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# In-seam Drilling Technologies for Underground Coal Mines

Y Liu<sup>1</sup>, P Dunn<sup>2</sup>, P Hatherly<sup>1</sup>

## ABSTRACT

There are several in-seam coal research projects currently under investigation by the Cooperative Research Centre for Mining Technology and Equipment (CMTE). The overall aim of the projects is to produce new technologies to enhance safety and the efficiency of in-seam gas drainage drilling. Results from high pressure waterjet rotary drilling trials indicate that by applying high pressure water to a rotary drill bit, the hole can be drilled to follow the planned trajectory very closely. Steerable drill bits for drilling long holes (>1 km) have been produced and trialed. A flexible high speed drilling system provides a capacity for rapid in-seam drilling, particularly suited to cross panel drainage. Geophysical tools are being developed to provide a geological steering capability and a better understanding of potential gas outbursts zones.

## INTRODUCTION

Established in 1991, the CMTE is recognised internationally as a centre of excellence with a track record for developing and delivering new technology to the Australian mining industry. The Centre has research programs in new mining and drilling systems, geological sensing, automation and design and reliability. Its research partners are The University of Queensland, Sydney University, Curtin University and CSIRO. The following Australian mining companies, equipment manufacturers and mining contractors are members of the Centre: BHP Coal Pty Ltd, Hamersley Iron Pty Ltd, Mining Technologies Australia Pty Ltd (MTA), Pasminco Australia Ltd, Technological Resources Pty Ltd, Shell Coal Ltd, WMC Resources Ltd, Aberfoyle Ltd and Advanced Mining Technologies (AMT).

Developing improved methods for in-seam drilling for gas drainage in underground coal mines has been highlighted by the industry and the CMTE as a research priority. The drilling related research includes a number of projects on in-seam gas drainage from coal seams including a flexible high speed drilling system for cross-panel gas drainage, high pressure waterjet rotary drilling for straight cross panel holes, steerable high pressure waterjet rotary drilling for long holes, tight radius drilling from the surface to access coal seams for pre-drainage and horizon sensing and logging of in-seam boreholes.

## COAL SEAM METHANE

The presence of methane within coal seams represents a significant hazard in underground coal mining. Prior to mining, the gas may need to be drained from the seam using drill holes drilled using one of two approaches. One is rotary drilling, in which torque is applied at the hole collar and transmitted to the drill bit along the drill string. The other is downhole motor (DHM) drilling. Here, as the name implies, a motor is located in the hole immediately behind the drill bit to provide the torque required for drilling. Holes drilled using DHM employ a bent-sub assembly which allows the drill head to be steered. The advantages of rotary drilling are that the capital cost of the drilling equipment is much less than for DHM and the rate of drilling is considerably greater than for DHM. The principal disadvantage of rotary drilling is that, at present,

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the drill cannot be steered during the drilling operation. A significant fraction of the holes that are drilled using the rotary method fail to reach their intended destination which results in the need to re-drill these holes. The importance of drilling rate in the cost effectiveness of the operation must be balanced with the ability to drill the holes in the places where they are needed.

The methane in coal seams is also a potential energy resource. In Australia there are a number of coal basins close to the major population centres of the east coast. These coal basins are estimated to contain in excess of  $10^{12}$  m<sup>3</sup> of methane (Paterson, 1990). Coal seam methane is easy to find and prove but comparatively expensive to extract. Currently the cost of coal bed methane, A\$5-7/GJig-joule, is at least double the cost of natural gas, A\$2-3/GJig-joule (Davis, 1995). The main reason for the higher extraction cost for coal seam methane is a lack of applicable economic drilling techniques. This is particularly true for Australian coal seams which generally have lower permeability and higher horizontal stresses than the US coal seams. Well enhancement techniques such as hydrofracing from a vertical well have not been economically successful in Australian coal seams. Conventional horizontal drilling from surface holes is also not cost effective as there are severe limitations in accessing multiple seams from a single vertical well. Improved drilling techniques for gas drainage in coal mining will also have an impact on the extraction of coal seam methane as an energy resource in its own right.

