Published as: A.D.S Gillies, M.H Kizil, H. W. Wu and T. Harvey. Improved Ventilation and use of Respirators to allow Safe Mining during Release of Coal Seam Hydrogen Sulphide, *Proceedings, First Mine Environment and Ventilation Symposium*, Dhanbad, India, Oxford and IBH Pub New Delhi, 7-17 December 2000.

Improved Ventilation and Use of Respirators to Allow Safe Mining During Release of Coal Seam Hydrogen Sulphide

by

ADS Gillies, MS Kizil and HW Wu

University of Queensland

ABSTRACT

Hydrogen Sulphide (H_2S) has been encountered within a number of Bowen Basin collieries, Central Queensland, Australia. High concentration occurrence during mining of a longwall panel raises a number of potential problems which demand greater understanding to allow efficient mining while maintaining safe and healthy environmental conditions. Mine ventilation approaches to allow safe working through control of the mine atmosphere and use of respirator filters are described. Computer ventilation network simulation models of the various alternative ventilation approaches with H_2S variations are developed, fan capacity examined and alternatives costed.

Filters represent a cost-effective and safe way (in the short term) for miners to work in a potentially lethal environment. A series of laboratory tests were undertaken under conditions simulated to represent the mine H_2S laden atmosphere in order to establish safe operating limits for some filter types available. It was demonstrated that the cartridge type filters far exceeded their assumed life and the Racal EP3 combination type filter can be used in conjunction with other filters on the Racal turbo unit for a conservatively estimated total of nine 8 hour shifts.

INTRODUCTION

The presence of H_2S in coal seams causes a significant number of operational and safety problems during mining that may result in low production and development rates, poor efficiency and high ventilation costs. High concentration occurrences during mining of development headings and longwall panels have raised a number of potential problems.

The occurrence of H_2S in coal seam gases is rare around the world although it has been detected in selected coal seams in North East Asia, France, the US and Australia. In Australia significant occurrences have been found in a number of mines in Queensland. H_2S is an extremely toxic gas and can cause death. Stringent limits apply to ensure safe practices when mining in the presence of the gas.

The mine ventilation system can be modified to allow safe production through the affected zones (O'Beirne and O'Mally, 1995). Designs for maximising safe production through affected future mine panels or development headings have been formulated. These may involve increasing face ventilation (eg to 70 m^3/s for a longwall panel), use of panel belt homotropal or panel and main belts homotropal ventilation, full homotropal panel ventilation, the gaining of exemption on maximum H_2S concentration Threshold Limit Value (TLV) levels permitted and use of forms of remote mining. In this paper, computer ventilation network simulation models of a whole mine with H_2S variations are developed, fan capacities examined and alternatives costed (Gillies, et al, 2000).

Filters represent a cost-effective and safe way (in the short term) for miners to work in a potentially lethal environment. The most vulnerable route of entry of toxic substances into the body is the respiratory tract and therefore the respirator becomes a very important piece of equipment for personal protection. This paper describes a series of laboratory tests undertaken under conditions simulated to represent the mine H_2S laden atmosphere in order to establish safe operating limits for some filter types available.

MINE VENTILATION CONTROLS

The existence of H_2S gas in a coal seam poses operational and health and safety problems. The mine ventilation system can be modified to maximise safe production through the affected zones. In most cases the best ventilation option on a longwall face is to use a full homotropal system (ventilation airflow in direction of coal flow on face and in longwall conveyor roads) and keep all operators on the intake side of the shearer. However current Queensland legislation prohibits this as it normally entails bringing intake air past old workings. An alternative system with antitropal ventilation on the face and homotropal ventilation in the panel conveyor road has been used at a number of mines with success. The H_2S emissions were controlled by increasing ventilation quantity and varying cutting rate.

For development sections an exhausting duct system can be used for face ventilation with homotropal ventilation in the conveyor road. This in conjunction with personal monitors and remote operation of the continuous miner enables operator exposure to H_2S to be limited. The production rate may have to be decreased to meet the gas emission levels set by the standards while mining through affected zones.

