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OUTBURSTS MANAGEMENT AND CONTROL

BY JOHN HANES

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ABSTRACT: This paper summarises some of the development of the understanding and management of outbursts in Australia, reviews the current situation and provides some thoughts on necessary research and development. It cannot be and is not comprehensive. Outbursts are better understood, prevented or controlled than they were 20 years ago. This is partly a result of the considerable amount of research into and documentation of outbursts and gas by a relatively small group of outburst pioneers supported by the coal industry. The result has been fewer outbursts in general, and the safe mining through a few potential outburst zones without risk to personnel. It is not time to rest on our laurels. Outburst and gas investigation needs to be continued, supported by industry, so that all outburst related phenomena and advances in gas management can be documented and communicated to all players.

INTRODUCTION

Hargraves, 1980 stated “The problem of instantaneous outbursts remains unsolved after over a century of events and the investigation of the mechanism of the phenomenon and means of treating it... There is no simple litmus test to identify with certainty that a coal is outburst prone. There is no simple alarm device to give adequate warning time of an impending outburst in a place. The understanding of the mechanics of the phenomenon is lacking... We are learning but disappointingly slowly”.

In 2001, are we any further towards understanding and solving the outburst problem in Australia? There has been a considerable increase in the understanding of outburst mechanisms and the methods to control outbursts in the intervening years since 1980, but the cost in lives has been too high. There is more work to be done.

Outburst research and investigations have been conducted in 3 main fields: prediction, prevention and control. Considerable progress was made during the last 20 years in the fields of prediction and prevention with lesser progress in control, mainly because of the relative success of preventative measures adopted by industry.

PREDICTION

Rank, gas composition, geometry

Hargraves (1980) associated increasing outburst proneness with increasing rank of coal. This was due to the higher capability of coals of higher rank to sorb gas. Carbon dioxide (CO₂) gas makes coal more prone to outbursts and the outbursts are more violent than with methane (CH₄) because of coal's higher sorptive capacity for CO₂. Hargraves recognized differing proneness of places in a mine based on world experience: the most prone place was in cross measure drivage or sinking into a seam, followed by drivage in seam, longwall advance, longwall retreat and pillar extraction. The only Australian outbursts at the time had occurred in development headings. Since then, in 1998, two outbursts occurred on a retreating longwall face at West Cliff Colliery (Walsh, 1999).

Geological Structures

Experience in the Bulli seam is that generally all outbursts have occurred when the face has intersected a geological structure, sometimes as small as a few centimetres width of mylonite with no vertical displacement. There have been some exceptions, one of which was a very small burst at Tower Colliery and a few relatively small bursts in CO₂ rich coal at West Cliff Colliery (Lama, 1994). Once a structure has been intersected with outburst signs in one heading it is assumed that its projected intersection in subsequent headings will also be outburst prone.

Outbursts at Collinsville occurred on structures (Biggam and Robinson, 1980) but outbursts at Leichhardt generally occurred without the presence of any major unusual structure. The Gemini seam was very heavily anisotropically cleated which reduced its bulk strength. The fatal outburst of 1978 occurred from coal which was partly brecciated. The brecciation was associated with thrust faulting indicated ahead of the face by high-resolution surface seismic.

In some locations, structures can be identified when intersected by drilling. This was more the case when rotary drilling was conducted as often the bit bogged on structures. With downhole motor drilling, a vigilant driller is required to detect minor structures during drilling. There is currently no device used during drilling to recognize structures intersected. Two devices have been developed with ACARP funding that promise to allow detection of structures during drilling. BHP Research developed a computer monitor and sensors which were fitted to a ProRam rotary drill rig to record changes in drilling parameters such as RPM, rod feed pressure, penetration rate, water inflow and outflow (Danell, 1999). Underground trials showed that minor structures could be identified during drilling and an outburst occurred on one identified structure during subsequent mining. Although this rig has been available to the industry for at least two years, it has sat idle. Sigra are developing a geosteering tool which incorporates a bit torque and thrust monitor for use behind a downhole motor. Laboratory trials have shown that the sensors can detect minor changes in the strength of the materials being drilled (Gray, 1997).

Although there has been some dalliance with other predictive tools such as microseismic and detection of radon gas, they have not been advanced to usable technology status for outburst prediction.

