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CASE STUDY
OUTBURST & GAS MANAGEMENT

Phil Eade[1]

INTRODUCTION

Illawarra Coal is part of Carbon Steel Materials that is in turn part of the BHP Billiton organization.

Illawarra Coal operates five underground coal mines, viz Appin, Tower, West Cliff, Cordeaux and Elouera. One of these mines is Cordeaux Mine which ceased production in April 2001 and is currently being operated on a care and maintenance basis until its ultimate future is decided. Approval for a new mine, Dendrobium, has been granted and construction has commenced with the aim of replacing dwindling Elouera Mine production and reserves by 2004.

Appin, Tower and West Cliff mine from the Bulli or No. 1 Seam of the Illawarra Coal Measures. This seam is considered very gassy by world standards and each mine has extensive underground gas drainage systems in place to control both gas emissions and the outburst hazard. Seam gas present is predominantly methane but some areas of the mines encounter high carbon dioxide levels, generally localised around geological structures within the seam.

BACKGROUND

A brief outline of the major features associated with gas management and outbursts is given below.

Appin Mine

Appin Mine was established in 1962 and is the oldest of the Division's operating mines. It is situated immediately south of the township of Appin, 37 kilometres from Wollongong. The Bulli Seam at depths of up to 550 metres, provides prime coking quality coal used mainly for making steel at Port Kembla, Newcastle and Whyalla.

Longwall mining was introduced at Appin in 1969. The bord and pillar extraction method used previously had not allowed the mine to achieve production levels required to keep the mine viable. Strata control and stress levels at the mining depths at Appin were the main issues faced in pillar extraction by continuous miner.

Extraction by longwall mining presented a new set of risks to be controlled. Due to the high seam gas content and the adjacent coal seams below, gas emissions around the longwall made managing gas levels, particularly methane, in the ventilation circuit and face area a difficult task. In addition, gas emissions, particularly from the virgin side of gate road development panels made ventilation of the mining developments difficult due to intake pollution and high return gas levels.

As a response to the gas emission problem a methane drainage system was introduced at Appin in 1981 including a surface suction plant and pipe reticulation of the gas to the surface.

Tower Mine

Tower Colliery is situated 40 kilometres north west of Wollongong, between the rural townships of Wilton and Douglas Park. Mining started there in the Bulli Seam in November 1978. Its boundaries enclose significant reserves of prime quality, low ash coking coal, which is used mainly to make steel.

[1] BHP Billiton Illawarra Coal

In early 1979, a large fault zone was encountered around the pit bottom area. As a result, contractors were engaged to drive through the stone and this halted coal production from June to October 1979.

Late in 1982, mining operations were wound down, mainly due to the economic recession at the time. A small workforce kept the mine operating at reduced output.

Mining operations remained at this reduced level until the mid 1980's, when it became clear that longwall mining was necessary for the mine's viability.

Tower, with its large reserves of prime coking coal, was selected to become a high producing longwall operation. Tower's operations were increased and finally, in March 1988, longwall mining began.

Tower Colliery is a gassy mine with high emissions. Effective methane drainage is essential for its continued safety. The methane drainage plant contains eight vacuum pumps linked to a network of underground pipes and drainage holes. Both longwall and development panel mining have benefited from the extensive methane drainage in place at Tower.

West Cliff Mine

West Cliff Mine commenced coal production in October 1976 following development by Coal Cliff Collieries Limited, owned by CRA Limited. The mine and associated infrastructure was purchased by BHP Billiton in March 1997 due to its fit with our other Bulli Seam operations. The seam is approximately 480 metres deep and workings are adjacent to the Appin holding.

As with the other two mines, soon after production commenced it became apparent that high gas levels in the mine ventilation system were detrimental to mine safety and productivity. Gas drainage studies began in 1978 and culminated in the successful commissioning of a gas drainage system, including surface exhausters, in March 1980. The mine experienced outbursts soon after production commenced with gas drainage soon becoming imperative to control the phenomenon. Longwall mining commenced around 1982 and current annual production is budgeted at over 2.3 million tonnes of run of mine coal.

Utilisation History

Methane drainage as practiced at Appin and Tower invariably results in the production of fuel gas with variable characteristics. Principally, this variation relates to composition and flow.

