Chapter 8
CONCLUSIONS

8.1   CONCLUSIONS

The conclusions of this research work undertaken to advance the control of respirable dust levels in longwall mining are summarised in the following sections.

8.1.1   Field investigations

The field experimental studies have been very useful in identifying some of the important parameters affecting dust transport and in characterizing dust cloud behaviour at longwall faces. It provided a comprehensive data base for the development of a dust control technique that is effective in minimising the dust exposure of miners working at the face. A brief outline of the observations from the field studies are as follows:

1)   The respirable dust concentration increases with distance towards the return end of the longwall face. However, the large variation in the dust gradients along the same longwall face indicated that the relationship between the dust level and distance from the intake end is complex and not easily generalised owing to the numerous factors involved. Furthermore, the average dust concentration levels could not be correlated with face activities, and it was necessary to conduct instantaneous dust sampling surveys to give a clear picture of respirable dust conditions at the face.

2) The dust distribution patterns are different for different phases of the cutting cycle, i.e the cutting, cleaning and sumping operations. Although the trend of respirable dust concentration profiles was consistent in the different longwall faces investigated, there were significant variations in dust levels. These variations could be attributed to the differences in ventilation plans, operating procedures and dust control techniques.

3) Under the same operating conditions, a higher cutting speed results in higher dust concentration levels. Misdirected water sprays on the shearer increases dust concentration at the rear drum operator's position.

4) A comparison of air quantity and respirable dust levels in different faces indicates that low air quantity and consequential low air velocity (less than 2.2 m/s), at the face could be one of the main reasons for the high dust concentration levels in the longwall faces A & C.

5) Cutting against the ventilation disperses more dust into the shearer operator's position than when cutting with the ventilation. However, when cutting with ventilation, the maingate cut-out, during which the drum makes a number of partial sumping cuts, produces a significant proportion of the total respirable dust.

6) There are large dust gradients, not only around the shearer, but also across the section of the longwall face. Dust levels over the AFC area were higher than those in the walkway between the chock legs and these differences exist even 50 m downwind of the shearer. Thus, the assumption that the dust cloud, under turbulent flow, becomes well mixed and uniform in a relatively short distance, is doubtful. Careful selection of a sampling site is therefore critical when

evaluating the effectiveness of any dust control technique. A change in sampling location during a survey can have a greater effect on the measured dust level than the dust control technique being evaluated.

7) Based on the air velocity and quantity data from the measurements, there was no indication of significant air leakage into the goaf. Air velocity profiles across the face showed that velocity is not uniform; it is highest over the AFC area and lowest in the walkway. Air velocity patterns in the walkway also differed from face to face depending on the type of supports used. Also, the spatial distribution of respirable dust depends largely on the airflow patterns. These variations are important considerations in the development of a dust control technique, as they affect the respirable dust behaviour and dispersion.

8) Sources other than the shearer, for example support advance, also contribute significantly to the total respirable dust concentration in a longwall face. Therefore, to reduce the longwall miners' exposure to these dust clouds requires that the development of control techniques focuses on reducing the dust that is already airborne. One such method of control could be the installation of separating elements, such as local airflow systems, between the AFC and walkway area.

8.1.2   Scrubber system for longwall face and field evaluation

1) A prototype air-powered venturi scrubber has been developed for use in longwall faces. The capacity of the scrubber is 0.5 m^3/s. The total length of the unit is 1.2 m and can be fitted in one chock shield very easily. The scrubber is self-cleansing, needs very low maintenance and is safe for use in hazardous conditions since it has no moving parts.

2) Laboratory studies showed that the average efficiency of the scrubber was 91% and a maximum efficiency of 92% was obtained at 2400 kPa pressure drop and a water flow rate of 6.0 l/min per 0.5 m^3/s of air.

3) A minimum of 0.4 m^3/s air quantity, or 50 m/s air velocity in the throat of the venturi, is required for effective atomisation of the water in the unit. The scrubber efficiency increases with an increase in water quantity.

4) To be most effective, the scrubber should operate at 0.05 m^3/s compressed air flow, at 400 kPa pressure, and with a water flow rate of 6.0 l/min at a normal 700 kPa pressure. In addition, the scrubber should be delivering a minimum air flow of 0.5 m^3/s at 10 m/s exit velocity and the scrubber discharge point should be located near the roof in the front walkway area.

5) Underground evaluation of the scrubber system provided protection efficiencies between 26 and 55%, at 3 m from the scrubber, with face air velocity between 4.5 and 2.0 m/s. The low efficiency (26%) in the faces with high air velocities is attributed to turbulence.

6) Experiments with two scrubbers installed also yields dust reductions of 57% at 3 m downstream of the scrubbers. Whilst two scrubbers do not increase the dust protection levels, they do increase the length of clean air zone from three chocks (4.5 m) to six chocks (9 m). For effective dust reductions in the walkway of the longwall face, a multi-scrubber system could be designed by installing scrubbers on every third chock. Thus, a 150 m longwall face would require approximately 12 to 18 scrubbers, depending on the dust conditions.

7)   The installation of scrubbers modifies the airflow patterns in a longwall face, particularly in the walkway.   These modified airflow patterns also contributes significantly in reducing the walkway dust concentration.

8)   Scrubber capacity, cleaned air exit velocity and scrubber location are the three important parameters of the system determining its protection efficiency. Furthermore, the air velocity in a longwall face determines the amount of turbulence and hence, the effectiveness of the system in reducing dust exposure.

