with a 180 degrees out of phase motion to cancel volume changes between the bit and pistons. In this case then there is further provided a valve 51 the operation of which is substantially the same as the valve as described in relation to the embodiment described in Fig 1 and, the purpose of which is to change the direction of flow being supplied from the high pressure source at 52 to direct this into the area 53 to effect the outward stroke of the central piston 43 while at the same time causing the reciprocal inward motion of the outer piston 44.

Again the function of effective piston areas is used in successive alignments so that as the respective piston that is in each case 42 and 44 is caused to accelerate respectively toward an outer impact location or toward an inner location, the effective piston drive areas are chosen so that there would be a reduced flow rate of liquid required if the speed of the piston was kept constant but as this is accelerating, will more match the area with the speed so as to reduce substantially changes in flow rate (and hence water hammer) in the pressure supply and return lines.

As will be now apparent, water at pressure coming through the conduit 52 and entering through channel 54 will pass through area 55 to impinge against piston drive area 56 then as the inner piston 43 rises through its inward stroke in succession piston drive area 57 and piston drive area 58 will engage respectively with cylinder segments 59 and 60.

As the effective forces here are essentially equal and opposite, when the pressure to return the inner piston member 43 is effected, this will in turn assist in providing effective force to cause the outer piston 44 to proceed through its outward stroke. During the outward stroke of the inner piston 43 there will be an initial pressure on piston drive areas 62 followed by drive area 63.

Likewise however for the inner piston 43 there will be an initial pressure on piston drive area 58 then in turn drive areas 59 and 56.

In this way the inner piston 43 is a master piston and the outer piston 44 acts as a slave piston. The balanced counter oscillation means that there is no net change in the volume of water between the pistons and bit if the annular impact area of the slave piston equals the circular impact area of the master piston. This arrangement has the further advantage that it reduces flow losses.

A significant advantage of this arrangement is the hydraulic linkage between the two pistons enables them to move together but 180 degrees out of phase and it furthermore provides a transfer of energy so that as either piston strikes the bit, the energy of the other piston is added to the striking piston. The mass of the striking piston is effectively equal to the mass of both pistons.

This arrangement furthermore has a potentially higher operating impact frequency than the previously described single piston design. The higher frequency can be partially exchanged for a longer stroke higher piston velocity and thus a higher impact energy. The selection of the relative piston segments and the cylinder segments is also chosen to make assembly of the apparatus convenient.

In the embodiment described above, the six (effective) piston drive areas are formed by only five actual piston areas (two inwards acting and three outwards acting).

Alternative embodiments have three inwards acting piston drive areas and three outward acting piston drive areas. These embodiments however have the disadvantage of additional tool length.

This then describes in a general sense the way in which two embodiments can be put into place and from which will be seen that significant reduction in water hammer can be achieved.

There are advantages in using the dual piston system in that energy is transferred to the bit at the end of each stroke and does not have to be stored or wasted at the end of the return stroke.

The single piston hammer does waste some energy at the end of the return stroke. The piston is "bounced" on a trapped volume of water at the end of the return stroke. During this period, some high pressure water is dumped to maintain flow and minimise water hammer. The energy in the dual piston hammer return stroke becomes impact energy. For a small energy loss penalty the valve ports fill in and round off the transitional water flow trough by allowing a metered leakage flow from supply to return when the piston is reversing and accelerating at the beginning of a stroke. Metered leakage or "dumping" of the pressurised supply liquid is used to maintain flow during the time when the piston is slowly moving and when it is stopped at the end of each stroke and when it is accelerating after impact. If the flow is suddenly stopped, the water supply, return and flushing water columns must suddenly decelerate and then accelerate. The result is high shock loads, noise and a reduction in performance.

While the above description refers to a valve to effect piston reversal other techniques are known and can be used for this function. For instance it is possible to use high pressure supply water alone to reverse the piston but the stroke would then need to be bigger for the same piston size and more energy would be lost.

While the present invention has been described in terms of preferred embodiments in order to facilitate better understanding of the invention, it should be realised that various modifications can be made without departing from the principles of the invention. Therefore, the invention should be understood to include all such modifications within its scope.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An hydraulically driven percussive hammer comprising

a hammer body having a piston bore,

a percussive drill bit at one end of said body,

a piston within said piston bore for reciprocating impact against said drill bit,

a plurality of piston driving areas comprising radially projecting surfaces, at least some of which have different surface areas, spaced along the outer surface of said piston arranged in two groups, a first group for driving said piston away from said drill bit, and a second group for driving said piston toward said drill bit, each said driving area having a bore sealing surface,

a plurality of piston sealing surfaces corresponding to each of said piston driving areas spaced along said piston bore engaged by said bore sealing surfaces,

fluid conduits for delivery of hydraulic fluid to said piston driving areas comprising a first conduit for delivery of said fluid at one end of said piston and a second conduit for delivery of said fluid at the other end of said piston, and

fluid control means to control flow to cause reciprocating movement of said piston,

said piston driving areas and said piston sealing surfaces arranged so that, in each said direction of travel of said piston, said fluid acts sequentially against said piston driving areas with each subsequent effective piston driving area being less than the last so that the flow rate of said fluid remains substantially constant.

2. An hydraulically driven percussive hammer according to claim 1 wherein said corresponding piston and bore sealing surfaces of each group are spaced so that, upstream corresponding piston and bore sealing surfaces are disengaged while downstream corresponding piston and bore sealing surfaces are engaged to allow said fluid to flow to the piston driving areas of said engaged piston and bore sealing surfaces.

