PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : E21B 7/18, 10/60

A1

(11) International Publication Number: WO 97/46786

(43) International Publication Date: 11 December 1997 (11.12.97)

(21) International Application Number: PCT/AU97/00341

(22) International Filing Date: 30 May 1997 (30.05.97)

(30) Priority Data:
PO 0229 4 June 1996 (04.06.96) AU

(71) Applicants (*for all designated States except US*): THE UNIVERSITY OF QUEENSLAND [AU/AU]; St. Lucia, QLD 4067 (AU). COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION [AU/AU]; 407 Royal Parade, Parkville, VIC 3052 (AU).

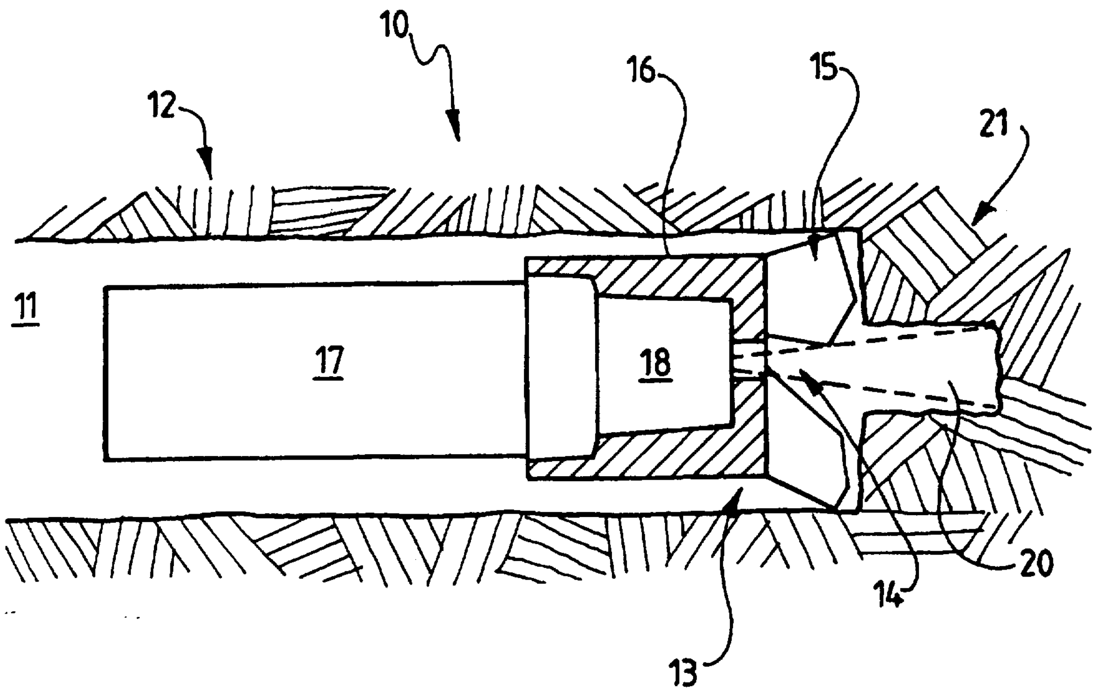
(72) Inventors; and
(75) Inventors/Applicants (*for US only*): DUNN, Paul, Gregory [AU/AU]; Experimental Mine, Isles Road, Indooroopilly, QLD 4068 (AU). STOCKWELL, Matthew [AU/AU]; Experimental Mine, Isles Road, Indooroopilly, QLD 4068 (AU). LIU, Yuzhou [CN/AU]; Experimental Mine, Isles Road, Indooroopilly, QLD 4068 (AU).

(74) Agent: CULLEN & CO.; Level 12, 240 Queen Street, Brisbane, QLD 4000 (AU).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, 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.

(54) Title: A DRILLING APPARATUS AND METHOD



(57) Abstract

A hydromechanical cutter for soft solids such as coal has most of the cutting done by central fluid cutters, but includes a peripheral mechanical cutter to keep the bore hole of uniform diameter. Straighter holes can be formed. The cutter can be deviated by having an angled fluid cutter which cuts into the bore wall to form a wash out when the fluid cutting pressure is increased.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

TITLE

A DRILLING APPARATUS AND METHOD

FIELD OF THE INVENTION

This invention relates to a drilling apparatus and method and particularly relates to a drilling apparatus and method to drill long, substantially straight holes in a solid such as coal.