Being mindful of methane's potential as an energy or chemical resource, BHP examined possible uses for the gas. Having due regard to its location and composition characteristics, it was concluded that the most viable economic use for the gas was for conversion to electrical energy for sale to the local electrical distribution authority.

In April 1986, BHP commissioned a nominal 14MW gas turbine alternator unit and associated gas compression, flame arrestor and gas filter ancillary plant at Appin Colliery. This unit consumed a portion of the captured gas available from the mine to produce electricity for sale to Prospect Electricity, now Integral Energy. Unfortunately this plant experienced a number of major failures and was permanently decommissioned. The gas turbine unit used distillate as a standby fuel for start up and to avoid shutdown during periods of transient loss of mine's gas fuel. Replacement of this unit was commissioned in 1995 in the form of gas engine based power plants of 94 MW nominal output distributed between Appin and Tower mine sites.

West Cliff followed a very similar path to that indicated above in relation to gas utilisation. Early in 1986 they commissioned a 12.5 MW nominal output gas turbine complete with a 4500 cubic metre capacity floating bell gas holder.

Outburst Experience

Appin, Tower and West Cliff Mines all mine coal from the Bulli Seam that has over the years exhibited a proneness to outburst. This experience has been well documented with numerous outburst events being recorded at these three and other Bulli Seam mines.

CURRENT PRACTICE

General

There exists a strong link between the management and control of gas emissions in the underground workings and the management and control of outbursts at the three mines. Gas drainage is the prime tool used in reducing pollution of intake ventilation flows by seam gas emissions and also to reduce the gas content of the coal to below predetermined threshold limits. These limits have been found, to date, to be largely successful in reducing the risk of an outburst event occurring.

The link appears most obvious with respect to in seam gas drainage where any gas that is drained from the coal prior to mining will reduce the gas content of that coal. Pre drainage of the coal prior to mining is a function of the location and density of the boreholes, the lead time the holes are draining prior to mining and the permeability of the coal to gas flow. The presence of geological structures and anomalies can also effect the homogenous draining of a block of coal.

Post drainage of gas is achieved by drilling boreholes at an angle below the operating longwall blocks to intersect the coal seams below and to collect a portion of the gas emanating from these coal seams as it migrates toward the longwall area. Goaf formation and resulting strata relaxation and fracturing makes the gas contained within the coal seams below the Bulli Seam a significant source of gas around the operating longwall area.

To complement the gas drainage in the control of the outburst hazard, each mine has a comprehensive outburst management plan aimed specifically at preventing outburst occurrences. Gas content and composition analysis of coal sampled ahead of mining is an integral feature of the outburst management plans. The detail and philosophy of these management plans will be further discussed later.

Gas drainage holes are often drilled well ahead of mining as an exploration tool to determine existence or otherwise of structure and anomalies. These holes are often over 1000 metres in length and they double as an early start to gas drainage as well as a valuable mine planning tool.

Appin Mine

Appin Mine produces around three million tonnes of run of mine coal per annum, with the majority from longwall retreating faces with widths in excess of 250 metres. Two heading gate roads are driven on both the maingate and tailgate side of the longwall panel.

Inseam Drilling

Appin utilise two Kempe K200 series hydraulic drill rigs with N size drill heads. For the year ending June 2001 over 45,000 metres of in seam drilling was completed and approximately 38,000 metres are scheduled for the current year.

The majority of in seam drilling is done from stubs driven in to the future longwall block from the virgin side gate road. The holes are drilled in a fan pattern with holes ranging from 320 metres to 450 metres in length. The objective of these holes is to drain both the longwall block and the next gate road development panel. Where relatively high permeability is thought to exist the hole extremities are designed to be 30 to 45 metres apart. Conversely, in areas where structures are known to exist, closer drilling patterns with hole spacings down to 10 metres are often employed due to lower permeabilities.

All in seam holes are drilled through 6 metre long, 100 millimetre diameter copper standpipes which are fully grouted into the coal. Hole diameters are nominally 92 millimetres using a PCD bit manufactured by Boart Longyear. An Acudrill Down Hole Motor (DHM) is used and when drilling, the drill string is generally rotated along with the DHM to give increased penetration rates. Rotating the drill rods in this manner results in a slightly larger than 92 millimetre hole. Drill rods are 3.0 metre NRQHP which are similar to CHD apart from the thread. They are manufactured by Boart Longyear.

