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ADVANCING COAL MINE VENTILATION INTO THE TWENTY FIRST CENTURY WITH HIGH PRODUCTIVITY MINING SYSTEMS

By

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ABSTRACT

The Australian mining industry can expect to be working internationally competitive high quality coal mines during the twenty-first century. Cost efficient mining methods such as high productivity longwall units with heavy reliance on remote control will be standard and worked by well paid and intensively trained operators.

Major changes in mine ventilation engineering can be expected in the use of computers and mine telemetry, the understanding of the mine environment and the frequency of mine disasters, the utilization of mine air contaminants for profitable purposes and the provision of a pleasant and comfortable work environment. New approaches to mine ventilation such as air recirculation will have been considered. There will be an increased need for highly trained ventilation engineers. With the present pace of technological change, quite revolutionary new approaches to mining and ventilation can be expected by the end of the twenty-first century.

INTRODUCTION

The twenty-first century dawns in about half one generation. If it is to be assumed the present rate of technological change in mining systems continues, then, major innovations can be expected by the beginning of the new century and gigantic leaps to fundamentally new approaches by the end of the one hundred years. Much change can be expected to be step by step or evolutionary, although some major shifts or revolutionary moves can also be anticipated.

The ventilation engineer can expect to be controlling mine atmospheric conditions in a new look mining industry. Australia is part of the world economy and international economic criteria will have increasing influence; Australian underground mines will be in competition with both the open cut sector and international trading competitors. Underground sourced coal will be good quality coking coal mined by cost efficient methods such as highly automated longwall units. A capital intensive industry demands highly skilled labour and high productivity will be maintained with a small, well paid and intensively trained workforce.

It can be expected that evolutionary developments in mine ventilation will have the greatest impact in areas in which intensive research is being undertaken. What are these areas?

An overview of technical papers submitted on coal mine ventilation to national and international symposia and conferences indicates areas of importance.

INTENSIVE RESEARCH AREAS

MINE GASES

Methane drainage

The use of both underground and surface holes to tap seam and goaf methane has progressed over the last decade in Australia from an experimental stage to proven technology. Legal obstacles have been overcome, safety considerations thought through and commercial gains are being made from the use of the gas. With this system the gas volume liberated into the mine ventilation network has been reduced in places by 50 percent. With higher methane levels at increased production levels and depths, this approach which turns a ventilation problem into a commercial profit is likely to become a very widespread practice. The technology is in place and research studies are continuing in a number of areas. New approaches to the handling of mixed gases such as carbon dioxide/methane are being investigated.

Implementation of drainage technology requires an ability to accurately drill long holes.

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Developments are of particular importance in the placement of in-seam holes. Long holes in advance of the face are needed for establishing geological stratigraphy in addition to detailing information on gas presence. High pressure water jet technology is providing new impetus in this area.

Gas flow characteristics

Considerable effort is presently being directed to establishing means for predicting gas flow into mine openings. Efforts are pointed to establishing gas presence in the seam and adjacent strata through both laboratory and underground physical measurements. Computer simulation approaches relying on techniques developed for geomechanical investigations are being used to estimate gas migration rates. Characterization of strata in Australian coal basins needs to be pursued further; the influence of dykes, faults and other disturbances needs further investigation. Research on outburst occurrence is proceeding apace.

It can be expected that within the next decade or so the necessary instrumentation, computer modelling approaches and understanding of Australian coal stratigraphy will have advanced to the point where planning to overcome mine gas problems can be undertaken with confidence.

Biotechnological control of methane

Methane oxidising bacteria can easily be grown under controlled laboratory conditions and have been successfully isolated from a number of Australian mines. These microorganisms oxidise methane into carbon dioxide and water. Laboratory studies have shown that the bacteria can remain active over an extended period and that the rate of oxidation is appreciable. Possibilities exist for a bacteria containing solution to be sprayed onto coal surfaces or pumped into the coal mass through boreholes in order to reduce the methane emission rate to the ventilation airstream. Direct removal of methane from air can also be investigated.

Biotechnology offers the possibility of a long term major advancement in mine gas control. It is the type of development that has potential to cause a re-think in mine ventilation in the twenty-first century.

DUST

Respirable dust

Medical investigations and regular X-ray checkups have increased awareness of respirable dust problems. The change to coal extraction by machine cutting has increased operator exposure to fine dust. Gravimetric measurement of respirable dust levels has become the industry standard. Recent attention has been given to the hazard of free silica in the airborne dust. How can respirable free silica levels throughout a mine be established accurately and what is a safe medical limit for this material are questions being asked.