3. An hydraulically driven percussive hammer according to claim 1 or 2 wherein said first group of piston and bore sealing surfaces to drive said piston away from

said drill bit comprises at least three said piston driving areas each having different surface areas.

4. An hydraulically driven percussive hammer according to any one of the preceding claims wherein said group of said piston and bore sealing surfaces to drive said piston toward said drill bit comprises at least two said piston driving areas.

5. An hydraulically driven percussive hammer according to any one of the preceding claims wherein after engagement by a preceding corresponding piston and bore sealing surface and as a following corresponding piston and bore sealing surface engages, said preceding corresponding piston and bore sealing surfaces disengage and allow venting of fluid past said preceding bore sealing surfaces.

6. An hydraulically driven percussive hammer according to any one of the preceding claims further comprises an exhaust port so that as said piston moves away from said drill bit, fluid displaced by the movement of said second group of piston driving areas is vented through said exhaust port.

7. An hydraulically driven percussive hammer according to claim 6 wherein said exhaust port is closed prior to said piston reaching the top of its movement which causes said piston to bounce against said fluid trapped by the closing of said exhaust port, thereby transferring a portion of the upwards stroke energy to the downward stroke.

8. An hydraulically driven percussive hammer according to any one of the preceding claims further comprising venting conduits that enable venting of high pressure fluid when the piston movement is decelerating or is stationary at the top or bottom of said reciprocating movement.

9. An hydraulically driven percussive hammer according to any one of the preceding claims wherein said fluid control means comprises a two position valve

which changes position as said piston reaches its lower and uppermost movement to thereby control flow.

10. An hydraulically driven percussive hammer according to claim 9 wherein said hydraulic fluid is used to move said valve.

11. An hydraulically driven percussive hammer according to claim 10 wherein said valve has surfaces against which said hydraulic fluid acts to move said valve.

12. An hydraulically driven percussive hammer according to claim 1 further comprising:

a second bore within said piston,

a second piston within said second bore for reciprocating impact against said drill bit, said second bore and piston each arranged in accordance with said piston and bore so that said piston is coupled to said second piston so that they move in opposite directions to one another relative to said bore.

13. An hydraulically driven percussive hammer as hereinbefore described with reference to and as illustrated in the accompanying figures 1 to 1g.

14. An hydraulically driven percussive hammer as hereinbefore described with reference to and as illustrated in the accompanying figure 2.

Dated this 17th day of December 1997.

SDS Pty Ltd
By its Patent Attorneys
MADDERNS

AUSTRALIAN PATENT OFFICE

ABSTRACT

An hydraulically driven percussive hammer for use with down-the-hole percussive hammer drilling, the hammer having a piston and liner combination which provides for multiple stages where there are successive effective piston drive areas of diminishing size for both return and impact directions which minimises peak pressures from hydraulic hammer effects.

