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REVIEW OF VENTILATION OPTIMISATION STRATEGIES DURING LONGWALL MOVES

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ABSTRACT

Occupational exposure limits for diesel particular matter (DPM) are progressively being adopted in a number of countries. Many of these follow the lead of the US Mine Safety and Health Administration initiated in 2008. In line with adoption of best practice it is accepted that all exposures should be reduced to as low as reasonably achievable. The management of diesel emissions and occupational exposures to those emissions requires an integrated strategy incorporating efforts from all key departments on a mine, including management, production, maintenance, supply and occupational health and safety.

Australian coal mine longwall moves rely on use of high powered diesel equipment such as chariots and other machines that produce exhaust pollutants of gases and DPM. To reduce mine personnel's exposure levels to DPM a hierarchy of controls can be followed. Minimising the use of diesel equipment, better operator positioning in relation to exposure source, using efficient engineering methods and adopting better ventilation to reduce concentrations through dilution are some of these controls which can eliminate exposures. Approaches generally adopted in Australian longwall mines currently rely on a combination of strategies such as optimisation of ventilation, use of diesel particulate filters and use of diesel tag boards that minimise the number of vehicles through recording entry and exit into working panels.

A study has been undertaken into the mine ventilation systems currently in use during longwall moves within Australian modern longwall extraction mines. This paper reviews current longwall section ventilation systems and discusses evolving changes being adopted to address the more complex problems in dealing with section DPM during phases of the operational moves. The effects of DPM on crew members as well as the diesel equipment operators within a longwall section are examined. Issues that should be considered in designing the longwall section ventilation during the moves are discussed.

INTRODUCTION

The invention of a compression ignition engine by Rudolph Diesel in the 1890s has contributed significantly to the productivity of many countries over the past 120 years, due to the widespread use of larger diesel powered equipment in most industrial activities. The use of diesel-powered plant in underground mining has steadily increased since the 1940s. During this time, diesel-driven mechanised machinery has replaced physical labour or pneumatically driven machines. Today there are a variety of mechanised diesel units for many underground operations.

The down side of using diesel machines in terms of occupational health has been the exposure of a large number of workers to the complex mixture of toxic gaseous, adsorbed organics and particulate components found in the raw exhaust emissions. The gaseous phase of diesel exhaust consists largely of the same gases found in air, such as nitrogen, oxygen, carbon dioxide and water vapour. The particulate fraction of the diesel exhaust aerosol consists of a solid carbon phase and ultra-fine droplets of a complex mix of semi-volatile organic compounds.

Exposure to the microscopic particles in diesel engine exhaust can lead to serious health problems including the incidence of cancers, heart disease and increased susceptibility to respiratory ailments of pneumonia, bronchitis, and asthma. The options for the treatment and reduction of diesel emissions have become a major area of concern for many mine operators. The basis for any complete DPM compliance strategy should be a comprehensive baseline study of the DPM present in the mine atmosphere including ambient air monitoring, analysis of monitored data, and development of a realistic plan for ambient DPM reduction. It is important that studies are taken on a real time basis to allow important sources of DPM in the mine atmosphere to be prioritised.

NIOSH has been closely involved in the development of instruments for measurement of airborne DPM for more than 20 years. The earliest approaches focused on shift average determinations with development of the SKC approach. Two real time DPM monitors have been developed since then. The first, the real time Diesel version of Personal Dust Monitor (D-PDM) was developed on the base of the successful Personal Dust Monitor (PDM) unit. The heart of the PDM is a miniaturised direct mass measuring sensor that measures mine dust. Changes were undertaken to the PDM (Gillies and Wu, 2008) to convert it to a DPM particulate submicrometer real time monitoring underground instrument which was named the D-PDM. The real time D-PDM unit continually reports levels of mine atmosphere submicrometer aerosol. The D-PDM results have been correlated with parallel SKC system DPM evaluations (Gillies, 2011). A phase of robustness and engineering testing has been undertaken to ensure the instrument can effectively assist mine management.

Another real time DPM measurement instrument, the FLIR Airtec, became commercially available in 2011 (Janisko and Noll, 2008; Noll and Janisko, 2007). It measures the Elemental Carbon (EC) component of DPM by a laser scattering approach. Both new instruments have been evaluated underground in robustness and reliability testing in some Australian coal mines and US metal/non-metal mines.

Where diesel equipment is operating in confined areas such as underground mines there is a significant risk of exposure. Levels in Australian underground coal mines have been measured at up to 0.37 mg/m^3 as EC (Joint Coal Board, 1999; Rogers, 2005), although levels up to 2.2 mg/m^3 have been measured, depending on job type and mining operation (Pratt *et al*, 1997).

Levels in Australian underground metalliferous mines have been measured up to 0.42 mg/m^3 EC (Rogers and Davies, 2001). Investigations in 2005 by SIMTARS also found elevated exposures in Queensland underground metalliferous mines (Hedges *et al*, 2007). For surface mining operations, forklift operators have been found to be the highest exposed group (Dabill, 2004). Levels up to 0.40 mg/m^3 have been measured for forklift operators, with a median of 0.075 mg/m^3 EC (Groves and Cain, 2000).

