Chapter 33

EXPLOSIONS, FIRES AND SPONTANEOUS COMBUSTION

By D Cliff, Chapter Editor, Director of Research, Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland
B Beamish, Chapter Co-Editor, Senior Lecturer in Mining Engineering, School of Engineering, The University of Queensland
P Cuddihy, Chapter Co-Editor, Mining Consultant
D Rowlands, Previous Chapter Editor

INTRODUCTION

This chapter presents an update of the information on explosions and fires prepared by Rowlands (1993). This reflects the significant changes and improvements that have occurred in the underground coal industry over the past decade. Sadly it also chronicles some of the major fires and explosions that have occurred in coal mines since then.

In both New South Wales (NSW) and Queensland, there have been major reviews of the legislation and a general shift to increased duty of care responsibility and less prescription. These reviews were tempered by the disasters that occurred at Moura No 2 in 1994 (a fire and subsequent explosion) and an inundation at Gretley in 1996.

As highlighted by Rowlands, as long as people are required to go underground to mine coal, and work in a breathable atmosphere, there will always be the potential for fires and explosions. Over the past ten years, there have been major advances both in technology and mine operational systems that have greatly reduced the risk to personnel from fires and explosions.

BACKGROUND

The last major underground coal mine fire/explosion in Australia resulting in loss of life, occurred on August 7, 1994 at Moura No 2 Mine. The disaster resulted in the loss of 11 lives, the closure of the mine and the galvanisation of industry to improve the management and prevention of fires and explosions in underground coal mines. Major changes have occurred in many areas including: ventilation management; the use of inertisation equipment; the management of principal hazards; and gas monitoring, analysis and interpretation.

Contrary to popular belief, fires are not uncommon events in underground coal mines. Table 1 outlines the fire related incidents in underground coal mines in NSW over the period 1999 to 2003. The data presented in the previous version of this chapter by Rowlands (1993) is included for comparison. Table 2 reports the same data for Queensland. Note that the classification of fire types has changed slightly since 1994 and thus it is not possible to separately identify all fire types in the recent data by the categories reported earlier and vice versa.

The type of fire has changed over the years. From 1963 to 1994 the most common fire was of electrical equipment, where as now it is either fixed or mobile plant, ie conveyor belts or vehicle fires. Vehicle fires are the most common fire in underground metalliferous mines as with over 200 being reported in Western Australia (WA) in the past three years. The frequency of occurrence in NSW has dropped from about 60 per year to less than 20. This no doubt reflects improved prevention techniques and equipment as well as a reduction in the number of underground coal mines in NSW.

This data does not take into account the scale of the fire or explosion. Thus at face value a frictional spark or minor belt roller fire rates the same as a mine closing due to a spontaneous combustion event. Spontaneous combustion or the self-heating of coal continues to occur with on average one event in Queensland and six in NSW per year (there are of course many more underground coal mines in NSW than Queensland – currently about three times as many). Fortunately these events have not caused any loss of life in the past five years but have resulted in significant economic loss. The most recent example is the placing of Southland mine on care and maintenance following a devastating fire adjacent to the active longwall block, in December 2003. Other significant examples include Dartbrook in 1997, 1999 and 2002, North Goonyella in 1997, and the fire in the open-cut mine due to intersection with old underground workings at Blair Athol in 1999.

Fires require the four elements: fuel, oxygen, heat generation and chemical reaction. Fuels are common in underground coal mines, ranging from; the coal itself; the methane seam gas included in the coal; introduced fuels such as diesel fuel and hydraulic fluid; and timber props, cogs and chocks. An array of potential ignition sources exist including: electrical sparks; frictional ignition from from cutting picks as well as through abrasion from belt rollers; spontaneous combustion; and hot surfaces. Good examples of the range of fires in underground coal mines can be seen from the recent history of fires in the USA. In the past five years there have been fires that have temporarily shut mines due to spontaneous combustion, frictional ignition of liquid hydrocarbons in a longwall goaf, vehicle fires, and waste material ignited by sparks from overhead electrical wires on a trolley car.

CASE STUDIES

Two case studies illustrate the recent experience of explosions in Australian coal mines.

Moura No 2, August 7 1994

The following information has been extracted virtually verbatim from the Warden's report into the disaster (Windridge, 1996).

Mining method

Moura No 2 mine was on the eastern side of the Bowen Basin in the state of Queensland 7 km to the east of the town of Moura, a coal mining centre, located about 450 km north west of Brisbane. The mine began operation

TABLE 1 - Fire related incidents in underground coal mines in NSW

Date	Total	Trailing cables	Other electrical	Brakes/ clutches	Bearings/ belts	Hot surfaces	Spontaneous combustion	Cutter picks	Shotfiring	Other
1999	23	4		1	10	nr	3	1	2	2
2000	38	2		4	19	nr	9	1	1	2
2001	40	7		13	13	nr	7			
2002	28	4		3	11	nr	5		4	1
2003	19	1		3	7	nr	6	1		1
					nr					
Total	**148**	**19**		**24**	**60**	**nr**	**30**	**4**	**7**	**6**
Av	30	4		5	12	nr	6	1	1	1
1963/94	1936	648	450	314	228	98	129	34	2	56
Av 1963/94	60	20	14	10	7	3	4	1	0	2

TABLE 2 - Fire related incidents in underground coal mines in Queensland

Date	Total	Trailing cables	Electrical	Brakes/ clutches	Bearings/ belts	Hot surfaces	Spontaneous combustion	Shotfiring	Other
1999*	0								
2000	2				1				1
2001	6				4				2
2002	14		1		3		3	1	6
2003	13				5	1	2	1	4
Total	**35**		**1**		**13**	**1**	**5**	**2**	**13**
Average	8		0.2		3	0.2	1	0.4	3
1963/1994	92	10	2	38		8	21	nr	13
Av1963/1994	3	0.3	0	1		0.3	0.7	nr	0.4

*Note this is for July to December 1999 only.
nr = not separately reported.

in 1970 and operated continuously thereafter up until the explosion. It employed around 170 persons and annual output varied between 550 000 and 650 000 t of raw coal. This came from two continuous miner production units working bord and pillar panels. Two other mines in the Moura area had major explosions in relatively recent times. In 1975, an explosion at Kianga mine cost 13 lives and in 1986, Moura No 4 mine (which is immediately adjacent to Moura No 2) exploded killing 12 men.

Moura No 2 mined the D seam, which is typically 4.5 to 5 m thick. Depth below the surface varies throughout the mine to something over 265 m. C Seam, which is about 40 m above the D seam, had been mined previously from the No 4 mine using the bord and pillar method. These workings were discontinued following the explosion at Moura No 4 in 1986. A and B Seams, which are reported to remain in place, also lie above D seam at vertical distances of approximately 125 and 100 m respectively.

The D seam is comprised of fairly soft, well-cleated coal. It is a gassy seam containing up to 15 m^3 per tonne of 98 per cent methane gas. There is no history of gas outbursts, with the seam being sufficiently permeable to enable effective methane drainage without the application of vacuum. The coal is known to be liable to spontaneous combustion.