BACKGROUND ART

In underground coal mining of gassy seams, it is important to drain the seam gases from the coal prior to excavation of the coal. Fairly small diameter bores are drilled into the coal seam to drain trapped methane. The bores need to be several hundred metres long and have a typical diameter of between 5cm - 15cm. Bore holes of 1 kilometre or more would also be useful, but difficulties exist with forming and dewatering the bore hole over such distances.

Other mining and petroleum operations also require bores to be drilled in relatively soft solids, for instance to provide samples, determine geological features and to drain water.

Conventionally, these bores have been drilled using a mechanical drill bit mounted at the end of a rotating steel drillstring. Down hole motor (DHM) drilling can be used to drill holes straight enough for gas drainage purposes, however, there are some existing disadvantages. Firstly, the productivity of DHM drilling is roughly half of that of rotary drilling. Secondly, there is an appreciable increase in the "down hole" capital cost. Lastly, the holes, and especially long holes, snake from side to side, and this can affect the gas drainage process and also limits the ultimate depth that any hole can go for a given rig capacity (reduced drag in hole).

Mechanical cutting suffers from three main disadvantages. The first disadvantage is the high torque required to turn the cutter and to rotate the drillstring. Also, a large feed force is required to push the drillstring along the bore and to ensure that the mechanical cutter is hard up against the coal face (or the face of the solid to be cut). This can cause buckling and torsion of the drillstring in the bore, and also contributes to undesired hole deviation.

The second main disadvantage with rotary drilling using mechanical cutters is the difficulty in keeping the bore straight as it is being drilled. For gas drainage, it is important that a number of accurately parallel straight bores are drilled into the coal seam to ensure that the seam gases are effectively drained. Should the bores deviate from each other, large areas of coal can be bypassed thereby forming a hazard from ineffective drainage of the seam. Also, deviation of the drillstring causes shorter holes to be drilled than otherwise required. For instance, it has been estimated that more than 50% of holes have problems of one sort or another. It is estimated that 46% of the holes do not go the required distance due to the drillstring deviation, or collapse, and up to 7% of the holes do not go in the desired direction, or intersect another hole by not being drilled straight. Non straight holes make it harder to push in the drill rods and increases the probability of the drill string buckling in the hole.

The third main disadvantage is that the drill string is not readily steerable.

Known attempts to straighten the drilled hole by adding stiffness to the drillstring, for instance, by using stabilisers, have met with only limited success, as making the drillstring stiffer and more inflexible does not form bore holes straight enough for long hole drilling.

It has been found that when boring gas drainage holes in coal seams, the weakness plane (main cleat) in the coal causes the mechanical cutter to follow the cleat and therefore to deviate from a required straight line. Where for gas drainage purposes it is necessary to drill holes at an angle other than normal to the main cleat direction, it has been found that the hole deviates to preferentially follow the main cleat direction.

Drilling systems using mechanical cutters and fluid jets are known. A common system uses mechanical cutting with the fluid jets functioning to flush away the cuttings from the cutter. US Patent 4,784,231 describes such a system.

Another known system uses a mechanical cutter with high pressure water jets which function to protect the mechanical cutting bit. US Patent 4,359,115 describes such a system.

Drilling systems using mainly mechanical cutting but also a small amount of fluid cutting are less well known. US Patent 4,106,577 describes a hydromechanical drilling device where most of the cutting is by a conventional roller cone but where a central high pressure water jet bit cuts a small diameter pilot hole in advance of the main mechanical cutter. This device does not overcome all the problems associated with mechanical drilling, such as the high torque and feed forces and deviation of the bore hole.

US Patent 4,535,853 describes a mechanical cutter having a central bursting cone shaped wedge and a peripheral cutter. Fluid jets are positioned peripherally to assist with the mechanical cutting. In one embodiment, the central wedge is removed and replaced with a single fluid cutting jet. This cutter does not overcome the disadvantage of irregular wall diameter as fluid cutting jets are positioned on the periphery of the cutter.

Another known drilling system uses pure fluid cutting without using any mechanical bit. Fluid cutting has a number of advantages. Firstly, there is less torque required and less feed force required as the cutting is done largely or wholly by fluid power as opposed to mechanical cutters. Another advantageous effect of fluid cutting is that a fluid cutting drill does not appear to be affected by the cleat in a coal seam. Thus, a fluid cutting assembly will drill a straighter hole than a purely mechanical cutting assembly.

However, while a fluid cutter does not appear to be influenced by the cleat in the coal, it still tends to droop downwardly resulting in the formation of a downwardly curving bore hole, which is unacceptable.

