Safety in Mines Research Advisory Committee

Final Report

Dust-control for thick-seam wall mines

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Research Agency	**:**	**CSIR Miningtek**
Project No.	**:**	**COL 807**
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Executive Summary

Project COL 807 was formulated to find ways of keeping down the dust in thick-seam wall operations to concentration levels of less than 5 mg/m^3 and to minimise the dust exposure of workers while maintaining adequate ventilation conditions along the wall face. A directive of the South African Department of Minerals and Energy (DME, 1997) required the dust-concentration level to be reduced below 5 mg/m^3 at the operator's position.

The principal objectives of the project were:
(1) to carry out an international literature survey of thick-seam wall mining dust-control techniques and their applications, (2) to evaluate the present performance of the dust-control system on the Joy shearer, and (3) to recommend alterations to the existing system or to propose a new dust-suppression system to improve dust control around the shearer.

The following relevant major conclusions are drawn from the international literature survey on thick wall dust-control techniques and the field trials on the thick South African shortwall section:

- Reviews of international literature on thick-seam wall dust-control techniques have indicated that longwall dust-control is still a problem area worldwide and broad dust-control techniques are available (Section 3). However, mine-specific and technical aspects of the control mechanisms are not reported in detail.
- The most common method for controlling the airborne dust in wall mining is the use of water sprays mounted on the shearer cutting drums. Techniques implemented for the control of shearer-generated dust include high drum-water flow rates, improved cutting techniques, shearer-clearer type external water spray systems and radio- remote control.
- The majority of the wall dust-control techniques have been developed in the USA for low seam wall mines and their application is specific to low to medium coal seam heights.
- Results from the preliminary field trials in South African wall mines (Series-1 trials), have indicated that the average air borne respirable dust (ARD) concentration at the sampling stations exceeded the DME directive (1997) of a limit of 5 mg/m^3. Similarly, the personal dust concentration levels are above the compliance level of 2 mg/m^3.
- The partially implemented CSIR-recommended Kloppersbos Shearer Spray Curtain

(KSSC) system (Series-2 trials) resulted in significant improvements (> 50%) in dust levels. The engineering concentration levels were below the DME directive of less than 5 mg/m^3, except at the tailgate position.

- The shield dust is the second major contributor of dust as observed in the tailgate engineering dust levels, as well as the personal sample values.
- In the quantitative risk assessment of a shortwall operation, using the field data, dust has been identified as both an explosion and a health risk. The risk rankings for explosions and health are 2 and 1 respectively (see Table 6c).

The baseline ARD concentration measurements and the available data on shortwall mines indicate that dust control in thick-seam wall mines is a continuing problem, which requires further research. A considerable improvement was observed from the partial implementation of the CSIR-recommended KSSC dust-control system. Finally, in order to overcome the thick-seam wall mine dust problems, the following areas of changes can be considered:

1. Maintain an average face air velocity of 2,5 m/s and a section return air velocity of 2,0 m/s.
2. Fully implement and evaluate the CSIR-recommended KSSC dust-control system as discussed, paying due attention to the physical shearer curtain, the sprays, the spray configuration and the belt curtains on the shearer.
3. Install, and evaluate the efficiency of, the physical shield curtains (conveyor belt or other flexible material) hanging from the shield structure inside the shield leg area at every 4th shield to reduce worker exposure.
4. The use of a custom-built scrubber system (low height and high width) fitted on to the shearer and positioned longitudinally at the middle of the shearer body is an option (for thick-seam wall mines) that may be considered by the mine in consultation with the equipment manufacturers.
5. In order to quantify the improvement in dust-control techniques in thick-seam wall mines, the dust-control components recommended above must be evaluated in the field, following the procedures and process used in SIMRAC projects COL 518 and COL 603.

List of abbreviations, symbols and terms

Abbreviations

ARD	Airborne Respirable Dust
AS	Australian Standards
AFC	Armoured Face Conveyor
COM	Chamber of Mines
CFD	Computational Fluid Dynamics
CWP	Coal Workers' Pneumoconioisis
DERDS	Double Ended Ranging Drum Shearer
DME	Department of Minerals and Energy
FB	Feeder Breaker
FM	Face Middle
HG	Head Gate
HGO	Head Gate Operator
JCB	Joint Coal Board
KSSC	Kloppersbos Shearer Spray Curtain
LTR	Last Through Road
LHS	Left hand side
MHSA	Mine Health and Safety Act
MSHA	Mine Safety and Health Administration
MRDE	Mine Research and Development Establishment
NARD	Normalised Airborne Respirable Dust
NSW	New South Wales
NCB	National Coal Board
NIOSH	National Institute of Occupational Safety and Health
RET	Return
RHS	Right hand side
SERDS	Single Ended Ranging Drum Shearer
SMP	Shearer Mid Point
SIMRAC	Safety In Mines Research Advisory Committee
SPSS	Single-Phase Spray System
TPSS	Two-Phase Spray System

TG	Tail Gate
TGO	Tail Gate Operator
USBM	United States Bureau of Mines
UK	United Kingdom
USA	United States of America

Symbols

m	metre
m/s	metres per second
m/min	meters/minute
m/s/m^2	metres per second per square metre
m^3/s	cubic metres per second
A	cross-sectional area of the roadway
m^2	square metres
mg/m^3	milligrams per cubic metre
kW	kilowatt
L/min	litres per minute
mm	millimetre
min/shift	minutes per shift
mg/s	milligram per second
g/m^3	gram per cubic meter

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1 Introduction

South Africa’s run-of-mine coal production for the year 1998 was 289,6 Mt and the coal industry employed 53 752 employees on average (COM, 2000). The ratio between opencast and underground mining in the South African coal industry is almost evenly split (48% to 52%) and the wall mining method is one of the most efficient methods for recovering underground coal. A South African study of personal dust exposure data from underground coal mines was analysed to assess the health risk to underground coal mine workers. The aim of the study was to determine exposure-response functions, for the incidence of both predicted and observed pneumoconiosis. The study indicated that in coal mines, the highest dust concentrations were experienced in longwall mining sections (COM, 2000). Exposure to high respirable dust concentrations, even in the absence of high quartz concentrations, was identified as a major problem in coal mines.

One of the focus areas of research is the improvement of the underground working environment through proper environmental control, thus improving the health of mine workers. A directive of the South African Department of Minerals and Energy (DME, 1997) required the dust-concentration level to be reduced below 5 mg/m^3 at the operator’s position.

Shortwall mining offers many advantages over continuous miner (CM) operations, in which controlling respirable dust is a severe problem. The most common method of controlling the airborne dust in wall mining is through the use of water sprays mounted on the shearer cutting drums. Techniques implemented for the control of shearer-generated dust included high drum-water flow rates, improved cutting techniques, shearer clearer-type external water spray systems, and radio- remote control. Most of these dust-control techniques were developed in the US for mines using low-seam wall mining (seam heights up to 2,5 m). The application of these US-developed techniques is limited to South African wall mining conditions where the maximum seam height is 2,5 m. Similarly, most of the Australian wall mines are also operating at maximum seam heights of 3,5m and extensive research work is being carried out for the purpose of reducing the respirable dust.

Project COL 807 was formulated to find ways of keeping down the dust in thick-seam wall operations to concentration levels of less than 5 mg/m^3 and to minimise the dust exposure of workers while maintaining adequate ventilation conditions along the wall face. The purpose of this project was to develop a new shortwall dust-control system to control respirable dust in the mines. The principal objectives of the project were: (1) to carry out an international survey on thick-seam wall mining dust-control techniques and their applications, (2) to evaluate the present performance of the dust-control system on the Joy shearer by determining the ambient ARD concentrations in the shortwall face, and (3) to recommend alterations to the existing system or to propose a new dust-suppression system, if required, for the shearer in terms of spray configuration, ventilation requirements and shield curtains to reduce the ARD levels.

2 Longwall mining technology

'Longwall mining technology' has been established as an underground coal-extraction method worldwide since its inception in the 17th century in the UK (Das, 1999). Present-day longwall faces are producing coal at an increasing rate. Longwall coal mining currently represents the most economic method for the removal of coal from seams too deep for opencast mining methods. Figure 2.1 shows a perspective and close-up views of a longwall mining system. The components of the longwall system are (Aziz, N. et al., 2000):

- Coal Plough or Coal Shearer
- Stage Loader
- Armoured Face Conveyor (AFC)
- Roof Supports

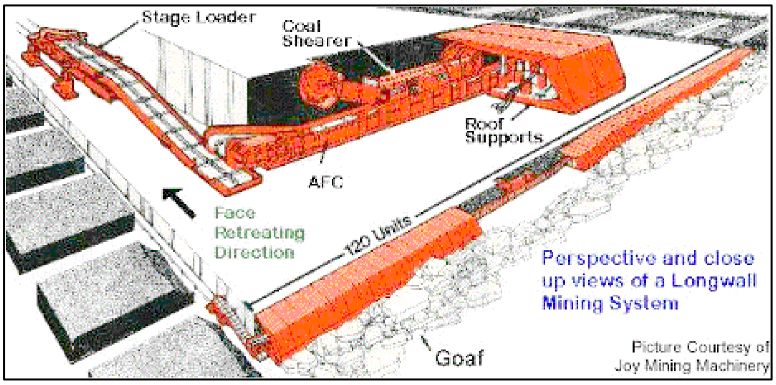


Figure 2.1 Perspective and close-up views of a longwall mining system (Source: Joy Mining Machinery)

Coal Plough: In the early years of longwall mining, the coal plough was widely used as an extraction apparatus and is most suitable for relatively soft coal seams. The coal plough does not have any rotating parts, and it consists of a series of picks that are pulled along the coal face and scrape the coal onto a conveyor. A typical coal plough installation is shown in Figure 2.2.

Coal Shearer: A typical shearer can be as long as 15 m and weigh in excess of 90 tonnes. The travelling speeds of shearers in Australia vary between 10 and 14 m/min. However, the speed of shearers is on the increase, and there is now a reported case of 45 m/min at Twenty Mile Colliery in the USA.

Figure 2.2 Coal plough in operation (Source: Australian Mining Monthly)

A typical shearer consists of the following components:

- Shearer drum or cutting head
- Ranging arm
- Cowls
- Self-haulage system
- Bretbly cable handler
- Shearer controls.

Shearer Drum or Cutting Head: In thick-seam wall mining method, the depth of the coal that is to be cut by a shearer drum (Figure 2.3) from the wall face on each traverse is called “web cut.” The depth of the web cut on each pass is determined by the width of the shearer drum. An average web width is between 0,8m and 1,0 m. Coal is cut from the face by rotary drums either single or double-ended drums.

Shearers with twin drums mounted on ranging arms are called double-ended ranging drum shearers (DERDS). Machines with a single drum on a ranging arm are known as single-ended ranging drum shearers (SERDS). Each cutting drum is normally mounted at the end of a ranging arm. The shearer drum diameter can be in excess of 2,0 m, e.g., the shearer at Dartbrook Mine in Australia has a drum diameter of 2,5 m. Water is supplied to the drum to assist in reducing dust during the coal-cutting operation. Water sprays can be applied at the pick face (know as ‘pick face flushing’) or at the back of the pick (known as ‘back face flushing’). These sprays are called drum sprays.

Figure 2.3 Shearer drum (Source: Long-Airdox Australia)

Ranging arm: A typical ranging arm of a shearer is shown in Figure 2.4. The purpose of the ranging arm is to enable coal to be cut from seams thicker than the diameter of the drum. The position of the ranging arm is controlled by a hydraulic lifting cylinder used by the shearer operator.

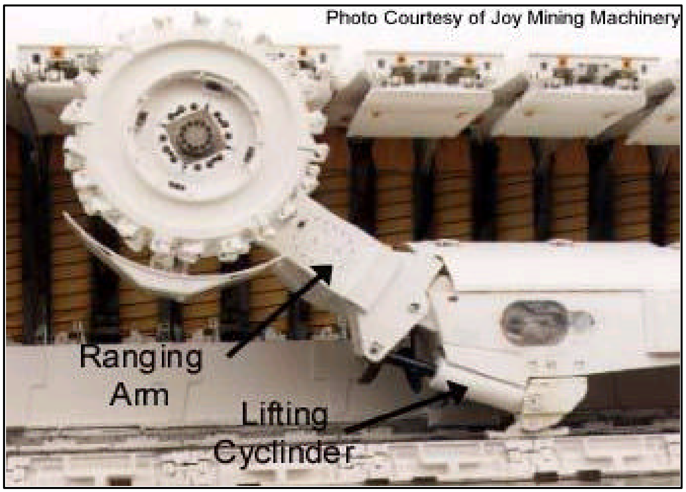


Figure 2.4 Ranging arm (Source: Joy Mining Machinery)

Cowls: Cowls are fitted to the ranging arm and can rotate 360° around the shearer drum (Figure 2.5). The function of the cowls is to improve the cleaning up of the coal face and to assist with dust suppression. The cowls can be rotated to different positions according to the cutting direction of the shearer and are controlled by the operator.

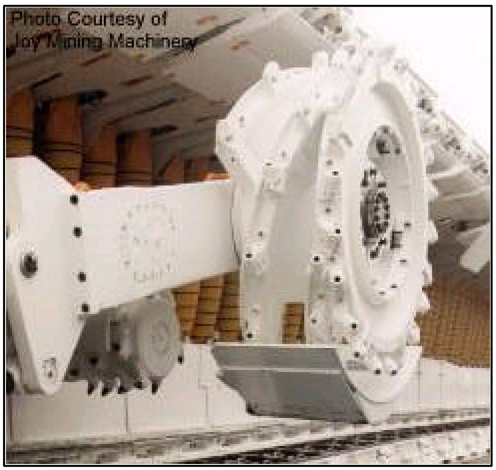


Figure 2.5 Cowl on the shearer drum (Source: Joy Mining Machinery)

Self-Haulage System: A shearer pulls itself along the face by using a sprocket to engage with the haulage system (Figure 2.6) which is fixed to the length of the armoured face conveyor (AFC). Generally, the shearer traction system is powered hydraulically. The shearer uses the AFC structure as its track to traverse along the face. The shearer is mounted on a set of rollers, or skids, which run along the front of the AFC structure.

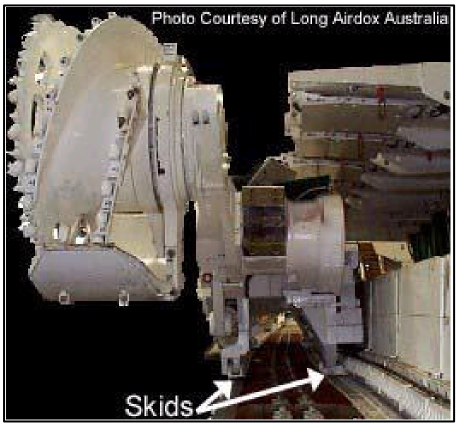


Figure 2.6 Self-haulage system (Source: Long Airdox Australia)

Bretby cable handler: Electric power is connected to the shearer via the Bretby cable handler housed in a channel mounted along the goaf side of the AFC. The Bretbly cable handler from the Long Airdox Electra 3000 is shown in Figure 2.7.

Figure 2.7 Bretby cable handler (Source: Long Airdox Australia)

Longwall mining represents the most cost-effective way to mine the coal from both the manpower and extractive ratio standpoint. Like any other mining methods, the extraction of coal generates large quantities of coal dust, which are extremely dangerous with regard to the associated explosion risk as well as long-term health. There is a need for continuous improvement of the control measures, such as engineering controls and administrative controls, in South African coal mines. In view of this, the current research project is focusing on the dust-control techniques available worldwide for reducing dust exposure and the probability of explosions in underground high-wall mines.

3 International thick-seam wall mining

The mining operation terms generally used, namely “shortwall” or “longwall,” are based on the length of the working face. The primary difference is that shortwalls are generally 46 to 61 m wide, while longwalls are 106 to 182 m wide (Stefanko, 1983).

A literature review and personal communications with coal mining experts were carried out into the South African classification of coal mining operations based on thickness (Hardman, 2001; Beukes, 2001). With the development of larger extraction machinery, the informal classifications have been changed over the years. For the purposes of this research on dust control in thick-seam wall mines, the methods of wall mining have been classified (van Neikerk, 2001), based on thickness, into the categories as shown in Table 3.

Table 3: Wall mining classification based on thickness (Van Neikerk, 2001)

Description	**Seam height, m**
Ultra-thin wall mining	0,0 to 1,2
Thin wall mining	1,2 to 1,8
Normal wall mining	1,8 to 3,5
Thick wall mining	3,5 to 5,0
Ultra-high wall mining	> 5.0

The worldwide literature survey on dust control in thick-seam wall mining was carried out with regard to the following countries: Australia, the USA, Poland, the UK, China, India, Slovenia and Japan.

3.1 Longwalls in Australia

Australia is one of the main coal producers in the world. The country currently has 34 operating longwalls, and produced approximately 71 million tons of coal in 1999/2000. Eleven of the longwalls are operating within the Queensland Bowen Basin and the remaining 23 are in the Western, Southern, Hunter and Newcastle regions of the NSW Sydney Basin. In 1999, longwall mines produced 25% of Australia's coal and 86% of the underground coal (Australia's longwalls, 2000). The average production of Australian longwall mines is half that of US longwalls. For comparison purposes, the Twenty Mile Coal Company in USA produces over eight million tons per annum, from 2,6 metre seams, and blocks 307 metres wide and 3 km in length.

The first Australian longwall was installed in 1963 using a coal plough in the Illawarra Coalfields. Currently, the coal plough is no longer used in Australian coal mines. However, it is still used in Germany and other European-coal producing countries, but in diminishing numbers. In Germany, the coal plough is being used in over 50% of the longwall mines and the last plough in the USA was phased out in 1999. The coal shearer is the only type of coal cutting machine that is used in Australia. Tables A1 and A2 (Appendix-A) summarise the details of longwall mines in Queensland and New South Wales respectively.

Some of the longwall mining highlights from Australia based on the JCB statistics are as follows (Nicholls, 2001):

- Each longwall system has a production rate of 1 200 tonnes/hour average capacity (some of the latest longwalls can produce at 5 000 tonnes/hour)
- Each longwall is relocated once a year, taking 42 days, and operates five days per week, 18 hours per day.
- Each longwall has a maintenance period of six hours per day, five days per week.

Figure 3.1a shows the plot of the number of operating Australian longwall mines according to their working seam height. It is observed that there are seven wall mines that are greater than 3,5 m in height.

