Bank 2000 Road Header Environment Control System for High Seam (5.1 m) South African Bord and Pillar Coal Mines

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ABSTRACT: The first boom-type road heading machines became widespread within the European coal mining industry in the 1960s for underground access roadway development. The first application of road headers (RHs) in South Africa was at the Premium Diamond Mine in 1979 and current use of these machines is now extensive in underground coal mines. Fundamental differences in the cutting action and general operation of RHs means that dust-control systems previously developed for continuous miners (CMs) are not universally applicable. Ventilation of the face area of a RH is more complex than for a CM in some respects, due to the physical layout of the machine and the nature of the movement of the boom, although there is much less positional movement of the machine itself during the cutting cycle. These differences necessitated the development of specific systems to ensure effective ventilation and dust control on road headers.

The paper discusses the results of a Safety In Mines Research Advisory Committee (SIMRAC) research study jointly carried out by the CSIR-Miningtek and IMCL (UK). The objective of the study is to reduce the engineering dust levels at the RH operator position below 5 mg/m^3, while maintaining adequate ventilation conditions in RH headings. The study involved initial simulation RH trials in a surface gallery in the UK (IMCL) and subsequent underground evaluation trials in a 5.1 m high bord and pillar RH section in South Africa. The research study concluded that the newly developed Bank 2000 Road Header Environment Control System was able to maintain the dust-concentration levels below 5 mg/m^3 design criterion at the operator position and that the measured methane concentrations were within the permissible 1.4% CH_4 per volume concentration levels. The engineering sample concentration level for an 8-hr period during the 17 full shift trials was 3.82 mg/m^3. The paper discusses the development of the spray design, spray configuration, individual system components and the field results of the new environment control system for high seam (> 5.1 m) road header sections.

1 INTRODUCTION

The first boom-type road heading machines became widespread within the European coal mining industry in the 1960s for underground access roadway development. The first application of road headers (RHs) in South Africa was at the Premium Diamond Mine in 1979 and current use of these machines is now extensive in underground coal mines. Fundamental differences in the cutting action and general operation of RHs means that dust-control systems previously developed for continuous miners (CMs) are not universally applicable. Ventilation of the face area of a RH is more complex than for a CM in some respects, due to the physical layout of the machine and the nature of the movement of the boom, although there is much less positional movement of the machine itself during the cutting cycle. These differences necessitated the development of specific systems to ensure effective ventilation and dust control on road headers.

A directive of the South African Department of Minerals and Energy (DME, 1997) required that the engineering dust-concentration level at the operator's cab position on continuous mining machines be reduced to below 5 mg/m^3. The paper discusses the results of a Safety In Mines Research Advisory Committee (SIMRAC) research study jointly carried out by the CSIR-Miningtek and IMCL (UK). The prime objective of the study is to reduce the engineering dust levels at the RH operator position below 5 mg/m^3, while maintaining adequate ventilation conditions in RH headings.

The research project was carried out in 3 phases. During the first phase of the project, an extensive literature review of past international (UK, USA, Germany and Poland) and South African research on RH best ventilation and dust-control practices were carried out (Hole and Belle, 1999).

The second phase of the project (Hole, 2000), involved initial simulation RH trials in a surface gallery at the IMCL laboratory in the UK. The objectives of the surface investigations were to evaluate and optimize existing ventilation and dust-control systems, identify non-functional systems and components, and provide recommendations for subsequent underground evaluations. The surface trials successfully identified the main requirements for effective environmental control on RH machines, including the development of an Optimized Spray System (OSS) for RH.

The evaluation of the ventilation and dust-control system proposed from the surface trials in an underground mine RH section was the main objective of the third phase of the project. The effectiveness of the ventilation systems was evaluated by using primary ventilation indicators, namely the methane gas concentration and the average dust-concentration levels. This paper discusses and summarizes the results of the third phase, i.e. the underground evaluation tests (Belle, Van Zyl and Du Plessis, 2001).

