

Compendium of Research Project Summaries on Fires and Explosions - 1994 to 2014

MHSC
Mine Health and Safety Council



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CEO's FOREWORD

The Mine Health and Safety Council (MHSC) is a public entity that is mandated, in terms of the Mine Health and Safety Act (MHSA), to advise the Minister of Mineral Resources on research programmes, regulations, standards, policies, procedures focused on minimising the occupational health and safety (OHS) risk at mines. The Council is also tasked with promoting a culture of health and safety in the mining industry.

The Council office executes the operational deliverables of the Council, including the provision of secretarial support to the Council and all its committees, managing research programmes, finances, communications and promotions, and liaising with other statutory bodies on matters relating to occupational health and safety at mines. Council provides a platform for stakeholder engagements on OHS matters.

The consequences associated with flammable gas explosions, coal dust explosions and fires are significant. Projects relating to eliminating, controlling and minimising the risk of explosions and fires in mines is pursued in the thrust area of Explosions and Fires, as well as emergency preparedness and response, and the monitoring of high risk areas such as hazardous locations in mines.

Fire in a mine or excavation, such as a transportation tunnel, is a serious hazard that could result in loss of life and revenue for the enterprise concerned. Mines contain significant amounts of fuel sources such as flammable material, fuels, lubricants, timber, rubber, plastics, paint and packaging materials. Coupled with these are numerous ignition sources such as self-heating of coal, flame from oxy-acetylene cutting and welding equipment, sparks, electrical short-circuits, machinery hot surfaces and friction that can initiate a fire.

The South African mining industry has, in the past, experienced several underground fire incidents. Underground fires are particularly dangerous due to the confined nature of excavations, the quantity of smoke and noxious fumes produced in relation to the limited quantity of fresh air present and the restricted ability to escape quickly from the mine. Since 2004, the industry accounted for 19 fatalities, 149 fire related injuries and a total of 71 dangerous occurrences directly related to fires. Surface operations encountered conveyer belt, plant structure and trackless mobile machinery fires during the same period.

In conclusion, the fire risk in any mine has to be managed properly. This is achieved by an assessment of the risks involved, monitoring of fire risk controls, good mine and ventilation system design, equipment and material selection, the preparation, implementation and enforcement of formal appropriate mine-specific standards.

Herein are synopses of research reports already completed by the MHSC within the thrust area of explosions and fires in the last 20 years.

Thabo Dube
Chief Executive Officer
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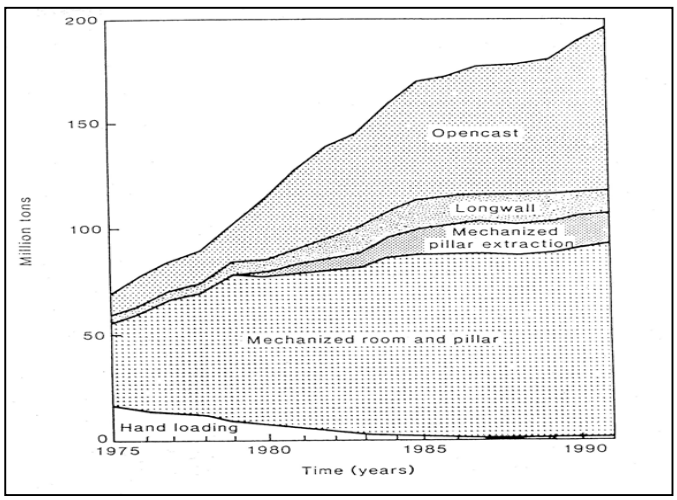


1. Review of practices for the prevention, detection and control of underground fires in coal mines

By W Holding, CSIR Mining Technology, Ref: COL 031, 1994

SUMMARY:

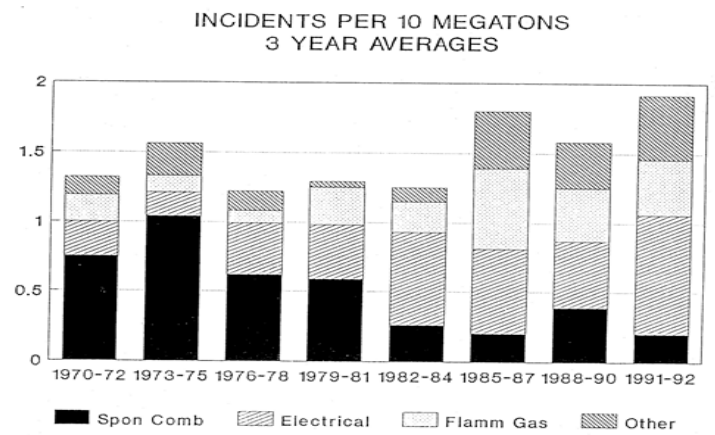
The COL 031 project deals with underground fires in coal mines. A statistical review is presented of the frequency of fires and flammable gas ignitions in South African underground coal mines, both on a simple numerical basis as well as in relation to underground coal production, for the years 1970 to 1992.



Incidents per 10 megatons (3 year averages)

From the above figure, where the incidents in the various categories of fires and ignitions per 10 megatons are illustrated, it is evident that the frequency of spontaneous combustion was less in the 1980's than it was in the 1970's and that this trend seems to have been maintained in the 1990's.

Electrical incidents have escalated somewhat since the late 1970's. This probably reflects the rising trends in mechanisation. (Figure below).



The increase in mechanization is reflected in the number of electrical and flammable gas incidents

Flammable gas incidents have also escalated, particularly since the mid 1980's. Again, this is probably a reflection of increased mechanisation. Fires due to other causes increased rather suddenly in 1985 and the trend has not been reversed over the period in question.

Detailed guidelines relating to the prevention, detection and control of underground fires in coal mines are presented in the project report. These guidelines are based partly on lessons to be learned from incidents recorded and on individual codes of practice already in existence on collieries and in mining groups.

Finally, in a series of appendices, theoretical and technical background information relating to underground fires is given for those practitioners who need to have easy access to such information.

CONCLUSION:
Some of the information contained in this report is based on experience, but a great deal of it has been derived from other sources. A study of these sources obviously add greatly to the value of the report.

2. Assessment of explosion barriers

By JJL du Plessis, MP Brandt and PS Vassard, CSIR Mining Technology, Ref: COL 010, 1995

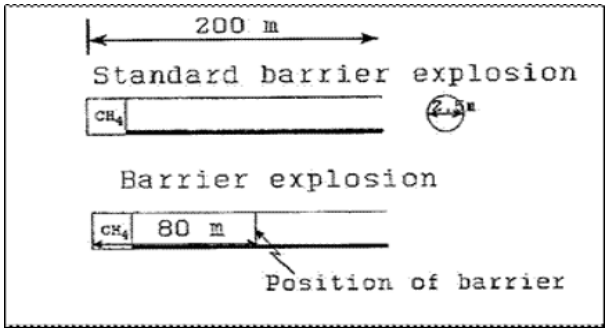
SUMMARY:

The effectiveness of different types of active and passive barriers to stop the flame propagation of coal dust explosions was evaluated in the 200m test gallery at the Kloppersbos Research Facility.

The passive barriers which have been tested include water trough barriers, stone dust barriers, and dispersed barriers and the active barriers include gas and a mixture of gas and water.

A standard test explosion was developed with enough wind pressure and flame propagation at 80m from the closed end of the gallery to activate passive water barriers, active water barriers and automatic belt roadway suppression systems.

The experimental layout for the standard explosion, standard barrier explosion and barrier explosions is depicted in the following figure below.



Experimental lay-out

The effectiveness of the systems were evaluated by determining the distance that the flame travelled. Table 1 illustrates the average distance beyond the position of the barriers where the flame was extinguished.

Barrier type	Flame extinguished at (m)
Water trough	20
Stone dust	5
Dispersed barrier	Inside barrier
Active suppression	15

Table 1: Barrier Comparison

CONCLUSION:

The results indicated in this report should be interpreted in the context of the experimental set-up and procedure described using a smooth, round gallery of 2,5 m diameter and a weak standard explosion which ensures effective operation of the passive barriers tested. This report presents results for an explosion with enough wind pressure to activate passive explosion barriers and the minimum pressure required to activate the passive explosion barriers was not ascertained. The results indicate that the barriers tested prevented the flame from passing 20m beyond the barrier when the barriers were installed 80m from the closed end of the gallery.

The water through barrier stopped flame propagation within 20m. It was found that if installed correctly and maintained properly, the light stone dust barrier would work effectively in stopping coal dust explosions from propagating. The developed dispersed barrier system shows great promise. Certain aspects still need to be addressed, which include the minimum pressure for activation and proper dispersal. The major advantages of this system are the ease of installation, the minimum maintenance required and the low cost of the system. The effectiveness and reliability of the active suppression system depends on the proper functioning of the sensors and the dispersal system.This requires qualified personnel.

3. Assesment of dispersed barrier

By JJL du Plessis and PS Vassard, CSIR Mining Technology, Ref: COL 236, 1995

SUMMARY:

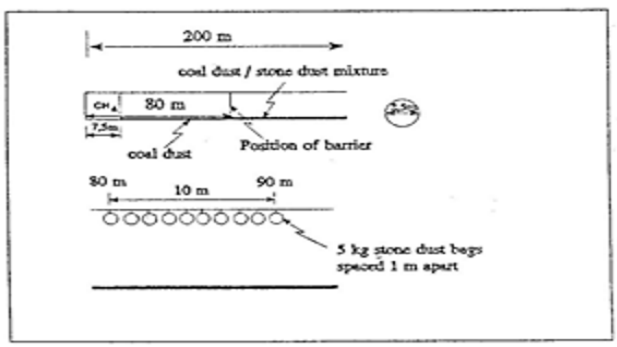
This project deals with the evaluation of the dispersed barrier system to stop propagation of coal dust explosions in the 200m test gallery at the Kloppersbosbos Research facility. The dispersed barrier system was tested in distinctively different applications: firstly, as a passive explosion barrier and. secondly. as a stone-dust supplement. i.e. to supplement the requirement where coal dust layering occurs in the underground environment.

