SPONTANEOUS COMBUSTION AT THE BLAIR ATHOL COAL MINE

S Prebble and A Self

1. History of Mining at Blair Athol Coal

Blair Athol Coal (BAC) is located approximately 25km north-west of Clermont and 240km south-west of Mackay in Central Queensland. BAC produces 11mtpa of export quality steaming coal, all of which is mined from the 30m thick Number 3 Seam. The coal is mined using 2 x P&H 2100 electric shovels and a fleet of 6 x Caterpillar 789 rear-dump trucks.

The No.3 Seam is overlaid by an average of 40m of overburden, which is removed by a BE1370 dragline, assisted by dozers. The overburden also incorporates the 1-2m thick No.2 Seam, which is spoiled with the overburden.

There is a long history of coal mining in the Blair Athol area. The deposit was initially discovered in 1864 with mining commencing in the 1890s. Initially the deposit was underground mined, and the extent of the underground workings can be seen in Figure 1. There were 4 significantly sized collieries and approximately 50% by area of the remaining deposit has been affected by underground workings.

The underground workings range from single level through to 3-level in some areas (1 level in the thin No.2 Seam and 2 levels in the 30m No.3 Seam). The mines were worked by hand-mining bord and pillar methods, with shafts for ventilation and access purposes. Typically roadways were taken 5m wide by 3m high, with pillars approximately 20m thick. Support was by timber props, most of which continue to be in place today, over 50 years later. Some of the collieries were divided into clearly identifiable panels, such as the Newcastle Colliery, whereas others followed no apparent plan, such as Blair Athol No.3 Colliery.

In 1936 the first attempt at significant scale open-cut workings was made. The method proved to be more economic than underground working and by the late 1950s most of the underground collieries were closed.

In the late 1970’s, the Blair Athol Coal joint venture was established by CRA (now Rio Tinto) together with ARCO and two Japanese power generation utilities. In 1984, the first shipment of coal was exported from the expanded open-cut operation.

2. Intersection of the Open-cut and Underground Workings

The old underground workings had previously been intersected in a number of locations. In some of these locations, the old workings had showed signs of advanced spontaneous combustion. The openings had been successfully treated by cooling with water, excavation of the heating coal and backfilling the openings with spoil.

The most significant intersection of the open-cut and underground workings to date was when strip 16 east intersected the Blair Athol No 3 Colliery in 1999. The No.3 Colliery, which closed in the 1950's, had a history of problems with heating. The No 3 Colliery consists of three levels of workings with a total volume of approximately 300,000m^3 (See Figure 2 for detail).

The first indications of a problem with heating were when overburden in strip 16 east of the open-cut was drilled and blasted in July 1999. A significant fire started in exposed coal at the end of the strip. This fire was successfully smothered with overburden and it was assumed that, when exposed, any heating in the old workings could be treated in the usual fashion.

However, as the dragline began to uncover the coal it became clear that the heating in this area would be of a much larger scale to that experienced before at BAC. A number of openings on top of coal and in the new highwall began to emit smoke and steam, as illustrated in Figure 3.

3. Significant Risks Associated with the Fires

A representative from the DME visited BAC to inspect the area and alerted BAC to two major hazards.

Firstly, dangerous concentrations of CO were present in the smoke venting from the workings. This included readings as high as 1,200 ppm (1.2%) CO.

Secondly, there was a risk that an explosive mixture of distilled gases from the fires could be present in the workings. The area of the mine was evacuated until the composition of the atmosphere within the workings could be determined. To gauge the scale of this hazard, it was calculated that if the total volume of the gas within the workings were to explode, the energy generated would be equivalent to 20 typical overburden blasts.

4. Management of Carbon Monoxide Risk

Carbon monoxide in the concentrations vented by the workings represents a threat to life. There was a lack of understanding of this hazard at BAC and so a number of training sessions were run for the whole workforce. All employees entering the underground workings area are required to carry CO monitors. A literature search indicated a lack of consistency as to appropriate CO exposure limits. After some discussion, the DME has recommended exposure limits of:

Time Weighted Average (8 hours)	30ppm
Short Term Exposure Limit (15 minutes)	200ppm
Absolute Limit	400ppm

If any of these limits are exceeded, the person must withdraw from the area for the remainder of their shift. Research indicates that these limits are appropriate to ensure blood carboxyhaemoglobin levels are maintained at acceptable levels.

5. Management of Explosion Risk

5.1 Monitoring

Before any action could be taken, more information was required on the atmosphere within the workings. A total of 8 x 150mm monitoring boreholes were drilled into the colliery from the surface, and a bundle tube system was set up to sample gas from the holes. Initially the mobile SIMTARS facility was used for continuous sampling, though BAC has since acquired its own gas chromatograph and trained samplers.

A typical analysis from the holes was 10% Carbon Monoxide, 12% Hydrogen, 4% Methane and less than 1% Oxygen; a very fuel rich, but inert, atmosphere. Such an atmosphere was somewhat outside that normally experienced in Australian mines. In order that the fires could be treated, but that employees were not exposed to an unacceptable risk of explosion, a novel approach to the setting of gas concentration trigger levels was required. Shane Stephan of the DME and Andrew Self of Australian Coal Mining Consultants were instrumental in developing this approach. The trigger levels adopted are discussed further in a related paper by Andrew Self.

