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A Review of Spontaneous Combustion Incidents

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B Ham[1]

ABSTRACT

Heatings, fires and explosions in New South Wales (NSW) and Queensland coal mines since 1972, are reviewed. Geological and mine settings are outlined. Where available, gas analysis and critical decisions are discussed. This paper updates work by NSW Department of Mineral Resources (1995) and the Queensland Department of Mines and Energy in a report on fires and explosion in Queensland coal mines (Richardson and Ham, 1996).

Incident data has important applications in terms of evidence-based risk assessment and identifying key issues to be integrated into competency based training programs. Predictive indicators are reviewed in terms of coal parameters in seams where the incidents occurred.

INTRODUCTION

Over the last five years there has been an increase in the number of spontaneous combustion incidents, culminating in the closure of Southland Colliery in December 2003. There have been some significant technical advances in risk identification and management of spontaneous. The changing demographics of managers and technical officers and legislated requirements for risk management and adequate training and maintenance of competency programs has created a need to review and analyse spontaneous combustion incidents. Since 1972, spontaneous combustion has caused three underground mine explosions with a total loss of 41 lives in Queensland and several extended and permanent pit closures in New South Wales.

BACKGROUND

The recommendations of the Inquiry into the 1994 Moura Mine disaster hastened the development of improved mining practices through:

1. legislation supporting risk management processes,
2. legislation supporting improved training and maintenance of competency programs,
3. improvements in monitoring,
4. improvements in emergency management,
5. the development of inertisation programs, and
6. improved incident reporting and analysis systems.

Most of these aspects are in continuous improvement processes.

One issue identified in the inquiry was the lack of a incident reporting system that made available information on the frequency and causes of spontaneous combustion (and other low frequency but high impact) incidents. To inform the Inspectorate and industry more generally, the Department commissioned the Mining Engineer from the Queensland Coal Board and a research officer from SIMTARS to review the monthly Inspectors reports from 1962 to 1995 and to extract incident data (Richardson and Ham, 1996). From 1996 to 1998 the Inspectorate developed an incident reporting system that was launched in 1999.

From about 1989, the New South Wales Inspectorate has been compiling and reporting on incident data as published by the Department of Mineral Resources (1995).

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The technology to monitor spontaneous combustion through continuous analysis of mines gases was developed by SIMTARS after the 1986 Moura Explosion and this process is continuously being refined Cliff *et al* (1994), Cliff (1995) and Cliff, Rowlands and Sleeman (1996).

The conventional wisdom of dealing with spontaneous combustion in mining panels was to extract the mining equipment and seal the area. The recent development of inertisation procedures to treat and manage developing heatings is a milestone in the prevention and control of spontaneous combustion in retreat mining (Task Group 5 [Moura Inquiry Implementation] Report, 1997). This approach enables confident mining using productive longwall technology that does not have the flexibility of the previous continuous miner systems (Humphries, 1999; Blanch and Stephan, 2000). The failures and successes reported by these authors has been a starting point for a revival in application of new technologies for spontaneous combustion management and associated training. Recent discussion forums include programs such as the Mackay Inertisation Seminar and presentations at the Colliery Managers Association Meeting in Belmont New South Wales.

REPORTING OF SPONTANEOUS COMBUSTION INCIDENTS

The standards of reporting and presenting spontaneous combustion incident data are slowly evolving but arguably not yet at a pace to meet the industry's needs. The legislation requires managers and engineers to effectively manage spontaneous combustion risk at mines and to maintain an adequate level of skill. The New South Wales Department of Mineral Resources (1996) published some useful guidance for spontaneous incident reporting in the NSW Spontaneous Combustion Management Code. The issues recommended to be included in spontaneous combustion incident reports are shown in Table 1.

TABLE 1

Recommended spontaneous combustion incident data set – NSW DMR.

Mine	Description of event	Gas capture/drainage
Seam(s)	Method of control	Geological factors
Proximate analysis	Ventilation details	Method of detection
Area and depth of origin	Mining systems issues	Monitoring results
Location of event	Panel design issues	Diary of events
Mine conditions	Ventilation issues	Diary of decisions
Environmental conditions	Pressure differential issues	Risk assessment reliability
Exposure time	Airways and appliances	Investigating officer

Research work on spontaneous combustion incident reporting funded by ACARP (Cliff, Moreby and Meadowcroft, 2003) helps fill this gap, but the issues of ownership, compilation, analysis and reporting of the data set still have to be addressed.

