Application of the QMRS GAG at Crinum North Mine

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Abstract

Final mine sealing was recently undertaken at BMA's Crinum North Mine located near Emerald, QLD. Due to the benign atmospheric environment at Crinum North, the Queensland Mines Rescue Service GAG unit was utilised to reduce oxygen levels throughout the underground atmosphere.

The GAG unit was utilised by way of a vertical borehole from surface to seam to successfully reduce oxygen levels throughout the mine workings. Application of the GAG unit enabled the underground workings to be classified as stable and inert and subsequently cease gas monitoring at Crinum North. The data and information obtained from this activity provides valuable information to the underground coal mining industry on successful application of the GAG in realistic situations.

This paper discusses the results obtained from this successful application of the GAG unit and touches on further work to be explored to provide the industry with a better understanding of how this method of inertisation can be successfully applied in both planned and emergency situations.

Introduction

Crinum North Mine was the third of three underground mines within the Gregory Crinum mining complex, located 35km North of Emerald in the Bowen Basin. Crinum North produced coal from 2012 to 2015 using the longwall method for coal extraction. Prior to Crinum North, coal was extracted from Crinum and Crinum East undergrounds. Coal was also extracted from Gregory open cut mine which was placed into care and maintenance in 2012.

Crinum North was predominantly a punch longwall mine with a small set of mains to the South, used to access three of the five longwall blocks. Crinum North contained longwall (LW) blocks 22-28. The length of each longwall block at Crinum North varied between 510m and 2550m. In November 2014 it was announced that LW28 would be the final longwall block of Crinum North with no further underground activities on the site following completion of this block. As such, the sealing of all underground areas was required to allow the site to move into care and maintenance.

The final sealing of Crinum North as an underground mine was separated into two stages. The first stage involved sealing of the northern part of the underground mine following the recovery of longwall equipment from LW26. The final stage involved the sealing of the remainder of all underground workings following cessation of production and salvage of underground equipment after longwall 28 second workings. This paper predominantly focusses on the final sealing of Crinum North and use of the Queensland Mines Rescue (QMRS) Górniczy Agregat Gaśniczy (GAG) unit for assisted inertisation of the underground atmosphere.

Gregory Crinum Complex

The two other underground mines of the complex; Crinum South & Crinum East, were worked from 1994 until 2008 and 2008 to 2012 respectively. Crinum South was a conventional underground mine accessed via two drifts from the surface and Crinum East was a punch longwall mine. Crinum East was sealed in 2013, and Crinum South sealed in 2015.

Gas levels throughout the Crinum lease were low and the gas environment benign. The predominant seam gas was carbon dioxide, with very little methane detected throughout the history of Crinum. Small amounts of methane were detected at Crinum East in the LW21 area. There were a number of hydrogen sulphide zones, however there were no zones present at Crinum North.

Longwalls 22, 23, 24, 25 & 27 at Crinum were sealed progressively following longwall extraction of the block. Sealed areas at Crinum progressed from fresh air to inert without passing through the explosive range. For this reason, assisted inertisation of sealed areas was not utilised at Crinum.

Ventilation System During Longwall 28 Production

The ventilation system prior to cessation of longwall 28 production consisted of two intake portals, which led to three intake roadways underground. Two of these roadways were travel roads and the third the mains belt road. The two travel roads provided intake air to the LW28 face, whilst the belt road provided intake air to 8 cut-through of the South Mains before moving directly into the returns.

Three regulators were in place underground. Two of these were located in the South Mains belt road and one in the LW28 cross-drive parallel to the longwall face. The air quantity on the longwall face was predominantly controlled by adjusting the LW28 cross-drive regulator.

The return roadway was through C & D headings (LW27 & LW22 cross-drives) through to the LW23 vent road, LW23 cross drive and LW24 cross-drive. Three main fans were in place at maingate A Heading, maingate 23 B Heading & maingate 24 B heading portals, however only two fans were running at any given time for the duration of LW28 second workings. Figure 1 shows the ventilation system when the longwall was at final position.