2 BACKGROUND

All the tests were conducted at Section # 13 of Bank Colliery (South Shaft) in a 5.1 m high bord-and-pillar RH (AM 85) section. In order to detect any improvement in the existing dust control system at the test section, the engineering dust concentrations measured by the mine operator (three months prior) were obtained for comparison purposes (Figure 1). An engineering sample is the dust sample taken at the pre-determined machine operator's position. The engineering sampler is switched on in the face area at the beginning of the shift where the machine is standing and is switched off at the end of the shift. The engineering sample enables to assess the effectiveness of the dust-control and ventilation systems in the section to be determined, as well as the administrative efficiency of the mine environment management. Mine dust samples were collected using a GME 008 cyclone sampler operated at 1.9 L/min. For the 28 production shifts, the average measured dust concentration was 10.83 mg/m^3. From the plot we observe that 22 of the 28 production shift dust concentrations at the operator's position (79 percent) were non-compliant, i.e. greater than > 5 mg/m^3.

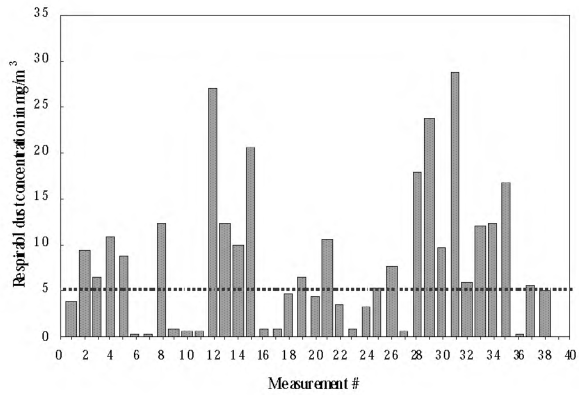

Figure 1. Background mine dust-concentration data.

3 ENVIRONMENT MONITORING

3.1 Dust monitoring

A pair of cyclones (GME 008) was positioned at the section intake. At the operator's position and section return, two cyclones and a real-time respirable dust monitor (Hund tyndallometer) were positioned. The gravimetric samplers consisted of an air pump that draws 2.2 L/min of air through a cyclone, which separates the airborne dust and collects only the fraction of respirable dust (< 10 µm) on a pre-weighed filter disc. The dust sample was weighed and the mass was determined according to the DME guidelines (1997). Real-time dust-sampling results allow the comparison of face-area dust concentrations under different ventilation and mining conditions. Using the mass of dust collected on the filters, the sample dust concentration is calculated. Since the dust sampling was carried out for the entire production period of the shift (excluding travel time), an 8-h time-weighted average dust concentration is determined assuming zero dust-load for the non-sampling period.

3.2 Methane monitoring

Two types of methane sensor were used, viz. the Crowcon Triple Plus and the Crowcon Custodian for methane monitoring. Both methane sensors were of the pellistor type and are equipped with data-logging abilities. The recording interval was set to 10 seconds. The Custodian methane sensors were placed on the RH, one at the operator's cab position and the other at the machine-mounted methane sensor on the jib (2.5 m from the face on the return-air side). The Triple Plus sensor was placed under the dust scrubber unit. After completion of the test shift, the sensors were removed from the RH, switched off and the time was noted. The stored data from the sensors were downloaded on the surface and then imported into a spreadsheet for analysis.

4 BANK 2000 RH DUST CONTROL SYSTEM

Initial Optimum Spray System (OSS) configuration that was used for the underground trials on the AM 85 RH machine was developed while keeping in mind the long headings of South African coal mines and use of auxiliary ventilation devices such as a jet fan or a force fan. The final configuration and the individual components of the system were developed through series of u/g trials in SA. The final dust control system on the RH that was developed underground is hereafter referred to as the "*Bank 2000 Road Header (RH) Dust Control System.*" The name was chosen to distinguish this dust-control system from the various dust-control systems currently employed in South African mines.