At present, the majority of available data is extracted from Inspectors monthly reports. While these reports were not prepared for educational or risk management purposes, collating and analysing the data provides some interesting perspectives on the nature of spontaneous combustion risk and how it has been assessed and managed.

Richardson and Ham (1996) reported on spontaneous combustion references in Queensland coal mining inspectors' reports. From 1972 to 1994, there were 39 reports of spontaneous combustion incidents in underground coal mines. A review of the literature has revealed a further eight incidents at mines including Newlands, Blair Athol and North Goonyella between 1997 and 2004.

OCCURRENCES OF SPONTANEOUS COMBUSTION INCIDENTS

A total of 51 spontaneous combustion incidents have been identified in Queensland between 1972 and 2004. These are listed in Appendix 1. The most devastating of these were Box Flat in 1972, Kianga in 1975 and Moura No 2 Mine in 1994. These incidents resulted in explosions that resulted in 17, 13 and 11 fatalities respectively as well as closures of the mines.

Most of the incidents (35) were located in the Bowen Basin as shown in Table 2. The pattern of mine closures in the West Moreton Field is reflected in the reduction of incidents, with only two events in the last 15 years.

TABLE 2

Heatings by district.

District	Heatings
West Moreton	15
Bowen Basin	35
Newcastle and Hunter	36
Other	2
Total	88

In classifying the mine-site location of incidents, the comments in the inspectors reports did not always provide adequate information particularly in relation to pillar extraction and pillar splitting. Using personal knowledge of operations and engineering judgements based on pillar stability issues, spontaneous combustion incidents have be subdivided by mine location as shown in Table 3. Most incidents occur in pillar splitting followed by pillar extraction. Recently, with the introduction of longwall operations in thicker seams and more active seams, a number of incidents have occurred in association with longwall mining. A few incidents have occurred in the pillars in main entries where the pressure differential between intakes and returns has caused spontaneous combustion in fissures in pillars.

TABLE 3

Incidents in Queensland by location.

Location	Incidents
Main Entries	8
Pillar splitting	18
Pillar Extraction	11
Longwall	6
Other	8

The other category includes spontaneous combustion associated with piles of broken coal, in open cut mines and also in re-opened old workings.

At first there appears to be a decrease in incidents in time as shown in Table 4, but when the effect of the closure of underground mines in the West Moreton is taken into account, the incidence of spontaneous combustion events is relatively constant over time.

TABLE 4

Incidents over time.

Year	Incidents Queensland
1971 - 1975	9
1976 - 1980	14
1981 - 1985	5
1986 - 1990	7
1991 - 1995	6
1996 - 2000	5
2001 - 2004	5

IMPACTS OF SPONTANEOUS COMBUSTION INCIDENTS

The examination of incidents is a useful part of the risk assessment process in that it provides some evidence of the adverse impacts of spontaneous combustion, which include:

- fatalities through blast trauma and asphyxiation from CO poisoning,
- mental disorders in survivors of disaster,
- mine closures,
- loss of equipment,
- loss of production,
- loss of reputation and market position,
- costs of distraction to management,
- costs of remedial and recovery measures,
- cost of disruption to communities,
- costs of preventative measures,
- costs of monitoring systems,
- costs of developing a spontaneous combustion management system, and
- costs of associated training.

SPONTANEOUS COMBUSTION RISK FACTORS AND CONTROLS

The examination of incidents is a useful part of the risk control process in that it provides some evidence of the successes and failures in assessing and controlling risk. For example:

- analysis of coal type and self-heating rates R_{70},
- review of mining methods,
- review of ventilation, control systems and management,
- review of atmospheric monitoring,
- review of inspection programs, and
- review of training.

Work in examining spontaneous combustion risk from a coal geology perspective was pioneered in Australia by Humphreys, Rowland and Cudmore (1981) and more recently developed by Beamish, Barakat and St George (2000 and 2001). The method used involves measuring the time a crushed coal sample takes to rise from 40°C to 70°C. This is called the self heating rate R_{70}

and is shown to be a function of coal rank (Beamish, in press) but is affected by ash (Beamish and Blazak, in press) and moisture content (Beamish and Hamilton, in press).

Using coal quality data from Department Natural Resources and Mines (2001) and Edwards (1975), the atomic hydrogen/carbon and oxygen/carbon rations and be calculated to estimate the Suggate Rank after Beamish (in press). This also facilitates an estimation of the self-heating rate R_{70}. Table 5 shows the estimated R_{70} values compared with actual results from various ACIRL tests in the 1980s.

TABLE 5

Suggate rank and R_{70} estimates and tests results.