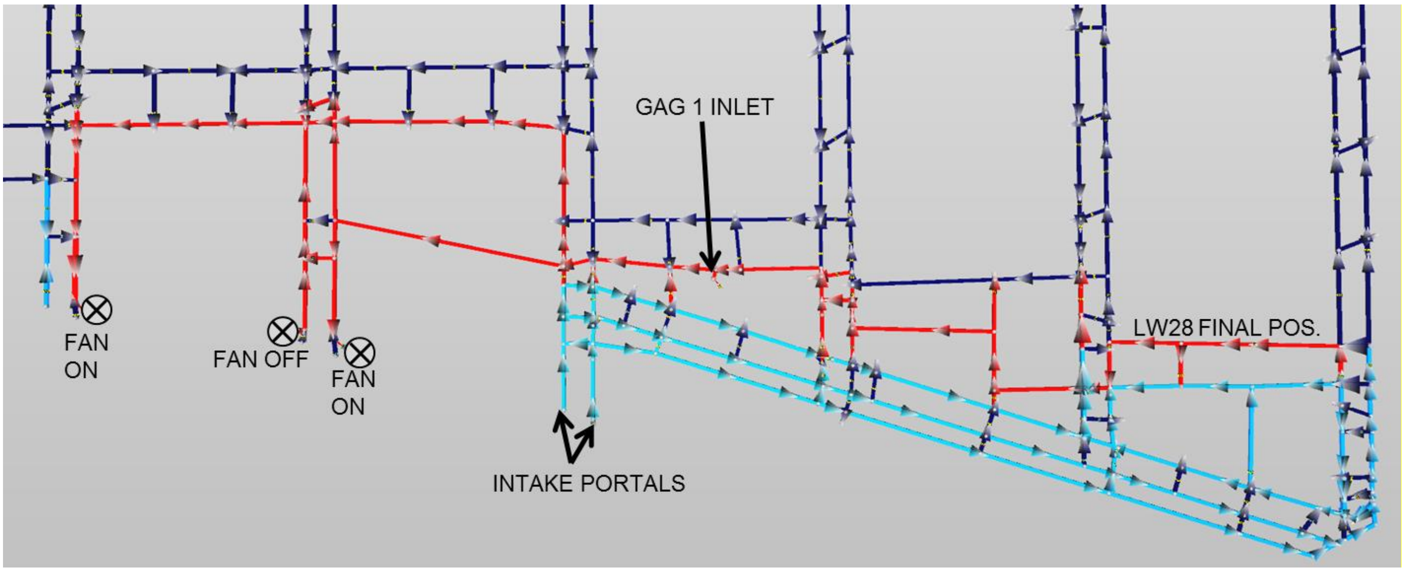

Figure 1 Ventilation system when LW28 at final position

Method of Sealing

Longwalls 22, 23, 24, 25 and 27 were sealed progressively following longwall recovery from the respective block. Following the extraction of LW26; the northern sections of Crinum North were sealed. This section of sealed area was allowed to self-inertise as previously sealed areas were. However due to the large area in respect to the longwall goaf present in the area this sealed area was unable to be classified as stable and inert until final mine sealing of Crinum North was completed. The southern sections of the underground workings were left unsealed for the remainder of second workings in LW28. Figure 2 shows the area left to be sealed for the final sealing of Crinum North.