The seam has some minor faulting within the mine area but nothing of a major nature and is free from intrusion by dykes or sills. It is not considered to be a particularly wet seam and in some areas was deemed to be quite dusty, especially where the seam had been pre-drained of methane gas. The immediate roof strata through to C seam consists mainly of competent beds of massive sandstones. The floor strata is sandstones and competent shales.

In general, panels were developed by forming solid coal pillars on the advance, which was the first phase of the coal extraction process 'first workings'. Once fully developed, the second phase of the operation was to partially extract the pillars while retreating from the panel 'second workings'. The design including that of 512 Panel, was for the goaf to remain open and be supported by leaving selected pillars either totally or partially in place. It was believed that an open and ventilated goaf would mitigate the risk of spontaneous combustion. On completing the extraction, the panel was abandoned and isolated from the rest of the mine by the erection of brick and cement rendered seals across all entries to the panel. These seals were erected at pre-determined locations and the foundations for them 'prep-seals' were constructed while the panel was being worked, to facilitate the speed of final sealing when necessary.

The design of 512 Panel was subject to several constraints. Its width was governed by the distance from 511 Panel to the 5 South development headings, and its length was determined by the extent of the methane drainage boreholes. It was expected that extraction would be completed in three to four months after development, and therefore within the presumed six month minimum incubation period of the D seam coal. The panel was designed to achieve, and did achieve, the highest rate of production of any previous panel at Moura No 2 mine.

The significant geometrical features of the panel are seen in Figure 1. Its overall dimensions were approximately 440 m long from the entries to the back rib and 170 m wide rib to rib. It was driven, using five headings, parallel to and on the south side of the previously extracted 511 Panel and was separated from it by a mandatory 45 m wide barrier pillar. A 37 m wide pillar on the opposite side separated 512 Panel from 5 South.

The No 1 heading of 512 Panel, adjacent to 5 South, was at the highest elevation in the panel and was the main return airway. Headings 2, 3 and 4 were intake airways and No 5 heading was used as an alternative main return with No 1 heading during panel development and as an occasional bleeder return during pillar extraction.

Prep-seals were erected in each of the five entries to the panel between the first (No 1) cut-through and the south return of 510 Panel. The seam thickness in 512 Panel was 4.5 m and its depth below the surface varied from 205 m at the top entry to 265 m at the diagonally opposite south-west corner. The seam, which in this area dipped to the west at eight to nine degrees, was separated from the C seam above by a 40 m thickness of predominantly massive sandstones. The seam level at the far end of the panel was approximately 45 m below that of the entry points. Correspondingly the No 5 heading (bottom return) was about 15 m below the No 1 heading (top return).

The area of coal to be extracted by 512 Panel had been pre-drained of methane over a period of 25 months by a pattern of boreholes. This had reduced the seam methane content from its original value of around 15 m^3 per tonne to about 1 m^3 per tonne. We now recognise that this level of pre drainage enhances the propensity of the coal to spontaneously combust as it opens the pores of the coal up to the entry of air. The area of solid coal to the south-west of the panel, which was to be mined at some time in the future, was being actively drained at the time of the explosion and approximately 5500 m^3 of methane per day was being extracted. The only other active methane drainage at the time of the explosion was in the 510 Panel development.

An essential design feature of 512 Panel was that the goaf should remain open and be ventilated throughout the operating life of the panel. This involved keeping 13 cut-through and the top return open for the purposes of ventilation and waste inspection. Strata control, with the need for regional stability, was therefore a dominant consideration. The design which was finally adopted divided the panel into three compartments of roughly equal size, separated by two rows of large compartment pillars across the panel. The size of the compartment pillars varied slightly, but they were, by and large, square and of typically 38-40 m side length. It should be noted, however, that the compartment pillars lying immediately adjacent to the top return were split by the line of the No 2 heading. The pillars formed within the compartments were all

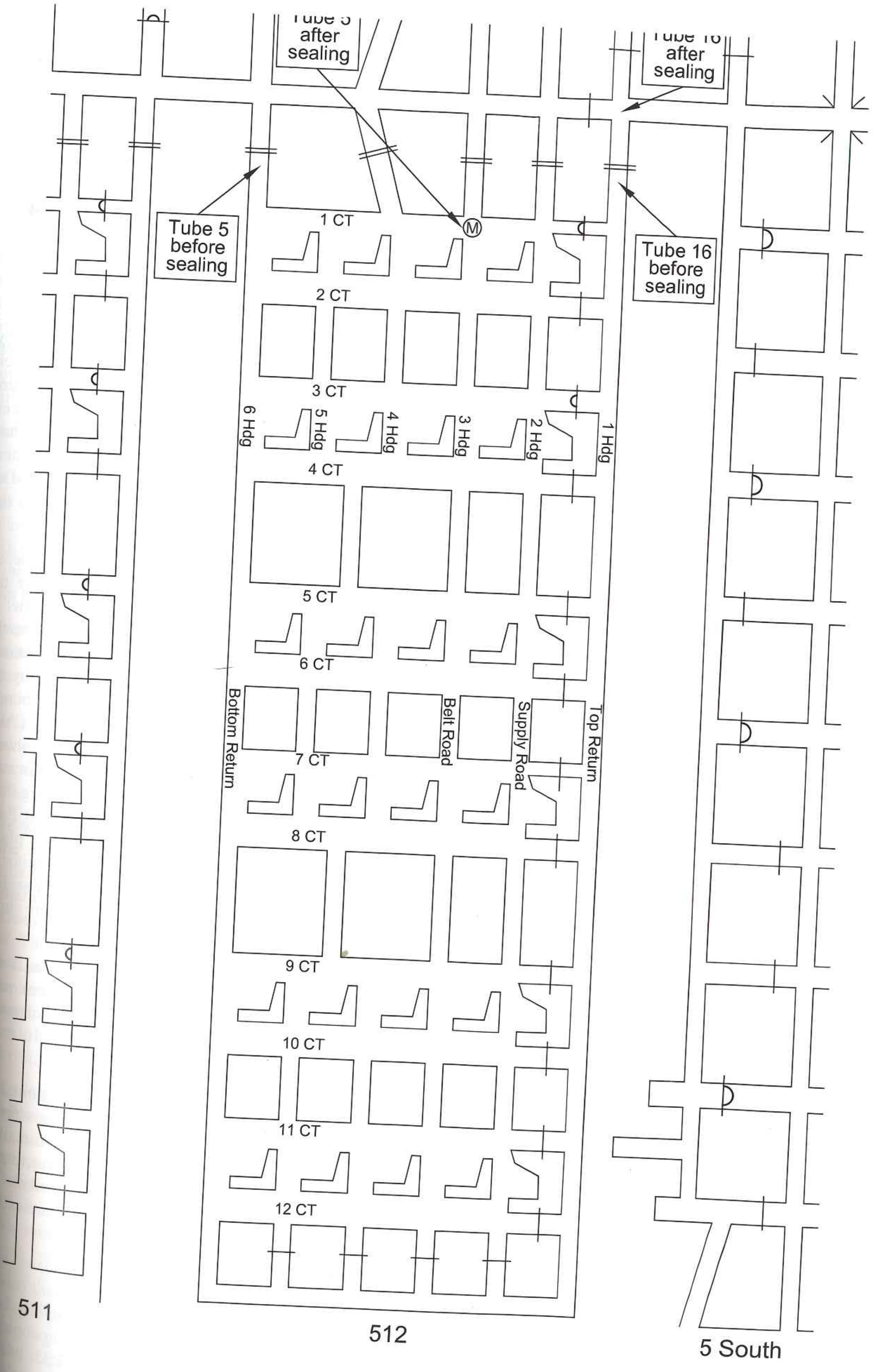

FIG 1 - 512 Panel Moura No 2 Mine

square with a side length of 23 m. These were arranged in equally spaced rows across the panel.