Ventilation network simulation models of the whole mine under various ventilation approaches can be developed, fan capacity examined and alternatives costed. The H_2S concentration level to be expected at all mine points can also be predicted as part of this exercise. Employee positioning is another key aspect during remote or partially remote mining sequences. Underground workers must be encouraged to stay on the intake side of the shearer rather than on return side, which has been contaminated by H_2S gas.

While mining through a H_2S gas zone alternative ventilation systems of conventional, partial and full homotropal ventilation may be considered to dilute the gas and reduce its effects on equipment and those people working underground. These approaches are discussed.

Conventional Ventilation System

In a longwall panel conventional (or U configuration) ventilation system, fresh air enters the longwall face through the maingate roads and contaminated air leaves the face through the tailgate road as seen in Figure 1. The air quantity required on the face depends on seam gas emissions such as methane and H_2S. It is generally around 30-40 m^3/s for seams of 2.0 to 3.0 m thickness.

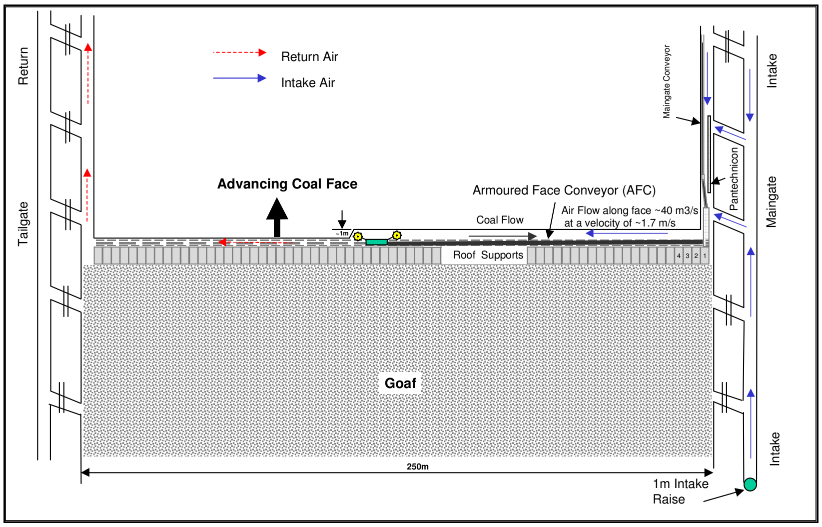

Figure 1. Conventional (antitropal face & belt airflow) ventilation system

This approach controls H_2S by diluting and carrying the liberated gas directly from sources to the return airway. When mining through an H_2S zone, the initial control should be through use of the conventional ventilation system and increasing the ventilation quantity to a level that is enough to keep H_2S concentration level below 10 ppm at the maingate end of the wall and 50 ppm at the tailgate end. The ventilation quantity should be increased in 10 m^3/s increments up to 60 m^3/s. If this is not sufficient to dilute the gas to the desired level then an alternative ventilation system should be considered.

The main disadvantage of this system is that intake air may be contaminated with H_2S gas released from the coal on the panel belt or during passage through the breaker and stage loader before reaching the longwall face.

Partial Homotropal Ventilation System

If an increase in the ventilation quantity does not reduce the H_2S level to below 10 ppm at the maingate and below 100 ppm at the tailgate, the partial homotropal ventilation system should be employed. As seen from Figure 2, a conventional ventilation system can be switched to a partial system by changing the belt road from intake to return. This prevents the coal travelling on the belt contaminating the intake air although there will still be some contamination from the stage loader and breaker. An axillary ventilation system can be set up around the stage loader and breaker sources to reduce the effects of this contamination on the system.

