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Published:

- with international search report (Art. 21(3))
— with amended claims (Art. 19(1))

(54) Title: FLUID DRILLING HEAD NOZZLE DESIGN

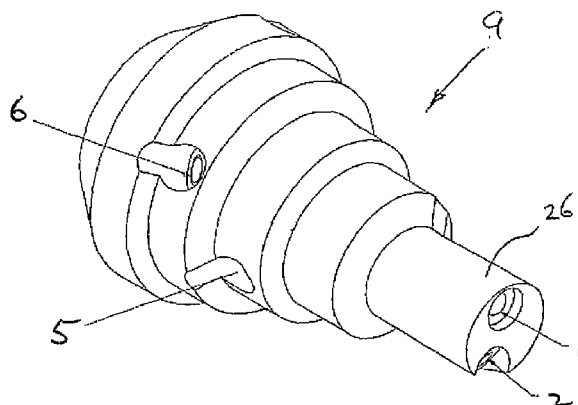


FIGURE 3

(57) Abstract: A fluid cutting head (8) of the type having a plurality of nozzles in a rotatable nozzle assembly (9) for cutting a bore hole in rock, has nozzles being arranged to be supplied with high pressure drilling fluid, forming jets positioned to cut adjacent rock. The nozzles include one or more generally axially facing pilot nozzles (1 and 2) and one or more generally radially facing reaming nozzles (3, 4, 5 and 6), at least the pilot nozzles being characterised by a non-tapering outlet section such that the jet issuing therefrom is of substantially constant cross-section in a zone immediately adjacent the outlet section. The pilot nozzles are located in a leading part (26) of the rotatable nozzle assembly (9), having a minimised diameter, while the reaming nozzles are located in the following part (27) of the rotatable nozzle assembly (9), formed in a step-wise fashion to keep the reaming nozzles close to the rock face.



Title of the Invention**"FLUID DRILLING HEAD NOZZLE DESIGN"**

[0001] This invention relates to the design of the nozzles and rotatable nozzle assembly for a fluid drilling head of the type generally described in our earlier international patent application PCT/AU02/01550 (international publication No. WO 03/042491 A1), the content of which is incorporated herein by way of cross reference.

Background of the Invention

[0002] In previously known forms of fluid drilling heads, it has been common to use a type of nozzle known as a "horn nozzle" having a diverging outlet portion designed to produce a powerful cavitation cloud for the cutting or breaking of rock in the drilling operation. Such a device is shown in Figure 2 of this specification.

[0003] Further research by the applicants has shown that while the cavitation cloud generated by horn nozzles of this type is indeed powerful, it is generated at a position remote from the nozzle outlet. The zone between the cavitation cloud and the nozzle outlet is a "dead zone" which is not effective in cutting rock adjacent to the nozzle outlet. Accordingly, placement of such nozzles to generate smooth and self-advancing geometry is very difficult due to the dead zone immediately in front of the pilot jets at the leading edge of the fluid cutting head, and effective design of the fluid cutting head is also difficult due to the physical size of the horn nozzles. Prior art devices of the type shown in Figure 2 need to be fed slowly into the bore hole to ensure the rock being cut stays remote from the front of the head. If the tool gets too close to the rock, the rock would be in the dead zone and a "stall" would result.

Summary of the Invention

[0004] The present invention therefore provides a fluid cutting head of the type having a plurality of nozzles in a rotatable nozzle assembly for cutting a bore hole in rock, said nozzles being arranged to be supplied with high pressure drilling fluid, forming jets positioned to cut adjacent rock, said nozzles including one or more generally axially facing pilot nozzles and one or more generally radially facing reaming nozzles, at least the pilot nozzles being characterised by a non-tapering outlet section such that the jet issuing therefrom is of substantially constant cross-section in a zone immediately adjacent the outlet section.

[0005] Preferably, the reaming nozzles are also characterised by a non-tapering outlet section such that the jet issuing therefrom is of substantially constant cross-section in a zone immediately adjacent the outlet section.

[0006] Preferably, the leading part of the rotatable nozzle assembly incorporating the pilot nozzles is of significantly lesser diameter than the following part of the rotatable nozzle assembly incorporating the reaming nozzles.

[0007] Preferably, the following part of the rotatable nozzle assembly is formed in a stepwise fashion of steps of progressively increasing diameters, there being one reaming nozzle located in each step such that the jet issuing from each reaming nozzle is located close to the adjacent bore hole surface.