5.2 Flooding

Flooding the colliery with water was identified as the most obvious technique to treat the fires. At BAC water is readily available, and the levels of the workings indicated that at least some water should be retained. Water was pumped down 2 x 150mm boreholes into the workings for several weeks. The water had limited success, only marginally reducing the level of combustible gases. Although there was no obvious outflow of water from the workings, neither was there any build-up of water level. It was assumed that the water had found a number of leakage paths from the workings.

By this stage, the uncovered strip of coal was burning strongly. The roof of a number of drives had burnt through to the surface, exposing roadways of glowing hot ashes (see Figure 4). A number of exposed drives were also burning with a blue flame. In order to calm the top of coal surface, the water was diverted straight over the highwall onto the top of coal. Mud and water were washed over the coal surface, smothering many of the more active fires. However, the atmosphere within the colliery remained rich with combustibles.

5.3 Isolation of Colliery

Given the limited success with the use of water, it was clear that the only way to control the explosion risk and continue mining operations would be to isolate the main section of the colliery from the current strip. The following sequence of steps was planned:

- Smother the burning top of coal with a thin layer of overburden.
- Flush the combustible gases out of the workings to remove the explosion risk.
- Mine out the coal which had been burning.
- Seal the openings in the highwall.
- Maintain an inert atmosphere.

Each step is described in further detail below and the planned outcome is illustrated in Figure 5.

5.4 Smothering of the Burning Coal with Overburden

The purpose of this step was to control the combustion of the top of coal surface and thus reduce smoke and CO emissions. A small section of the highwall was drilled and blasted to remove another 'slice' of overburden. This material was then pushed out over the burning coal using dozers, forming a cover of 3m over the top of coal.

5.5 Flushing of Gases from the Workings

This was the key step in controlling the explosion risk. By displacing the combustible gases (Hydrogen, Methane and Carbon Monoxide) with inert gases, personnel could be sent back into the area to treat the fires. After taking advice from a number of sources in the industry, three main tools have been utilised to flush the combustibles out of the workings

A) GAG Jet Engine

The GAG 3a was identified as the best available tool to quickly flush out the workings. The GAG generates up to 20m^3/s of inert gas, a much greater capacity than the other options considered. QMRS owns two GAGs, which have been developed from a Polish military trainer aircraft engine. The engine is fitted with a custom-made afterburner and a diffusive cooler to ensure that the engine no longer develops thrust or allows a flame to enter the atmosphere.

In order for the GAG to access the underground workings, a 900mm hole was drilled into the workings from the surface. The borehole was fitted with an 800mm internal diameter sleeve, with an elbow and T-piece fitted above ground. The elbow was fitted with a knife gate to seal the workings from the atmosphere, and an explosion vent valve to protect the GAG in emergencies. This arrangement, illustrated in Figure 6, allows the GAG to be vented to atmosphere while the oxygen level of the output is tuned. The output is then diverted down the borehole.

Initially there were some reservations as to how the GAG would perform due to back-pressure created by the elbow, 50m tube and unknown resistance of the workings. However, the GAG has proved itself to be well capable of inertising the workings at BAC, with no back-pressure problems. The GAG has typically generated output of around 17.5m^3/s of inert gas at less than 0.1% Oxygen, and this has been adequate to generate an inert atmosphere within the workings in between 1 and

4 hours. The GAG output is primarily composed of Nitrogen and Carbon Dioxide. In total 5 GAG campaigns have been run at BAC.

There have been some teething troubles with the GAG. Most problems have centred around the flame stability in the afterburner unit. After some modifications, GAG engine 2 has proved itself to be reliable while GAG engine 1 remains rather temperamental in its operation. Some more development is required to make the GAG a robust, reliable unit.

Running the GAG is also a major logistical exercise. QMRS recommend a minimum of 6 operators and it can be a challenge putting a team together at short notice. BAC acknowledges the assistance given by other mines in making labour available. Fuel consumption of Jet A-1 is up to 2,000 litres/hr (dependent on back pressure) and up to 40,000 litres/hr of fresh water are also required. That said, the GAG remains the best tool to rapidly knock down a dangerous mine atmosphere.

B) Tomlinson Boiler

The Tomlinson Boiler generates cooled, compressed inert gas from the combustion of fuel and oxygen in a furnace. Typical output is 75% Nitrogen, 12.5% Carbon Dioxide, 10% water vapour and, importantly, less than 2% Oxygen.

BAC has had a Boiler on hire from Brambles Coal Services since August 1999. This Boiler is rated at 0.25m³/sec, making it one of the smaller units available. It is relatively simple to operate and maintain. Once started, the Boiler runs unmanned, and automatically stops if the oxygen output exceeds 3%. The water tank attached to the Boiler (40,000 litres) requires draining and refilling every day. Fuel consumption is 70 litres/hr with a tank of fuel lasting 50 hours. BAC has purchased a 0.5 m³/s capacity Boiler from Tomlinson, with delivery expected in August 2000.

