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Evolution and application of in-seam drilling for gas drainage

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ABSTRACT

The presence of seam gas in the form of methane or carbon dioxide presents a hazard to underground coal mining operations. In-seam drilling has been undertaken for the past three decades for gas drainage to reduce the risk of gas outburst and lower the concentrations of seam gas in the underground ventilation. The drilling practices have reflected the standards of the times and have evolved with the development of technology and equipment and the needs to provide a safe mining environment underground. Early practice was to adapt equipment from other fields, with rotary drilling being the only form of drilling available. This form of drainage allowed various levels of gas drainage coverage but with changing emphasis, research and development within the coal industry has created specific equipment, technology and practices to accurately place in-seam boreholes to provide efficient and effective gas drainage. Research into gas content determination established a standard for the process and safe levels for mining operations to continue. Surveying technology improved from the wire-line, single-shot Eastman survey instruments which was time-dependent on borehole depth to electronic instruments located in the drill string which transmitted accurate survey data to the drilling crew without time delays. This allowed improved directional control and increased drilling rates. Directional drilling technology has now been established as the industry standard to provide effective gas drainage drilling. Exploration was identified as an additional benefit with directional drilling as it has the ability to provide exploration data from long boreholes. The ability of the technology to provide safe and reliable means to investigate the need for inrush protection and water drainage ahead of mining has been established. Directional drilling technology has now been introduced to the Chinese coal industry for gas drainage through a practice of auditing, design, supply, training and ongoing support. Experienced drilling crews can offer site specific gas drainage drilling services utilising the latest equipment and technology.

1. Introduction

Explosions and outbursts resulting from seam gas are a constant threat in the underground coal mining industry. Mining depths have progressively increased with the resultant increases in seam gas content and pressure while improvements in technology have allowed increases in mining advance rates. This has resulted in an increased risk of outburst during mining development and higher gas emissions during mining.

Research and development in Australia and other countries has constantly being directed towards making underground coal mining a safer working environment. After several areas of research were identified, some were eliminated as being unreliable or ineffective so research and development was directed towards the key areas of assessment and prevention: (1) drilling for gas drainage to reduce the risk of outburst and lower gas levels in the mine ventilation; (2) gas content determination prior to gas drainage to allow gas reservoir assessment; and (3) gas content assessment to confirm gas drainage has been effective prior to mining.

Gas drainage drilling has also allowed controlled removal of gas from the underground environment, and in the event that the primary seam gas is methane, provides an energy source for conversion to power while reducing the greenhouse effects.

The development of in-seam drilling in Australia can be defined by three periods: (1) the initial period on rotary drilling for gas drainage and preliminary development of a gas content determination method; (2) the evolution from rotary drilling to directional drilling and the establishment of an Australian standard for gas content determination and safe gas content levels; and (3) the required use of Outburst Management Plans (OMP) utilising directional drilling and gas content assessment.

Directional drilling technology has been introduced to the Chinese coal industry. Problems were experienced with adverse drilling environments commonly found in Chinese coal mines. A practice of auditing mines to ensure drilling objectives are achievable then supplying the full system of drilling equipment plus

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training and service support has proved successful. A contract drilling service has also been established to provide gas drainage drilling.

2. Rotary drilling to 1994

2.1. Background

Initially, the only form of drilling available was open-hole rotary drilling. Some technology was gleaned from work in the United States of America on rotary in-seam drilling for gas drainage while most drilling was developed in and for Australian conditions [1–3].

In-seam rotary drilling was directed ahead of development and across longwall blocks to intersect proposed development panels in advance of mining to effect pre-drainage. Cross-measure post drainage rotary drilling was directed at an angle down under each longwall block to cross the expected fracture zone to attempt to draw off gas released from the under-lying seams during longwall extraction.

2.2. Drill rigs

The drill rigs used through this period were mostly rigs designed for "hard-rock" mining applications such as the Craelius Diamec 251 (Fig. 1a) and the Kempe U4-450 (Fig. 1b) or low-capacity "home-made" units [4,5]. The hard rock rigs required replacement of all aluminium parts with steel components and the power units fitted with a flameproof electrical motor and starter. The rigs were required to operate at slower rotational speeds with higher torque and higher penetration rates than normally used in "hard-rock" core drilling.

