Have we won the war on the continuous miner dust?

By Andrew Thomson. Presidential address delivered at the 59th Annual General Meeting of the Mine Ventilation Society of SA

Introduction

Increased coal production has lead to greater mine environmental problems underground such as the generation of dust, production of noise and release of methane and coal dust in the environment with an increased risk of explosions. This required immediate attention. Studies have shown that the risk of progression to a higher category of pneumoconiosis due to coal dust exposure increases with increasing intensity of the exposure, represented by the mean dust concentration, and with increasing cumulative exposure, represented by the product of intensity and duration. Therefore, adequate dust control measures are necessary and coal industry has taken proactive steps to reduce these dust levels. This paper will address some of the more recent achievements in overcoming the problem posed by coal dust as the prime cause of coal worker's pneumoconiosis (CWP). In addition, the paper deals with the challenges that faced the coal mining industry during the phasing in of continuous miners. These new mining methods increased the dust loads and explosion risks. This paper briefly details the innovative ideas introduced and adopted by the coal industry to meet these challenges, which, initially, were thought to be insurmountable.

Coal mining in South Africa

The first reported discovery of coal in the interior of South Africa was in the mid-1830 when coal was mined in Natal. The earliest exploitation of modern times was probably Natal where, in a letter dated 29th August 1842, a Captain Smith mentions that a wagon load of coal brought to Pietermaritzburg was sold. In the late 1860s, coal trade at Dundee, commenced when one Peter Smith charged ten shillings for a load for coal dug by the buyer from a coal outcrop in a stream. A more sophisticated approach was attempted at Molteno where a mine was opened in 1864.

An early start on a South African time scale was made in at least three of the four provinces. However, until the discovery of diamonds in 1867 and the Witwatersrand gold in 1886, coal mining as such satisfied a very small domestic demand. Diamond mining lead to the initial surge in coal demand. With the discovery of the gold mining industry and the development in Johannesburg, the gold mines at the Reef offered new opportunities for coal.

***Figure 1**: Miners loading coal after a blast at the old Navigation Colliery in the early 1990s*

By 1920, the output of all operating collieries in South Africa had attained an annual figure of 9,5 million tonnes and total in-situ reserves were estimated to be 23 billion tonnes in three main areas - Witbank/Springs, Natal and Vereeniging. Some of the most recent estimates; the country's total in-situ reserves are calculated to be 121 billion tonnes.

In more recent times, the internal consumption of coal specifically for power generation and chemical synthesis has become all-important. At present, the organisations, which are the largest consumers of coal in South Africa, are Eskom, Sasol and Iscor. In the early 1970s production was increased dramatically. By 1986, coal production had reached 177 million tonnes per annum. The three different markets all expanding at the same time, viz., international demand, synthetic fuel, and fuel for electricity which are briefly discussed below.

International demand: Internationally, the demand for coal was given a boost by two oil shocks, in 1973 and 1979. With the boom in the export market the government built a 550-km rail link from the Witbank/Middelburg coalfields to Richards bay harbour on the East Coast. The coal producers formed a partnership for the construction of a capacity coal terminal at this deepwater harbour.

Synthetic Fuel: The second growth factor was the decision, following the oil embargoes, to build two domestic synthetic fuel plants in order to reduce the country's dependence on imported oil. That led to the construction of Sasol's two new plants at Secunda.

Fuel for Electricity: The third expansion market was Escom, the national electricity generator. During the same period, consumption of electricity grew to such an extent that coal supplied for electricity generation increased from 20 million tonnes per annum in 1969 to 80 million tonnes in 1996.

As a result of these developments, coal is today second only to gold in terms of South Africa's foreign exchange earnings and is the country's major energy supplier.

Mining methods

Two basic underground methods, board and pillar and longwall are employed in the South African mines for coal extraction.

Board and Pillar method: The simpler of the two methods, grew naturally out of the need to recover more coal, as mining operations became deeper and more expensive. This system involves driving tunnels into the coal seam with wider openings mined off from them. Thick pillars of coal are left to support the overhead strata of earth and rock (overburden).

Modern longwall method: Two widely spaced tunnels are driven into the coal seam from the main haulage tunnel and are linked by a fourth tunnel. Coal is removed by mining one of the sides of this fourth tunnel usually on retreat. Figure 2 shows the perspective and close up views of a typical longwall mining system

Mechanisation and Automation

The two principal methods of underground-mechanised mining are conventional or continuous mining. Conventional mining (very few mines practice this method) involves the following sequence of operations, viz.,

- Supporting the roof
- Drilling
- Blasting
- Loading.