The purpose of the dispersed explosion barrier is to stop the flame from propagating by ensuring adequate stone dust throughout the mine and thus limiting, or even obviating the need for re-stonedusting of work areas where coal-dust layering does occur.

A standard test explosion against which the effectiveness of the disbursed explosion barrier may be tested has been determined and various methods of closing the stone dust bag have been evaluated.

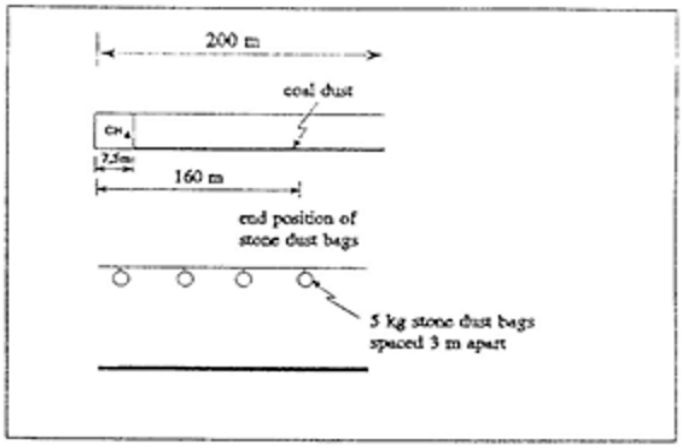
The standard test is a simulation of low-pressure coal dust explosion, as experienced in practice, for the purpose of determining the effectiveness of the barrier in stopping the flame from propagating.

For the evaluation of the initial systems a development explosion was used. The test set-up showing the placement of the stone dust bags for this is illustrated in the figure below



Test layout for development explosion

The initial tests were carried out to determine the best way of closing the bag and the most suitable type for the bag to give good dispersion of the stone-dust in the event of a weak dynamic pressure wave reaching the stone dust bag. The test layout for the dispersed barrier explosions is depicted in the following figure.



Test layout dispersed barrier explosion

Although the tests were conducted under extreme conditions. i.e. where no stone dust was mixed into coal dust, the stone dust bags were still able to stop flame propagation, and thus were successful

4. Reduce the methane hazards in collieries

By FJ van Zyl and P Linzer, CSIR Mining Technology, Ref: COL 030, 1996

SUMMARY:

The scope of the project was to examine the various options available to the industry to combat the methane risk in collieries, as well as to establish, quantitatively if possible, the effectiveness and/ or accuracy of specific methods and to improve them. Areas which were investigated included the detection of methane in mechanized mining sections, mathematical modelling for the prediction of methane emission from coal, and the determination of the effectiveness of ventilation systems using computational fluid dynamics (CFD) and in situ measurements.

The influence of barometric pressure fluctuations on methane emission rates and the benefits of methane drainage systems were also investigated.

The most common means of detecting methane in the underground mining environment is by means of filament and catalytic oxidation (pellistor) detectors. Methane can be detected in various other ways, e.g. by electromechanical means, optical methods, thermal conductivity gas detectors, acoustic gas detectors and various laboratory based techniques. From these methods, the most promising as an alternate underground low level (0 % - 5 %) methane monitoring technique is the non-dispersive infrared

range of optical gas analysers. This, in combination with a literature review, highlighted the use of accurate, robust and cost effective alternatives to current catalytic oxidation based sensors .

Current catalytic oxidation sensors in use do not operate well in regions of excessive dust and humidity, as found in the immediate vicinity of the cutting drum of continuous/mechanical miner. This is an important monitoring position from a methane hazard point of view as this is the main region of methane detection from the cutting drum region; the possibility of drawing a gas sample from this region and analysing it by conventional means was therefore investigated. A hydraulic driven rotor brush system and venturi spray system with demister were investigated as means of sample drawing. Dependency on machine power, bulkiness, time delay from sample time to analysing, inlet clogging and limited flexibility of the systems were cited as the major drawbacks of these systems which were not pursued further.

After the difficulties experienced with the sample drawing units, a continuous multi-channel methane monitoring and recording unit was developed for research into the durability of the catalytic based sensor and sensor protection evaluation, as well as for observation of general methane behaviour around an active mechanical miner. The multi-channel methane monitoring unit is an autonomous unit with six methane monitoring points and is easy to install. It can further be utilized for quantitative ventilation analysis and corresponding optimum sensor placements. Comprehensive methane data was obtained for various mechanical miners in diverse mining situations and conditions.

The main observation which arose during the CFD simulations and underground monitoring of actual ventilation set-ups was that methane behaviour and related methane levels could be closely linked to prevailing air flow patterns, unlike dust behaviour. This led to the conclusion that areas of poor ventilation, where a source of methane is evident, have a greater potential for increased methane levels.

A region which is especially prone to these conditions is the region under the cutting boom. Normal ventilation conditions tend not to introduce sufficient fresh air into this area, and combined with the increased methane emission from the cutting process and air roll induced by the cutting drum rotation, give rise to increased methane levels. The situation is further aggravated as the mechanical miner moves into a first lift, further restricting ventilation reach to the mechanical miner cutting head.

Most methane prediction packages, mathematical or empirical, have been developed for foreign coal fields and, in most cases, for specific applications. With the distinct advantages of simulation over empirical prediction, a comprehensive two-dimensional mathematical, unsteady state, dual-porosity, single-phase, numerical methane simulator was derived with South African coal characteristics as inputs. The simulator will simulate accurately the effects of gas contributions from any practical mining situation, however, the accuracy is dependent on the reliability of the input data.

Barometric pressure fluctuations have, in the past, been associated with increases in underground methane levels. From a study comprised of 35 methane-related incidents and barometric pressure fluctuations, it was found that the most likely scenario for a methane ignition to occur, from a barometric pressure point of view, is during a diurnal pressure drop.

CONCLUSIONS:

With the present level of technology, the likelihood of measuring methane concentrations at a coal face in the range of 0,2 - 2,0 per cent with acceptable accuracy, is doubtful. The fastest way of detecting methane by means of catalytic based sensors is to measure methane at the point where it is released. The development of the intrinsically safe multi-channel methane monitoring system (MMMS) has definite potential in both the research and production realms. Simulation models of methane flow and release have the ability to simulate any practical mining situation The accuracy and reliability of the answers they generate will depend mostly on the degree of detail and accuracy of the input data received. There is a link between general barometric pressure behaviour and methane levels. Initial analysis suggest that a sudden decrease in barometric pressure can cause a substantial increase in methane levels, and the inverse also seems to hold true with indications that the process is time dependent. A broader database is needed to predict trends more accurately. The limited information available on drainage rates, seam pressures, contents and physical properties suggests that methane drainage may not be as successful in South Africa as it is elsewhere if practised in the same way.

5. Determine the feasibility of techniques for simulating coal dust explosions

By TJ Kirstein, CSIR Mining Technology, Ref: COL 104, 1996

SUMMARY:

The prime objective of SIMCOL 104 was to assess the feasibility of reliably simulating the coal dust explosions taking place in the Kloppersbos tunnel with a computer model. Secondary objectives aimed to investigate the viability of simulating methane explosion suppression techniques, developing methods for minimizing dangers of coal dust explosions, and implementing these simulations in complex mining geometrics.

To achieve the above goals, a literature survey was undertaken to ascertain whether a computer program which can be used to address the problem that exists, and also to identify the most successful models of coal dust explosions and methane explosions.

In addition, a number of research groups were identified that have individually simulated aspects of the problem, including gas explosion and steady-state coal dust combustion and detonation.

Group	Program	Current Capability	Maturity
Tel-Tek	EXSIM	Gas explosions	Moderate
CMR	FLACS	Gas explosions, dust being devlp.	High
TNO	REAGAS	Gas explosions	Moderate
CD/MREL	IFSAS	Explosions (inviscid)	High
WANSW	Green	Gas explosions	Low
B-GAS	COBRA	Gas explosions	Unknown
UK AEA	FLOW3D	General, fires and gas explosions	High

Available Software

Established and validated programs to be considered as a basis for simulating explosions are depicted in the table.

If any of the above computer programs are obtained either by purchase or through collaboration, a number of activities will have to be performed to achieve useful simulation results. The program will have to be ported onto the computer system available, compilation differences removed, and the results verified by running a number of test cases. The capability to predict gas explosion propagation through complex geometries will then exist in South Africa if FLACS, EXSIM, REAGAS or Green=s program is selected. IFSAS in its current form is inviscid and does not have the capability to consider viscous flows. FLOW3D may require additional modification to reach the level of capabilities of the gas explosion programs. This program should be able to simulate methane explosions in the Kloppersbos tunnel and in a mining layout with a similar level of confidence as in the gas industry, i.e. about 50 per cent accuracy on overpressure. The reliability of this base CFD software will largely depend on which program is selected as each reached a different level of maturity and validation.

When this program has been used to analyse methane explosions, the next step will be to add the components necessary to simulate coal dust. This process will involve both numerical and experimental development. Numerical development will take place in the areas where the effect of the dust can be simulated by mathematical models. Experimental development will be essential in areas where the physical phenomena cannot be modelled at present and an empirical model will have to be linked to the numerical model. Experimental measurements will also be necessary for validation, unless suitable experimental data already exists.

