IMPROVING MINE CONDITIONS WITH REAL TIME MONITORING OF RESPIRABLE DUST

ADS Gillies and HW Wu

Fourth School of Mine Ventilation, October 2006

Gillies Wu Mining Technology Pty Ltd

The Minserve Group

1 Swann Road Taringa Queensland 4068

Telephone 61 7 33776700

s.gillies@minserve.com.au

h.wu@minserve.com.au

Published as 95. A.D.S. Gillies and H.W. Wu, Improving mine conditions with real time monitoring of respirable dust, Proceedings, *Fourth School of Mine Ventilation, Polish Acad. of Sci. Mine Ventilation Section of the Mining Committee*, Cracow, October 2006 211-227.

LIST OF FIGURES

ABSTRACT

A new personal respirable dust monitor developed by Thermo Electron Corporation under a project funded by the US National Institute of Safety and Health (NIOSH) has generated promising results in underground coal mine testing performed in the US recently. An Australian Coal Association Research Project funded study has been undertaken to evaluate this new real-time dust monitor for personal respirable dust evaluation use particularly in engineering studies. It is believed to be the first personal dust monitor instrument (PDM) for use on mine faces that reliably delivers a near-real-time reading. It can quickly highlight high dust situations and allow the situation to be corrected.

The instrument has been tested for robustness and potential to be used as an engineering tool to evaluate the effectiveness of dust control strategies. This project has evaluated the ability of the new PDM to quickly and accurately measure changes to longwall and development section dust levels at manned points after implementation of changes and improvements. Extensive tests have been undertaken at a number of Australian underground mines.

The technology that forms the heart of the personal PDM, the TEOM® system, is unique in its ability to collect suspended particles on a filter while simultaneously determining the accumulated mass. The monitor internally measures the true particle mass collected on its filter and results do not exhibit the same sensitivity to water spray as optically based measurement approaches. The technique achieves microgram level mass resolution even in the hostile mine environment, and reports dust loading data on a continuous basis. Using the device, miners and mine operators have the ability to view both the cumulative and projected end-of-shift mass concentration values, as well as a short-term 5 minute short term running averages. It is believed to be the first personal dust monitor instrument that reliably delivers a near-real-time reading.

INTRODUCTION

A new personal respirable dust monitor developed by the company Rupprecht and Patashnick (now Thermo Electron) in the US under a project funded by National Institute of Safety and Health (NIOSH) has generated promising results in underground coal mine testing performed in the US recently (Volkwein et al, 2004a and 2004b). Results from an Australian Coal Association Research Project (ACARP) funded study undertaken to evaluate this new real-time dust monitor for personal respirable dust evaluation particularly in engineering studies have been described by Gillies and Wu, 2005, Gillies, 2005 and Gillies and Wu, 2006.

This paper describes some results from mine studies that have been undertaken using the real-time personal dust monitor (PDM).

The technology that forms the heart of the PDM, the TEOM® system, is unique in its ability to collect suspended particles on a filter while simultaneously determining the accumulated mass. The monitor internally measures the true particle mass collected on its filter and results do not exhibit the same sensitivity to water spray as optically based measurement approaches. The technique achieves microgram level mass resolution even in the hostile mine environment, and reports dust loading data on a continuous basis. Using the device, miners and mine operators have the ability to view both cumulative and projected end-of-shift mass concentration values, as well as a short-term 5, 15 or 30 minute running average. It is believed to be the first personal dust monitor instrument that reliably delivers a near-real-time reading.

The instrument has potential to be used as an engineering tool to evaluate the effectiveness of dust control strategies. Being a personal dust monitor, the instrument measures the airborne dust from the breathing zone region and so has many advantages over instruments that measure from a fixed-point location. It delivers a near-real-time reading and so can quickly highlight high dust situations and allow the situation to be corrected.

An ACARP supported research project completed by one of the authors, (Gillies, 2001) entitled "Dust Measurement and Control in Thick Seam Mining" ACARP C9002 highlighted some areas for new approaches and research to allow improvement of dust conditions within extraction panels within Australia's emerging thick seam coal industry. Industry, management, technical engineering staff and the workforce all give strong recognition to the challenge of dust as an increasing hazard particularly as higher production levels are achieved.

The underground workplace in both a continuous miner and longwall face environment has varying respirable dust conditions due to aspects such as ventilation conditions and air velocity, shearer activity and design, chock movement, AFC movement, manning position, face time of individual personnel, outbye conditions and dust levels in intake air and measurement instrument behaviour.

Many mines have observed a lack of repeatability in dust monitoring that is not easily explained. This study has evaluated the instrument as an engineering tool that can assess the effectiveness of a single change to improve dust levels in sufficiently short a time that other aspects have not changed.

EVALUATION OF THE PDM AS AN ENGINEERING TOOL

In the US the incidence of coal workers pneumoconiosis (CWP) has been declining for a least the past 35 years. Production levels at mines have been continually increasing and the development of dust control technologies for the working place atmosphere to protect workers has become more difficult and complex. Improved dust monitoring of coal mine dust concentrations offers a new means of protecting miners' health by more quickly identifying anomalous dust conditions.

Despite the decline in CWP, coal mine dust is still implicated in the US in the premature deaths of miners. In response, the US Secretary of Labour and the Federal Advisory Committee on the Elimination of Pneumoconiosis among Coal Mine Workers recommended that better monitoring of coal miner dust exposures be used as a method to improve miner health. In consultation with labour, industry, and government, NIOSH issued a contract to Rupprecht & Patashnick Co., Inc. (R&P), to develop a one-piece PDM. The objective of this work was to miniaturise the TEOM® technology into a form suitable for a person-wearable monitor that would enable accurate end-of-shift dust exposure information to be available to miners. Furthermore, any person-wearable dust monitor should minimize the burden to the wearer by incorporating the monitor into the mine worker's cap lamp battery, with exposure data continually displayed during the shift to enable workers and management to react to changes in dust exposure.

The PDM is configured to provide accurate respirable dust personal exposure information in a form that is convenient to wear by a miner. Respirable dust exposure data displayed by the device has two main objectives:

- providing the miner and mine operator with timely values to avoid overexposure to dust by making any necessary changes during the course of a work shift, and
- computing an accurate end-of-shift statistic for a miner's average respirable dust exposure.

The mass sensor in the PDM holds the key to the accurate, time-resolved dust concentration measurements. The inertial, gravimetric equivalent, mass measurement technique used in the device typically provides a limit of detection on par with that of the most sensitive laboratory-based microbalances. Similar to the integrated sampling method, the PDM contains a sampling system that collects particles on a filter located downstream of a respirable cyclone. In contrast to the current lapel worn personal method, however, the PDM mass measurement is performed continuously during a working shift in a mine instead of being delayed by the days or weeks required for a laboratory analysis.

The PDM is a respirable dust sampler and a gravimetric equivalent analysis instrument that is part of a belt-worn mine cap lamp battery. The main components of the device include a cap lamp and sample inlet located on the end of an umbilical cable, a belt-mounted enclosure containing the respirable dust cyclone, sampling, and mass measurement system, and a charging and communication module used to transmit data between the monitor and a PC while charging its lithium ion batteries for the next shift. Figure 1 illustrates the components typically carried by the miner, while Figure 2 shows the PDM with the charging and communication module. The PDM is designed to withstand the harsh conditions found in the mine environment, with the system designed to meet MSHA intrinsic safety type approval requirements.

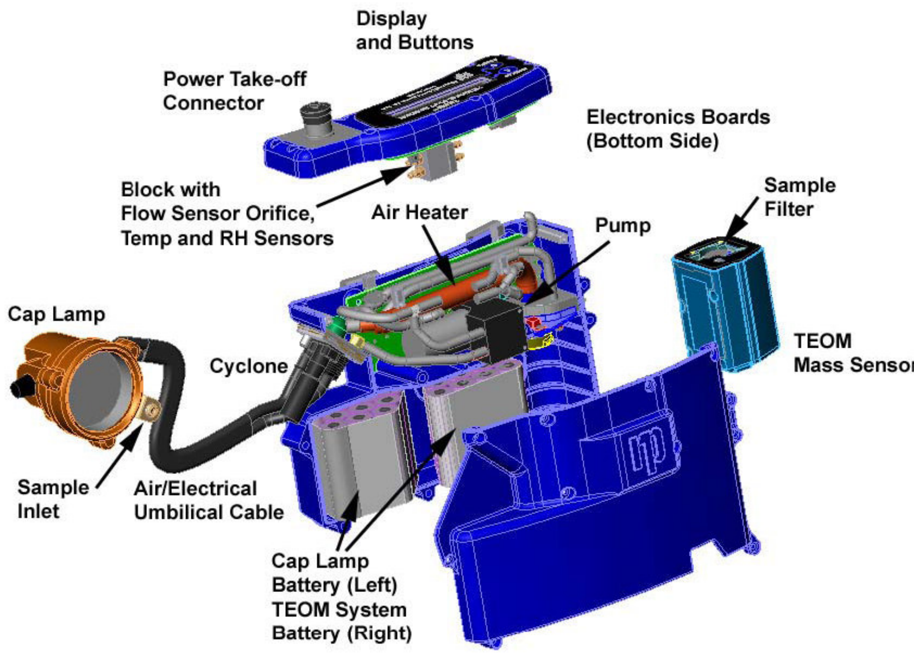

Figure 1 Major components of the PDM.