Continuous mining has replaced the sequential conventional mining method. A single machine, the continuous miner, breaks off the coal from the seam and transfers it back to the haulage transport system. Most mines use these continuous miner machines which have a considerable mining capacity. This has grown considerably over the years. In 1981, these machines would have typically an average productive capacity of 20 000 tones/month, during the past decade (1995) substantial increases were achieved to records of 50 000 tones/month and currently reports of average production range between 85 000 to 90 000 tones/month. Figure 3 shows the production trend in average South African coalmine sections.

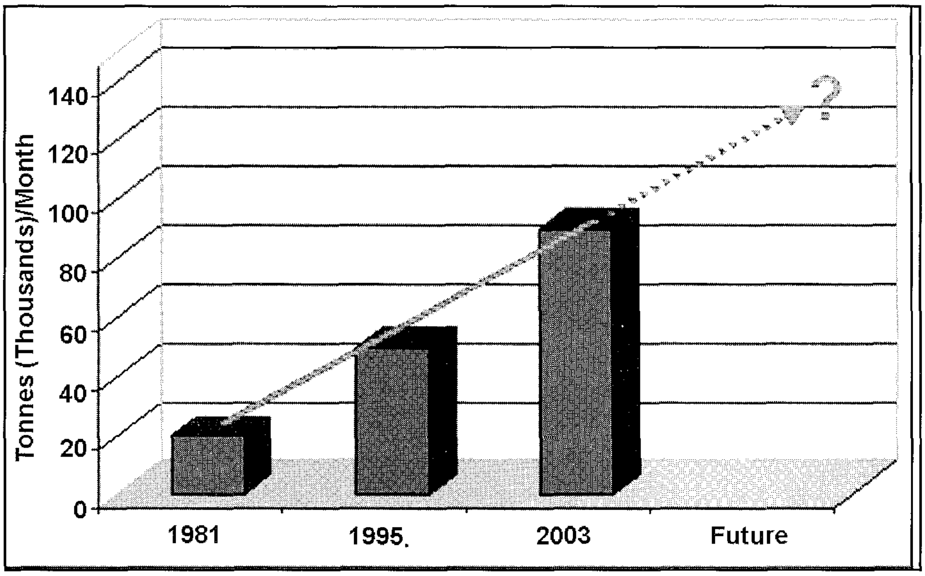

Figure 3: *Coal production trends in the South African coal mine sections*

The challenges

Increased coal production has led to greater underground environmental problems that needed immediate attention. Such challenges are dust, noise, methane, coal dust explosions etc., The hazard posed by coal dust in the coal mines in causing coal worker's pneumoconiosis (CWP) was becoming increasingly serious and wide-spread. Studies have shown that the risk of progression to a higher category of pneumoconiosis due to coal dust exposure increases with increasing intensity of the exposure, represented by the mean dust concentration, and with increasing cumulative exposure, represented by the product of intensity and duration. High dust concentrations due to the cutting and falling action of the coal is not only detrimental to the health of employees exposed, but results in a cloud of float dust entering the return airway system, with a corresponding increased risk of a coal dust explosion. Therefore, adequate dust control measures are necessary and coal industry took a proactive step in reduction of dust levels.

Unlike dust control systems developed elsewhere, South African conditions are considered unique requiring the design of dust control systems specifically for conditions encountered here. Some of the critical aspects in South African mining sections influencing environmental control are:

- Mining conditions and ventilation systems are different.
- The most commonly used ventilation and dust-control systems are on-