The development phase of 512 Panel started in November 1993 and comprised 7.5 m wide × 3 m high headings and cut-throughs to form the layout of pillars described above.

The extraction phase of the operation, which started on 29 April 1994, involved rib-stripping alternate rows of those pillars within the compartment areas to leave narrow L-shaped stooks between adjacent rows of intact pillars. This was, in effect, a 'take a row, leave a row' method of extraction.

The extraction phase also involved the systematic mining of the approximately 1.5 m thickness of bottom coal by ramping down in the exposed coal floor to the base of the seam with the continuous miner. When cutting bottom coal the continuous miner was operated remotely to avoid persons being exposed to the hazard of the resulting high ribs.

In 512 Panel, bottom coal was taken by a succession of repetitive ramps such that the operator was always outside the ramp area and thus not exposed to high ribs. This led to a coal canch at the start of the ramp area followed by a sequence of large serrations of solid coal across the width of the final floor. It was planned to take bottom coal throughout the panel except along cut-through 13 and along the top return.

No additional supports were required to be set during the extraction phase. There was a requirement to spread up to 300 kg of stone dust into the extracted area each shift while mining. After extraction, there were exposed roof spans of up to 25 m, or thereabouts, with the potential for localised falls of ground in the goaf exacerbated by some geological faults and areas of flaky roof.

The final sealing of 512 Panel, which was done on 6 August and continued into 7 August, used Tecrete seals, a type not previously used for that purpose at Moura No 2. The Tecrete seal is characterised by the erection of a wall of wire mesh baskets into which a proprietary type of plaster is poured. The plaster hardens and strengthens with time to eventually provide a final seal which is said to meet statutory requirements.

During the development phase of 512 Panel, the top and bottom returns were used alternatively as the main return for the panel, depending on the location of the working place at the time. When pillars were being developed on the lower or northern side to the panel, the bottom return was deployed as the main return. Conversely when developing the upper or southern side of the panel, the top return was made the main return.

During the extraction phase, the top return became the main return for the panel, with the bottom return being used for only part of the time. The intention was that as much as possible of the air entering the panel should be made to pass through the goaf before leaving the panel. When, however, the bottom return was being rib-stripped and on those occasions when bottom coal was being mined up-dip from the bottom return, it was deemed necessary to open the regulator in the bottom return to cause adequate ventilation to pass over the continuous miner. At all other times the intention was that the bottom return regulator should be shut.

The quantity of air flowing in 512 Panel during pillar extraction was varied between 35 and 55 m^3/s according to changing circumstances both in 512 Panel and elsewhere in the mine. After entering the panel along the intake headings, the air was directed to the working face, across the continuous miner and finally into the goaf using brattice ventilation. The amount of air allowed to leak through the brattice line and directly into the goaf was controlled by the 'tightness' of the brattice.

The distribution of air in the goaf was controlled by regulators erected across headings 2, 3, 4 and 5 between 12 and 13 cut-throughs. In addition, stoppings were erected in each of the cut-throughs 1 to 12 between headings 1 and 2. Those in cut-throughs 11 and 12 had 1 m^2 and 2 m^2 apertures respectively and the one in cut-through 9 had a 3 m × 1 m flap that could be opened or closed, all of which was to control air flow through the goaf as panel extraction proceeded.

When extracting pillars in seams liable to spontaneous combustion there was a statutory requirement for the quantity and quality of air flowing through the panel to be measured and recorded every week. Moreover, the concentration of carbon monoxide, oxygen, methane and carbon dioxide was continuously monitored by the Maihak Unor gas analysis system from two tube bundle sampling points, one located in the bottom return (Point No 5) and one in the top return (Point No 16). It should be noted that at the time of sealing 512 Panel, the location of these measuring points was changed. Measuring Point No 16 was moved into the south return of 510 Panel outbye of 512 Panel. Measuring Point No 5 was placed behind the 512 Panel seal in No 3 heading to monitor the composition of the atmosphere in the panel after sealing. The location of the tube bundle sample points are shown in Figure 1.

The Maihak Unor system at Moura No 2 was a tube bundle type gas sampling and analysing system which took samples of air from 12 pre-determined locations in the mine, including Measuring Points 5 and 16 at 512 Panel.

In addition to the Maihak Unor system, Moura No 2 also had a Computer Assisted Mine Gas Analysis System (CAMGAS). This system is based on the use of gas chromatographs (GC) and is capable of detecting and measuring several more gases than the Maihak Unor system, most notably those gases that can be indicative of the presence and progression of a mine fire.

Nature and cause of explosion

An underground explosion at the Moura No 2 mine ultimately resulted in the death of 11 people. The explosion occurred at approximately 23:35 hours on Sunday 7 August 1994. This was followed by a second and much more violent explosion at 12:20 hours on Tuesday 9 August which apparently devastated the mine and led to the decision to seal it.

At the time of the first explosion there were 21 people in the mine, nine of whom were working in the North West section, 11 were deployed to the southern area of the mine and one was working in the Main Dips belt area. Those in the southern area of the mine comprised eight in the 5 South crew, a beltman, and a sealing contractor with an assisting miner. Approximately 20 minutes after the first explosion ten of the men underground escaped to the surface safely without external aid. Those who escaped comprised the nine persons in the North West panel and the one person in the Main Dips. All those who escaped from the mine did so with the aid of carbon monoxide filter self rescuers. The evidence was that these became hot during use, indicating that the wearers were in a carbon monoxide contaminated atmosphere.

The North West panel crew utilised transport available in the section at the time of the explosion. Their passage out of the mine was impeded by poor visibility and there was evidence that some of the survivors were physically distressed when they reached the surface. Communication with the crew in the 5 South panel was lost at the moment of the first explosion. No persons returned to the surface from the southern area of the mine.

Expert opinion, in evidence to the Inquiry, was unanimous in concluding that the first explosion most probably occurred in the 512 Panel, located on the Southern side of the mine. The explosion was generally considered to have been a relatively weak methane explosion. There was some evidence from the analysis of the post explosion gases that propagation by coal dust may have occurred into the 5 South Panel.