Figure 2 PDM installed on charging/communication module.

A 2.2 litre per minute flow of particle-laden air from the mine atmosphere enters an inlet mounted on the bill of the miner's hard hat, and passes through conductive tubing before reaching the Higgins and Dewell (HD) cyclone at the entrance of the PDM. The sample stream with respirable particles that exits from the cyclone is then conditioned in a heated section of tubing to remove excess moisture. As the air stream subsequently passes through the mass sensor, an exchangeable filter cartridge collects the respirable particles. The mass sensor can be removed from the PDM (Figure 3) to change the particle collection filter and clean the unit after the end of each work shift.

Figure 3 Installing a sample filter in the mass sensor.

Downstream of the mass sensor the filtered air sample flows through an orifice used in conjunction with a differential pressure measurement to determine the volumetric flow rate. The system computer uses this information to maintain a constant volumetric sample flow by varying the speed of a DC pump.

At the heart of the TEOM mass sensor is a hollow tube called the tapered element that is clamped at its base and is free to oscillate at its narrow end (Figure 4). The exchangeable filter cartridge mounted on its narrow end collects the respirable particles contained in the air stream that pass from the entrance of the mass sensor through the tapered element. Electronic components positioned around the tapered element cause the tube to oscillate at its natural (or resonant) frequency. As additional mass collects on the sample filter, the natural oscillating frequency decreases as a direct result. This approach uses first principles of physics to determine the mass change of the filter, and is not subject to uncertainties related to particle size, colour, shape or composition.

Built-in sample conditioning to remove excess moisture minimizes the PDM's response to airborne water droplets. The PDM determines the mass concentration of respirable dust in the mine environment by dividing the mass (as determined by the frequency change) collected on its filter over a given period of time by the volume of the air sample that passed through the system during the same time frame.

The PDM internally stores the readings from its built-in environmental sensors and mass sensor for latter downloading, and provides summary information on a continuous basis to the miner through the display located on top of the battery case. The display continuously shows the latest values for the cumulative mass concentration, the current dust concentration, and the miner's end-of-shift projected exposure. Through this interface, miners can gauge their current dust exposure, as well as the effectiveness of actions taken to reduce the in-mine dust concentration.

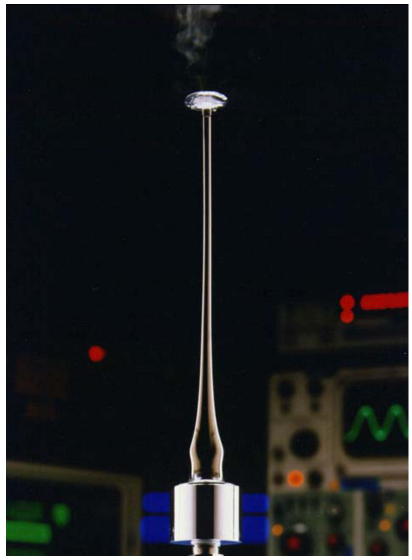

Figure 4 Tapered element with exchangeable filter mounted on narrow end.

AUSTRALIAN RESPIRABLE DUST EVALUATIONS

Two and at times three PDM units have been used simultaneously in a number of coal mines to measure conditions and to evaluate the effectiveness of dust control strategies. Since introduction to Australia in April 2005 PDMs have been used at a significant number of mines to evaluate respirable dust conditions in coal mine development sections, in longwall panels, in bord and pillar workings and outbye at points of dust interest. Data has been analysed to pin point high dust make locationss and allow better maintenance procedures and miner positioning to be achieved. Some examples illustrating these tests are given.

Development headings

Tests were undertaken at a development face to monitor the dust exposure levels of various equipment operators. The PDM units can give 5, 15 and 30 minute rolling averages of dust concentration. For engineering evaluation purposes it is better to use shorter time rolling average dust concentration data as the quicker response to monitored changes shows more significant dust concentration variations.

As shown in Figure 5 PDM units were put on continuous miner (CM), bolter and shuttle car (SC) operators in tests commencing at 8:15 pm. The face crew was replaced at 9:10 pm by the second crew as the first crews were released for crib break. The results of the PDM tests are shown in Figure 5 as 15 minute average dust levels.

During the tests an unplanned event took place. The end cap of ventilation ducting in an inactive adjacent face of the development section was sucked in and caused reduction in the ventilation air quantity available to the face being monitored from $7.5m^3/s$ to $4.3m^3/s$. This caused a significant loss of suction head in the ventilation ducting at the face resulting in the dust-laden air at the face billowing back onto operators. All PDMs worn by the three operators have registered sharp rises in dust level. In fact this unplanned event was first noticed by one of the operators who had checked the real time display on the PDM he was wearing at the time. The failure of the end cap piece in the inactive face was soon rectified and the normal ventilation flow re-established. Readings from all PDMs show the immediate reduction in duct concentration upon rectification.

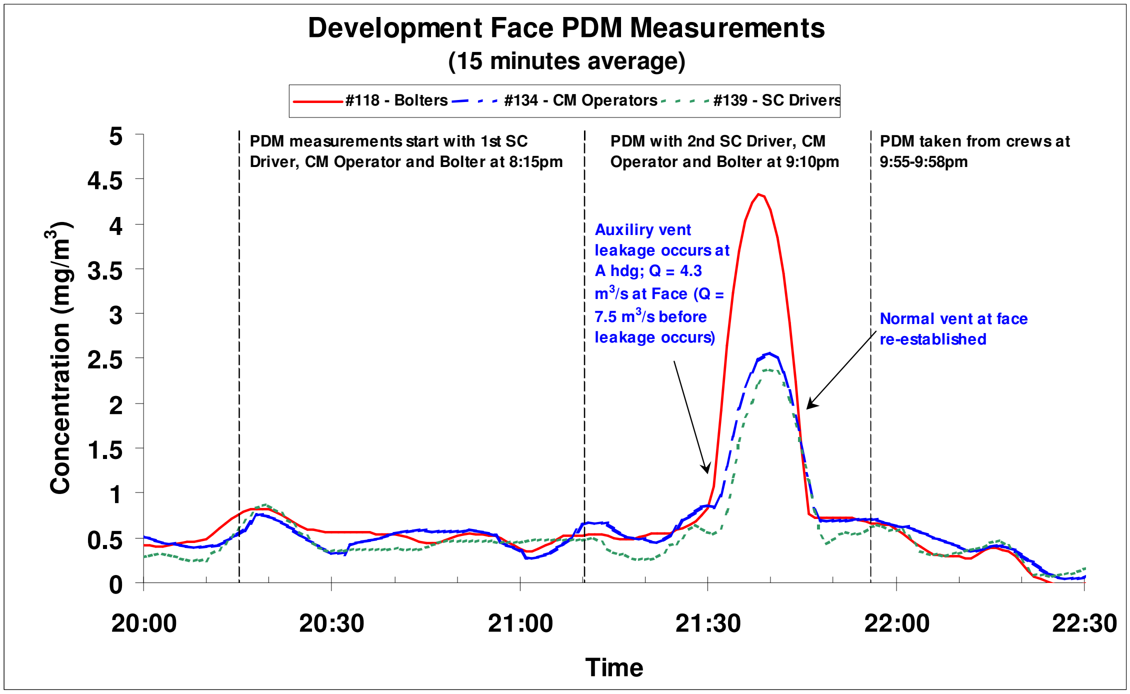

Figure 5 Development Face PDM results.

In a second test as shown in Figure 6 a development face was monitored. One PDM was worn by the CM operator and one by the bolter. The CM operator was using a remote control unit and stood on the right of the heading. The bolter was using the left hand machine mounted unit. Ventilation to the face area was good and ducting was extended approximately every 25 minutes.