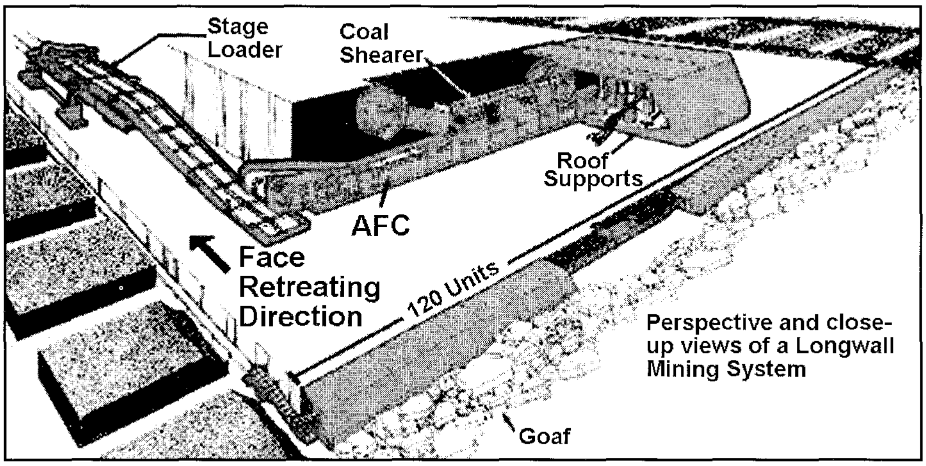

Figure 2: *Perspective and close up views of a longwall mining system*

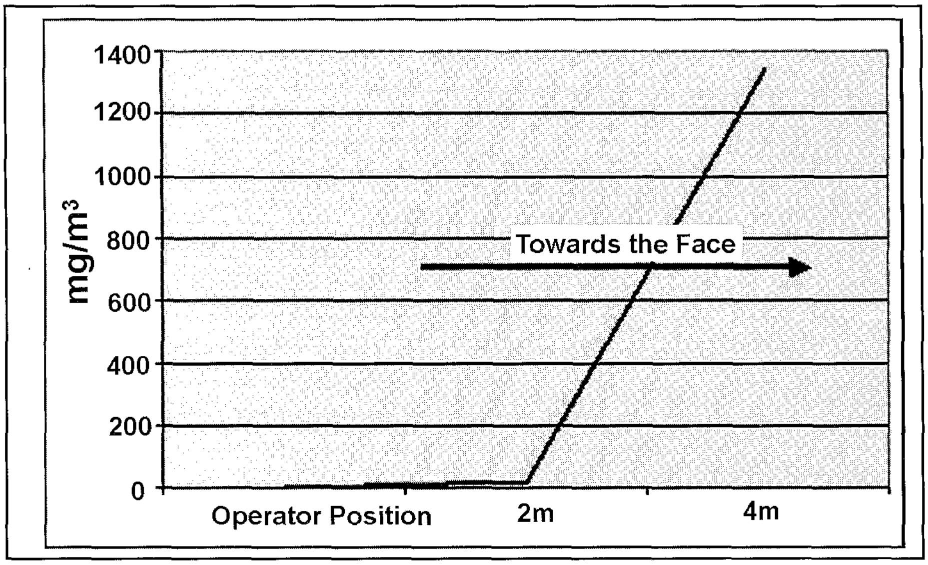

***Figure 4**: Typical measured dust levels in a coal mine heading*

board scrubbers, spray fan systems and auxiliary ventilation devices such as jet fans and force fans.

- The ventilation systems used in South African coal mines result in long headings, and the airflow patterns are more complex than those reported and studied for other mines.
- Furthermore, the rate of advance per shift in headings in South African mines is comparatively greater than those in European or US mines. Thus, the consequent increases in methane gas emissions and coal dust generated require special provisions to ensure effective ventilation and dust control systems on road headers

During coal cutting, respirable and non-respirable dust fractions measured at the face and in the operator cabin vary and are wide-ranging. However, there is a steep concentration gradient around the continuous mining machine operator cabin and closer to the face area. The results re-affirm local and other studies in that dust concentration increases super-linearly at positions closer to the source. Figure 4 shows the typical trend of dust levels based on the measurements carried out in an underground section.

Therefore, controlling dust simultaneously with methane became a major challenge as coal production increased in South African coalmines. The coal mining industry was faced with the challenge of solving the dust related problems created by the newly introduced evolution of continuous miners in conjunction with the rigorous guidelines set by the Department of Minerals and Energy (DME) for Ventilating Mechanical Miner Sections.

In 1997, a Directive from the South African Department of Minerals and Energy (DME) was sent to all coalmines instructing them to reduce the dust-concentration level to below 5 mg/m^3 at the operator's cab position on continuous mining machines for the sampling period.