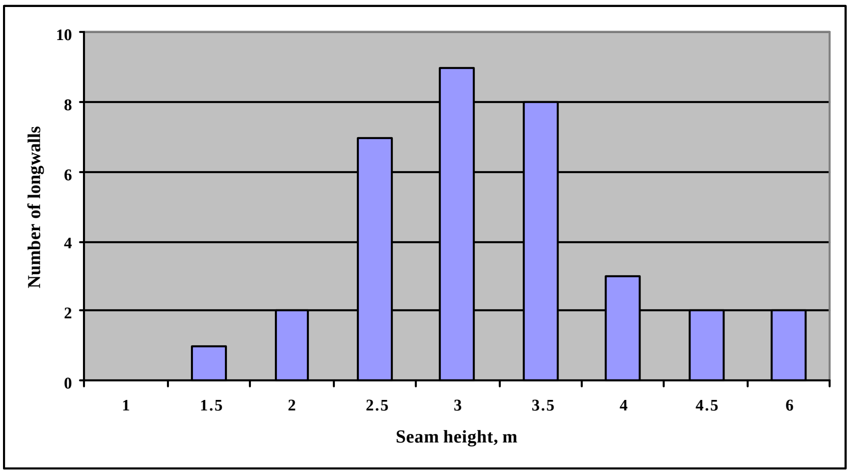


Figure 3.1 Australian operational longwall heights (1999-2000)

3.1.1 Dust levels

It was reported that following the introduction of longwall mining, there has been a steady increase in the incidence of non-compliance respirable dust samples, i.e. in the order of 15 to 20 % of the samples taken, with the dust concentrations being up to 6,0 mg/m^3 (Land, 1998). Workers engaged in longwall mining in the Southern Coalfields of New South Wales were considered to be at highest risk due to the nature of longwall mining, which produces higher dust exposures than older and less productive mechanical mining methods (JCB, 1991). The progression index (PI), an indication of the progression of Coal Workers Pneumoconiosis (CWP), for underground longwall miners was 20% higher than in a control group of surface miners. The study concluded that an increase in longwall mining was considered to be a cause for concern regarding dust exposures, and it was considered that the prevention of pneumoconiosis depends on continuing the monitoring of dust exposure levels and continuing all current preventative engineering developments to lower dust exposure.

The exposure standard for respirable coal dust in the coal mining industry in Australia is currently 3,0 mg/m^3, based on the pneumoconiosis research findings of the British National Coal Board (Jacobsen et al., 1970). The measurement methods (Standards Australia, 1987) for respirable coal dust exposure are based on the British methods [Coal Mines Regulation Act, 1982 and regulations (NSW); Coal Mining Act, 1925 (QLD) and regulations; Coal Mines Regulation Act, 1946 (WA) and regulations], which conform to the recommendations of the British Medical Research Council ("Johannesburg Curve"). Surveillance studies on the prevalence of pneumoconiosis in New South Wales (Griffiths, 1988) and Western Australia (Holman et al, 1988) have revealed that clinically significant pneumoconiosis is being eliminated. However, it is still uncertain whether other health effects, such as chronic bronchitis and obstructive lung disease, will also be well controlled. From the pneumoconiosis point of view, the NSW coal mining industry now boasts one of the lowest prevalences of occupational lung diseases of any coal mining center in the world (Griffits and Koelmeyer, 1991).

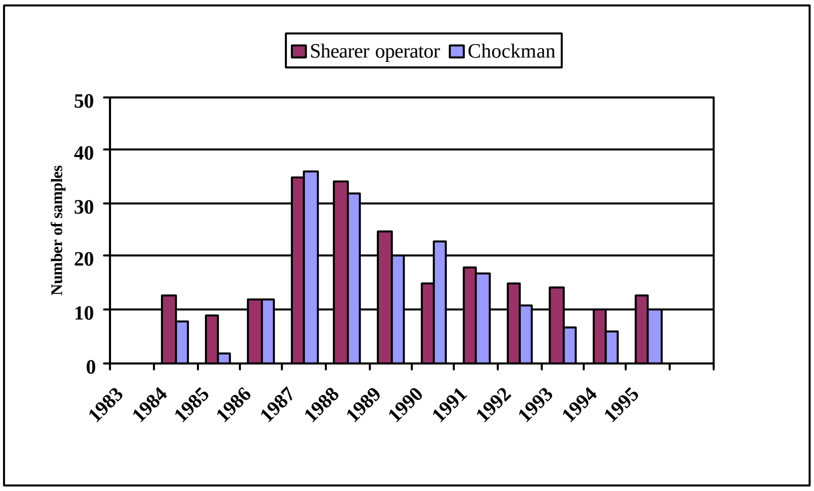


Figure 3.1.1 Australian longwall face samples exceeding the 3,0 mg/m^3 limit (1984-1995)

Figure 3.1.1 shows the number of longwall face samples exceeding the 3,0 mg/m^3 limit over the years 1984 to 1995. During this period, significant changes occurred, viz. the number of longwall faces has doubled and the average daily longwall face output has increased from 4 000 to over 8 000 tonnes per day. Analysis of longwall dust samples for quartz has indicated that there is a 25% chance of exceeding the specified limit of 0,15 mg of respirable quartz/m^3 of air (Glover and Cram, 1997).

3.1.2 Australian dust-control mechanisms

There are no accurate and clearly documented descriptions of effective dust-control mechanisms and measurement techniques in Australian longwall mines. In the available published literature, no detailed description of the types of dust-control system, the spray types, numbers and spray configuration or water flow rates used were found, but the following observations are made:

- Water sprays along with the shearer clearer spray bar (developed by the USBM), constructed from polyurethane, to contain the dust-laden air on the face side of the shearer, have been widely used.
- Use has been made of a number of sprays and polyurethane deflector screens magnetically mounted on the shearer body to direct dust laden air away from the personnel walk-way at the face (JCB, Technical Bulletin No. 12).
- The face air quantities in Australian longwalls varied from 25 m^3/s up to approximately 100 m^3/s with face velocities up to 4,0 m/s. The gas content of the coal seams varies in content from 0,1 m^3/t up to 22 m^3/t (Mayes and Gillies, 2000).
- Intake contamination onto the longwall face was reduced by the introduction of homotropal ventilation, allowing clean intake air onto the face. The alternative with anti-tropal ventilation has been to enclose the stage loader and to use internally mounted sprays and strategically placed sprays at the armoured face conveyor (AFC) to the stage loader.
- Stage loader-extraction fan and sprays have also been used (JCB Technical Bulletin No 13).
- To eliminate the build-up of dust on chocks, regular hosing/cleaning by the face crew, of allocated section of the face, has been successful. Canopy sprays have been tried in South Bulga mine and Metropolitan colliery, but these required too much maintenance.

- The majority of the face workers spend their time on the headgate side (fresh air side) of the face. Face management ensures that the longwall machine operator adheres to the face operating procedures to limit his dust exposure.
- Where dust exposure cannot be maintained below the specified limit, respirators are used as the last line of defence.
- Historically, wetting agents or surfactants have been used over a number of years in NSW underground coal mines with minimum success. Laboratory tests with wetting agents have shown a remarkable ability to wet coal dust although underground trials have proved inconsistent (Hewitt and Aziz, 1993).
- There was a mention of the use of a "hanging fan" along the face area in order to dilute the methane and provide effective ventilation.

3.2 Longwalls in the USA

The longwall mining method was brought into the United States in 1875 by immigrating miners from Wales, and for the next 75 years this method remained as a manual operation in small advancing faces. As mechanized longwall equipment became available in the 1950's, the profile of the panel changed from a series of small faces to a single face developed across a large rectangular panel, marking the beginning of modern longwall mining. With the introduction of self-advancing hydraulic roof support in the early 1960s and the enactment of MHSA (1969), longwall mining gradually started challenging the predominant bord-and-pillar technique.

Longwall mining operations now accounts for approximately 50% of the underground coal produced in the US (Energy Information Administration, 2000). A total of 22 longwalls were operating in West Virginia and Pennsylvania (Meister, 2001). In 1999, approximately 75% of longwall mines operated with shearer horsepower at 746 kw (1000 hp) or greater. From the 1980s to the 1990s, the average US production has been increased from 810 tons/shift to 3180 tons/shift (Niewiadomski, 2000). Today, one-third of the longwall faces have face widths greater than 305 m and longwall panels that measure 3,0 km or longer (Anon., 2000).

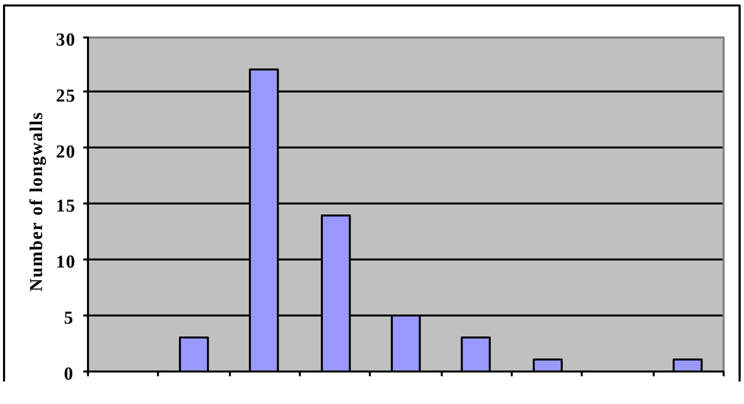


Figure 3.2 American operational longwall heights (1999-2000)

Figure 3.2 shows a plot of the number of operating American longwall mines according to their working seam heights. It is observed that there are five wall mines that are greater than 3,5 m in height.

3.2.1 Dust levels

Although advances have been made in mitigating airborne respirable dust along longwall faces, many operations still have difficulty maintaining compliance with the federal dust standard of 2,0 mg/m^3. During the period of 1995 through 1999, mine operators and MSHA inspectors collected 9 968 and 1 365 dust samples respectively. Analysis of these dust samples showed that 20% of the mine operator samples and 19% of the MSHA samples (Niewiadomski, 1999) exceeded the 2 mg/m^3 dust standard. The most recent results (1992-1996) of the Coal Workers X-ray Surveillance Program (Anon., 1999) indicated that approximately 8% of the miners who were examined, who had at least 25 years of mining experience, were diagnosed with (CWP) (category 1/0+).

Figure 3.2.1 compares the contributions of longwall dust from the major sources during the 1980s and 1990s (Colinet and Jankowski, 1997). The operator and MSHA dust sample data (1999) for 55 longwalls was analysed for concentration levels, mining height and production. The plots of seam height versus minimum, maximum and average dust concentration levels recorded by the operator and MSHA authorities are shown in Figures A1 and A2 (Appendix-A) respectively. Similarly, the plots of average production versus the dust concentration levels recorded by the operator and MSHA authorities are shown in Figures A3 and A4 (Appendix-A) respectively.

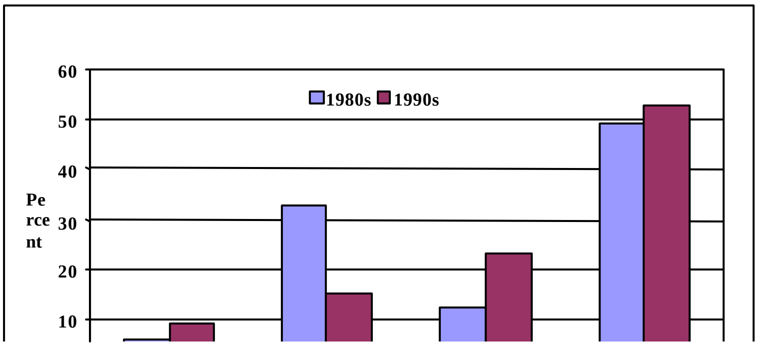


Figure 3.2.1 Comparison of longwall dust source contributions (Source: Colinet and Jankowski, 1997)

The concentration data indicates that the majority of the US wall mining (< 3,0 m high) still record the maximum concentration levels above 5,0 mg/m^3/shift, indicating the magnitude of the problem. However, the plots of production versus concentration does not clearly indicate that the dust concentration levels increase with the increase in coal production.

3.2.2 American dust-control mechanisms

- ***Ventilation procedures***

The typical longwall in the United States ventilates the face with air flowing from the headgate to the tailgate utilising a bi-directional cutting sequence. As with all mining methods, ventilation is one of the primary means of controlling dust and methane in longwall operations.

Increase in air velocity: During the early 1980s, face air velocities ranged from 0,6 to 3,3 m/s (Jankowski and Organiscak, 1983), while average production was 810 tons/shift in 1981 (Niewiadomski, 2000). During the early 1990s, the range of air velocities increased to 1,0 to 7,6 m/s (Colinet and Jankowski, 1997), while the average production nearly increased four-fold to 3 180 tons/shift in 1993 (Niewiadomski, 2000). Minimum average face air velocity of 2,0 to 2,3 m/sec appears to control respirable dust in three ways: higher face air velocities provide greater air quantities for better dilution across the face, help to confine shearer dust to the face, and lower contamination in the walkway (Jankowski and Colinet, 2000).

Use of a gob curtain: A gob curtain (Figure 3.2.2a) installed between the first support and the rib in the headgate entry can force the ventilation airstream to make a 90° turn down the longwall entry rather than leaking into the gob. Previous research (Jankowski and

Organiscak, 1983) indicated that the average face air velocity with the gob curtain installed was approximately 35% greater than without the gob curtain. The biggest improvement due to the curtain was seen at the first 25 to 30 supports, where increased air volume lowered dust concentrations through dilution. In addition, a number of US longwall operations have extended the brattice curtain along the first five to ten shields to further reduce leakage into the gob area and increase airflow down the face. Previous research by the USBM indicated that approximately 75% of US longwalls were utilizing gob curtains (Colinet and Jankowski, 1997).

Headgate drum curtain: Longwall shearer operators are exposed to high levels of dust when the headgate drum cuts into the headgate entry. As the cutting drum advances into the entry, it is exposed to the primary ventilation airstream. The high-velocity air passes through and over the cutting drum, resulting in large quantities of dust being carried in the walkway and over the shearer operators. To overcome this problem, a cut-out curtain (Figure 3.2.2b) is located 1,2 to 1,8 m (installed tightly against the roof and it must extend sufficiently into the headgate entry) back from the corner of the face to provide maximum shielding from the dust and not to interfere with the cutting cycle. The cut-out curtain redirects the primary air so that it flows out and around the drum (Jankowski, 1986).

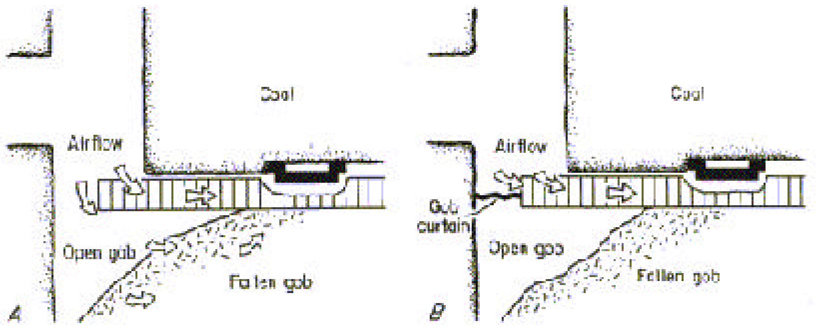


Figure 3.2.2a Installation of a gob curtain at longwall headgate (Source: Rider and Colinet, 2001)

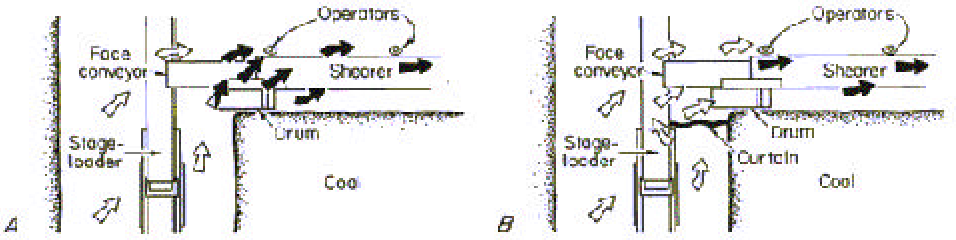


Figure 3.2.2b Location of cut out curtain at longwall headgate (Source: Rider and Colinet, 2001)

The results of the field trials (Jankowski, 1986) indicated that the cut-out curtain reduced the exposure of the tailgate shearer drum operator by 50% to 60% as the headgate drum cut into the entry.

- ***Water spray systems***

In the United States, all operational shearer drums since the late 1970's have been equipped with drum-mounted water sprays. The intent of the drum-mounted sprays is to apply water directly at the point of coal fracture for dust suppression and to add moisture to the product to minimize dust liberation during the transport of the coal along the conveyor off the longwall face. Once respirable dust becomes airborne and is entrained by the primary airstream, it is then carried throughout the entire cross-sectional volume of the longwall face.

Water sprays are very effective air-moving devices and when mounted on the shearer body can act very much like small fans that move air and entrain dust in the direction of the airflow. A shearer-clearer spray system (Jayaraman et al., 1985) takes advantage of the air-moving capabilities of water sprays. This system (Figure 3.2.2c) consists of several shearer water sprays mounted on the spray bar oriented downwind and one or more passive barriers that split the airflow around the shearer into clean and contaminated air splits. Past research has shown that the shearer-clearer can reduce operator dust exposures by approximately 40%. Over 90% of U.S. longwall shearers are equipped with shearer-clearer spray systems.

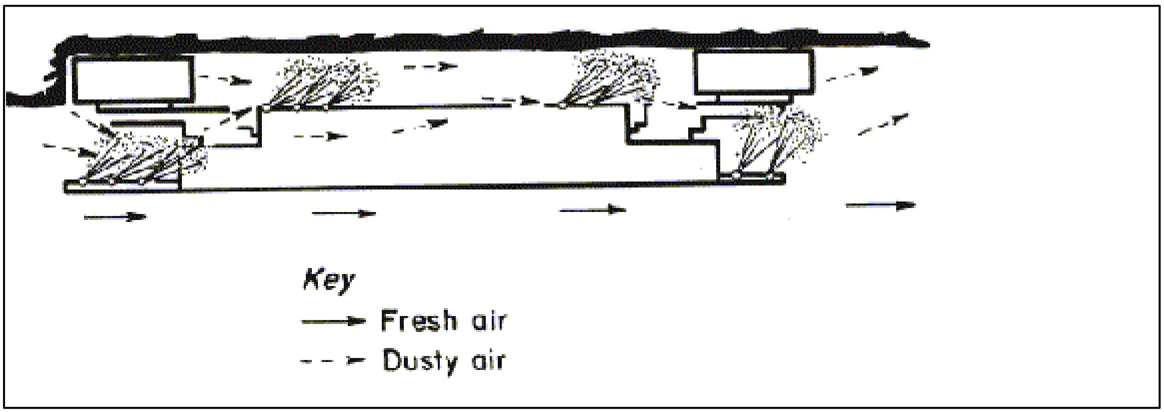


Figure 3.2.2c A typical shearer-clearer spray system (Source: Jayaraman et al., 1985)

- ***Shield dust***

As shown in Figure 3.2.1, the amount of dust contributed by the shields has increased over the years (and decreased from other dust sources). This could be partly due to the intensified focus of research in other areas, and partly to the increased rate of shield advancement with increased production. As shield supports are lowered and advanced, broken coal and rock fall (gob fall) from the top of the shield canopy directly into the airstream ventilating the longwall face. In addition, it has been noted that the air velocities being found on longwall faces have significantly increased. These factors combine to increase the potential for entraining greater quantities of dust during shield advance (Chekan, Listak and Colinet, 2001).