Brief Description of the Drawings

[0008] Notwithstanding any other forms that may fall within its scope, one preferred form of the invention will now be described by way of example only with reference to the accompanying drawings, in which:

[0009] Figure 1 is side view of a fluid drilling head according to the invention;

[0010] Figure 2 is a diagrammatic representation of a prior art fluid drilling head showing the formation of cavitation clouds remote from the nozzle outlets;

[0011] Figure 3 is a right hand perspective view of the rotatable nozzle assembly of a fluid drilling head according to the invention;

[0012] Figure 4 is a left hand perspective view of the rotatable nozzle assembly of a fluid drilling head according to the invention;

[0013] Figure 5 is an end view of the rotatable nozzle assembly shown in Figures 3 and 4;

[0014] Figure 6 is a side view of the rotatable nozzle assembly shown in Figures 3 and 4, and

[0015] Figure 7 is a cross-sectional view through a nozzle of the type used in the fluid drilling head according to the invention.

Detailed description of the Preferred Embodiments of the Invention

[0016] In the preferred form of the invention, a fluid drilling head 8 typically has a rotatable nozzle assembly 9 and may incorporate other features such as a gauging ring 10 mounted at the leading end of a drill head body 11.

[0017] The more detailed configuration of the rotatable nozzle assembly 9 will be described below with reference to Figures 3 to 7, which demonstrate how the nozzle design and placement can be optimised to overcome the problems of a typical prior art fluid drilling head of the type shown at 12 in Figure 2.

[0018] In the typical prior art fluid drilling heads, the rotatable nozzle assembly 13 is provided with pilot nozzles 14 and reaming nozzles 15 which are typically of a "horn nozzle" design having a diverging outlet portion. Nozzles of this type generate

powerful cavitation clouds shown diagrammatically at 16 which are effective in cutting and breaking up rock. It has been found through careful laboratory testing that while the cavitation clouds 16 generated by the nozzles 14 and 15 are indeed powerful, they are remote from the nozzle outlets as clearly shown in Figure 2 resulting in a "dead zone" 17 between the cavitation cloud 16 and the nozzle outlets. Because of the dead zone, prior art tools of this nature need to be fed slowly into the hole to ensure that the rock being cut stays remote from the front surface 18 of the head. Once the front surface 18 advances too quickly into the rock face, the cavitation cloud 16 is no longer effective and the jet issues against the rock face in the dead zone 17.

[0019] The present invention overcomes this deficit by providing nozzles of the type shown in Figure 7 where the nozzle 18 is typically inserted into a hole 19 formed in the rotatable nozzle assembly 20 and secured in place by a threaded engagement 21.

[0020] The nozzle is typically formed to sit in a counter bore 22 such that the top of the nozzle thread 23 sits flush with the base of the counter bore.

[0021] While the inlet portion 24 of each nozzle is typically tapered inwardly to increase the velocity of the high pressure water pumped through the nozzle, the outlet section 25 is formed of non-tapering section as is clearly seen in Figure 7 such that the jet issuing therefrom is of substantially constant cross-section in the zone immediately adjacent the outlet section.

[0022] It has been found that the use of nozzles formed to this configuration results in a jet which is effective at cutting or breaking rock immediately adjacent the outlet from the nozzle, so avoiding the dead zone 17 typically found in the prior art nozzle configurations.

[0023] In order to maximise the rock cutting effect of nozzles of this type, it has also been found most effective to form the rotatable nozzle assembly in steps such that the

leading part 26 incorporating the pilot nozzles forming jet 1 and jet 2 is of significantly lesser diameter than the following part 27 of the rotatable nozzle assembly incorporating the reaming nozzles.

[0024] The reaming nozzles 3, 4, 5, and 6 are typically located to provide reaming jets as shown in Figures 3 and 4 and are located at 29, 30, 31 and 32 respectively as can be clearly seen in Figure 6.

[0025] In this manner, the following part 27 of the rotatable nozzle assembly 9 is formed in a stepwise fashion of progressively increasing diameters, there being one reaming nozzle located in each step such that the jet issuing from each reaming nozzle is located close to the adjacent bore hole surface.