The directive stated as follows:

- *"No continuous miner (CM) heading must be developed further than 12m from the last row of permanent support or from the point of auxiliary ventilation; and*
- *Only ventilation systems that can ensure, at all times, a maximum dust reading of 5 mg/m^3, measured at the drivers position on the continuous miner (CM), must be employed."*

The objective of these regulations was twofold: firstly, to ensure the effective control of dust and secondly, to ensure the dilution of flammable gas to acceptable levels by providing sufficient fresh air. Within the guidelines, distinction was made between "Primary" and "Secondary" ventilation systems. The main objectives of the primary system are:

- To ensure that ventilation systems are in place,
- To ensure sufficient air reaches the last through road and
- To prevent the possibility of secondary ventilation systems recirculating"

The objectives of the secondary ventilation systems are:

- To supply a flow of air, of at least 0,4m/s, past the operator's position to contain dust roll back
- To dilute the methane and the dust generated to acceptable levels
- A flammable gas concentration of less than 1,4%.
- To render this mixture harmless and to remove it in a controlled manner
- To capture the dust and transport it to an air-cleaning mechanism

To achieve these objectives, the secondary ventilation system must incorporate both:

- An on-board force system, and
- A scrubber system

In addition to statutory risk assessment sampling, the relevant DME

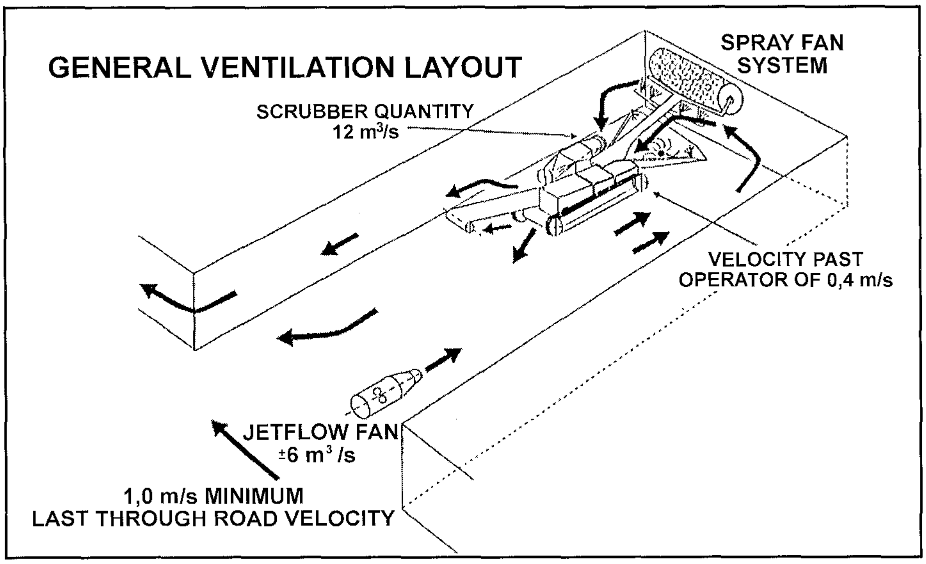

***Figure 5:** General ventilation layout of a typical coal mine heading*

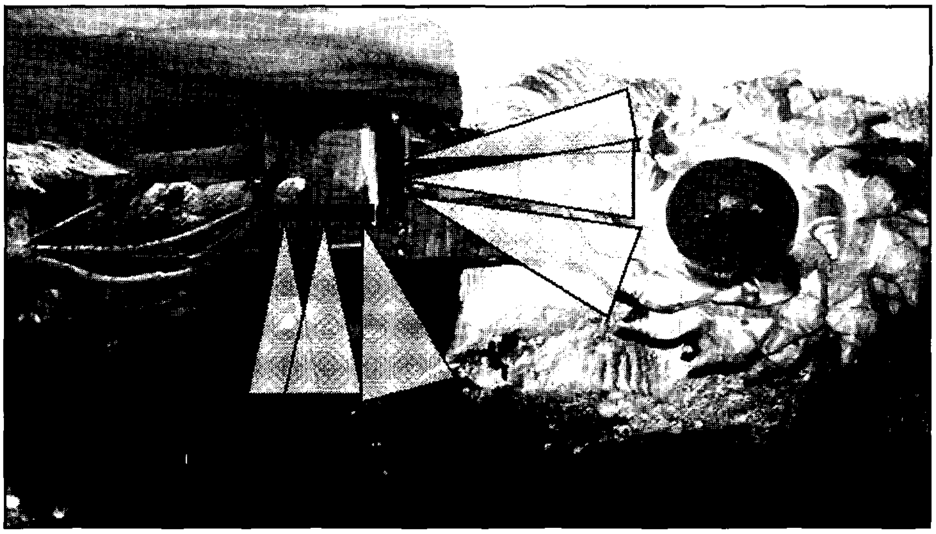

Figure 6: *Final configuration of a dust control system*

guidelines include a compliance test for assessing the effectiveness of the secondary ventilation system in terms of dust condition. This compliance test requires one gravimetric dust sample to be taken per day from each mechanical miner. The acceptable dust concentration over an eight hour period (TWA) is 5 mg/m^3.

Dust control case study

The dual requirement for controlling both dust and methane in headings may be conflicting and therefore presents major challenges in coalmines. The most effective means to prevent methane from accumulating is to force air into the heading. Sufficient air released onto the face will ensure no methane will accumulate. However, the effect of forcing ventilation with respect to dust control is to disperse the dust created during cutting by the energy imparted by the force fan. In this section, the efforts made by one coal mining group in controlling the dust levels are discussed. Figure 5 shows the typical general ventilation layout of a coal mine heading.