The final configuration of the sprays (Figure 2) as installed on the AM 85 RH machine consists of a number of water spray blocks, air movers and an on-board scrubber. The system consists of a total of 38 sprays, including seven air movers (three air movers on the flight conveyor and four-tube air movers on the LHS computer box). The detailed descriptions of the individual components as shown on the drawings are as follows:

- On-board scrubber: A wet fan scrubber (capacity of 17 m^3/s) fitted with an inlet cone and a scrubber-outlet deflector plate discharge directed at 45° outward from the machine.
- Water to the spray system: Water pressure in the range of 1 500 kPa (15 bar) to 2 000 kPa (20 bar) and a minimum water flow rate of 120 L/min.
- Type of nozzles: Hollow-cone nozzles with a single-inlet diameter of 1.6 mm and an outlet diameter of 2.0 mm.
- Position A: Single four-tube air mover positioned on the computer box near left-hand-side (LHS) spade of the machine, spraying towards the LHS corner of the face in order to contain and suppress falling total dust.
- Position B (jib spray): A spray block with four sprays positioned at the jib at an angle of 45° from the vertical plane, acting as a water curtain as the boom moved across the face, sweeping and clearing the dust underneath the boom.
- Position E, F and G: A total of nine directional water sprays in three spray blocks located on the upper surface of the jib frame (behind the cutter head) arranged in a 'spray-fan' pattern. These sprays are angled to one side to promote the ventilation of the face by other components of the dust system and to wet the face around the cutting head.
- Positions D and H: Two spray blocks each consisting of three water sprays installed on the LHS and RHS of the cutting head, directing the sprays covering the corners of the cutting drum.
- Positions C and I: Jib spray blocks with three sprays were positioned on the LHS and RHS of the jib frame with a spray nozzle configuration of 0°/0°/20°. The intended function of the downward-facing spray blocks on the jib is to ensure proper ventilation of the area beneath the jib, particularly the loading zone.
- Positions J and K: Two spray blocks, each consisting of three sprays installed on the RHS of the machine. One spray block positioned on the side of the scrubber and the other spray block was positioned on the bottom of the machine. The purpose of the spray blocks located on the RHS body of the machine is to oppose the outflow of any air past the scrubber inlet to the right of the machine and to contain the dust cloud and improve effective dust scrubber capture by the scrubber.
- Air movers: The three air movers positioned on the flight conveyor spraying downwards at an angle grater than 45° from the horizontal onto the conveyor was to prevent dust rollback and to wet the coal on the flight conveyor.
- Physical half-curtain: The half-curtain covers an area from the scrubber on the LHS of the machine to the middle of the machine over the flight conveyor. This curtain consists of a conveyor belt positioned approximately 1 m from the scrubber inlet.
- Belt cover over conveyor discharge: The belt cover positioned at the end of conveyor discharge prevents both the airborne dust recirculating to the fresh intake air and the escaped dust reaching the shuttle car operator.
- Concave spade plate: Visual observations during the trials indicated that the RH operator's position was exposed to frequent very high dust-concentration levels. A concave spade plate was then added on the LHS of the RH at the spade position. In high seam coal mining headings, the control of total dust is difficult as the water sprays or air movers alone will not be able to contain the rollback of dust towards the operator. The principle of operation of the concave spade plate, as shown in Figure 3, is as follows: The spade plate is approximately 30 inches high and 22 inches wide and is positioned at the spade.