In recent years, occupational exposure limits for DPM are progressively being adopted in a number of countries. Many of these follow the lead of the US Mine Safety and Health Administration initiated in 2008. In line with adoption of best practice it is accepted that all exposures should be reduced to as low as reasonably achievable. There is currently no national exposure standard for DPM. However, a number of regulatory agencies in Australia have adopted the Australian Institute of Occupational Hygienists exposure limit recommendation of 0.1 mg/m^3 as EC measured as a time-weighted average over eight hours (adjusted for extended work shifts). The management of diesel emissions and occupational exposures to those emissions requires an integrated strategy incorporating efforts from all key departments on a mine, including management, production, maintenance, supply and occupational health and safety.

Australian coal mine longwall moves rely on use of high powered diesel equipment of chariots and other machines that produces very high exhaust pollutants of gases and DPM. Many Australian coal mines have trouble meeting DPM “Target Limits” during all phases of the operational moves. “Target limits” used generally follow the NSW Guidelines for DPM: 0.1 mg/m^3 of EC or 0.2 mg/m^3 of Submicron Particulate.

The extensive use of diesel-powered equipment in underground mines makes it challenging to control workers’ exposure to submicron aerosols and noxious gases emitted by those engines. In order to protect workers, mines need to establish a comprehensive program based on a multifaceted and integrated approach. To reduce mine personnel’s exposure levels to DPM. Bugarski *et al* (2011) suggested that the following hierarchy of controls should be considered and followed:

- Curtail emissions of the DPM and toxic gases at the source;
- Control pollutants after they are released in the underground mine environment; and
- Use administrative controls to reduce exposures of underground miners to pollutants.

Curtail Emissions or Elimination

Total elimination of the use of diesel powered machines in underground coal mines is generally impractical as electric options under current technology are not sufficiently versatile and are limited by range. It is possible to reduce diesel emissions with the uptake of tier 3 or better engine for the diesel machines used. However, within underground coal mines the majority of current diesel machines available are generally pre tier 3 and were designed in the 1950s.

The use of low sulphur or other low-emission fuels and low sulphur lubricants is a way of reducing diesel emissions. Low sulphur fuels with sulphur less than 500 ppm have been reduced even further. Some have been reduced to less than 5 ppm and are classified as ultra-low sulphur diesel. Fuel regulations in Australia mandate a maximum sulphur content of 10 ppm.

Another control that can be used is the use of emission control devices such as pleated diesel exhaust filters on diesel machines used to reduce diesel emissions by either removing solid fractions or converting pollutants into less harmful emissions. DPM filter systems can efficiently trap the solid fraction of diesel emissions and emerging technologies also suggest an ability to remove the fraction of nanoparticle size. Engine design, mine operating parameters and engine duty cycle should also be considered as part of the filter selection.

Isolation

It is possible to reduce the DPM exposure levels of workers by isolating workers from the source of the diesel emissions. This can be done by limiting size of crews working downstream or inbye of diesel equipment operations; through job rotation of miners employed on known heavy and intensive diesel use activities and the use of a diesel tag boards system that limits the number of diesel machines in use relative to air quantities available in each ventilation split.

Administrative Controls

Various administrative or engineering controls can be applied to reduce workers exposure to DPM and some examples of these controls are as follows:

- Understand past and current personal exposure situations at operating sites through continuous personal DPM exposure monitoring programs under normal production, development and change out phases.
- Ventilation required as specified by regulations may not be adequate to protect against DPM as until recently limits have mainly been based only on gas dilution requirements.
- Quality of air supplied to the section.
- Quality and frequency of servicing of machines.
- Training and education of workers (particularly machine operators) about the impact of DPM controls and strategies that can be applied. This could include the following:
    - Ensuring services are done.
    - Correct use of machines for task.
    - Complying with diesel tag board operations.
- Driving or operating machines according to conditions.
- Understanding impacts on workers positioned inbye of machines and direction of ventilation airflow.
- Hot machines perform poorly so radiator should be cleaned regularly to remove mud and dirt from exterior.
- Avoid leaving machines idling unnecessarily and avoid vehicle convoys.
- Air flow along working faces must comply with regulations.
- Personal Protective Equipment (PPE) must be available for use.

Approaches adopted in Australian coal mines currently rely on a combination of the following strategies:

- Optimisation of ventilation.
- Use of diesel tag boards that minimise number of vehicles working in installation and salvage panels.
- Use of diesel particulate filters.

EXAMPLES OF DPM CONTROL STRATEGIES AT SOME AUSTRALIAN MINES

Over the last 8 years, 24 real time DPM surveys have been conducted at nine Australian underground longwall mines during their longwall operational moves with 164 DPM sample point measurements identified for background DPM readings from outbye areas, longwall recovery face areas and longwall installation face areas. Table 1 shows a summary of the ranges of DPM and control strategies observed in these real time DPM surveys during longwall moves in these Australian longwall operations.

A number of examples are given in the following sections to illustrate DPM monitoring in Australian coal mines during longwall move operational activities. Results from DPM monitoring using real time DPM instruments are shown from three Australian coal mines with a particular emphasis given to the longwall panel ventilation arrangements and diesel vehicle travel routes. DPM control strategies utilised by these mines during their longwall move activities are also described.