Shield spray systems that wet material on top of the shield canopy are available but the effectiveness of these systems has not been documented. Several mines have indicated that it is difficult to maintain the shield sprays throughout the life of a longwall panel. Wetting can be an effective means of controlling shield dust. However, to achieve maximum benefits from water sprays, it is imperative that the sprays be maintained to function as designed.

3.3 Longwalls in the United Kingdom (UK)

Coal mining in the UK is a £1,500 million-a-year industry producing 41 million tonnes in 1998, and coal is the raw energy for 37% of the electricity generated. Between 1994 and 1997, coal production hovered around the 50 million tonnes-a-year level (UK DTI, 2001). Currently, there are 16 producing underground mines in the UK, which includes 15 longwall faces, face lengths range from 250 m to 300 m (Creedy, 2001). Most production is by mechanized 'retreating' longwall mining, although there are still a few 'advancing' faces in operation. Face extraction heights in the UK are generally within the range 1,5 to 4,0 m and seam gradients do not exceed 15°. Most of the thick wall dust-control practices appear to be the same as those in US mines, but the latest dust-control practices are not well documented.

3.4 Longwalls in China

There is little or no literature information currently available with regard to either the operating conditions in Chinese mines or the dust-control techniques being employed in the mines. Chinese coal seams (4,0 to 6,0 m) are mined with continuous miners and by means of longwalls. The need for thick-seam wall mine dust control (Jinyu et al., 1999) exists as the Chinese mining delegation that recently visited CSIR-Miningtek identified thick-seam wall dust control as one of the areas needing assistance from South Africa.

3.5 Longwalls in India

Longwall mining in India dates back to the early 1960s, with Anderson shearers along and props. The first mechanized powered-support longwall caving face was introduced in 1978 (Das, 1999). A summary of the extraction details and seam thicknesses of the sophisticated mechanised caved longwall faces in India is shown in Table A3 (Appendix-A). Similar to the Chinese longwall mines, little or no literature information was available on controlling dust in Indian longwall mines. A study carried out in an Indian longwall mine (V.K.7 incline of SCCL), at the tailgate, showed that the respirable dust produced per cut was reduced from 2,5 to 1,3 mg/m^3, when the speed of the drum was reduced from 45 rpm to 33 rpm. All the shearers used in the Indian longwall were equipped with the pick-face flushing system of internal drum sprays (Kumar, 2000). However, no details on the spray configuration or the dust levels in the longwall mines were reported in the literature.

3.6 Longwalls in Poland

Coal mining activities in Poland commenced in the 19th century (Palarski, 1999). Currently, there are 45 underground mines in operation, with a production of 109,2 million tons in 1999. The current mining practice in Poland is dominated by longwalls operating in seams between 1,5 m to 4,5 m in height. However, during the last several years the number of operating longwalls has stabilized, bringing the total number to 232 by the end of 1999. Table 3.6 shows the main specification of Polish longwalls.

The pneumoconiosis hazard is one of the most serious problems in Polish coal mining with the average number of cases exceeding 500 per year (Lebecki, 2000). CWP is responsible for 77% of deaths among retired Polish coal miners (Koziel et al., 1999). According to the data, out of 460 longwalls about 80% of the samples belonged to the Polish classification of degrees II and III of respirable dust hazard (serious). The total number of underground miners exceeded 200 000. The highest risk occurred in seven collieries characterized by deep and thin seams of dry high-rank coal. In 1997 the number of new cases was 107, which corresponds to 28% of the total number of cases in the whole of Polish coal mining. The total indemnity paid by the Gliwice Coal Mining Company was PLN 2.1 million.

At present there are 67 operating coal mines working on coal deposits that vary in depth from 100 to 1 200 m. The coal seams being exploited vary in thickness from 1,4 m up to 8,0 m, with an average thickness of 2,1 m and an average longwall length of 180 m. Most of the Polish operating longwalls are operated in coal seam thicknesses and widths similar to those of US longwalls. The shearer water flow rates, face ventilation quantities and production rates measured in the USA were more than double the levels measured in Poland. Whereas shearer drum cowls, drum sprays and external sprays are commonplace in the US, there is little or no use of these in Poland (same as in South Africa). Also, uni-directional cutting practices are more widely used in the US longwalls than in Poland (Organiscak et al., 1999).

Table 3.6 Longwall specifications (Palarski, 1999)

	Factor	Units
1	Number of longwalls	232
2	Mining depth (average)	630 m
3	Panel width (average)	210 m
4	Panel length (average)	850 m
5	Cutting height (average)	2,38 m
6	Number of gate entries	2
7	Depth of cut	0,8 m
8	Average production	2209,5 tonnes per day

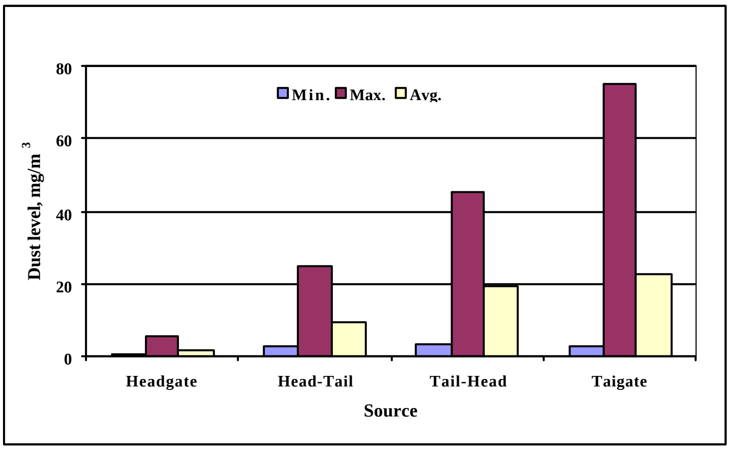


Figure 3.6 Dust levels measured in eight surveyed Polish longwall mines

A comparative study of eight Polish and 13 US longwalls by Organiscak et al. (1999) gave an insight into the dust problems in Polish longwall mines and the control technologies implemented. This is summarized in Table A4 (Appendix-A). The dust concentration levels measured in eight mines surveyed are plotted in Figure 3.6.

3.7 Longwalls in Slovenia

In Slovenia coal is exploited in only one of the two mines. The coal extraction is by means of a double-drum shearer with a cutting height of 3,0 to 4,0 m. The length of the longwalls varies from 80 to 160 m (Zerdin and Dervaric, 2000). It can be inferred that thick-seam wall mining exists in Slovenia, similar to the Chinese longwall sub-level-extraction system. However, no literature information is available on either the dust concentration levels along the longwall face or the ventilation and dust-control systems.

3.8 Longwalls in Japan

The history of Japan's coal mining industry goes back to 200 years ago, peaking at 843 coal mines in operation and production amounting to 55 million tons per year. By 1997, only two underground mines were in operation, producing 6 million tons/year (Deguchi, 2001).

The number of those diagnosed as suffering from pneumoconiosis in Japan was 653 in 1995, of whom three were workers in the coal mining industry. The number of those suffering from pneumoconiosis itself is not so large. The occurrence of new sufferers in the coal mining industry is about 1,8 times the overall average (Nakanishi et al., 1997). In

Japan, as in Germany, the working environment measuring method is mainly practiced, and the personal exposure measuring method is rarely used. No information was available on dust-control measures or on the dust levels in Japanese thick-seam wall mines.

4 Summary of longwall dust-control technologies

The continued development of CWP in coal mine workers and the magnitude of overexposures to respirable dust in longwall mining occupations illustrate the need for improved dust-control technologies in underground coal mines. The dust control measures discussed in past research publications are broad control techniques for assisting mines to select the appropriate dust-control approach for the unique conditions that exist in their longwall mining operation.

The most common method for controlling the airborne dust in longwalls is by means of water sprays mounted on the shearer cutting drums (Wirch and Jankowski, 1995). Techniques implemented for the control of shearer-generated dust included high drumwater flow rates (Jankowski and Organiscak, 1984), improved cutting techniques (Ludlow and Jankowski, 1984; Wirch et al., 1988), shearer-clearer-type external water spray systems (Jayaraman et al., 1985), radio remote control (Bureau of Mines, 1984), high-pressure, inward-facing drum sprays (Jankowski and Kelly, 1988) and reverse drum rotation (Jankowski et al., 1988). It has been suggested that to move air and redirect the dust away from the operator in a longwall face, the spray pressure should be at least 1 035 kPa. To suppress dust before it becomes airborne, spray pressure should be kept below 690 kPa (Technology News, 1986). Several laboratory studies (Jayaraman et al., 1989; Whitehead and Jayaraman, 1990; Jayaraman et al., 1991; Alaboyun, 1989; Hu, 1992 and Belle, 1996) have shown that the dust collection efficiency of two-phase spray systems (TPSS) is greater than that of single-phase spray systems (SPSS).

The use of additives or surfactants to promote wetting in dust-control has been studied before. Since most coals are not easily wetted by water, it seems logical to add a surfactant to the spray water. There is wide disagreement about the effectiveness of surfactants. Many operators claim a significant reduction in dust levels, while others say there is no improvement. Wettability, as defined by the capillary rise test, means that a coal sample absorbs a quantity of water equal to at least 15% of its weight within 15 minutes (Kost et al., 1980). Results from a US study have indicated that the use of a surfactant can reduce airborne dust levels; however, the results cannot be applied to all coal seams or surfactants (Kost et al., 1980).

Most of these dust-control techniques were developed in the US for low-seam longwall mines (seam heights up to 2,5 m). The application of these US-developed techniques is limited to South African high-seam longwall conditions in which the operating seam height is 4,1 m. Augmenting the existing dust-control problems in South African coal mines is the fact that South African coal seams generate approximately four times more dust than the US coal seams and thus poses a serious health and safety threat to the underground coal mine workers.

Studies have shown (Tomb et.al.,1991, Breuer, 1972) that with adequate moisture on the coal, such as that provided by sprays, air flow may be increased without significantly increasing the dust entrainment at the face. Other studies have examined velocities from 0,5 to 4,6 m/s, and showed that a minimum longwall face air velocity of 2,0 to 2,3 m/s is required for proper dilution of dust along the face (Foster-Miller Assc., 1982, Breuer, 1972). However, due to the presence of methane, higher air velocities are often required for dilution of gas. When air velocity increases above 2,0 m/s, an increase in dust levels can occur if the moisture content of the dust is insufficient to prevent entrainment into the airstream (Hall, 1956, Hodkinson, 1960). A more recent study (Tomb et.al.,1991) shows that as face air quantities have increased, even beyond 5,1 m/s, dust exposure levels due to dust generated along the face decrease when adequate controls are used. Currently, some US longwall operations are using face velocities in excess of 7,6 m/s.

These studies clearly indicate that higher air velocities (not currently used in South African mines) do not increase dust generation from controlled sources such as the shearer or stage loader if adequate dust-control systems are employed. However, this observation may not be the case for shield dust (Chekan et al., 2001). As previously stated, water can be an effective means of controlling dust. However, sprays on the tops of shields are difficult to maintain and as a result soon become inoperable.

More importantly, controlling shield dust using increased air dilution is difficult because increasing the air velocity provides greater potential for dust entrainment since the dust falls directly into the airstream under the canopy edges.

This entrainment, in the absence of effective control technology, is the most likely source of increased dust contribution from the shields. Currently, NIOSH is carrying out research work in this area (Chekan et al., 2001).

From the literature studies on thick-wall dust-control techniques, it was found that broad dust-control principles do exist in the literature. However, mine-specific and detailed technical aspects of the control mechanisms are not described. Also, most of the dust-control techniques have been developed in the USA and their application is specific to low to medium coal seam heights.

The following table (Table 4) is a list of the broad dust-control techniques that can be used, adapted to the South African scenarios; the list is based on the international thick-seam dust-control research.

Table 4 Thick-seam wall mining dust control techniques

Recommendations	Dust-control technique
Intake controls	Increase intake air quantity
	Modify out-bye ventilation system
	Change out-by work activities
Headgate controls	Increase face air quantity
	Install gob and cut-out curtains
	Increase headgate water pressure
	Increase headgate water quantity
	Improve headgate enclosure
	Install homo-tropal ventilation system.
Support controls	Increase face air quantity

	Install gob curtain
	Line back of supports with belting
	Institute support wash-down program
	Install support remote controls
	Water –infusion of panels
Worker position changes	Install machine remote control
	Improve directional spray orientation
	Install passive barrier on machine.
Machine controls	Increase face air quantity
	Install gob air curtain
	Increase machine water pressure
	Increase no. internal sprays
	Increase number of external sprays and spray configuration
	Add surfactant/foam to water
	Install passive barrier on machine
	Reduce cutting drum speed and add drum cowl

5 Preliminary field evaluation

5.1 Current South African conditions

Currently in South Africa three mines are extracting coal by short-wall mining method. Table 5.1 shows the details of the operational parameters of individual mines.

Table 5.1: Wall mining operation in South Africa (Source: Machill, B., 2001)

Operational parameters	**Mine name**		
	Matla No. 2	Arnot No. 8 shaft	New Denmark, Okhozini Shaft
Seam name	4 seam	-	-
Seam height, m	4,5	3,5	2
Seam classification	Thick	Normal	Normal
Face width, m	120	127	235
Average production rate, t/month	350 000	150 000	150 000
Cutting direction	Right to Left	Left to Right	Right to Left

Shearer haulage speed, m/min	9	12	7
Web width, m	1,0	0,8	0,7
Drum cowls present?	No	No	No
Air velocity, m/sec	1,5	1,5	1,5
Shearer water quantity, L/min	400	80	100
Shearer water pressure, Mpa	2	2	1

The next section of this report describes the results of two series of field evaluations carried out underground at a thick-seam Joy shortwall shearer section (Mine A). The principal objective of the project was to determine the preliminary dust levels with the existing dust-control systems by determining the ambient Airborne Respirable Dust (ARD) concentrations in the shortwall section. During the second series of tests, CSIR-Miningtek recommended a few modifications to the dust-control system and improvements were evaluated in terms of the reduction in dust levels.

In this mine the coal seam is extracted by both shortwall and continuous mining methods. It was learned that, with the existing shearer dust-control design, the average monthly personal respirable dust concentration level at the tail end of the machine was ranging from 10 mg/m^3 to 12 mg/m^3. The peak production from this section for a single month reached rates as high as 450 000 tons. Figures 5.1a and b shows the dust levels obtained from Mine A (Thick-seam) and Mine B (Normal seam) in the shortwall sections.

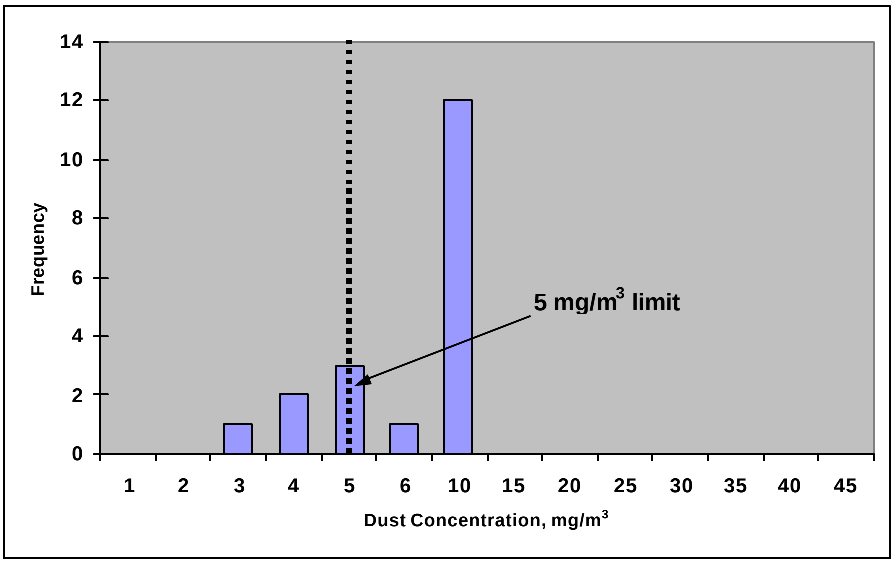


Figure 5.1a: Dust levels (month) in a thick-seam shortwall section (Mine A)

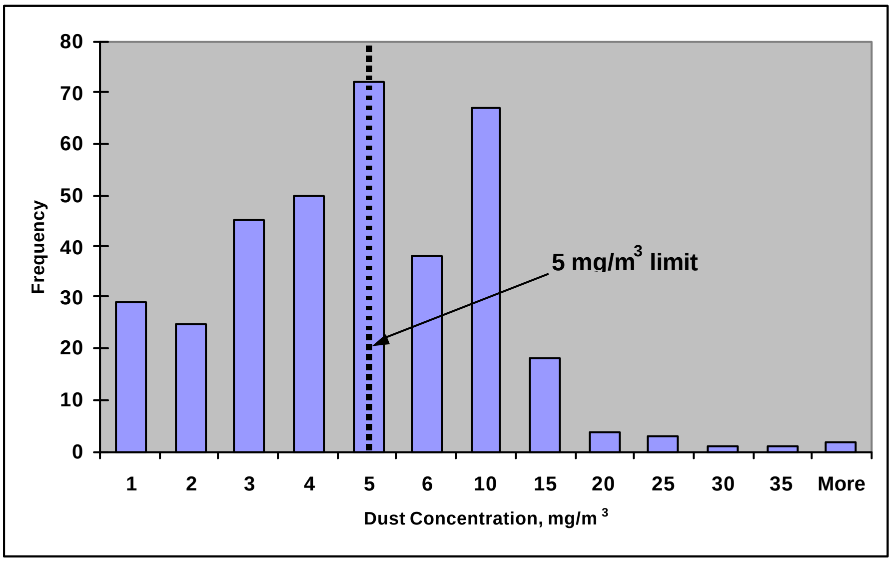


Figure 5.1b: Dust levels (annual) in a normal seam shortwall section (Mine B)

From Mine A data (thick-seam), we observe that 68% of the samples exceeded the 5,0 mg/m^3 engineering concentration limit. Similarly, the analyses of Mine B (Normal seam) data indicate that 41% of the samples exceeded the 5,0 mg/m^3 engineering concentration limit.