At times where openings to the workings have been reasonably well sealed, the Boiler has been capable of maintaining an inert atmosphere. However, as soon as significant leakage is present, the Boiler is not effective. Overall the Boiler has been a relatively cheap and simple method of generating inert gas. However, availability has been an issue, with the Boiler running for 244 days out of 284 (86% availability). A higher availability should be achievable with a thorough proactive maintenance programme.

C) Floxal Unit

BAC has temporarily acquired the services of a Floxal Nitrogen-generating unit. The Floxal, owned by Air Liquide, produces Nitrogen by filtering air through a special polymer membrane. The output is rated at 0.125 m³, comprising 97% Nitrogen.

The low flow rate from the Floxal limits its ability to maintain an inert atmosphere in BAC's application. However, this is offset with very low maintenance and high availability. Power is the only input required, and availability of 98% is quoted. To date an availability of 100% has been achieved at BAC.

A higher capacity Floxal unit has the potential for a wide application in the coal mining industry.

5.6 Mining of Burning Material

With the explosion risk under control, the next step was to mine out the burning material. This was undertaken using shovel and trucks, mining through at the level of the bottom of the lower workings.

The material being mined was very hot and quick to flare up when exposed to air. Water was readily available to spray on the mining face and all operators carried carbon monoxide monitors. Extra tyre temperature checks were carried out on the trucks working in the area.

As mining progressed, some open drives were encountered close to the highwall. Within hours of these drives being exposed to fresh air, strong fires were burning, carrying combustion products back into the workings. Full-time monitoring of the atmosphere was required to ensure that operators were not exposed to an explosion risk.

Two such fires can be seen in Figure 7. These particular fires generated enough combustible gases to trigger the explosion limits within the workings, requiring the area to be evacuated. It was several weeks before the fires could be brought safely back under control.

From this point onwards, any exposed openings were immediately backfilled with dirt to reduce fires.

5.7 Sealing of Openings

In order to minimise fresh air leakage into the workings, it is essential that all exposed drives are sealed as thoroughly as possible. Where fires are burning strongly in the drives, the safest option is to push bulk dirt into the opening from a distance. However, in situations where inactive drives have been exposed, there is the opportunity to create a more effective seal.

BAC has trialed sealing with polyurethane compounds and expanding concretes. However, neither of these methods is cost-effective given the number of openings that BAC are required to seal. Also, most of these seals only need to stay in place for a maximum of 12 months.

Sealing of openings with compacted overburden material has been identified as the best option. To facilitate this sealing, an employee at BAC designed a "plugger" attachment for a D10 dozer. The plugger attaches to the ripper frame and allows the dozer to compact material into an opening without actually entering it. The plugger is illustrated in Figure 8. Where possible, damp clay material is used, and is compacted 5m deep into the opening. In this fashion sound, competent seals can be achieved.

5.8 Maintaining an Inert Atmosphere

It is considered that BAC's new Tomlinson Boiler will be adequate to maintain an inert atmosphere within the workings in the long term. This will be conditional on all leakage paths being adequately sealed.

6. Backfilling

A trial was undertaken of bulk backfilling the colliery. If the colliery could be filled from the surface via a borehole, the risk of explosion could be eliminated, or at the very least the volume of the workings could be reduced.

The first step was to identify a suitable material which would flow away from the bottom of the borehole but would contain enough solids so as not to flow out of the workings via cracks and fissures. Following discussions with a number of companies, the most cost-effective material was found to be a mixture of a sandy loam material from BAC, water and detergent.

The material was mixed in a trommel and poured into the workings via a 150mm borehole. In total 5,000m^3 of solids were pumped down the hole before the material backed up into the hole. The backfill seemed to be effective in reducing combustion activity in the immediate area surrounding it. However, it was impossible to say exactly what the fill had achieved and where it had run to. Backfilling the whole colliery was also going to be an expensive and lengthy exercise. Backfilling trials are continuing.

7. Future Strategies

At the time of writing the material in strip 16 east at BAC is still being mined.

The key learning from strip 16 east is that the strip of coal being exposed must be isolated from the remaining colliery as early as possible. Provided that this isolation is complete, the risk of forming an explosive mixture within the workings is greatly reduced. There may still be fires in the exposed coal, but these can be quickly treated so long as access to the area is maintained at all times.

Ideally, the isolation of the new strip from the remaining colliery would be carried out well ahead of the mining process starting. To do this requires either entry into the workings to build seals in the relevant drives, or creating a seal via boreholes from the surface. Entry into the workings is not considered to be an acceptable risk at this stage. Efforts are concentrating on sealing drives via boreholes from the surface. As yet, a reliable method of forming such a seal has not been identified.

While work is continuing on the development of sealing techniques, a trial of an isolation technique using the dragline has been planned for the last quarter of 2000. The dragline, while exposing coal in the usual fashion, will excavate a deep key cut against the highwall to completely expose any underground openings. Any such openings will then immediately be backfilled with overburden, placed by the dragline. The key to success will be to ensure that any drives are exposed for the minimum possible time, and that airtight seals are constructed.