Gas pressure and gas content

Gas pressure measurements are useful indicators of the potential for outburst. Lama, 1983 stated that the safe gas pressure at a distance of 5 m of the face was 0.6 MPa. Wood and Hanes (1982) provided detailed seam gas pressures for outburst prone and benign coal at Leichhardt Colliery. Fig. 1 summarises the relationship found between gas pressure, gas content and outburst proneness. In one location which had outburst on shotfiring, a gas pressure of 2 MPa was subsequently recorded at a depth of 2 m into the face in a hole drilled perpendicular to the cleat. Lama (1983) described gas pressure measurements at West Cliff Colliery.

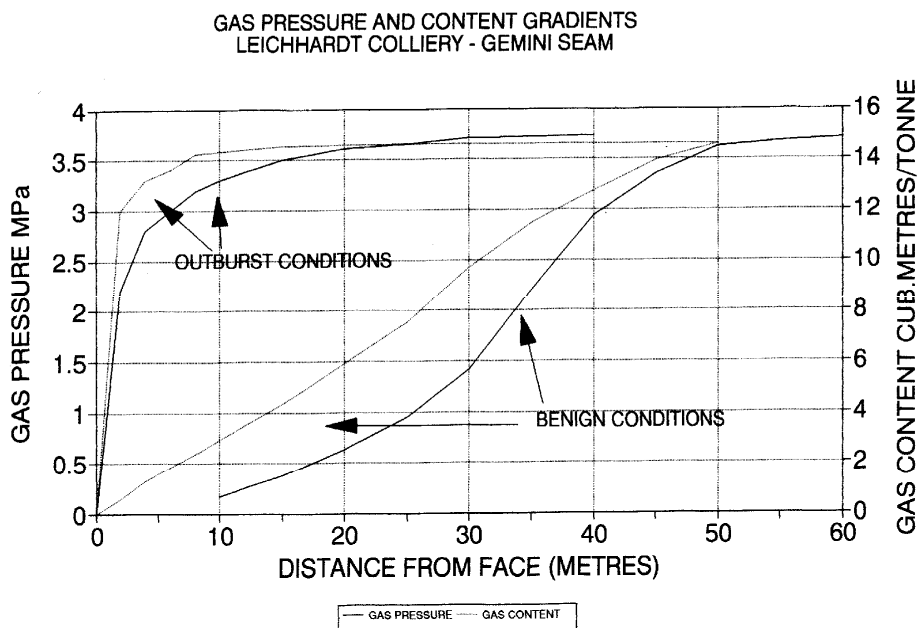


Fig. 1 After Wood and Hanes, 1982

His early gas investigations lead Hargraves (1965) to develop his gas emission meter to measure an index of gassiness. This was a relatively simple device which had a container for sized coal cuttings taken from a standard length (2 m) hole in the face. The gas emitted by the cuttings pushed a slug of mercury or glycol along a clear plastic tube. The amount of gas emitted during a standard time (6 minutes) was recorded as the gassiness index. The index was used successfully at Metropolitan Colliery to identify when an outburst was imminent. The meter was also used at Collinsville (Biggam and Robinson, 1980) and Leichhardt (Moore and Hanes, 1980) Collieries. At Leichhardt Colliery, the emission meter showed a positive change from very low index numbers with benign coal to very high (1.8 cc/g) numbers with outburst prone coal (Wood and Hanes, 1982). The meter required dry coal for accuracy and outburst prone coal at Leichhardt Colliery was typically wet. The use of the emission meter was frowned upon at the time because it required a delay to mining while a hole was drilled in the face and the index recorded, and the procedure was prone to abuse. However, this author has no doubts that the emission meter, when intelligently used can provide useful information about outburst proneness for little effort and expense.

In the late 1970's the USBM technique for gas content measurement was applied in Australia. In this method, coal core samples were sealed in a canister and the emitted gas was bled off into an inverted, water filled measuring cylinder. A plot of the initial desorbed volume against the square root of time in minutes allowed a back projection to estimate the amount of gas lost from the time the sample was removed from any hydrostatic pressure in the sampling environment to the time sorption volume measurement commenced. In some cases, after completion of desorption, the coal was crushed and the residual gas volume was measured. Different coals displayed different desorption characteristics, e.g. it could take 2 months to desorb a core sample of Bulli seam whereas the Gemini seam totally desorbed in a day or two. Residual gas in the Gemini seam was minimal, whereas some samples of Bulli seam have been reported to contain up to 50% of the total gas a residual after desorption. To speed up the desorption process, measurement of desorption during crushing of the sample was introduced. This introduced some problems which were investigated by ACARP Project C6023 (Saghafi and Williams 1998) which found interlaboratory differences of up to 20% of the total reported gas content. ACARP Project C8024 is investigating these differences in an attempt to improve the reliability of desorption testing.