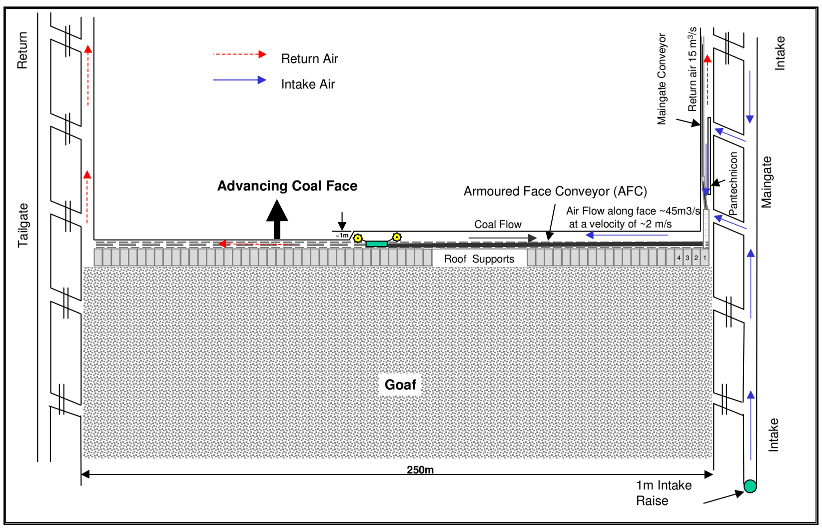

Figure 2. Partial homotropal ventilation system

At one mine the partial homotropal ventilation system with axillary ventilation was used while mining through an H_2S affected zone. The belt road was changed to return from intake and the intake air delivered from the maingate A Heading was split between the face and the belt road. The ventilation quantity was set to 15 m^3/s along the beltroad and in excess of 45 m^3/s along the face.

Three Venturi fans (compressed air blowers) were mounted on the Breaker Stage Loader (BSL) to remove the H_2S gas liberated during the breakage and transfer of coal from face to panel conveyors. The fans sucked air from above the breaker and were connected to a 650 mm ducting running along the BSL and linked to a 100 m long 900 mm ducting hung over the belt and dumping contaminated air into maingate B Heading return. Although the ducting was difficult to move as the face advanced and a large quantity of compressed air was needed to run the fans the system prevented a high quantity of liberated gas from contaminating the intake air and reduced the level of H_2S at the maingate dramatically. In the future it is recommended that electrical fans rather than air blowers are used for this task.

Full Homotropal Ventilation System

If increasing the panel ventilation quantity or adoption of partial homotropal ventilation is not sufficient to reduce the level of H_2S gas concentration to a desired level at the maingate (below 10 ppm) and tailgate (below 200 ppm) then a full homotropal ventilation system should be employed. Under this system the panel airflow direction is reversed in order to eliminate the problem of intake air being contaminated by the sources of H_2S as seen in the Figure 3. In other words, all the sources of H_2S stay on the return side and uncontaminated fresh air is supplied to the face. The belt road becomes the sole panel return. It should be noted that under this approach significant production changes would have to be made in terms of positions from which miners are deployed from.

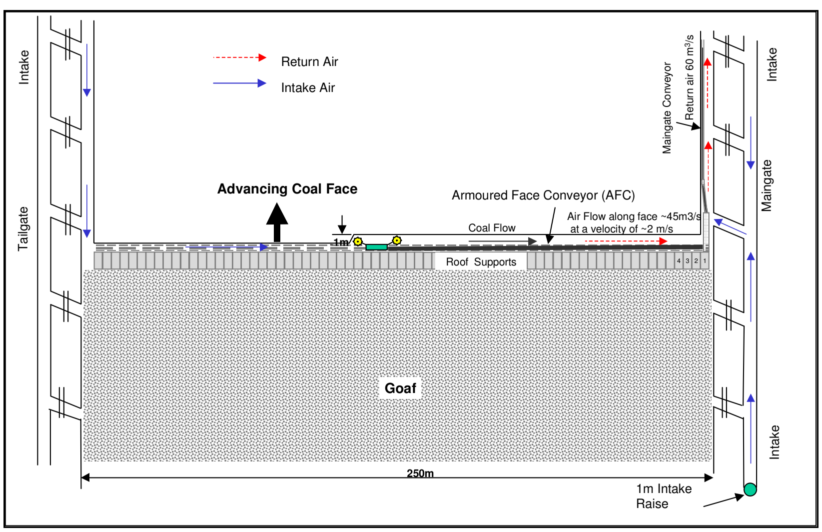

Figure 3. Full homotropal ventilation system

Currently, there are some limitations to switching to this ventilation system as Queensland regulations do not normally permit intake air to pass adjacent to old workings as in this method without construction of double stoppings.