## SUMMARY OF CMTE GAS DRAINAGE DRILLING PROJECTS

### High pressure waterjet rotary drilling

In an effort to improve longwall productivity and address current safety issues associated with methane drainage, the CMTE has been investigating the applicability of high pressure water (20 to 40 MPa) for rotary drilling at both Appin (BHP Coal) and Dartbrook (Shell Coal) mines. The project builds on previous experience obtained under NERDDC (National Energy Research, Development and Demonstration Council) funding (Kennerley, 1993). The main objective of CMTE's work is to drill straight cross panel gas drainage holes and long gas drainage holes along the length of longwall blocks.

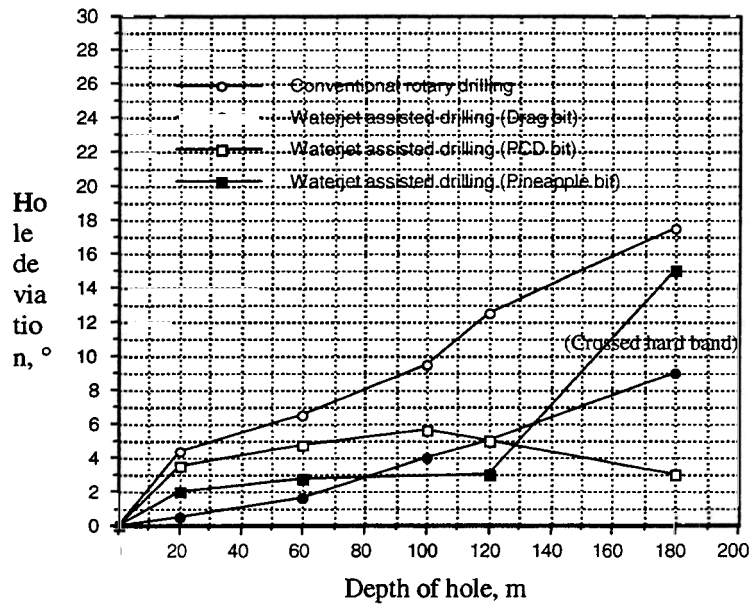
#### *High pressure waterjet rotary drilling for straight cross-panel gas drainage holes*

This project was supported by the Australian Coal Association Research Program (ACARP project no. C5028) and both Appin and Dartbrook Mines. The ultimate aim was to drill straighter and more accurate in-seam cross panel holes for methane drainage at a productivity greater than that achievable by DHM drilling technology.

A high pressure water pump (250 l/min at 80 MPa), suitable for use in the underground coal mine environment, was designed and manufactured for the drilling trials. As in Kennerley's work high pressure BQ drill string was used. Three types of high pressure drill bit (drag bit, PCD bit and pineapple bit) were ~~tested during~~ used in the field trials. Diamec 252 and Diamec 262 drill rigs were used. Phase 1 underground trials were conducted at Appin Colliery (Dunn, Liu and Stockwell, 1997). Subsequent tests (Phase 2) were at the Dartbrook Mine. All holes drilled were surveyed with an Eastman single shot camera (either pumped down or post-survey).

The following are the main findings:

1. High pressure waterjet rotary drilling has demonstrated significantly improved hole straightness over conventional rotary drilling. The average hole deviation, for the holes drilled by a PCD drill bit, was 7.6 metres. This was less than a quarter of the deviation of conventional rotary drilling (Fig. 1).



**Fig. 1 - Hole deviations for conventional and waterjet**

2. High pressure waterjet rotary drilling significantly increased the penetration (up to 80% improvement in instantaneous penetration rates). Feed pressures were substantially reduced to around a quarter of that required for conventional rotary drilling and torque pressures were reduced to around 80%.
3. The nominal coal cuttings size (50% passing) were reduced (Fig. 2). This may facilitate the cleaning of hole cuttings.
4. High pressure waterjet rotary drilling consumes about same amount of water as conventional rotary drilling (approximately 150 l/min) and less than DHM drilling (220 l/min).