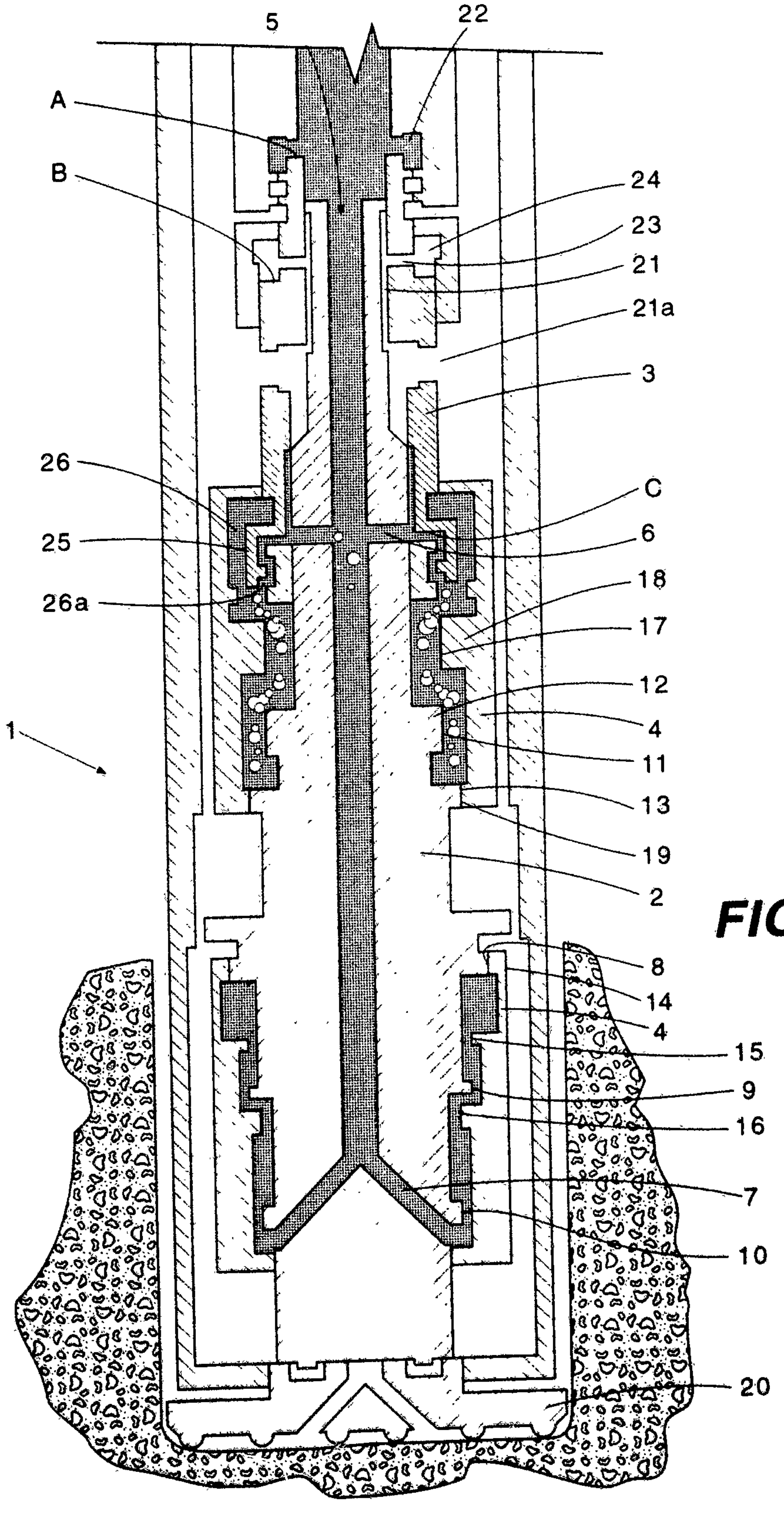

5
22
A
B
24
23
21
21a
3
26
C
25
6
26a
18
17
12
4
11
1
13
19
2
8
14
4
15
9
16
7
10
20