The control of both dust and methane requires a strict balance of the various systems to achieve a reasonable level of control of both hazards. If the force ventilation system is not effective, methane could accumulate in the heading while if its effect is too strong it can act to drive dust past the scrubber inlet resulting in poor dust capturing efficiency of the scrubber, excessive dust levels around the machine and uncontrolled releases of dust into the return air.

Initially problems were experienced with the dust extraction units in that initial scrubber designs were not capable of handling the quantities of air required on a continual basis. The scrubbers also required excessive maintenance. To comply legally and ensure total dust capture, air extraction quantities of between 11 and 13 m^3/s were required. A typical scrubber can handle as much as 250kg of fine dust per shift captured on a 1,5 m^2 mesh screen.

During the study, the original dust extraction units consisted of an extraction fan positioned behind a series of screens and demisters. Experience indicated that these units were unsuitable for handling the desired quantities of air to ensure that good environmental conditions were maintained in compliance with the regulatory requirements and the ever-increasing production rates delivered from the mechanical miner machines.

The continuous miner supplier was requested to provide a dust extraction unit as an integral component of the machine. Part of the contract agreement was that the supplier would be involved with the development of the scrubber unit that would be capable of performing the required task.

The system that was designed as part of this request operates on the basic principles of a wet scrubber. The dust-laden air passes through a screen that is kept constantly wetted by water sprays sited immediately in front of it. The filter screen acts to hold the water in the path of the airflow encouraging intimate mixing between the water and dust so that the dust is wetted and removed by the water, which, in turn, drains from the screen. Behind the screen, mist eliminators are used to remove any water blown through the screen, allowing clean, dry air to be discharged from the scrubber. Respirable dust collection efficiencies in excess of 90% of coal dust have been achieved with such systems. Figure 6 shows the final configuration of a dust control system developed during the case study.

Dust sampling strategy and results

The sampling methodology is seen as key factor in this investigation and much thought was given to this aspect. In conjunction with the CSIR-