Lama (1995) reported on his extensive work to determine safe working gas content thresholds for the Bulli seam. He stated "The proposed threshold values based upon total gas content using coal sampling from underground are 9.4 m³/t for methane and 6.4 m³/t for carbon dioxide under conditions when mining close to geological structures and high rate advance (25m/day). These threshold values can be raised to 12 m³/t for methane and 10 m³/t for carbon dioxide when it is known that no geological structures are present within 5m of the excavation during development of headings in virgin areas. The suggested threshold values present outburst coefficients for the Bulli seam that are safer when compared with those used in many overseas countries". These coefficients were conservatively adopted by most of the Australian mining industry as a basis for safe mining.

Sigra developed a device, under ACARP funding (Project number C3072) (Gray, 1997) to allow drilling of in-seam drainage holes while maintaining pressure within the borehole above desorption pressure. This device can be easily adapted to any drill rig and has an attachment for sampling undesorbed drill cuttings. Its use will allow rapid determination of gas content or gas pressure of cuttings and will greatly assist gas investigations and outburst management. It also promises saving of time and costs associated with routine desorption testing. The device has been ready for field testing for some time, but no colliery has offered to test it.

Williams (2000) modified the gas content threshold approach of Lama to incorporate his desorption rate index. He believes that in an outburst, once the restraining coal barrier fails or is breached, then desorption rate becomes a key factor, and it is here that the more rapid desorption of CO₂ over CH₄ takes over. GeoGAS's Desorption Rate Index provides a different approach to setting outburst thresholds according to inherent differences in desorption rate of the subject coal compared to the benchmark coals (Appin, West Cliff Metropolitan Bulli Seam). For different coal seams and regions, the threshold 900 DRI is reached for quite contrasting gas contents (Fig. 2).

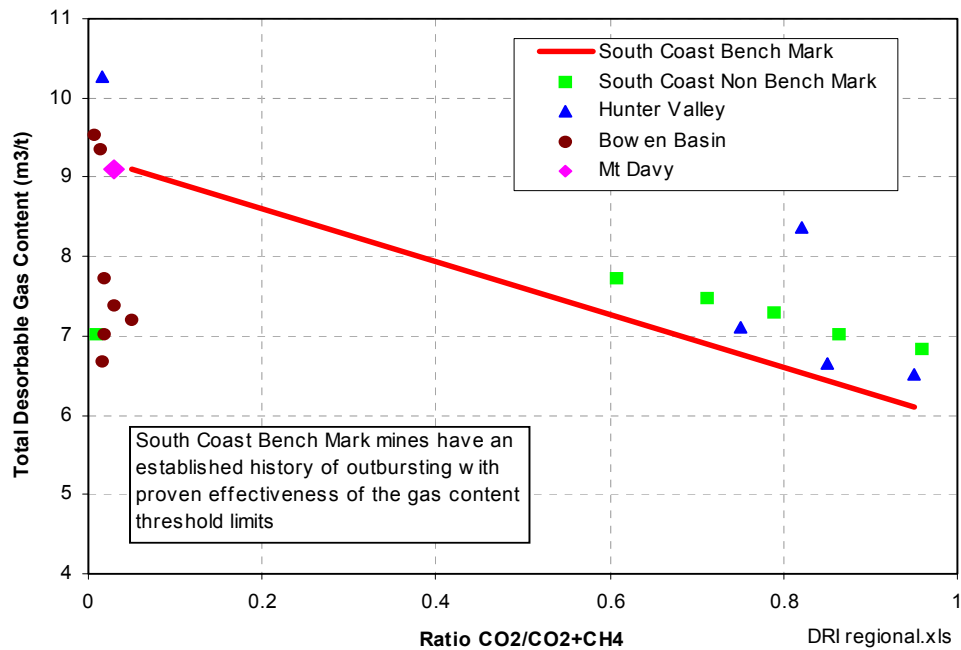


Fig. 2 After Williams, 2000

Mathematical modelling of gas data incorporating geological structure and anisotropy permeability data is now becoming available to help in the understanding of outburst mechanisms and gas management. ACARP Project C9023, Numerical Modelling of Outburst Mechanisms and the Role of Mixed Gas Desorption, conducted by Choi and Wold, is an extension of work completed in ACARP Project C6024. Current ACARP Project C9023, Numerical Modelling of Outburst Mechanisms and the Role of Mixed Gas Desorption is an extension of work completed in ACARP Project C6024. The aim of the new project is to be able to predict the volume of coal and gas that may be involved in an outburst. The likelihood and the consequence are both important considerations in risk analyses. Outbursts can be considered to be caused by the interaction between fluid pressure and rock deformation, leading to the failure of the rock while enough energy is still trapped in sufficient volume of free gas under high enough pressure to cause an outburst. The latter (gas pressure) is related to the gas content (used in the threshold) and gas drainage prior to mining. The modelling requires input of reliable field measurements of gas pressure, rock stress etc.