Instrument developments are focused on the introduction of units which can give instantaneous dust concentration readings. Those such as the SIMSLIN can be directly calibrated to a gravimetric standard while those in a second category; the HUND and the MINIRAM types need to be calibrated for dust characteristics in a specific mine. Some questions exist on the influence of other airborne materials (such as water droplets) on instantaneous dust concentration readings when undertaken using a light scattering technique. The tying of instantaneous dust measurement units into a remote sensing or telemetry system will greatly advance knowledge on mine dust problems.

Strong effort is being expended in improving dust suppression in both bord and pillar and longwall units. Principal research areas involve:

1. ventilation; better approaches to directing available air and the separation of dust laden air from where men move,
2. scrubbers; development of continuous miner mounted units and longwall shearer extraction systems,
3. sprays; the mounting and directing of spray banks and the use of compressed air and high pressure water to improve suppression efficiency.

Coal characterization to establish why some coals produce more dust than others is being followed up. The influence of seam moisture levels is important and seam water infusion using boreholes in advance of the face may reduce problems.

Evolutionary developments in suppression systems, particularly where severe problems have been encountered on longwall faces, are continuing to show promise. These, coupled with better instrumentation and knowledge of seam chemical and physical characteristics, must confidently lead to a progressive ability to reduce respirable dust problems.

Dust explosibility

Coal dust explosions, despite significant research effort and the implementation of tight regulations controlling such aspects as limestone dusting, use of barriers and spillage clean up, have remained *all too* frequent. Since 1970, Australia has experienced five major coal dust exposion disasters with the lost of over 50 lives.

Research directions being pursued include:

(a) sources of ignition and particularly forms of frictional ignition,

(b) the use of alternative inerting dusts to limestone,

(c) the explosive characteristics of methane/coal dust mixtures,

(d) the mathematical modelling of an explosion propagation.

Major effort is being expended in countries such as the U.S., Britain and Poland to further research on this hazard. This is one of the most critical areas in mining today where an improvement in the safety record is essential. Strong research efforts are likely to continue well into the twenty-first century.

FIRES

Important areas within this topic includes simulation and analysis of fire propagation, safety in event of fires, fire suppresion and sources of fires including spontaneous combustion and gas explosions.

Fire Propagation

Traditionally preventive measures to reduce fire risk have been based on lessons learnt from past experiences of real incidences. In analysing fire propagation, assessment of case studies continues to be of great importance.

Important research is being undertaken to develop efficient computer packages which use network analysis algorithms to establish fire advance rates through mine openings. These are being prepared in a Personal Computer form and work is continuing to ensure that modelled predictions represent actual fire behaviour. Efforts are being made to develop computer systems which assist crisis decision making; these store and assess relevant data and by simulating ventilation behaviour enable responsible decisions to be made with predictable results.

Research continues into the impact of use of different materials and the impact of entry air velocities on fire propagation

Safety

Improved emergency procedures to ensure the safety of men following ignition continue to be developed. Remote data acquisition and alarm systems progressively are being refined. Effective mine communication systems and emergency training approaches are being thought through. The use of body-worn self-contained self-rescuers and the establishment of mine refuge bays are receiving attention in a number of overseas countries. The results of the introduction of self-contained self-rescuers in the South African mining industry will be watched with interest in Australia.

Fire suppression

New approaches which have gained attention include the use of inert gases such as nitrogen to fight fires. This method has been reported to have been used in Europe for about 15 years and was made use of during the Moura Disaster in 1986. Economic generation and supply of the gas, including vaporization techniques are important. Control of spontaneous combustion is an application area.

Another suppression technique being examined involves the infusion of chemical gel material through holes into pillars to create an air seal and suppress an ignited fire or spontaneous combustion.

Gas explosions

Despite extensive research over many years, there is incomplete understanding of the explosibility limits of complex gas mixtures. Through the use of computer analytical approaches, solutions to establish explosible limits of gas mixtures containing any number of combustible and inert components are being proposed.

OTHER AREAS OF SIGNIFICANT RESEARCH

The efficiency of coal mining systems is significantly reduced in many parts of the world by difficulties with gas control, dust and fire safety (including gas explosions). Major research projects are and will continue to attack these problems; progressive solutions to the problems can be expected to maintain the competitiveness of underground mining. A number of other areas of research are being pursued anhd will change the face of coal mine ventilation.