After the development of the coal component of the numerical model, this program should be able to meet the objectives of the project. This means that the safety needs of the mining industry can be addressed by means of numerical simulation. This will only be true if the development program is successful, which is by no means guaranteed because it has never been achieved to date. The simulation accuracy should only be limited to the present level of numerical simulation technology and the level of approximation employed. Confidence in the simulation can only be measured and developed through validation, i.e. comparison of numerical results with experimental results.

Opinions on whether coal dust explosions can be successfully simulated are varied. The established mining industry is sceptical (USBM, UKHSE), the applied research companies (CD, MREL, CMR, TNO) believe that with sufficient funding the main features can be modelled, and the universities believe that given sufficient effort it can be done. It is generally agreed that this problem combines all the possible complexities a numerical model could have and would be a model at the leading edge of numerical research. This confirms that it will be critical to select a development path, which offers a suitable risk to investment balance. Experimental input to this process will also be essential in the realms of empirical model development and validation.

The cost of developing a gas explosion model into a coal dust explosion simulation program is determined by the development method employed. The method that will be used is not defined at present, but if a development strategy similar to the gas industry is used, i.e. incremental improvement, an approximate cost can be determined.

CONCLUSION:

No simulation program exists which could reliably simulate the coal dust explosions in the Kloppersbos tunnel facility. No organisation, national or international, is considering this problem directly at present. A development plan to achieve a reliable simulation of coal dust explosions covering three areas, namely, one-dimensional, three-dimensional simulation and an analytical approach, is recommended.

6. Identify methods to reduce the risk of explosions and fires caused by frictional ignition hazards

By HR Phillips, University of the Witwatersrand,
Ref: COL 226, 1996

SUMMARY:
The project has three primary outputs, namely, a literature review of the research conducted worldwide into the phenomenon of frictional ignition, a review of whether machines currently used in South Africa comply with known principles for reducing frictional ignition risks, and, finally, recommendations for improving the situation.

The literature research identified 155 papers, articles, reports and books directly related to this topic. Contact has been established with five research centres and a visit was made to the Health and Safety Executive (UK) laboratory at Buxton.

Machine manufacturers have supplied information for the study, as has the Department of Minerals and Energy Affairs and the South African coal mining industry.

While metal on metal or rock on rock ignitions are still hazards in modern coal mining, the vast majority of frictional ignitions are situations where small pockets of methane in air are ignited by a spark from a cutting machine. While better ventilation of working faces can significantly reduce the risk of ignition or ensure that any ignition remains a harmless event, with the flame localised and easily extinguished, the potential for disastrous consequences remains. . While an average of just under two frictional ignitions are recorded each year in South African collieries, every effort must be made to reduce the risk of explosions and fires caused by this phenomenon.

The main results of the very considerable body of research that has been devoted to cutter pick ignitions highlighted the following four significant aspects:

For a frictional ignition to occur, cutter picks must come into contact with strata containing either quartz or iron pyrites. Quartzitic rock must contain at least 30 per cent of fairly coarse quartz grains before the risk of ignition becomes significant. It is, therefore, possible to use petrographic and other analytical techniques to undertake a risk assessment of any site where a machine is to be deployed.

The sources of frictional ignitions are not sparks but smears of melted quartz that are left on the rock surface as a result of rubbing friction. The risk of frictional ignition rises rapidly when worn tools, which need higher cutting forces and energy, are used. It follows from this that one of the most effective precautions against frictional ignitions caused by shearers, continuous miners and coal cutters is to maintain picks in good condition and to change them before they wear excessively.

Research has shown conclusively that reducing pick speed reduces the risk of frictional ignitions because the length of hot spot also decreases. Because the performance of longwall shearers tends to be limited by the rotational power available to the drums rather than the haulage force, it has been possible to reduce drum rotational speeds significantly, with some machines operating at 19 rpm. The consequent reduction in pick speed has probably had a major impact on the frequency of frictional ignitions caused by shearers. Continuous miners, on the other hand, tend to be limited by the thrust generated between their tracks and the floor. Experience with modern, heavy continuous miners has shown that rotational speed can be reduced, certainly to 37 rpm, with no adverse effect on production and improved dust readings. However, with a 1 m diameter drum this would still produce pick speeds of nearly 2 m/s, i.e. well above the 1 to 1,5 m/s at which the frictional ignition risk starts to diminish. Currently there appears to be no prospect of continuous miners being manufactured with the required rotational speeds of below 20 rpm.

Overall, the most effective means of preventing frictional ignitions during cutting is to spray water directly behind the pick, parallel to its direction of travel. This quenches the hot spot within the lag time for methane ignition, provided such important criteria as quantity, droplet size and, to a much lesser extent, minimum water velocity are met. Research has produced proven designs of suppression systems to be used in conjunction with all common types of pick. For many years cutting drums on longwall shearers and some roadheaders have been equipped with phased water supplies, to supply nozzles in front of and behind individual picks. However, wet heads are not yet commercially available for continuous miners because of technical problems associated with large-diameter rotary water seals.

CONCLUSION:
Research into frictional ignition hazards and their prevention has been conducted continuously since the mid-1920's. Major programmes have been carried out in Germany, Poland, the former Soviet Union, the United Kingdom and the United States, with significant contributions from Belgium, France and several other countries. Since the late 1980's the volume of work has declined very significantly, with only some European Community funded research and an Australian initiative providing current data. The results of all this research can be characterised as conclusive and repetitious, in that most of the major findings have been confirmed by several research groups working independently.

While metal on metal or rock on rock ignitions are still hazards in modern coal mining, the vast majority of frictional ignitions are situations where small pockets of methane in air are ignited by a spark from a cutting machine. While better ventilation of working faces can significantly reduce the risk of ignition or ensure that any ignition remains a harmless event, with the flame localised and easily extinguished, the potential for disastrous consequences remains. While an average of just under 2 frictional ignitions are recorded each year in South African collieries, every effort must be made to reduce the risk of explosions and fires caused by this phenomenon.

7. Methane prediction in collieries

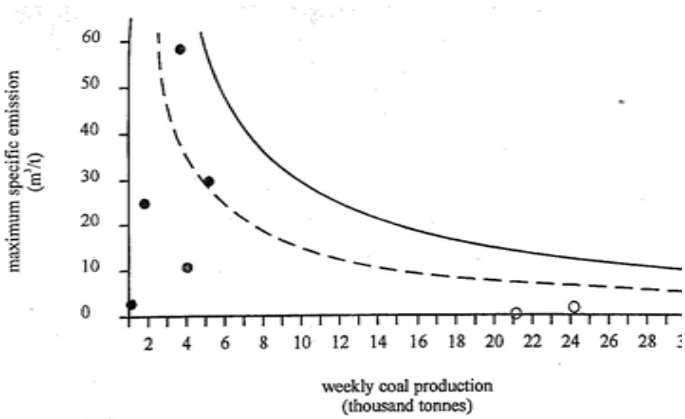
By DP Creedy, Wardell Armstrong, Ref: COL 303, 1996

SUMMARY:

The primary aim of the project was to assess the current status of research on methane emission prediction for collieries in South Africa in comparison with methods used and advances achieved elsewhere in the world. South African research on methane prediction has lacked a clarity of direction, probably as a result of insufficient contact with the research programmes of other major coal mining nations, too few researchers and a shortage of research expertise. Considerable effort has been devoted to measuring gas-related properties of coal seams at a few, unusually high gas emission sites, using both in situation and laboratory techniques. Underground methane emission investigations have been generally limited in scope with a strong, but misplaced, emphasis on studies of the effect of barometric pressure on gas emission rates indicative of a lack of appreciation of fundamental principles.

Nevertheless, useful work has been done on the characterisation of the reservoir properties of South African coals, an advanced gas flow simulator has been developed, and a range of underground investigation tools designed and tested.

Gas emission problems in South African coal mines seem to arise mostly as a result of locally disrupted ventilation systems, accumulations of gas in the cutting zone of continuous miners where adequate local ventilation is difficult to sustain with the methods in current use and also when mining in proximity to igneous intrusions or faults when unusually high gas flows may be encountered. Initial indications are that methane gas concentrations in the return airways of South African bord and pillar workings are relatively low, and generally not a constraint on coal production rates, whereas on a few longwalls gas emissions could attain critical levels due to the high coal extraction rates sometimes achieved.



The maximum specific emission controllable with ventilation aid

Practical methane emission prediction methods have been developed in countries where longwall methods of mining are predominant. As a result of improved mechanisation of longwalls, gas emission rates have increased commensurate with the increases in coal production rates achieved. In these circumstances, gas prediction tools have proved invaluable for planning ventilation and gas control requirements to ensure coal production targets can be met.

Most of the established gas emission prediction methods used at collieries elsewhere in the world are empirical. Few having a sound theoretical basis but all apparently successful in their countries of origin. Some models are also applicable to board and pillar methods of mining but have not been proven outside their country of origin. In general, these models are relatively simple to use, attuned to local conditions and needs, have known limitations and are based on

physical principles understood by the user.

No commercially available software has been identified which could be readily applied to South African coal mines to satisfy the practical needs of environmental engineers. However, an existing, soundly based, empirical gas prediction model could be adapted for application to South African longwalls. Development of a more sophisticated gas flow simulator could not be justified given the relatively few longwall operations in South Africa.

8. Systems to limit coal dust and methane explosions in coal mines

By JJL du Plessis and PS Vassard, CSIR Mining Technology, Ref: COL 322, 1997

SUMMARY:
This project deals with research into reducing the methane and coal dust explosion hazard in a cost-effective manner and has led to the development of a new method for building stone dust barriers. The method makes use of a previous concept of containing stone dust in a bag, but incorporates a new means of rupturing the bag. The closing mechanism was adapted, and by balancing the stone dust content with the bag, a new mechanism for rupturing the bags was developed. This is the first time the principle of containing stone dust in a bag has been applied effectively, despite numerous attempts worldwide.