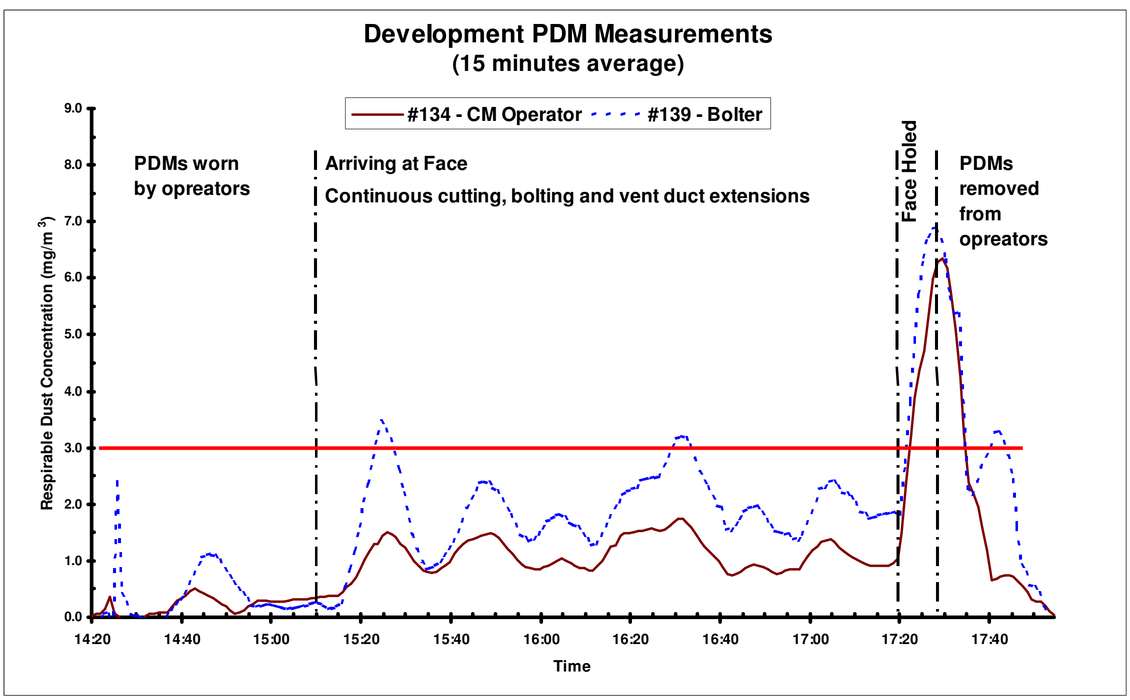

Figure 6 Development Face PDM results.

The exposure levels experienced by the CM operator who was standing very close to the open end of the exhausting ducting and so was in the best face area ventilation stream were consistently lower that those recorded by the bolter. During the period from 17:20 the CM holed through to a previously mined cut through. It is clear that the detrimental change caused in face ventilation from the hole through overwhelmed any change in relative exposure recorded by the two face crews because of the geographic positioning.

In a third heading test were undertaken at a development face to monitor the dust exposure levels of CM, bolter and SC operators as shown in Figure 7. Ventilation at the development face was generally well maintained and dust levels appeared consistent for all face operators. A hole through in mining the cut through from Heading A to B occurred towards the end of shift. Ventilation at the face was disturbed when the hole through occurred and dust concentration levels experienced by all operators were increased.

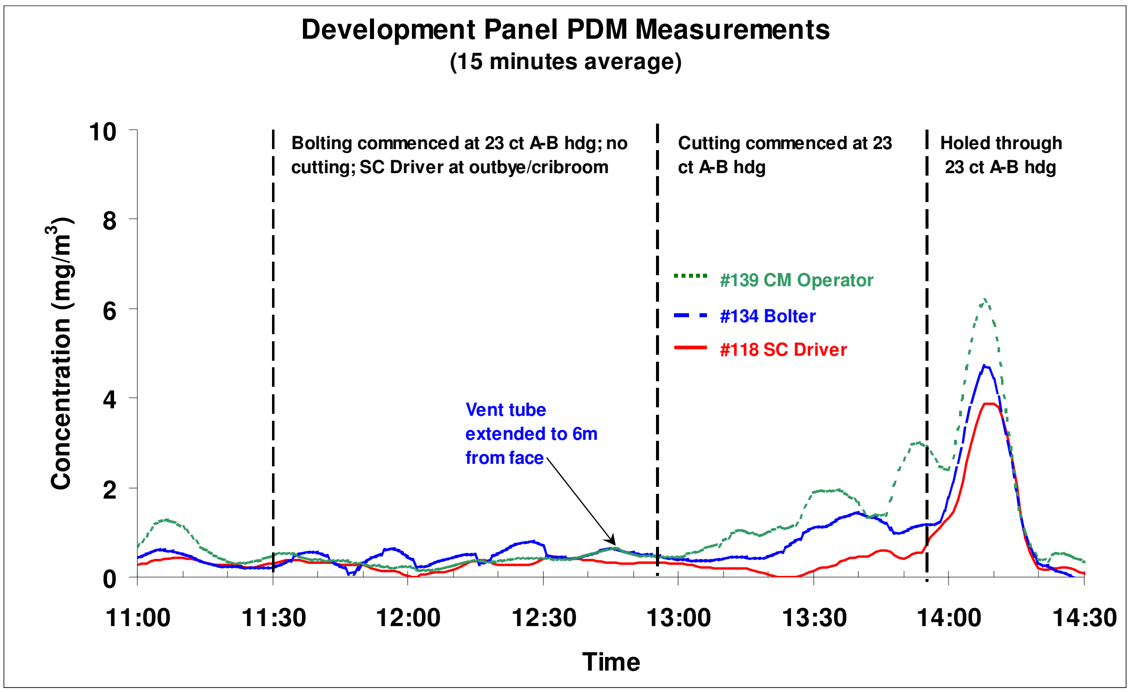

Figure 7 PDM results at development face during cut through holed through.

In Figure 7, it also can be seen that immediately before hole through the face ventilation condition was deteriorating as the ventilation ducting was not extended during the last few metres of mining. The dust levels experienced by both CM operator and bolter, as they were standing right behind or on the machine were gradually increasing. However, dust levels experienced by the SC driver remained fairly constant before the hole-through.

During the face cut the dust readings on all PDMs increased as the distance from the end of the ventilation ducting was greater. This increase occurred consistently and was from about 0.5 to 3.0 mg/m^3 before hole through. A curve has been fitted to the trace to indicate that dust levels increase following exponential relationships with equation $y = 0.5666e^{0.0275x}$ and correlation coefficient of $R^2 = 0.8729$ for CM Operator and equation $y = 0.3138e^{0.0289x}$ and correlation coefficient of $R^2 = 0.8355$ for CM Operator. Fluid flow mixing relationships follow exponential relationships. Figure 8 examines in detail these extraction periods over 70 minutes with the “curve fit” relationships imposed.

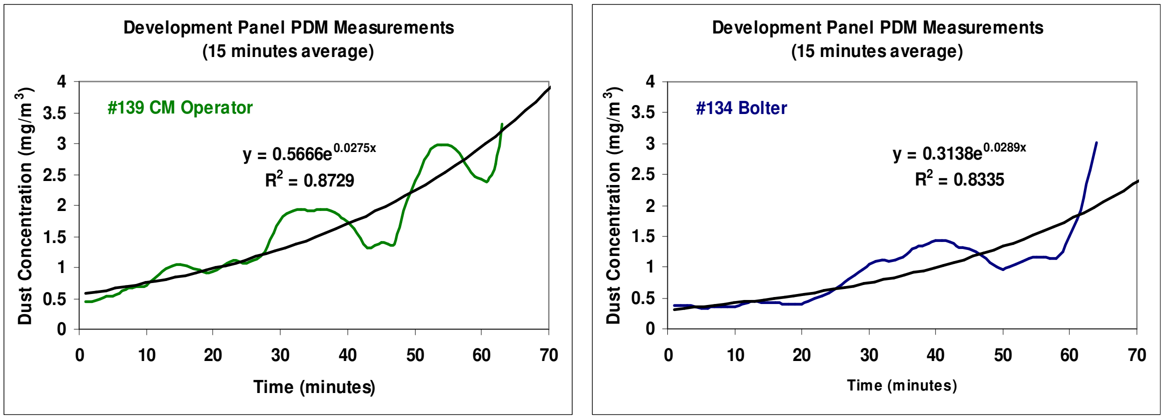

Figure 8 Exponential relationships

Longwalls

The longwall panel has a number of potential dust sources. A detailed survey can assist in evaluating the contribution of each component source, show the contribution from a number of major sources and the cumulative dust level faced by a miner at different points throughout the panel. Figure 9 gives a breakdown of dust make across different sources within a longwall panel. The particular LW under study ran from Chock 1 at the Main Gate (MG) to Chock 114 at the Tail Gate (TG). A number of reading sequences were taken just inbye the MG at Chock 8 or just outbye the TG at Chock 110. Dust makes for a number of measurements sequences are set down and average values calculated.