[0026] This has been found to be most effective in maximising the operation of each reaming jet, allowing the reaming jets to issue from their nozzles close to the surface of the bore hole to be reamed and enlarged until the final bore hole diameter is achieved. Ultimately, the bore hole diameter is controlled by the gauging ring 10.

[0027] This effect is optimised by reducing the diameter of the leading part 26 as much as physically possible so that the pilot jet rock cutting function is reduced compared with the progressive enlargement of the bore hole diameter from the reaming jets in the following stepped parts 27.

[0028] Combined with the use of nozzles of the type described above, this allows the reaming jets to operate close to the rock face and increase the diameter of the bore in a step-wise manner. Their rearward facing orientation of the reaming jets also allows much more efficient rock breaking at this close proximity.

[0029] Laboratory testing has shown that the zone within about 5 mm of the outlet from each reaming jet is very destructive, and much more so than the remote cavitation cloud of the horn nozzles used in prior art devices.

[0030] The actual diameters of the nozzle outlets are selected depending on the nature of the rock to be cut, as is the pressure of the water supplied to the nozzles through the fluid drilling head. Testing has shown that drilling is effective at pressures of 48 MPa to 73 MPa. 48 MPa is better in bright coals, and 73 MPa is better in claystone bands and sandstone.

[0031] Nozzle diameters vary depending on the material and nozzle location. The front pilot nozzles need be no greater than 0.7mm to 1.0 mm in diameter. It is best to minimise these sizes to improve net tool forward thrust, and a small change makes a big difference as they point virtually straight ahead. The reamers work well in the range between 0.5mm and 1.3mm, again depending on the coal conditions. The 310 m hole was drilled with 0.8 straight ahead, 0.9 forward angled, and 1.1 in the three reamers in this head. This, however, produced a penetration rate of around 1m/min.

[0032] In this manner, a rotatable nozzle assembly for a fluid drilling head can be provided which allows faster drilling rates than has previously been achieved with prior art drilling heads and further allows more accurate control of the bore hole size, and the effective location of the reaming nozzles.

Claims

1. A fluid cutting head of the type having a plurality of nozzles in a rotatable nozzle assembly for cutting a bore hole in rock, said nozzles being arranged to be supplied with high pressure drilling fluid, forming jets positioned to cut adjacent rock, said nozzles including one or more generally axially facing pilot nozzles and one or more generally radially facing reaming nozzles, at least the pilot nozzles being characterised by a non-tapering outlet section such that the jet issuing therefrom is of substantially constant cross-section in a zone immediately adjacent the outlet section.
2. A fluid cutting head as claimed in claim 1, wherein the reaming nozzles are also characterised by a non-tapering outlet section such that the jet issuing therefrom is of substantially constant cross-section in a zone immediately adjacent the outlet section.
3. A fluid cutting head as claimed in claim 2 wherein the reaming nozzles are orientated such that the jets issuing therefrom are angled rearwardly relative to the direction of travel of the cutting head.
4. A fluid cutting head as claimed in any one of the preceding claims, wherein the leading part of the rotatable nozzle assembly incorporating the pilot nozzles is of significantly lesser diameter than the following part of the rotatable nozzle assembly incorporating the reaming nozzles.
5. A fluid cutting head as claimed in claim 4, wherein the following part of the rotatable nozzle assembly is formed in a stepwise fashion of steps of progressively increasing diameters, there being at least one reaming nozzle located in each step such that the jet issuing from each reaming nozzle is located close to the adjacent bore hole surface.