Mine A

Mine A is a highly gassy underground longwall mine with face cutting heights from 2.8 to 3.1 m. Typical longwall panels are 200 m wide and about 3,200 m long with twin heading gate roads. Faces accommodate 134 four-leg chock shields. Real time DPM surveys were undertaken over two days. These exercises monitored various ventilation arrangements of the longwall face move during chock shield transport to the installation roadway. Figure 1 shows longwall panel ventilation arrangements and two chock shield transport routes during Mine A surveys. Both maingate (MG) and tailgate (TG) travel roads were used as intakes and MG belt road was used as panel return with a back borehole (0.95 m dia.) also exhausting 12 m^3/s.

On Day 1, ventilation and diesel travel routes were not optimised. About 45 m^3/s ventilation was measured in the MG and 24 m^3/s was in the TG. Loaded chock shield carriers travelled in and out through TG as a section of longwall back road was being concreted. Chock shields were unloaded at TG end of the installation face and then picked up by an electric mule to transport them into final positions along the face road. DPM sources are mainly from chock shield carriers, loaders, service and light vehicles. Only five chock shields were transported and installed over the six hours monitoring duration period. Outbye background DPM levels averaged at 0.076 mg/m^3 and DPM levels at installation face were extremely high at 0.452 mg/m^3.

On Day 2, panel ventilation was improved and a better chock shield carrier traveling route was arranged with the use of the back road. Loaded chock shield carriers travelled in along the MG and out through TG. About 50 m^3/s ventilation was measured in the MG and 35 m^3/s in the TG. Four chock shield carriers were available and a total of 10 chock shields were transported and installed over the six hours monitoring period. Outbye background DPM levels similar to Day 1 were averaged at 0.067 mg/m^3 and DPM levels at installation face were reduced but still significant at 0.289 mg/m^3. Compared with Day 1 DPM levels measured, a reduction of 35% in DPM levels at the installation face was achieved even although twice of chock shields were installed in a similar time frame.

It was straight forward to analyse results for arrival and departure times of diesel machines at the face with real time DPM monitoring. Interpretation could be made on whether the machine travelled down gate roads either with a speed faster than the air velocity (and so with high exhaust concentrations trailing) or with a speed slower than the air velocity (and so with high exhaust concentrations in advance). Figure 2 clearly demonstrated the ability of the D-PDM units to detect variations of DPM levels in the atmosphere as the chock shield carriers travelled into the installation face from TG end of face and then came out from TG end of the longwall face. Significant submicron DPM readings were recorded due to the large number (10) of chock shields that were transported during the shift. Levels of DPM recorded in the second half of the shift were higher. The condition of the back road had become poor and some chock shield carriers were slower and having difficulty travelling through.

Close examination of results from #108 monitoring the DPM downstream of the TG and back road showed when the chock shield carriers travelled in from the TG. In three cases they arrived at the TG end of the face in advance of the peak level of the DPM cloud. This indicated that the carriers were generally travelling at higher average speed than air velocity. However some chock shield carriers arrived slightly later indicating slower machine travel speed than air velocity. The time difference and also the peak concentration depend on the air velocity and chock shield carriers' travel speeds. In theory if the chock shield carrier travels at the same speed as air velocity the peak concentration will be extremely high (at the concentration of the raw exhaust) and the carrier will arrive at the same time as the concentration peak.

Mine B

Mine B is another gassy underground longwall mine with mining heights from 2.8 to 3.1 m. Typical longwall panels are 300 m wide using 174 two-leg chock shields and about 3400 m long with twin heading gate roads. Mine B tests were undertaken over 3 days. These exercises monitored various ventilation arrangements of longwall face move during chock shield transport to the installation roadway. Figure 3 shows longwall ventilation arrangement for tests and the positions of the D-PDM monitors #106 and #108 during the tests. During the survey period loaded chock carriers travelled in and out through the TG. There was a total of 43 m^3/s of air in the longwall installation panel with a back borehole downcasting about 11 m^3/s and the rest from panel gateroads. Three chock shield carriers were available and a total of four chock shields were moved.

Mine B results were analysed to identify sources and levels of DPM within the panel as shown in Table 2. By strategically placing the real time DPM monitors within the longwall panel various sources of the DPM could be identified. The DPM sources (µg/s) in Table 2 are calculated by knowing the air quantity (m^3/s) and the

DPM concentration (µg/m^3) at various locations within the panel ventilation circuit. There were significant DPM levels in TG Heading D due to outbye traffic and in particular the passage of chock shield carriers in the Mains intake air stream to the panel TG. There were also significant DPM levels added along the longwall face due to installation activities for chock shields by “shunting mules” or loaders. The largest source was from chock shield carriers that carried individual chock shields along the length of the TG to reach the face.

As discussed by Dabill (2004) exposure of drivers of diesel vehicle to DPM can be limited by the vehicle traveling direction and the ventilation system. For vehicles travelling against the ventilation attempts should always be made to try to ensure the engine is trailing the driver. Under these conditions driver exposure to DPM will be low if no other vehicle are inbye. However, travelling against the ventilation flow with the engine forward can lead to very high driver exposure and where possible this should be avoided or at the very least reduced to as short a time as possible.