There was no evidence on which to reach a conclusion on the circumstances leading to the second explosion. It is likely, however, that the first explosion may have resulted in several open fires spread throughout its zone of influence which could have continued to burn for many hours. There could have been several potential sources of methane to create a further and much larger explosive atmosphere, one such possibility being the result of damage from the first explosion to the methane drainage system in that part of the mine. Another is the breaching of previously sealed areas by the first explosion.

Sealing of the mine removed any opportunity for underground entry for purposes of inspection and investigation to assist in determining causal factors. The only post sealing underground evidence has come from borehole camera work in the vicinity of 511 and 512 Panel seal sites and the results of gas analyses from borehole samples.

On the basis of the available evidence the Inquiry concluded that sealing of the 512 Panel after completion of production, resulted in the build up of methane to explosive concentrations within the panel. Evidence before the Inquiry also strongly indicated that a heating arising from spontaneous combustion of coal was present in the panel for some time prior to sealing. The heating was of sufficient intensity to act as a source of ignition for gas in the panel, and this combination was the immediate cause of the first explosion.

Endeavour Colliery, June 28 1995

The following information has been derived from the paper by Anderson, Urosek and Stephan (1997).

Mine details

The Endeavour Colliery was operated by Powercoal Pty Ltd and was located in the central coast of NSW. The mine had been in operation for about 30 years producing about 600 000 t of export coal per year from two production sections. The coal was mined by two continuous miners and transported by shuttle cars to conveyors for removal from the pit. The coal was mined from the Great Northern Seam which ranged in thickness from 1.8 m to 3.5 m, with a normal working height of 2.5 m. A continuous mining method utilising partial pillar extraction was in use at the time of the explosion. The immediate roof is a massive 30 m thick conglomerate.

The event

On June 28, 1995 at about 9:50 am an explosion occurred underground in the 300 Panel. There were 30 miners underground at the time, all of whom evacuated safely.

Conclusions

A bleeder system to remove hazardous accumulations of methane from the 300 Panel goaf had not been established. This lack of such a bleeder system allowed methane to accumulate in the goaf. During a large roof fall, methane was pushed from the goaf into the working places of the 300 panel. Men working at the face reported a windblast. The ventilation system did not prevent the inrush of methane onto the section and it was not capable of diluting this methane below explosive levels. This explosive mixture of methane was most likely ignited in the No 21 cross-cut approximately between No 1 and No 3 headings. The non-flameproof condition of a coupling device in the shuttle car cable appears to be the most likely ignition source. The ensuing explosion resulted in damage to portions of the 300 Panel, the 400 Panel and in 8 West. This explosion was of sufficient force to reportedly knock over a number of persons without causing any severe physical trauma. In addition it caused damage to ventilation controls.

THE HAZARDS CREATED BY FIRES AND EXPLOSIONS

A fire or explosion can pose many threats to the underground workforce. These range from the production of toxic gases and heat, the reduction in oxygen to levels insufficient to sustain life, through to the inability to escape due to low visibility in smoke. Secondary hazards need to be considered as well, for example a fire is one hazard, but if the fire propagates into areas containing flammable gases the hazard can become one of explosion rather than fire. Insufficient oxygen may mean that diesel transports will not function and escape must be on foot, wearing SCSR or CABA. This can be very hazardous and personnel need to be highly trained and supported by clearly marked escape ways, assisted by lifelines or by 'blind man's' sticks. Damage to mine roadways and structures from the heat and combustion of the roof or rib coal can also occur. In addition the buoyancy of the post fire gas plume may interfere with the normal ventilation circuit within the mine and may cause reversal of the flow, as occurred during the belt fire at Appin Colliery in 1976.

Coal fires can create their own explosive gas atmospheres. Hot coal, in the absence of sufficient air for complete combustion, will pyrolyse or incompletely combust, producing high concentrations of hydrogen, carbon monoxide, methane and higher hydrocarbons such as ethylene and ethane. There have been a number of incidents in recent years where the post combustion gas stream contained high concentrations of hydrogen and carbon monoxide, which if mixed with fresh air and recirculated over the fire source could create a major explosion. This was identified as the probable cause of the death of 13 miners at Box Flat in 1972.

Details on Mine Fire management can be found in *Mine Fires in Australian Underground Coal Mines* (Cliff *et al*, 1998). This text contains an overview of the chemistry of the fire process as well as description of the different types of fires, their hazards, monitoring and control. Fire fighting is a specialist task and best left to those who are trained to undertake it. The text *Emergency Preparedness* published by the NSW Mines Rescue Service (NSWMRS) gives an excellent overview of the complexities of fire fighting as well as outlining the evacuation hazards posed by mine fires and methods of coping with them (NSWMRS, 2001).

CURRENT PREVENTIVE PRACTICE

General

The Warden's inquiry into the Moura No 2 Mine disaster recommended a number of key reforms to the management of spontaneous combustion with relevance to the prevention and control of fires and explosions (Windridge, 1996).

The Inquiry made recommendations in relation to the following:

1. spontaneous combustion management,
2. mine safety management plans,
3. training and communications,
4. statutory certificates,
5. ventilation officer,
6. self-rescue breathing apparatus,
7. emergency escape facilities,
8. gas monitoring system protocols,
9. sealing - designs and procedures,
10. withdrawal of persons,
11. inertisation,
12. research into spontaneous combustion,
13. panel design,
14. mine surface facilities,
15. literature and other training support, and
16. future inquiries.

There have been some key developments in matters relating to fires and explosions.

Principal hazard management plans

Under the Queensland legislation, the Safety and Health Management System (SHMS) for the mine must include Principal Hazard Management Plans (PHMP) for at least:

1. spontaneous combustion,
2. mine ventilation,
3. emergency response,
4. strata control,
5. gas management, and
6. methane drainage.

Each plan must contain the process for reducing the risk of that hazard to an acceptable level and may contain:

1. introduction,
2. identified hazards,
3. control procedures,
4. roles and responsibilities,
5. resources required,
6. action response plans,
7. communications,
8. training,
9. corrective action,
10. review,
11. audit,
12. document control, and
13. records.

Note that this was stipulated under the previous legislation but under the current legislation, there is no guideline for what has to be included in a PHMP. In practice, most mines now remove Communication, Training, Corrective Action, Review and Audits as these are common to all PHMPs and are contained in the whole of the SHMS.

Recognised Risk Management processes have to be followed to formulate these PHMPs.

The Moura inquiry recommended collection and analysis of available information on spontaneous combustion. As a result of this recommendation, a number of publications were prepared by Cliff *et al* (1996); Richardson *et al* (1997) and White *et al* (1997).

In NSW, the Spontaneous Combustion Management Code (Department of Mineral Resources, 1996) contains very similar requirements.

Detailed information on spontaneous combustion assessment and control can be found in the review of spontaneous combustion carried out by Cliff and Bofinger (1998).

This document focused on:

1. the chemistry of the combustion process,
2. laboratory testing for assessing the inherent propensity of coal to spontaneously combust,
3. interpretation of gas atmospheres,
4. inertisation, and
5. monitoring equipment and techniques.