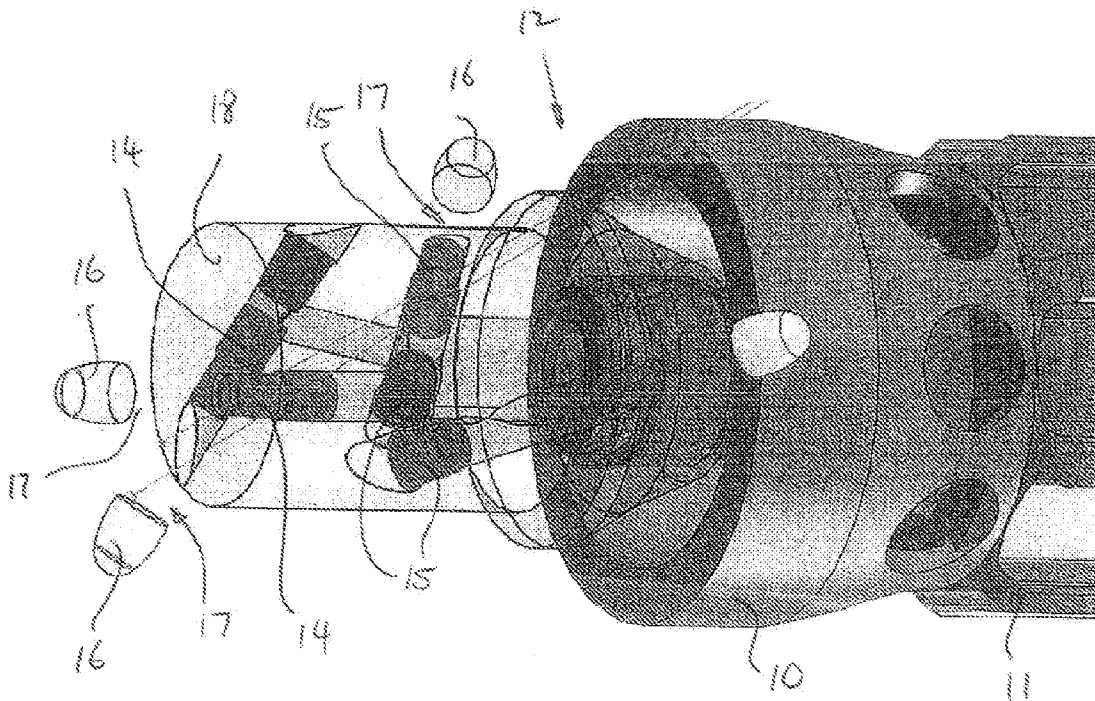
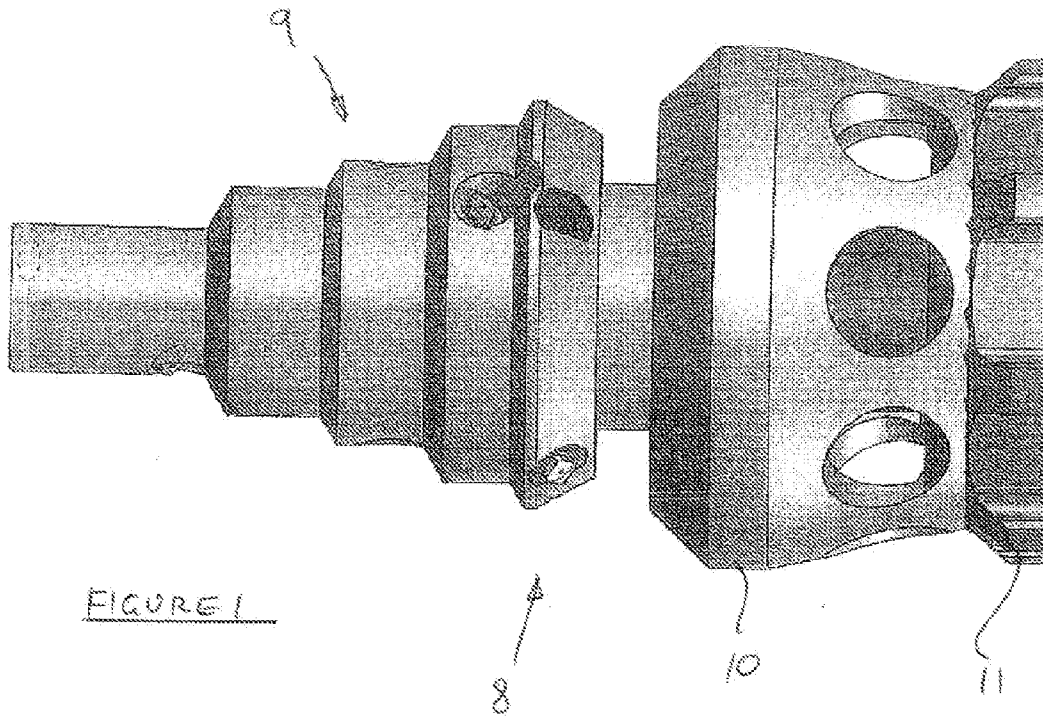
6. A fluid cutting head as claimed in any one of the preceding claims wherein one or more of the nozzles have an inlet portion of inwardly tapering section upstream of the non-tapering outlet section.
7. A fluid cutting head as claimed in any one of the preceding claims wherein the pilot nozzles have an internal diameter less than 1.0 mm.
8. A fluid cutting head as claimed in any one of the preceding claims wherein the reaming nozzles have an internal diameter less than 1.3 mm.
9. A fluid cutting head as claimed in claim 8 wherein the reaming nozzles have an internal diameter between 0.5 mm and 1.3 mm.
10. A fluid cutting head when constructed arranged and operable substantially as described herein with reference to the accompanying drawings.