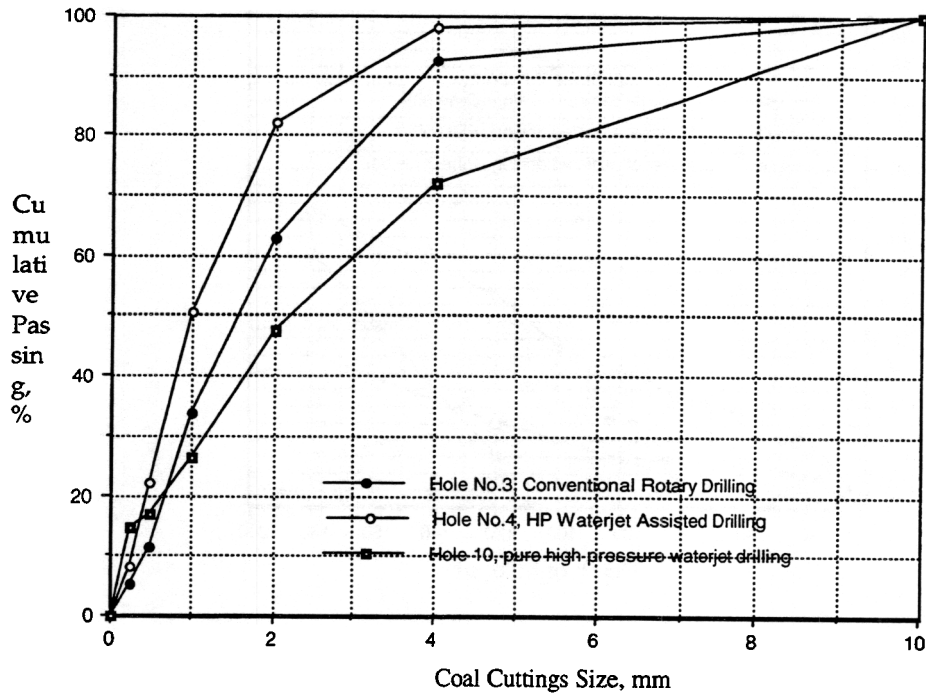


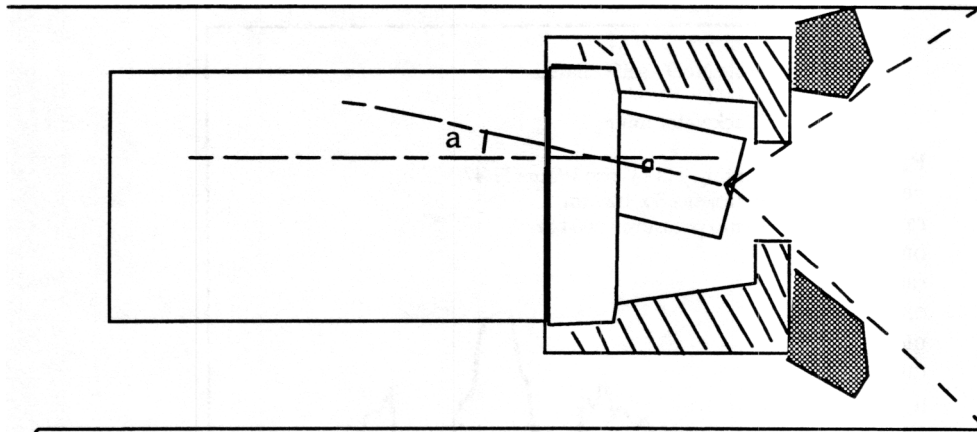
Fig. 2 - Coal cuttings size distribution

### *High pressure waterjet longhole rotary drilling*

Given the improved hole straightness and reduced feed and torque pressure forces, together with reduced cutting size, the extension of the cross panel drilling work into longhole drilling clearly has some potential. A project financially supported by the Australian Coal Association Research Program (ACARP project no. C6028) and with significant support from Dartbrook Mine has been established.