9)   Along with a high dust collection efficiency, the venturi scrubber also possesses most of the other characteristics desirable for a good underground scrubber. Some of the advantages of this prototype air powered scrubber are:

     a.   simple and very compact;

     b.   no fan or electric / hydraulic motor to maintain;

     c.   virtually maintenance free - no clogging, self cleaning;

     d.   high pressure water pumps are not required;

     e.   no electricity needed - very safe and no inherent permissibility problems;

     f.   does not need any special facilities;

     g.   can be easily installed in a longwall face;

     h.   uses very little water compared with water powered scrubber.

10)   Owing to its simplicity and flexibility the scrubber has a number of other applications including:

     a.   in a shearer extraction drum or as a shearer mounted scrubber;

     b.   at transfer points;

     c   at tailgate worker's position.

8.1.3   Modelling studies and validation by field measurements

1)   A three dimensional model of a longwall face has been developed and finite element techniques have been successfully applied to supplement the field investigations.   The particle path plots provided a qualitative understanding of the airflow characteristics at the longwall face.

2)   The results of mathematical simulations of air velocities and dust concentration levels across the longwall face are in agreement with the results from field measurements, except in the regions very close to the boundary walls.

3)   The predicted particle flow paths for two cutting directions and comparisons with field observations, confirmed that cutting against the ventilation disperses more dust into the walkway of the longwall face.

4)   The predicted protection efficiency of the scrubber system was very close to the field measured values.

5)   Simulations of other dust control techniques such as curtain-over-shearer, air curtains, face curtains, etc also closely agreed with the field results obtained by other researchers.   In general, the protection efficiency of the dust control techniques predicted by the model was very close to the field values.

6)   The results of modelling the 'curtain-on-in-bye-side of the downwind drum' control technique indicates that the technique is effective in controlling dust dispersion at the downwind maingate cutting drum when cutting with ventilation.   'curtain-on-in-bye-side of the shearer upwind drum' dust control

technique could also be very effective in controlling the shearer operators' dust exposure in both cutting directions.

7) The close agreement between the modelling results and field measured values suggests that finite element modelling techniques are useful for a thorough understanding of air flow and dust distribution patterns in a longwall face. It has been shown that the finite element modelling techniques are capable of predicting the effect of different ventilation systems and dust control techniques on the behaviour of dust, and are an invaluable tool in the development of new dust control techniques.

8) The ability of mathematical modelling to manipulate variables such as air velocity and the dust control mechanism and to examine the effect on dust behaviour, makes it a quick and economical method for investigating new dust control designs before proceeding to the field. It is also a useful supplement to studies on viable dust control techniques.

Based on the above findings, it can be concluded that the finite element longwall face model can be confidently used to simulate airflow patterns, dust concentration levels, respirable dust particle behaviour and to ascertain the effectiveness of dust control techniques.

8.2   SUGGESTIONS FOR FURTHER RESEARCH

This research has provided a comprehensive understanding of respirable dust behaviour and has promoted the advance of longwall dust control technology through the development of a new dust control technique, but there is still scope for further research in this area. Such research should be pursued on dust control techniques which separates the AFC and walkway areas. The concept of isolating the cutting zone from the ventilation air stream, with different curtain configurations, should also be pursued further.

Consideration should be given to integrating the scrubbing units into the powered support system. In the future, when high capacity, high pressure, compact, mine approved fans are available, attention may be given to replacing the compressed air power source with electrically powered fans. The use of electrical fans would make the sequencing of scrubber units very easy, as well as being integrated into the powered supports.

Research should be undertaken on the concept of agglomerating the respirable dust particles into larger particles. One approach would be the application of high powered ultrasonic transducers with, or without, water. Ultrasonic agglomerators could also be used as a pre-conditioners, in-front of the scrubbers, to reduce their load which would make it easier for the scrubbers to collect the larger particles.

Field investigations should continue to gather more data on the transient and spatial dust concentration distribution in longwall faces which have different physical and operating characteristics. Future studies should focus on designing appropriate sampling plans for data collection on secondary dust sources, such as dust from support movement, coal spalling and goaf falls.

Mathematical modelling of the longwall face is another important area which merits further work for a better understanding of secondary airflows around the shearer and dust distribution. Comparative analyses of the mathematical modelling predictions and experimental results highlight areas which need additional modelling. In its present form, the model can predict dust behaviour at the face very closely, but can only provide rough estimates of behaviour very close to boundary walls. To solve this problem, fine mesh needs to be used near the walls. The present model, limited to 40 m in length due to computer capacity, can only be used to simulate dust concentration profiles around the shearer and across the face. A full length model should be developed to simulate the dust profiles along the full length of the longwall face.

In addition, a better fit between the simulated and field results near the blocked regions could be achieved if the components of the longwall face were individually modelled and evaluated with experimental data. Further modelling should include the simulation of total dust behaviour, i.e. include particles larger than 10 microns, to determine the interaction between particles. The modelling of large particles, which have inertia and a relative velocity with respect to airflow, requires separate equations for particle transport. All these additional features require greater computer capacity for simulations.

The trend of increased production from longwall faces and the consequent increase in dust generation will necessitate the use of finite element techniques to simulate airflow patterns and pollutant behaviour in underground coal mines. Developments in the computer hardware technology will also facilitate the use of finite element techniques in airflow modelling in underground coal mines. Application of these techniques to the analysis of other environmental problems in underground coal mines is also recommended.