LW Face PDM Measurement Results

Average Dust Reading over One Shearer Cycle, mg/m^3

	Test No	Chock 8 (Legs)	MG man	TG man	Chock man	Inby Chock man	Chock 110 (Legs)	Comments
NS 17/10/05	1		1.00	1.12				Shadowing operators
NS 17/10/05	2		1.11		1.52			Shadowing operators
NS 17/10/05	3						3.90	Fixed position test
AS 18/10/05	1		1.53				4.57	Shearer Clearer off
AS 18/10/05	2		1.58				4.65	Shearer Clearer off
AS 19/10/05	1	0.89	1.29					AFC dust only
AS 19/10/05	2	1.12	1.62					AFC and Bank Push dust
AS 19/10/05	4	1.64				4.26		AFC, Shearer & Chock dust
AS 19/10/05	6		1.51			3.18		Shearer & Chock dusts
AS 20/10/05	1			1.53				Outside airstream (5 min ave)
AS 20/10/05	2			1.47				Outside airstream (30 min ave)
Average		1.22	1.38	1.37	1.52	3.72	4.37	

Figure 9 Dust make across different sources within a longwall panel.

Tests were carried out as set down in Figure 10 to monitor the dust suppression efficiency of sprays in the BSL and at the belt transfer point where the longwall belt and the main trunk belt met. For the BSL test, one PDM was placed outbye of BSL, the second PDM was placed on top of the BSL inbye of the spray and the third PDM further inbye of the BSL at Chock 8. During the test, BSL sprays were on initially and then disconnected for about 30 minutes and then reconnected again. The results show that with the sprays off dust concentration levels downstream of the BSL were dramatically increased while the dust concentration level upstream of BSL remained constant with little variations.

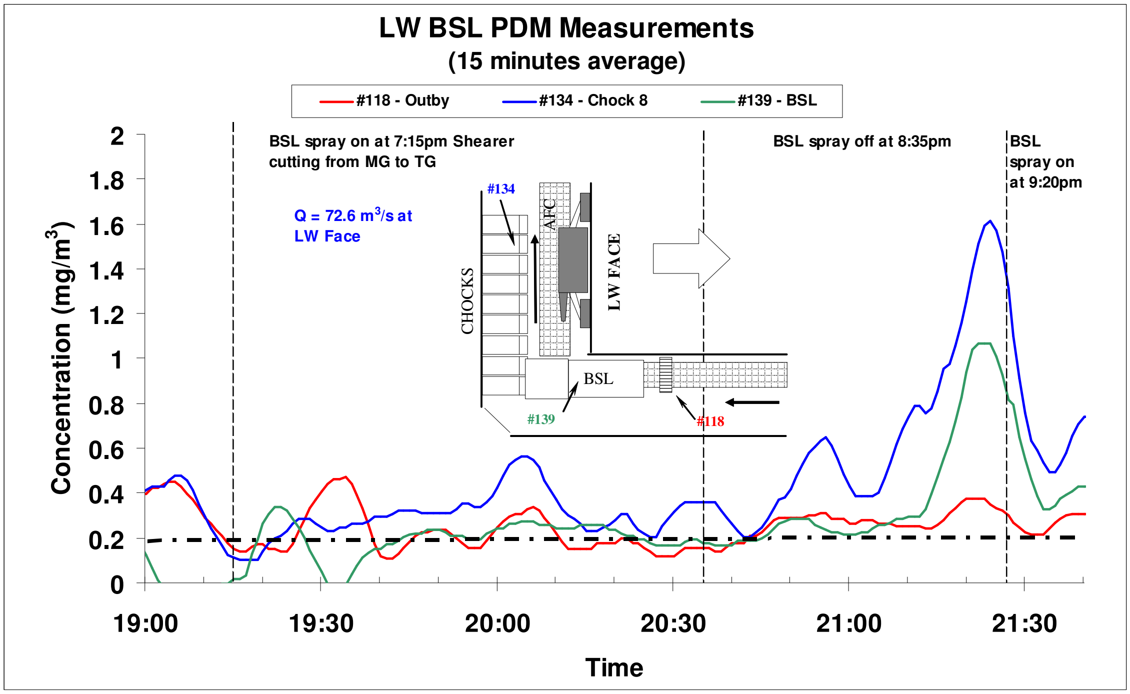

Figure 10 Dust make across a Longwall BSL PDM results – 15 minute average.

It was found that the fluctuations in dust levels measured by the PDM upstream of the BSL correlated well with whether there is coal loaded on the conveyor belt or not. When there is no coal loaded on the belt the dust levels of intake air upstream of the BSL were measured at less than 0.2 mg/m^3. It is possible to draw a horizontal line as shown in Figure 10 to indicate whether there is coal on the belt or not.

In undertaking LW studies it is important to maintain consistency with measurement conditions along the face activities. Figure 11 indicates studies undertaken over the majority of a shift. The shearer position data was downloaded from the mine monitoring system. A cutting sequence took on average about slightly less than an hour. It can be seen in the figure that seven cutting cycles occurred across the 7 hour study time period with good regularity. One early period of 45 minutes of cutting was lost to belt structure removal.

Measurements were carried out at LW face positions monitoring the dust levels experienced by shearer and chock operators in a unidirectional mining cutting sequence. Results of these tests are shown in Figure 12 to 16 for various operator position combinations.

Figure 12 illustrates monitoring dust make across the length of a shearer when cutting. One PDM 134 was worn by a person who shadowed the MG shearer operators for a cutting cycle during unidirectional cutting. The other PDM 139 was worn shadowing the TG operator. The shearer position data was downloaded from the mine monitoring system and indicated that the shearer was cutting from MG to TG first and then cutting from TG back to MG during the test. The results showed the increase in dust exposure faced by the TG operator over the MG operator. The unusual anomalous “bump” in the PDM 139 result trace at about 15:45 is put down to a significant face-slabbing fall the significance of which was very obvious to those nearby.

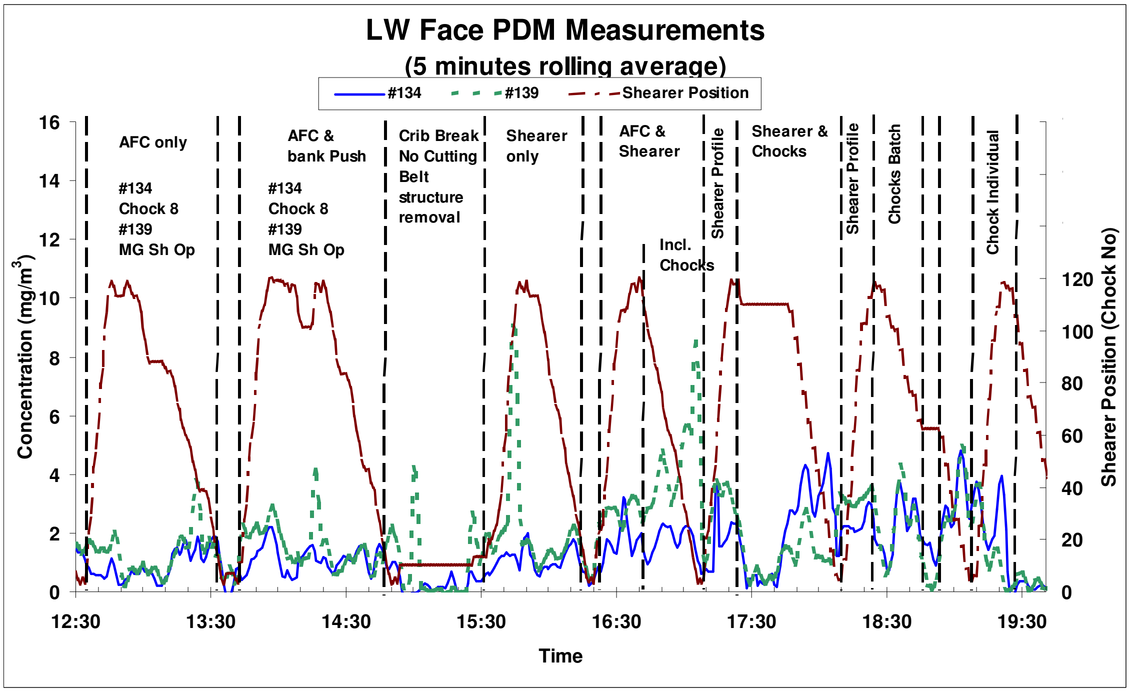

Figure 11 LW Face Dust Surveys Shearer Position and dust monitored points m Levels