Boreholes are surveyed using a MECCA survey tool manufactured by AMT with the tool down the hole and communicating to the hole collar via the drill string and Mecca system. Information received from the survey tool is logged and includes survey tool azimuth, distance down the hole whether left or right of the standpipe, whether above or below the standpipe and the direction the drill bit is facing.

Drillers log each hole in a book every six metres. Information logged includes visual colour and nature of cuttings and return water, whether drilling conditions hard or soft, gas surges while drilling and any other unusual events.

Inseam pre-drainage typically reduces seam gas contents from 14 cubic metres per tonne to between 2.5 and 4.5 cubic metres per tonne provided holes are drilled with a lead time of between five and six months. This assumes homogenous permeability and areas clear of structure. Where this is not the case additional or earlier drilling is required

Cross Measure Drilling
Two Kempe 200 series hydraulic drill rigs with B size drill head are used to drill cross measure gas drainage holes beneath the longwall blocks. For the year ending June 2001, over 32,000 metres of hole were drilled with 35,000 metres scheduled for the current year.

The cross measure holes are drilled from the roadway adjacent to the operating longwall which is 45 metres from the maingate and are rotary drilled. Where pillar lengths are 150 metres, drill sites are established at 50 metre intervals. Each site comprises five boreholes, three of which are drilled at minus 20 degrees and two at minus 25 degrees. Four of the holes are angled back toward the approaching longwall while the fifth is drilled normal to the gate road direction. These holes are designed to intersect the Balgownie and Wongawilli Seams below the Bulli Seam being mined

The holes are drilled using 1.5 metre long BW drill rods and 65 millimetre diameter PCD drill bits, both supplied by Boart Longyear. Length of hole varies between 90 and 120 metres depending upon declination, inter seam burden and general dip and target the base of the Wongawilli Seam. All holes are drilled through 3.0 metre standpipes with nominal bore of 80 millimetres which are fully grouted into the floor.

All holes are cased with slotted casing from just above the Balgownie Seam intersection to the bottom of the holes. Although the top section of the hole is not cased, it does not appear to have affected hole drainage performance. Drillers log each hole as they extend rods, recording stone and coal intersections.

Weekly gas balances around the longwall block indicate a gas capture efficiency of approximately 45 to 55 percent. There would indicate that approximately equal volumes of gas around the longwall panel report to the ventilation current and the gas drainage system.

Goaf Drainage
Currently Appin drain very little gas from old goaf areas. Approximately 150 litres per second of methane is being drawn from a worked out area of the mine. This has in the past been up to 350 litres per second but difficulties in effectively sealing the areas to stop dilution with air has reduced this figure.

Outburst Management
Core sampling for both gas composition and content is carried out in line with the Appin Mine Outburst Management Plan. They are taken at 150 metre intervals and more often where structures are suspected. All cores are sent to our Technical Services Laboratory for analysis and reporting.

Philosophy and detail of the Outburst Management Plans will be described later.

Tower Mine

Tower Mine is budgeted to produce between 1.3 and 1.4 million tonnes of run of mine coal in the current financial year. The presence of geological structures and in some areas difficult gas drainage and drilling conditions have severely hampered the mine's production capacity.

In Seam Drilling
The mine employs 2 Kempe 37 Kw drill rigs utilising 3 metre NQ Longyear Mecca rods, downhole motors and 96.1mm diameter Longyear and Wadam PCD bits to drill approximately 23,500 metres of in seam branched holes per year. Due to poor gas drainage conditions it is likely that this quantity of drilling will be exceeded in the current year.

Holes are drilled through a 100 mm diameter, or sometimes 150 mm, 6 metre copper standpipe that is fully grouted in to the coal. All holes are surveyed with Mecca or Acoustic survey tools and are logged by the drillers for survey and any anomalies encountered whilst drilling. These records are kept on file for future reference.