Recent experiences at one Australian colliery indicated that it was unable to control the H_2S concentration levels to keep workers in a "safe environment" as defined as TWA 10 ppm for 8 hour shift, STEL 15 ppm for 15 min average, and an instantaneous peak of no more than 50 ppm after using various measures with acceptable production rates.

It is believed that these levels can only be achieved with acceptable production levels unless an alternative full homotropal ventilation system at the longwall face with some air passing through a back return is used. The alternative full homotropal system is as shown in Figure 4.

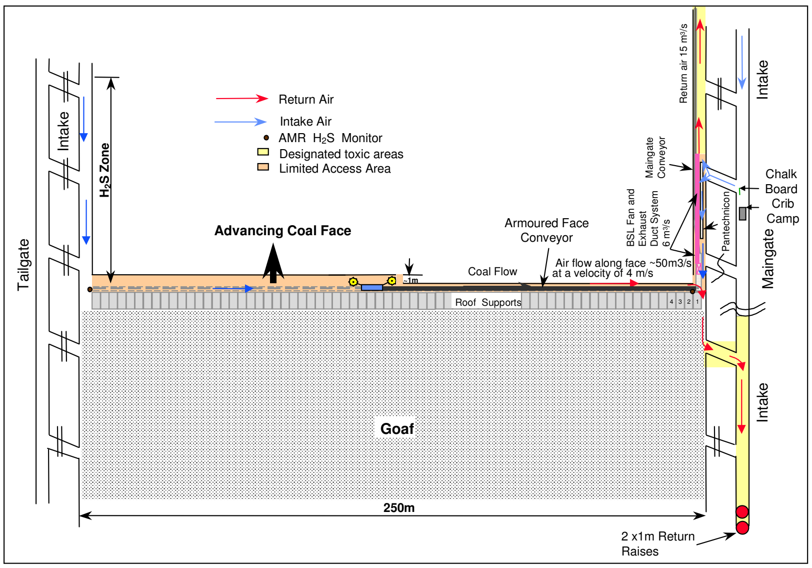

Figure 4. Alternative full homotropal system

Results of Ventilation Network Simulations

To illustrate the capacity of the alternative ventilation approaches to handle H_2S problems computer ventilation network analysis simulations using the commercially available program Ventsim were undertaken on a mine system with the capacity to ventilate the three approaches illustrated above. A summary of important features from the network simulations for the three alternative ventilation approaches is shown in Table 1.

Table 1. Summary of simulation results for three alternatives

Important Features	Conventional Ventilation System	Partial Homotropal System	Full Homotropal System
Total mine airflow (m^3/s)	221	221	210
Total face airflow (m^3/s)	57	57	41
Total raisebore airflow (m^3/s)	15	15	12
Total motor electrical power (kW)	742	744	767
Annual power cost	$227,600	$228,400	$235,400

For the conventional mine ventilation approach, it should be noted that the mine ventilation demand for sufficient airflow to service two development faces (25 to 30 m^3/s each), Mains and Gateroad segregation stopping leakage and the longwall face with substantial airflow for H_2S dilution are met.

It can be seen that the partial homotropal approach places only minor additional load on the system available air and power demands. As it significantly reduces the amount of H_2S carried back onto the face in the conventional system it is strongly recommended for use when face H_2S concentrations are significant. It should be noted that the mine ventilation demand is again met for sufficient airflow to service two development faces (25 to 30 m^3/s each), Mains and Gateroad segregation stopping leakage and the longwall face with substantial airflow for H_2S dilution.