Figure 5.1c shows the relationship between the shortwall production levels and the measured dust concentrations. From the plot, we observe that the increase in production is not a reflection of increase in dust levels in the section.

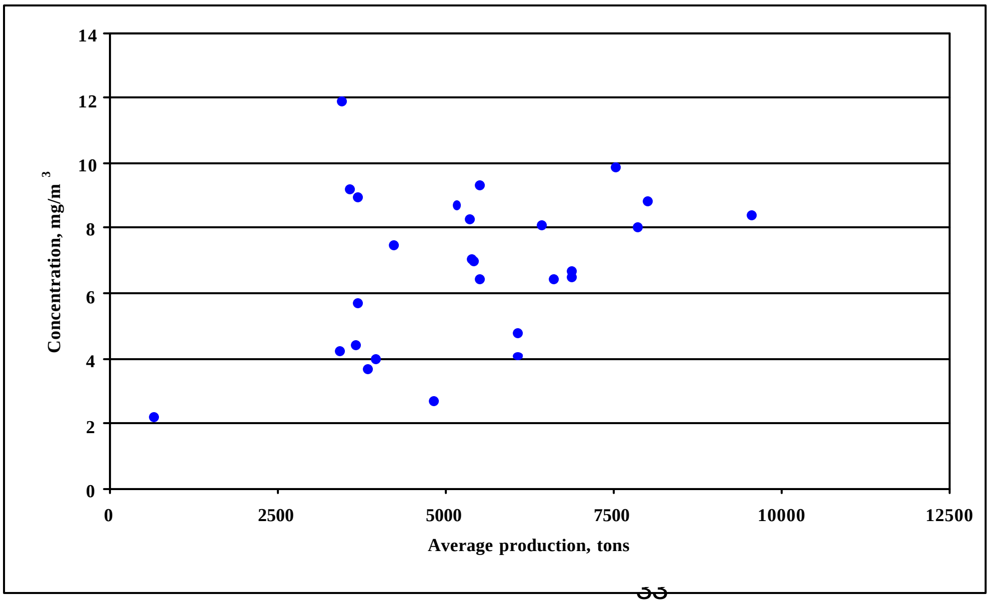


Figure 5.1c: Relationship between average production and measured dust concentration levels in a thick-seam shortwall section (Mine A)

5.2 Underground trials

5.2.1 Existing shearer dust-control system

The shortwall section used a double-end drum shearer (6L) to extract a web of coal 0,9 m deep and 3,9 m high in both directions (head-to-tail and tail-to-head) for a length of 114 m. Seventy six two-legged, 700-ton shields were used to support the roof on the face. These shields were advanced behind the shearer during both passes. The shearer and shortwall face were checked for air velocity and type of spray nozzles. The spray nozzles deployed were checked for spray type, and functionality. The total operating water pressure on the machine was 2,5 MPa with a total water flow rate of 400 L/min. Of this amount, 200 L/min of water was used for the drum sprays and 200 L/min of water for the external sprays. Each drum of the shearer was equipped with 37 sprays for pick face cooling and dust suppression. The spray bars on left-hand-side (LHS) and right-hand-side (RHS) of the shearer were equipped with 14 and nine sprays respectively. Ten more sprays were mounted on the middle of the shearer body. The external sprays were oriented towards the tailgate as the shortwall face was ventilated by directing the air from the headgate (HG) to the tailgate (TG). A view of the dust suppression system on the shearer is shown in Figure 5.2.1.

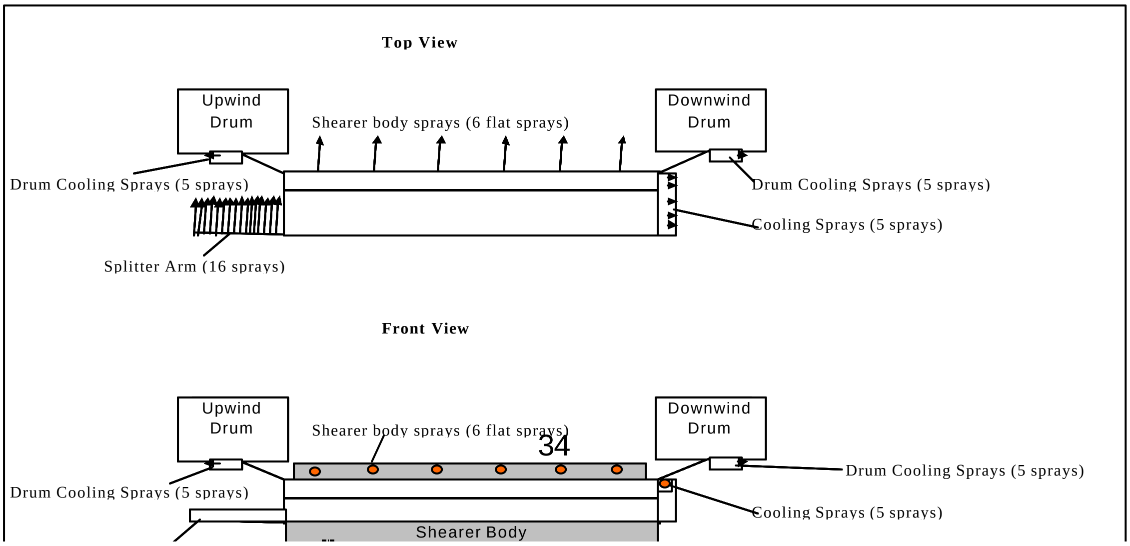


Figure 5.2.1 Existing shearer dust-control system

5.2.2 Sampling procedure

The experimental procedure was designed to accomplish the following tasks: air quantity survey, airborne respirable dust (ARD) survey and measurement of personnel dust exposure. Time studies of the shearer and shield movement were also conducted to correlate the airborne dust concentrations with face activities. The sampling plan used during the two series of experiment is shown in Figure 5.2.2.

Air quantity survey

Air velocities were measured in the shortwall intake, the middle of the face and the section return, and the corresponding air quantities at measured stations were calculated.

Airborne respirable dust (ARD) sampling definitions

Numerous sampling definitions are used in the field of occupational hygiene and the mine environment control. Those used in this report are given below:

Personal sampling: A personal sampler collects the dust in the breathing zone of a worker while he is performing his occupational duties during a work shift. In this sampling method, the worker wears the sampling train (cyclone, pump, tube, sample filter) for the entire shift. In the first series of tests, personal sampling was carried out on the headgate operator (HGO) and tailgate operator (TGO). The sampler was operated during the time this person was at the face and in the vicinity of the tailgate and the headgate drum. However, during the second series of tests, a representative personal sample of the shortwall section was measured to avoid obstructions to the face workers.

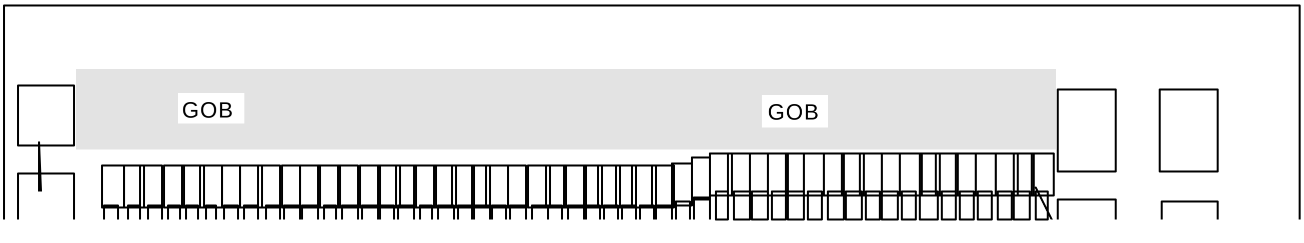


Figure 5.2.2 The sampling plan used along the shortwall face during the experiments

Area or environmental sampling: An area or environmental sample is the dust sample taken at a fixed location in the workplace in a particular environment or area of interest. The dust sample reflects the average concentration in the area of interest and does not reflect the exposure of any worker in that area. In this study the area sampling was carried out at a fixed location in the section intake, section return (RET), headgate (shield 24/22), face-middle (shield 48/45), and tailgate (shield 72/66).

Engineering sampling: An engineering sample is the dust sample taken at a “predetermined” position (Belle and Du Plessis, 1999). It is the dust sample taken to determine the dust concentration near machinery, tipping points, air filters, etc. to characterize the emission source or the effectiveness of dust-suppression or control measures. The engineering sampler is switched on at the face area at the beginning of the shift at its pre-determined position and is switched off before it leaves the face area at the end of the shift. Furthermore, it aims to evaluate both the management (administrative effectiveness) of the dust-control system and effectiveness of the dust-control system (engineering). In this study, the engineering sample was collected at the shearer mid-point (SMP).

The ARD concentrations along the shortwall face were measured at three locations [shield 24/22-HG, shield 48/45-middle of the face (FM) and shield 72/66-TG]. The sampling package at each station consisted of two gravimetric respirable dust samplers. A real-time aerosol monitor (Hund Tyndallometer) was included in every other sampling package on the shortwall face. Gravimetric samplers were also placed in the section RET, SMP and in-bye of the FB.

Dust monitoring instrumentation

The dust-monitoring set-up contained two gravimetric samplers (Higgins-Dewell type cyclones), which were operated at a flow rate of 2,2 L/min according to the new ISO/CEN/ACGIH respirable curve. The gravimetric samplers consist of an air pump, a mini-cyclone, which selectively collects the fraction of airborne respirable dust particles of less than 10 µm on a pre-weighed filter disc. Filters from the samplers were weighed on an analytical electronic balance with an accuracy of 0,0001 mg. The procedure for determining the particulate mass was followed as per the DME guidelines. Well-maintained pumps were used to avoid the effect of pump pulsations and fluctuations in the flow rate.

5.2.3 Data analysis

The dust concentrations presented throughout this report reflect gravimetric dust measurements taken over a specific sampling period. The gravimetric concentration was calculated using the mass of the dust collected over the duration and flow rate. Using the mass of dust collected on the filters, the sample dust concentration (SC) in mg/m^3 is obtained as follows:

$$SC = \frac{(C_f - C_i)}{(Fl \times T)} \qquad (1)$$

where:

C_i = initial filter mass in mg

C_f = final filter mass in mg

Fl = sample flow rate in m^3/min

T = sampling time in min

An 8-h estimate of the dust concentration levels was determined, assuming zero dust-load for the non-sampling period.

5.3 Underground evaluation – Series 1

The results of the Series –1 trials performed in the shortwall panel are summarized and discussed below.

Air quantity

The air velocities measured during the experiment are shown in Table A5 (Appendix-A). The air quantities at different stations on the shortwall face are plotted in Figure 5.3a. Using the section return dimensions of 4,0 m height and 7,0 m width, the air quantities in the section were estimated. The arithmetic average of the estimated air quantities during the test period (33,6 m^3/sec; 36,4 m^3/sec; 45,92 m^3/sec) was 38,64 m^3/sec.

Airborne respirable dust (ARD) survey

The measured ARD concentrations during this experiment are shown in Table A6 (Appendix-A). The ARD concentration data discussed in this report represent the airborne dust levels measured by gravimetric samplers for the duration of the experiment (more than five hours).

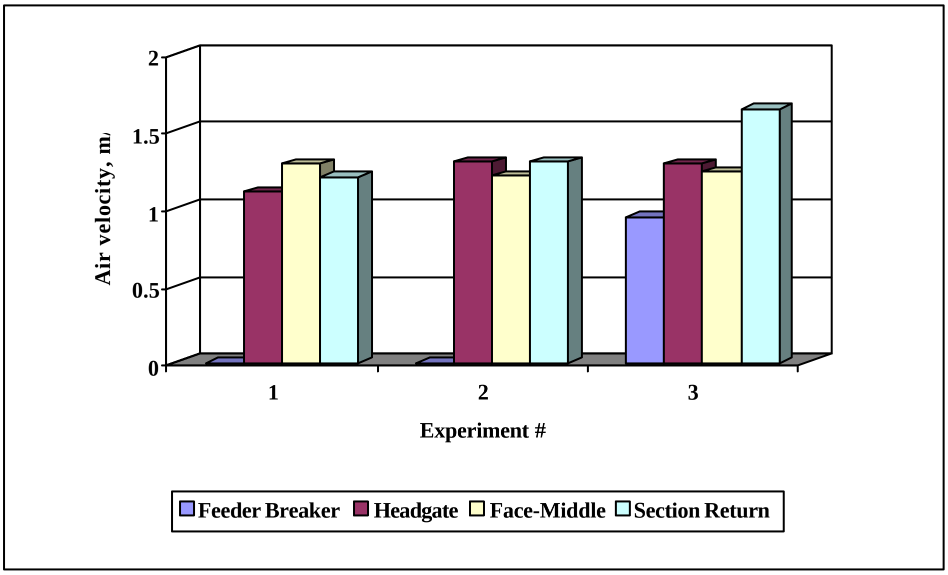


Figure 5.3a: Measured air velocities along the shortwall section

The arithmetic ARD concentration averages for the sampling period and for an 8-hr period in the last open cross-cut immediately out-bye the face (or the in-bye position of the feeder-breaker) were 5,37 mg/m^3 and 3,49 mg/m^3, respectively. The high ARD concentration in-bye the feeder-breaker may be due to the dust generated in the stage loader-crusher, and to the high instantaneous ARD concentrations during the headgate cut-out. In general, the ARD concentrations on the shortwall face increased from the headgate to the tailgate (Figures 5.1.4b). The average of the ARD concentrations (headgate and tailgate) in the face area from the three tests was 6,24 mg/m^3 for an 8-hr period. During test # 3, the measured ARD concentration in the middle of the face for an 8-

hr period was 7,55 mg/m^3. The average production during the three tests was 3 665 tons /shift.

The average measured ARD concentration at the shearer mid-point from three tests was 9,98 mg/m^3 for an 8-h sampling period. This indicates that a large amount of respirable dust generated from the headgate drum was rolling back towards the walkway area along the face, affecting the shearer operators. Similarly, the measured return ARD concentrations were higher than all the measured concentrations in the section. The average ARD concentration in the section return from three tests was 18,05 mg/m^3 for an 8-h sampling period. From this we can infer that a significant amount of dust has escaped to the section return and that the existing dust-suppression system is ineffective. The major dust-generating source that is contributing to such high concentrations, apart from the shearer, could be the roof support system.

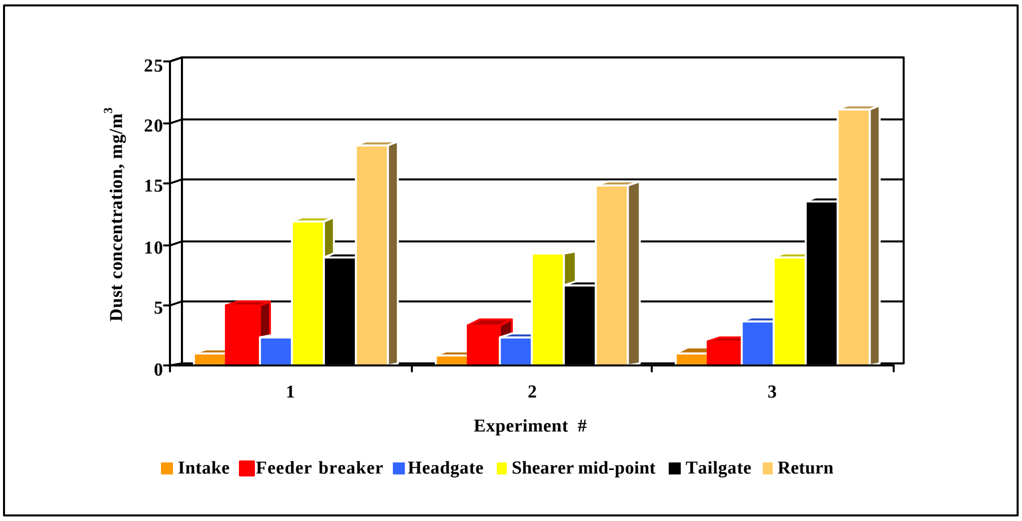


Figure 5.3b: Measured ARD concentrations (8-h) along the shortwall section

The instantaneous ARD concentrations at various points along the face as recorded by the Hund Tyndallometer are shown in Figures A5, A6 and A7 (Appendix-A). The peaks of the instantaneous ARD concentration data are wider at the downwind stations due to the fact that the primary source of dust, the shearer stays upwind of these points for progressively longer periods. Similar observations can be made from the return ARD concentration profile.

Ambient ARD concentrations versus personnel exposure

The personal ARD exposures of the person closest to the tailgate shearer operator were 6,09 and 4,40 mg/m^3 (sampling period and 8-h, respectively). The personal ARD exposures of the person closest to the headgate shearer operator on the shortwall face were 4,66 and 3,47 mg/m^3 (sampling period and 8-h, respectively). Hence, the personal ARD exposure of the headgate shearer operator was only 77,69% of that of the tailgate shearer operator. The K factor, i.e. the ratio between the measured personal exposure level and the 2 mg/m^3 standard, for the headgate operator and tailgate operator were 1,74 and 2,2 respectively, indicating that the personal exposure levels were non-compliant. No relationship could be detected between the area concentrations along the shortwall face and personnel exposures (Figure 5.3c).

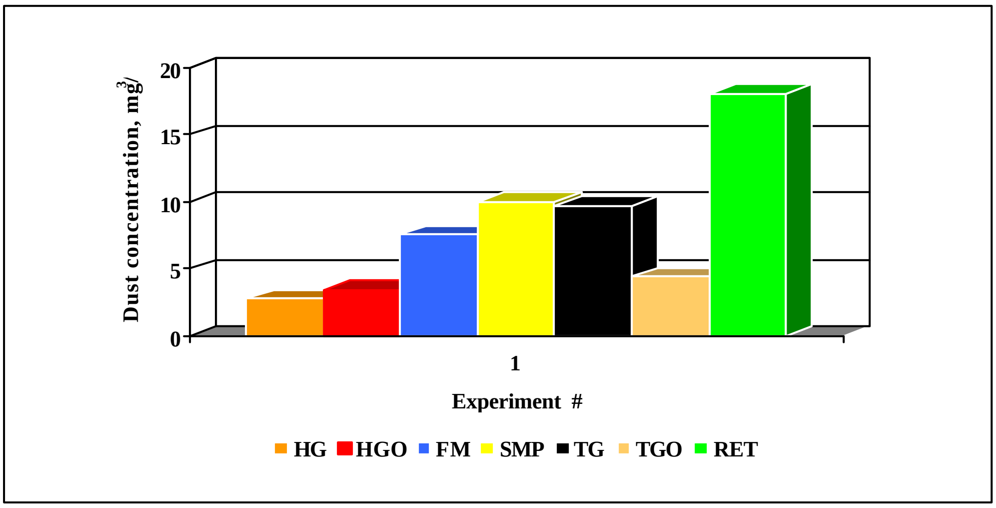


Figure 5.3c: Relationship between area sample and personal sample ARD concentration levels

In Figure A6 (Appendix-A), we observe that the real-time personal dust exposure of the headgate operator was at reasonably high levels during the shearer cutting operations. The personal exposure levels of the headgate operator (3,47 mg/m^3) and tailgate operator (4,4 mg/m^3) were above the 2,0 mg/m^3 standard. The effect of local ventilation on area concentrations, the use of the shearer spray systems to move dust away from the miners, and the use of remote control and administrative practices to keep miners away from dust may lead to poor correlations between area concentrations and personnel exposure. Analysis of the results of these experiments indicates that personnel sampling and engineering sampling should be used for two important but distinct purposes. Engineering sampling could be used to estimate the contributions of various dust sources to the ambient dust concentration in a mining section, and to analyse the efficacy of dust-control techniques. Personal sampling is more suitable for assessing the dust exposure of mine personnel.