It is more difficult to minimise exposure when travelling with the airflow as no matter what speed the vehicle travels the driver is likely to be exposed. It is important for the vehicle not to travel at the same speed as the ventilation air velocity as the vehicle driver will be operating in an ever increasing concentration of diesel exhaust emissions and consequently exposure could be very high. If the vehicle is likely to be travelling faster than the ventilation airflow then have the engine trailing and if the vehicle is slower than the ventilation have it orientated with the engine forward of the driver. By observing these practices or rules exposure to DPM will be kept to a minimum but will not be eliminated altogether. Table 3 demonstrates on vehicle speed and ventilation air velocity over a single travel route, Mine B TG Heading D, for chock shield delivery to the installation face. Points that can be established from Mine B data are as follows:

- In these specific tests chock shield carriers travel at higher average speed than air velocity.
- However on poor roads there could be slower machine travel speed than air velocity.
- The time difference and the peak concentration will depend on the air route, whether the air is travelling with or against the carrier direction, the air velocity as a function of the air quantity and chock shield carriers’ travel speeds.
- In theory if the chock shield carrier travels with the air at the same speed as air velocity the peak concentration around the vehicle will be extremely high.
- A possible reduction in DPM driver exposure could have been achieved by consideration of the following.
- TG travel route panel air quantity could be increased.
- Alternatively TG could be re-routed, for instance air into panel up D Heading and return down C Heading.
- Increase in air velocity may result in relative air velocity and vehicle speed being very similar. This is to be avoided if vehicle travels with air as would have happened if vehicles came into the panel up D Heading.
- Best if vehicle travels against airflow direction.
- Best conditions would be achieved if air came into panel up D Heading and returned down C Heading and traffic was in the opposite direction and drove up C and down D Headings. In this configuration vehicles would always travel against air. If the vehicle exhaust outlet trails the driver then exhaust will pass away from the driver in both directions of travel.

Mine C

Mine C is also a gassy underground longwall mine with mining heights ranging from 4.1 to 4.5 m. Typical longwall panels are 250 m wide using 151 two-leg large and heavy chock shields and about 2500 m to 4000 m long with twin heading gate roads. The majority of diesel vehicles used for the longwall move at Mine C were fitted with exhaust filters. Electric and diesel powered dozers were used in the recovery face to pull chock shields off the face. However, only diesel powered dozers or loaders were used in the installation activities to reposition chock shields to their final positions. Diesel Tag Board systems were used at all major ventilation splits to manage and control diesel exhaust.

In order to assist in pre-planning and optimising DPM control strategies, real time DPM surveys were undertaken prior to and during the longwall move at Mine C. Outbye DPM levels of the longwall recovery and installation panels were measured and ranged from 0.043 to 0.061 mg/m^3. This is about 26% of the “Target Levels” of 0.2 mg/m^3 and is within the ranges of normal outbye background levels that have been observed at various longwall mines over the years.

For one of the longwall installation panels observed in Mine C, a total of about 115 m^3/s of air was available with 45 m^3/s of fresh air was planned to be supplied via a back panel shaft, 30 m^3/s from MG mid panel borehole and 40 m^3/s from Mains. MG B Heading (Belt Road) and TG A Heading served as returns with 60 m^3/s return via MG and 55 m^3/s via TG as shown in Figure 4.

A list of possible travel routes for chock shield chariots that could be considered is as follows:

1. Loaded chariots in from TG A Heading and empty chariots out via MG A Heading.
2. Loaded chariots in from MG A Heading and empty chariots out via TG A Heading.
3. Loaded chariots in from MG A Heading and empty chariots out via MG A Heading.
4. Loaded chariots in from TG A Heading and empty chariots out via TG A Heading.

The availability of travel routes for chariots bringing in chock shields into longwall installation panels is subject to conditions of roadways and other activities that need to be undertaken in the roadways. Examples included possible requirements of installing secondary supports in TG roadway prior to longwall panel production commencing. From the viewpoint of the ventilation arrangement, traffic and diesel exhaust dilution, the preferred travel route would follow option number 1. Under this loaded chariots are traveling in from TG A Heading against airflow direction and empty chariots are traveling out via MG A Heading which is against airflow direction as well (as shown in Figure 5). In this option, chariots will be traveling in a loop with no chariots passing each other. While traveling in and out of the panel, chariots will be traveling against the airflow direction which will provide the maximum diesel exhaust dilutions and reduce the exposure levels of the chariots operators.

Possibly highest DPM contaminated air would be in TG A Heading with loaded chariots traveling in. However, this heavily contaminated air would not travel across the face road but exhaust directly into Mains returns. It should be noted that option No 1 and also travel route options, No 2 and No 4 will only be available if the roadway condition of TG A Heading is good enough to allow chariots traffic and there is no need for pre-installation of second supports in the TG A Heading prior to the new longwall production commencing.

If TG A Heading is not available, the only option left for the chariot travel route is option No 3 where loaded chariots traveling in from MG A Heading and empty chariots traveling out also in MG A Heading as shown in Figure 6. In this situation, chariot operators would be subjected to higher DPM exposures when traveling in in MG A Heading as it will travel in the same direction as ventilation airflow. This type of chariot travel route arrangement has been largely adopted in the previous longwall moves at Mine C due to unavailability of the TG roadway for chariot travel.