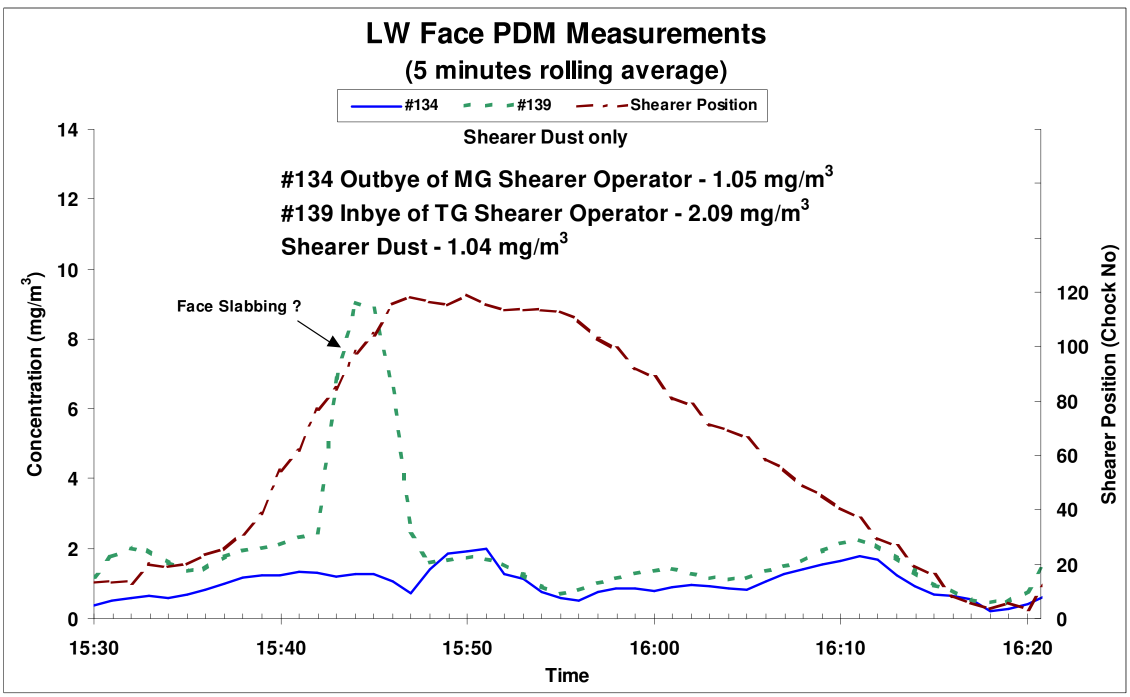

Figure 12 Relative dust make experienced by MG and TG shearer operators.

Figure 13 illustrates dust exposure at the MG Shearer and TG Chock operator positions as the cutting sequences moves along the LW face. This shows under Unidi cutting that during the TG to MG cutting sequence operators are advancing chocks downstream of the shearer and so experience relatively high dust exposures. After snaking at the MG end chock operators following the shearer are upstream of the unit and so experience relatively lower dust exposures. The results indicate that the MG shearer operator was subjected to relatively high dust level exposure when cutting from MG to TG. When cutting from TG to MG the dust level experienced by the MG shearer operator was much lower.

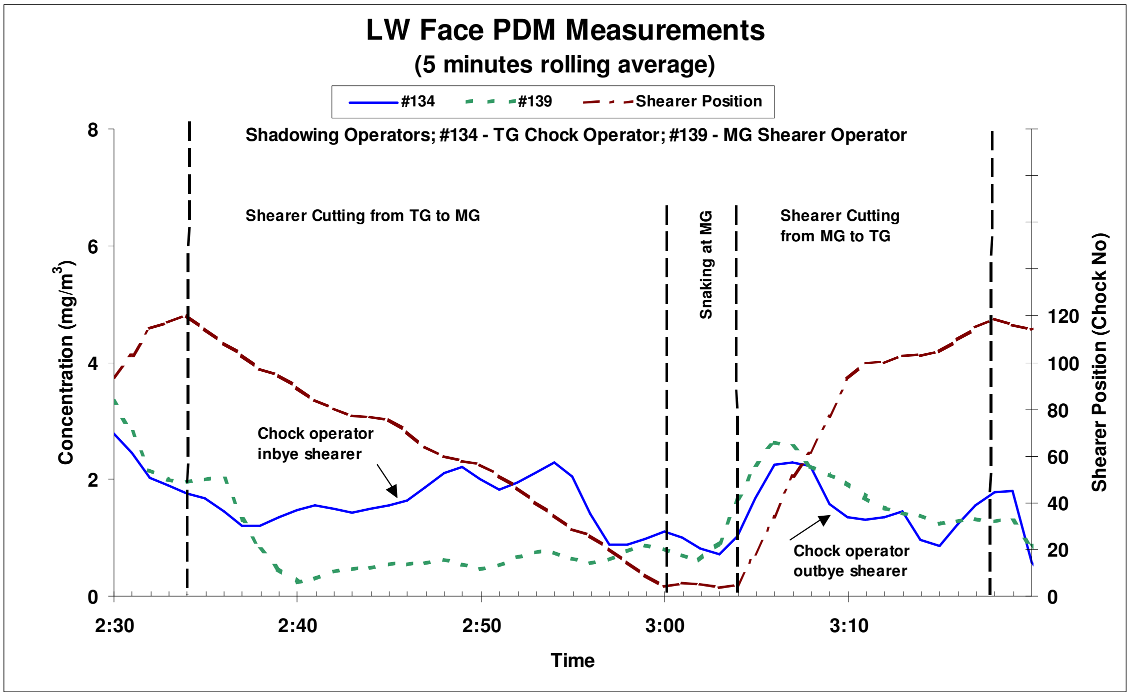

Figure 13 Relative dust make experienced by MG shearer and TG Chock operators.

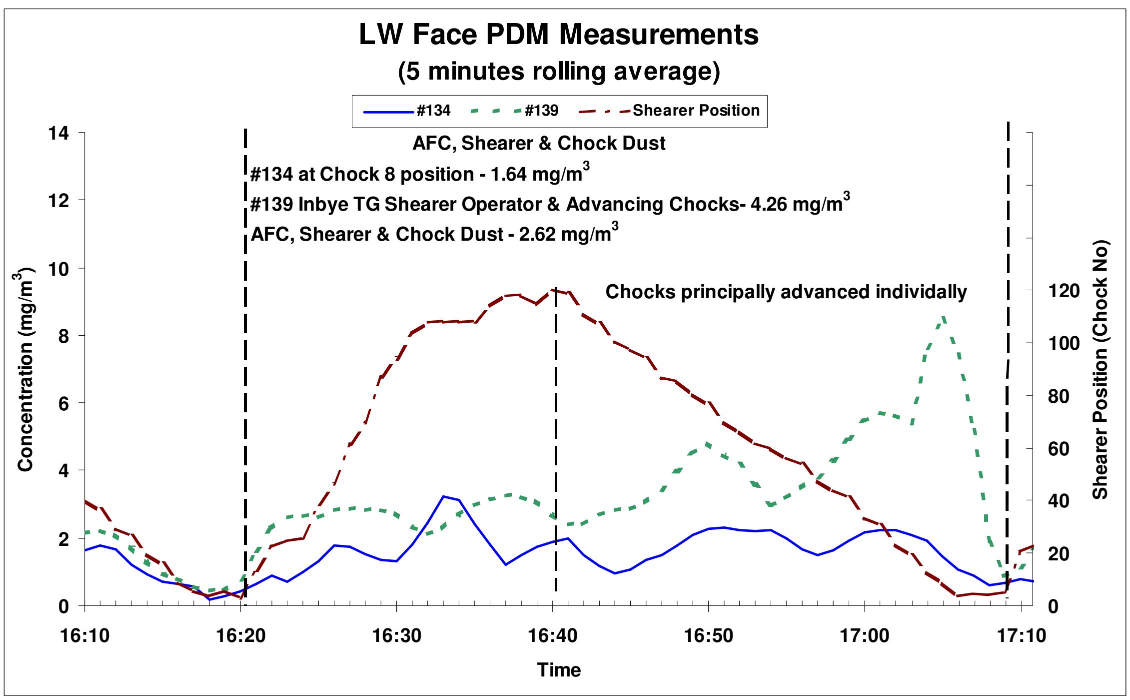

Figure 14 Relative dust make experienced by MG shearer and TG Chock operators.