Remote monitoring and computer use

The electronic revolution has already made sweeping changes to industry and society. Mining has followed most other engineering branches in adopting computer usage as a tool with widespread application. The computer has established a dominant position in system network analysis and heat load/climatic conditioning prediction. It is an essential component of ventilation telemetric systems which have been finding their way into mines in the last decade. Major developments are foreseen, particularly where PC units and user-friendly interactive programs are in use.

1. Telemetric systems will be found in all mines, monitoring, controlling and ensuring the safety of all ventilated areas. Optic fibre technology

with the advantages of intrinsic safety, freedom from electromagnetic interference and ability to transmit information rapidly will be dominant. As optic fibre transmission is possible over long distances, the light source, detector and ancilliary equipment will be located on the surface with only the optic fibre and passive sensor head underground. In conjunction developments will take place in regulation and control of fan pressure and quantity, airflow direction, regulator response and air door operation.

2. Development of intelligent ***expert systems*** which can give advice on aspects such as methane or dust control and will handle normal control functions in telemetric systems will be seen.
3. Direct co-ordination between ventilation network modelling and mining system design during the planning phase is envisaged.
4. Greater use of complex or sophisticated mathematics in the analysis of ventilation networks, gas control and fan performance will be found.
5. Increased use of mathematical models for handling and reducing ventilation survey data for analysis and design will be found.

Developments in computer usage and remote monitoring can be expected to occur quickly and the developments listed above are confidently expected to be in use by the first years of the twenty-first century.

Recirculation

Recirculation of face air is being investigated and in fact is in use in some overseas countries. Climatic control difficulties have forced investigations in South African and Canadian metalliferous mines and British Coal has incorporated some recirculation systems underground where depth, mechanisation and distance of working areas from surface connections presented an obstacle to conventional approaches.

A successful recirculation system must have fail-safe airflow control and ensure that contaminants in the face air current are at acceptable levels. Recirculation research has concentrated effort on climatic control. Apparently airborne dust control can be handled confidently with new developments in atomizing spray technology. Biotechnological developments in the use of bacteria may lead to major advances in methane gas control. Overseas research is leading the way in recirculation developments. While statutory exemptions or legislative changes would be needed in an Australian context, arduous conditions in the future will lead to its consideration.

Contaminants in diesel exhausts

Underground diesel engines have been in use in Australian coal and metalliferous mines for many years without apparent significant problems. However, substantial research continues overseas on diesel exhaust emissions due to both the harmful health effects of pollutants and the high costs associated with providing adequate ventilation to sustain a healthy working environment.

Key research areas include:

1. scrubber design and particulate filter systems,
2. engine regulation,
3. introduction of air conditioned cabs to isolate the driver from the contaminated atmosphere,
4. use of diesel generation electric drive mobile vehicles (with battery backup for overload situations) to allow use of smaller more efficient diesel engines, and
5. long term medical implications of breathing diesel exhaust contaminated atmospheres.

Results from this research can be predicted to lead to progressive modifications in engine operation and scrubber design and changes to ventilation requirements.

NEW LOOK MINE VENTILATION

Legislation and engineering advancement have progressively improved mine atmospheric conditions throughout this century. Hartman (1987) has observed that although contaminant threshold limits are still based on human safety and tolerance considerations, there is an increasing expression of concern for human comfort. On an industry comparison basis, mining has a very poor accident and injury record, many tasks are arduous and conditions are still dirty and uncomfortable. Mining has to pay a premium to attract employees now. Cost competitiveness in attracting highly trained operators for the capital intensive mines of the future means the concern for quality of life in the underground workplace will be a big issue.

Manufacturing industry has gone through a small revolution in making pleasant and comfortable working conditions commonplace. In mines, ventilation will have to become truly an air conditioning process where physical quality control (temperature and humidity) and chemical conditioning (toxic and dangerous gas as examples) are stringently observed. There is general public concern for the quality of life and employee expectations move with these aspirations.

The push for an improved quality of life for miners will, in addition, demand that the industry's safety record is improved. In fact, demands that catastrophic disasters become a thing of the past will become very strong. Hartman (1987) has stated that the technology is in place to permit realization of a disaster-free underground environment today. Mine fires, gas and dust explosions cause most atmospheric transmitted disasters. The strong base of research findings must be expanded and developments adapted and applied to ensure that each unique mining situation is in a disaster free condition. Remote monitoring systems that both detect and respond are an important step in achieving this goal. All parties and most importantly mine operators, unions and governments must set this goal and work to its attainment.