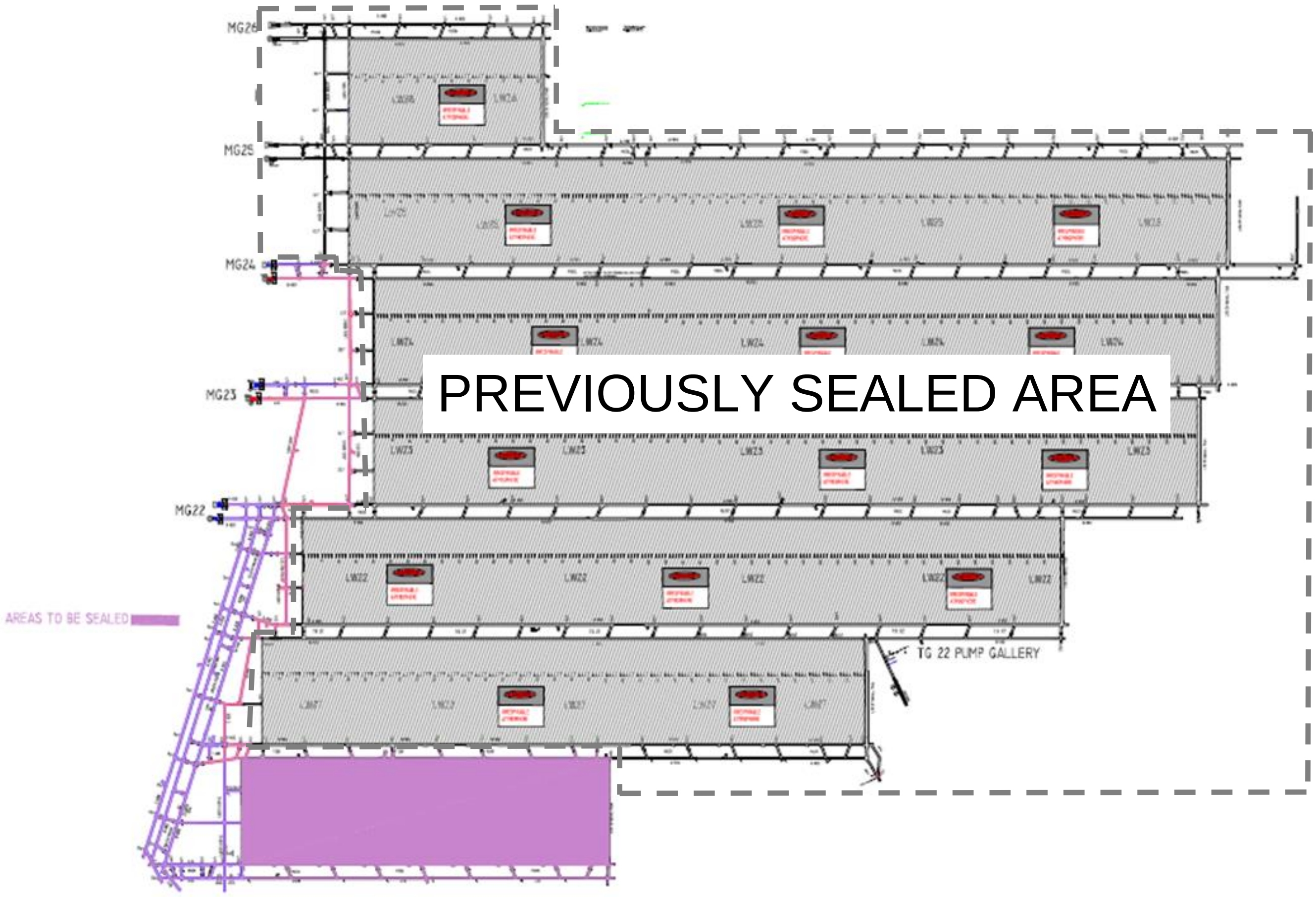

Figure 2 Crinum North mine plan including areas to be sealed

All seals for both stages 1 and 2 of final mine sealing for Crinum North were installed at portal entries as close as possible to the surface in competent strata. Each seal was a type E (70kPa) seal, constructed of a backing frame and sprayed to thickness with Aquacrete Wet Repel. These seals were chosen due to the benign nature of the underground atmosphere at Crinum North and to meet legislative requirements of seals between the surface and entrance to a mine.