FIG 1

171297 64195

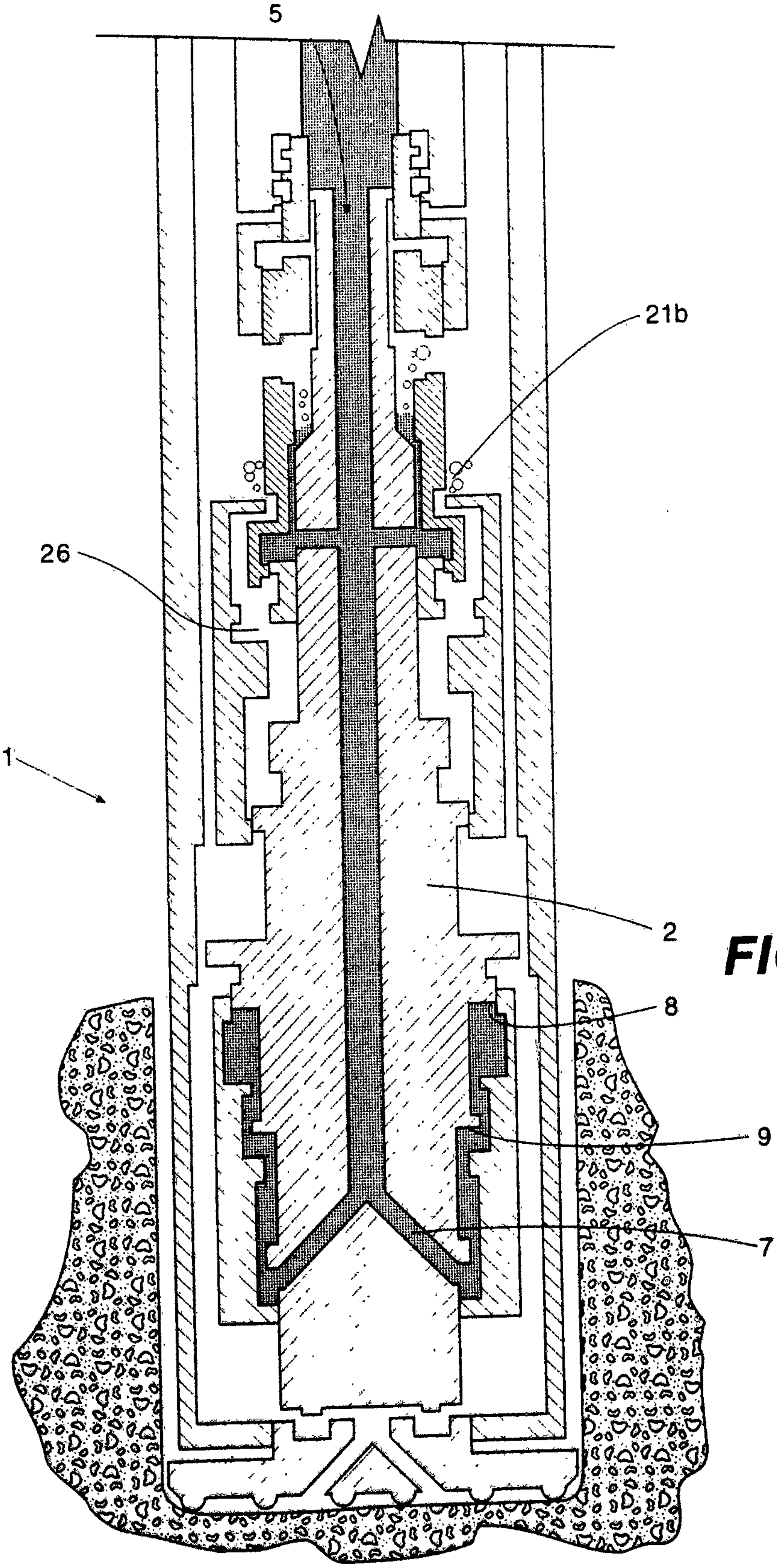


FIG 1a

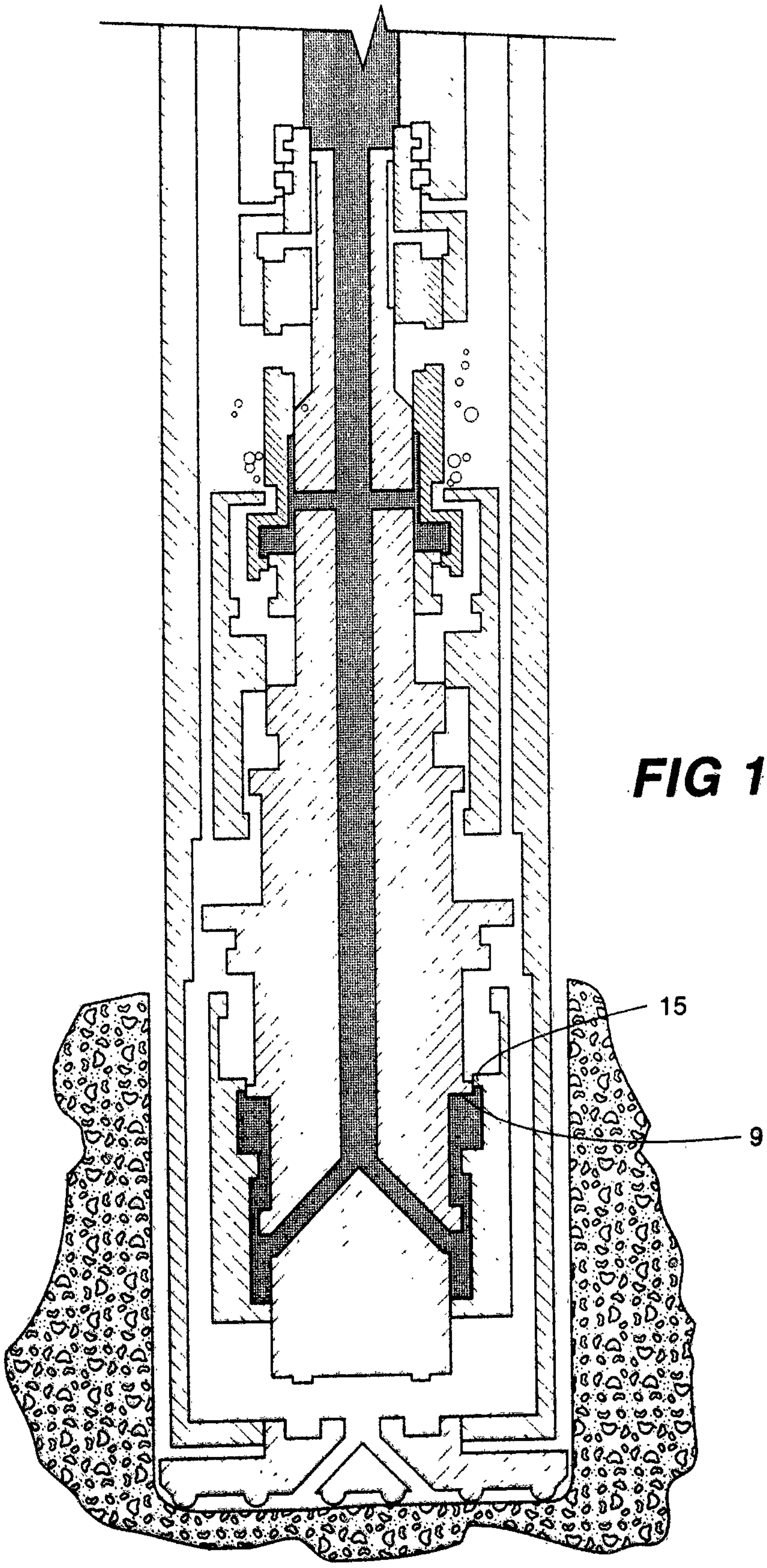


FIG 1b

17127/95

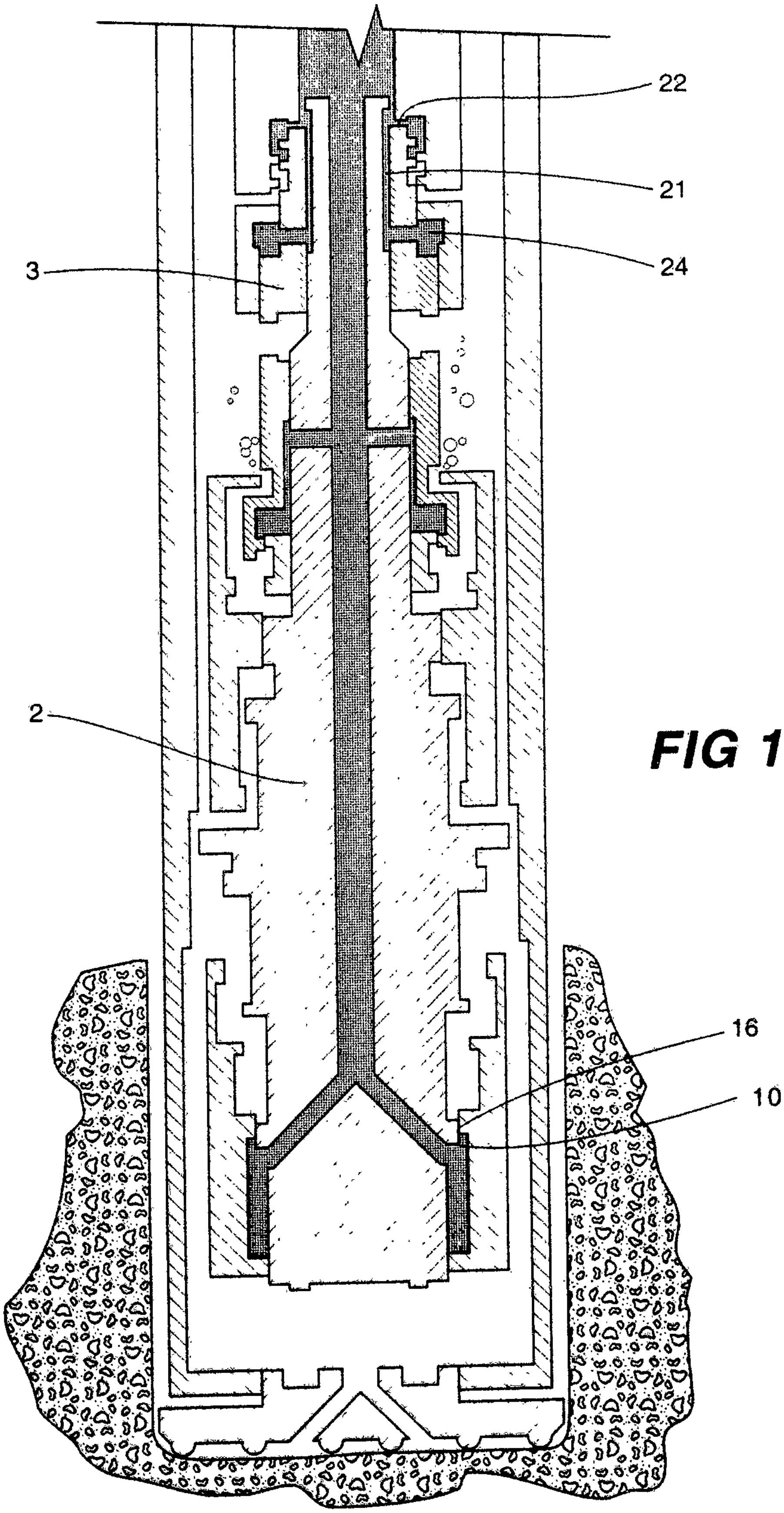


FIG 1c

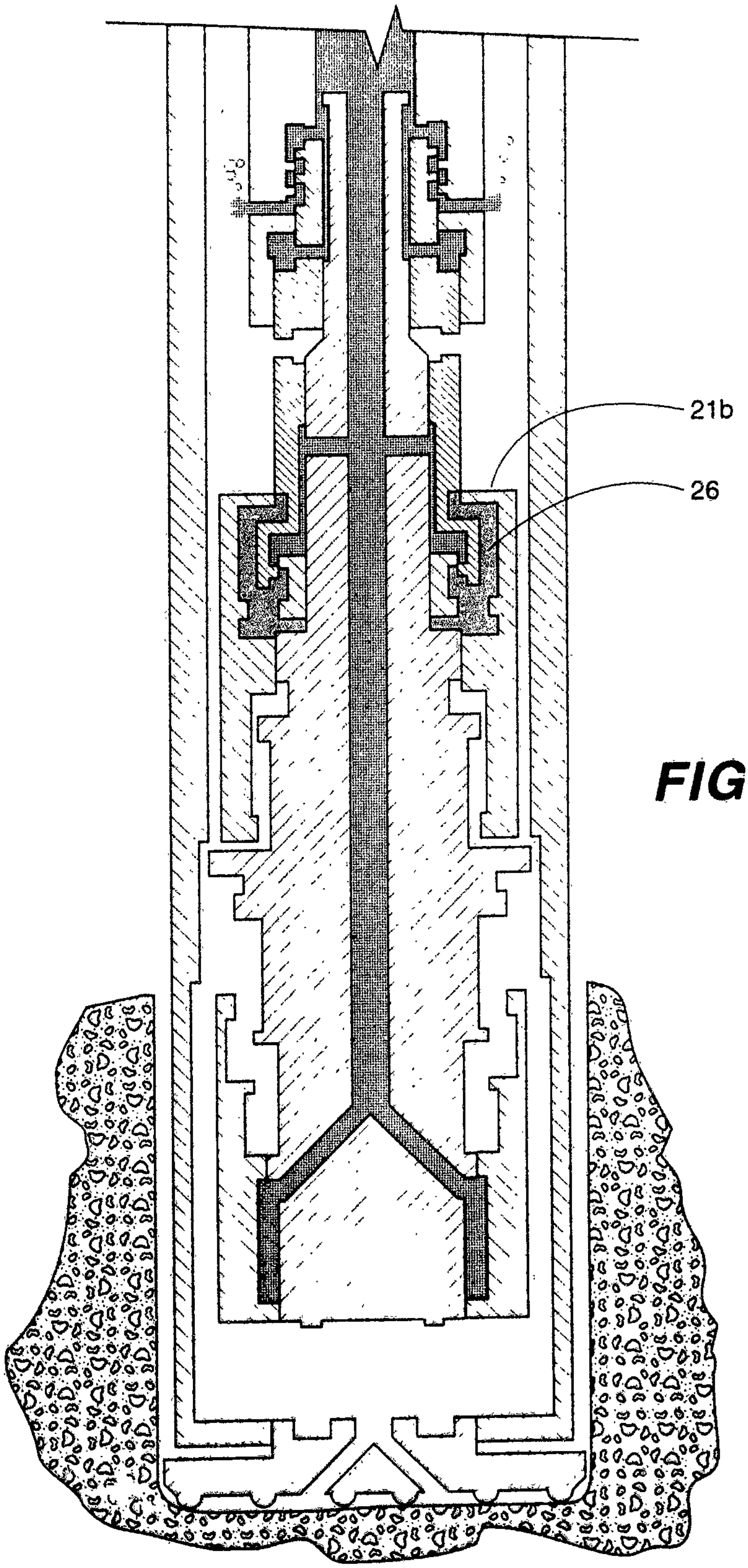


FIG 1d

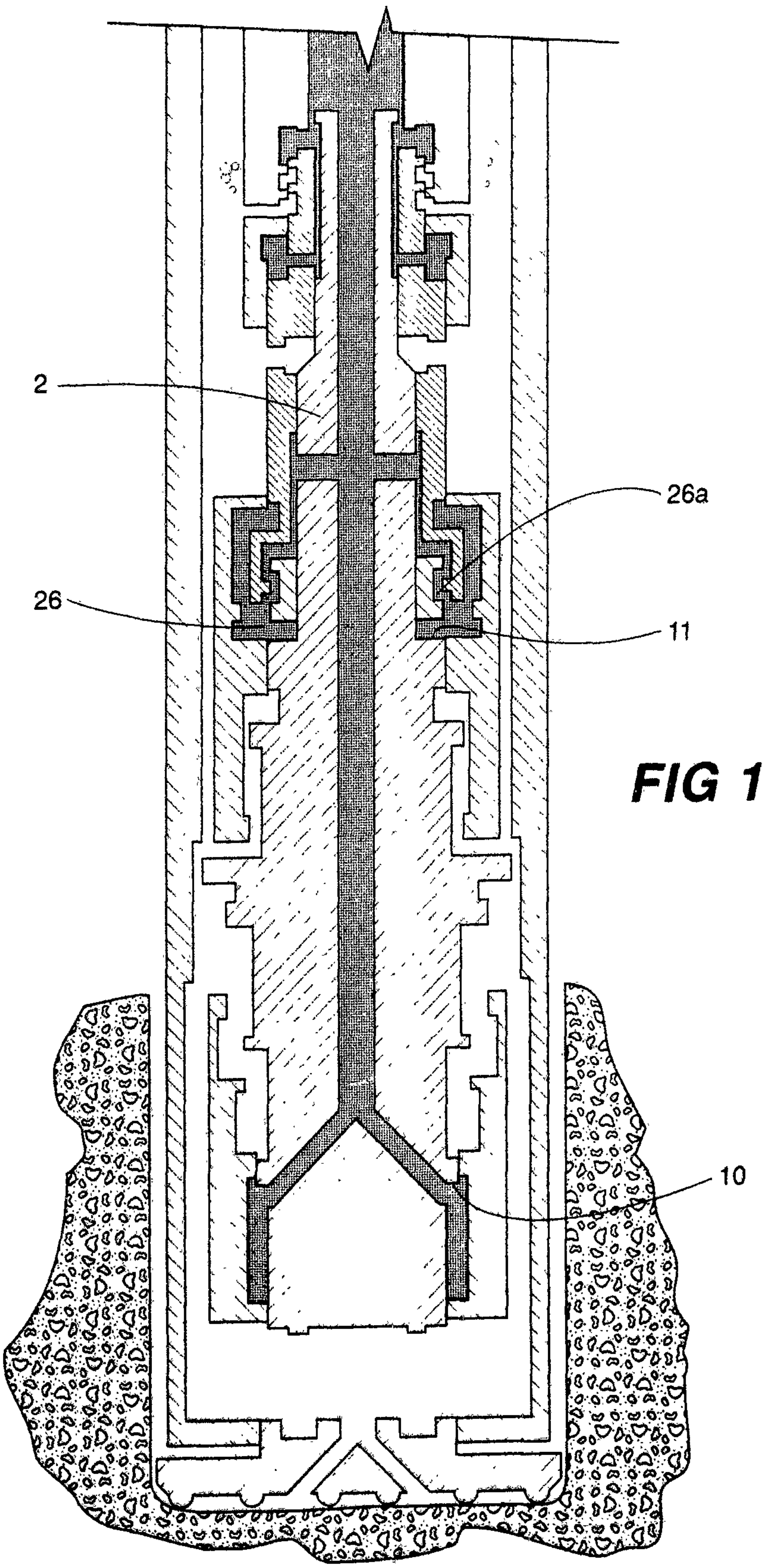


FIG 1e

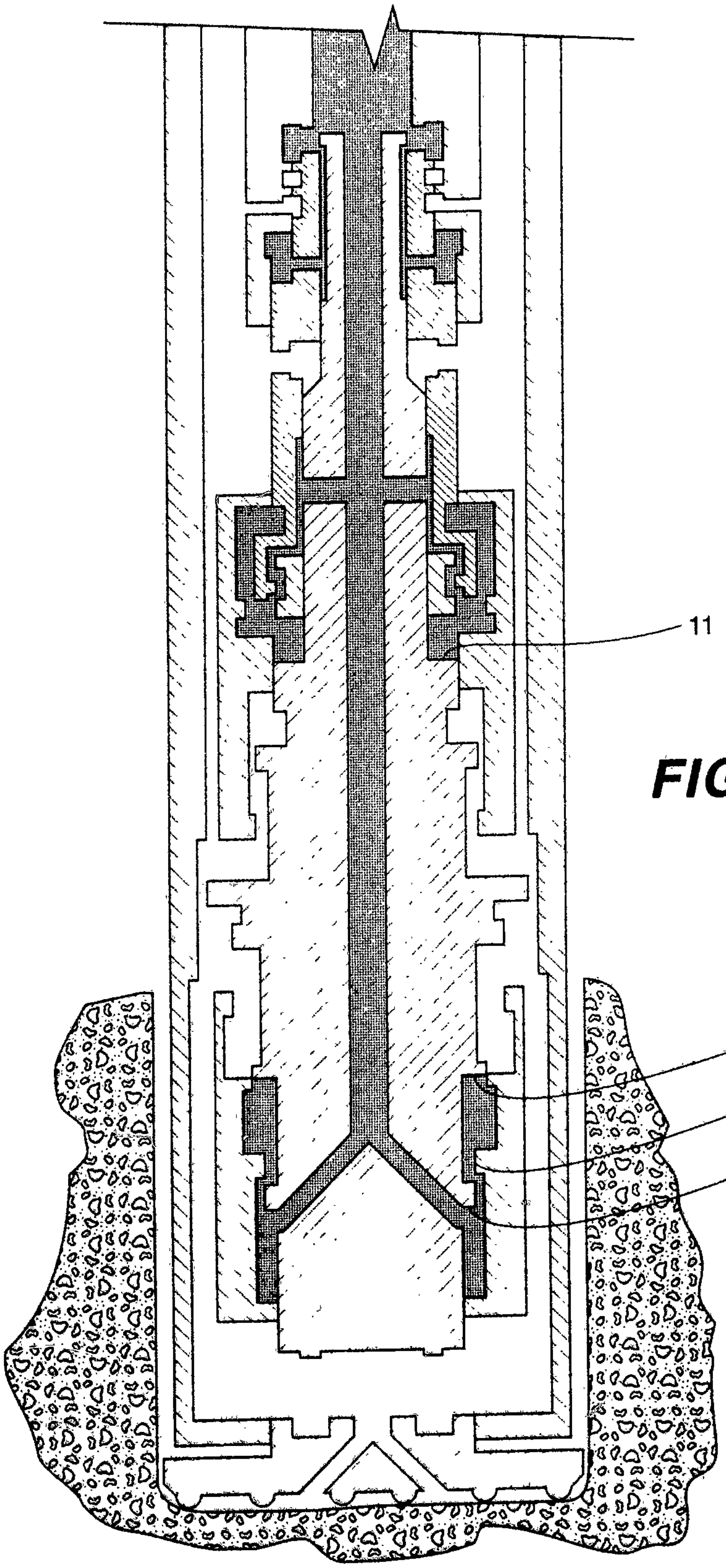


FIG 1f