Seam/State	Atomic H/C	Atomic O/C	Suggate rank	Self-heating rate R_{70}	
				Estimate	Test result
Queensland					
Bowen	0.67	0.04	13	0.05	0
Blake	0.65	0.06	14	0	0
Castor/Argo	0.68	0.04	13	0.2	
Peak Downs	0.66	0.03	15	0	
Castor/Argo	0.68	0.05	14	0.2	
Moura A, B, C & D	0.75	0.07	12	1	0.4
Amberley Series	0.97	0.11	9	9	1.5
Ipswich CM	0.89	0.11	9	9	1.2
Blair Athol	0.67	0.10	11	2	
Newlands Lower	0.71	0.07	12	1	0.4
Middle Goonyella	0.72	0.04	14	0	
New South Wales					
Dudley	0.80	0.07	12	1	
Greta	0.85	0.08	11	1.5	
Great Northern	0.73	0.09	12	1	
Ulan	0.70	0.08	12	1	

Beamish and Daly (2004) report on the increased risk of a heating when gas drainage is applied. Gas drainage dries the coal and increases available reactive surface area and decreases the heat adsorbed in removing moisture. In laboratory tests, the time for a dried sample to heat (25°C to 200°C) decreased from 22 days to seven days.

RISK MANAGEMENT PROCESSES

Given the low frequency and more importantly the severity of recent incidents, particularly in New South Wales, it is necessary to review the risk management processes and understand why the risk management systems have failed (Brady, 2004). The legislation in both Queensland and New South Wales requires mine operators to adopt a risk management process for control of major hazards such as spontaneous combustion incidents and particularly related mine fires and explosions.

The Department of Mineral Resources (1996, 1997a, 1997b, and 2000) in New South Wales has published numerous documents directly or indirectly related to spontaneous combustion. These include spontaneous combustion management code MDG 1006 and a detailed guide to risk assessment processes MDG 1010. While useful, these guides provide the framework and not the detail for spontaneous combustion risk management.

APPLICATIONS TO TRAINING

The analysis of incidents provides an evidence base for assessing whether there are flaws in the spontaneous combustion risk management processes and how improvements may be made in relation to training and maintenance of competency.

The current focus of the Simtars' spontaneous combustion training packages (Cliff, Rowland and Sleeman, 1996, revised 2004) is on knowledge of spontaneous combustion. The current trend in general training programs established by the Australian National Training Authority (2004) and the National Mining Industry Training Advisory Body (2004) is to present necessary knowledge, but then ensure that the candidates have the necessary skills to effectively apply that knowledge. When the skill is demonstrated, achievement of competence is acknowledged. Spontaneous combustion management is the focus of the following units:

MNC.U101.A Apply spontaneous combustion management measures

MNC.U102.A Establish spontaneous combustion management plan

MNC.U103.A Implement spontaneous combustion management plan

MNC.U104.A Apply spontaneous combustion management plan

There is also a spontaneous combustion component at the establish, implement, apply and monitor levels of units that cover:

1. ventilation management plans,
2. manage, operate and maintain the mine ventilation system,
3. gas management plan,
4. mining method and strata management systems, and
5. emergency preparedness management systems.

The application of new technologies demands new skills to be developed in the workforce. The inflexibility of longwall mining has increased the potential losses from a spontaneous combustion incident, but the development of inertisation technology appears to offer an effective control if preparation, monitoring and control actions are well executed. These new skills need to be formally developed and training implemented within the Coal Training Package and at sites where the risk needs to be controlled.

The rapid change in ventilation and gas monitoring options associated with the introduction of inertisation options is providing a significant challenge for professionals to maintain their competency.

CONCLUSIONS

Spontaneous combustions incidents are low frequency but high impact events that can affect most underground and some surface mines. The effective management of spontaneous combustion incidents relies on sophisticated technology and rapid decision making by a skilled and informed workforce.

The legislation requires mine operators to have hazard management plans for spontaneous combustion. These plans should ensure effective monitoring systems and management procedures are in place. These management systems include a training component that needs to be regularly updated as staff turn-over and technology advances.

The understanding and analysis of spontaneous combustion incidents does not in itself prevent future events, but this analysis needs to be used to develop skills in identifying and managing risks. The analysis of incidents also may be used as a tool to test, audit and develop safety management systems.

Geotechnical assessment of spontaneous risk is a useful tool, but practical experience shows that even when a low risk is shown by either a high Suggate rank or a low self-heating rate, a residual risk remains. Geological features such as roof coal, floor coal and high pyrites are associated with increased risk. Testing needs to consider separate bands of coal. A small but reactive band might be all that is required to initiate a heating.