Seals were installed progressively as per sealing management plans, ensuring hazards were effectively managed for those constructing the seals. Main ventilation fans which were in place at belt portals were utilised to maintain ventilation through seal sites for construction of the seals.

Stage 2 of sealing also involved the sealing of all remaining open large boreholes, with the exception of one left open but capped for the purposes of monitoring water levels. These boreholes included all pump boreholes located on the maingate of LW27 and the 2 GAG boreholes. All holes were backfilled prior to sealing with the exception of one GAG borehole which was used for the inertisation.

<u>Underground Atmosphere Inertisation</u>

Throughout the history of Crinum underground, the atmosphere remained benign and following sealing, would progress from fresh air to fuel lean inert without passing through the explosive range. For this reason, inertisation of the atmosphere had not been previously undertaken at Crinum.

Due to the large area remaining for the final sealing of Crinum North, it was decided to explore using the QMRS GAG for assisted inertisation of the underground atmosphere. The primary purpose of this was to accelerate inertisation and eliminate ongoing gas monitoring requirements following the transition of the Gregory Crinum complex into care and maintenance. It was expected that the LW28 goaf would self-inertise within a matter of weeks following restriction of ventilation through the goaf, however the remaining 8km of open roadways underground were expected to take considerable time to self-inertise. Gas monitoring results from Crinum East final sealing following LW21 extraction showed that it took three months for oxygen levels to fall below 8% at the portals.

Due to the aquifer above Crinum North, ongoing pumping from the goaf was required during production to manage water levels behind the active longwall face. These pumps were turned off during the extraction of LW28, however water levels were estimated to take one year to reach the portals, and as such water would not be able to be used as a suitable inertisation tool for the mine.

QMRS was contacted by BMA to investigate the use of the GAG unit. It was decided that the underground inertisation of Crinum North would be the scheduled GAG training for December 2015. Completing the exercise as a training run enabled the underground inertisation to be cost effective and provide a mine site run for GAG operators. Given the benign nature of the underground environment and the purpose of the inertisation to reduce oxygen levels rather than prevent or minimise the time the sealed area spent in the explosive range, the risk should the exercise had not been successful was minimal.

The Crinum North construction involved installation of two GAG docking stations for emergency sealing purposes. These stations were GAG inlet elbows on the surface with a borehole drilled into the mine workings along the LW22 and LW23 cross-drives 300m away from each other. The locations of these boreholes are shown Figure 3. During production, both of these roadways were used as return roadways.