PREVENTION

Hargraves (1980) summarised outburst preventative measures under the following categories:

- Mining method and geometry – avoidance of seam entries, use of longwall advance, and avoidance of leaving coal in the roof;
- Seam destressing – The use of large diameter holes and high pressure water infusion; and
- Seam gas pre-drainage.

Mining method and geometry

Australian coal mining appears locked into bord and pillar or longwall mining. Advancing longwall has not been favoured.

Seam destressing

Hargraves and others tested the drilling of large diameter holes into the face to reduce stress and gas concentrations at Metropolitan, Corrimal, Leichhardt and Collinsville Collieries. Hargraves (1983) reported that at Corrimal Colliery, drilling of 300mm diameter holes through structured coal was accompanied by stress release manifestations. Advance holes were drilled until drilling no longer produced stress release manifestations. He reported that “sometimes during the boring of routine advance relaxation holes of 300mm diameter and length up to 80m (using scrolls for cutting return) at Metropolitan Colliery some stress manifestations occurred, at least collapse

of the hole as with Corrimal...but perhaps a minor outburst in the hole with surges of gas emission from the hole. Further advance of the bit would stall the drill and the operators learned to continue rotation without feed until cuttings return ceased before restoring feed to the drill". He reported also "the effective diameter of de-stressing holes has been determined by progressive increase of diameter until the cuttings produced exceeded the volume of the hole".

At Leichhardt Colliery, 300mm diameter holes were tried with little apparent success. There was no obvious deformation of the holes and no obvious gas emission from the holes, but bumping noises were reported during drilling. The drilling of 100mm holes in a pattern of two rows of five holes each around 28m long was adopted for outburst prevention. The holes were drilled on a back shift and mining usually commenced the following day. Numerous outbursts occurred in predrilled coal. Where mining closely followed drilling, outbursts typically occurred. Long standing times after drilling reduced the frequency and size of outbursts. This was reported by Wood and Hanes (1982) summarising events leading up to the fatal outburst of December 1978. "In A North Intakes, the heading in which the major 500t outburst of 1/12178 occurred, 100mm relief holes produced a positive effect. The face was drilled in June 1978 with ten 100mm holes each about 28m long and left to stand until 7th November. The advance of the section covered by the holes was under good conditions and rate of advance increased. Mining induced cleavage was absent until near the end of the holes and the ribs tended to spall rather than be 'hard', i.e. pick marks over their full height. Near the end of the holes the ribs 'hardened' and some mining induced cleavage occurred. A further five holes were then drilled and mining recommenced. Three bursts occurred in the following three days with drivage over 12 m. The bursts ranged in size from 50t to 500t. It is concluded that the holes, drilled and allowed to stand for four months were successful in preventing outbursts and in minimising outburst related strain".

Lama (1983) described the effectiveness of large diameter advance holes to drain a fault at West Cliff Colliery in 1976. Three 100mm diameter holes were drilled in each of 4 headings to intersect a mylonite zone. "Violent ejections of pulverized coal occurred at intervals of almost every 10 minutes in the initial stages and continued for almost 24 hours with the material thrown out to a distance of 20m...Further driving of the heading after an elapse of 140 hours produced no violent outbursts...".

Ward (1980) described the use of pulsed infusion shotfiring as an outburst prevention technique. Three holes, each 6m long were drilled in the face, infused with water and shotfired. He reported, "With the introduction of pulsed infusion shotfiring, the need for multi-entry development panels was reduced due to the quicker degassing and destressing effect on the coal. Working conditions were improved also as roadways could be driven better on line and productivity increased due to lesser man hours used than in boring large holes and less time was lost in flitting machines".