The project builds on the previous project by attempting to develop steerable drill bits which can be used in conjunction with the existing downhole equipment. The objective is to drill in-seam holes (>1000 m) along a longwall block. Drilling longitudinally along a coal block could increase the time available for gas drainage and improve equipment access in longwall roadway development. Three types of steerable drill bit were designed and manufactured, and trialed at Dartbrook Mine:

1. PCD drill bit with an off central jet,
2. PCD drill bit with a free rotational waterjet cutting nozzle (Fig. 3), and
3. PCD bit with a bent sub.



**Fig. 3 - Off-Centered FR nozzle**

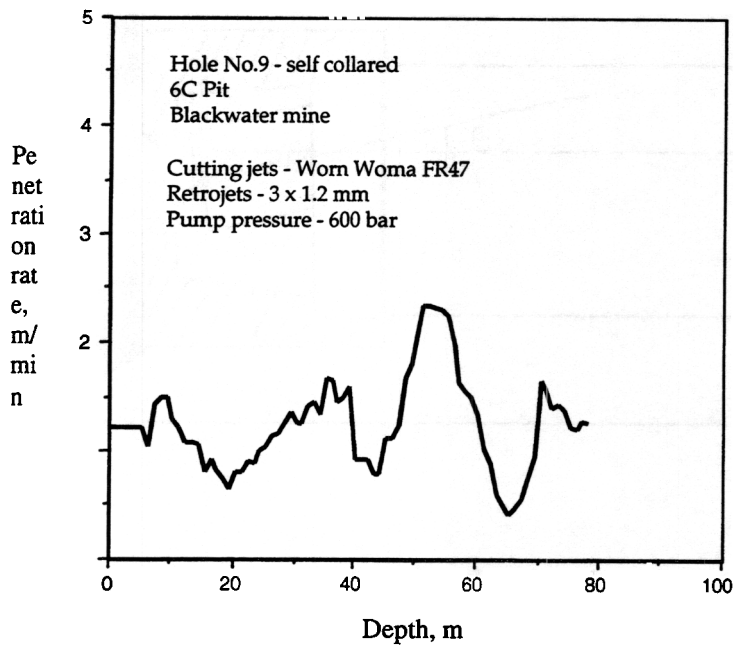
The field trials were conducted with the same drilling equipment used previously. Tests were undertaken using high and conventional water pressures with all three types of bit. Holes were drilled across panel and also into a pillar to observe damage caused to the coal by drilling. At this stage a problem of the trending to the floor has not been completely resolved. There are four current findings:

1. Holes are straighter using high pressure water\_(this supports the earlier finding from the previous underground trials).
2. Rotary drill holes using the high pressure down-hole assembly and drill string trend towards the floor at conventional water pressure as well as at high water pressures.
3. The coal was not damaged as much by the high pressure water as was thought during previous underground trials.
4. PCD drill bits appear to be very aggressive. This may limit the potential for steering rotary drills with this type of drill bit.

#### **High speed high pressure waterjet cross-panel drilling**

The high speed high pressure waterjet cross-panel gas drainage drilling system uses a self-propelled cutting nozzle and flexible hose to drill holes in coal. The ultimate aim of this project is to develop a drilling system which can drill considerably faster than current rotary or DHM drilling methods. The system does not require the making and breaking of rod connections. The technique of the self-propelled waterjet cutting nozzle comes from the tight radius drilling (TRD) project being conducted by CMTE in conjunction with BHP Coal. The self-drilling device uses high pressure water forced out of the back of the drilling head to propel the device forward. Cutting waterjets at the front of the drilling device, in a self-spinning head arrangement, excavate the coal in front of the drilling head.

The first prototype drilling assembly was a retro-jet and self-rotating cutting nozzle assembly for non-directional drilling developed by Kennerley (1993). Subsequent trials were carried out into a coal seam exposed in a highwall of an open cut mine (Trueman et al, 1995). The system used a pressure of 60 MPa and a flow rate of 150 l/min. It drilled up to 100 m (drilling distance was limited by the length of hose available) with penetration rates from 0.3 to 2.5 m/min (Fig. 4).