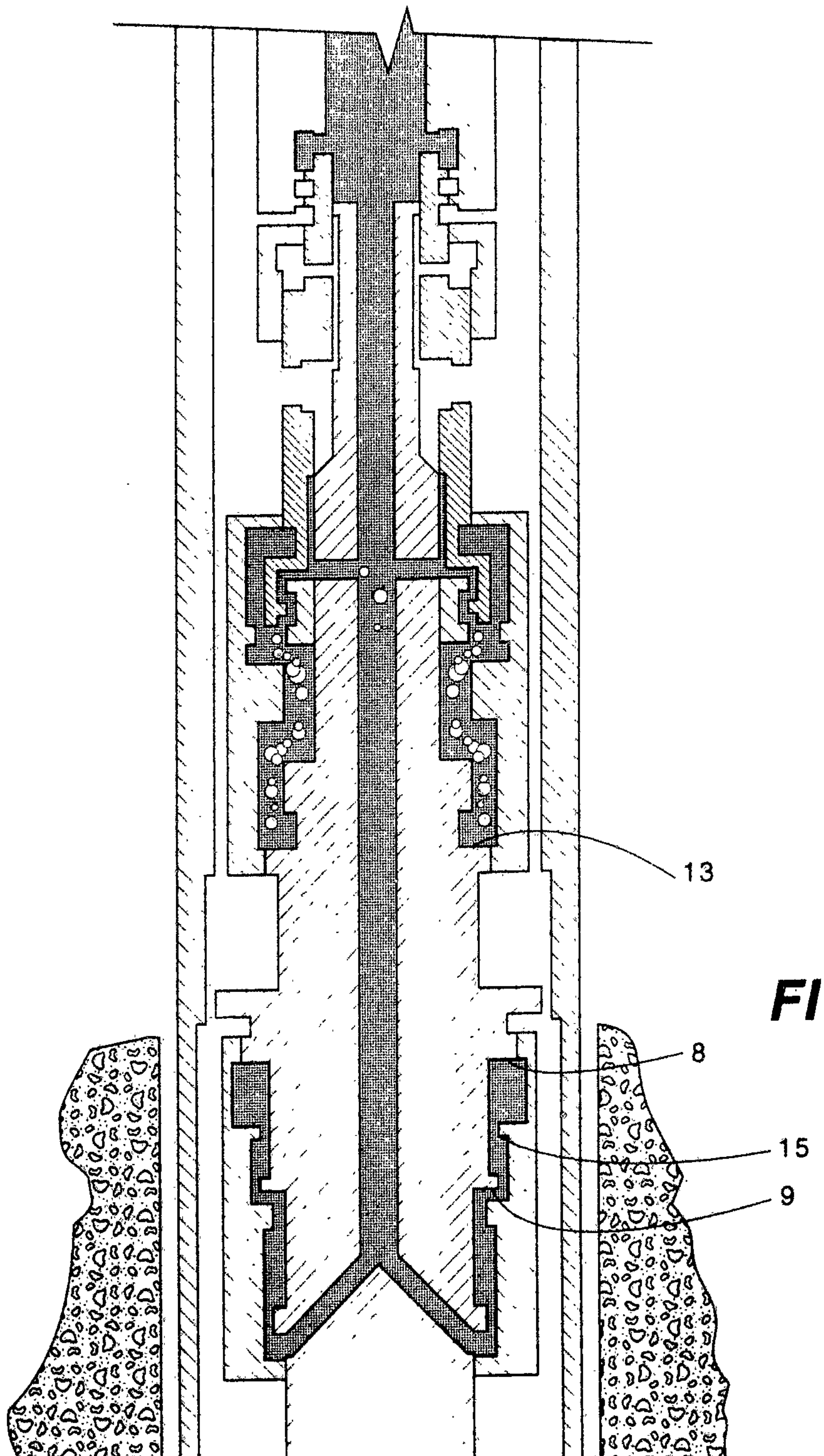


FIG 1g

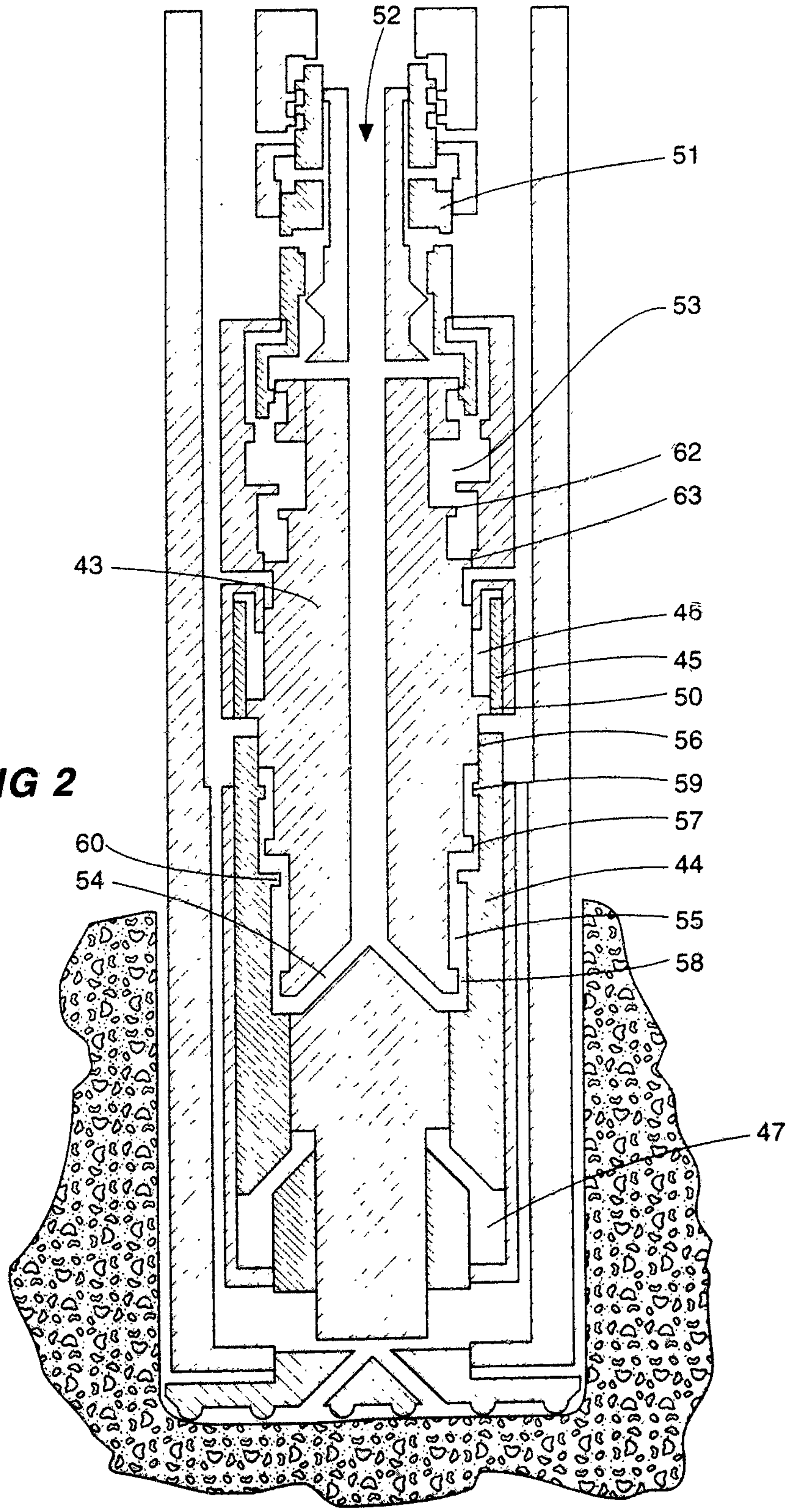


FIG 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 94/00165

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.^{5} E21B 4/14

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 E21B 4/14, 1/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US, A, 4660658 (Gustafsson) 28 April 1987 (28.04.87)	
A	WO, A, 93/20322 (SDS PTY. LTD.) 14 October 1993 (14.10.93)	
A	WO, A, 92/12323 (SANDVIK AB) 23 July 1992 (23.07.92)	
A	WO, A, 92/01138 (GUSTAFSSON) 23 January 1992 (23.01.92)	
A	WO, A, 89/00638 (ATLAS COPCO AB) 26 January 1989 (26.01.89)	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family 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	Date of mailing of the international search report
22 June 1994 (22.06.94)	29 June 1994 (29.06.94)

Name and mailing address of the ISA/AU

AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION
PO BOX 200
WODEN ACT 2606
AUSTRALIA

Facsimile No. 06 2853929

Authorized officer

S.K. Ghosh

S.K. GHOSH

Telephone No. (06) 2832163

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4660658	EP	171374	JP	61014392	NO	852510
		SE	8403370				
WO	9320322	AU	38178/93				
WO	9212323	AU	11735/92	SE	9100092		
WO	9201138	AU	61442/90	EP	543806		
WO	8900638	AU	20790/88	EP	394255	FI	900176
		NO	900176	SE	8702860	US	5014796
		US	5107944				

END OF ANNEX