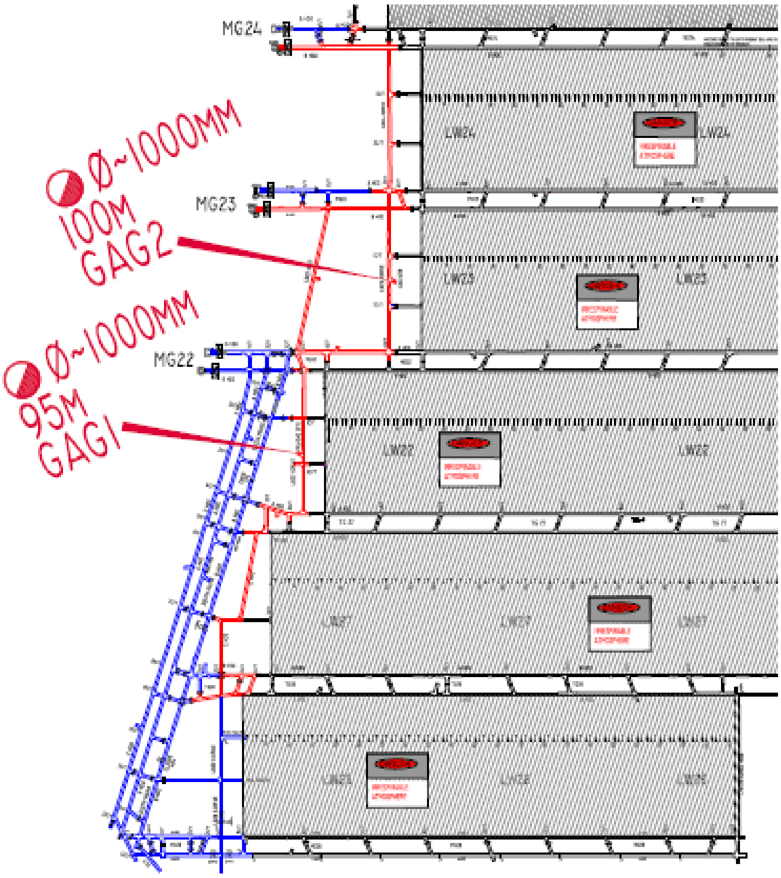

Figure 3 Location of GAG boreholes

GAG1 borehole which intersected the LW22 cross-drive was chosen as the injection point for the GAG. This was chosen due to it being most central to the mine workings. It was recognised that the GAG would essentially need to work in the reverse of the ventilation system which was in place for production, to reach the LW28 final position and MG22 intake portals.

The ventilation system underground was left as-is; with the exception of opening a regulator in a parallel roadway to the LW28 final position, for all final sealing activities including underground inertisation. The purpose of opening the regulator in parallel to the LW28 final position was to remove as much ventilation as possible from the LW28 face to allow the LW28 goaf to self-inertise at a faster rate. It was expected that the majority of the LW28 goaf would be inert at the time of the GAG run.

An option of constructing a stopping close to the GAG inlet was explored, which would direct most of the GAG product in one direction rather than two, was investigated. The construction of a stopping in the single return roadway for LW28 would have complicated the ventilation system for construction of the portal seals.

Three of the six final seals were constructed with hatches that were left open until the GAG had started. These were put in place to allow venting of the existing underground atmosphere to enable a more successful inertisation. Without these hatches backpressure would have been placed on the GAG unit. Hatches were put in place at maingate 22 A heading, maingate 23 A heading and maingate 24 B Heading. These hatches also provided a ventilation path to allow construction of the final seals with the main fans still running.

These hatches were intended to stay open until a trigger of below 8% oxygen was reached at the hatch. Closing of the hatches was to be completed under instruction from the Underground Mine Manager in consultation with the Ventilation Officer. Personnel closing the hatches were Mines Rescue trained personnel wearing CABA when entering the portal area.

One main fan was left running until the day of the GAG run to continue ventilating the underground mine. The fan was running at only 40%, ventilating in through two hatches and returning through the third.

Some modelling was undertaken using Ventsim to estimate the time it would take to complete the inertisation and expected results. The simulation showed the reverse of the ventilation system which was in place during production. The simulation was also unable to take into account migration into the LW28 goaf and through the adjacent goaves.

Gas Monitoring Strategy

It was recognised that for the best understanding of how the GAG operated and inertised the underground in this situation, gas monitoring points would need to be put in place at strategic locations to provide that understanding.

All real time monitoring inbye of portal seals was decommissioned during the underground demobilisation. This ensured that no gas monitoring cables would be running through seals. Real time gas monitors were left at portals to satisfy gas monitoring requirements for explosion risk zone boundaries and as per the Crinum Safety and Health Management System. In addition to these boundaries, where hatches were left open, real time gas monitors were left outside the hatches. The monitors in place were detecting for oxygen, carbon monoxide and carbon dioxide. The purpose of these monitors was to provide an indication of when GAG product had reached the portal hatch. The limitations of these sensors were well understood, and it was understood that these monitors were to be used as an indicator only. The advantage of using these was the absence of a delay in detecting when the GAG product had reached the hatches.

Tube bundle monitoring was put in place at selected locations around the underground mine. The purpose of these locations was to be able to gain the best understanding of the GAG product migration throughout the underground workings. Figure 4 shows the location of these monitoring points.