5.3.1 Series 1 conclusions

The major conclusions from the three trials conducted at the thick-seam wall mine, Mine A, are summarized as follows:

- In general, ARD concentrations on the shortwall face increased from the HG to the TG and the section return. The average ARD concentration at the three sampling stations on the face was 6,89 mg/m^3 for an 8-h period.
- The arithmetic ARD concentration averages for the sampling period and for an 8-h period in-bye the FB were 5,37 mg/m^3 and 3,49 mg/m^3, respectively. The high ARD concentration in-bye the feeder-breaker may be due to the dust generated during crushing and the high instantaneous ARD concentrations during the HG cut. A considerable reduction in the ARD concentration near the HG end of the shortwall face may be achieved by devoting greater attention to the dust sources in this area of the face.
- The average measured ARD concentration at the shearer mid-point from the three tests was 9,98 mg/m^3 for an 8-h sampling period. This indicates that a large amount of respirable dust was being generated from the headgate drum and was rolling back towards the walkway area along the face, affecting the shearer operators.
- The arithmetic average ARD concentration in the section return from the three tests was 18,05 mg/m^3 for an 8-h sampling period. From this we can infer that a significant amount of dust has escaped to the section return, indicating that the existing dust suppression system is ineffective. A major dust-generating source that is contributing to high dust concentrations, apart from the shearer, could be the roof support system.
- The peaks of the instantaneous ARD concentration data are wider at the downwind stations due to the fact that the primary source of dust, the shearer, stays upwind of these points for progressively longer periods. Similar observations can be made from the return ARD concentration profile.
- The personal ARD exposures of the sampling team who were in the vicinity of the HG and TG shearer operators were 3,47 and 4,40 mg/m^3, respectively; .

5.4 Underground evaluation - Series 2

From the Series-1 ARD concentration measurements, at all specified locations, it was found that the concentration levels had exceeded the legal limit of 5 mg/m^3. Considering the seriousness of the dust problems at various identified positions as well as in the section return, CSIR- Miningtek proposed a few modifications to the thick-seam shortwall section. In order to overcome the dust problems, the following broad areas of change at the shortwall face were recommended before the start of the second series of underground evaluations:

1. It was recommended that the minimum air velocity be greater than 2,0 m/s and that an optimum air velocity of 2,5 m/s be maintained at the face.
2. Implement the recommended Kloppersbos Shearer Spray Curtain (KSSC) dust-control system as discussed in Appendix A (Figure 5.4).

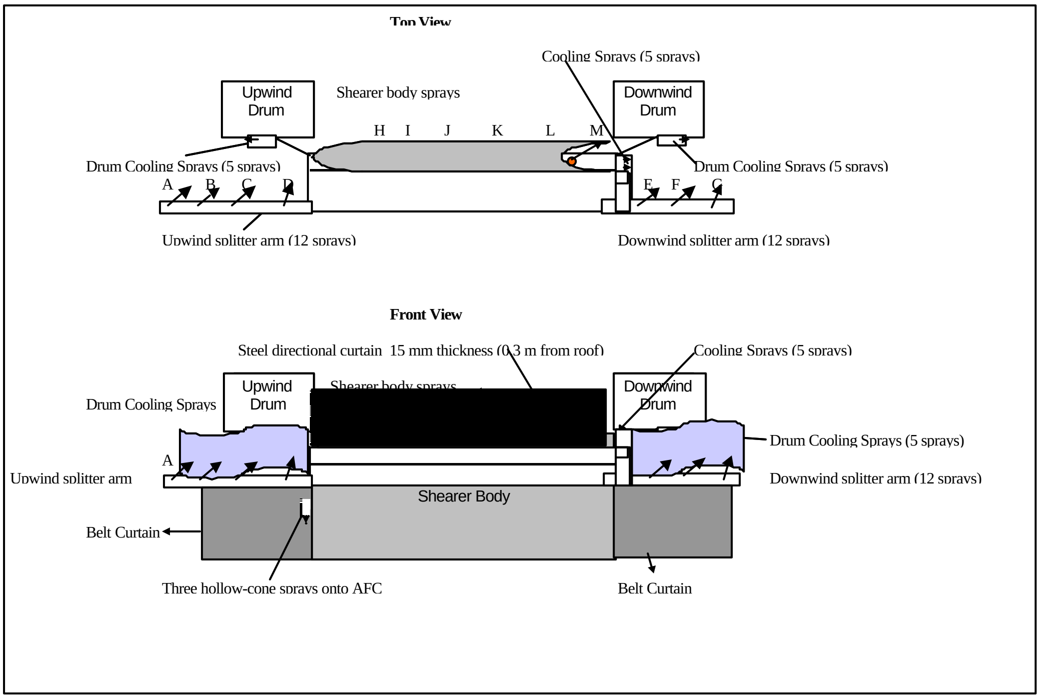


Figure 5.4: Proposed Kloppersbos Shearer Spray Curtain (KSSC) dust-control system

5.4.1 Revised test section

During the second series of underground evaluations, the shortwall was moved to a different section and the following changes were made:

- The shortwall shearer remained the same with the anti-tropal ventilation (same as with the Series-1 tests). The shortwall had sixty-six two-legged, 700-ton shields to support the roof at the face, in effect reducing the length of the face. These shields were advanced behind the shearer during both passes.
- The headgate and tailgate spray bars were extended as recommended. The shearer headgate and tailgate spray bars, and the spray configuration remained the same as before. The headgate and tailgate shearer spray bars were equipped with 12 sprays each.
- Each spray bar had five flat sprays positioned in-line with the conveyor belts, spraying downwards, preventing dust escape and suppressing it. Also, in-between the two spray bars, the shearer body had 10 more flat sprays spraying downwards, suppressing any escaped dust from the shearer body and the cable handler.
- The total operating water pressure on the machine was 2,5 Mpa, with a total water flow rate of 400 L/min. Of this amount, 100 L/min of water was used for the drum sprays and 300 L/min of water was used for the external sprays.
- Each drum of the shearer was equipped with 37 sprays for pick face cooling and dust suppression. The ten sprays mounted on the middle of the shearer body were not operational during the tests.
- Both spray bars were fitted with steel directional physical curtains. After the second test, part of the head gate steel physical curtain was removed (by the mine) and a spray block with three flat sprays was added to the head gate spray bar.
- The velocity along the face was marginally increased compared with the first series of tests.

5.4.2 Series-2 results

The results of the Series –2 trials performed in the shortwall panel are summarized and discussed below.

Air quantity

The air velocities measured during the experiment are shown in Table A8 (Appendix-A). The air quantities at the different stations at the shortwall face are plotted in Figure 5.4.2a. With the section return dimensions of 4,0 m height and 7,0 m width, the air quantities in the section were estimated. The arithmetic average of the estimated air quantities during the test period (39,2 m^3/sec; 39,2 m^3/sec; 42,0 m^3/sec; 39,2 m^3/sec 39,2 m^3/sec) was 39,76 m^3/sec.

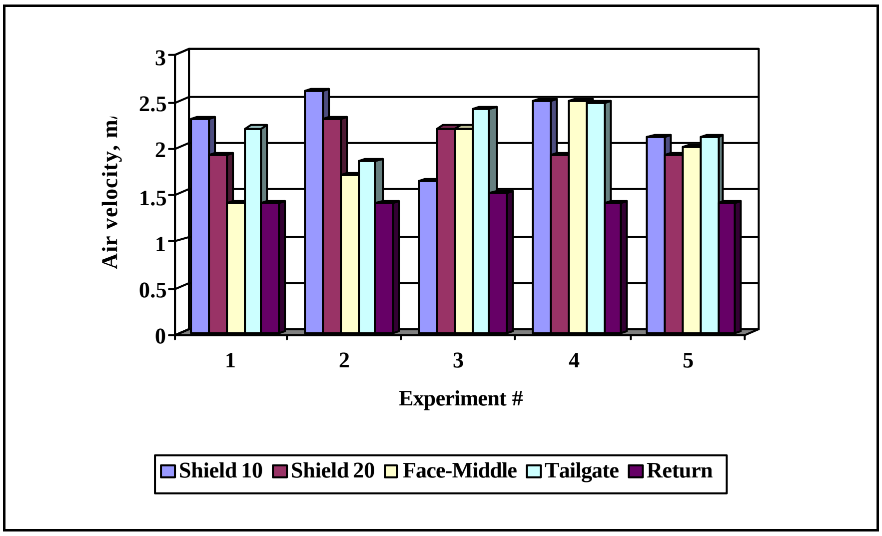
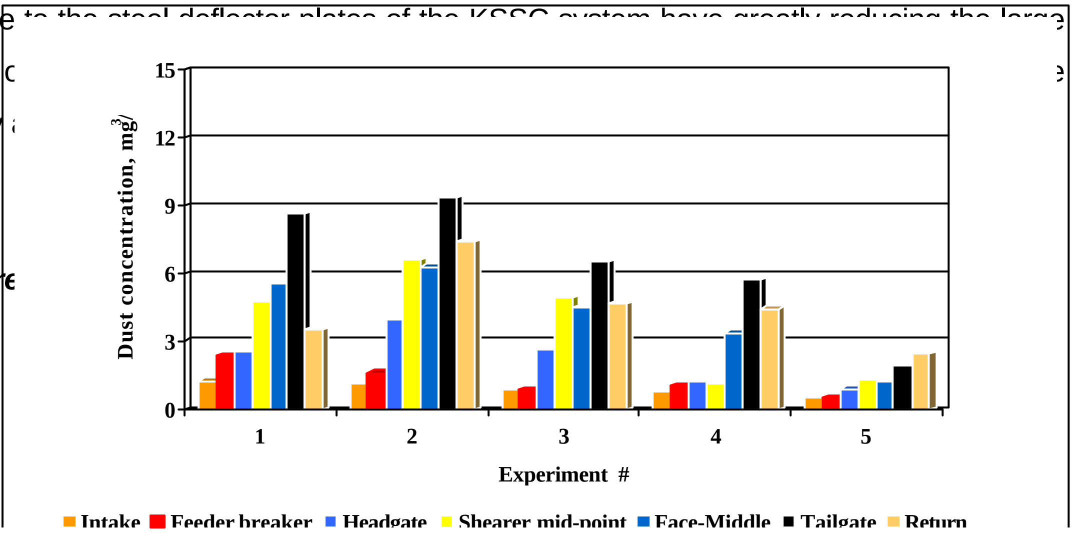


Figure 5.2.2a Measured air velocities along the shortwall section

Airborne respirable dust (ARD) survey

The measured ARD concentrations are shown in Table A9 (Appendix-A). The ARD concentration data discussed in this report represent the airborne dust levels measured by gravimetric samplers during the duration of the experiment (longer than five hours). The arithmetic ARD concentration average for the sampling period and for an 8-h period in the last open cross-cut immediately out-bye the face (or the in-bye position of the feeder breaker) were 1,98 mg/m^3 and 1,28 mg/m^3, respectively. The reduction in the ARD concentration in-bye the feeder-breaker is due to the control measures taken at the stage loader-crusher in the second series of tests.

In general, the ARD concentrations at the shortwall face increased from the HG to the TG (Figure 5.4.2b). The average of the ARD concentration (HG, face-middle and TG) in the face area from five tests was 4,32 mg/m^3 for an 8-h period. The average production during the three tests was 5 244 tons /shift. The average measured ARD concentration at the shearer mid-point from five tests was 3,74 mg/m^3 for an 8-h sampling period. This is most likely due to the steel deflector plates of the KSSG system have greatly reducing the large amount c e walkway



Figure

The measured TG ARD concentrations were higher than all the measured concentrations in the shortwall section. The average ARD concentration in the tailgate from five tests was 6,41 mg/m^3 for an 8-h sampling period. From this we can infer that a significant amount of generated dust has escaped downwind of the shearer towards the section return. With the comparatively low concentrations at the shearer mid-point and the middle of the face, the additional dust may possibly be due to the movement of the shield along the face. This was also confirmed by observations during the studies along the face. The shearer deflector plates are effective in containing the dust, but the sprays on the machine need to conform to the recommended configuration.

The average ARD concentration in the section return from five tests was 4,48 mg/m^3 for an 8-h sampling period. The instantaneous ARD concentrations at various points along the face as recorded by the Hund Tyndallometer are shown in Figures A9 to A13 (Appendix-A). When the real-time concentration levels are compared with the base-line study, the recorded peak concentration levels are found to be significantly reduced. This can be attributed to the containment of dust towards the face area and the prevention of roll-back of airborne dust towards the walkway area. The peaks of the instantaneous ARD concentration data are wider in the tailgate station due to the fact that the primary source of dust, the shearer, stays upwind of these points for progressively longer periods.

5.5 Comparison of the dust-control systems

Various factors can have an impact on test conditions when comparing the performance of the recommended system in controlling the respirable dust levels in and around the shearer. The coal production, sampling time, intake dust-concentration levels, section return velocity and water flow rate to the shearer were variables identified as having a potentially significant impact on the dust generated becoming airborne during coal-cutting operations. From these parameters, the Normalized Airborne Respirable Dust (NARD) at the shearer mid-point was calculated.

In order to enable a comparison to be made between shifts with varying ventilation quantities, a baseline return-air velocity or section ventilation quantity was chosen. The proportion of ventilation quantity to the base-case number was taken as the scaled ventilation quantity. Since the comparison was made across the data set, the “sample mean” was the best choice for the base-case section return velocity or section ventilation quantity. Cutting time adjustments were made by employing the tons/minute approach while determining the NARD generated.

The following factors were used in the formula for determining the actual mass of airborne respirable dust generated during the sampling period: 0,0022 (sampling rate); 1,405 (average section return velocity); and 312,5 (average water flow rate). These adjustments were necessary for comparing the amount of respirable dust generated and not suppressed by the dust-control system during coal cutting, with varying ventilation quantities, water flow rates, cutting times and test conditions.

Incorporating the above-mentioned factors, the following formula was used to calculate the NARD generated:

$$\mathrm{NARD} = \left(\frac{(C_O - C_I) \times 0.0022 \times S_T \times C_T \times V_A \times W_A}{P_S \times V_R \times W_M} \right) \qquad (2)$$

where:

C_O = concentration at the shearer mid-point in mg/m^3
C_I = concentration at the intake in mg/m^3
S_T = sampling time in minutes
C_T = cutting time in minutes
V_A = average face return velocity during the test period in m/s (1,405 m/s)
W_A = average water flow rate to the machine in L/min (312,5 L/min).
P_S = average production during the shift in tons
V_R = face return velocity during the shift in m/s
W_M = water flow rate to the machine during the shift in L/min.

Figure 5.5a shows the shearer mid-point dust concentration levels for an estimated 8-h period. The plot demonstrates that the recommended system performed better than the previous one. At the shearer mid-point, the average 8-h engineering sample concentration without the KSSC system was 9,98 mg/m^3 (3 tests), and with the KSSC system it was 3,74 mg/m^3 (5 tests)- a reduction of approximately 62%. Similarly, an estimated 8-h shortwall section concentration level for the shearer dust-control without the KSSC system was 7,58 mg/m^3 (3 tests), and 3,33 mg/m^3 (5 tests)- a reduction of approximately 56%.

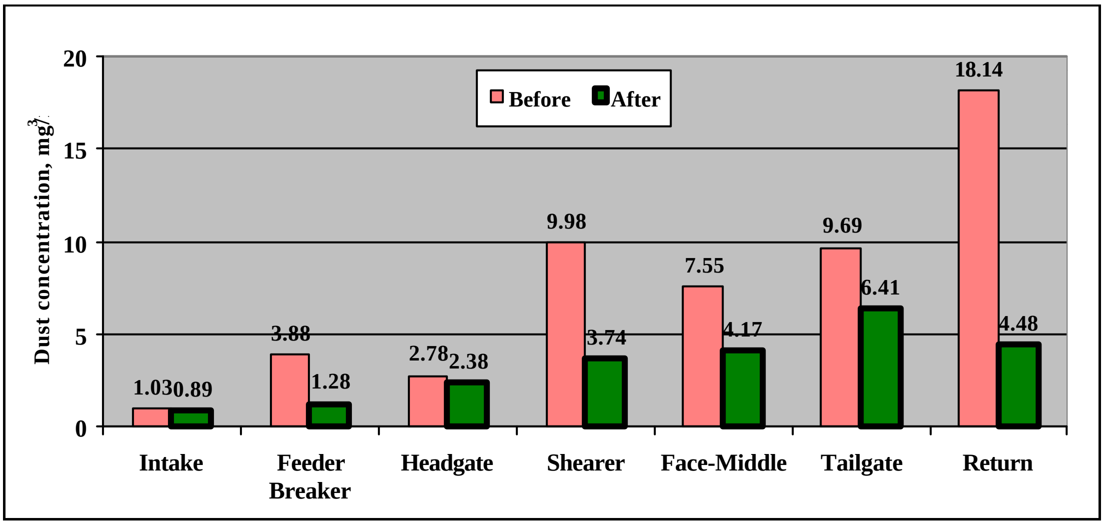


Figure 5.5a Dust concentration levels (8-h period) before and after implementation of the KSSC system

The NARD levels at the shearer mid-point position (mg/ton) are calculated using equation (2). The results are plotted in Figure 5.5b. The average NARD level for Series 1 (Tests 1 to 3) was 0,064 mg/ton of coal. Similarly, the average NARD level for Series 2 (Tests # 4, 5, 6, 7 and 8) was 0,010 mg/ton of coal. From the results we can infer that the performance ratio of the dust-control systems without and with the KSSC system for the underground test conditions was 6.43:1, representing a significant improvement, despite only parts of the KSSC system implemented.