As would be expected the full homotropal approach increases total mine impedance and reduces total airflow through the mine fans. The mine has sufficient capacity to maintain a normally accepted adequate longwall face airflow of 40 m^3/s while servicing two development units and other demands. Electrical power demand and power cost increase over the partial homotropal ventilation alternative is only 5 percent greater.

RESPIRATORY PROTECTIVE EQUIPMENT

Filters represent a cost-effective and safe way (in the short term) for miners to work in a potentially lethal environment. The most vulnerable route of entry of toxic substances into the body is the respiratory tract and therefore the respirator becomes a very important piece of equipment for personal protection (Hall and Sing, 1988). The most important part of the respirator is the canister through which inflow air is drawn and filtered.

A series of laboratory tests were undertaken under conditions simulated to represent the mine H_2S laden atmosphere in order to establish safe operating limits for some filter types available (Croker, 1996). An initial set of tests was undertaken to determine the efficiency of cartridge type filters. The tested filters were of a combination type that filtered both the stated gas and particulate.

The particulate filter section consisted of glass coated fibres and the gas filter section was a layer of impregnated activated carbon. The cartridges were tested at H_2S concentration of 148 ppm for duration of a 12.7 hours and found to maintain 100 percent efficiency throughout. It was demonstrated that the cartridges far exceeded their assumed life.

A second set of tests was carried out to test Racal Health and Safety EP3 type filters used on a Racal powered turbo unit attached to an airstream helmet as shown in Figure 5 (Lennon, 1997). The air-stream helmet uses a stream of air across the face to provide a positive pressure on the miner's face and effectively seal the face from the outside atmosphere acting in a similar way to a full-faced respirator (Racal Health & Safety, 1996). The main purpose of the experiment was to test the helmet in an atmosphere of 50 ppm H_2S concentration and 100 percent humidity and determine the life of the cartridges.

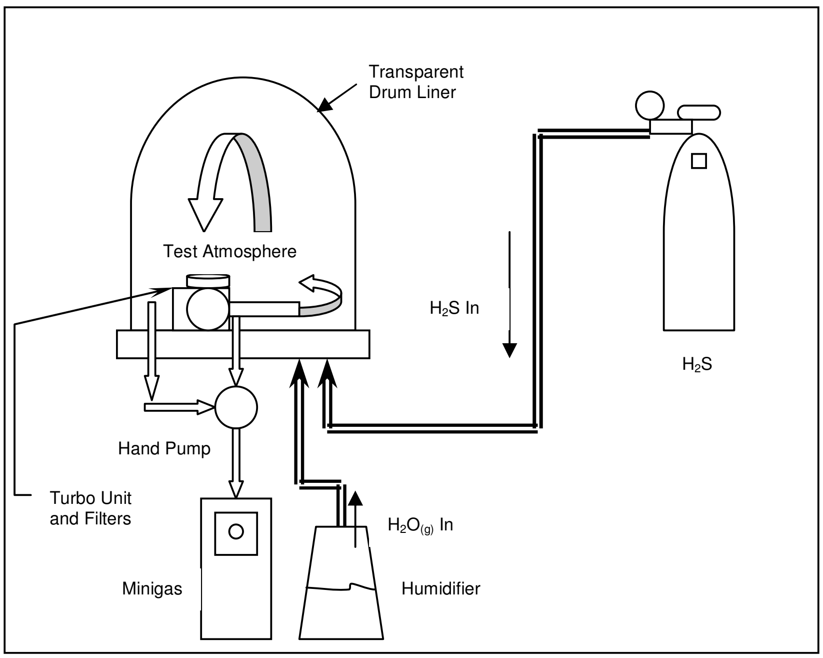

Figure 5. Schematic of experimental setup

Results and Discussion

In testing the filters two variables were being measured:

- the filter efficiency, and
- the breakthrough time of the filters

These two factors can be used as the main indicators of suitability of filters in an underground environment. Economic considerations also play a role in a selection determination.