Figure 14 illustrates dust exposure variation in manned positions along the length of the face. PDM 134 monitored at chock 8 stationary position while PDM shadowed the TG Shearer operator during MG to TG cutting and the Chock operator position TG to MG as the cutting sequences moved along the LW face. This again shows under Unidi cutting that during the TG to MG cutting sequence operators are advancing chocks downstream of the shearer and so experience relatively high dust exposures The PDM 139 trace shows this increasing dust exposure level. The figure shows that integration under the two position curves gives the difference in dust make which equates to total from AFC, Shearer and Chock operation. This has been calculated as 2.62 mg/m^3 for this test.

Figure 15 examines dust make difference experienced by MG and TG shearers operators and measures this at 1.04mg/m^3. The anomalous high dust measurement at 15:45 is concluded to represent a significant face slab fall that was noted at that time.

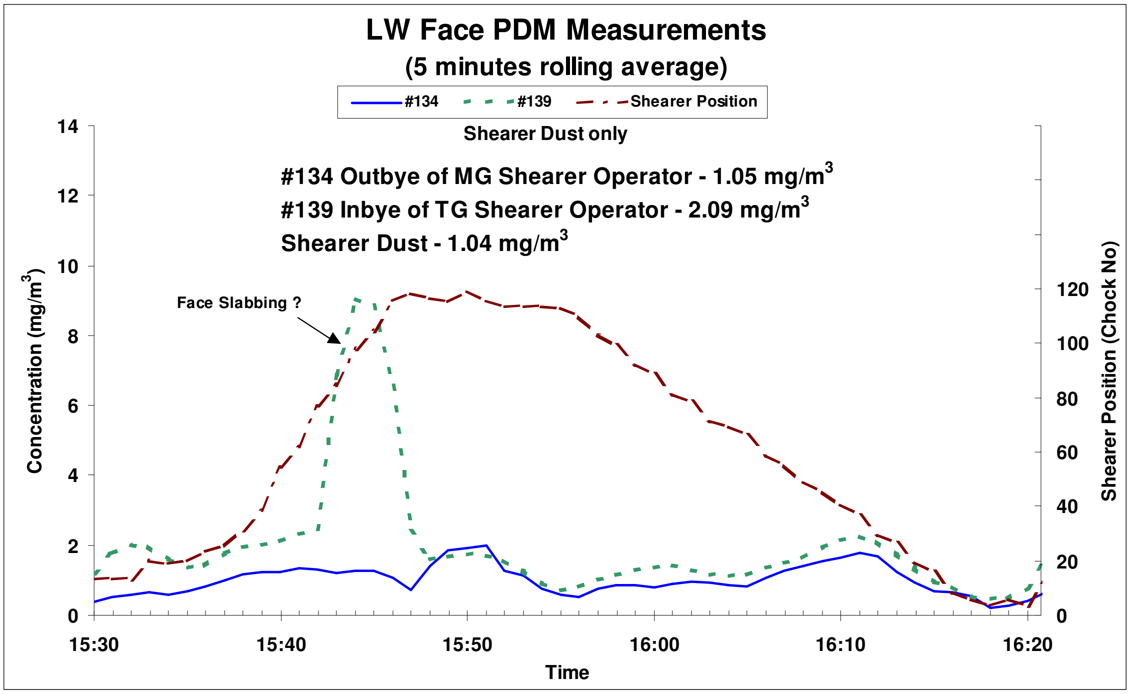

Figure 15 Relative dust make experienced at MG end of the face and the operator position closest to the TG.

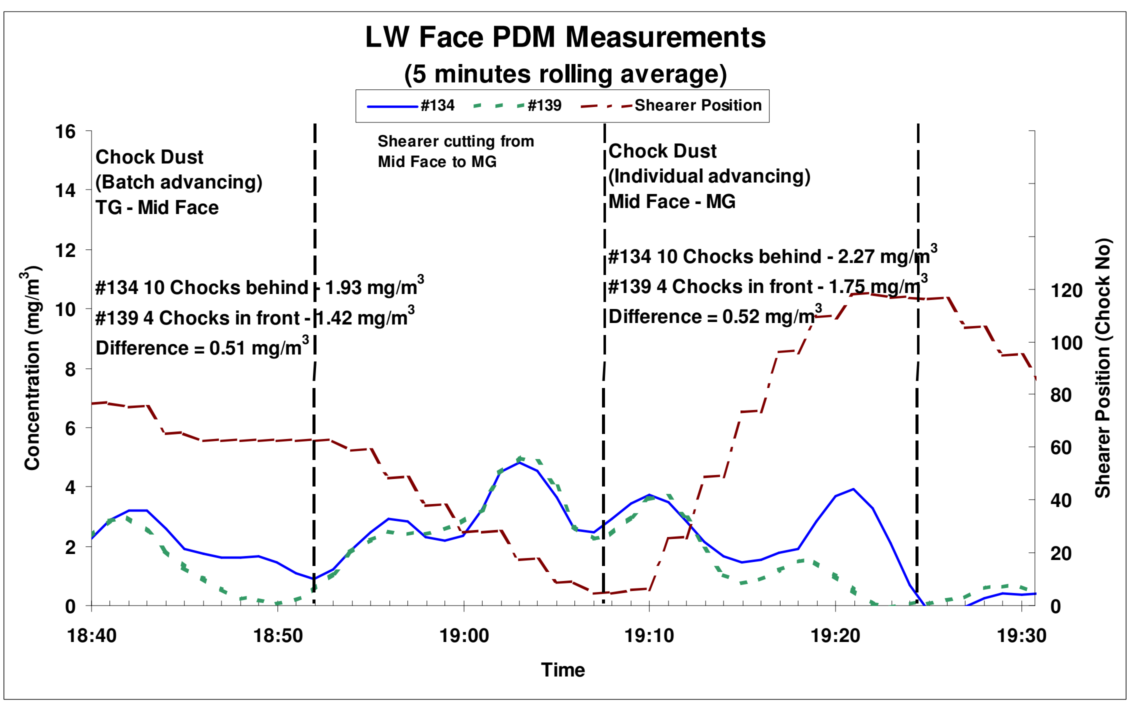

Figure 16 Average dust make from batch and individual chock advance operations.

Figure 16 examines whether dust make is greater during chock advance by batch (five chocks together) or individual advancement. The conclusion is that there is no significant difference.

Figure 17 examines variation of dust make with shearer advance rates. Two TG to MG cuts were examined; one taking over about 41 minutes for the cut and one only taking 24 minutes. It is clear that the at the same shearer position the dust exposure of average 1.72 mg/m^3 for the faster cut is greater than for the slower at mg/m^3.

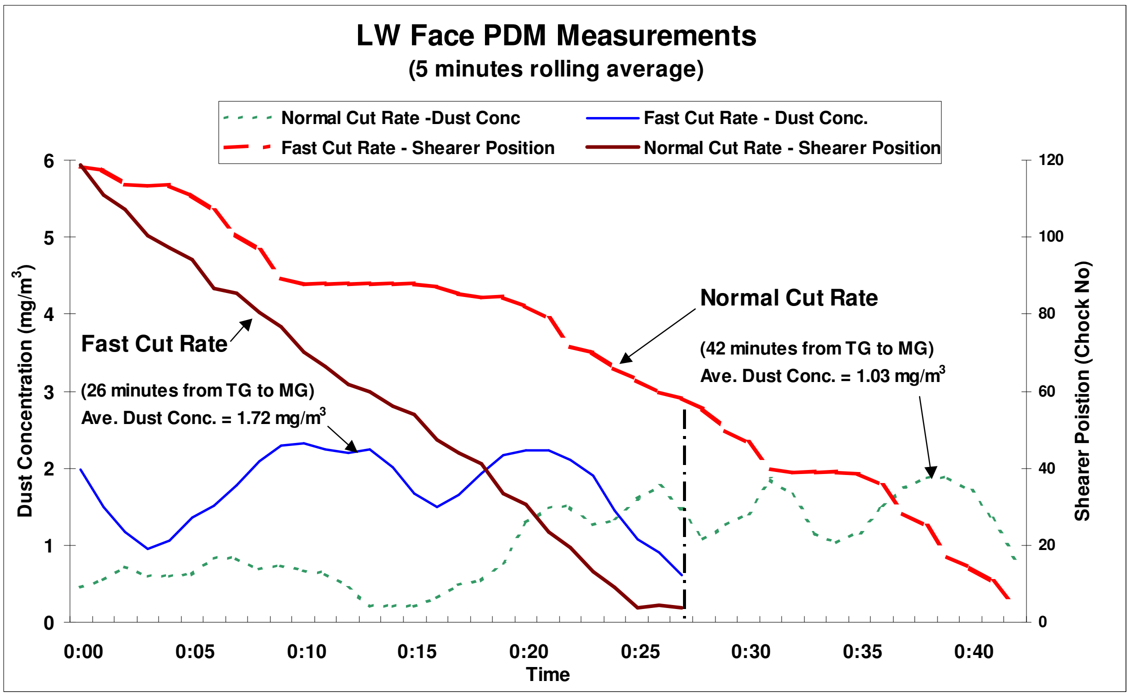

Figure 17 Variation of dust make with shearer advance rates

As would be expected there is a clear relationship between these relationships and both produce a dust make of about 175g for each cut. This was calculated based on LW face ventilation quantity was maintained approximately at 70 m^3/s.

