REACHING GREATER DEPTHS

Stephen Kravits and Bruce Rusby, Target Drilling, US, and Joanne Reilly and Gary DuBois, RAG Cumberland Resources, US discuss the maximization of in-mine horizontal longhole technology.

Figure 1 Permissible drill used to drill in-mine longholes.

Figure 2 DDM MECCA uphole monitor box calculates and displays high resolution survey data.

Target Drilling's real-time directionally drilled horizontal CBM longholes have improved coal mining productivity by effectively shielding longwall gateroad development from methane emissions and increasing degasification time for future longwall gateroad developments. In-mine longholes have also successfully been used for exploration and degasification of adjacent coalbeds.

Background

Mine operators worldwide have long accepted in-mine horizontal CBM boreholes as a cost effective method to reduce coalbed methane emissions during mine development, enhancing safety and increasing coal productivity. Using real-time, permissible DDM MECCA technology, Target Drilling has successfully implemented in-mine horizontal CBM longhole technology in coal mines, significantly increasing degasification time, reducing methane delays and thereby improving mining productivity.

Based in Pittsburgh, Pennsylvania, Target Drilling, formerly AMT Drilling International, has been directionally drilling in-mine horizontal boreholes to depths greater than 1219m (4000 ft). For the past four years, it has used its permissible, real-time DDM MECCA technology gateroad development from coalbed methane emissions. To date, it has directionally drilled nearly 243,840m (800,000 ft) of in-mine horizontal CBM borehole. This includes 170,688m (560,000ft) of cross-panel boreholes, 243.8 m to 72 m (800 to 2500 ft), used to degas the longwall panel and future gateroad development; 15,240m (50,000 ft) of borehole, 762m to 1006m (2500 to 3300ft) in length; 6096m (20,000ft) of borehole (or longhole), 1006m to 1219m (3300 to 4000 ft); and 48,640m (160,000ft) of longholes greater than 1219m (4000 ft).

Target has directionally drilled 33 CBM horizontal longholes greater than 1219m (4000ft), including the world's longest in-mine horizontal borehole at 1537m (5045ft). Extreme horizontal and vertical trajectories have also been achieved, to maximize degasification of specifically targeted areas.

The focus of this article is to discuses Target's real-time directional drilling longhole technology and the objectives and benefits of two applications of its horizontal CBM longhole technology.

Real-time directional drilling longhole technology

Equipment

Target's permissible steering system, the DDM MECCA (downhole drill monitor utilizing modular electronically connected cable assembly), is the key to the company's real-time directional drilling technology. A permissible longhole drill, with thrust capability of 18,144kg (40,000lbs) is used to supply weight to a 3 5/8" PDC bit, by maintaining hydraulic pressure on JKS Boyles NT drill rods and downhole motor (Figure 1). A nonmagnetic high torque low speed downhole motor is used to directionally drill the boreholes. Downhole motors are positive displacement motors, hydraulically driven by a triple piston pump, mounted on the drill that converts hydraulic horsepower to mechanical horsepower, providing bit rotational speed and torque, without rotating the drill rods. Consequently, orienting the downhole motor's bent housing while drilling controls vertical and horizontal trajectories.

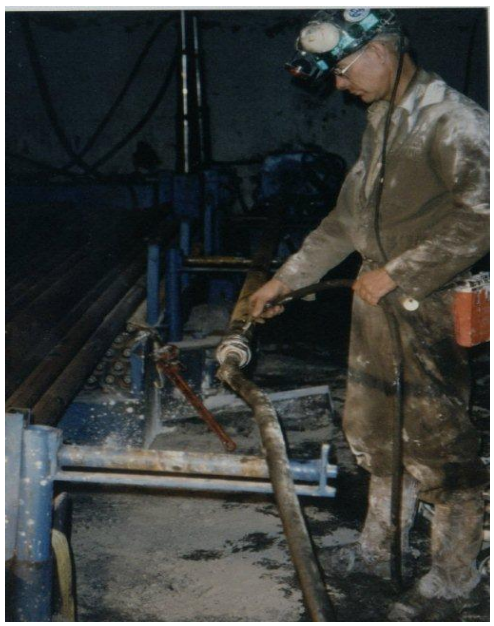

Figure 3 Surveys take less than 5 seconds after connecting MECCA to uphole monitor box with signal cable.