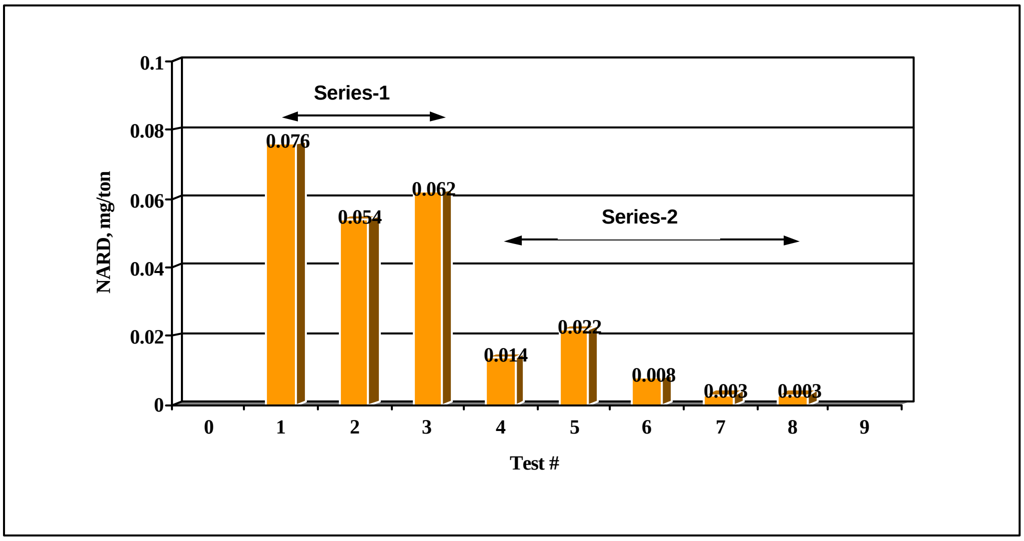


Figure 5.5b: Comparison of NARD (mg/ton) at the shearer mid-point before and after implementation of the KSSC system

5.6 Shield dust

In order to quantify the shield dust, a time study was carried out along the shortwall face with respect to the shearer position. The real-time dust monitor along with the gravimetric samplers was positioned at the middle of the face (Shield 45). Using the time-study data, the dust-concentration levels at the shields were estimated for the production period when the shearer was downwind of Shield 45. The percentage contribution of the dust sources upwind of Shield 45, i.e. shearer, shields, feeder-breaker and intake dust, was calculated and is shown in Figure 5.6a.

As recorded in the US longwall mines, the amount of dust contributed by the shields has increased over the years (and decreased from other dust sources), as shown in Figure 3.2.1 in Section 3.2.1. This could be partly due to the intensified focus of research in other areas, and partly to the increased rate of shield advancement with increased production. As shield supports are lowered and advanced, broken coal and rock fall (gob fall) from the top of the shield canopy directly into the airstream ventilating the longwall face.

The dust deposited on the shield operation box and the shield base was collected along the shortwall face. The dust samples were analysed for size using the sieve analysis technique and a Fritsch size analyser. The plot of the size analysis based on mass is shown in Figure 5.6b. From the results it is noted that 55% of the sample mass was less than 500 microns in size. Similarly, 6,6% of the mass of the deposited sample dust collected (1 181,23 g) was of respirable size (less than 10 microns). This indicates that in terms of dust-concentration levels, the falling shield dust contributes significantly to the levels of airborne respirable dust.

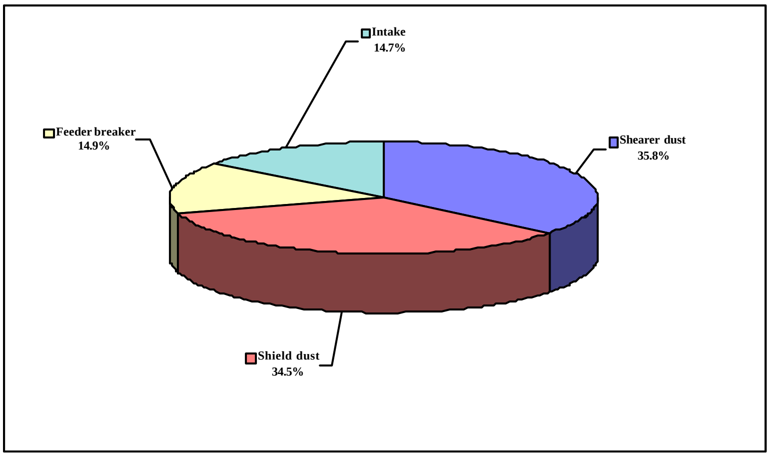


Figure 5.6a Contribution of various dust sources in a shortwall section

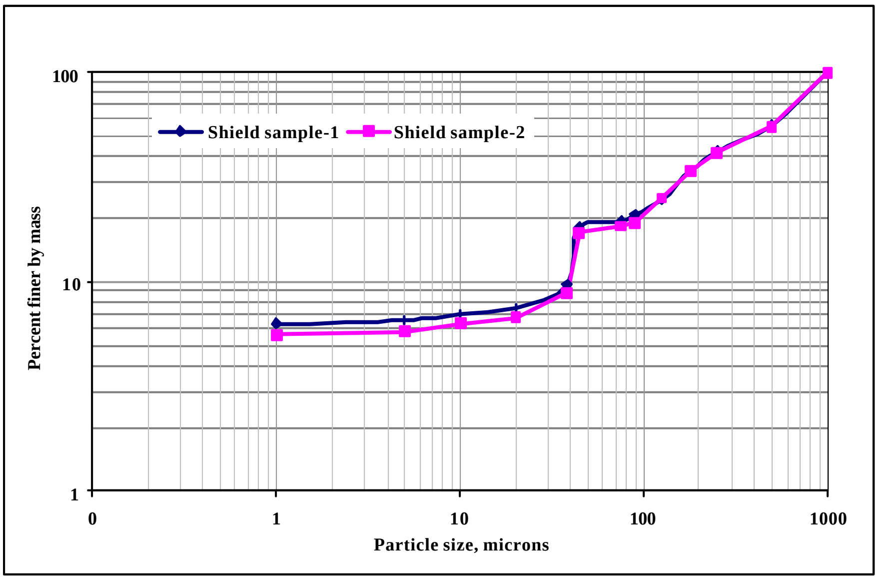


Figure 5.6b: Size analysis of the deposited shield dust

In order to control shield dust, shield spray systems that wet material on top of the shield canopy are available, but the effectiveness of these systems has not been documented. Mines have indicated that it is difficult to maintain the shield sprays throughout the life of a longwall panel. Wetting can be an effective means of controlling shield dust, but to achieve maximum benefits from water sprays, it is imperative that the sprays be maintained to function as designed. The application of water appeared to work during the last two days of the underground test work. During the KSSC system Tests 4 and 5, a large amount of seam water was trickling down from the shields, thus wetting the shield dust between the roof and the shields. The influence was clearly visible during the tests. However, shield sprays have been tested in other countries and the need for frequent maintenance and mal-functioning of the sprays were clearly the reasons discouraging their application.

The shield dust is the second major contributor of dust as observed in the tailgate engineering dust levels as well as the personal sample values. Therefore, a more practical approach is recommended to alleviate the shield dust. This can achieved by installing shield-air-curtains. The application of a shield-air-curtain would increase the face air velocity and also prevent re-entrainment of the shield dust on to the walkway during shield movement, thus lowering the dust exposure to the face workers. Shield curtains (conveyor belt or any other flexible material) can be used (Figure 5.6c) at every 4th shield from headgate to tailgate. It is expected that the application of shield curtains would effectively reduce the exposure of both the TG operator and the shield (chock) operator to dust.

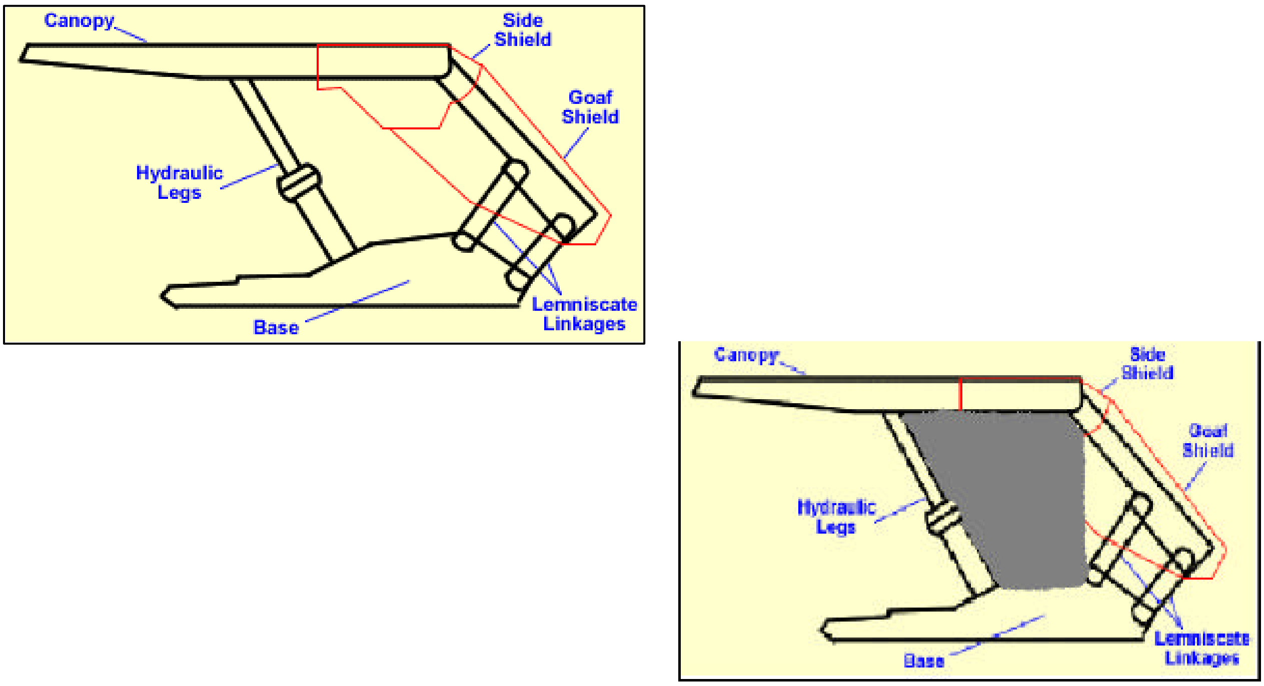


Figure 5.6c: View of application of shield (left) curtains (right) to roof support systems

5.7 Quartz analysis

Selected dust samples were analysed for their quartz content and the results of the laboratory analysis are shown in Table 5.7. It is noted that the quartz content in the engineering samples collected was greater than 10%, thus reducing the compliance limit to < 0,2 mg/m^3. However, the analysis of the personal samples representative of the shortwall "supervisor" showed that they were below 5%, except in one case.

Table 5.7: The results of laboratory quartz analysis on the dust samples

Dust sample	% Alpha-quartz	8-hr concentration	Calculated quartz-limit
Headgate	> 10%	2,05	0, 203
Tailgate	> 10%	7, 32	0,154
Shearer Mid-point	> 10%	10, 41	0, 146
Section return	> 10%	4,12	0,156

Personal sample-1	2,1%	2,88	2,0
Personal sample-2	0, 4%	4,36	2,0
Personal sample-3	5,6%	6,65	1,79
Personal sample–4	3,8%	1,12	2,0
Personal sample-5	4,3%	1,00	2,0

5.8 Field evaluation conclusions

In summary, two systems were evaluated in the preliminary trials, viz.,:

- Series 1: Original mine dust-control system
- Series 2: KSSC dust-control system

Under the conditions tested at the thick-seam (Mine A) shortwall section, the KSSC results were encouraging compared with the previous shearer dust-control system. The partially implemented KSSC system brought about significant improvements (> 50%) in the dust levels (engineering concentration levels and personal sampling values) despite the small number of recommended changes made. The critical changes, that were made to the shearer were: the directional physical curtain (steel plate), belt curtains and the headgate scrubber-hood control. The directional physical curtain (steel plate) mounted on the shearer spray bars survived without being damaged for the entire duration of the test. The engineering concentration levels were below the DME directive of less than 5 mg/m^3, except at the tailgate position. Furthermore, the comments from the operator indicated that the visibility in the cutting zone was much improved. It is believed that this will lead to safer working conditions and further improved production rates. The possible reasons for the high dust levels at the tailgate position are the entrainment of contained airborne dust in the face area (due to incorrect spray configuration on the machine) escaping towards the walkway, and the shield dust.

The shield dust is a major contributor of dust as observed in the tailgate engineering dust levels as well as the personal sample values. This can be alleviated by increasing the walkway air velocity and installing shield-air-curtains at every 4th shield. This shield-air-curtain would increase the face air velocity and also prevent re-entrainment of shield dust on to the walkway downwind, thus lowering the dust exposure of the face workers. The tests prove once again that the maintenance of the critical elements of the whole dust-control system, viz. water flow rate, external spray configuration, individual components of the dust-control system and section ventilation is extremely important in order to reduce the dust levels below the legal limits. It was noted that the recommended water sprays and the spray configuration had not been implemented on the shearer. CSIR- Miningtek is confident that the KSSC system would meet the requirements of the DME directive of 1997, i.e. engineering concentration levels of less than 5 mg/m^3 at all positions, when all the components of the system are fully equipped and maintained on the machine.

6 Risk assessment

According to Chapter 2 (11) of South African Mine Health and Safety Act 29 of 1996, every manager is required to assess and respond to risk. In view of this, as part of the research study, a risk assessment was carried out. Risk is the quantitative measure of the size and potential impact of a hazard (injury or disease). The field results and literature information derived from the extensive worldwide study on longwall dust were used to develop practical information tool on longwall health and safety risk regarding dust control. The intention of the study is to effectively transfer the field results and recommendations to mine risk assessors and risk managers to assist them in protecting the workers from overexposure to dust.

In the quantitative risk assessment of a longwall operation, dust has been identified as a health and safety hazard. Hazards may be chronic or acute. Respirable coal dust (or total dust) is regarded a chronic health hazard. However, the accumulation of a large quantity of total coal dust in a longwall return airway could be an acute safety hazard from a coal dust explosion perspective. For each job, in each operation, it is possible, at least in principle, to rank all hazards in a semi-quantitative way. A matrix of probability and consequence can be used for the acute hazards.

Australian epidemiological data shows that the prevalence of 'black lung' had been greatly reduced by 1960 and virtually eliminated by the late 1980s (Figure 6a). In the United States, a reduction in 'black lung' was not seen until the mid-1970s. As a consequence, from 1980 to 1991 compensation payments for coal- workers pneumoconiosis in the US totalled the equivalent of R 15.5 billion, in contrast to compensation payments in Australia of about R 25 million over the same period.

The following risk-ranking model (Australian Standards 3931:1988) as shown in Figure 6b was used for the risk assessment. Tables 6a and b show the probability and consequence categories that were used for evaluation purposes.

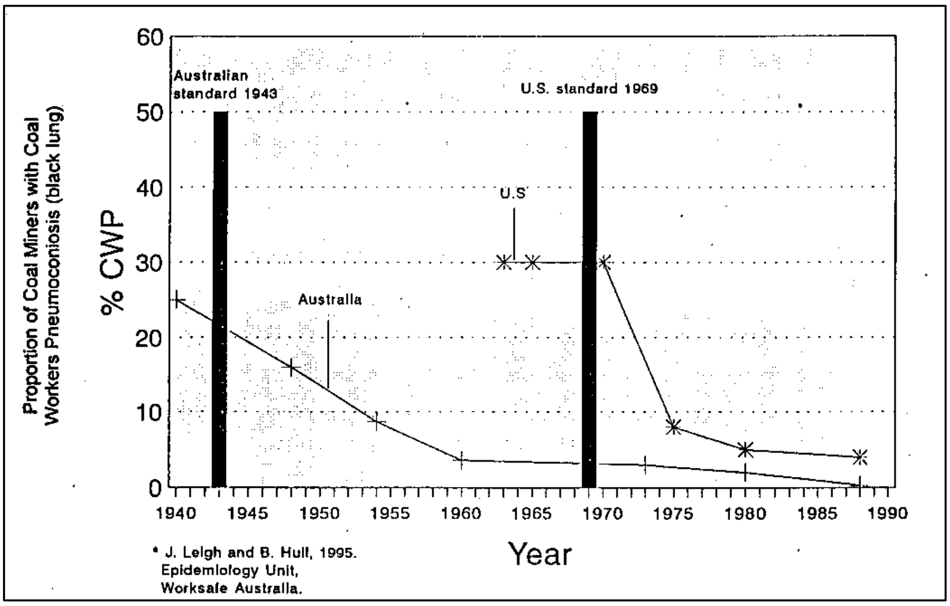
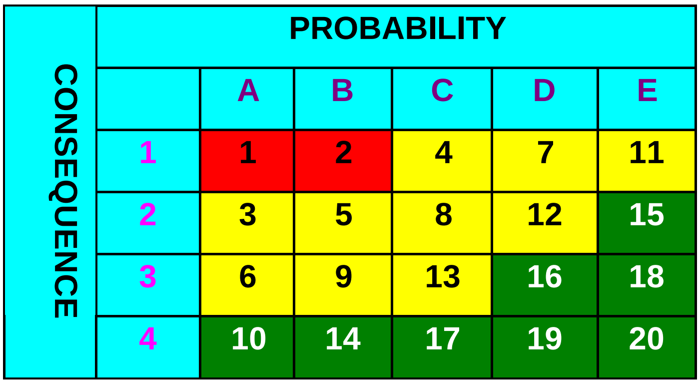


Figure 6a Australian and American CWP cases (Source: Australian Standards 3931:1988)



CONSEQUENCE	PROBABILITY					
		A	B	C	D	E
	1	1	2	4	7	11
	2	3	5	8	12	15
	3	6	9	13	16	18
	4	10	14	17	19	20

Figure 6b Risk Ranking Model (Source: AS 3931:1988)

For the dust explosion (acute) safety hazard, the risk equals the probability of a dust explosion multiplied by the consequence value (damage and injury costs). For the health (chronic) hazard, the risk is equal to the time-integrated exposure multiplied by the 'dose response.' Exposure equals average concentration multiplied by time exposed (for example, mg/m^3 of respirable dust times years of work). Therefore, the acute dust explosion hazard risk can be reduced by reducing the probability or consequence value, and the chronic health hazard risk can be reduced by reducing the concentration or time. With the available field data and expert opinion the risk assessment for thick seam wall mining was derived and is summarised in Table 6c.