The first five stages of the test were run with three filters in place on the turbo unit. Stage 6 of the test was run with only two filters. This was due to an apparent breakthrough being reached on one of the filters. The results from these stages are plotted in Figure 6 with efficiency of the filter and H_2S concentration in the artificial atmosphere and in the exhaust stream of the filters. The graph clearly shows breakthrough of the first cartridge and then the other two cartridges.

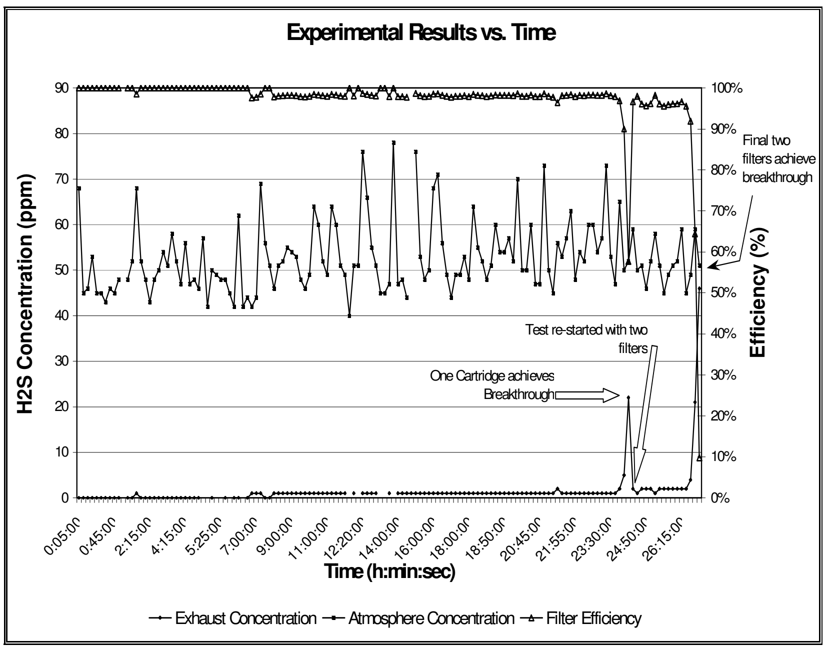

Figure 6. Experimental results on Racal EP3 Filters

The tests have established a breakthrough time of around 26 hours at a concentration of 50 ppm H_2S, a flowrate of 160 l/min and 100 percent humidity. It is important to note that this breakthrough time is for three Racal EP3 combination type filters in parallel. The breakthrough time is expressed in terms of three filters because the turbo unit must have three attached filters for use in hazardous environments. This turbo unit is connected to an airstream helmet to supply the "cleaned" air to the miner.

This breakthrough time can be used to estimate the actual working time three filters could experience at the face. An important point to be made is to emphasise the differences between the laboratory and actual mine condition.

The controlled system has a constant H_2S concentration, constant humidity and no dust build up on the particulate filter. The actual working conditions have highly variable H_2S concentrations, generally lower humidity and dust exposure. These factors make it difficult for an estimation of mine life to be made. The approximate cost of each filter is Australian $150. Extending the use life of each filter to its capacity equates to huge savings compared to adopting an approach of daily disposal of used filters.

The tests provided some important results for mine workings facing H_2S exposures. Mine conditions would vary from the laboratory test situation and some interpretation would be necessary to answer the questions: "How long will the filters last on a working mine face?" Several factors therefore must be considered:

- The average or long term working face H_2S concentration being experienced is likely to be a significantly lower than 50 ppm,
- The expected humidity at the face will be somewhat lower than that in the test condition, and
- Finally, is it possible to gain forewarning of the breakthrough point?

Firstly, a level of 50 ppm was chosen for tests as it represented approximately a maximum short term exposure concentration likely to be experienced on a face mining through a H_2S affected coal seam. An average concentration of about a third of this or less is likely to be that which may be found. Tests would be needed to establish whether the relationship between these two concentrations is a linear or exponential time distribution or something else. A conservative assumption of linear should be assumed without further information.