- Fast Cut Rate: 24 minutes and average duct concentration = 1.72 mg/m^3
  Estimated Dust Make = 70 m^3/s ×24mins×60s×1.72 mg/m^3 = 173.38g
- Fast Cut Rate: 41 minutes and average duct concentration = 1.03 mg/m^3
  Estimated Dust Make = 70 m^3/s ×41mins×60s×1.03 mg/m^3 = 177.39g

One comment is that dust make can be reduced by slowing of cut rate. Another observation is that dust concentration in the atmosphere at the face can be increased through increase in dilution with greater ventilation rate.

PDM tests were undertaken to examine the dust exposure levels of MG and TG shearer operators and the chockman along a longwall face during bidirectional cutting. As shown in Figure18 it was found that when the shearer was cutting from MG to TG, both MG and TG shearer operators can experience higher dust concentration levels than when snaking at either end of the face or when cutting from TG to MG. In general the chockman experienced less dust than shearer operators during cutting as the chockman usually stands outbye of the shearer. However when snaking at the TG end the chockman may experience short periods of high exposure standing inbye of the shearer. Advances in automation of shearer cutting and chock advance and reliability of systems will influence miner positing and exposure levels.

Figure 18 shows a significant anomalous reading which is suspected to be tied to a major goaf fall that occurred during the test. This is similar to that referred to in discussing Figure 15 tests.

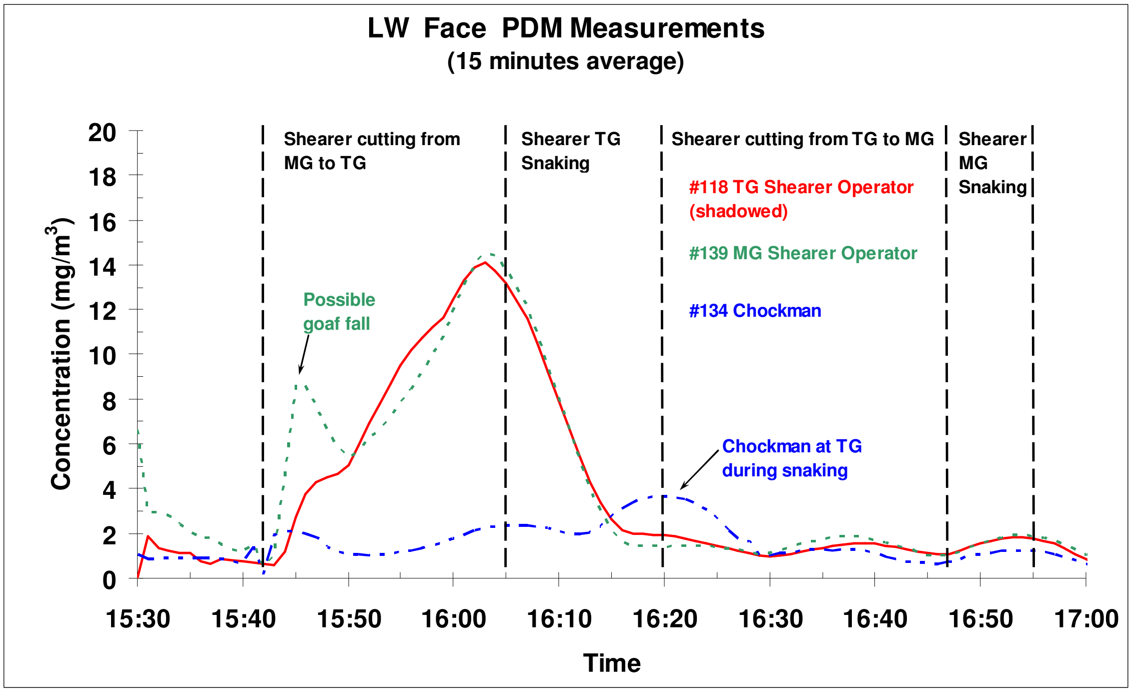

Figure 18 Shearer operators and chockman PDM results under bidirectional cutting.

Belt Transfer Points

Results of PDM tests on a belt transfer point are shown in Figure 19. Information about the tonnage on the belt during the tests was also obtained from the mine control and monitoring system. It should be noted that the tonnage was measured about 1 km away from the belt transfer point. The belt data tonnage was shifted horizontally along the timeline to take this into account.

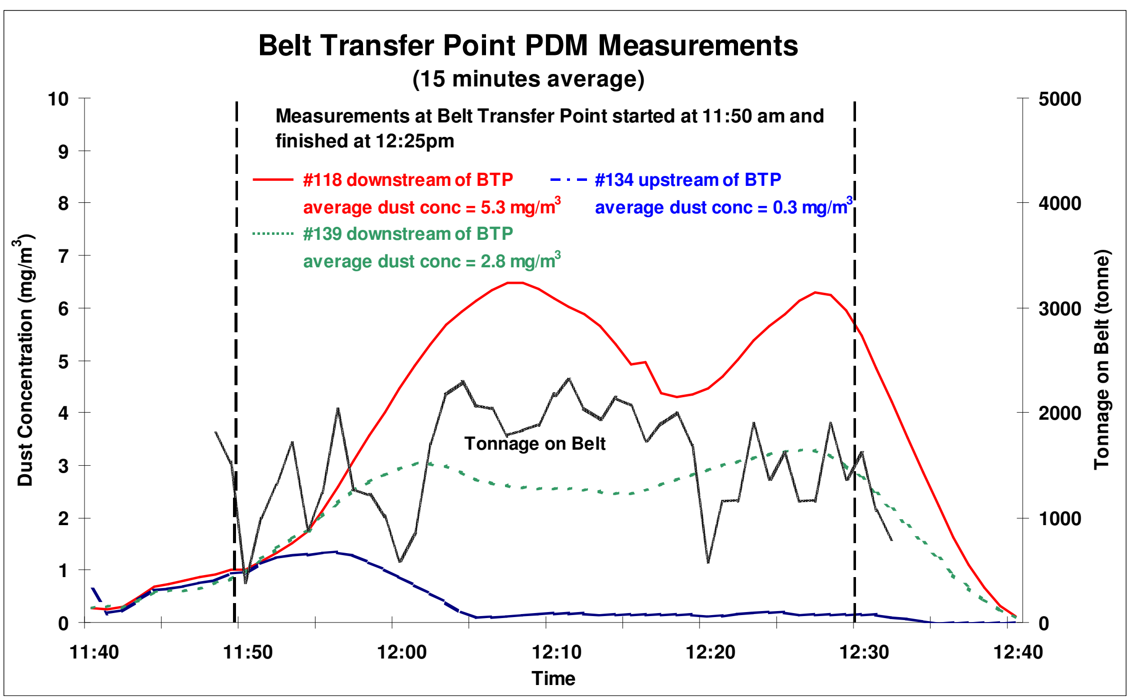

Figure 19 Belt transfer point PDM results.

It can be seen that the dust concentration measured correlates well with the amount of coal transported on the belt. The more coal transported on the belt, the higher dust concentration levels at belt transfer point.

Air Stream Helmets

Tests on air stream helmets were carried out at the same belt transfer point as discussed for Figure 19. Two air stream helmets were used with one worn under normal operating condition and the other worn with both the pre and main filters (as shown in Figure 20) removed. All three PDMs were used, one sampling the background atmospheric dust level and the other two sampling the air inside the two test air stream helmets. The results of the air stream helmet tests are shown in Figure 21.