Laboratory tests for assessing the inherent propensity of coal to spontaneously combust generally fall into three categories:

1. Small-scale (grams), usually on crushed coal (<212 microns) to ensure the test is completed in a short period of time (hours to days). The common tests used in Australia are R_{70} (Humphreys, Rowlands and Cudmore, 1980; Beamish, Barakat and St George, 2001), Crossing Point Temperature (CPT) (Barve and Mahadevin, 1994) and Relative Ignition Temperature (RIT) (Moreby, 1997). Another test used in the UK (Singh and Demirbilek, 1987) determines an index based on the Initial Rate of Heating (IRH) and Total Temperature Rise (TTR). Moxon and Richardson (1985) developed a similar test in Australia. In the US, an index parameter known as the minimum Self-Heating Temperature (SHT_{min}) (Smith and Lazzara, 1987) is used.
2. Medium-scale (kilograms) using bulk as-received coal to ensure the coal tested is representative of the coal being mined and incorporates the effects of moisture and seamgas in the coal. This testing has recently been introduced in Australia at The University of Queensland (Beamish *et al*, 2002, 2003) and tests can take from days to weeks to complete. The test has an added benefit of obtaining the off-gas evolution pattern coincident with the coal self-heating.
3. Large-scale (tonnes) using bulk as-received coal to ensure the coal tested is representative of the coal being mined and incorporates the effects of moisture and seamgas in the coal. A limited number of these tests have been performed in Australia at Simtars (Cliff *et al*, 1998) due to the length of time needed to complete a test (in the order of months). The cost of these tests increases with the scale of the test.

The interpretation of gas atmospheres associated with spontaneous combustion has relied on analysis of gas evolution from small-scale tests (Chamberlain, Hall and Thirlaway, 1970; Hurst and Jones, 1985; Cliff *et al*, 1994) using high airflow to mass ratios, which are not really what is encountered in the coal mine environment. Generally the opposite is the case. Consequently, recent findings from the medium- and large-scale testing (Cliff *et al*, 1998) has shown that it is time to re-evaluate some of the earlier findings and interpretations of gas evolution from coal self-heating. In particular, it is now evident that hydrogen is produced in appreciable quantities from low temperature oxidation (<95°C) where low airflow/coal mass ratios exist (Grossman, Davidi and Cohen, 1991, 1993; Beamish and Jabouri, 2005). Hence the original perception of the presence of hydrogen as an indicator of an advanced heating needs to be viewed with the other gas indicators before making a judgement of this nature. Further work is being done on this anomaly using the medium-scale testing at The University of Queensland as part of ACARP project C12018. Further information may be obtained from *Spontaneous Combustion in Australian Underground Coal Mines* (Cliff, Rowlands and Sleeman, 1996).

Walters (1996) gives a very concise summary of the processes and factors affecting coal self-heating. Knowing the inherent propensity of a coal to spontaneously combust is only one part of the equation that estimates the likelihood of a coal in an underground coal mine developing a heating. There are many factors that influence this including:

1. *Quality of coal*: The overall quality of the coal needs to be considered in particular the rank and mineral matter content of the coal. Lower rank coals are considered to have a higher inherent propensity to spontaneously combust. A coal with a high ash content where the mineral matter is clays, quartz or carbonates will have a lower inherent propensity to spontaneously combust due to the high heat capacity of these minerals. However, if the mineral matter is finely disseminated pyrite the inherent propensity of the coal to spontaneously combust is increased due to the pyrite also generating heat and disintegrating creating fresh coal surfaces for oxidation to take place (Walters, 1996). Additionally, pyrite has a relatively low heat capacity compared with other mineral matter as detailed above. Surprisingly, the petrographic effects in relation to spontaneous combustion are not well defined.
2. *Moisture content*: The presence of moisture in the coal has a moderating effect on its reactivity. Numerical models of coal self-heating developed by Schmal, Duyzer and van Heuven (1985), Arisoy and Akgun (1994) and Monazam, Shadle and Shamsi (1998) all show how the presence of moisture extends the time taken to reach thermal runaway.

3. *Coal thermal conductivity*: Coals of low thermal conductivity are more vulnerable to spontaneous combustion. Heat is accumulated due to low heat loss.

4. *Permeability of coal*: This has significance at both a macro and micro level as low permeability coal will hinder the access of air to oxidation sites in the coal. Faulting and areas of sheared coal may provide pathways for air to enter the coal.

5. *Coal particle size*: The smaller the coal particle, the greater is the exposed surface area and the higher the propensity to spontaneous combustion. In laboratory experiments, smaller particle size fractions are used in order to obtain results within a short period of time. In mining, areas where crushed or broken coal accumulates present the greatest hazard of spontaneous combustion (Kim, 1977).

6. *Seam gas content and composition*: In practice, a coal mine with high methane gas emission seldom has a self-heating problem (Feng, 1985). The emission process is likely to create an inert atmosphere near the surface of coal and may retard the low-temperature oxidation process. However, as the emission of methane falls sharply with time, coal matrix shrinkage occurs causing cleats to widen and the coal surface that is exposed to oxidation increases (Feng, Chakravorty and Cochrave, 1973). The presence of carbon dioxide in the seam gas complicates the gas evolution signature as a heating develops and this must be taken into consideration when developing action/response plans.

7. *Previous oxidation (aging effect)*: Fresh coal is relatively more reactive to oxygen compared to a weathered or old coal (Cudmore and Sanders, 1984). This effect is graphically illustrated by repeated R_{70} tests on stored coal (Beamish, St George and Barakat, 2000).

8. *Initial coal temperature*: The exothermic reaction of oxygen with coal is the main cause of spontaneous combustion (Cudmore and Sanders, 1984), and like many other chemical reactions the rate is influenced by the temperature; the higher the temperature, the faster the rate at which coal reacts with oxygen. This is significant in the areas where heat generated by oxidation accumulates, or in the presence of a thermal anomaly (Kim, 1977). In particular, knowledge of the geothermal gradient of the mine is essential for this reason.

9. *Air temperature*: The effect of changing air temperature influences the transfer of moisture through the coal. In some areas moisture will be condensing on the coal which can cause an increase in temperature from the heat of wetting effect and in other areas the coal can dry out locally making it more susceptible to oxidation (Bhat and Agarwal, 1996).

10. *Airflow rate*: Air has a dual effect for it provides oxygen necessary for oxidation of the coal and dissipates the heat generated by the oxidation process. A very high flow rate provides almost unlimited oxygen, but dissipates heat efficiently. However this should not be misconstrued to mean feeding a heating high airflow will help to control it. A low flow rate restricts the amount of oxygen available. In mining, a more critical flow rate would be one that provides sufficient oxygen for widespread oxidation but does not dissipate the generated heat (Kim, 1977).

11. *Amount and nature of coal left in goaf*: This relates to a critical pile thickness needed for the coal to insulate itself and prevent heat losses as well as the particle size distribution of the coal which will affect the rate at which the oxidation reaction can take place. (Note again that a substance like PUR is also a very good insulator and when coal is encased in PUR it is effectively placed in an insulated oven and heated to 152°C.)