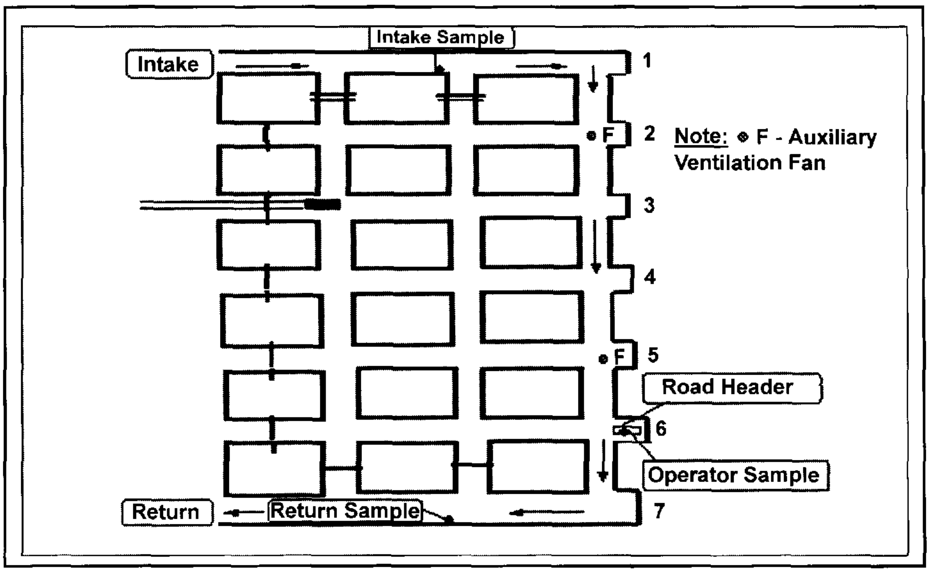

Figure 7: *General layout of a test section*

Miningtek, it was agreed that the correct method to evaluate the problem was to use a system that could record variation in dust levels. The real-time dust results would have to be interpreted in time intervals short enough to expose changing conditions.

The dust sampling train included Hund Tyndallometer, a real-time dust-monitoring instrument in parallel with respirable gravimetric dust sampling instruments at every dust sampling position identified.

The Hund tyndallometer is a dust-monitoring instrument that operates on the scatter light principle. An infrared light beam generated by a gas diode passes through the measuring chamber. The particles in the primary beam reflect (scatters) the light. The instrument measures the scattered light reflected by the particles at an angle of 70 degrees to the direction of the primary beam. The use of this scattering angle in combination with the light wavelength of 950 nm ensures that only particles which can respond approximately to the deposition probability of the respirable dust will be recorded. This selected measuring principle does not evaluate particles with the size greater than 8 microns. The measurement is a scattered light intensity value and is directly proportional to the dust concentration.

The gravimetric respirable dust samples taken in parallel with the tyndallometer recorders were used to correct the tyndallometer readings to eliminate possible influence from moisture. The sequential tyndallometer measuring intervals for the test was set at every eight seconds.

Dust concentrations were monitored at the following positions during the case study as shown in a typical coalmine section layout in Figure 7. The dust sampling for the case study were as follows:

- Intake dust (last through road)
- In mechanical miner cab
- Shuttle car operator position
- Mechanical miner return (last through road)
- Section return (last permanent stopping)

Dust sampling results

Section intakes: From the test conducted it was confirmed that the contribution of intake dust levels at the continuous miner to be minor.

Out-bye the mechanical miner: The location of this sampling point was in the last through road and downstream of the heading being mined by the continuous miner. During the test period, the dust levels at this position averaged to 1,8mg/m^3 with the highest real-time Hund reading recorded being 11,0 mg/m^3.

Out-bye the section: The section return position, located at the last permanent stopping, indicates the total contamination reporting from the section activities and is a good indication of how well the dust control is maintained in the face area the average of 1,53 mg/m^3.

Shuttle car operator position: The dust levels recorded at the shuttle car averaged at 1,54 mg/m^3.

Lessons learned: Do's and don'ts of dust control

From the extensive case study, several lessons learned which are relevant to controlling the dust levels in the coalmines. Sub standard conditions, sometimes observed during the tests and that would contribute to excessive dust loads, are summarised as follows:

- Poorly maintained dust scrubber units
- Incorrectly positioned jet fans
- Poor distribution of ventilation to the last through road - on-board scrubber recirculates air to a point where the respirable dust in the recirculated air increased progressively.
- When cutting the top right hand corner of the face, dust roll back is usually bad and can be further exacerbated when this is carried out at speed.
- When there is a delay in the return of a shuttle car to the continuous miner, cutting and storing of coal on the blade and in the face area continues. When the shuttle car returns loading of this pre-cut coal takes place without the full effect of the cutting head spray system. The secondary comminution effect of loading this stored coal results in dust generation that can by-pass the scrubber inlet, thus contaminating the area behind the continuous miner and causing high dust levels at the operator position
- When sumping in the continuous miner cutting head is close to the floor, the dust generated is blown-out at the bottom and bypasses the inlet to the scrubber positioned high up on the continuous miner.