Table 6a Probability category for the risk ranking model

Probability category	Definition
A	Possibility of repeated incidents
B	Isolated incidents known to have occurred
C	Possibility of occurring some time
D	Unlikely to occur
E	Practically impossible

Table 6b Consequence category for the risk ranking model

Consequence category	Definition
1	Serious long or short-term health effects that may be fatal
2	Serious adverse health effects that would require off-site medical treatment
3	Non-life-threatening health effects that may require on-site first aid treatment
4	Little if any adverse health effects

Table 6c Risk assessment for thick-seam wall mining

Risk category	Risk rank	Colour
Explosion Risk	2	Red
Health Risk	1	Red

7 Conclusions

The following relevant major conclusions are drawn from the international literature survey on thick-seam wall dust-control techniques and the field trials on the thick South African shortwall sections:

- Reviews of international literature on thick-seam wall dust-control techniques have indicated that longwall dust control is still a problem area worldwide and broad dust-control techniques are available (Section-3). However, mine-specific and technical aspects of the control mechanisms are not reported in detail.
- The most common method for controlling airborne dust in wall mining is the use of water sprays mounted on the shearer cutting drums. Techniques implemented for the control of shearer-generated dust include high drum-water flow rates, improved cutting techniques, shearer-clearer-type external water spray systems and radio-remote control.
- The majority of the wall dust-control techniques have been developed in the USA for low seam wall mines and their application is specific to low to medium coal seam heights.
- Results from the preliminary field trials in South African wall mines (Seris- 1 trials), have indicated that the average dust concentration at the sampling stations exceeded the DME directive (1997) of a maximum of 5,0 mg/m^3. Similarly, the personal dust concentration levels are above the compliance level of 2 mg/m^3.
- The partially implemented CSIR-recommended Kloppersbos Sherarer Spray Curtain (KSSC) system (Series- 2 trials) showed significant improvements (> 50%) in dust levels (engineering concentration levels and personal sampling values). The engineering concentration levels were below the DME directive of less than 5 mg/m^3, except at the tailgate position.
- The shield dust is a major contributor of dust, as observed in the tailgate engineering dust levels, as well as the personal sample values.
- In the quantitative risk assessment of a shortwall operation, using the field data, dust has been identified as both an explosion and a health risk. The risk rankings for explosion and health risk are 2 and 1 respectively (see Table 5c).

8 Recommendations

The baseline ARD concentration measurements and the available data on shortwall mines indicate that dust control in thick-seam wall mines is a continuing problem, which requires further research. A considerable improvement was observed from the partial implementation of the CSIR-recommended KSSC dust-control system. Finally, in order to overcome the thick wall mine dust problems, the following broad areas of changes can be considered for implementation in thick wall mining faces:

1. Maintain an average face air velocity of 2,5 m/s and a section return velocity of 2,0 m/s.
2. Fully implement and evaluate the CSIR-recommended Kloppersbos Shearer Spray Curtain (KSSC) dust-control system as discussed (Section 4.2.1), paying due attention to the physical shearer curtain, the sprays, the spray configuration and the belt curtains on the shearer.
3. Implement an effective maintenance program to ensure compliance operation of all KSSC dust-control system components.
4. Install, and evaluate the efficiency of, the physical shield curtains (conveyor belt or other flexible material) hanging from the shield structure inside the shield leg area at every 4th shield (see Section 4.2.5) in reducing worker exposure.
5. The use of custom-built scrubber system (low height and high width) fitted on to the shearer and positioned longitudinally at the middle of the shearer body is an option (for thick-seam wall mines) that may be considered by the mine in consultation with the equipment manufacturers.
6. In order to quantify the improvement in dust-control techniques in thick-seam wall mines, the dust-control components recommended above must be evaluated in the field, following the procedures and process used in the SIMRAC projects COL 518 and COL 603.

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Appendix A

Table A1 Queensland longwall mines (July 1999-June 2000)

Mine name	**Seam name**	**Thickness, m**	**Production, tons**
Alliance Colliery	German Creek	1,8 - 2,0	1 278 000
Crinum Colliery	Lilyvale	3,4 - 3,6	4 184 100
Central Colliery	German Creek	1,8 - 2,6	2 227 000
Southern Colliery	German Creek	2,7 - 3,1	2 704 900
Kenmare Colliery	Aries	3,1 - 3,5	929 600
Kestrel Colliery	German Creek	2,8 - 3,2	3 800 000
Moranbah Colliery	Goonyella Middle	4,3	3 817 700
Newlands Colliery	Upper Newlands	6,0	5 276 300
North Goonyella Colliery	Goonyella Middle	4,5	3 113 300
Oaky Creek No.1 Colliery	German Creek	2,8 - 3,6	3 785 200
Oaky North Colliery	German Creek	4,0	2 097 600

Table A2 New South Wales longwall mines (July 1999-June 2000)

Region	**Mine name**	**Seam name**	**Thickness, m**	**Production**
NSW-New Castle	Moonee	Great Northern	3,1	1 209 200
	New Wallsend No.2	Young Wallsend	2,8	824 200
	Newstan	West Borehole	3,0 – 4,2	2 231 100
	Southland	Greta	3,2 – 3,6	840 100
	Teralba	Yard	1,5	640 500
	West Wallsend	West Borehole	4,9	2 418 900
	Wyee Colliery	Fassifern and Great Northern	3,2 & 2,3	984 400
NSW-Southern	Appin	Bulli	2,4 – 3,3	2 093 800
	Bellambi West	Bulli	2,5	1 084 900
	Cordeaux	Bulli	2,1 – 2,7	807 300
	Elouera	Wongawilli	3,0 - 3,7	1 601 600
	Metropolitan	Bulli	3,2	289 500
	Tahmoor	Bulli	1,9 – 2,3	1 421 200
	Tower	Bulli	2,5 – 3,2	1 218 500
	West Cliff	Bulli	2,3 – 2,7	1 223 800
NSW-Western	Angus Place	Lithgow	3,0	1 942 900
	Baal Bone	Lithgow	2,1 – 3,0	1 319 500
	Springvale	Lithgow	2,7 – 3,1	1 633 400
	Ulan	Ulan	2,9 – 3,2	2 644 300
NSW-Hunter	Cumnock	Lower Pikes Gully	1,8 – 2,2	2 203 500
	Dartbrook	Wynn	3,9	3 009 300
	South Bulga	Lower Whybrow	2,45	4 180 100

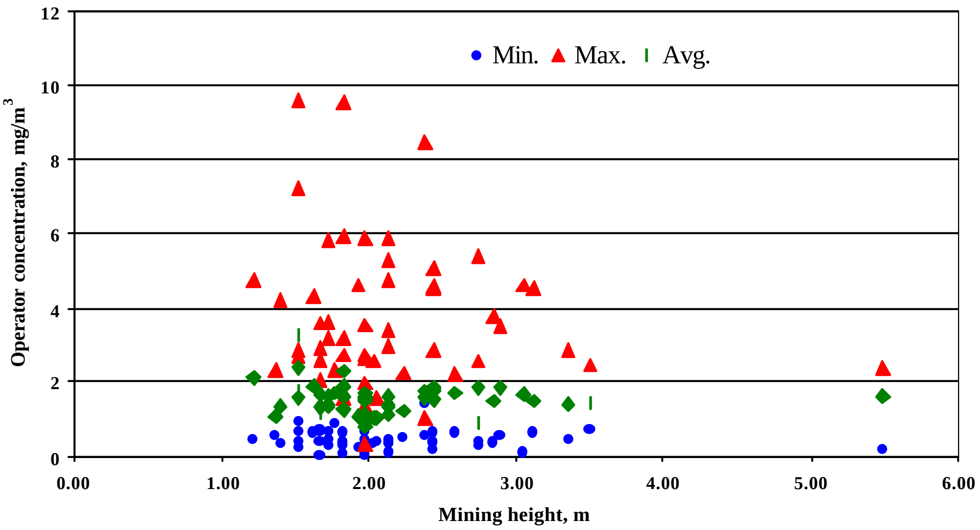

Figure A1 Mining height versus operator dust concentration data (1999)

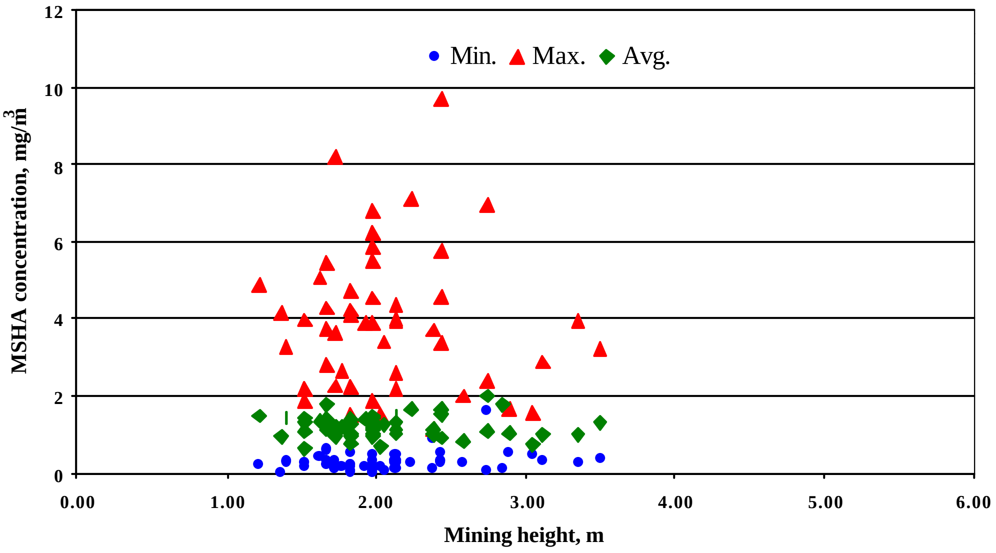

Figure A2 Mining height versus MSHA dust concentration data (1999)

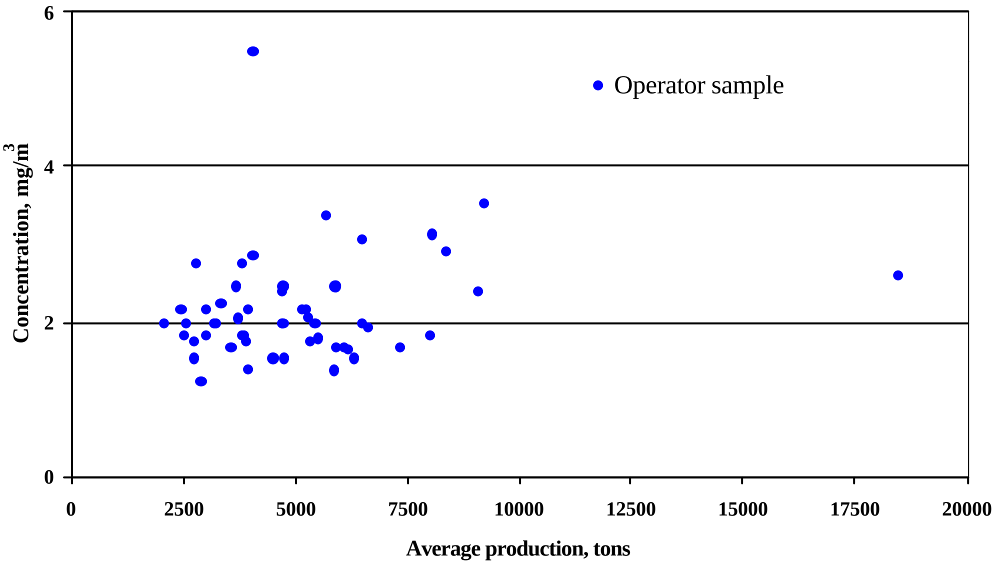

Figure A3 Average production during the sampling versus operator dust concentration data (1999)

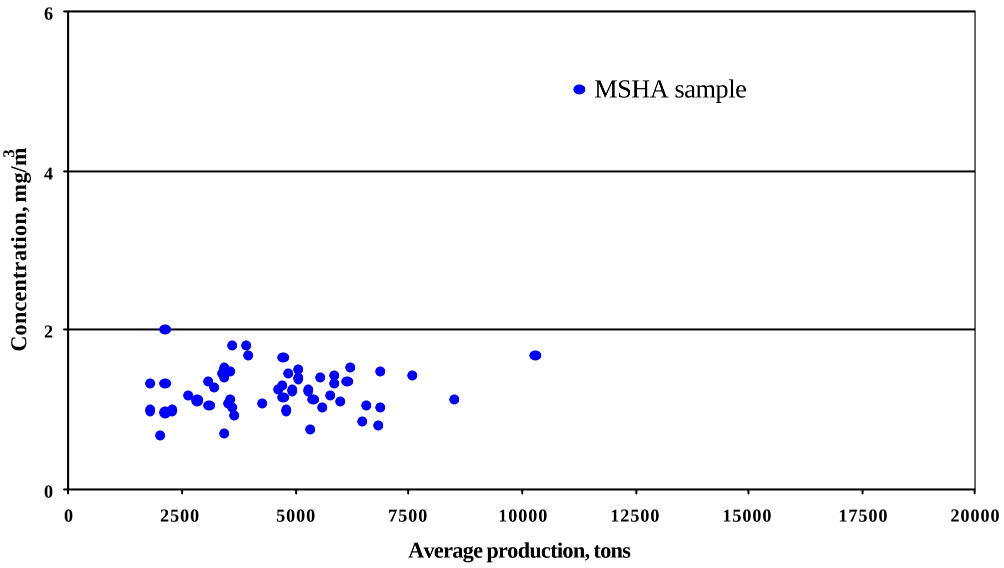

Figure A4 Average production during the sampling versus MSHA dust concentration data (1999)

Table A3 Details of parameters of highly mechanised caved Indian longwall faces (Das, 1999)

Mine name	**Seam**	**Thickness, m**	**Working height, m**	**Surface depth, m**
Pathakhera	Upper workable	1,4 to 1,6	1,4 to 1,6	90 - 91
Seetapur	Hatnol	0,9 to 2,2	1,8	561 - 534
Dhemomain	Borachuk	2,4 to 3,1	3,0	180
Singareni	No. 3 Seam	10,5	3,2	50-110

Table A4 Comparison of longwall parameters measured in Poland and US coal mines (Organiscak et al., 1999)

Operational parameters	**Polish longwalls**	**US longwalls**
	Mean [min., max.]	Mean [min., max.]
Face width, m	210 [150, 250]	219 [152,259]
Seam height, m	2,4 [1,5, 3,0]	2,3 [1,7, 3,4]
Production rate, mt/hr	482 [270, 605]	1308 [678, 2124]
Cutting sequence	100% Bi-directional	38% Bi-directional
	0 % Uni-directional	62% Uni-directional
Shearer haulage speed, m/min	4,1 [2,5, 6,0] (Cutting)	9,0 [4,3, 21,5] (Cutting)
	No Clean-up passes	14,1 [7,6, 18,9] (Clean-up)
Web width, m	0,68 [0,60, 0,80]	0,82 [0,38, 1,02]
Drum cowls	38% have drum cowls	100% have drum cowls
Air velocity, m/s	1,3 [0,6, 1,7]	2,5 [1,0, 7,6]
Air quantity, m^3/min	546 [150, 810]	1152 [228, 3000]
Water spray usage	100% external	100% external
	12% internal	100% internal
Sharer-clearer spray system	0 % have system	92% have system
Shearer water quantity, L/min	159 [70, 250]	377 [265, 568]
Shearer water pressure, Mpa	1,6 [1,2, 2,5]	1,0 [0,2, 2,1]
Headgate dust level, mg/m^3	1,6 [0,5, 5,5]	1,1 [0,4, 1,8]
Shearer H-T dust level, mg/m^3	9,3 [2,8, 25,0]	3,8 [0,7, 11,0]

Shearer T-H dust level, mg/m^3	19,5 [3,2, 45,0]	3,9 [0,7, 7,2]
Tailgate dust level, mg/m^3	22,5 [3,1, 75,0]	3,5 [1,0, 10,0]

Table A5 Measured air velocities along the shortwall face

Experiment #	Feeder breaker	Headgate	Middle of the face	Return
1	DNM	1,10	1,28	1,2
2	DNM	1,30	1,21	1,3
3	0,94	1,28	1,23	1,64

DNM: did not measure

Table A6 Measured respirable dust concentrations along the shortwall face

Sampling Location	Test # 1		Test # 2		Test # 3	
	SP	8-h	SP	8-h	SP	8-h
Section intake	1,37	1,05	1,18	0,86	1,79	1,14
Feeder-breaker	6,21	5,03	4,87	3,44	5,03	2,02
Headgate	3,28	2,29	4,24	2,31	5,68	3,73
Shearer mid-point	13,87	11,84	12,82	9,19	20,08	8,90
Middle-face	DNM	DNM	DNM	DNM	11,69	7,55
Tailgate	10,58	8,93	9,17	6,66	20,80	13,50
Section return	21,60	18,09	20,55	14,90	31,17	21,17
Headgate operator	4,39	3,41	4,92	3,53	DNM	DNM
Tailgate operator	DNM	DNM	6,09	4,40	DNM	DNM

SP: sampling period; DNM: did not measure

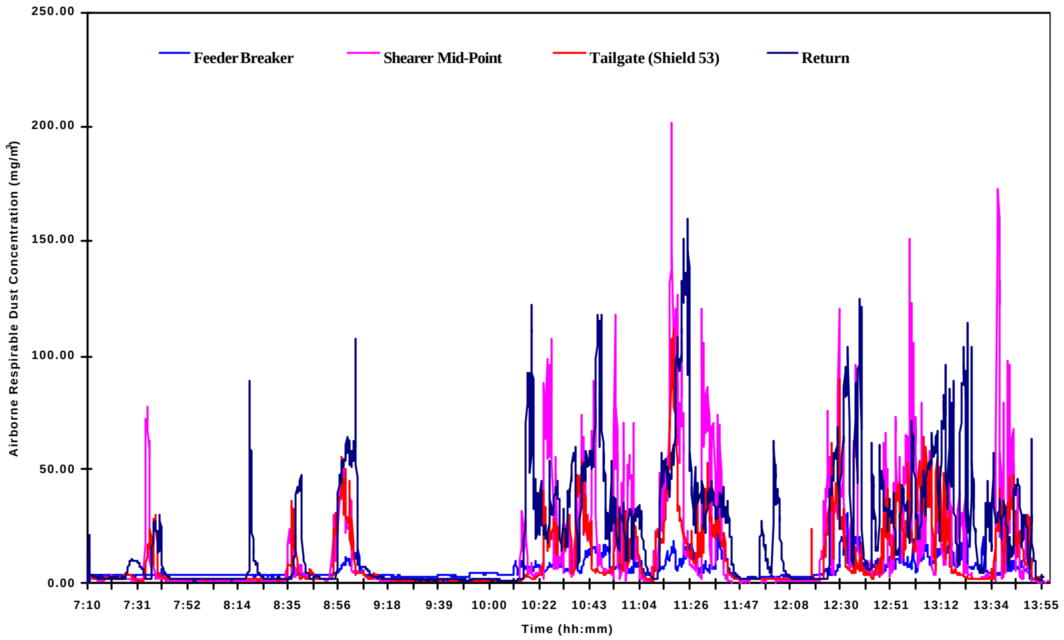

Figure A5 ARD concentration profile recorded by Hund in the shortwall section, Test # 1