As mentioned before the DPM exposure levels of operators will depend on vehicle speeds and air velocities. A large difference between vehicle speed and air velocity will result in lower exposure levels. In this option, the air in MG A Heading should be plentiful and if possible dump some air into MG B Heading before it reaches the installation face. Fresh air from panel back shaft will be less exposed to diesel activity as TG A Heading is not used for traffic in this case. Therefore, it is more favourable to use air from the panel back shaft to sweep across the installation face to provide lower DPM laden air to crew working at the face.

During Mine C longwall move real time DPM monitoring was undertaken over parts of four day shifts. It was found that results from D-PDM unit placed at mid-face of the installation face showed the average DPM levels at this position were only 60% to 75% of the “Target Limits”. It was also noticed that at the installation face crews were positioned working upstream of some hard working heavy diesel units such as ED40 repositioning chock shields and chock shield chariots unloading chock shields. Air quantities and ventilation circuit arrangements at the longwall installation panel appeared sufficient for diluting exhaust from diesel activities taking place during the survey period.

Data from the mine vehicle tracking system recorded for longwall installation panel at Diesel Tag Board location (MG A Heading 1-2ct) were examined as well. These vehicle movements in the travel road (MG A Heading) were plotted against the DPM recorded by D-PDM units and correlations were observed between vehicle movements and recorded DPM levels when possible DPM influence periods of vehicles traveling inbye and outbye were considered. Based on survey results, it was concluded that Diesel control strategies used in Mine C such as optimising panel ventilation design and arrangement, the use of Diesel Tag Board and fitting exhaust filters for their diesel fleet during the longwall move were effective in reduction of DPM exposure levels of face crews and equipment operators when compared with other mining operations.

LONGWALL MOVE PANEL VENTILATION DESIGN CONSIDERATIONS

Longwall moves rely on use of high diesel powered equipment of chock shield movers (carriers or chariots) and other diesel powered machines that produces high levels of exhaust of gases and DPM. Many Australian coal mines find it a challenge to meet DPM "Target Limits" during all phases of longwall operational moves. "Target" limits used generally follow the New South Wales Guidelines for DPM of 0.1 mg/m^3 EC or alternatively a limit of 0.2 mg/m^3 Submicron Particulate.

Approaches adopted in Australian coal mines rely as a first step on both ensuring there is enough air and optimisation of the ventilation system design. Issues that should be considered in optimising the longwall panel ventilation design include:

- Maximise and maintain face air quantity where chock shield recovery, movement or installation activity is occurring to reduce DPM concentration level through dilution.
- Design panel ventilation arrangements to have all moving machinery (or at least loaded machinery) travelling in the opposite direction to ventilation air flow.
- Where machinery cannot be moved against airflow ensure that air velocity is significantly higher than machine speed to ensure that a plume of exhaust does not hang over the travelling equipment.
- Try to have parallel transport roadways so that movement occurs in a circuit with loaded machines travelling inbye on one road and outbye on a parallel adjacent road.
- Ensure face ventilation is designed in a way that face crews are working upstream of machinery and in particular machinery that is working on faces loading or unloading and positioning chock shields.
- Divide available air so that the majority is passing along the roadways in which loaded machinery travels that has to work hard.
- Monitor DPM with real-time instruments so that points where "Target" limits are not being met are readily identified and improvements are made during the current longwall move or in planning for the next longwall move.

Past experiences show that no one simple solution exists in managing and controlling DPM in mine atmosphere. An assessment of exposures to DPM levels in Australian coal mines has found that higher exposures generally occur where there are bad road or wet and difficult) conditions, inadequate engine maintenance practices and excessively hardworking engines. Factors which result in lower DPM levels or exposures include use of low sulphur fuel, appropriate engine maintenance programs, positive and careful driving attitudes, good roadway conditions, good approaches to panel ventilation arrangement and control and effective control of diesel powered vehicles in the longwall panel. Reduction in the exposure of underground miners to diesel pollutants requires the involvement of several key departments of mining companies, including those responsible for health and safety, engine or vehicle maintenance, mine ventilation, and production, as well as the departments responsible for acquiring vehicles, engines, exhaust after treatment systems, fuel, and lubricating oil. Coordination of efforts between various mine departments will need to be coordinated and attention to detail is necessary to sustain successful DPM control strategies.

CONCLUSIONS

Real time DPM Surveys have been undertaken at various Australian coal mines at points of expected high atmospheric DPM such as during longwall face moves over the last nine years. This paper has closely examined the influence of aspects of the mine ventilation system on underground DPM pollution within the underground mine environment in evaluations of longwall moves. Some observations have been made on the current state of longwall panel ventilation and various DPM control strategies used within the Australian coal mining industry. Issues could be considered in designing longwall panel ventilation arrangements in preparation of longwall moves have been presented.

There have been predictions for many years that mine operations are about to move dramatically towards the provision of a pleasant and comfortable work environment or put another way a mining environment based on quality of life. In the last five years there have been dramatic improvements in many aspects of mine ventilation in a substantial number of both coal and metalliferous mines. Awareness of DPM is receiving much emphasis at present. Newly emerging real time monitors will assist in the enhancement of health and safety within the underground mine environment. Improvements in productivity that result from raising of mine atmosphere quality are the most likely to receive financial priority.