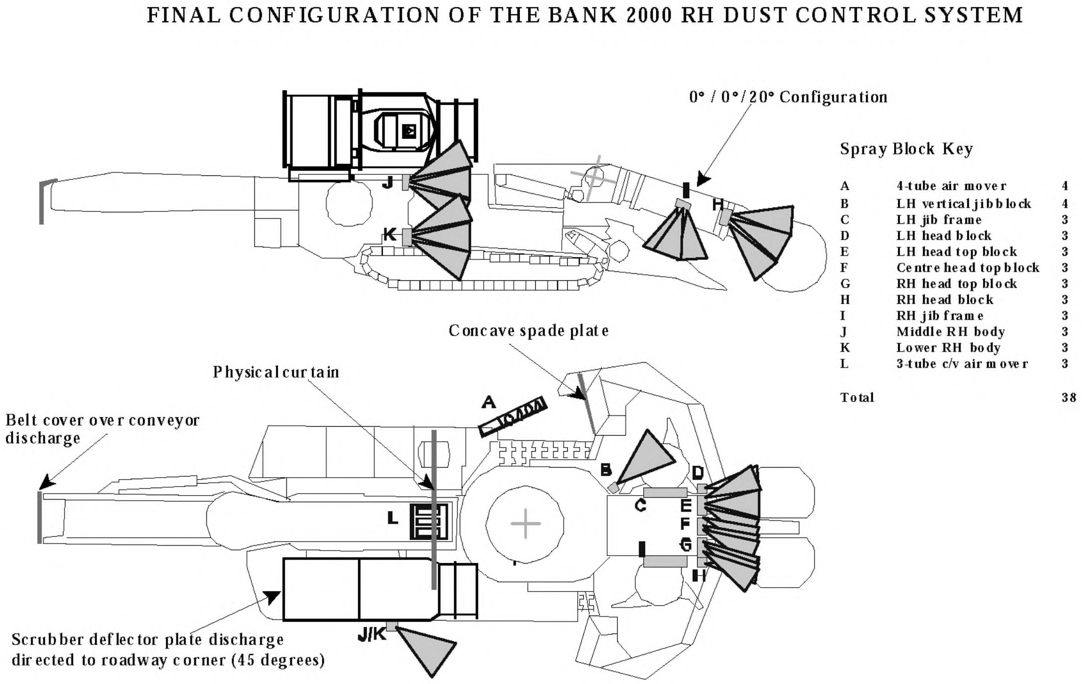

Figure 2. Final configuration of the Bank 2000 RH dust control system.

The concave shape of the plate prevents or slows down the momentum of the rollback dust, prevents further travel towards the operator's position and acts as a physical shield. As the falling dust rolls towards the concave spade plate, due to its concave shape, the dust travels backwards towards the face. On the other hand, when auxiliary ventilation such as a jet fan and column are used, the concave shape of the spade plate does not act as a shield and prevent the fresh air from reaching the face area.

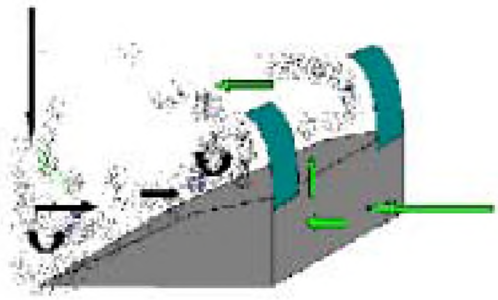

Figure 3. Operation of concave spade plate.

A total of 17 tests were conducted on the Bank 2000 RH dust control system. In all the underground tests, no auxiliary ventilation devices such as a force fan or jet fan were used. To optimize the Bank 2000 RH dust control system, a number of critical changes were made during the underground tests to achieve the desired environmental conditions through various changes to the dust-control elements as discussed earlier. The test conditions and the changes made in order to obtain the final system from Tests 1 to 17 are summarized in Table 1.

Table 1. Test conditions-Bank 2000 RH dust control system.

Test #	WP	S	C	D	F	J	HC
1 to 4	8	P	A	A	A	A	A
5 to 8	16	S*	A	A	A	A	P
9 to 11	16	A	A	A	A	P	P
12	16	S**	P	A	P	P	P
13 to 17	16	S**	P	P	P	P	P

WP – Water pressure; S - Four-tube air mover on the spade position; C - Spade concave plate; D - 45° scrubber deflector plate; F - Flight conveyor belt cover; J – Left-hand jib sprays; S* - Four-tube air mover on the spade position but not working; S** - Four-tube air-mover present at the RH computer box; P - Present, A - absent.

4.1 Underground results

Table 2 shows the dust-concentration levels at the intake, operator and return for an 8-hr period during the development of the Bank 2000 RH dust control system. It was observed during the tests that the falling total dust cloud, which gathered momentum during its course, was partially contained by the non-operational four-tube air movers positioned at the spade on the LHS. External sprays were able to wet both the roof and the face area. The addition and repositioning of the physical half-curtain was very effective. When the RH was cutting beyond 20 m from the LTR, the smooth flow of air was lost in the absence of the shuttle car. However, when the shuttle car was present, the air was directed from the operator's side towards the face. When the RH was cutting the bottom half of the face area, the operator's position was clean and clearly visible. In the absence of the 45° deflector plate, when the flight conveyor was partially blocked by large chunks of coal, more dust was generated due to friction and this became airborne from flight conveyor in the direction of the shuttle car operator's position.