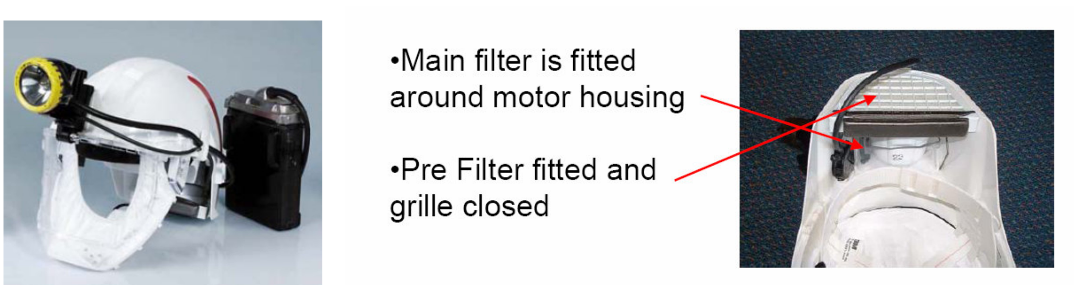

Figure 20 Photographs of air stream helmet and the filters used.

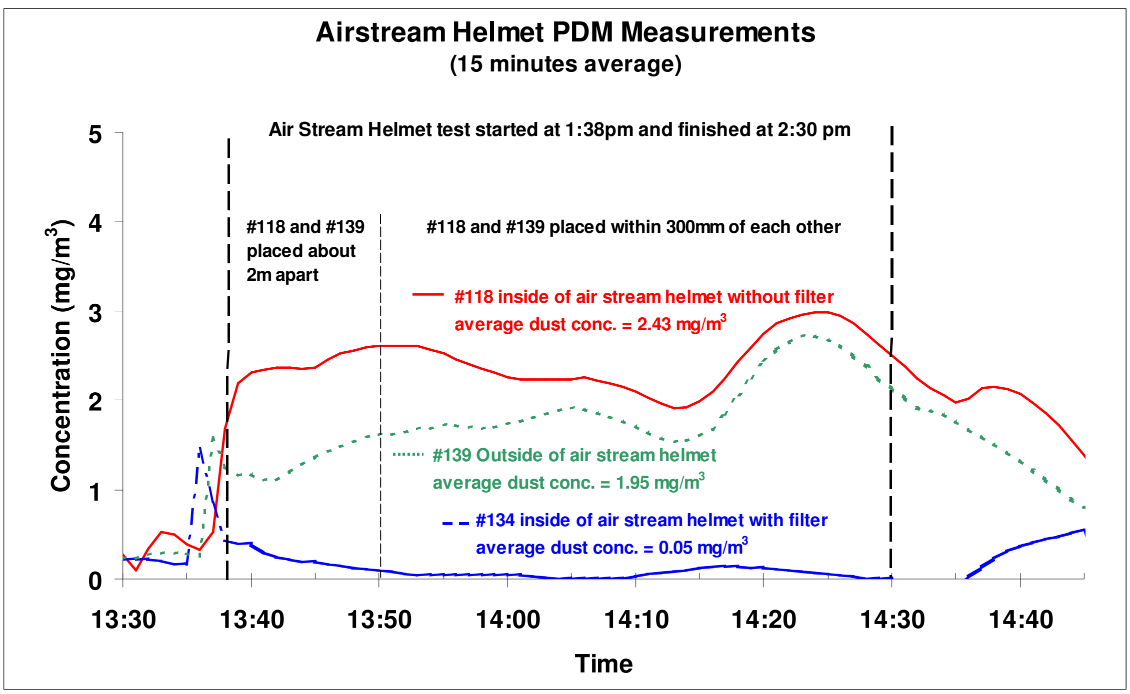

Figure 21 Air steam helmet PDM results

An average dust concentration of 0.05 mg/m^3 was measured inside the normal operating air stream helmet during the 40 minutes test period. This demonstrates that the filters used by air stream helmet can filter out most of the respirable dust. Without the filters in place, average dust concentration inside the air stream helmet was consistently higher than the dust levels measured in the outside atmosphere. A similar phenomenon was reported by others when attempting to measure dust levels inside and outside air conditional cabs (Volkwein 2005). It was concluded that an enclosed space acts as a dust trap when a jet stream injects dust laden air into a constrained space leading to higher than background dust level. In addition the jet stream in the enclosed space would keep the dust suspending longer.

Caplan et al. (1973) maintain that in air streams with velocities up to 1.5 m/s neither the air velocity nor the cyclone inlet orientation has any impact on the dust concentration measured by a sampler. However, at air velocities over 1.5 m/s, both the air velocity and the cyclone inlet orientation have an impact. Cecala et al. (1983) found that when the Dorr-Oliver cyclone inlet is pointed directly into the wind, it over samples when the air velocity exceeds 4 m/s. At very high velocities of 10 m/s it over-samples by 35 precent. When the cyclone inlet is at a right angle to the wind or pointed downwind it under-samples when the air velocity exceeds 1.5 m/s.

Cecala et al. (1983) also tested a shielded cyclone to see if a shield would reduce the over- and under-sampling. The shield was a 25 mm wide strip of aluminium sheet bent into a cylinder. This cylinder was then wrapped around the top of the cyclone and bolted to the hole in the back of the vortex finder clamp. Testing showed that the shield successfully reduced both the over- and under-sampling to within 14 percent of the true value when tested to a velocity of 10 m/s.

These evaluations were done with the traditional lapel worn personal samplers with ordinary pumps operating across the normal range of flow rates. Flow rates from these pumps are affected by conditions such as the resistance of the filter as it is loaded during sampling and hose arrangement. The pump used by the PDM has a self regulating flow rate function to correct the response to external conditions and maintains a constant flow rate throughout the measurement period. Examination of flow rates recorded in PDM data files during the air stream helmet tests showed that through out the tests the flow rates of the three PDM units remained at a constant of 2.2 litres per minutes. Therefore it should not be either over or under sampling as suggested by Cecala et al.

CONCLUSIONS AND RECOMMEDATIONS

Based on the tests conducted, it is concluded that the PDM has demonstrated its potential use as an engineering tool to locate and assess various sources of dust during normal mining operations. The principles and concepts used to identify and fix some of the higher dust levels are generally common sense and would be easy for most miners to understand.

However, to make the most effective use of this information, training and experience in using this type of technology will be very important. Experience with the data from the unit will help miners gain confidence to use the information to maintain reduced or safe dust levels during mining.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of the various mine site managers, engineers and ventilation officers who supported this ACARP project examining the PDM unit and the subsequent evaluation projects undertaken across a diversity of colliery conditions.. Their efforts ensured that the principal development and mine site testing aims of the project were accomplished and a significant contribution made to future mine health and safety in Australia.

REFERENCES

Caplan KJ, Doemeny LJ, Sorenson S, 1973. Evaluation of coal mine dust personal sampler performance. U.S. Department of Health, Education, and Welfare contract PHCPE-R-70-0036

Cecala AB, Volkwein JC, Timko RJ, Williams KL 1983. Velocity and orientation effects on the 10-mm Dorr-Oliver cyclone. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, RI 8764. NTIS No. PB 83-214387.

Gillies, A D S, 2001. Dust measurement and control in thick seam mining, Australian Coal Association Research Program Grant C9002, August 2001

Gillies, A.D.S and Wu, H.W. Evaluation of a new real time personal dust meter for engineering studies on mine faces, *Proc Queensland Mining Industry Health and Safety Conference*, Townsville, 119-132 August 2005.

Gillies, A D S, 2005. Evaluation of a New Real Time Personal Dust Meter for Engineering Studies on Mine Faces. Australian Coal Association Research Program Grant C14010 Report, September 2005.

Gillies, A.D.S and Wu, H.W. Evaluation of a new real time personal dust monitor for engineering studies. *Proc Eleventh US Mine Ventilation Symposium, State College, Pennsylvania,* Balkema, The Netherlands, June 2006.

Volkwein, J.C., Thimons, E., Yanak, C., Dunham, D., Patashnick, H. & Rupprecht, E. Implementing a New Personal Dust Monitor as an Engineering Tool, 2004a. *Proc 10th US Mine Ventilation Symposium,* Balkeima, May 2004.

Volkwein, J.C., Vinson, R.P., McWilliams, L.J., Tuchman, D.P. and Mischler, S.E, 2004b. Performance of a new personal respirable dust monitor for mine use, RI 9663, National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Pittsburgh, PA, June 2004.

Volkwein, J.C., 2005. Personal communication. April 2005.