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FIGURE CAPTIONS

FIG 1 – Longwall panel ventilation and chock shields transport route arrangements of Mine A.

FIG 2 – Observations on results at monitor #108 fixed location.

FIG 3 – Longwall panel ventilation and chock shield transport route arrangements of Mine B.

FIG 4 – Proposed ventilation arrangement in longwall installation panel of Mine C.

FIG 5 – Possible chariot travel route option No 1.

FIG 6 – Possible chariot travel route option No 3.

TABLE CAPTIONS

TABLE 1

Summary of DPM ranges observed and controls used at Australian coal mines during longwall moves.

TABLE 2

Sources of DPM identified in the longwall installation panel.

TABLE 3

Data on chock shield carrier speeds and air velocities.

FIGURES

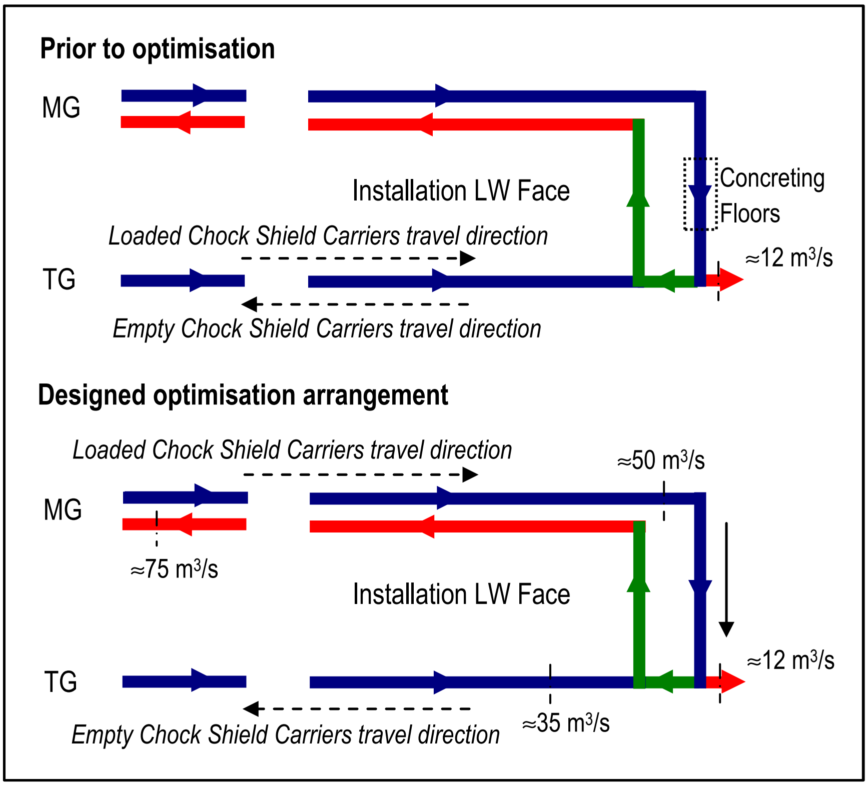

FIG 1 – Longwall panel ventilation and chock shields transport route arrangements of Mine A.