Table 2. Average dust concentrations for an 8-hr period.

Test #	Intake	Operator	Return
1	0.192	2.272	0.718
2	1.420	5.681	2.075
3	0.257	1.225	0.364
4	0.156	1.944	0.874
5	0.465	3.383	1.183
6	0.146	7.610	1.780
7	0.296	3.711	4.610
8	0.389	5.525	4.505
9	1.275	4.219	1.802
10	0.503	7.726	2.310
11	0.743	3.513	7.236
12	0.260	5.489	7.722
13	0.248	1.474	1.069
14	0.574	3.337	2.338
15	0.239	2.919	1.753
16	0.361	2.303	1.292
17	0.263	2.688	1.441

The box plots of the concentration levels at the section intake, RH operator position and section return are shown in Figure 4 below.

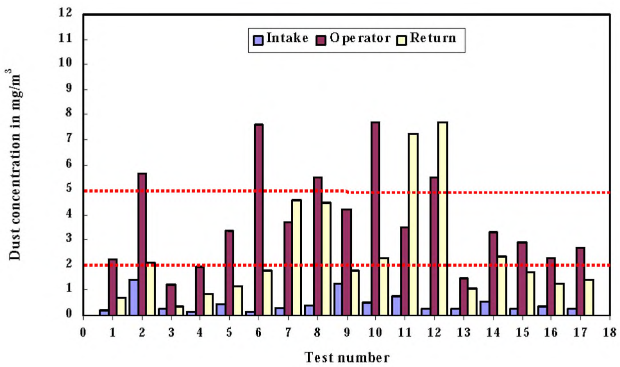

Figure 4. Dust concentration levels during the u/g trials.

The average coal production for the 17 production shifts was 840 tons, with a maximum production of 1680 tons. During Tests 5, 7, 8, 11 and 12, Section 13 was stone dusted in between the shifts. Therefore, stone dust influenced the samples in the section return. For this reason, the section return dust-concentration readings for those specific shifts were ignored in the calculations. The calculated average return dust-concentration levels during the tests (12 tests) for the sampling period and the 8-h TWA were therefore 2.28 mg/m^3 and 1.78 mg/m^3 respectively. During Test 17, poor section ventilation was observed due to the presence of the dyke at the section intake road and this required that the ventilation layout of the section be altered since most of the air was passing through the previous split and thus short-circuiting the air directly to the return.

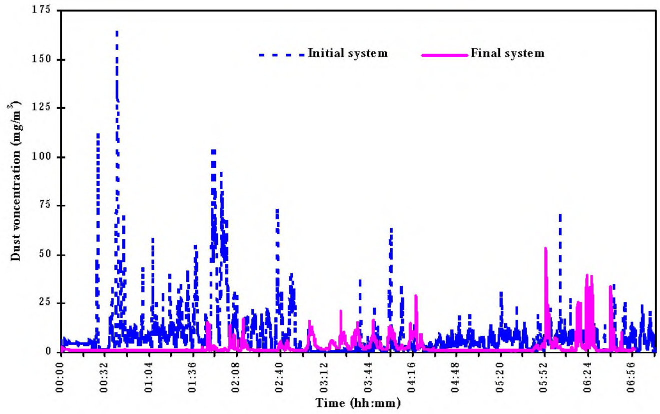

Figure 5. Comparison of real-time dust concentration levels.

The improvement in the dust control system is also observed from the peak concentrations recorded by the real-time monitors. As shown in Figure 5, it is observed that the final system greatly reduced the peak concentration levels as well as the frequency of the peak levels at the operator's position. The calculated average dust-concentration levels (17 tests) at the section intake, operator and section return for the sampling period were 0.46 mg/m^3, 3.82 mg/m^3 and 2.53 mg/m^3 respectively. The average sampling time for evaluating the entire system was 375 minutes.