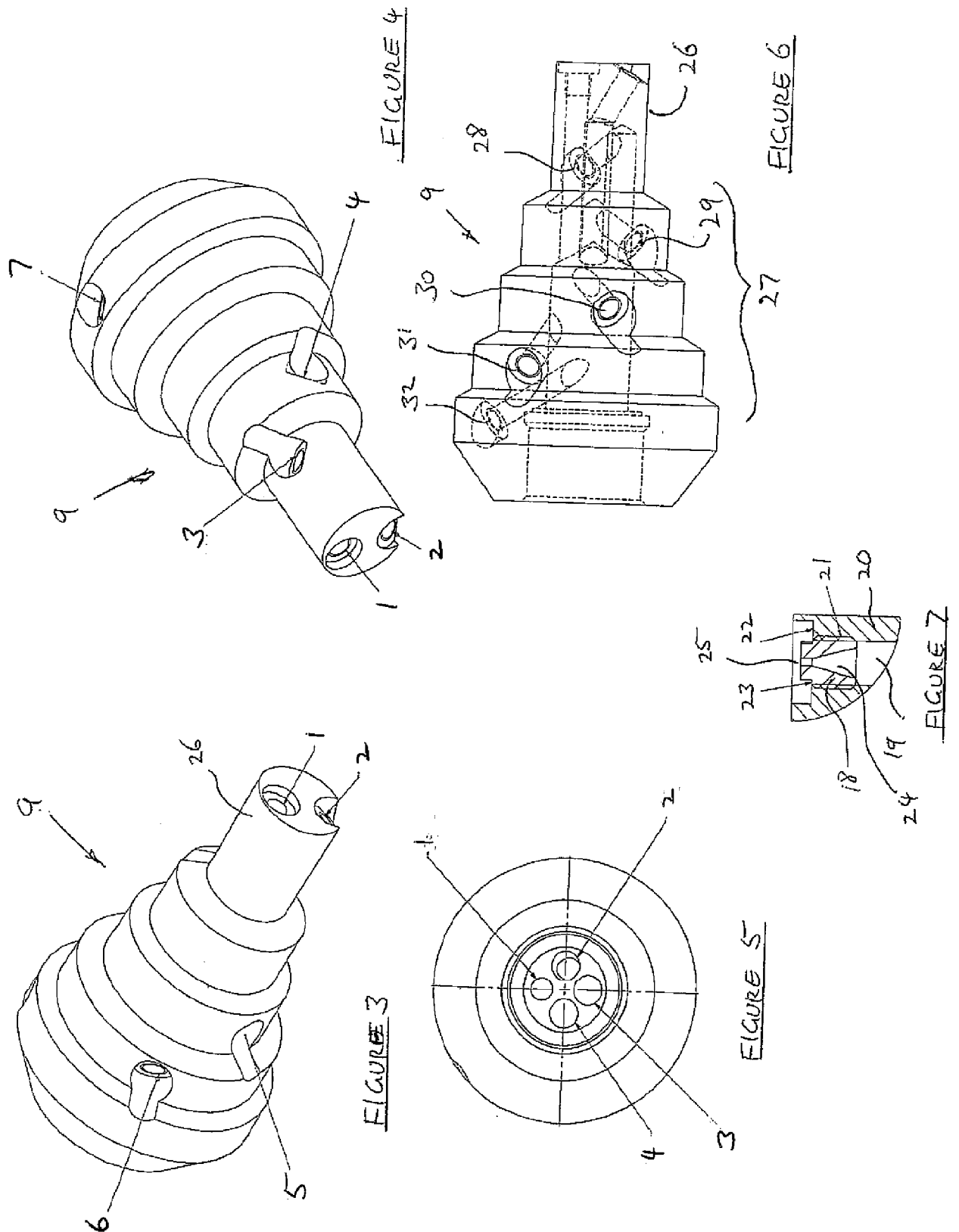
AMENDED CLAIMS
received by the International Bureau on
21 June 2012 (21.06.12)