Secondly, the test atmosphere was assumed to be at 100 percent humidity. The face humidity is generally expected in Queensland mines to be about 80 to 85 percent and this has an effect on the "sharpness" of the breakthrough curve and to the displacement of the curve. With a lower humidity the sharpness of the curve would decrease leading to a longer period over which breakthrough occurs. The lower humidity will also push the curve to the right thus increasing time before breakthrough. The extent of these changes is difficult to predict without further detailed tests.

The breakthrough point with safety margin can only objectively be predicted from extrapolation of test data results to the individual mine situation. Atmospheric mine conditions will vary and one approach to incorporating the mine situation would be through use of an extensive monitoring system which continually monitored the face for H_2S concentrations. From these records a model could be established to calculate the exposure of the filter to H_2S and so predict the breakthrough time.

In general, the cartridges far exceeded their assumed life and disproved “accepted thinking” in the mining industry. This perception was that the filters have a factor of safety of ten (meaning that the filters would decrease the concentration of H_2S in the atmosphere to 10 percent of the original value), have a life of eight hours at a concentration of 100 ppm and have a dramatically reduced use-life at a concentration of 150 ppm.

It has been observed that current mine practice is to only use filters for a shift. Filter use can be extended with significant financial savings. To do this systematically each filter will have to be identified with a serial number in order to track its use. With model and serial number identification a system could be put in place to ensure no filter reached breakthrough point.

CONCLUSIONS AND RECOMMENDATIONS

The mine ventilation system can be modified to allow safe production through H_2S affected zones. Designs for maximising safe production through affected mine panel or development headings have been tested. These involve increasing face ventilation rates, use of panel belt homotropal or panel and main belts homotropal ventilation, full homotropal panel ventilation, the gaining exemption on maximum H_2S concentration levels permitted and use of forms of remote mining. Ventilation network simulation models of the whole mine with H_2S variations have been developed, fan capacity examined and alternatives costed. Employee positioning is another key aspect during remote or partially remote mining sequences.

The findings from respirator experiment were that the Racal EP3 combination type filter can be used in parallel with other filters on the Racal turbo unit for longer than generally accepted current practice.

It is recommended that further filter investigations are undertaken on the effect of varying humidity on breakthrough, the effect of high dust levels on the life of the particulate filter, examination of other H_2S filters recommended by Racal for the gas which comply with Australian Standards and comparison of performance and a full scale underground test of filter performance.

ACKNOWLEDGMENT

The study was undertaken with funding from the Australian Coal Association Research Program and Queensland coal mines. This support and the generous assistance of company personnel is acknowledged. The contributions and assistance of Christopher Croker and Matthew Lennon are also recorded with thanks.

REFERENCES

O'Beirne, T. and O'Mally, A. 1995. Risk Review of Mining Through the H_2S Zone at Capcoal Southern, Capricorn Coal Internal Report. Queensland. Australia.

Croker, C., 1996. Eliminating the Hydrogen Sulphide Hazard at Southern Colliery with the use of Impregnated Carbon Respirators, Bachelor of Engineering Thesis, The University of Queensland.

Gillies, A.D.S., et al. 2000. Maximising Coal Production in the Presence of H_2S Seam Gas, Final Report to Australian Coal Association Research Program, The University of Queensland, Department of Mining, Minerals and Materials Engineering. Australia.

Hall, C. R., and Sing, K. S. W., 1988. Protection – the Black Art, Chemistry in Britain, Royal Society of Chemistry, Vol. 24 No. 7, London, pp. 670-674.

Lennon, M., 1997. Efficiency of Hydrogen Sulphide Respirators Filters, Bachelor of Engineering Thesis, The University of Queensland.

Racal Health & Safety. 1996. Breathe Easy Plus - Range of Powered Respirators. Advertising Brochure/Manual.