4.2 Discussion of critical issues

The following observations were made during the trials with the Bank 2000 RH dust control system:

- The Bank 2000 RH dust control system was able to control the dust adequately and to ventilate the face area of the heading effectively.
- In the absence of auxiliary ventilation devices such as a jet fan or force fan, beyond 20 m from the LTR, the on-board scrubber along with the sprays must not be allowed to stop in between the cutting periods.
- When the RH was cutting at a height of 5.1 m on the LHS top coal, frequent recurrent very high dust-concentration levels at the operator's cabin position were observed. The introduction of the concave spade plate greatly reduced the trend (Figure 5).
- The dust concentration peaked when the RH holed through splits and at the beginning of a fresh cut (heading or split) as the face environment is then not confined.
- In the initial tests (Tests 1 to 12), the deflector plates of the scrubber discharge were horizontal,

thus blowing the discharge air over the RH flight conveyor and causing the re-circulation of dust back to the operator's position.

- The jib spray block (B) augmented with the concave spade plate suppressed the dust in the face area when the RH was cutting the top LHS of the face area. The effectiveness of the concave spade plate was visible, as the dust is deposited on the concave side of the spade plate where it is suppressed by the water sprays positioned at the LHS jib. It is hoped that a concave spade plate on both sides of the RH spade may prove to work even better, preventing the escape of the dust towards the section return.
- The for-tube air movers positioned near the left-hand-side (LHS) spraying LHS corner of the face, in conjunction with the concave spade plate, suppressed the falling and contained total dust. The primary purpose of the air movers is to aid the flow of air around the machine and ensure effective ventilation of the face on the side furthest from the scrubber inlet, particularly when there is no additional auxiliary ventilation.
- When the physical half-curtain is just inside the heading, dust rollback from the LHS reduced dramatically.
- It was observed that when the RH boom was moving from right to left while cutting the top 1/3 area, the dust rollback towards the operator was at its highest.
- In the absence of auxiliary ventilation (jet fan or force fan), in the deep heading, the operator's side was ventilated when the shuttle car was waiting to load the coal in the heading behind the RH.

4.3 *Methane concentration and in-heading gas release rate results*

For all the tests the maximum methane levels did not exceed 0.3% methane in air by volume, with an average of below 0.1% methane by volume. During the test series the in-heading gas release rate for three samples was determined to verify the recorded low methane levels. This rate was determined by using the standard direct test method for determining the gas content of coal (Van Zyl, pers. comm.). The calculated gas release rate while the coal is cut in the heading is used as an indicator of the gas released in the heading during cutting. Test was carried while the RH was cutting a straight at a depth of 21 m from the LTR. The In-heading gas release rate and in-heading gas released per minute at a cutting rate of 7 ton/min were 16 L/ton/min and 112 L/min respectively. Due to the low in heading gas release rates, and the large area available for methane dilution around the jib, the generally low methane levels recorded around the RH was expected.

5 CONCLUSIONS

In conclusion, the critical elements of the Bank 2000 RH Dust Control System are as follows:

- Hollow-cone single-inlet nozzles — 1.6 mm (inlet) / 2.0 mm (outlet)
- Physical half-curtain
- Air movers on the flight conveyor
- Air movers at the LHS of the operator, behind the spade position and near the computer box
- Jib sprays-position and angle
- New concave spade plate on the LHS and RHS of the RH
- Flight conveyor discharge cover
- 45 degree scrubber deflector plate
- Water pressure of 15 to 20 bar
- Effective dust scrubber system.

The Optimum Spray System (OSS) configuration evaluated in the surface trials were modified underground with few additional components for effective control the dust at the operator position. In the end, with the addition of various system components, it can be claimed that several systems were evaluated during the test period for achieving the DME directive. The Bank 2000 RH dust control system was able to control the dust adequately and to ventilate the face area of the heading effectively. The 8-h TWA dust-concentration level at the operator position was 2.54 mg/m^3, i.e. below the 5.0 mg/m^3 limit. Also, the personal exposure levels of the remote RH operator with final Bank 2000 RH dust control system was below 2 mg/m^3 (Belle, unpubl.).

For the scenarios tested in this particular section of the mine, the methane concentrations were within the permissible 1.4 % CH_4 per volume concentration levels. It is also extremely important to maintain the Bank 2000 RH dust control system design, spray configuration and individual components in order to keep the dust concentrations below the legal limits. Although each mine and section differs in its operation, the use of a combination of the ventilation and dust-control systems evaluated in this research project will be able to bring the dust levels within the regulatory requirements.

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