The DDM MECCA provides borehole navigation. Specifically, it is used to transmit real-time, high-resolution borehole data including azimuth, pitch, elevation and left/right position from the collar (Figure 2). DDM borehole positional data is transmitted via MECCA from the downhole unit to the uphole monitor box in less than 5 seconds, regardless of borehole depth, permitting faster, more accurate drilling of horizontal boreholes (Figure 3).

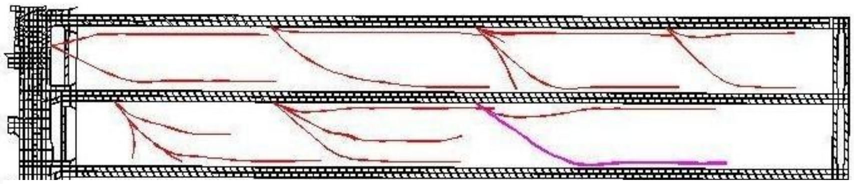

Figure 4 In-mine horizontal CBM longholes drilled by Target Drilling at RAG Cumberland Resources shielding longwall gateroad development.

Real-time DDM horizontal CBM borehole procedures

During the real-time directional drilling of the horizontal boreholes, vertical trajectory within the coal and desired lateral or horizontal trajectories are simultaneously maintained. After setting orientation of the being housing to achieve desired borehole trajectory using the DDM, drilling is resumed for a 3m (10ft) interval. Drilling is then suspended to turn off the triple piston pump that supplies the water driving the downhole motor. A DDM survey is taken and a 10ft drill rod is added to the string (if 9m or 12.2 m (30ft or 40ft) drill pipe sections have not been used). The actual DDM survey, which includes activating the downhole sensors to measure borehole transmitting the raw survey data vi the MECCA uphole, and calculating elevation and left/right coordinates at the DDM depth, takes less than 5 seconds. The total process of turning off the water pump, taking the real-time DDM survey, projecting bit position and turning on the triple piston pump to set the bent housing orientation for the next 3m (10ft) drilling interval, and resuming drilling, takes several minutes. Therefore a high degree of directional control is achieved because borehole position is calculated every 3m (10ft). This permits changes in borehole steering without sacrificing drilling time, resulting in drilling productivity of up to 15.24m (500ft) per shift in coalbeds, with thickness of less than 1.22m (4ft).

While maintaining desired horizontal trajectory, the borehole is intentionally steered to periodically intercept the roof rock above the coal. This helps to accurately determine coalbed elevation and dip. Changes in directional drilling parameters, combined with DDM measured elevations, are the determining factors in rod interception. The DDM drill string is then relocated in the borehole to a suitable position in the coal in the parent borehole, to initiate a sidetrack or branch. Once the sidetrack or branch has been completed below the previous elevation of the parent borehole, the segment of borehole that intercepted the roof rock is abandoned or eliminated from the parent borehole. Consequently, in CBM boreholes targeting a coalbed, the entire parent borehole is directionally drilled in coal with numerous abandoned branches.

The heart of the DDM MECCA is the sensor package located in the explosion proof, watertight downhole probe. The sensor package is comprised of a three-axis, flux-gate magnetometer and three orthogonal accelerometers, used to measure the relative position of the downhole probe to the earth's magnetic field and gravitation vector. The inherent accuracy of the sensor package incorporated in the DDM is within 0.5° for azimuth and 0.25° for inclination. These accuracies can be maintained, provided that an accurate measure of declination in the mine at the drill site can be made. Considering the numerous potential sources of magnetic interference in an underground mine, DDM measured azimuth for each borehole is compared to mine surveyed azimuth at each longhole before a collar pipe of standpipe is installed. The difference in the mine surveyed collar azimuth and the DDM azimuth is then input in the DDM as the declination of the DDM for the longhole. When mining intercepts a borehole, their positions are surveyed and compared to the DDM calculated position. Survey closures are conducted to determine if further declination adjustments of the DDM are required.

Horizontal CBM longholes at Cumberland Mine

Drilling results

Located in southwestern Pennsylvania, RAG Cumberland Resources' Cumberland mine is a high output longwall mine extracting the approximately 2.14m (7ft) thick Pittsburgh coalbed. The Pittsburgh coalbed generally exhibits an approximate in-place gas content of 75ft³ per t (standard 120 day desorption test with no residual gas added). Higher than normal methane concentrations, contained or trapped in gas cells created by impermeable clay veins, are also common in the Pittsburgh coalbed.