Typically a fan pattern is used across future longwall blocks with 20 metre spacings between adjacent holes and lengths up to 400 metres. With short lead times and difficult drainage conditions, hole spacings have at times been reduced to as low as 8 metres. Significant issues have related to the inability to drill effective drainage holes in one particular area due to holes collapsing. Remote mining on development has been necessary at times where it has not been possible to reduce gas contents of the coal below the outburst threshold limits. Some success has been experienced in these structured areas with drilling into the roof over the anomaly where hole stability is improved in order to access coal ahead of the face for drainage.

Cross Measure Drilling
A Longyear LMC 55 drill rig is used to drill cross measure boreholes to intersect the underlying Wongawilli Seam ahead of the operating longwall face. Around 12000 metres are rotary drilled annually with this rig utilising Longyear and Wadam 65 mm PCD bits and 1.5 metre long BQ rods. Steel standpipes of 75 mm diameter and 6 metres in length are fully grouted into the coal.

A fan pattern is used with varying dip angles and length up 150 metres. Holes are not surveyed but return water colour is monitored and recorded by the drillers. Casing of the holes has not been practiced in the past but a trial is being planned.

Overall with in seam and cross measure drainage, gas capture around the longwall panel approaches 50% of the gas desorbed and emitted.

Goaf Drainage
Tower does not currently drain gas from old goaf areas although drainage from a recently sealed area of the mine is being investiaged.

Outburst Management
Core sampling for both gas composition and content is carried out in line with the Tower Outburst Management Plan. All cores are sent to the Technical Services Laboratory for analysis and reporting. In areas where the coal is difficult to drain, many cores show minimal desorption until they are crushed, after which significant quantities of gas are released. Measured gas contents over 15 cubic metres per tonne have been recorded.

West Cliff Mine

The West Cliff Mine is currently mining the third longwall panel in a block of coal adjacent to old workings at Appin. The previous longwall domain at West Cliff was characterised by areas of high gas content in excess of 20 cubic metres/tonne, ranging in composition from 90% plus methane to 90% carbon dioxide. Methane predominates in the current area which is intersected by a number of geological structures which present a challenge to gas drilling and drainage

In Seam Drilling
West Cliff utilise two Kempe K200 Drill Rigs recently transferred from Tower Mine and one Longyear LMC55 Rig to drill between 65 and 70,000 metres of in seam hole annually. Downhole Motor directional drilling is used in conjunction with acoustic DDM Upgrades and Mecca survey instruments to guide and accurately plot hole trajectory. Holes are surveyed at 6 metre intervals.

In seam holes are drilled in a modified fan pattern across the longwall block. Each hole is generally branched once with holes sub parallel to each other ahead of the next gate road development. Standpipes of 100mm diameter and 5 metres in length are grouted into the hole collar. They are either copper or galvanised steel depending upon the collar location in relation to mining activity. Hole diameter is 96 mm and length varies between 320 and 1000 metres. The longer or more irregular holes double as exploration holes and are typically drilled to prove structure or to provide drainage around difficult to drill or drain areas. PCD bits are used in conjunction with CHD76 rods if the acoustic survey tool employed or NRQ-HP rods if Mecca tool used.

All holes are logged for anomalies by the drillers and records kept for future reference. Development of a survey and drilling system with the ability to distinguish between roof and floor strata and to provide feedback for guidance is seen as a very useful potential improvement to increase drilling and drainage efficiency.

Cross Measure Drilling
A Longyear LMC55 rig is used to rotary drill between 22 and 25,000 metres of cross measure hole annually. They are drilled using 1.5 metre long BWJ rods and 65mm PCD bits and stabilisers. Galvanised steel standpipes, three metres in length, are used on each hole. A fan pattern of four to five holes angled below and toward the advancing

longwall face at a declination of 20 to 28 degrees is drilled with up to four sites per pillar length. Holes are not surveyed but are logged and recorded by drillers. Hole length varies between 130 and 165 metres in length.

Perforated casing of 48 mm diameter has been trialled on cross measure holes but has not yielded improvements in efficiency or gas flows under current West Cliff conditions. Gas drainage performance based upon cross measure flows only indicates capture efficiencies of between 30 – 40% around the longwall block.

Goaf Drainage
Goaf drainage is not practised at West Cliff due to past inability to control leakage and purity levels.

Outburst Management
Core sampling for both gas composition and content is carried out in line with the West Cliff Outburst Management Plan. All cores are sent to the Technical Services Laboratory for analysis and reporting.