12. *Thickness of seam*: Where thick seams are being mined there is a greater potential for coal to be left either as roof or floor of the working section, which will eventually be left behind in extracted areas.

13. *Seam gas drainage*: Gas drainage of a coal seam prior to mining removes both the gas and moisture from the seam. The end result is that the coal is now more susceptible to self-heating as two natural inhibitors to oxidation have been removed (Beamish and Daly, 2004). Gas drainage also alters the seam gas composition and subsequently the off-gas evolution pattern associated with the coal self-heating.

14. *Nature of the immediate roof*: If the immediate roof contains carbonaceous rocks or even small rider seams with a reasonable propensity to spontaneously combust, then a heating may develop if this material falls into the excavated area and is exposed to air.

15. *Regularity and continuity of working*: Face stoppages for any reason, either mechanical or geotechnical, increase the residence time of broken coal to air exposure. Caution and vigilant monitoring of the mine atmosphere is needed in these situations.

16. *Nature and control of goaf falls*: Rapid sequential caving of the goaf will assist with consolidation and hence provide resistance to air leakage.

17. *Method of working*: Areas where fine coal particles accumulate, with large coal surface area exposed to oxidation; air leakage around and through fissured pillars and into abandoned areas of the mine; and change in ventilation, may cause air leakage or may suddenly bring moist air into contact with dry coal. All of these situations can contribute to increased spontaneous combustion potential.

18. *Ventilation paths*: How air can travel through goafs and pillars to cause spontaneous combustion to occur.

EDUCATION AND TRAINING

In common with industry in general, there has been a complete overhaul of the education and training process for all levels of mine workers within the Australian coal mining industry. A series of competencies have been defined by industry working groups to reflect the functions in an underground coal mine. Competencies cover not only demonstration of knowledge but also demonstrations of skills and the practical application of those skills and knowledge. Further details on the content of these competencies can be obtained via the Queensland Mining Industry Training Advisory Board website (http://www.qmitab.com.au/). Competencies apply not only to statutory officials but to mine workers in general. Statutory officials are required to demonstrate competency in a range of subjects including: Spontaneous Combustion Management, Ventilation, Emergency Preparedness, Risk Management, Gas Management and Drainage, Strata Control, Outburst Management, Inundation, Mine Services and Mine Transportation.

Personnel need to be trained as appropriate to their work function in prevention, detection and control of fires, as well as in self escape.

VENTILATION CONTROL

The standard of ventilation control devices has been defined in terms of overpressure resistance and construction in Schedule 4 – Ventilation Control Devices And Design Criteria of the Queensland Coal Mining Safety and Health Regulation 2001. Section 350(1) and Schedule 9, contain the definition of the 'type' of ventilation control device required by Section 352.

Ventilation control device

The design criteria for ventilation control devices includes:

1. brattice line or temporary stopping – antistatic and fire resistant,
2. mine entry airlock – capable of withstanding an overpressure of 70 kPa while it is open,
3. separation stopping for a primary escapeway – antistatic, fire resistant and of substantial construction providing for minimal leakage,
4. stopping, overcast or regulator installed as part of the main ventilation system – capable of withstanding an overpressure of 35 kPa,
5. stopping, overcast or regulator installed as part of the ventilation system for a panel – capable of withstanding an overpressure of 14kPa during the life of the panel,
6. type B seal – capable of withstanding an overpressure of 35 kPa,
7. type C seal – capable of withstanding an overpressure of 140 kPa,
8. type D seal – capable of withstanding an overpressure of 345 kPa,
9. type E seal – capable of withstanding an overpressure of 70 kPa, and
10. ventilation ducting – antistatic and fire resistant.

Section 325 of the Coal Mines Safety and Health Regulation (Queensland Government, 2001) specifies the type of seal required for sealing an area as follows:

'(1) The underground mine manager must ensure a seal installed, other than at the surface, at the mine is of a following type—(See schedule 4 (Ventilation control devices and design criteria) for the design criteria for each type)

(a) if the level of naturally occurring flammable gas at the mine is insufficient to reach the lower explosive limit for the gas under any circumstances—type B;

(b) if persons remain underground when an explosive atmosphere exists and there is a possibility of spontaneous combustion or incendive spark or other ignition source—type D;

(c) for an underground mine, or part of an underground mine, not mentioned in paragraph (a) or (b)—type C.

(2) The underground mine manager must ensure a type E seal is used for sealing the entrance to the mine mentioned in section 156(2)(b) (Section 156 (Entry air locks and emergency mine sealing)).'

As well as improving the quality of seals, ventilation management systems in place in underground mines now focus on minimising air entering goaf areas, and maximising low oxygen goaf zones. These systems often necessitate the use of external inertisation to assist in the removal of oxygen from goaf areas. Pressure balancing to prevent air flow into sensitive areas is also common.

In an emergency, having seals in place can mean that hazardous areas can be isolated from the rest of mine in a matter of minutes. These emergency seals are usually airtight but do not have any significant explosion resistance. Their function is to exclude air (oxygen) from the fire to prevent the fire from propagating or causing an explosion.

ELIMINATING SOURCES OF IGNITION

Coal miners have always been very wary of potential ignition sources in underground coal mines. Coal mine regulations and mine managers rules/standard operating procedures control potential ignition sources. Such things as cigarettes, lighters and matches (commonly referred to as contraband) are banned from underground coal mines. Equipment used underground must be safe to use in the proposed area of application. If there is potential for explosion it must either be intrinsically safe (IS) or flameproof. Equipment which is neither flameproof nor IS may be used in outbye areas where the risk of explosion is minimal provided strict controls are maintained, such as monitoring of the atmosphere for methane and the provision of fire fighting equipment. Additional controls such as increased ventilation, methane drainage and pick path sprays are put in place in areas where frictional ignition is a possibility.

Cutting and welding can only be done after a risk assessment has been undertaken to identify all site specific hazards and then under strict supervision with inspection of the work areas prior, during and post hot work to ensure that a fire does not eventuate. Fuel and other flammable liquids must be transported under strict guidelines and usually in special spill resistant containers.

The use of Polyurethane Resin (PUR) and explosives can introduce significant heat and these have contributed to a number of events that have been attributed to spontaneous combustion.

The first event was at the Leichhardt Colliery (approx January 1981) where a spontaneous combustion occurred in an area of coal that had been shotfired several months earlier and left. At North Goonyella, there were three events that can all be traced back to the use of significant amounts of PUR. PUR cures with an exothermal temperature of 152ºC. When coal is encapsuled in a block of PUR, it is raised to 152ºC and then both PUR and coal act as insulators, effectively sealing in the heat. This then leads to an accelerating oxidation rate that is blamed on spontaneous combustion. The last spontaneous event at North Goonyella occurred after 20 000 L of PUR had been injected into the longwall face.

Electrical circuits have fast response circuit-breakers to minimise the potential for sparking.

A high standard of housekeeping and an effective maintenance scheme can prevent fires on conveyor belts through removal of any accumulations of piles of coal dust, or by replacement of any worn rollers or bearings. Regular thorough inspections and or monitoring of conveyor belts are vital to prevent fires occurring.