The attainment of acceptable human conditions demands precise physiological knowledge. Mine ventilation engineers cannot work alone but must work as a team with physicians and other medically qualified people. Medical input has had a significant role in the uranium industry in assessing and controlling radiation exposure. Increased medical attention to the influence of mine diesel contaminants, respirable dust and toxic gases on employee health will surely pay dividends. A greater medical involvement in both mine research and mine operations is predicted with confidence.

The first line of defence in mine ventilation has been the implementation of a dilution strategy; the provision of a sufficient quantity of air to reduce the contaminant, whether it is a gas, dust or heat, to an acceptable level. As mines move deeper and system productions are raised, the ventilation load and the cost of reaching acceptable dilution values will increase significantly. More thought will be given to turning the contaminant to a productive use. Mining operations which are advanced in the development of methane drainage systems are aware that there can be profits in becoming producers and suppliers of natural gas. The trend will be to remove high contaminant loads from the ventilation stream and if possible turn them to a saleable product. The increase in geothermal gradient as mines move deeper may mean that the resultant heat load in return air can be turned to a useful purpose.

Mine ventilation cost as established by Murphy (1985) can make up 20 percent of the mine operating budget. This level may increase in the future and difficult mine ventilation conditions at depth are likely to cause some thought to be given to the definition of acceptable or safe atmospheric conditions. At present, it is considered that ***the mine atmosphere must be sufficiently free of contaminants to permit each miner the opportunity to work underground for the period of his entire working life without incurring any disability or occupation related disease.***

Can acceptable conditions for the miner be maintained by isolating men from the atmosphere when it is carrying peak contaminant levels? Dust and heat loads often peak during coal cutting. Placement of men in air conditioned cabs or under forced air hoods may, with appropriate safety restrictions, be the answer. In this scenario under conditions of high productivity in a capital intensive mining system, the section ventilation air quality would have to be such as to be measured as safe during non-production periods (to allow inspection, maintenance). During production periods, the contaminant level in this air stream may rise above levels considered acceptable for long term working conditions, but safe if men are normally isolated and only exposed to it when travelling in an emergency from the section using self-contained self-rescuers.

Finally some thought must be given to the question ***why ventilate a mine.***

Mines have always been hostile environments which in the past have been sites of labour intensive activity. Technological developments with sophisticated machines, sensors and communication devices mean that the presence of man at the operating face during production is less and less necessary. Remote continuous miners which cut a short distance in front of the operator have been in use for a number of years. It is perhaps a small step to isolate the machine from the operator completely. The introduction of robots into other industries should be noted.

If man is removed from the production zone, so is the need to observe normal ventilation standards. (The need for access for equipment installation and maintenance will be discussed shortly). If mine ventilation is removed, the mine opening will adjust to a methane rich atmosphere. With ventilating air and oxygen absent or in very low concentrations, regulations dictating use of enclosed motors, flameproof structures and intrinsically safe apparatus could be discarded. Mining control would be exercised from the surface, or from a normally ventilated point underground.

In this revolutionary proposed remotely controlled mining system, equipment installation and maintenance would be undertaken by men breathing with life support systems. Men work (and even live for considerable periods) both underwater and in space. The methane rich production zone as a similar zone hostile to mankind would be accessed by wearing a self contained breathing pack (a form of air recycling SCUBA unit) or through use of an umbilical cord. A separate emergency breathing pack for use in case of unit failure would be carried. Teams of men would enter the isolated production zone through air locks and work in much the same way as aquanauts or astronauts have been able to accomplish major tasks in their airless environments.

This latter approach to develop an isolated remote mining strategy cannot be expected to be considered practical for some time. However, given the pace of technological change at present, a revolutionary concept now may become an economic approach in 50 or 100 years.

CONCLUSIONS

New developments in mine ventilation have been examined by a review of present areas of intensive research activity. Major changes can be expected by the early years of the twenty-first century in the use of computers and remote monitoring systems, the understanding of the mine environment and the frequency of mine disasters, the utilization of mine air contaminants for profitable purposes and the provision of a pleasant and comfortable work environment. New approaches to ventilation such as air recirculation will have been considered. The skills of highly trained mine ventilation engineers will be needed more and more as mining moves deeper and to higher levels of productivity. With the present pace of technological change, quite revolutionary new approaches to mining and ventilation can be expected by the end of the twenty-first century.

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