An attempt has been made to provide some directional steering to a fluid cutter. This known fluid cutter has a rotating nozzle attached to a non-rotating steel drillstring. Behind the rotating nozzle is a bent sub. The bent sub can be rotated by rotation of the drillstring and this in turn effects steering of the fluid cutter. However, it is found that with a bent sub and rotating nozzle arrangement, acceptable holes can still not be bored and it is considered most likely that rotation of the bent sub causes snaking of the bore hole, which limits the ultimate length of the hole.

It is known to provide a mechanical cutter with a fluid nozzle where the fluid functions to flush away the chips to reduce wear on the cutter caused by reducing the regrinding action of the chips. The fluid can also function to clean the grinding teeth of the cutter. The fluid nozzle is not designed for cutting and does not cut the coal in an area where the mechanical cutter will not also cut.

After much research and experimentation, an apparatus and method has now been developed which can allow the formation of acceptably straight bores in a solid such as (but not limited to) coal. This allows for more effective gas drainage, and reduces the risk of outbursts of gas or explosions occurring in the mine caused by a large body of solid not being properly drained due to deviation of the bores.

OBJECT OF THE INVENTION

It is an object of the invention to provide a method an apparatus which may overcome the abovementioned disadvantages or provide the public with a useful or commercial choice.

In one form, the invention resides in a method for drilling holes in a solid such as coal, the method comprising using a combination of simultaneous fluid cutting and mechanical cutting characterised in that the fluid cutting is performed in the central area of the hole to be drilled, and the mechanical cutting is performed in the peripheral area of the hole to be drilled.

In another form, the invention resides in a cutting apparatus for forming holes in a solid such as coal, the apparatus having a leading cutting face having at least one fluid cutter to cut a central area of the hole and at least one mechanical cutter to cut a peripheral area of the hole.

While not wishing to be bound by theory, it appears that the conventional fluid only cutters are not able to cut a smooth wall bore of the correct size. It appears that the fluid only cutters cut a bore which is larger than necessary and irregular in diameter and this results in the fluid cutter drooping downwardly by a gravity effect, and also produces an unstable hole which can affect gas drainage.

The method and apparatus according to the invention minimises drooping of the bore hole by providing a combination of peripheral mechanical cutting to ensure that the bore hole is of an acceptable constant diameter to create a stable hole, and central area fluid cutting to cut the central area . This combination enhances the efficiency of the drilling action.

A further advantageous property of the method and apparatus is that the combination of fluid and mechanical cutting can result in smaller cuttings which are easier to flush from the borehole.

The abovementioned disadvantages of mechanical cutting are greatly reduced by having a major portion, and preferably almost all of the cutting of the hole done by the fluid cutters. It is preferred that more than 50% and preferably 50% - 90% of the hole is cut by the fluid cutters, with the remainder minor portion being cut by the mechanical cutter.

The cutting apparatus may have a main body portion and a forward or leading cutting face. The cutting face may be rotatable relative to the main body portion (with a non-rotating drillstring), or may be fixed to the main body portion such that the drillstring is rotated to rotate the apparatus.

It is preferred that the at least one fluid cutter is positioned in a central area on the cutting face. The fluid cutter may comprise one or more high pressure nozzles. High pressure fluid can be passed through the drillstring or through an hydraulic hose and to the fluid cutter.

The fluid pressure can vary between 10 - 100MPa in coal, with a preferred range being between 20 - 40MPa. In other harder materials, higher pressures of up to 400MPa may be required. The pressure should be such that when drilling a straight hole, the fluid cutters cut the central area of the bore without extending the cutting to the peripheral area and this will vary depending on the solid .

A typical fluid flow range is between about 100 to 250 litres per minute, and the preferred fluid is water which may optionally contain additives, for instance acids to provide a dilute acidic solution. Thus the fluid cutting can be seen as high pressure/low volume relative to flushing nozzles.

The one or more nozzles are positioned such that high pressure fluid cuts only a central area of the bore to be cut. By central area is meant the area in front of the fluid cutter and extending from a central point up to but not including the peripheral area of the bore.

The nozzle(s) can be fixed relative to the remainder of the apparatus, and/or can comprise a spinning nozzle(s). The nozzles can jet cutting fluid in line with the direction of travel of the apparatus, but can also be inclined to direct cutting fluid towards the periphery. A combination of in line nozzles and angled nozzles can be used. If an angled nozzle is used, the pressure should be adjusted such that the cutting fluid does not cut beyond the central area.