Gas Utilisation

The drained mine gas from Appin, Tower and West Cliff is currently utilised in power stations located at both Appin and Tower. The gas turbine at West Cliff was decommissioned when repair was not economically justified and an alternative generation source became available at Appin

The gas drainage systems at Appin and Tower Mines are interconnected via a physical link joining the two mines underground. Drained mine gas captured in the pipeline can effectively be used to feed either utilisation plant. Currently some Appin mine gas is diverted to Tower to supplement that power station's fuel supply. In addition both power stations are connected to natural gas from the AGL system which can also be used as a supplementary source of fuel when economics permit

Mine gas that is collected from the West Cliff methane drainage system is reticulated to the Appin power plant via an overland pipeline connecting the two sites.

The Appin power station consists of 54 gas engines with a nominal generating capacity of 1 MW each while the Tower power station comprises 40 such units. The electricity generated is sold to Integral Energy under a long term agreement. The power stations are owned and operated by Energy Developments Limited who are contracted to BHP Billiton to produce electricity from the mine gas.

OUTBURST MANAGEMENT PLANS

The three mines utilise a Mine Safety Management System approach to manage the outburst and gas related hazards. More particularly an Outburst Management Plan, specific to each mine, is used with the stated objective of effectively controlling the risks associated with outburst. The detailed plans are based upon common principles with some variation between sites arising from different mining conditions, history and experience.

Plans set out the methodologies and activities that are mandatory for predicting potential for outburst and, as far as practicable, preventing their occurrence. Elements of the plans address the protection of personnel from the effects of an outburst should all other barriers be found to be deficient in any way. Threshold levels of methane and carbon dioxide are central to the prediction and prevention strategies in the plans. They nominate the gas content levels above which no mining will take place or where specific full risk assessments must be used to determine the risk of mining. Threshold limits for 100% methane range from 9 to 9.5 cubic metres per tonne while for 100% carbon dioxide, the range is from 5 to 6 cubic metres per tonne.

The Outburst Management Plans contain many controls and measures to ensure the effectiveness of the plan to control the outburst risk. Some of the main measures include

- Drilling, gas drainage and sampling requirements
- Collection of relevant information
- Stipulation of decision making and communication procedures
- Clear allocation of responsibilities under the plan
- Training both in the operation of the plan as well as in the recognition of outburst warning signs
- First response equipment and planning in the event of an outburst occurring

The plans are constantly under review with formal audit requirements built in to keep them current, effective and up to date.

GAS DRAINAGE PERFORMANCE

The table below is a record of the volume of methane captured at the group mines for the year ending June 2001. The *gas captured* represents the volume reporting to the surface of the mines in the gas drainage pipeline. The *ventilation gas* is that gas which reports to the ventilating air circulating around the mine and exhausting to the atmosphere at the surface.

	Gas Captured metres^{3}x 10^6	Ventilation Gas metres^{3}x 10^6	Total Gas Make metres^{3}x 10^6	Proportion Gas Capture
Appin	92.5	171.3	263.8	35%
Tower	58.6	136.4	195	30%
West Cliff	46.9	117.3	164.2	29%
TOTAL	198	425	**623**	**32%**

The *proportion gas capture* represents the gas drainage efficiency for the mine and shows significant room for increase if technology and gas drainage techniques are improved. Captured methane represents an opportunity to recover a proportion of gas drainage costs through utilisation provided a viable economic arrangement can be established. In addition, as the gas capture increases, the risk of mining related gas delays and outburst occurrences is reduced.

Technologies designed to utilise methane contained within the ventilation stream are actively being investigated and trialled. There is also an environmental link with potential green house gas reductions if the methane emissions can be effectively utilised and burnt.

OPERATIONAL ISSUES

There are many issues that confront our mines and operators in relation to outburst control and gas management. A selection of these are noted and discussed briefly in the points that follow. They are meant to act as thought provokers and a rough checklist of areas our operators perceive could provide increased safety and efficiency to underground mining if further examined. Issues are not presented in any particular order or priority.

Outburst Threshold Limit Review

There is often the temptation to increase gas content threshold limits for samples that return just above the limit analyses. A factor of safety no doubt exists in the setting of the limits but it is very difficult to scientifically quantify what it is in a specific case. A better understanding of the outburst mechanism is required to justify significant variation to the threshold limits. At least some research should continue understanding this fundamental end of the research spectrum.