In the worst spontaneous combustion related disasters, common factors include poor mine planning, a reluctance to acknowledge the seriousness of the situation, inadequate information and inadequate training of key decision makers.

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APPENDIX 1

Queensland spontaneous combustion incidents.

Date	Mine	Worksite	Description	Reference
31/7/1972	Box Flat No 8	Extraction panel	Explosion occurred while sealing a fire – 17 fatalities	Richardson and Ham, 1996
1977	Box Flat No 8	Goaf	Heating in fallen goaf material	Richardson and Ham, 1996
1/3/1977	Box Flat No 8	Panel returns	Test revealed CO, hydrogen and ethylene	Richardson and Ham, 1996
1/6/1977	Box Flat No 8	Panel returns	Completed panel sealed after evidence of heating	Richardson and Ham, 1996
3/6/1983	Box Flat No 8	Main returns/goaf area	Detect smoke and 45 ppm CO, withdraw men, seal entries	Richardson and Ham, 1996
1/4/1989	Collinsville No 2	Return 32 C section	Measure 17 ppm CO and seal panel	Richardson and Ham, 1996
1/12/1986	Collinsville No 2	Pillar extraction section	Measure 16 ppm CO	Richardson and Ham, 1996
1/7/1993	Collinsville No 2	Pillar extraction section	Measure CO and seal area	Richardson and Ham, 1996
8/10/1981	Collinsville No 2	Pillar heating	Measure 30 ppm CO in Draeger Tuber	Richardson and Ham, 1996
1/3/1980	Collinsville No 2	Pillar extraction – Panel 56 Level	CO measured	Richardson and Ham, 1996
1981	Collinsville No 2	Pillar exctraction	Sealed when heating detected	Richardson and Ham, 1996
1/9/1984	Collinsville No 2	Goaf area	Sealed after rising CO levels	Richardson and Ham, 1996
1/2/1977	Collinsville No 3	Goaf area – Western section	Heating detected	Richardson and Ham, 1996
19/10/1978	Collinsville No 3	Goaf area – Eastern section	Sealed after heating detected – 98 ppm CO behind seal	Richardson and Ham, 1996
1977	Collinsville No 3	Crushed seal	Ventilation leak causes rising CO	Richardson and Ham, 1996
1977	Collinsville No 3	Pillar extraction	Heating occurred eight weeks after commencing, area sealed	Richardson and Ham, 1996
1/11/1988	Cook	Goaf area	Measure 100 ppm CO	Richardson and Ham, 1996
1/4/1974	Dacon No 3	Goaf area	Heating sealed	Richardson and Ham, 1996
1/10/1991	Harrow Creek	Abandoned workings	Suspect fire reported	Richardson and Ham, 1996
20/9/1975	Kianga No 1	Underground bord and pillar workings	Explosion – 13 fatalities	Richardson and Ham, 1996
1974	Laleham No 1	Main returns	Heating in pillars between main intakes and returns	Richardson and Ham, 1996
1975	Laleham No 1	Main returns	Heating in pillars between main intakes and returns	Richardson and Ham, 1996
1976	Laleham No 1	Main returns	Heating in pillars between main intakes and returns	Richardson and Ham, 1996
1977	Laleham No 1	Main returns	Heating in pillars between main intakes and returns	Richardson and Ham, 1996
1/6/1982	Laleham No 1	Pillar near main tunnel	Smoke detected and area sealed	Richardson and Ham, 1996
1/1/1982	Leichardt Colliery	Heap of shot coal	Smoke detected	Richardson and Ham, 1996
1973	Moura No 1	Panel	Heating reported	Richardson and Ham, 1996
1975	Moura No 1	Panel	Heating reported – panel sealed	Richardson and Ham, 1996
1/4/1986	Moura No 2	Panel goaf	High CO reported and panel sealed	Richardson and Ham, 1996
1/8/1994	Moura No 2	Extracted panel	Aggressive heating leading to explosion	Richardson and Ham, 1996
1/8/1993	Moura No 4	Entry pillar	Rising CO detected	Richardson and Ham, 1996
1/4/1979	New Hope No 5	Panel – 13 West	Measure 55 ppm CO	Richardson and Ham, 1996
1972	New Witwood No 3	Opencut encountered old workings	Fire developed	Richardson and Ham, 1996
1/3/1974	Nornamton No 1	Sealed mine	Advanced heating – 6% CO	Richardson and Ham, 1996
1/3/1986	Oakleigh No 3	Retreating panel	After fall 200 ppm CO reported, men with drawn	Richardson and Ham, 1996
1/7/1979	Oakleigh No 3	Over lying old workings	Measured 25 ppm CO	Richardson and Ham, 1996
1/12/1977	Southern Cross No 11	Abandoned panel	Heating reported	Richardson and Ham, 1996
27/12/1980	Southern Cross No 11	Extracted panel	Sealed on rising CO	Richardson and Ham, 1996
1/10/1991	Western Leases No 1	Panel extraction – split pillars, extract bottoms	Heating detected	Richardson and Ham, 1996
5/6/1989	Western Leases No 1	Panel extraction – split pillars, extract bottoms	Heating 89 ppm CO when panel sealed	Spon Com Commonwealth Course
April 1998	Newlands Underground	Pillar near main portal	Heatings in fractured pillars	Humphries, 1999
May 1998	Newlands Underground	Pillar near main portal	Heatings in fractured pillars	Humphries, 1999
28/12/1997	North Goonyella	Longwall 4 south panel	Measure 25 ppm CO in general body and 0.4% hydrogen in goaf area – apply Tomlinson Boiler inertisation	Blanch and Stephan, 2000