The cutting face also includes a peripheral mechanical cutter to mechanically cut the peripheral area of the bore but not the central area of the bore. The type of mechanical cutter can vary and may include a drag drill bit, a PDC (Polycrystalline Diamond Compact) drill bit or a Pineapple-shaped drill bit (tungsten carbide).

It is possible to position at least one additional mechanical cutter bit inwardly from the peripheral area to assist in the cutting of the central area, but the majority of the cutting in this area will be by the fluid cutters.

The mechanical cutter cuts a peripheral area of the bore by which is meant the outer part of the bore not cut by the fluid cutter. The peripheral area of the bore is preferably the same or only slightly larger than the diameter of the cutting apparatus.

By having a peripheral mechanical cutter arrangement, the diameter of the bore can be maintained fairly constant over the length of the bore. This in turn minimises droop of the bore by what appears to be gravity effect as the cutter moves along, and minimises hole instability. If desired, stabilisers can be fitted to the drill string.

It is preferred that the fluid cutter cuts the majority of the bore as fluid cutting is independent of the cleat effect, but that the fluid cutter does not cut the peripheral portion of the bore which is to be cut by the mechanical cutter which allows the bore to have a much more constant diameter along its length which minimises the droop effect, and minimises hole instability.

It is found that the method and apparatus according to the invention allows acceptably straight bore holes to be drilled in coal for several hundred metres with a water pressure of about 20MPa and a water flow rate of about 150 litres per minute. The method and apparatus requires about a quarter of the feed force required for normal rotary drilling, this being due to the fluid cutter cutting a significant portion of the bore while the mechanical cutter cuts only a minor portion of the bore.

BRIEF DESCRIPTION OF THE FIGURES

An embodiment of the invention will be described with reference to the following drawings in which

Figure 1 is a schematic view of a cutting apparatus according to a first embodiment of the invention.

Figures 2A and 2B illustrate section and end views of the forward part of a cutting apparatus according to a second embodiment of the invention.

Figures 3A and 3B illustrate section and end views of the forward part of a cutting apparatus according to a third embodiment of the invention.

Figures 4A and 4B illustrate section and end views of the forward part of a cutting apparatus according to a fourth embodiment of the invention.

BEST MODE

Referring to Figure 1, there is shown a cutting apparatus 10 for cutting a bore 11 in a coal seam 12. Cutting apparatus 10 has a leading cutting face 13 which has a central fluid cutter 14 in the form of a high pressure nozzle, and a peripheral mechanical cutter 15 which can be of various types. Mechanical cutter 15 is attached to a cutter head 16 which is itself attached to a main body portion 17, or a drillstring. High pressure fluid of about 20 MPa passes through the drillstring (or an auxiliary hose), into fluid chamber 18 and through nozzle 14 to fluid cut a central area 20 in the coal seam. Nozzle 14 is designed to only cut a central portion as illustrated in Figure 1 and does not cut a peripheral portion 21. The peripheral portion 21 is cut by the mechanical cutter 15 which can provide a much greater degree of control of the bore hole diameter, and cutter 21 is not designed to cut the central portion 20.

Referring to figure 2A and 2B there is illustrated the cutting head 25 of the cutting apparatus. Cutting head 25 is mounted for spinning rotation according to known techniques. Cutting head 25 is formed from steel and has three lobes 29-31. The cutting head has three fluid cutting nozzles 26 -28. Two of the nozzles 26,27 pass high pressure (about 20MPa) fluid directly in front of the cutting head to damage the central zone of the coal, or other solid being cut. The third nozzle 28 is angled at about 30 degrees to pass high pressure fluid towards the periphery of the bore. The fluid pressure is regulated such that the third nozzle cuts the central area of the solid inwardly from the periphery, when a straight bore is being cut. For coal, a fluid pressure of about 20 MPa is satisfactory. If the fluid pressure is too high, third nozzle will start to cut into the peripheral area and this is not desirable when a straight hole is to be cut.