Regular inspection and proper maintenance is also vital in reducing the potential for fires to occur on mobile plant and at transfer points on conveyor belts.

Good housekeeping also extends to the removal of other fuel sources that may propagate a spark into open fire. This includes waste paper, oily rags, waste timber and not disposing of waste oil underground.

INHIBITING THE COMBUSTION PROCESS

Chemical inhibitors that interfere with the combustion reaction chemistry have been trialled but as yet are not regularly used to control spontaneous combustion.

There is still a long way to go in understanding the complex chemistry of spontaneous combustion and the factors that affect and initiate it. Current research is shedding light on the role of moisture, initial temperature, permeability and porosity.

Stone dust whether applied onto all exposed coal surfaces or positioned in barriers, acts as an inhibitor for coal dust explosions. In NSW and in some overseas countries water barriers are also common.

In mines overseas active fire suppression systems are in use in areas where frictional ignition is a problem. These systems trigger when the first flash of a methane ignition is detected and deluge the target area with a fire suppressant that interrupts the combustion process.

Static explosion suppression barriers are no longer mandatory in Queensland. More emphasis is placed on adequate stone dusting and other fire and explosion suppression techniques. Transportable barriers are now in place in some mines. These use shopping bag like containers of stone dust that can be distributed to optimise the efficiency of the suppression technique. These bags overcome some of the problems found with traditional barriers in terms of triggering and staying active long enough to suppress propagating explosions.

The traditional fire fighting foams are being challenged by new generation chemicals that attack the combustion process as well as isolating the fuel from the air supply.

Water has been widely used to interfere in the combustion process both as a heat sink and also to separate the fuel and air. Water can fill up the pores of the coal preventing ingress of air and oxidation from occurring. It can also fill cracks and crevices and reduce the potential for air ingress into goaf or pillars. Other materials such as gunnite and various clay mixtures have also been used to this end as described below.

Another way of inhibiting the combustion process is the removal of potential fuels, for example using air-cooled transformers rather than oil filled, or using nitrogen in tyres rather than air. Fire Resistant and Antistatic (FRAS) materials also impede the propagation of fires.

Inertisation/inundation

One area that has changed significantly over the past ten years is the use of inertisation techniques both to fight fires and pre-emptively to prevent problems from occurring in goafs. One of the negative aspects of inertisation is that it can mask the chemical indicators of the fire/explosion and thus making interpretation of the size and intensity of a fire difficult.

Self-inertisation

Self-inertisation occurs when an area is sealed and becomes inert. This occurs by reduction in oxygen content below that which would sustain fire (through slow reaction with the coal to produce carbon dioxide and water) and/or displacement by seam/goaf gas, to reduce the oxygen level below the flammable limit.

External inertisation

A range of materials has been introduced into sealed areas to prevent or control fires in goafs.

Solids

Fly ash and various cementatious mixtures have been used to reduce unwanted ventilation into goaf areas and remotely isolate fire zones from the rest of the mine, such as at Laleham in 1982. Foams have also been trialled for this purpose and showed promise at Dartbrook in 2002. Grouts of various sorts have historically been used to fill voids and reduce ventilation paths. Huntly West Mine in New Zealand used a bentonite clay mix to fill the voids in the immediate goaf.

Water

Water has been successfully used to either partially flood or completely flood an area of the mine. The water can be used to form a seal to prevent air ingress into an area or to actively cover broken coal to prevent oxidation from occurring. Water is only effective where the area dips in the right direction and the area can be made water tight. Water was successfully used to inert a panel at United Colliery in 2001.

Nitrogen

Mineshield

Mineshield is a system for vaporising liquefied nitrogen or carbon dioxide. It was used in 1986 to assist in the recovery of Moura No.4 mine. It has been widely used in NSW where the system is based. Most recently it was successfully used over a five month period to control an extensive heating system at Dartbrook Colliery in 2002. It is capable of delivering up to 3 m^3/sec of high purity nitrogen, though for extended periods of time it is not practical to deliver more than 1 m^3/sec, due to difficulties in continuity of long-term supply.

Pressure Swing Absorption (PSA)

In this system nitrogen is produced by separating it from air using membrane filter technology. There are a range of commercial systems available and widely used in general industry to produce an inert atmosphere. It is generally only capable of producing less than 0.2 m^3/s. It has been used in the coal mining industry to fill haul truck tyres with inert gas to prevent tyre fires. It has been used a number of times to proactively inert goafs to prevent advance oxidation from occurring. This system is essentially self-contained and only requires an external power supply.

Inert gas generators

Inert gas generator (IGG) functions by combusting a fuel replacing the oxygen in the inlet air with carbon dioxide and water vapour. Often additional water vapour is added to reduce the exhaust temperature of the IGG. There are currently two different types of IGGs in use, one utilises the exhaust gases from a small jet engine (GAG) and the other uses the exhaust gases from an industrial boiler.

IGG-GAG

Following Moura No 2 the Queensland Government purchased two jet engine inert gas generating systems known as GAG from Poland. They are currently stationed with the Queensland Mines Rescue Service. Aviation fuel is burnt in the dethrusted jet engine where combustion is completed using an afterburner and cooled using water. It is capable of producing up to 30 m^3/s of wet inert gas (< three per cent O_2). It has been successfully demonstrated at Collinsville both inerting a mine from the surface and also when taken underground close to the area of interest. It was instrumental in controlling the fires in the underground workings at Blair Athol and more recently in the USA at Consol No 8 mine. It was so successful there that a system has been purchased by a US company to fight future fires.

The major limitations of this system currently are the water supply and fuel requirements, the need to have special docking stations constructed and the complexity of getting the inert gas to the area of interest if used from the surface.

Ventilation software is being developed to assist in optimising the deployment and inertisation of GAG systems.

IGG-Boiler

This is a low volume version where an industrial diesel boiler is used as the combustor. This is capable of up to 0.5 m^3/s of inert gas (<one per cent O_2). It has been widely used in Queensland to promote an inert atmosphere in sealed areas to prevent spontaneous combustion and to control active heatings at North Goonyella. It has been coupled very successfully with Computational Fluid Dynamics (CFD) to optimise pre-emptive inertisation of areas.

Initial trials demonstrated the ability of this device to operate reliably for extended periods of time (over three weeks). It is essentially self-contained, because it is a low volume device. Its fuel and water consumption requirements are much lower than the GAG.

The unit comes complete with a compressor that is capable of delivering the gas through small pipelines over significant distances (several kilometres) and down boreholes.

Its major limitation is the maximum volume it can generate in order to control an active heating or rapidly inert a sealed area.

Carbon dioxide

Carbon dioxide can be used to inert areas either as the product of combustion as described above or as liquid CO_2 vaporised in Mineshield (as was successfully used at Wallarah Colliery in 2001). Carbon dioxide is much denser than nitrogen at the same temperature and can be very useful when filling areas down dip. It can also be directly introduced in gas form or as a solid.