**Fig. 4 - Drilling rates, borehole No. 9**

The drilling assembly has been redesigned for greater pressure (115 MPa) and flow rates (234 l/min) and their number of retrojets has been increased in order to significantly increase thrust. These modifications resulted in a significant improvement in drilling performance. A 100 m borehole typically took 50 minutes to drill and the best rate of penetration was achieved when 194 m was drilled in 42 minutes. The drilling assembly also has a tendency to remain within a narrow band of the coal seam. We are currently addressing the guidance (steering and surveying) of such a drill assembly for use underground (ACARP funded research).

#### **Sensing and logging for in-seam boreholes**

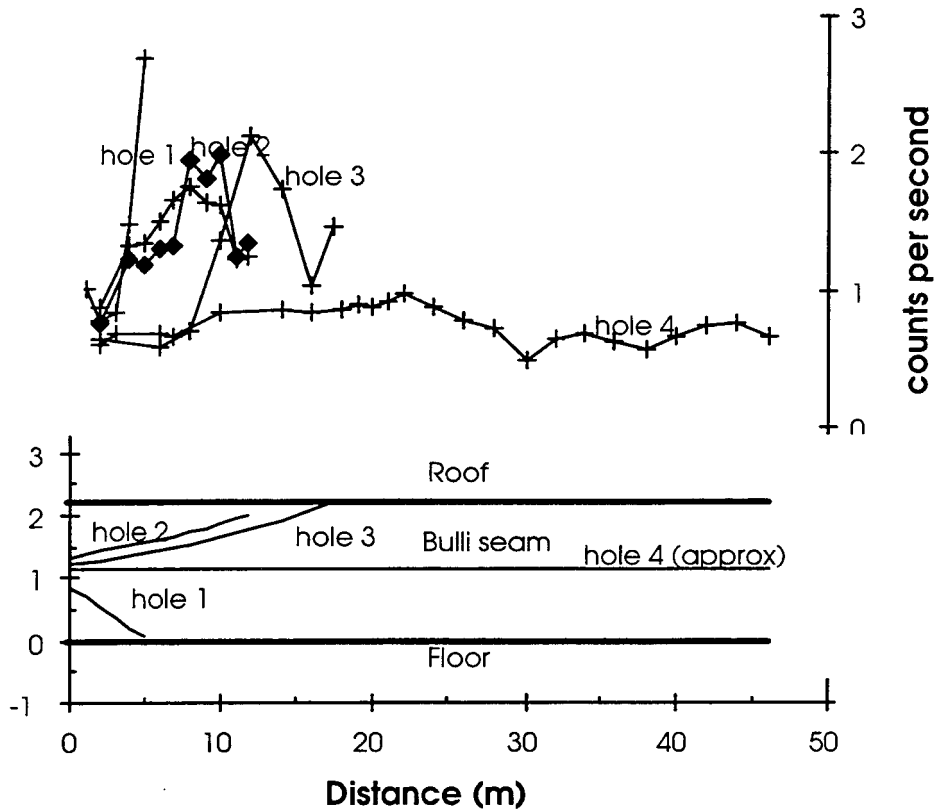
For the drilling of in-seam boreholes for coal seam gas drainage and exploration to be more effective, there also exists the need for information on geological conditions, the orientation of the drill bit and the position of the hole within the seam. While tools are available to determine the orientation of the hole, geological conditions can only be established on the basis of drill cuttings and drill performance. Seam position needs to be established by periodically deviating holes to check for the location of the coal seam roof. Neither of these are satisfactory solutions.

To provide a means of testing for the position of the hole within the seam, CMTE has designed and built a proof of concept radiometric tool (Hatherly et al, 1996). Test results from the West Cliff Mine, Fig. 5, show that it is feasible to guide a downhole motor drill on the basis of the radiometric profile in a coal seam. The radiometric profile is related to the ash profile in the seam and allows for the possibility of tracking a borehole's position without the need to get close (30 cm) to the roof or floor before readings can be taken.