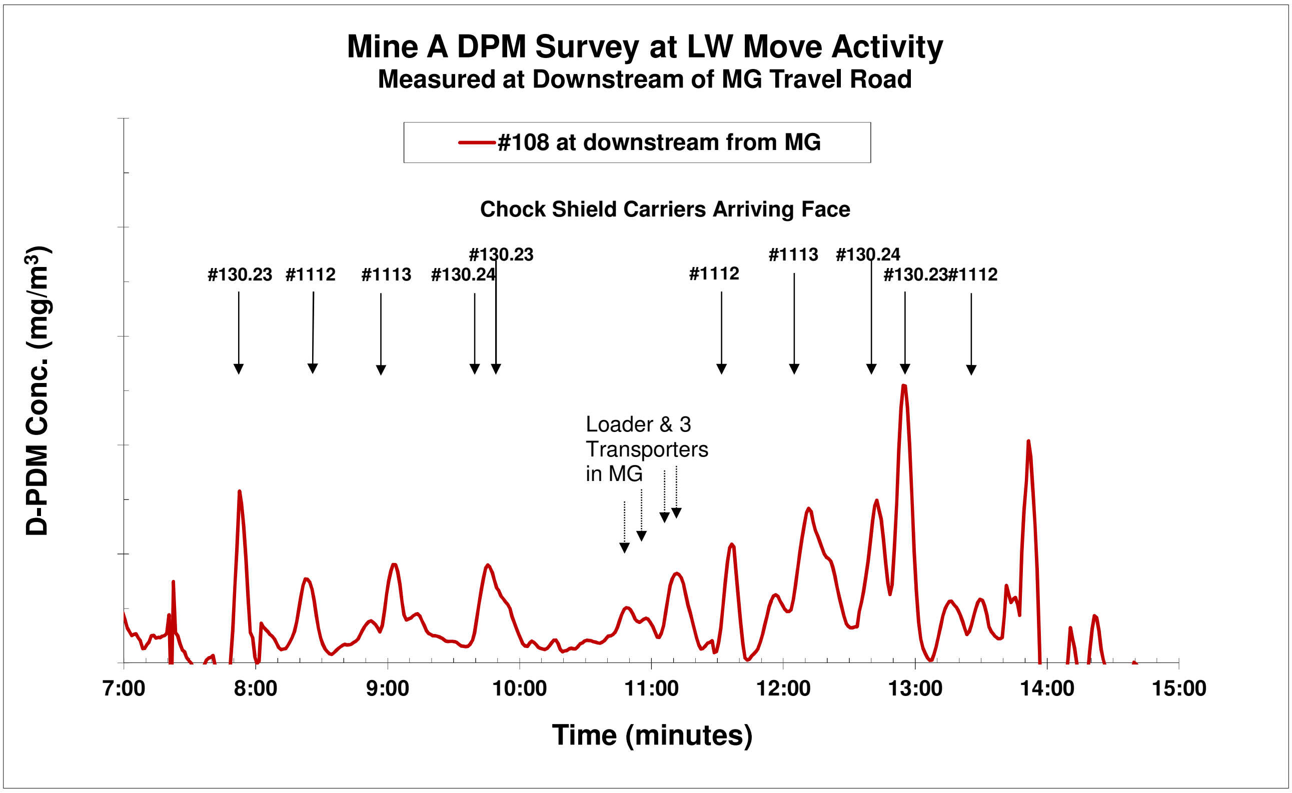

FIG 2 – Observations on results at monitor #108 fixed location.

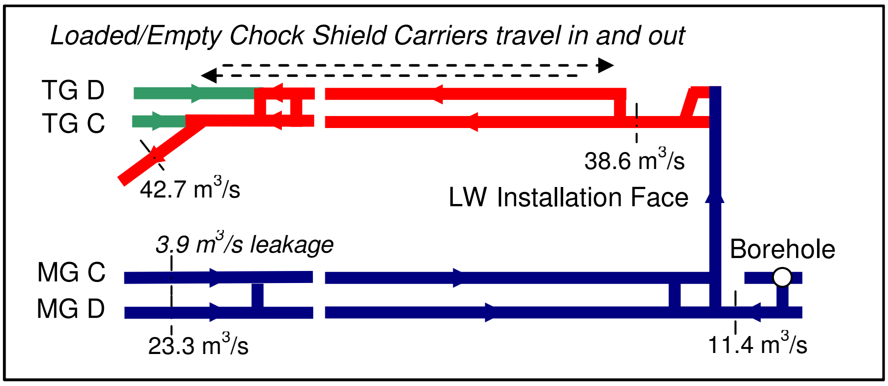

FIG 3 – Longwall panel ventilation and chock shield transport route arrangements of Mine B.

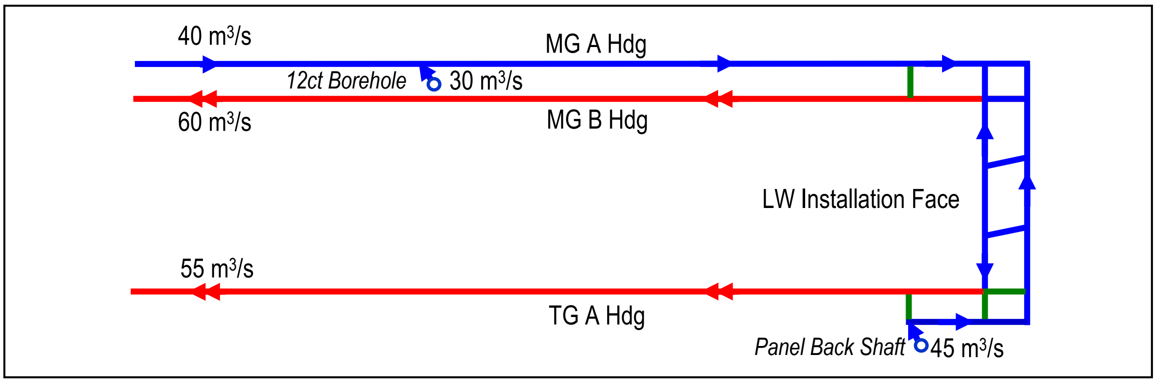

FIG 4 – Proposed ventilation arrangement in longwall installation panel of Mine C.

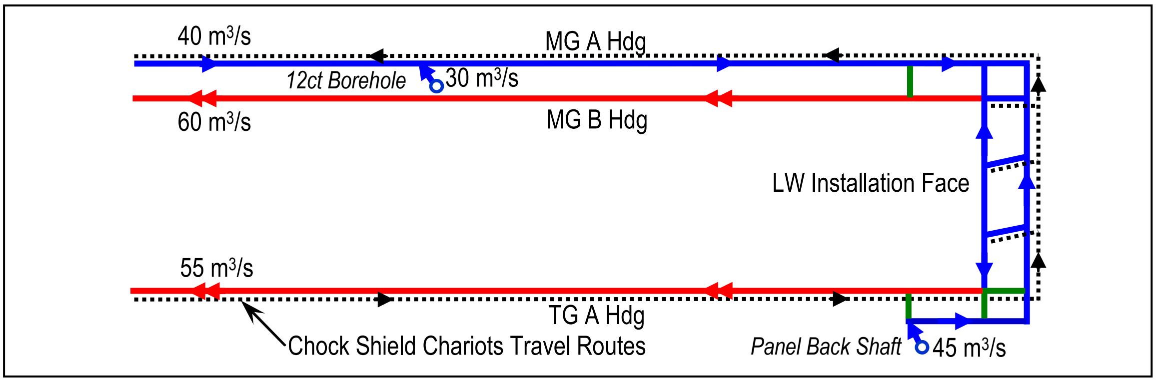

FIG 5 – Possible chariot travel route option No 1.