How to maintain low dust levels

- Poor ventilation conditions in a section such as low last through road velocities, resulting in air jet fans recirculating or any auxiliary supply of ventilation, causes dust build-up at the operator's position when dust break-out in the face occurs. The onset of these conditions should be avoided
- Maintain the ventilation system in good order to counter the effects of face breakout. Regardless of the occasional dust breakout in the face, which contaminates the operator position, the contamination does not reach the shuttle car operator or the last through road position downstream of the heading being cut if this is ventilated adequately.
- Good ventilation system operation will also ensure that the majority of the dust generated in the face under normal cutting conditions is captured by the dust scrubber system. With good ventilation system operation, the dust levels out-bye from the scrubbers are low enough to ensure that the recirculated portion of the scrubber air does not result in dust build-up.
- In the case where no air jet fans are used, the discharge energy of the larger scrubber is such that a portion of the return from the scrubber is blown all the way to the last through road, thereby ensuring air replenishment from the intake. Obviously shorter pillar centres (18m) contribute favourably to this effect.
- The quantity of air handled by the scrubber plays a major role in the containment of dust breakout or roll back from the face. This should be maximised. The forward velocity of air towards the face, past the operator's position is critical to contain this roll back. The air for this effect is provided by a combining the re-circulated portion from the on-board scrubber and the air supply form the force fan system or air jet fan.

- The quantity of air handled by the scrubber should be such that the forward velocity over the mechanical miner towards the face, when a 100% recirulation of air occurs, must be 0,6m/s, or more, if the size of the mechanical miner is ignored in the heading.
- During the tests, the respirable dust levels out-bye the section were found to be extremely low thus indicating that most of the dust generated from the cutting process is contained in the face area. From this finding, it can be further assumed that the larger dust particles, that can be termed nuisance dust, are also contained in the face zone. This fact has major benefits from a coal dust perspective and enhances the effectiveness of stone dusting and washing down operations.
- The water supply and distribution patterns for the water spray nozzles on the mechanical miners are important in maintaining adequate and effective water spray patterns.
- Wet scrubber requirements must comply with the following requirements:
  - Efficiency of the on-board scrubber must be adequate to ensure that the recirculated component of total quantity does not result in respirable dust build-up at the operator position. High air pressure differentials are required to ensure high efficiencies.
  - The water distribution system on the scrubber mesh screens must be of a design that ensures ongoing flushing of these screens to prevent clogging that would result in an increase in air flow resistance and a commensurate decrease in the quantity of air handled by the fan.
  - The air quantity handled by the scrubber must be suffucuent to contain roll back and dust break out.
  - The inlet of the scrubber should be as close to the face as practically possible with due regard given to protecting the scrubber from physical damage.
  - The pre-humidification of the dust-laden air before impingement of the mesh screens is essential to ensure maximum coagulation of fine dust particles. This can only be accomplished by very efficient counter-flow spray nozzle pattern at the intake to the scrubber, or by the spinning action of the wet fan concept.
- The maintenance of the water spray systems to both the cutting head and the wet scrubber is critical. Bearing in mind that these scrubbers can handle as much as 250kg of fine dust per shift, the screen irrigation system and the slurry outlet from the scrubber must be in good working order at all times.
- The primary knock down of the major portion of the dust generated by the cutting head is accomplished by the head spray systems. The maintenance of both the spray systems and the water supply to the system is an area that demands constant attention.

Conclusions

A major challenge remains for the mining ventilation and occupational hygiene engineers to stay abreast of the ever-changing technologies. It remains a challenge to ensure that in-house innovations should be tried and tested to improve the worker environment further. The successes achieved in this test indicate the constant vigilance of the coal mining industry when driven by the passion to succeed and take up the challenges facing it.

In conjunction with the dust project for the improvement of environmental conditions in these complex issues, the research work into the control of continuous miner dust created in headings by SIMRAC (Safety in Mines Research Advisory Committee) was also incorporated as part of the work to define the most viable configuration for these continuous miner sections. Coalmines are using these dust control systems extensively and achievements in reducing the exposure levels have been significant.

The coal mining industry also continuously monitors developments in dust control systems to reduce further dust exposures in coalmine headings. One of such dust control technology is the application of wet head systems which has been tested in a South African mine. There appears to be a need for the fine-tuning of the wet-head system to withstands harsh conditions to which it is subjected.

One of the critical observations made during dust control exercise was the collaboration and active involvement of equipment manufactures. This has become an essential component of the programme for the continuous improvement of health and safety in our mines.

The assistance rendered by Anglo Coal management toward ongoing improvement of conditions is both gratifying and fulfilling. Also, the support being offered in resolving important issues that impact directly on health will ensure that the working environment will be more acceptable to all workers.

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