Mining productivity during longwall gateroad development can be hindered when mining into these clay veins. To date, Target has applied its real-time directional drilling techniques to complete 14 in-mine CBM horizontal boreholes shielding longwall gateroad development at Cumberland mine (Figure 4). In addition to installing longholes shielding active continuous miner development longholes have been steered across the longwall panel where they are then turned to parallel the number three entry of future longwall gateroad development of the next panel. This provides up to eighteen months of degasification time for the continuous miner section.

While navigating a horizontal radius of 305m (1000ft) to cross the panel, the longholes have been maintained within the coalbed vertically to final depths of greater than 1219m (4000ft). When the desired final depths have been less than 1219m (4000ft), radii of less than 305m (1000ft) have been successfully completed while maintaining vertical borehole trajectory of the parent borehole within the coalbed. The longholes crossing the longwall panel also provide degasification benefit to the longwall panel itself. Methane produces from the borehole is routed through a polyethylene pipe to a borehole drilled from the surface into the mine entry.

The procedures for mining through the longholes with the continuous miner and the longwall shearer were designed and implemented by RAG Cumberland with approval for the Mine Safety and Health Administration. Several days prior to each cut-through, the boreholes are water-infused, becoming completely filled. Due to the undulation of the borehole, only minor amounts of water flow from the borehole upon interception. If the borehole intercepted is on the longwall face, mining continues until the borehole wellhead is intercepted. If the intercepted borehole is located on an active development section, the borehole is filled with grout so that mining can proceed.

After completing the first longholes strictly using a declination measured at the collar of each longhole, the first planned mine-through of a longhole was achieved, indicating a placement inaccuracy of less than 0.2° at approximately 1250m (4100ft). Shortly after the first continuous miner longhole mine-through, the longwall mined into two longholes indicating placement inaccuracy of approximately 0.5° and 0.7°. It was determined that a consistent shift or swing to the north in declination was a required correction. A fourth min-through of a longhole occurred when the continuous miner on 82 Butt gateroad development intercepted a longhole. No mine-through of any longhole had occurred by the time this longhole initiated. Therefore the declination measured at the start of the borehole was the only declination information available, considering underground magnetic interference. The declination measured and used at the start of this longhole was uncharacteristically approximately 1° less than declinations used on previous longholes.

After studying longhole placement accuracy for the four longholes that were mined into, it was determined that an average DDM declination for longholes drilled in the mine consistently resulted in a placement accuracy of at least 0.5°. However, DDM declination measurements are till conducted at the start of each longhole. These measurements are then compared to mine surveyed declination at each longhole and to the average declination used on previous mining intercepted longholes.

Degasification Results

In-mine horizontal CBM boreholes have proven effective in reducing methane emissions. Short horizontal boreholes (less than 305m (1000ft)) generally provide less degasification time than longer boreholes. Immediate relief from methane can be experienced at the continuous miner gateroad development using horizontal boreholes capturing the 'free' gas contained in the cleats. In fact, continuous miner development has mined approximately 30.5m (100ft) pas the end of a producing longhole and experienced an immediate increase in methane concentration at the face. Conversely, longholes directionally drilled across the longwall panel shielding future gateroad development, to be mined up to 18 months later, are not only effective in capturing free gas but also in desorbing gas from the coal matrix, therefore increasing degasification effectiveness. Lastly, the longholes are kept on production until mined into by the longwall or continuous miner, when they are flooded with water under pressure.

With initial gas production from the longholes often exceeding 500Mcfd, measured underground at the horizontal wellhead using a delta tube and magnehelic gauge, significant benefit to the continuous miner development section has been experienced. The positive effect of the horizontal boreholes can be measured by the reduction in downtime associated with delays caused by excessive methane on the development sections. Methane measured at the mining face must be kept below 1 percent methane. The mining machinery must be shut down when the methane rises to or exceeds this percentage. Each minute the equipment is shut down is counted as a delay minute where coal cannot be mined and production is lost. For example, the methane delay minutes for the mining of 64 Butt (with three horizontal longholes providing degasification) were reduced to 900mins, compared to 3880mins mining the previous 55 Butt section with degasification coverage provided by two longholes. This is a 77 percent reduction in methane delays.