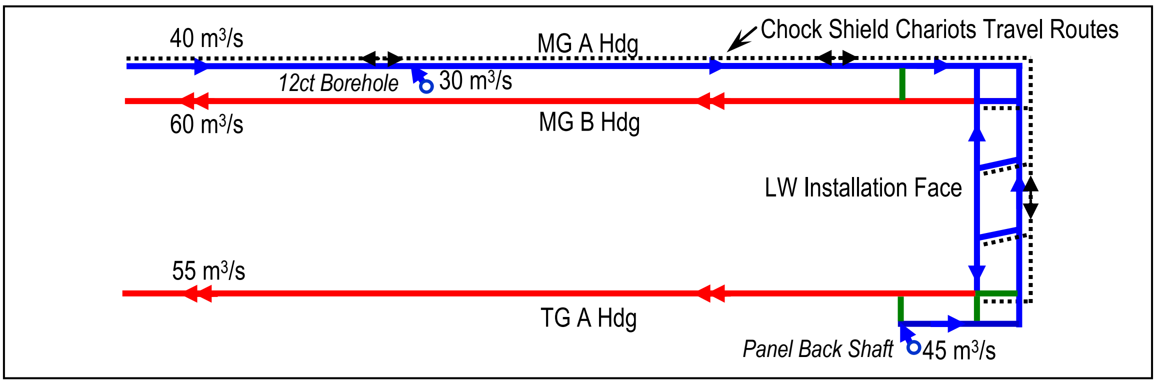

FIG 6 – Possible chariot travel route option No 3.

TABLES

TABLE 1

Summary of DPM ranges observed and controls used at Australian coal mines during longwall moves.

Mine	Type	Outbye Background		Recovery Panels		Installation Panels		DPM Control Strategies
		No of Sample	Range (mg/m^3)	No of Sample	Range (mg/m^3)	No of Sample	Range (mg/m^3)	
I	LW Punch	3	0.020-0.024	2	0.035-0.052	3	0.137-0.176	Diesel tag boards, electric mule
II	LW	3	0.067-0.103	2	0.175-0.812	5	0.137-0.447	Diesel tag boards
III	LW Punch	0	-	2	0.113-0.121	3	0.119-0.209	Diesel tag boards, electric mule
IV	LW	8	0.057-0.089	9	0.087-0.183	8	0.125-0.583	Diesel tag boards, electric mule, panel, ventilation optimisation, back panel intake shaft
V	LW	12	0.025-0.099	16	0.118-0.289	24	0.102-0.256	Diesel tag boards, electric dozer, ventilation optimisation, panel intake shafts, exhaust filters
VI	LW	0	-	0	-	17	0.136-0.695	Diesel tag boards, diesel & electric dozer at installation, back panel exhaust shaft
VII	LW	4	0.037-0.069	8	0.153-0.272	15	0.150-0.409	Diesel tag boards, back panel intake boreholes
VIII	LW	2	0.108-0.126	3	0.160-0.295	5	0.208-1.076	Diesel tag boards, electric mule
IX	LW	2	0.067-0.076	4	0.076-0.289	4	0.190-0.452	Electric mule, panel ventilation optimisation, back panel exhaust shaft

TABLE 2

Sources of DPM identified in the longwall installation panel.

Location	Sources		Comments
	μg/s	%	
MG, C & D Hdgs	3.03	18.6	Mains air at MG panel entrance
Borehole	0.00	0.0	Situated at the back of Longwall panel, fresh air
Longwall Face	4.77	29.2	Shunting Mule or loaders
TG D Hdg	6.96	42.6	Chock shield chariots travel way
TG C Hdg	0.00	0.0	No diesel activity
Leakages	1.57	9.6	Mains air via coffin seal & double doors
Measured Total	**16.32**	**100.0**	

TABLE 3

Data on chock shield carrier speeds and air velocities.

Time	Location	In/Out	Distance (m)	Time (mins)	Speed (m/s)	Air Vel (m/s)	Air Travel Time (mins)
Chock Shield Carrier APS 1306							
09:53	TG 2ct	In	3,400	34	1.66	1.29	43.9
10:27	Face						
Against Air	**Machine/Air Relative Velocity =**					**2.95**	
10:31	Face	Out	3,400	26	2.18	1.29	43.9
10:57	TG 2ct						
With Air	**Machine/Air Relative Velocity =**					**0.89**	
Chock Shield Carrier CC 1112							
10:12	TG 2ct	In	3,250	28	1.93	1.29	41.9
10:40	TG 36ct						
Against Air	**Machine/Air Relative Velocity =**					**3.22**	
10:50	TG 36ct	Out	3,250	17	3.18	1.29	41.9
11:07	TG 2ct						
With Air	**Machine/Air Relative Velocity =**					**1.89**	