Claims

1. A fluid cutting head of the type having a plurality of nozzles in a rotatable nozzle assembly for hydraulically cutting a bore hole in rock, said nozzles being arranged to be supplied with high pressure drilling fluid, forming jets positioned to cut adjacent rock, said nozzles including one or more generally axially facing pilot nozzles and one or more generally radially facing reaming nozzles, at least the pilot nozzles being characterised by a non-tapering outlet section such that the jet issuing therefrom is of substantially constant cross-section in a zone immediately adjacent the outlet section, and wherein the leading part of the rotatable nozzle assembly incorporating the pilot nozzles is of significantly lesser diameter than the following part of the rotatable nozzle assembly incorporating the reaming nozzles.
2. A fluid cutting head as claimed in claim 1, wherein the reaming nozzles are also characterised by a non-tapering outlet section such that the jet issuing therefrom is of substantially constant cross-section in a zone immediately adjacent the outlet section.
3. A fluid cutting head as claimed in claim 2 wherein the reaming nozzles are orientated such that the jets issuing therefrom are angled rearwardly relative to the direction of travel of the cutting head.
4. A fluid cutting head as claimed in any one of the preceding claims, wherein the following part of the rotatable nozzle assembly is formed in a stepwise fashion of steps of progressively increasing diameters, there being at least one reaming nozzle located in each step such that the jet issuing from each reaming nozzle is located close to the adjacent bore hole surface.

5. A fluid cutting head as claimed in any one of the preceding claims wherein one or more of the nozzles have an inlet portion of inwardly tapering section upstream of the non-tapering outlet section.
6. A fluid cutting head as claimed in any one of the preceding claims wherein the pilot nozzles have an internal diameter less than 1.0 mm.
7. A fluid cutting head as claimed in any one of the preceding claims wherein the reaming nozzles have an internal diameter less than 1.3 mm.
8. A fluid cutting head as claimed in claim 7 wherein the reaming nozzles have an internal diameter between 0.5 mm and 1.3 mm.
9. A fluid cutting head when constructed arranged and operable substantially as described herein with reference to the accompanying drawings.





INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2012/000168

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

E21B 7/18 (2006.01)*E21B 10/60* (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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 practicable, search terms used)

EPODOC & Derwent WPI: IPC & ECLA E21B 7/18/low, E21B 10/18, 10/60, 10/26/low with keywords fluid, liquid, water, gas, air, spray, jet, nozzle, constant, even, uniform, cylindrical, cross-section, non-varying, non-tapering, and the like

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4106577 A (SUMMERS) 15 August 1978 Abstract, Col 2 line 43-54; Figures 1 and 2	1-9
Y	WO 2003/042491 A1 (CRC FOR MINING TECHNOLOGY & EQUIPMENT) 22 May 2003 Abstract; Figures 1 & 2	1-9
Y	US 5199512 A (CURLETT) 06 April 1993 Abstract; Figures 1, 9 & 12	1-9



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

"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

"E" earlier application or patent but published on or after the international filing date

"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

"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)

"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

"O" document referring to an oral disclosure, use, exhibition or other means

"&" document member of the same patent family

"P" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search
22 March 2012

Date of mailing of the international search report
13/04/2012

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2012/000168

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Harris, H D et al., Cutting Rock with Waterjets, National Research Council of Canada, Ottawa KIA OR6, Canada; US Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755, USA; Received 25 January 1974, Available online 26 February 2003 [retrieved on 23 March 2012], Retrieved from the internet <URL: http://www.sciencedirect.com/science/article/pii/0148906274930988 > Abstract	1-9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2012/000168**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 10
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

This claim does not comply with Rule 6.2(a) because it relies on references to the description and/or drawings.
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2012/000168

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	4106577	NONE					
WO	03042491	BR	0214166	CA	2467003	CN	1623027
		CO	5590978	EP	1454029	PL	370861
		US	2005034901	US	7083011	ZA	200403930
US	5199512	AU	85209/91	BR	9106809	CA	2087539
		EP	0591196	JP	H06507216	NO	930772
		US	5291957	US	5542486	WO	9204528
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.							
END OF ANNEX							