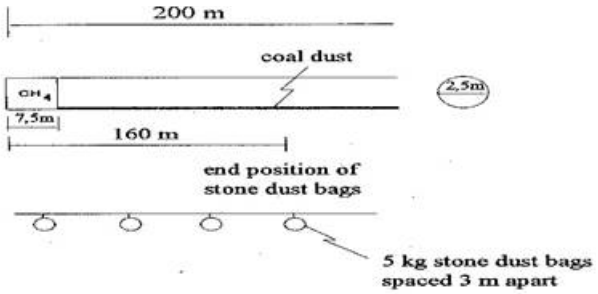
In the development and evaluation phase of the research, the bags were tested extensively in the 200-m test gallery at Kloppersbos. During these tests, it became evident that the bags could be made to rupture and spread stone dust even when subjected to low dynamic pressures.

Limited test work done during August 1995 at the DMT Research Facility indicated that for the specific plastic bag tested, a minimum dynamic pressure of 6,5 kPa was required. Subsequent improvement in the quality specification of the plastic bag resulted in a minimum dynamic pressure of approximately 3,0 kPa being required for effective operation.

The standard test explosion that was developed to evaluate different barrier types (an explosion with enough wind pressure and flame propagation at 80 m from the closed end of the gallery to activate passive barrier systems) was utilised in the initial tests.

The dispersed barrier was evaluated in terms of its effectiveness in preventing further flame propagation. The dispersed barrier system was tested for a number of different applications: as a stone dust supplement, i.e. to supplement the legal requirement where coal dust layering occurs, and as a passive explosion barrier (as a concentrated and distributed barrier system).

The test layout for the explosion in which stone dust bags were used as a supplement is illustrated in the figure below.



Test layout for explosion in which bags were used as a supplement

The use of stone dust bags as a stone dust supplement showed great promise and the flame propagation was effectively stopped in every explosion (table below) although further test work is required to prove the principle of operation.

Description	Flame extinguished (m)	Flame visible at gallery mouth
Stone dust bags	125	NO
Stone dust bags	95	NO
Stone dust bags	100	NO
Stone dust bags	170	NO
Stone dust bags	150	NO

Stone dust supplement results

In the light of the Leon Commission's report, the application of the stone dust bags in the form of a single concentrated passive barrier was also investigated.

The ability to prevent flame propagation was evaluated against the results of the barrier explosion. A weak, standard barrier explosion was developed for testing explosion barrier systems. It was similar to an initiating 9 per cent methane/air mixture explosion of 36 m volume with a wind pressure of approximately 25 kPa, and with flame propagation throughout the gallery from coal dust combustion, without the production of additional pressure. The mean delay time (between flame and dynamic pressure wave) for the standard explosion was 400 to 600 ms.

In the tests conducted to assess the barrier's use as a passive explosion barrier, the flame propagation was stopped effectively. At the lower limit of the normal passive stone dust barrier requirement (100 kg/m^5),

flame propagation was effectively inhibited for both the concentrated and distributed barrier systems tested.

CONCLUSION:

With the establishment of this facility, the South African coal mining industry now has the means to test and modify active suppression systems to suit its particular needs. By using systems based on overseas technology, which have been adapted to suit South African conditions, valuable time is saved. Such systems can be customized for local implementation without incurring development costs. In the event of these overseas systems not being suitable, a facility now exists to assist in the development of local systems. The successful suppression of the methane ignitions has highlighted the importance of the Explostop system in reducing the risk of underground methane ignitions developing into coal dust explosions. The establishment and use of this facility has made and can make a significant contribution to the understanding of methane explosions and to reducing the residual risk of underground explosions. From the results of the latest tests, it is evident that the system under investigation has the potential to reduce significantly the risk of methane ignitions developing into coal dust explosions.

9. The occurrence, emission and ignition of combustible strata gases in Witwatersrand gold mines and Bushveld platinum mines, and means of ameliorating related ignition and explosion hazards

By A P Cook, Itasca Africa (Pty) Ltd, Ref: GAP 504, 1998

SUMMARY:

The output of the project comprised three main sections, literature, gas incidents and accidents, and technical interviews with mine personnel. This approach was key to measuring the occurrence, emission and ignition of combustible strata gases in Witwatersrand gold mines and Bushveld platinum mines, and findings a means of ameliorating related ignition and explosion hazards

Literature covered combustible gas emissions in mining operations in South Africa and other countries, as well as the geological origins of methane. All gas emissions reported at the DME from 1987 to 1997 were reviewed, a total of 1914, as well as 32 accident reports. Technical interviews were conducted on 33 individual mines, to evaluate the approach taken by the mines and ventilation practitioners to combustible gas emissions.

Combustible gases are reported from hard rock and other non-coal mining operations all around the world, and occur in numerous strata and ores. Methane is the predominant gas, although often associated with other hydrocarbons and hydrogen. The geological origins of methane can be determined by isotopic analysis of the carbon and hydrogen in the methane, with the carbon isotope 13C the main indicator. This classifies the methane as being of biogenic or abiogenic origin, from either an original bacterial type origin or not. Biogenic methane is further classified into recent, such as landfill and coal origins, or more ancient, such as thermogenic gas. Abiogenic methane is classified as hydrothermal, from volcanic intrusions through carbon bearing strata, or from the earth's mantle.

South African gold mine methane could be bacterial, hydrothermal, abiogenic or a mixture of all of these. Platinum mine methane is almost certainly abiogenic.

The number of flammable gas reports and accidents are increasing steadily for both gold and platinum mines, with the highest number of occurrences being in development, and commonly from diamond drill or cover drill holes. There are both regional and mine by mine variations in occurrences, but this is influenced by different reporting priorities on different mines.

Gold mines have more ignition related accidents, whereas the platinum mines have face outbursts during drilling, usually without ignition. The most common causes leading to gas accidents are changes to the ventilation, lack of testing for gas, and contraband, and of those of gas ignitions are contraband and illegal tampering with caplamps.

There is a general lack of awareness of the hazards of methane on mines, with only four mines considering combustible gases to be a problem. It is likely that methane is regularly emitted from strata but the normal ventilation is sufficient to control it. Very few reports have methane above five per cent in the general body. These factors, and the number of accidents involving ventilation and gas testing, indicates this lack of awareness.

CONCLUSION:

Increasing trends in combustible gas incidents and accidents are in contrast to the industry-wide perception that combustible gases do not present a significant problem. Uncertainty as to the origins and transport mechanisms of gas within the strata make emissions difficult to predict, so although the ventilation is adequate to control the normal situation, sudden emissions do create problems.

Adjustments to ventilation arrangements, inadequate testing for gas and contraband contribute to almost every accident in South African mines. All of these are avoidable and manageable causes, as found by this study.

10. Remote flammable gas detection/ measuring device

By V A Kononov, CSIR Devision of Mining Technology, Ref: COL 601, 1999

SUMMARY:
This research report presents the results of an evaluation of the existing open path remote flammable gas detection/monitoring technology and provides recommendations on possible limited implementation of this technology and future development for improving safety in South African mines.

Open path remote gas sensing instruments involve an infrared beam of a specific wavelength travelling through the atmosphere and being attenuated by the gas of interest. A range of commercial equipment is available for military and industrial use. No portable commercial equipment suitable for underground application has been identified. Some R&D aimed at the development of an open path remote flammable gas measuring device has been carried out in the USA, but the device never reached the stage of a commercial prototype.

Moreover, an evaluation of the effectiveness of these devices and the method itself demonstrated that the method of open path, remote flammable gas measurement, in its existing form does not comply with the current safety regulations and hence should not be used for routine underground flammable gas monitoring. The main problem of the method used lies in the fact that it provides an integrated measurement of gas concentration along the path, or, in other words, a percentage of gas concentration per metre. It is impossible to identify an area with a dangerous level of flammable gas using this method. The measurement of flammable gas concentration in a sealed area seems to be the only possible application of existing open path remote methane detectors. The reason for this is that there is no significant air movement in sealed areas and the methane and air mixture remains relatively homogeneous. Therefore, an integrated measurement of methane concentration per metre will directly correspond to the actual point concentration of the gas.

The South African coal mining industry requires flammable gas monitoring of a dangerous zone from a safe position. Therefore, it is proposed that the time sampling or ranging open path remote sensing methodology be developed for underground application. This is a more sophisticated technology enabling the distribution of flammable gas concentration along the open path to be determined, thus ensuring that the safety regulation requirements for routine methane monitoring and early warning are met.

CONCLUSION:

The open path remote gas sensing technology was originated for military use and from the early 1970's was accepted for atmosphere monitoring of chemical plants, etc. However, devices are bulky and expensive. Some development has been done in using the technology in underground conditions but these devices have never reached the level of a commercial prototype. The open path remote gas sensor provides the only true integrated (averaged) concentration of methane per metre along a path. It does not detect areas where a dangerous level of methane has built-up. From the point of view of safety and the current regulation requirements, such a measurement in its existing form is inadequate for underground mine safety and could even be dangerous.