Seam gas predrainage

Hargraves (1980) wrote "To prevent a gas phenomenon in the course of mining, it is necessary to degas the zone to be mined sufficiently to reduce the gas content below the content for proneness. Outbursting coals are almost invariably high rank which involves high sorptive capacity and low permeability, making degassing of virgin coal more difficult".

A full-scale drainage program was commenced at West Cliff Colliery in 1980 (Lama, 1983). Kelly (1983) described the effectiveness of pre-drainage commenced at Appin Colliery in 1981. All holes were drilled with a Kempe U4-450 rotary drill rig; 50 % drainage was achieved after 60 days, 70% after 100 days and 90% after 240 days drainage.

In-seam predrainage of the gas is routinely successfully applied at Appin, Tower, West Cliff and Tahmoor Collieries in the Illawarra, at Dartbrook Colliery in the Hunter Valley and at Cental, Southern and North Goonyella Collieries in Central Queensland. It has dramatically reduced the number of outbursts in the Illawarra collieries, but learning has come at a price.

Predrainage was initially conducted with rotary drilling. In 1993, the industry drilled 300 km of rotary drilling and 160 km of guided drilling. In 2000, around 300 km of guided drilling and 50km of rotary drilling are conducted. It was accepted that rotary-drilled holes deviated from their initial trajectory, but it was assumed that they deviated consistently to align sub-parallel to the dominant cleat. Following a fatal outburst in 1994 from a face at West Cliff Colliery which was "protected" by 4 rotary holes, many rotary-drilled holes at the various mines were surveyed and found to be very inconsistent in deviation. Rotary drilling was rapidly dropped as a means of gas drainage ahead of development panels in outburst-prone coal in the Illawarra. Lama and Bodziony (1996) stated that the outburst occurred in coal with 18 m³/t mainly (98%) CO₂. The outburst occurred on a strike-slip fault which had been

previously intersected in another heading 45m away without incident. Four gas drainage holes were rotary drilled from the face 60m outbye the eventual outburst site. Each of the holes had deviated to the left and at the outburst site, they were on the left rib line, one above another. The strike-slip fault zone, projected from the previous heading, was intersected safely on the left rib, but the deputy implemented outburst-mining procedures and removed all personnel from the face except the miner driver who was in an enclosed cab. An unexpected second strike-slip fault occurred inbye the first and when cutting recommenced on the right hand side of the face, about 200t of coal was ejected. The miner driver was killed. Lama and Bodziony (1996) state "This outburst resulted in development of comprehensive outburst management procedures which form the basis of mining of the Bulli seam".

Since the 1994 fatality, essentially all drilling for gas drainage in the major gassy mines of New South Wales and Queensland has been conducted using downhole motor and survey tools so that the locations of the holes are known within the accepted accuracy envelope of long hole drilling. Test cores are taken, usually in the "worst possible location" with respect to gas contents, to test drainage effectiveness prior to mining.

Predrainage has, in general, nearly eliminated the threat of outbursts in today's collieries. The exceptions are represented by Tahmoor, Appin, West Cliff, Metropolitan and North Goonyella Collieries (to date) in poorly defined zones of low permeability. These zones, in some cases adjacent to geological structures and in other cases, best represented by Tahmoor Colliery, with little to no association with geological structure. In some cases, they can be drilled, but refuse to give up their gas. In other cases, such as at Tower Colliery, where they cannot be drilled, they become a drilling equipment graveyard. ACARP are funding a research project in 2001 to try to understand the nature of these low permeability zones.

CONTROL

Control of outbursts has mainly centred on controlling the time at which an outburst will occur so that no personnel are endangered during the outburst. Hargraves (1980) described the primary control method as "by inducer shotfiring, devised by Marsault in France in 1892. It involves a simultaneous round of shots to advance the entire heading face. by over-boring, over-charging and firing from a safe or remote distance... The number of inducements is significantly greater than the number of outbursts which would occur spontaneously".

Simultaneous shotfiring was used at Leichhardt Colliery in 1974 to induce outbursts during drivage of around a couple of hundred metres. The drivage was in an area that experienced daily outbursts when driven by continuous miner (without predrainage). Ward (1980) described the use of mining by full-face shotfiring with millisecond delay detonators for roadway development at Metropolitan Colliery. He stated that many outbursts were induced. Phillips, 2000 reported that in recent work at Metropolitan Colliery, virgin gas content is 13 m³/t and in one area, the gas content remained at virgin level even after considerable drainage time. There was no obvious structural cause for the low permeability. The area was mined by grunching in 1998. Grunching in recent times has not induced any outbursts at Metropolitan. Shotfiring or grunching was also used at Tahmoor Colliery in 2000 to mine an impermeable zone which could not be drained to below the gas threshold for safe mining (Wynn, 2000).