An unexpected benefit from the horizontal boreholes was the reduction in mining delays from the water produced from the roof. Delay time from water was decreased by 65 percent to less than 700mins during the mining of 64 Butt section compared to almost 2000mins during the mining of 45 Butt section. Chart recorders have recently been installed on the surface borehole to accurately measure the methane produced on a daily basis.

Interestingly, mining operation personnel can measure the difference in methane in the shielded entries when the boreholes are producing or shut in. Methane measured in the shielded entries increases when there are gaps between the boreholes (resulting in an unshielded expanse of entry). This observation resulted in the drilling of short cross-panel boreholes to cover the gapped area.

In-mine horizontal exploration

Exploration/ de-pressurization

Target Drilling was contracted to drill an exploratory longhole with the primary purpose of locating and characterizing a suspected but undocumented fault zone ahead of development mining. A secondary purpose of the longhole was to provide de-pressurization of the fault zone by providing a conduit for water and gas drainage.

The mine is a large western US underground longwall coal mine, with production in excess of 7 million tpa. Faults encountered in the mine have ranged from 0.6m to 6m (2 to 20ft). Water and methane gas contained within the faulted rock have been pressurized up to 250psi experiencing outflows up to 10,000gpm. Development mining has been hazardous to both personnel and equipment, due to these conditions.

Longhole plan

The longhole was collared in the mineable coal seam (43.9 m (12ft) thick), with 54.9m (180ft) of casing, set to seal one known fault zone from water and gas discharge from a second unknown fault zone expected to be encountered with the longhole. Collar equipment included a full port drill through globe valve, a blow out preventer rated at 500psi, a gas-water separator, and a gas dilution zone.

The selected drilling horizon was a secondary coal seam of variable thickness of 2 to 4ft situated 16.8m (55ft) below the mineable seam and directly above a massive sandstone. The thin drilling horizon in the coal seam and the massive sandstone was to provide obvious distinctive stratigraphic markers in maintaining the proper horizon and defining the fault displacement if encountered. Drilling in the lower coal also kept the longhole out of the mineable coal seam where development and longwall mining could intercept it. Federal regulations require longholes to be plugged before mining and would limit the serviceable life of the longhole for water and methane drainage if drilled in the mineable coal. Additionally, the massive sandstone has been known to be the primary storage unit for water in the faulted zone. Placing the longhole at the upper contract f the sandstone would allow for maximum drainage in the faulted zone.

Longhole drilling results

The possibility of intercepting a highly pressurized fault zone required that the casing withstood a minimum of 300psi. The longhole was steered to intercept the lower unlikeable coal seam with an average dip grade of 2° to 3°. The contact between the coal and surrounding sandstone was distinct. However, maintaining control of the longhole when drilling in the upper part of the massive sandstone was difficult, due to the soft characteristics of the rock. At a horizontal depth of 1195m (3920ft), the fault was intercepted, producing a water flow of 240gpm (Figure 5). An initial shut-in pressure of 250psi was recorded. The longhole was continued beyond the faulted zone for stratigraphic correlation of coal seams and displacement determination. The longhole was completed to a horizontal depth of 1247m (4090ft).

Longhole exploration/ depressurization results

The primary objective, i.e. to intercept and characterize the fault zone for location and displacement, was achieved for the most part. The fault zone was located with the width identified. However, due to the length of the longhole, discharge of high volume water, and lack of available thrust from the drill, accurate stratigraphic interpretation could not be achieved beyond 1195m (3920ft). Displacement values of the fault zone had to be inferred without a high degree of certainty. The secondary objective of de-pressurization was successfully completed. The longholes initial shut-in pressure was 250psi. During the following three months the longhole was left open to drain. Gas and water flows diminished from 240gpm at 250psi to 100gpm at 50psi. Water flow rates continue to decrease.

Conclusion

Target Drilling's real-time directionally drilled horizontal CBM longholes to depths greater than 1219m (4000ft) have significantly improved coal mining productivity by effectively shielding longwall gateroad development from methane emissions and increasing degasification time for future longwall gateroad developments at numerous North American coal mines. In-mine longholes have also been used successfully for exploration and de-pressurization of adjacent coalbeds in advance of mining.

References

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