Measuring methane concentration in a sealed area seems to be the only possible application of the current open path remote methane detectors. The reason for this is that there is no significant air movement in sealed areas and the methane and air mixture is relatively homogeneous. Therefore, integrated measurement of methane concentration per metre will directly correspond to the point concentration measurement. In order to use open path remote flammable gas sensing, it is proposed that the time sampling or ranging open path remote sensing methodology be developed. The operational distance of the proposed detection device depends on the conditions of underground atmosphere as the device will use light scattering off dust particles and vapour molecules. It is assumed that this more sophisticated technology will enable the point distribution of methane concentration along an open path to be obtained. This, in turn, will allow the regulation requirements for routine methane monitoring and early warning to be met.

11. Design, construction and testing of underground seals

By A P Cook, J N Van Der Merwe, Itasca Africa (Pty) Ltd., Ref: COL 502, 2000

SUMMARY:
Research in the USA and Europe has shown that explosion proof seals can be developed from a variety of materials and designs, but are generally built to suit availability of material, and are over-designed, with actual designs based on trial and error. Explosion proof seals are generally defined as capable of withstanding pressures of 20 psi, but have been tested at pressures above 300 psi. The US regulations concerning the construction of seals are based on the long-term explosion research programmes carried out by MSHA, and in particular, the more recent work during the 1990's at the Lake Lynn facility.

Regulations state that a seal must withstand a static horizontal pressure of 20 psi and although there are construction details given, any alternative construction is permitted if it meets this pressure requirement, and is fire retardant.

In addition to the pressure requirement, MSHA have air leakage guidelines that a seal must withstand after an explosion, and recommend it should maintain its operation for a minimum of one hour after an explosion.

Approval of seals is by full-scale explosion testing at Lake Lynn, where seals are exposed to explosions producing 20 psi (140 kPa), and then tested for leakage.

Looking to the Australian approved standards for ventilation control, they too do not address the structural design or material requirements for seals, but also require an overpressure of 140 kPa, and this within 24 hours of construction.

Approved systems for seal construction from MSHA are concrete blocks, Omega 384 foam blocks, cementitious foam seals and polymer foam seals. These all have approved methods of construction. There are no effective small-scale tests, or non-destructive in situ tests for designs, materials or existing seals. Further work should be carried out to investigate small scale testing, and an evaluation method for existing seals.

Essentially, the US definition of explosion proof seals is limiting, and ensures an effective one-hour operation of a seal post-explosion. This needs to be further considered for the South African application and context, and whether the seal must maintain the mine operations as well as provide escape time.

CONCLUSION:

The definition and requirements of explosion proof seals as applied in the USA and Australia may not meet with South African requirements. The seals are defined to meet requirements as relatively short life post explosion, and may not necessarily remain operational in terms of maintaining the operating functions of the mine, after the shorter-term life saving requirements.

12. Bagged stone dust barrier evaluations in a bord-and-pillar mine

By J J L du Plessis, E S Weiss and K L Cashdolla, CSIR Miningtek, National Institute for OccupatioNal Safety and Health (NIOSH), Pittsburgh Research Laboratory (PRL), Pittsburgh, Pennsylvania, U.S.A., Ref: COL 501, 2000

SUMMARY:
A project to evaluate the South African bagged stone dust barrier was successfully completed at the US National Institute for Occupational Safety and Health (NIOSH), Pittsburgh Research Laboratory (PRL), Lake Lynn Experimental Mine (LLEM) during the period November 1999 to May 2000. The tests were conducted in a three-entry section of the LLEM.

The primary objective of the work was to evaluate the performance of the distributed and concentrated bagged barriers in a multiple-entry mine section. To this end, two evaluation explosions were used. The

fuel zone of the first explosion type was only in the centre B-drift, and the barrier was also installed in B-drift. The distributed barrier extended from about 74 to 169 m and the concentrated barrier extended from about 74 to 104 m in B-drift. In the second explosion type, coal-stone dust fuel mixtures were placed in all three drifts. A total of six explosions, two baseline and four barrier evaluation explosions, were conducted. Two explosions each were used to evaluate the distributed and concentrated barriers.

The distributed barrier was successful in both types of explosion tests in inhibiting flame propagation. The flame extended further for the explosion tests in which the dust was loaded in all three entries compared with dust loaded only in the centre entry, but in both cases the flame was stopped within the barrier zone. The concentrated barrier was also successful in stopping flame propagation in both explosion tests.

From the full-scale experimental mine test results, it can be concluded that both bagged barrier designs were effective in stopping coal dust explosions in the multiple entries of the LLEM.

CONCLUSION:
The major findings of the B-drift methane test results against the individually suspended barrier bags with the seal in crosscut 1 between B- and C-drifts are:

- The bags operated at dynamic pressures as low as 4 kPa
- The static pressures in A-, B-, and C-drifts quickly balance to equal pressures except near the ignition position in B-drift.
- Bags suspended in the crosscuts did not distribute stone dust effectively in the areas where pressure equalization occurred.
- The bags in the drifts (A, B, and C) operated effectively
- The stone dust bag at position 29, just outbye of the methane ignition zone, operated and dispersed effectively, indicating a rapid time response prior to flame arrival.

13. Inertisation of sealed coal mine panels using microbial organisms

By D P Creedy, C Burton, A Sharman, H R Phillips and J J Alexander, Wardell Armstrong, Ref: COL 604, 2000

SUMMARY:
Methane can accumulate in sealed areas of bord-and-pillar workings and, under certain circumstances, could be ignited, which presents risks for workers. The aim of this report was to naturally occurring, harmless, micro-organisms to remove methane from underground coal mine atmospheres.

Results of a world-wide literature survey, complemented by laboratory testing on mine water samples, were used as a basis for assessing the applicability of the technology to conditions in South African coal mines.

CONCLUSION:
Technical information and data have been gathered which indicate the feasibility of applying biological methods to reduce methane risks in sealed areas of South African coal mines. A field trial is now required to demonstrate the practicality of the approach and provide the basis for designing an operational system.

14. Quantification of methane behaviour in continuous miner headings using a controlled environment

By F J van Zyl and B K Belle, CSIR Miningtek , Ref: COL 619, 2000

SUMMARY:
In order to quantitatively assess the effect a ventilation system has on in-heading methane control around a continuous miner, the amount of methane released into the heading needs to be known. This could only be carried out in the controlled environment of a test gallery.

The aim of this project was to determine the methane control and dilution ability of the retrofitted hood and half-curtain ventilation systems. The two systems were tested in the full-scale ventilation test gallery at CSIR Miningtek's Kloppersbos Test Facility.

The effect of three variables were investigated during the test series, namely the distance of the force column outlet from the face, the pressure of the water supply to the spray fan system, and the rate of methane release into the test section. The tests were conducted for an identified worst-case scenario under static ventilation conditions.

For all the tests, the two ventilation systems complied with the regulatory requirements that have been laid down. The only exception was that for the retrofitted hood system, the air velocity over the operator's cab was insufficient when the outlet of the force column was more than 20 m from the face.

The test results indicate that the half-curtain system has better methane control and dilution abilities than the retrofitted hood system for the scenario tested. It

also came to light that when the force column outlet is moved further than 20 m from the face, its effect on in-heading ventilation conditions is very limited. With a water supply pressure of 15 bar, the face-sweep effect of the water spray system is more pronounced than with a supply pressure of 20 bar.

CONCLUSION:

Both the ventilation systems are able to keep the peak methane levels below the maximum allowable levels for the methane emission levels of 80 L/ min, 200 L/min and 600 L/min. It is clear that for the same scrubber unit and force column set-up, the half-curtain ventilation system has better in-heading methane dilution and controllability than the retrofitted hood system at a methane emission level of 600 L/min. During the tests with a methane emission level of 600 L/min, it was found that when the force column outlet is moved further than 20 m from the face, its effect is significantly reduced. At 25 m, a negative flow over the cab is induced when the on-board ventilation is switched off (scrubber and spray fan system). The half-curtain system promotes the 'sweeping action' across the face better than the retrofitted hood system during the methane release rate of 600 L/min. This may be related to the location of the scrubber inlets. Better 'face sweeping' is obtained with a water supply pressure of 15 bar than with 20 bar at methane release rates of 80 L/min, 200 L/min and 600 L/min. The half-curtain ventilation system is able to maintain the required ventilation across the operator's cab for all test conditions. For the retrofitted hood system, this requirement is not met when the force column is 25 m from the face. To determine the percentage methane recirculation, it will be necessary to measure the methane levels at the scrubber outlet.

15. Development and evaluation of a new prototype P&T system to determine in-heading gas release rate

By F J van Zyl, CSIR Miningtek, Ref: COL 622, 2001

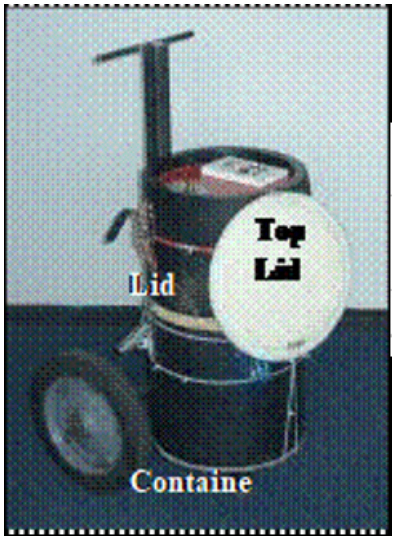
SUMMARY:
In order to quantify the potential methane hazard in underground coal mines, it is necessary to determine the in-seam methane content and an expected gas release rate during production. Various methods for estimating this have been proposed, ranging from empirical formulae to direct measurement of the methane released from coal samples in the form of drill chippings or cores.

These methods generally suffer similar drawbacks, i.e. they are site-specific, have long time delays before data become available, use small sample sizes and/or inaccurate estimation methods, often involve cumbersome test and post-test procedures, etc. Despite their shortcomings, these are the only methods currently available to the industry.