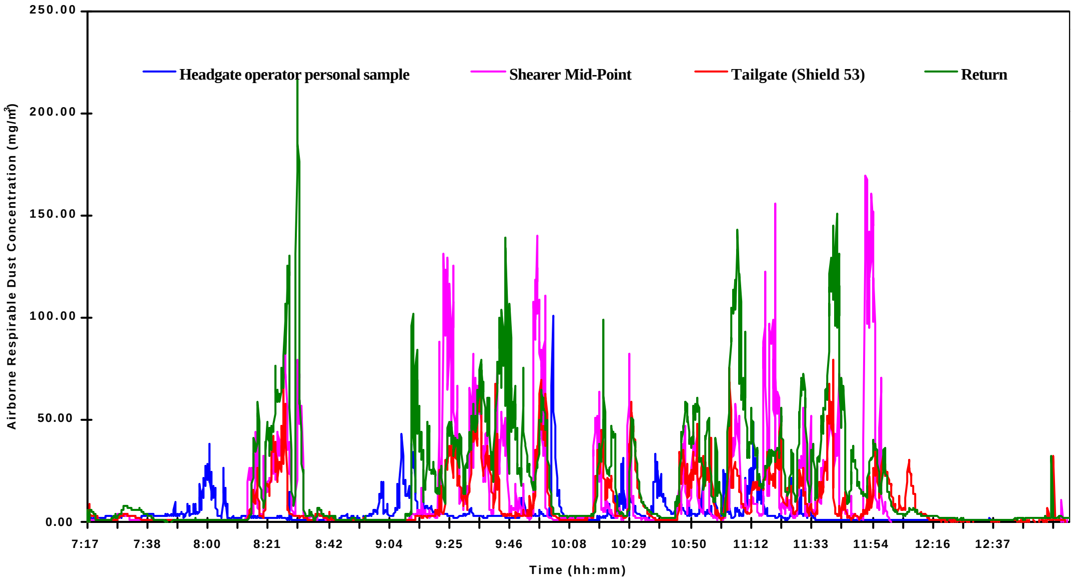

Figure A6 ARD concentration profile recorded by Hund in the shortwall section, Test # 2

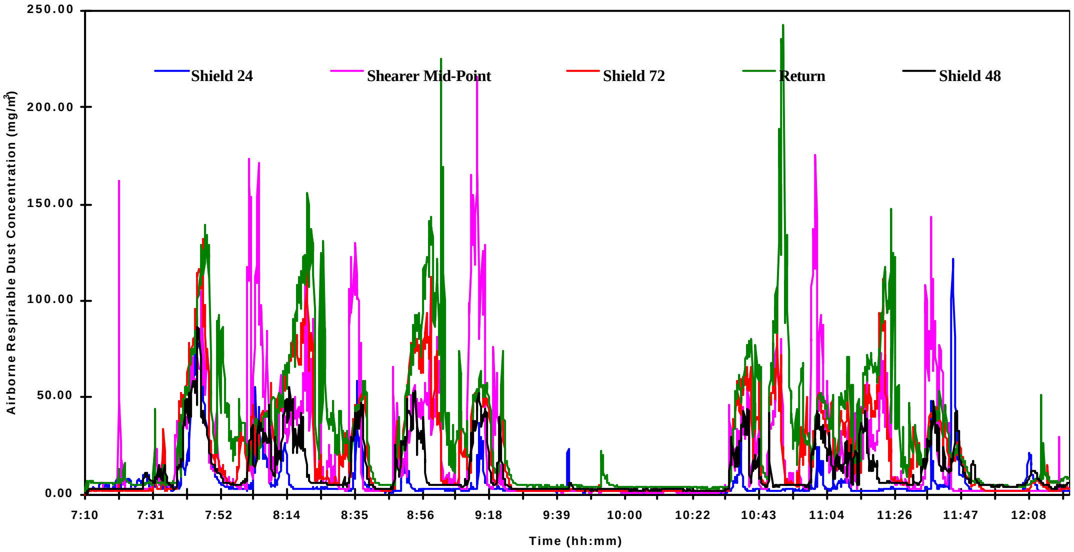

Figure A7 ARD concentration profile recorded by Hund in the shortwall section, Test # 3

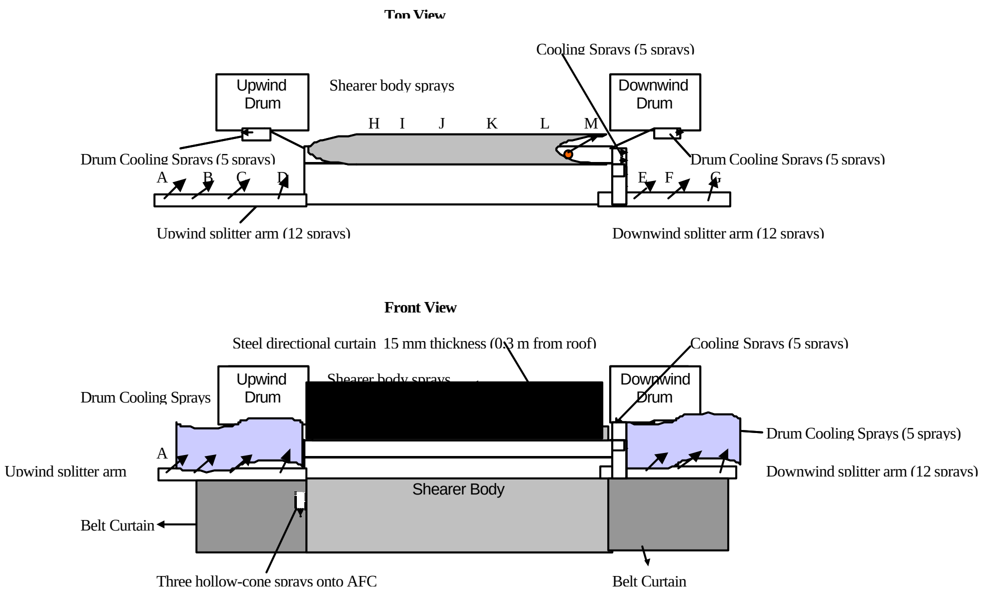

Figure 5.4: Proposed Kloppersbos Shearer Spray Curtain (KSSC) dust-control system

Kloppersbos Shearer Spray Curtain (KSSC) System

The principle of the proposed Kloppersbos Shearer Spray Curtain (KSSC) design is that the sprays would suppress and confine the airborne dust to the face area through sprays and physical curtains, thereby creating a clean air split over the walkway and redirecting the escaped ARD downwind towards the return air. The design is most effective with the use of the recommended nozzle type, optimum water pressure and flow rate on both the external and drum sprays and maintaining a minimum air velocity of 2,0 m/s. Figure A8 shows the design of the proposed Kloppersbos Shearer Spray Curtain (KSSC) dust-control system. Table A7 shows the nozzle orientation for the KSSC dust-control system. The proposed KSSC design specifications are as follows:

- The length of the upwind splitter arm must extend beyond 0,35 m from the cutting edge of the upwind drum. New nozzles must be fitted in accordance with the designed configuration.
- The downwind splitter arm, at least 1,25 m from the end of the tail-end drum, must be added, together with a designed spray configuration to guide and contain the dust.
- Hollow-cone nozzles (1,6 mm/ 2,0 mm) must be used as external spray nozzles. The external spray pressure should be in the range between 15 and 20 bar at the nozzle.
- The nozzles on the body of the shearer should be positioned at an angle ranging from 15° to 45° in the direction of the return air. The positions of the external nozzles are designed are in such a way that debris will not block them and they require minimum maintenance.
- Conveyor belting is to be used in the front-end and tail-end body of the shearer; this will contain the dust inside the walkway. Use of a shearer body **directional physical dust curtain** (15 mm steel) is recommended to assist in containing the escaped dust or rollback dust spilling over the walkway. The front-end and tail- end curtains must be flexible and the shearer body's physical curtain must be strong enough to operate under tough conditions. Flexible belt conveyors are to be hung from the sides of the front-end, the tail-end and the body of the shearer (Figure A8). The height of the belt-curtain on the shearer body must be approximately 0,8 m and the length must be equivalent to that of the the body of the shearer.
- The optimum drum spray pressure is in the range of 5 to 7 bar. The total water flow to the drum sprays must be in the range of 200 to 250 L/min.

Table A7 Nozzle orientation for the Kloppersbos Shearer Spray Curtain (KSSC) dust-control system

External sprays	Spray block	Nozzles/Spray block	Nozzle Orientation (degrees)	
			Horizontal	**Vertical**
Upwind Splitter Arm	A, B, C	3	(15°, 15°, 15°)	(30°, 30°, 30°)
	D	3	(15°, 15°, 15°)	(20°, 0°, 0°)
Downwind Splitter Arm	E, F, G	3	(15°, 15°, 15°)	(30°, 30°, 30°)
Shearer Body	H, I, J, K, L, M	2	(15°, 15°)	(30°, 30°)
Total Sprays	(3*3 + 1*3+ 3*3 + 6*2) = 33			

Spray blocks are positioned at equal distance from each other; Length of upwind splitter arm is 3,80 m; Length of the downwind splitter arm is 2,50 m; Length of the shearer body is 6,0 m.

Table A8 Measured air velocities along the shortwall face

Experiment #	Shield 10	Shield 20	Face-middle	Tailgate	Return
1	2,3	1,9	1,4	2,2	1,4
2	2,6	2,3	1,7	1,85	1,4
3	1,64	2,2	2,2	2,4	1,5
4	2,5	1,92	2,5	2,48	1,4
5	2,1	1,9	2	2,1	1,4

DNM: did not measure

Table A9 Measured respirable dust concentrations along the shortwall face-2

Sampling Location	Test # 1		Test # 2		Test # 3		Test # 4		Test # 5	
	SP	**8-h**	**SP**	**8-h**	**SP**	**8-h**	**SP**	**8-h**	**SP**	**8-h**
Section intake	1,73	1,24	1,57	1,08	1,13	0,86	1,07	0,80	1,47	0,46
Feeder-breaker	3.19	2.37	2.34	1.61	1.22	0.87	1.45	1.04	1.72	0.51
Head gate	3.54	2.54	5.52	3.91	3.53	2.61	1.73	1.21	2.85	0.89
SMP	6.43	4.70	9.27	6.60	6.65	4.94	2.67	1.14	4.19	1.29
Middle-face	7.83	5.54	9.12	6.29	6.09	4.44	4.67	3.36	4.11	1.23
Tailgate	11.77	8.63	13.18	9.30	9.55	6.54	7.95	5.73	6.23	1.87
Section return	5.91	3.46	10.49	7.41	6.14	4.62	6.09	4.43	8.08	2.47
Personal sample	4.53	2.88	5.72	4.36	8.51	6.65	8.68	1.12	2.59	1.00

SP: Sampling Period; SMP: Shearer Mid Point

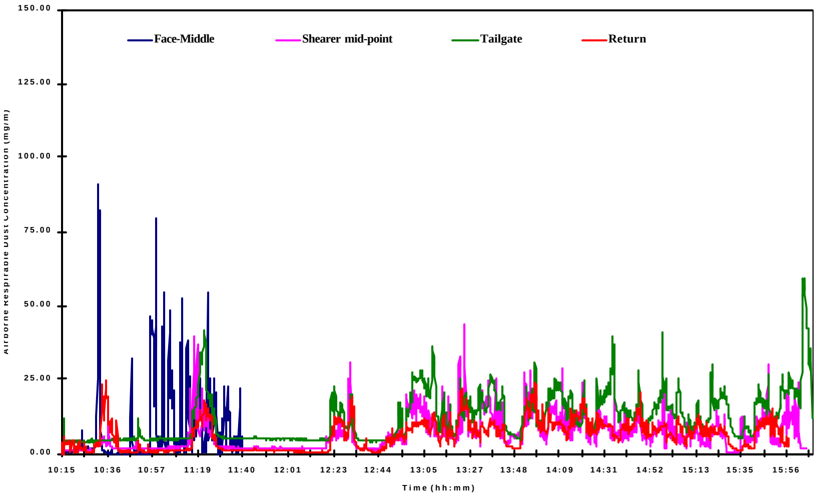

Figure A9 ARD concentration profile recorded by Hund in shortwall, Test # 1

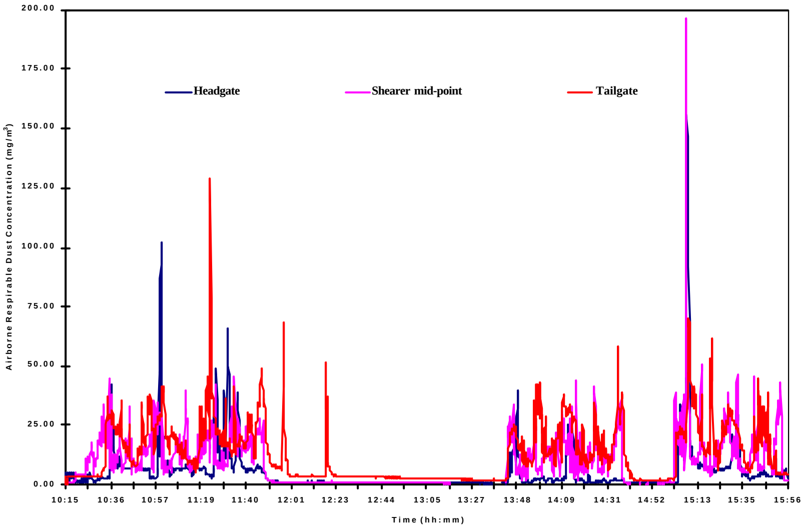

Figure A10 ARD concentration profile recorded by Hund in shortwall, Test # 2

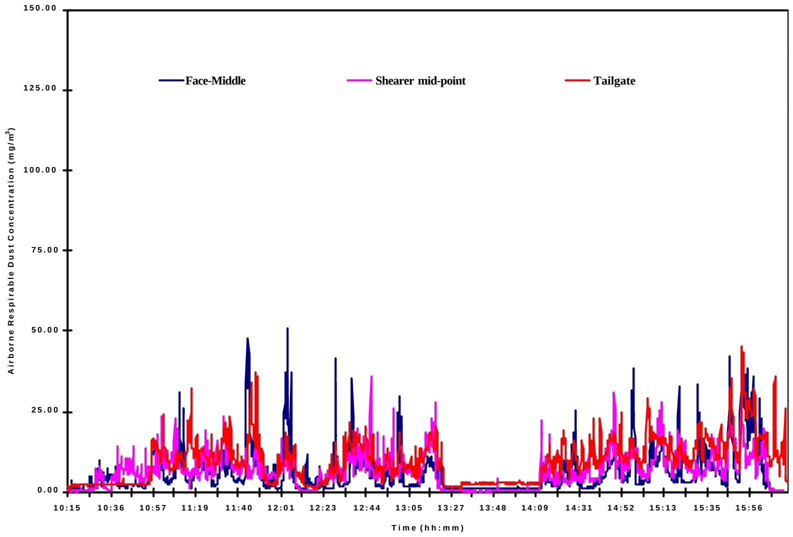

Figure A11 ARD concentration profile recorded by Hund in shortwall, Test # 3

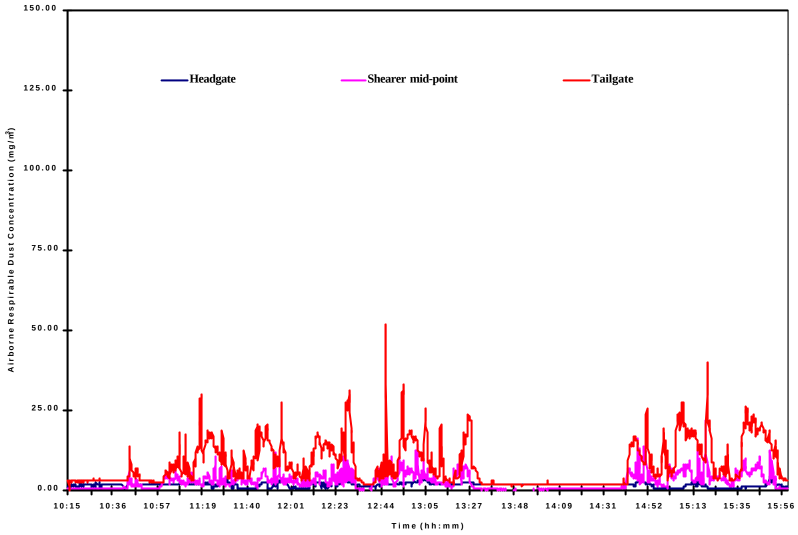

Figure A12 ARD concentration profile recorded by Hund in shortwall, Test # 4

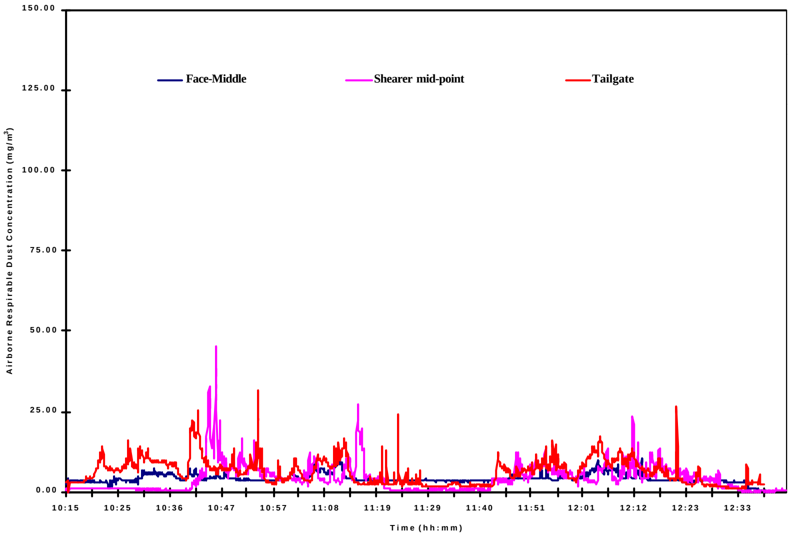

Figure A13 ARD concentration profile recorded by Hund in shortwall, Test # 5