MONITORING

Gas monitoring systems have gone through major improvements in recent years with sophisticated computer technology assisting improved analysis systems. Mines now routinely use a combination of real time sensors and tube bundle systems to analyse the mine atmosphere and monitor the status of sealed areas. All underground coal mines in Queensland and a growing number in NSW are augmenting this with Gas Chromatography (GC) to allow a wider range of gases to be uniquely identified. GCs are capable of determining gas concentrations over a much wider range than the other systems.

Selection of what system to use depends on the requirements of the monitoring in that area of the mine. Fast response would suggest real time sensors, whereas detection of CO_2 and cost effectiveness would favour tube bundle systems. Real time sensors often do not function correctly in low oxygen environments and flammable gas sensors can be significantly cross sensitive to other gases.

Tube bundle systems consist of a series of plastic tubes continuously extracting samples from points underground which are analysed sequentially by a bank of analysers on the surface. The analysers typically are infrared for methane, carbon monoxide and carbon dioxide and paramagnetic for oxygen.

The new generation gas chromatographs are capable of undertaking analysis of a sample in less than two minutes, and uniquely resolving all the gases of interest including hydrogen, ethane and ethylene, which neither sensors nor tube bundle systems can identify.

Equally important with having good analysers is the need to have a computer/PLC based control/monitoring system capable of detecting abnormal concentrations as quickly as possible, carrying out trending and interpretation and maintaining a reliable system. Modern systems offer remote access, variable sample selection protocols and multilevel discriminatory alarming protocols. This in turn must be backed up with properly trained and practised personnel.

Smoke detection is not widely used in Australian underground coal mines unlike the USA, where it is commonly used to detect conveyor belt fires. Details of current gas analysis and trending techniques may be found in Interpretation of Mine Atmospheres (Cliff, Hester and Bafinger, 1999) as well as the NSW Mines Rescue Station text (NSWMRS, 2001).

One issue that is often not given sufficient attention until it is too late, is the reliability/representativeness of gas monitoring locations. Often after an event, investigations have identified that the sensor was faulty or the tube damaged and not accurately reporting the mine atmosphere from where it was assumed to be monitoring. There is no substitute for regular maintenance and ensuring that all systems are functioning properly. In addition, adequate knowledge of such parameters as tube delay times (the time it takes for a sample to get through the tube to the analysis point), and the expected pressure drop up the tube, can prevent faulty diagnosis from occurring. Regular tube integrity checks and sensor calibrations are essential.

COMPUTER MODELLING

There are now a range of computer models that can simulate the ventilation system of an underground mine. These can be used to simulate the effects of a fire in the mine and assist in its control. One model even makes allowance for the buoyancy effects of the fire on the mine ventilation system.

Other computer modelling utilises Computational Fluid Dynamics to simulate the flow in goafs and sealed areas. This has been successfully used to optimise the use of low flow inertisation devices both proactively and to control active heatings.

THE FUTURE

Technology is being developed to allow remote access to sealed areas to monitor for the presence, intensity and extent of mine fires.

Mine monitoring systems continue to evolve and improve and some are currently being developed to embody real time risk management techniques.

Inertisation systems continue to evolve and soon the GAG will be able to utilise standard boreholes to deliver the exhaust gas into the mine.

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MINE RESCUE

By M Bird, Chapter Editor, General Manager, Mines Rescue Services New South Wales
J McKendry, Co-Editor, President, Mine Managers Association of Australia
J Strang, Previous Chapter Editor
P MacKenzie-Wood, Previous Chapter Co-Editor

INTRODUCTION

Mine rescue stations, manned by professionally trained staff, are located in the mining districts of New South Wales (NSW) and Queensland to provide a service to the underground coal industry. The service includes providing emergency response vehicles equipped with breathing apparatus and other equipment that can be rapidly deployed to mine sites. Other responsibilities include the training of mine employees as rescue brigadesmen to use breathing apparatus and the provision of expert advice in mine rescue.

Irrespirable atmospheres may occur in mines as a result of methane and coal dust explosions, gas outbursts, seam gas build up in poorly ventilated areas, and mine fires. Breathing apparatus may be required for saving life, for fire fighting operations and for the work of sealing-off underground fires. Mines rescue brigadesmen wearing self-contained breathing apparatus may carry out subsequent inspections of sealed-off areas.

Legislation in NSW and Queensland requires mines to provide escape apparatus for all persons underground and to develop underground emergency systems so that persons can 'self escape' through harmful atmospheres that may be present. The rescue service has been involved in the training of mine workers and the provision of expert advice on mine emergency systems.

The increasing use of Compressed Air Breathing Apparatus (CABA) for this purpose has led to a further development for response to an incident. An in-seam response system using CABA operated by trained persons at or near the incident site provides a more rapid response, although this response is limited in capability compared to that provided by the mine rescue teams. There is a need for both systems to be maintained and integrated.

DEVELOPMENT OF RESCUE STATIONS

In 1909 the Queensland Department of Mines moved to establish a mines rescue brigade in Queensland. In 1910 a Rescue Committee was appointed to act with the Ambulance Brigade and local inspectors of mines. Four coal miners, ex members of the Queensland Ambulance Transport Brigade, and six new volunteers undertook a course of instruction in first aid and the use of rescue apparatus. They became the first mine rescue team in Australasia.

In 1915 a Rescue Station was erected at North Ipswich on the property of the Ambulance Brigade. The Queensland Mining Act, 1920, was amended to provide for a mine rescue organisation and the first fully equipped mines rescue station was built at Booval in 1923. Other Queensland rescue stations were built at Moura, Blackwater and Collinsville in the period 1970 to 1981 and a station was built at Dysart in 1984.

In NSW, in 1902, the Mount Kembla mine disaster resulted in 95 deaths. Another six died at Stanford Merthyr Colliery at South Maitland.

In 1923, 21 men died in the disastrous fire and explosion at the Bellbird Colliery at South Maitland. Because organised rescue facilities were not available in NSW mineworkers from the area formed rescue teams to recover the mine. They used PROTO breathing apparatus borrowed from the NSW Fire Brigade.

Public reaction to the Bellbird Disaster together with the experience gained in the use of breathing apparatus during the re-entry operations at Bellbird Colliery resulted in the NSW Government introducing legislation to establish a mines rescue station in each of the State's four coal mining districts.

The building of those four rescue stations was completed in 1926. Since then, the South Maitland Rescue Station was decommissioned and a new station, Hunter Valley Mine Rescue Station, was constructed at Singleton, reflecting the decline of mining in the South Maitland coalfield and increasing activity in the Singleton area.

In Victoria a rescue station was established in the 1920s at the State Coal Mines complex at Wonthaggi. Two underground explosions in 1931 and 1937 resulted in the loss of 20 lives. Teams equipped with breathing apparatus carried out recovery work. The rescue service was disbanded when the State Coal Mine closed in 1968.

In Tasmania a mines rescue team was organised by the Cornwall Coal Company following a fatal methane explosion at Duncan Colliery in 1977. The Newcastle mines rescue station gave assistance in the formation and equipping of this group in 1981. Mine based rescue teams continue to be active at coal and metalliferous mines.