Based on this information, was decided to investigate alternative methods that would be inexpensive, easy to use by mine personnel, robust enough for use in a production section, and provide information in as short a time as possible. To overcome the above drawbacks, a new approach was explored that would eliminate as far as possible the current drawbacks.

Initial investigations were focused on a theoretical gas release rate model, which postulates that five parameters govern the rate of gas release from cut coal. The model was modified to simulate pressure build-up due to gas release into a hermetically sealed environment. The test was performed physically by sealing a cut coal sample in a canister and measuring the pressure build-up due to gas release. The theoretical model's pressure vs time pressure curve was then 'adjusted' by varying the identified governing parameters to fit the measured curve. This will uniquely describe the parameters governing gas release, thus allowing the theoretical model to be used to calculate the gas release rate and content for the coal seam under ambient conditions. Although the actual and theoretical pressure curves were similar in shape, it proved very difficult to refine the gas release model sufficiently to give a unique set of governing parameters, as convergence of the solution could not be found. As the hardware for the experiment had already been built, it was decided to investigate the option of using the Ideal Gas Law to determine the rate of gas release from the cut coal for the first 30 minutes after it has been cut from the face. This will give a good indication of the gas generated during production at the face, which is a high-risk area with regard to the ignition of gas explosions

The results obtained are encouraging. Due to the nature of the system, it provides advantages, which includes: accurate results, is easier to operate than current systems as it is semi-automated, has self-diagnostic abilities to increase confidence, and the quality of the data allows parameters to be developed that will give advance warning of increasing gas release levels. The system data can also be incorporated into current gas release rate databases or systems.



The P&T In-Heading Gas Release Rate System

No.	Mine	P&T System* (m³/ton)	Direct Test Method (m³/ton)
1	Mine A	0,13	0,10
2	Mine A	0,09	0,07
3	Mine B	0,00	0,01
4	Mine B	0,00	Not detected
5	Mine B	0,00	Not detected
6	Mine C	0,00	Not detected
7	Mine C	0,00	Not detected

Initial P&T System results

CONCLUSION:

The theoretical simulation of gas desorption from broken coal is a very complex matter which is difficult to solve in a practical way. The gas desorption model that was originally developed is unable, in its current form, to simulate the gas release from broken coal accurately enough. If such a model can be developed successfully, the proposed P&T System will be well suited to provide field data for inputs. The concept of using a gas desorption model based on data on pressure build-up due to the desorption of gas from coal in a container to determine in-seam gas content is sound. Of course, extensive resources and time would be required to solve the model adequately for it to be used commercially. Moreover, such an outcome is not guaranteed. By using the Ideal Gas Law, the data on pressure build-up in a hermetically sealed canister can be used to accurately predict the rate of gas release for the first 30 minutes of cut coal from the face. By using a regression equation, with regression coefficients of > 0,99 achieved, the lost gas from the coal sample can be easily and accurately determined. Due to the nature of the operation of the P&T System, it can be used to easily and accurately determine the gas release rate from and gas content of broken coal in a heading for the first 30 minutes after it has been cut from the seam. The semi-automated operation of the P&T System confers positive data integrity evaluation, and hence reliable results. The system allows gas release rate monitoring to be done easily, in house. The digital format allows effective record keeping. The quantity and quality of the data allow release rate indicators to be developed for predicting potentially hazardous conditions. The P&T System needs to be made more ergonomically suitable for general underground use. If possible, the system needs to be able to give in situ results. The information generated by the P&T System can be incorporated into currently available gas content prediction tools, e.g. the “on-the-spot” methane rating system.

16. Strategies to monitor non-homogeneous atmospheres in sealed off panels in coal mines

By D R Hardman, D P Creedy and H R Phillips, University of the Witwatersrand , Ref: COL 602, 2001

SUMMARY:

Many South African coal mines contain large areas sealed off from the mine ventilation. These areas contain an atmosphere sampled only at or near the seals. The research described in this report was commissioned to examine whether the current methods of monitoring sealed off areas are adequate, how South African practice compares with the methods used in other countries and whether alternative monitoring systems exist.

The research has shown that monitoring deep within sealed areas is not normally a major concern worldwide and that periphery or near-seal sampling is normal. When circumstances indicate the need for multi-point sampling in sealed areas, the accepted method is the tube bundle system, where samples are drawn through small diameter tubes to a central (usually surface) installation and the atmosphere from each tube is sampled sequentially prior to being analysed for the presence of a range of gases.

Although the report identifies a number of factors which increase the risk of the occurrence of non-homogeneous atmospheres in a sealed off area, the one tube bundle installation in South Africa for which data has been analysed has indicated a remarkably uniform atmosphere, where all the sampling points gave readings very similar to standard near-seal observations.

The alternative to the tube bundle system is to use standard, fixed-point gas sampling apparatus. Because these instruments need a power supply, routine maintenance and regular calibration, their use in a sealed off area cannot be recommended.

Overall, no new or novel devices could be identified during this study but two concepts, both using infra-red detection of flammable gases, do appear to have potential, however this would require considerable research and development before they would become viable alternatives to the tube bundle system.

CONCLUSION:
The primary objectives of this research were to review the practical problems in monitoring the non-homogeneous air content of sealed-off panels, to identify the technologies available for this purpose and to identify and recommend strategies to measure non-homogeneous atmospheres in sealed areas.

Some of this work has been impossible to accomplish since, for a number of reasons, there is little interest in this topic worldwide and the only work undertaken in South Africa has indicated that the atmosphere in the particular sealed panel investigated was homogeneous over a wide area. As mentioned earlier, there is more research to be done in this area in order to develop alternatives to

17. Ranging open path remote methane detection/monitoring device

By Dr V A Kononov, B S Spottiswoode, F Germishuizen, CSIR Miningtek, Ref: GEN 705, 2001

SUMMARY:
The main conclusion of project COL601 was that the method of underground open path, remote flammable gas measurement, in its existing form, does not comply with the current safety regulations. The problem with the method used lies in the fact that it provides an integrated measurement of gas concentration along the path, or, in other words, a percentage of gas concentration per metre.

Therefore, it was proposed, after investigation, that a time Ranging Open Path Remote Sensing (ROPRES) device should be developed. This technology enables the distribution of flammable gas concentration along the open path to be determined, thus ensuring that the safety regulation requirements for routine methane monitoring and early warning are met.

The employed technology is a form of Differential Absorption Light Detection and Ranging (DIAL).

In essence, short impulses of two wavelengths of infrared laser light are projected along the path of interest. This light is backscattered off the dust particles in the air and is collected by a receiving telescope. One wavelength, the primary, is matched to a strong absorption line of the gas species of interest. The other, the reference, is unattenuated by this gas but lies at a wavelength close enough to the primary wavelength to ensure that differences in transmission characteristics are negligible. The methane concentration at any particular distance from the sources can be resolved from the two received signals by analysing their ratio at a time corresponding to that taken for the light to travel from the transmitter to the area of interest and back to the receiver.

It is impossible to apply current DIAL technology directly for use underground, as the best spatial resolution of such a system is only about 15-30 m. This limitation is due to both optical timing aspects and to a lack of backscattering particles in the atmosphere. To understand this fully, a theoretical study was undertaken to determine the expected backscattered radiation from the dust of a typical mining atmosphere. The results of this were used to specify system requirements.

The study finds that due to the substantial amount of airborne dust in the mine atmosphere and due to the advent of a new convolution-based DIAL technique, a proposed system fit for underground application (1-2m spatial resolution) is feasible. The hardware and processing software for the ROPRES system has subsequently been developed and tested in laboratory conditions.

In line with this, a testing rig was designed and built in order to conduct a laboratory test of the device. The rig consists of a 8 m long 800 mm diameter rotating steel tunnel sealed at both ends with polyethylene membranes and filled with a mixture of methane and air. Fans installed in the tunnel serves to circulate the introduced dust and to provide a homogeneous methane mixture. Methane concentration was monitored by a methane sensor. A modified NLC's laboratory laser was used for testing.

Subsequent tests have confirmed theoretical results in that the amount of backscattered radiation in a mining atmosphere is sufficient for obtaining 1-2 m spatial resolution.

Thus, the concept of ranging open path remote flammable gas detection/monitoring has been verified.

18.Inertisation strategies and practices in underground coal mines

By J J L du Plessis and D v Niekerk , CSIR Miningtek, Ref: SIMCOL 701, 2002

SUMMARY:
The purpose of the SIMCOL 701 project was to develop an Inertisation Strategy for use in the in-bye areas of SA underground fiery collieries based on an evaluation of worldwide best practice and an adaptation of these methods (techniques) for use in the current conditions in SA coal mines. The report alludes to the significant health and safety risks associated with Flammable Gas (FG) ignition / explosions and consequent coal dust ignitions / explosions.

The research included an international review of various risk treatment techniques that can be used to eliminate, control or minimize the significant risks associated with FG ignition/explosions and consequent coal dust explosions. These Risk Treatment Techniques (RTTs) are described in detail of the report.

The report concludes that any Inertisation Strategy must be based on an efficacious Hazard Identification and Risk Assessment (HIRA), the risk treatment steps prescribed by the relevant articles of the MHSA and be composed of an appropriate selection (portfolio) of RTTs capable of eliminating, controlling and/or minimizing the significant health and safety hazards/ risks identified and assessed as part of the mine's HIRA.

CONCLUSION:
The process of managing the risk of underground explosions, even though it is familiar, is not as simple as it is generally believed to be. Apart from the engineering controls, aspects such as the human factor and management influence play a significant role. At present, there are very few processes that incorporate the human role or the management role into the risk assessment and management process.