Each of the lobes 29-31 has a forwardly projecting mechanical cutting bit 32 - 34. The bits are positioned to cut and smooth the periphery of the bore, and the bits extend beyond the fluid nozzles 26 - 28. One additional bit 35 is positioned adjacent the nozzles and this bit assists in cutting away the central area of the solid being cut. This bit is however ancillary to the main cutting of the central area which is carried out by the fluid cutters

Referring to figures 3A and 3B, a third embodiment of the invention is illustrated. In this embodiment, like parts have been given like numbers. The main difference is that fixed nozzles 27, 28 in figures 2A, 2B have been replaced by a single in line spinning nozzle 40. Nozzle 40 is more or less of known design and has two jets 41, 42 offset at 45 degrees to each other. When nozzle 40 spins, the two jets 41, 42 form a cone of cutting fluid which extends straight ahead. Nozzle 40 is positioned 20mm. from the centre line of the cutting head. Again, the pressure needs to be regulated to ensure that the cone of cutting fluid cuts only the central portion of the coal or other solid, and does not extend into the peripheral area when a straight bore is being cut.

Figures 4A and 4B illustrate a variation of the cutting head of figures 3A and 3B, where the spinning nozzle 43 is angled towards the periphery of the bore to be cut.

In each of the embodiments, the fluid cutters are designed to cut most of the hole, with the mechanical cutter cutting only a minor portion. Typically, over 50% and usually 50% - 90% of the hole is cut by the fluid cutters. This arrangement gives the advantages of fluid cutting (straighter holes, less power consumption) while minimising the disadvantages of fluid cutting (irregular bore hole size)

The reason for having the angled or offset fixed nozzle 28 (see figures 2A, 2B), or the spinning nozzles of figures 3A,3B,4A and 4B, is to allow the cutting apparatus to change direction at any desired position, for instance, should the bore require deviation. In brief, this is achieved by stopping the drill string, increasing the fluid pressure to deliberately allow the angles or spinning fluid nozzles to cut into the periphery of the bore. This provides a wash out cavity in the bore wall, and the apparatus will pass into the wash out cavity.

In an example, a bore is cut in coal using the drill of figures 3 or 4 and at a pressure of 20 MPa which prevents the offset nozzles from cutting into the periphery of the bore as the drill advances. If bore deviation is required, the drill string is stopped. The cutting head is positioned (for instance by slight rotation of the drill string) to point the offset nozzle towards the desired part of the bore hole wall. The water pressure is raised to 40 MPa which will cause the offset nozzle to cut towards and into the periphery of the bore wall. The remaining nozzles will continue to cut straight ahead. The bore wall is washed out, or cavitised, by the offset nozzle. Forward thrust is resumed on the drill string which will cause the cutting apparatus to move into the wash out area and thus change direction. The water pressure is reduced to 20 MPa and the straight hole drilling process is continued.

It can be seen that the apparatus and the method allows acceptably straight long bore holes to be drilled. The feed forces and the torque forces are considerably less as much of the cutting is done by the fluid cutter which does not require the cutter to be forced hard-up against the coal seam. The peripheral mechanical cutter cuts only a relatively small portion of the bore and therefore requires reduced torque and much less feed force to make it operate effectively.

It should be appreciated that various other changes and modifications may be made to the embodiment described without departing from the spirit or scope of the invention.

CLAIMS:

1. A cutting apparatus for forming holes in a solid such as coal, the apparatus having a leading cutting face having at least one fluid cutter to cut a major central area of the hole and at least one mechanical cutter to cut a minor peripheral area of the hole.

2. The apparatus of claim 1 having a main body portion and a forward or leading cutting face.

3. The apparatus of claim 2, wherein at least one fluid cutter comprising a fluid nozzle is positioned in a central area of the cutting face.

4. The apparatus of claim 3, wherein a plurality of said fluid nozzles are provided.

5. The apparatus of claim 4, wherein at least one said nozzle aims fluid towards the periphery of the hole.

6. The apparatus of claim 5, wherein the fluid pressure at the nozzles is such that when drilling a straight hole, the fluid cutters cut the central area of the bore without extending the cutting to the peripheral area.

7. The apparatus of claim 6, wherein the fluid pressure is between 10 - 100MPa, and preferably between 20 - 40MPa.

8. The apparatus of claim 5, wherein the nozzle(s) are fixed relative to the remainder of the apparatus, and/or can comprise a spinning nozzle(s).

9. The apparatus of claim 1, wherein the cutting face includes a peripheral mechanical cutter to mechanically cut the peripheral area of the bore but not the central area of the bore.

10 The apparatus of claim 9, wherein at least one additional mechanical cutter bit is spaced inwardly from the peripheral area to assist in the cutting of the central area.

11. The apparatus of claim 1, wherein the fluid cutter cuts more that 50% of the hole, and preferably cuts more that 80% of the hole.

12. A method for drilling holes in a solid such as coal, the method comprising using a combination of simultaneous fluid cutting and mechanical cutting characterised in that the fluid cutting is performed in the central area of the hole to be drilled, and the mechanical cutting is performed in the peripheral area of the hole to be drilled.