Difficult to Drill Areas

Difficult to drill areas of mines are often encountered in inseam gas drainage drilling. The coal may be soft with subsequent hole instability or highly stressed as in areas surrounding geological intrusions or structures. Drilling to reduce gas contents below threshold limits is therefore hampered with subsequent risk of discontinuities in mining operations.

Some mines have successfully traversed such local zones by drilling into the roof or floor in the area of the disturbed zone to drain coal on the other side. Casing of holes as they are being drilled or shortly thereafter may aid stability through such zones. Drill bit technology also needs to be considered where varying material is encountered in the one hole and to optimise drill rates.

Difficult to Drain Areas

A common issue across our mines arises when mine planning and access do not allow adequate lead time to drain seam gas content to acceptable levels. The most common response to this problem is to increase hole density and reduce space between holes in the drainage pattern. Some areas of the mines have been encountered where regardless of this response the seam gas will still not drain at any appreciable rate. Other approaches may be considered, including:

- A number of mines have successfully fractured horizontal in seam holes with high pressure water and have successfully stimulated increased gas flows
- In some cases where the drainage holes are connected to a source of suction it may be possible to provide additional negative pressure to further enhance desorption rates
- In individual critical cases it may be beneficial to ream out the hole to provide both a reduction of resistance to flow and an increased surface area for the desorption process
- Early identification of difficult to drain areas may give additional lead time for drainage to occur by flagging up the need for early drilling. Some research in the microscopic investigation of samples is showing promise in this aspect.

Planning

Although significant planning of gas drainage and drilling takes place there is probably still more that could be done to optimise the gas drainage and drilling performance. One mine has noted that results have been improved by involving the actual driller to a greater degree in planning and taking into account as many variables as practical with past performance feedback.

Similarly an ergonomic review of the drilling site has designed out bad work practice, enhanced OHS aspects of the task and improved drilling rates.

Mine planning has a role to play in outburst and gas management in that lead time is necessary to drill and drain to reduce gas content of the coal efficiently. Unexpected adverse geology can often lead to mine development in areas with little notice. Gas drainage to acceptable levels may still be possible by increasing the density of drilling but is not likely to be as cost effective or efficient compared to an area where ample warning is available.

Hole Trajectory

The majority of in seam holes are currently surveyed in three dimensions. This is necessary to confirm hole and sample location. Currently the general method of establishing the hole location in relation to the seam floor or roof is by periodically touching these interfaces. A system of continuously monitoring borehole location relative to roof and floor would greatly enhance drilling performance.

Flow Monitoring and Feedback

There is likely to be a benefit from case studies of gas flow performance as feedback mechanism for design of future holes. This is no doubt done to some degree for both in seam and cross measure drainage but more extensive surveys and analysis could no doubt increase efficiency. The potential benefit lies in detailed case studies of high flowing holes in comparison to surrounding low flowing ones. The reason for the variation is important.

Determination of Outburst Potential

Authorisation to mine must be accompanied by confirmation that gas content of the coal ahead of mining is below a threshold limit. This generally involves drilling and sampling. Gas analysis of the coal samples can be complete

in around three hours at the laboratory but more realistically, taking into account the drilling component, twenty-four hours is more likely.

An on site method of determining gas content or proneness, particularly where levels prove to be either well above or well below the limits, would be beneficial in saving potential delay times waiting for results or increasing gas drainage activity. The laboratory analysis may still be necessary to determine the near limit values but may be superfluous in determining the obvious pass or obvious fail sample results.

CONCLUSIONS

Outburst and gas management is generally effectively managed at the three mines as described. However there is always the need to improve understanding of the outburst phenomenon and the mechanism of gas drainage. This need is primarily driven by safety concerns resulting from outbursts or gas emissions not being effectively controlled. The efficiency of the control measures has an obvious potential impact on productivity and economic viability of the coal mining operations. There is always room for improvement.

There exists a definite link between gas drainage and outburst control. This link can be extended to gas utilisation and even to greenhouse gas control as that debate continues. The latter two issues may become substantial drivers that influence the safety and productivity of operations.

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