19.An investigation into the conditions under which HFC134a may become flammable

By A.P. Kramers, CSIR Miningtek, Ref: GAP 806, 2002

SUMMARY:
A catastrophic failure of an underground refrigeration plant, retrofitted with HFC134a (or R134a) refrigerant (Tua Tona 1999), highlighted the need to investigate and understand conditions under which HFC134a may become dangerous or explosive.

HFC134a has been rated as non-flammable and non-toxic at standard temperatures and pressures by both American (ASHRAE Standards 15 and 34) and European standards (BS 4434: 1995).

Previous research (Schröeder et al 1995, Dekleva et al 1993, Reed and Rizzo 1991) investigated the flammability of HFC134a at elevated temperatures and pressures. Schröeder et al (1995) concluded that HFC134a can become flammable at temperatures exceeding 280°C at standard pressure or in a 34% oxygen enriched atmosphere (at standard temperature and pressure).A small quantity of combustible substances (6.5% propane for example) was shown to reduce the lower flammability limit of a propane/HFC134a/air mixture (Schröeder 1995). The contribution of the lubricant to the flammability of HFC134a was not clear.

Delving further, the literature review and findings of the Tau Tona accident report (Department of Minerals and Energy 1999), identified a single possible scenario whereby a HFC134a/lubricant/air mixture may become explosive. The mechanism involved the escape of HFC134a/lubricant past the overheated bearing surfaces of a failing compressor. Experimentation that realistically replicated the likely scenario was used to explore this possibility however, despite rigorous efforts, no flammability was observed.

Too many variables exist (presence of lubricant, additives and hot metal catalysts) to positively state the exact mechanism for the cause of the Tua Tona explosion.

CONCLUSION:
Although rigorous attempts were made to ignite the HFC134a and HFC134a/lubricant mixture at conditions similar to those encountered during compressor failure (passing it over a hot wire ignition source at temperatures in the range 600-800°C) no flammability was detected. We must note that any refrigeration equipment components and bearings experiencing these temperatures would experience catastrophic mechanical failure and hence, this represents a highly abnormal condition.

20. Prevention of spontaneous combustion of backfilled plant waste material

By SAAdamski, CSIR Miningtek, Ref: COL 713, 2003

SUMMARY:
Since Grootegeluk Coal Mine commenced operation in 1980, all plant discards and inter-burden material have been stacked on discards dumps, a practice that has led to the spontaneous combustion of the waste material on these dumps. From 1980 to 1988 many large-scale and laboratory tests were conducted to determine the factors that contribute to spontaneous combustion, but no successful method of preventing or containing the problem was formulated.

Further research into this problem during 1988 by a new team led to the project 'Safe backfilling of the waste material into the operating pit at Grootegeluk Coal Mine', which was included in the Coaltech 2020 portfolio of projects and comprised SIMRAC Project COL713. Existing problems and past failures were re-analysed and all contributing factors identified. Reactivity tests of all waste materials and investigations of the contributing factors culminated in the construction of a reactivity model. A mathematical risk model was also constructed to evaluate methods of waste handling, based on the existing database of information as well as on all contributing factors. Newly-identified aspects relating to sealing methods for these compartments were examined, and ultimately backfilling into prebuilt compartments was identified as the best method for waste handling. All materials available for sealing, including power station ash, were tested. Overburden from the mine itself, which is available in bulk and is the cheapest of all the materials tested, was identified as the optimum material for sealing the mine's reactive waste material.

On 20 May 2000, a large-scale test of inter-burden backfilling commenced. During March, April and May 2001, two compartments containing inter-burden material with coal from bench 7B and plant discards, respectively, were constructed. The project was implemented successfully; all compartments are stable, and currently all backfilling is based on the same assumptions as those proven in the large-scale test.

Since then, the successful implementation of the method has resulted in savings of approximately R10m per annum.

21. Technology transfer of flammable gas hazard reduction in hard rock fiery mines

By F.J. van Zyl, K. van Dyk and E. Sampson, CSIR Miningtek, Ref: SIM 040401, 2005

SUMMARY:

The aim of this desk-top study is to provide a broad understanding of the information that is available that can be used to assist the hard rock mining industry to ameliorate the risk of flammable gas ignitions in their mines. In parallel to this, the potential gaps in knowledge were also identified. Information was gathered from international research agencies, debates in literature, the Mine Health and Safety Council research, and industry needs.

Due to the complexity of the problem, the information gathered was classed into two broad categories, namely; explosion prevention and explosion protection. A further sub-division was created with regard to the area of impact of the identified information. These were classified into three main areas namely, technology, management and human factors i.e. employees.

The main findings from the study are listed as follows:

Due to the sporadic occurrence of flammable gas in the SA hard rock mining industry, the key area for immediate future research has to been in the area of the prediction of the presence and behaviour of flammable gas, both form a strategic and operational perspective. This would entail national systems to report and predict the potential of gas, to developing leading indicators on specific mine by using neural networks, seismic techniques, etc. Secondly, it is of critical importance to be able to accurately measure the lower explosibility level (LEL) of the flammable gas mixtures found in hard rock mines. Although there are emerging monitoring techniques being developed, i.e. the use of infra-red, it is essential that reliable and accurate equipment developed and technologies either be revisited (UK multi gas pellistor based system), adapted or developed to allow for accurate general and wide ranging applications, including personal monitoring strategies. In controlling flammable gas in underground atmospheres, cognisance needs to be taken of the fact that this needs to be done at the gas source, and on a mine wide basis. This requires that technologies be developed to control it at source, and be developed to accurately predict its behaviour with regard to ventilation strategies for dilution. When developing Codes of Practice to ameliorate the risk of flammable gas, good guidelines exist from the Department of Mineral and Energy. There is, however, scope for management to take into consideration the people

that will carry out the prevention actions. Significant work has been conducted by the Mine Health and Safety Council to effectively develop management models to meet this need It is recommended that there is continued training of management to ensure state of the art systems is an area were research efforts can be directed towards. The content and presentation training material and a system for Continued Professional Development systems can be considered. The primary need in the human factors field is to close the gap between classroom and underground regarding awareness training. The need exists to address the content, presentation and measurement of outcomes of the training. Work has been done on behaviour -ased safety, however, it has not been effectively implemented in industry. The main aim of research should be to prevent explosions from occurring. Certain technologies were identified during this study, which could be used to assist in the protection against gas explosions. These were the design of explosion seals, active suppression systems and

22. Development of a ranging open path remote methane detector

By Brink, A.v.Z., CSIR Miningtek, Ref: SIM 02 04 04, 2005

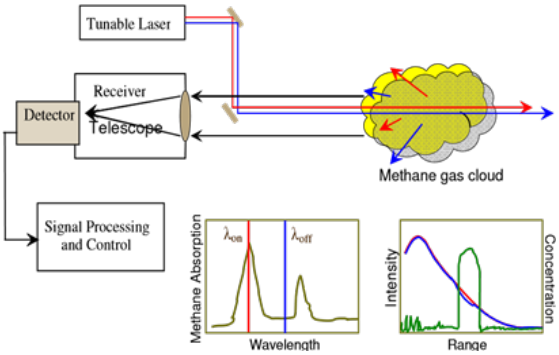
SUMMARY:
An earlier SIMRAC project, GEN 705, successfully demonstrated that the Open Path Remote Sensing (OPRES) based technology could be used for the detection of methane gas in the mining environment. The technology is based on differential absorption light detection and ranging (DIAL) that uses tuneable laser radiation to detect the absorption of methane in the atmosphere. High spatial resolution (<1 m) and good concentration discrimination (~0.1%) were envisaged.

The detection principles had also been demonstrated with the use of a laboratory laser source together with a dedicated detection system that was developed by the National Laser Centre.

The objective of this project was to develop an autonomous methane ranging open path remote detector for laboratory and underground tests. The development of a compact laser source to be integrated with the detection system was a further objective.
This project was primarily undertaken by the National Laser Centre.

The employed technology, DIAL, is a form of optical radar. Short impulses of two wavelengths of infrared laser light are projected along the path of interest. This light is backscattered off the dust particles in the air and is collected by a receiving telescope. One wavelength, the primary, is matched to a strong absorption line of the gas species of interest, as shown in Figure 1. The other, the reference, is unattenuated by this gas but lies at a wavelength close enough to the primary wavelength to ensure that differences in transmission characteristics are negligible. The methane concentration at any particular distance from the sources can be resolved from the two received signals by analysing their ratio at a time corresponding to that taken for the light to travel from the transmitter to the area of interest and back to the receiver.





Principle of Operation

Ultimately, the project did not succeed in achieving its objectives because the original concept developed for the remote detection of methane failed in several aspects. The initial design was analysed and areas for improvement that would result in a compact portable methane detection system have been identified. The development of the new OPO (optical parametric oscillator) has started.

The OPO intended for the detection of methane was designed and modelled. The results from the simulation of the OPO's performance indicate that this OPO will be highly suitable for spectroscopic applications and can be successfully adapted to a portable methane detector.

Although some problems were experienced with the laser source design, resulting in an inability to perform the final methane detection sensitivity tests, it is believed that the current process to design a narrow linewidth laser source will result in a technology demonstrator that can be thoroughly tested before further product miniaturisation and ruggedisation are attempted.

It is recommended that should any future work be supported or required by the Mine Health and Safety Council, the National Laser Centre should be the primary contractor. CSIR Mining Technology could play a leading role with respect to industrialisation, underground testing and intrinsic certification.

CONCLUSION:
The project did not succeed in achieving its objectives because the original concept developed for the remote detection of methane failed in several aspects. The initial design was analysed and areas for improvement identified that will result in a compact portable methane detection system. The development of the new OPO (optical parametric oscillator) has started. The OPO intended for the detection of methane was designed and modelled.