Current work to develop a production tool is being funded by ACARP and is being undertaken in collaboration with Dr Ian Gray of SIGRA. The intention is to develop a combined tool which will reside permanently behind the drill bit and provide:

1. a survey capability,
2. the ability to monitor the position of the hole with respect to the roof and floor,
3. the ability to monitor drill thrust, torque and rpm, and

- the option to add additional geophysical sensors such as resistivity and sonic

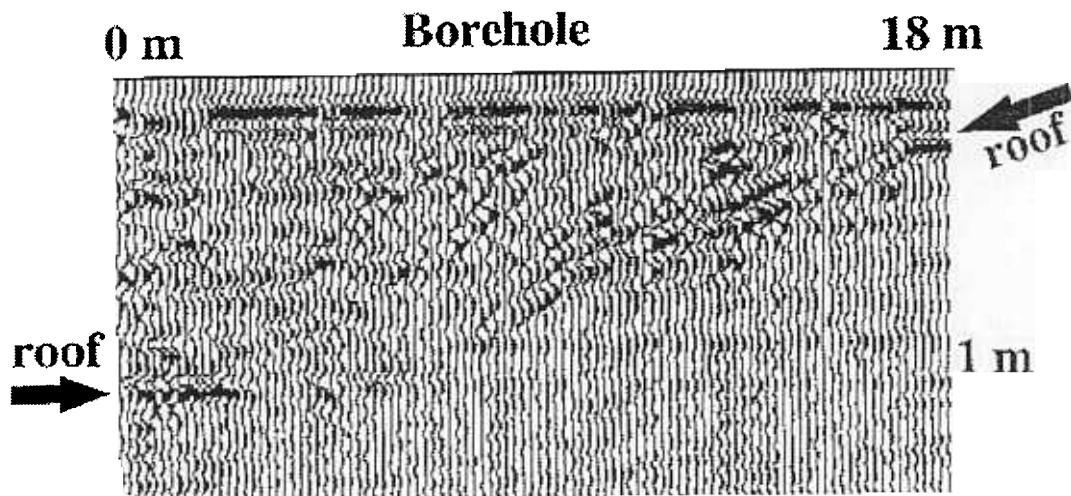


**Fig. 5 - Four boreholes drilled at West Cliff Colliery show increased material gamma counts as the holes deviate away from the mid-seam position**

The tool will be modular and be able to communicate through the drill string via the cable systems currently available or via a cableless system currently under development at SIGRA. A users interface will be provided.

To infer geological conditions CMTE in collaboration with CSIRO Division of Telecommunications and Industrial Physics is developing borehole radar and dielectric techniques (Hatherly et al, 1996). We have designed and built probes for HQ and NQ size drill rods. These tools can also be used to provide information on the location of the roof/floor (Fig. 6). The basic design uses radar centre frequencies of about 500 MHz. Initial tests of the dielectric tool suggest that it might be able to give a ready indication of the existence of mylonite zones intersecting a borehole. This is also the subject of on-going ACARP funded research.





**Fig. 6 - Results from a radar seam profiling the coal seam roof from an in-seam borehole**

## CONCLUSIONS

As Australia's coal mining trends towards underground operations and deeper coal seams, gas drainage is becoming an increasingly prevalent and costly component of mining. CMTE's drilling research is directed at improving the efficiency of gas drainage by developing faster, steerable drills equipped with the sensing technology to allow them to remain on path within an undulating coal seam. There are a number of significant technological challenges which need to be addressed but through the combination of fundamental research and field trials these are being progressively solved. Current targets are to:

1. perfect a waterjet steerable drill bit to enable the drilling of in-seam drainage boreholes along a significant proportion of the length of a longwall panel,
2. overcome the tendency of holes to drop towards the floor of the seam,
3. continue the development of the high speed, high pressure waterjet cross panel drilling system,
4. implement seam following and geological logging sensors for use with DHM drilling,
5. integrate these sensors with the various waterjet drilling technologies.

Commercialisation of these developments is being pursued through collaboration with mining companies, drilling suppliers and contractors and actively contributing to industry meetings of drill operators.

## ACKNOWLEDGMENT

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