13. The method of claim 12, wherein the fluid cutting pressure is about 20 MPa when a straight hole is to be formed.

14. The method of claim 13, wherein a portion of cutting fluid is directed to the hole side wall and when a change in cutting direction is desired, the fluid pressure is increased to cause the cutting fluid to cut a cavity into the hole wall to form a change in cutting direction, whereafter the fluid pressure is reduced such that the cutting fluid does not cut into the hole side wall

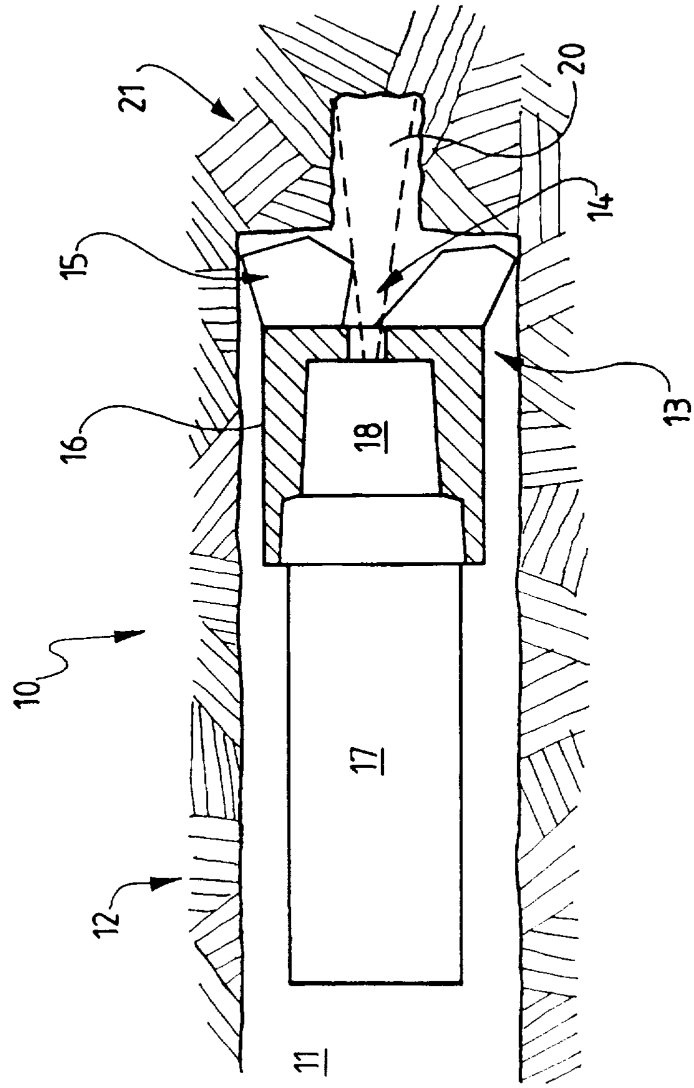


Fig. 1

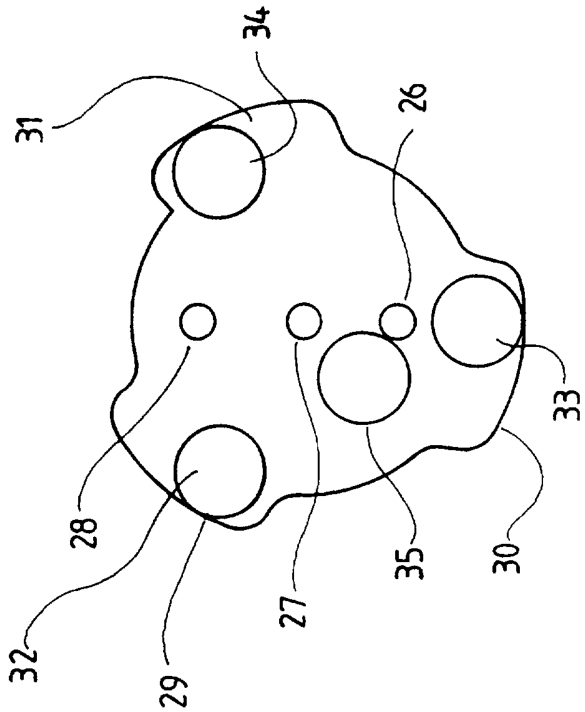


Fig. 2B

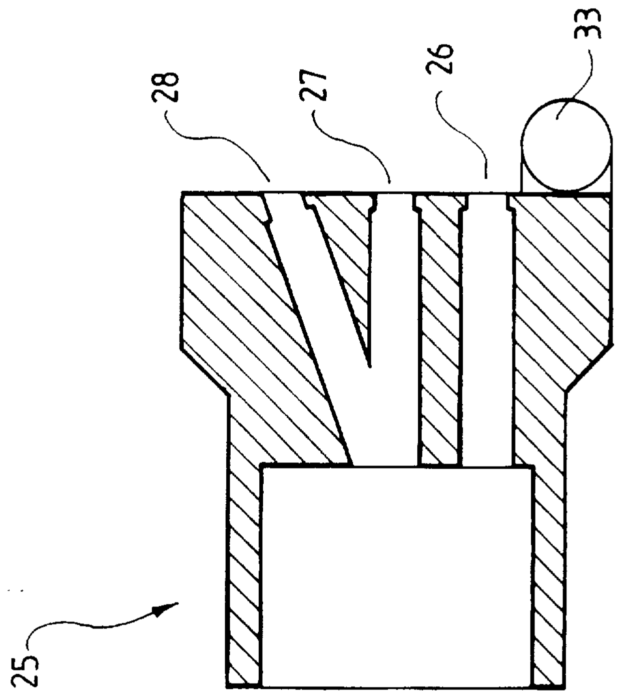


Fig. 2A

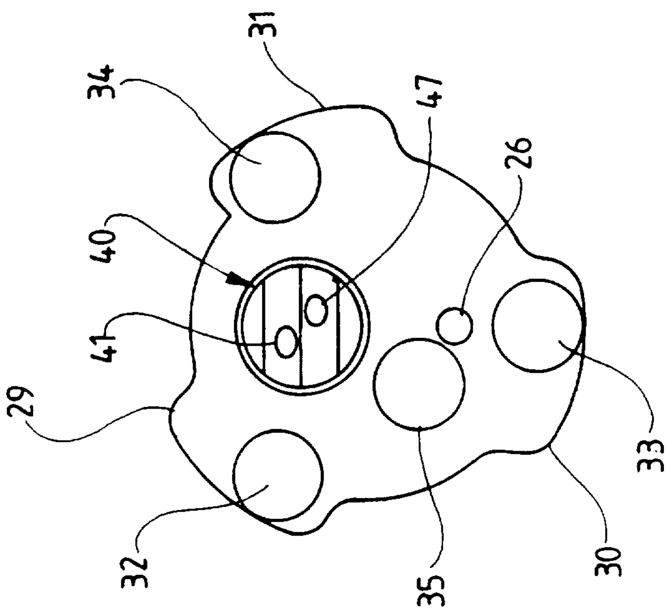


Fig. 3B

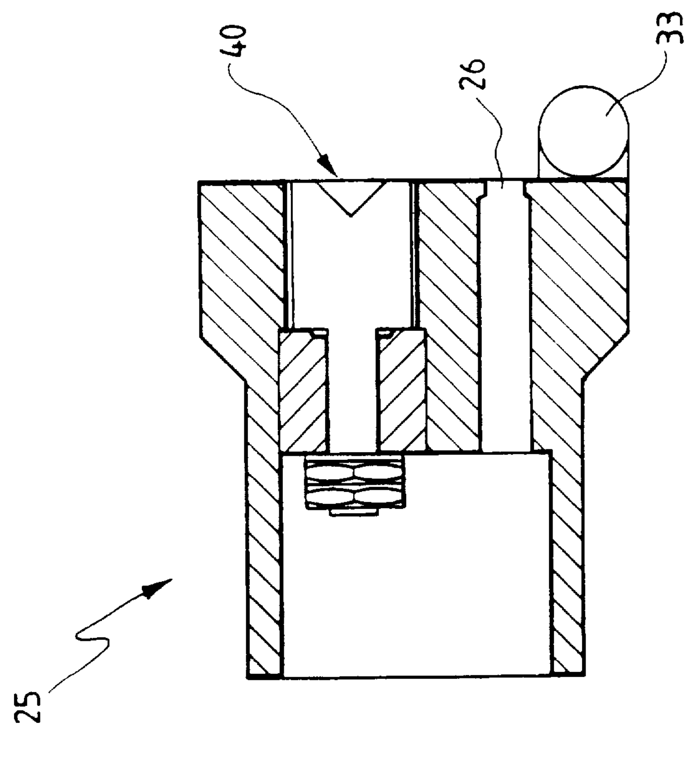


Fig. 3A

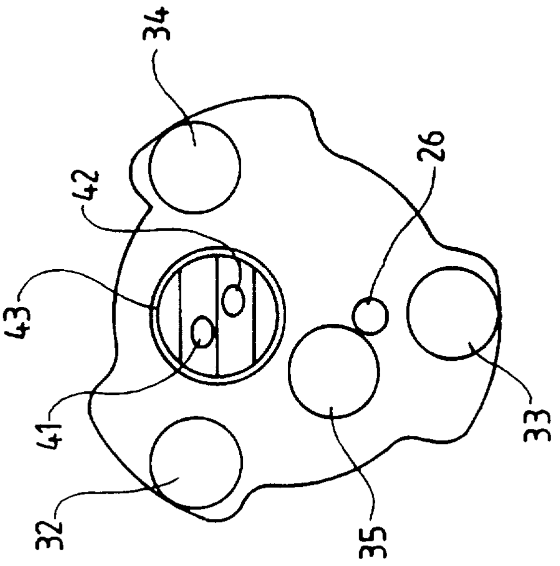


Fig. 4B

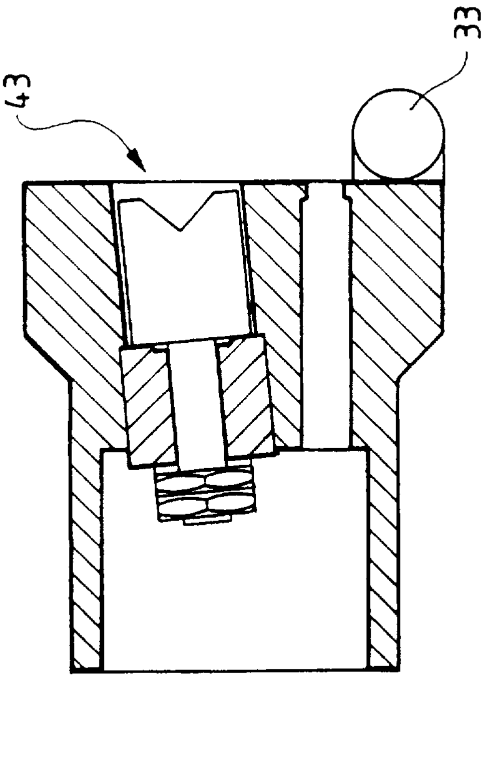


Fig. 4A

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00341