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23. The role of static electricity in the ignition of mine fires and explosions

By E Ngwenya, E de Villiers, K H H Reading,
CSIR Miningtek, Ref: SIM 30163-01, 2008

SUMMARY:
This report forms part of an information search into the role of static electricity in the ignition of mine fires and explosions. The investigation was undertaken by a university student, Ezlam Ngwenya to provide him with experience in searching for and analysing information on a specific project. The information was primarily sourced from the internet and comprised various reports of government agencies, technical reports, records and mine documents to give an understanding of the causes, frequency and seriousness of explosions and mine fires. This information was analysed to determine the causes and methods to reduce static electrical charge. The theory of static generation and discharge were researched to understand the concept of static electricity. The theory was applied to the mining environment to understand where a static charge could be generated and what were the conditions necessary for a mine fire or gas explosion to occur.

The safety statistics showed that, mine fires and explosions resulted in multiple mine fatalities globally. The analysis showed that where the cause of ignition of fires and explosions was inconclusive, static electricity was mentioned as a potential cause of ignition of fire and explosion. Only two records were found where static electricity was explicitly identified as the source of ignition of fire and subsequent explosion.

Whilst the South African safety statistics identified no incidences where static electricity was the direct or potential cause of explosions or fires, the worldwide scan did identify that static electrical charges had

ignited gas explosions. In the South African mining industry, codes of practice relating to flammable gas focus primarily on identifying the sources of flammable gas and the actions required to prevent an accumulation of gases. In the codes of practice, static electricity is mentioned as a possible source of ignition of gases.

24. Development, evaluation and testing of an alternative onboard continuous miner scrubbers and force fan in-heading ventilation system for continuous miner headings in South African coalmines

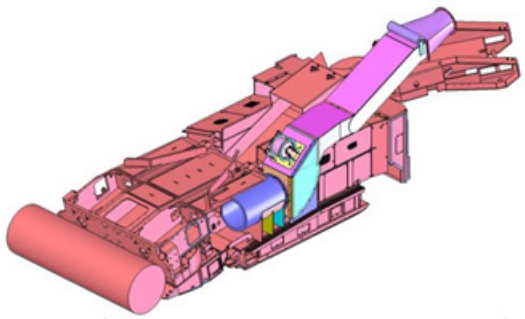
By RW Ottermann, NDL , Burger, AJ von Wielligh , BE @UP, University of Pretoria , Ref: SIM 050401, 2012

SUMMARY:
An alternative to on-board continuous miner scrubbers and force in-heading fan ventilation system was developed. The system was successfully evaluated and demonstrated to industry. Increased effectiveness of in-heading ventilation with lower flammable gas and airborne dust concentrations was demonstrated and the noise levels were slightly lower. The research finds that making use of this system in coalmines would have the following impact:

- Reduced risk of airborne particles and thereby reducing pneumoconiosis.Reduced risk of coal dust explosions caused by airborne particles.
- Reduced risk of methane explosions
- Reduced risk of methane explosions.

After a literature survey, measurement of underground conditions and consultations with industry and equipment manufacturers, the project was defined and a project scope was agreed on. Concepts were generated and the designs were done making use of Computational Fluid Dynamic (CFD) modelling. The design, building and testing of the prototype scrubbers was an iterative process, including an Experimental Development Model (XDM), prototype, modified prototype and prototype to be fitted on Continuous Miner. After evaluations, a new design was developed and a new prototype built before being retested. The system developed consists of the following sub-systems:

- Ventilation system (take positive control of airflow):
  The fan of the scrubber is connected to ducting, which channels the air out of the boxcut and a jet fan positioned at the entrance of the boxcut forces fresh air into the boxcut.
- A new scrubber making use of a rotating cloth, which is continuously cleaned by a water spray system.
- Use of surfactants.



Solid model of the new scrubber fitted on a continuous miner.

The system and sub-systems were extensively tested at the Kloppersbos test facility of the CSIR. A Continuous Miner (CM) was transported to Kloppersbos to be able to evaluate the system on a real CM.

The use of surfactants, with resultant lower dust levels, was successfully tested and demonstrated at Kloppersbos as well as underground at Sasol Mining Much work was done on the underground evaluation of the scrubber, including the design and building of a new scrubber specifically for these tests. However, it must be noted that several problems were encountered, which prevented these tests taking place. Due to the problems encountered, it was decided by the MHSC that the project should be concluded without the underground evaluations of the prototype scrubber and ventilation systems. The underground evaluations will however be done at a later stage in conjunction with Sasol Mining.

Technology transfer was done through a number of demonstrations and workshops, which were attended by representatives of industry, MHSC and labour. Industry and the MHSC were involved in the project with the scoping of the project, evaluations of the prototypes as well as suggesting certain additional work to the project. A poster of the project was exhibited at the Mine Health and Safety Summit and a presentation about the project was given at a conference of the Mine Ventilation Society.

CONCLUSION:
An alternative to on-board continuous miner scrubbers and force in-heading fan ventilation system was developed. The system developed consists of the following sub-systems:

•Ventilation system (take positive control of airflow):
The fan of the scrubber is connected to ducting which channels the air out of the boxcut and a jet fan positioned at the entrance of the boxcut forces fresh air into the boxcut.

- A new scrubber making use of a rotating cloth, which is continuously cleaned by a water spray system.
- Use of surfactants.

25. The Identification and Prediction of the Pressurised Gases in the Bushveld Complex Platinum

By Dr G Henry and Mrs F. Brovko, CSIR Centre for Mining Innovation, Ref: SIM 1304901, 2014

SUMMARY:
South Africa is the world's largest producer of platinum group metals. Mining on the two main ore-bearing reefs – the Merensky Reef and the UG2 Reef - began on the outcrops, and is now conducted at depths >1 000m. In 2007, a pressurised gas outburst occurred during underground operations at Impala Platinum Holding Limited's (Implats) 11 Shaft. Investigations into this outburst and several subsequent ones at other Implats shafts, found that they were a phenomena unique to the Bushveld Complex. These outbursts result in loss-time injuries to the rock drill operators.

The Safety in Mines Research Advisory Council recognised in 2013 that the pressurised gas problem will grow as mining becomes deeper, and initiated a project to study the phenomenon, implemented through the Mine Health and Safety Council. The project was put out to tender, and the Council for Scientific and Industrial Research (CSIR) was the successful bidder.

The project started in October 2013 with a literature review and kick-off meetings with the four major platinum mining companies – Implats, Anglo American Platinum Limited (Angloplats), Lonmin Plc (Lonmin) and Northam Platinum Limited (Northam). The companies were all highly supportive of the project. During the course of the study, a number of significant challenges arose that had a major impact on the successful and timely conclusion of the project. These were communicated to SIMRAC and the MHSC together with a request for guidance going forward. Following the presentation of the progress report to SIMRAC on the 17th June 2014, a decision was taken by the Committee on the 3rd July 2014 to stop the project with immediate effect because of the high risks involved. This final report forms part of the closure documentation requested by the MHSC.

The completed literature review has shown that the pressurised gas outbursts are unique to the Bushveld Complex, however, there is no published information about them. The current project is thus important to gain a fundamental understanding of the pressured gas outbursts, encompassing the nature and sources of the gases, where the gases occur and how they are transported.

This new information will inform the development of a pressurised gas mitigation strategy for the mining companies.

As a result of early project closure, on-mine studies have concluded. The major challenge was the platinum miners' strike that disrupted communication with the platinum mining companies and hindered on-mine studies for 5 months.

Preliminary interpretations indicate that all the pressured gas outbursts are directly or indirectly related to geological features or a combination of such features. These include faults/shear zones, joints, dolerite and lamprophyre dykes, iron-rich ultramafic pegmatites (IRUPs), felsic pegmatites and potholes. Preliminary argon-argon age dating indicates that the felsic pegmatites are of Bushveld age (~2 050 million years old (Ma)), the dolerites are Karoo aged (~214-217 Ma) and the lamprophyres are ~140 Ma in age. This suggests that the pressurised gases probably associated with these intrusions are of different ages. A reconnaissance fluid inclusion study on a halite-natrolite rock, associated with a major pressurised gas outburst, indicates that there in probably no water in the small fluid inclusions found in one sample. Further Raman microspectrometric work is needed to identify the volatile phases that could be carbon dioxide, methane, ethane or nitrogen.

Four underground mines visits conducted at sites where pressured gas outbursts occurred confirm that the outbursts are associated with geological features. This recognition will be important in the formulation of a Standard Operating Procedure for geological data flow for the mines.

A financial summary of the expenses incurred to date on the project is included in this final report. It is strongly recommended that SIMRAC and the MHSC pursue a revised study to fully understand the pressurised gas outbursts, and their mitigation, as these outbursts will continue to be a major safety problem in the future, as platinum mining becomes deeper. The findings of this study are a sound foundation for the new study.

CONCLUSION:

Following the presentation of the progress report to SIMRAC on the 17th June 2014, a decision was taken by the Committee on the 3rd July 2014 to stop the project with immediate effect because of the high risks involved. This document represents the final report.

We note here that the pressurized gas outbursts will continue to be a significant problem in the platinum mining industry in the future as mining progresses to greater depths. They are not well understood, and will cost the mining company in time, money and injuries/deaths if sustainable mitigating actions are not implemented.

This SIMRAC project has highlighted the different risks involved in such a complex problem, and should be seen as the first step in a much-needed study that SIMRAC should undertake going forward. If nothing is done, the loss of time and money due to injury or death as a result of the next pressurized gas outburst will testify to the critical need for such a study.



Notes:



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