The mounting and securing of the rigs was modified to suit the mobility requirements in and about coal mines. With the requirement of high volumes of rotary drilling, hydraulic rigs which provide coordinated "automatic" rod handling were preferred. A safety feature was to have mechanically operated jaws in either chuck or rod holder to secure the rods to prevent them being ejected from the hole if power failed.

Any gas monitoring was by a combination of CO_2 Draeger tubes, hand held CH_4 monitors or "Blinky Bill" methane detectors hung at the site. The specifications of the rigs used and their nominal depth capacities are listed in Table 1.

2.3. Rods

Most of the modified "hard-rock" rigs were limited to BQ size jaws. BQ rods were the favoured rods since they were readily available from the coring/exploration industry and offered parallel side profile suitable for automatic rod handling. The Q series rods also allowed pump-in wire-line surveying when needed. A variety of API, Q and W series rods were used with the "home-made" rigs.

Table 1
Modified hard-rock drill rigs.

Drill rig	Power supply	Mounting	Rod capacity	Nominal depth (m)
Diamec 250	Air/hydraulic	Track	BQ/BCQ	250
Diamec 251	Electric/hydraulic	Sled	BQ	350
Acker "Big John"	Electric/hydraulic	Tyred	BQ	500+
Kempe U4-450	Electric/hydraulic	Sled	BQ	500+
Air tracks	Air/hydraulic	Track	AW/BW	100
Mindrill	Air/hydraulic	Sled	AW	30–40

2.4. Bits

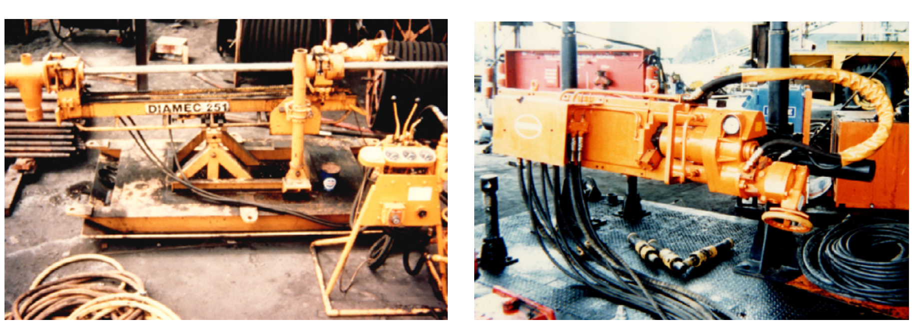
The only bits available through to the mid-80s were tungsten carbide or roller cone (Tri-cone) bits. The tungsten carbide bits were capable of drilling coal but were very limited when stone roof or floor was intersected. Holes were either terminated or attempts were made to deflect them back into the seam using roller cone bits. Access to the "Widia" bit system of 65 mm diameter pilot bit and 80 mm diameter reamer allowed good coal penetration with a configuration which readily deflected off low-angled stone intersections.

Roller cone bits were used in stone for cross-measure drilling until the Widia bits became available. The 65 mm Widia pilot bit was used with A size rods to good effect but required regular sharpening.

In 1984, the first polycrystalline diamond (PCD) bit was offered from USA for trial by ACIRL. This bit was steel bodied with PCD cutting blanks mounted on tungsten carbide pillars secured into the face of the bit. Each PCD blank was a 12 mm tungsten carbide disc with a 1 mm polycrystalline matrix bonded to the face of the disc. This bit offered good, on-going penetration in stone and the convex face shape allowed deflection out of low-angled stone intersections when in-seam drilling [4]. Longyear produced 65 and 80 mm diameter PCD bits using a cast matrix face bonded to a threaded steel body. These bit designs required some modification to overcome abrasion, mounting stability and flushing problems as they were identified.

2.5. Drilling patterns

Three modes were used to try to provide effective coverage of target drainage areas:



(a) Diamec 251 drill rigs (b) Kempe U4-450 drill rig

Fig. 1. Diamec 251 and Kempe U4-450 drill rigs [4,5].