Wynn and Case (1995) described the application of an ABM20 miner to remote mining of hazardous coal. They stated "Essentially all that was required was a flameproof video camera, a flameproof video monitor, a communications system to link the two and a system to link the radio control to the miner...". A suspected fault was previously mined in the left hand heading using the encapsulated 12CM miner and outburst mining procedures. As suspected, a significant outburst occurred on the fault. The miner driver was adequately protected by the system but clearly of the opinion that it was not an experience he would knowingly go through again...The ABM was then advanced in the right hand heading towards the fault...Normal outburst rates of 2m/shift were achieved. When the fault was reached and the machine started to cut up through it, a major (80t +) outburst occurred. This was witnessed on the monitor by the crew in the fresh air base. We believe this was the world's first televised outburst". ACARP Project C3035 developed a separately ventilated control room for use in mining of hazardous zones.

Benson (2000) provided information on the successful mining of a gassy impermeable zone at Tower Colliery by remote mining. Tower Colliery experienced an outburst on Saturday morning 9/12/00 whilst remote mining in MG19. The event occurred on a thrust fault inbye of the dyke which had been mined through. The gas content was 13m³/t. "An outburst occurred in a controlled environment. No person was in the area at the time and no injuries were sustained and all correct procedures were followed. Remote mining was in progress in the maingate 19 panel B heading. This obligated the coal cutting to be performed from a remote operating station (ROS) located approximately 275m outbye the face area. No operators were allowed inbye this remote operating station or in the

return airway whilst the cutting process was in progress. The area the outburst occurred was inbye of a 1m dyke and the coal was in virgin gas state due to an inability to drill and drain the methane below the 9m³/t threshold level. The procedure developed for this process was being followed strictly. The procedure was developed as an outcome of an extensive risk analysis process. The miner operator during the shift experienced two power losses at the miner due to gas tripping off the miner. No significant signs were observed during the face inspections, carried out by both the deputy and miner driver, after the first power loss. When the face was inspected after the second power loss, the deputy observed a cavity in the right hand side on the corner of the face and rib”.

CONCLUSIONS

Hargraves (1980) stated “The tendency to regard the maximum size of previous outbursts as the maximum size of future outbursts is an attitude fraught with danger...even outbursts regarded as small may involve hazards seemingly out of proportion to their size”. At Leichhardt Colliery, most outbursts induced by the continuous miner produced 1 to around 50t of coal. There was a tendency to think of these outbursts as the norm. The fatal outburst was 500t. There have been tendencies in the industry in the past and presently to refuse to recognize the early signs as outburst-related phenomena. Many names have been used to describe these phenomena including “dynamic gas phenomena, puffers, blowers, etc”. The early signs should be recognized as warnings and thorough investigations of virgin gas content and pressure should be conducted in conditions as conducive to outbursting as possible. The occurrences of outburst related phenomena and their investigations should be thoroughly documented, and preferably published to increase communication on outbursts throughout the industry. Without documentation, much valuable information is lost. There is also a need to involve researchers and industry consultants in the investigation and documentation of outbursts and gas phenomena to maintain some continuity in the development of outburst knowledge. In recent years, the industry has lost the active participation of two great outburst researchers, Dr Alan Hargraves and Dr Ripu Lama, who advanced the understanding of outbursts in Australia to new levels. Their publications represent a great legacy to the industry, but unless their examples of promoting outburst research and knowledge are followed, more outbursts will occur when not expected.

Fatalities from outbursts seem to have occurred when the industry thought it had outbursts under control. Each fatality has spurred the industry to improve outburst management and control. This learning cycle has to be broken. The industry cannot afford to lose more lives because it thinks outbursts are under control. There is a need to continually review and update the understanding of outburst mechanisms and to question safety procedures regarding outburst management. How do we know that the gas has been uniformly drained from the coal surrounding the entire length of a drainage hole? In branched holes, how do we know that all branches have drained effectively? Can we be certain that a drainage hole has not crossed an impermeable zone which has not drained? What causes impermeable zones? Can all personnel recognize when mining or geological conditions change from normal? There are many other questions which remain unanswered and there are probably questions not asked.

Understanding of outbursts and development of technology to investigate and prevent outbursts advanced during the second half of the 20th Century and must continue to advance during the 21st Century.

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