APPENDIX 1 (continued)

Queensland spontaneous combustion incidents.

Date	Mine	Worksite	Description	Reference
11/11/1998	North Goonyella	Longwall 1 North panel	Rising Graham's ratio, goaf CO 387 ppm – application of inertisation	Blanch and Stephan, 2000
25/9/1999	North Goonyella	Longwall 5 South panel	Rising CO causes panel to be sealed and inerted	Blanch and Stephan, 2000
19/3/2003	Withheld C Qld	Longwall	Rising CO in area subject to inertisation, mine evacuated	NRM Incident Database
10/1/2004	Witheld C Qld	Open cut machine	An excavator operator observed smoke. A floor plate was lifted and coal fines were discovered smoldering in the 50 mm gap between the floor plate and the top of the fuel tank	NRM Incident Database
18/7/2004	Withheld C Qld	Longwall	The Tomlinson Boiler was being used to assist inertisation of SLW1, suffered a functional failure and injected high levels of CO into the goaf area	NRM Incident Database
18/8/2004	Withheld C Qld	Goaf area	Carbon monoxide was detected behind the seal at a trigger level that required evacuation of the mine (>500 ppm)	NRM Incident Database
28/8/2004	Withheld	Opencut	Fire in pre-strip hole at King 4 (East)5 – Interburden shot heating up where some king seam coal remains	NRM Incident Database

APPENDIX 2

New South Wales spontaneous combustion incidents.

Date	Mine	Worksite	Description	Reference
13/1/1974	Abedare North	Section entries	Fire in roof coal over stopping, 1000 ppm CO	Lyne and Sneddon, 1981
Nov 1975	Abedare North	Main pillars	Sealed mine Borehold placed ash used to seal area	MacKenzie-Wood and Ellis, 1981
14/11/1977	Abedare North	Goaf area	Failure of seals	Lyne and Sneddon, 1981
8/1/1979	West Wallsend No 2		Fire and explosion	MacKenzie-Wood and Ellis, 1981
20/2/1979	Burwood Colliery		Fire	MacKenzie-Wood and Ellis, 1981
7/12/1979	Lampton Colliery	Goaf	Failure of seals	MacKenzie-Wood and Ellis, 1981
1989 to 1995	All UG mines – 11			DMR, 1995
1989 to 1995	All O/C mines – 6			DMR, 1995
1989 to 1995	All prep plants – 8			DMR, 1995
April 1989	Munmorah State		Nitrogen inertisation used	Connolly, 1990. *Coal Journal* vol 27, p 7-15
1991	Ulan	Longwall	Goaf fire resulted in pit closure for many months	Healey, 1995. DMR Spon Com Seminar Mudgee
16/5/02	Dartbrook	Longwall goaf fire	Mineshield inertisation at 4 t/min – 10 500 tonnes	Coal Services Annual Report, 2002-03
15/12/2002	Beltana	Pillar main returns	Pillar heating near fan	Coal Services Annual Report, 2002-03
1/4/2003	Beltana	Pillar main returns	Pillar fire near outcrop	Coal Services Annual Report, 2002-03
24/12/2003	Southland	Longwall goaf fire	Mine shield used, mine sealed	Southland Colliery Emergency – Gymipe Gold http://www.gympiegold.com.au