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: E21B 7/18, 10/60

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 7/18, 10/60

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: E21B 7/18, 10/60

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
1. CUTTER OR BIT: OR SLIT:
2. PERIPHERAL OR CENTRAL: OR CENTRE OR CENTER

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
X	US 4 106 577 A (SUMMERS) 15 August 1978 see figure 1	1-14
X	US 4 262 757 A (JOHNSON JR. et al) 21 April 1981 see figures 1 and 5	1-14
A	US 4 341 273 A (WALKER et al) 27 July 1982	

[X] Further documents are listed in the continuation of Box C

[X] 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
27 June 1997

Date of mailing of the international search report
02 JUL 1997

Name and mailing address of the ISA/AU
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION
PO BOX 200
WODEN ACT 2606
AUSTRALIA Facsimile No.: (06) 285 3929

Authorized officer

S. GHOSH

Telephone No.: (06) 283 2163

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00341

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
A	US 4 543 427 A (WANG et al) 13 August 1985	
A	US 4 535 853 A (IPPOLITO et al) 20 August 1985	
A	US 4 624 327 A (REICHMAN) 25 November 1986	
P, A	US 5 542 486 A (CURLETT) 6 August 1996	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/AU 97/00341

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	4 106 577	NONE					
US	4 262 757	CA	1 100 126	US	4 391 339		
US	4 341 273	CA	1 159 441	EP	043 609	JP	57/044095
		MX	152 782				
US	4 534 427	NONE					
US	4 535 853	AU	22786/83	CA	1 202 955	EP	114 016
		FR	2 538 442	JP	59/173482	ZA	8 309 456
		AU	50645/85	BR	8 506 979	DK	2736/86
		EP	198 060	MX	162 577	NO	862 365
US	4 624 327	WO	86/02403	US	4 691 790		
US	5 542 486	AU	85209/91	BR	9 106 809	EP	591 196
		NO	930 772	US	5 199 512	WO	92/04528
		US	5 291 957				

END OF ANNEX