It was recognised that any tube bundle lines running close to the injection point of the GAG exhaust would be susceptible to damage due to the high temperature of the GAG product, as seen in previous uses of the unit (Watkinson *et al.*, 2015). Prior to sealing, all tube bundle runs were reviewed and where necessary, relocated away from the injection point.

Tube bundle points which were in place from the Crinum North stage 1 sealing were left in place. During the run of the GAG, these tube bundle points were disabled to allow the best understanding of gas migration the area undergoing inertisation at the time.

Bag sampling was completed as per the sealing management plan prior to and following the run of the GAG unit, however bag samples were not taken during the run of the GAG unit.

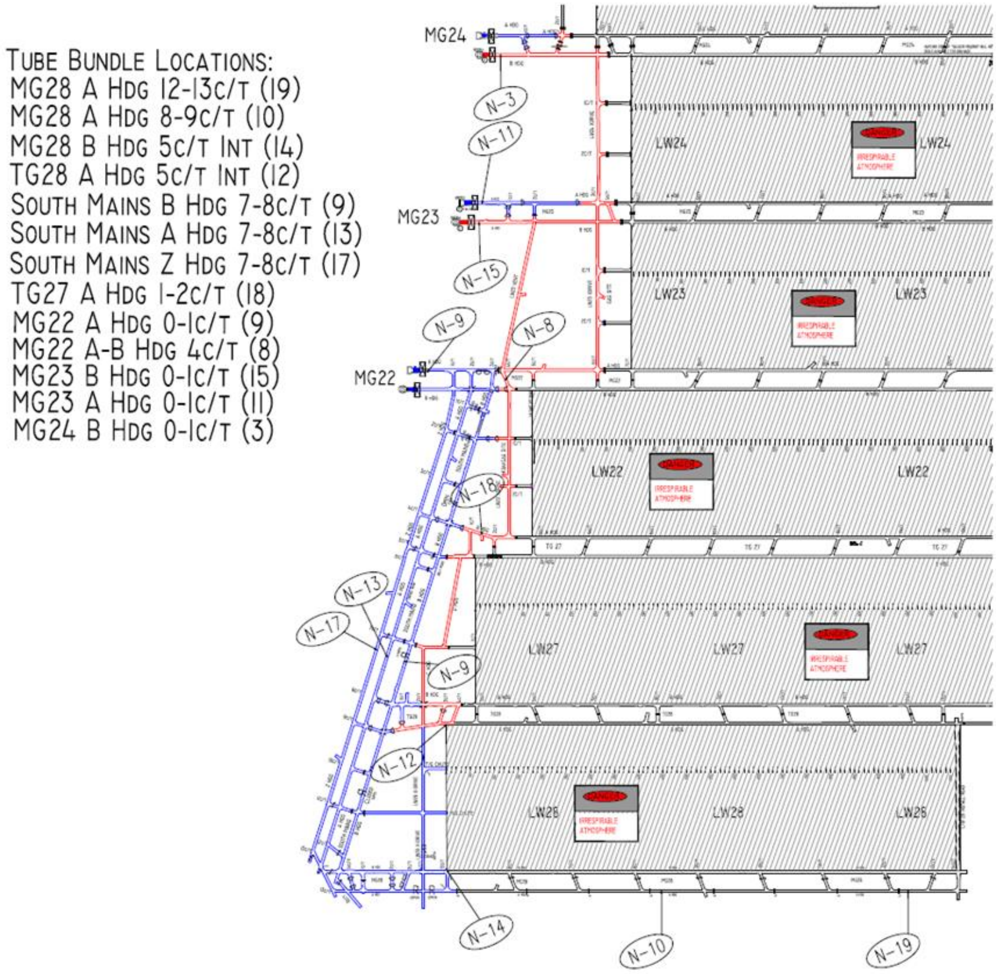

Figure 4 Location of tube bundle monitoring points

Portable gas detectors (MSA Altair 5X) were also used during the GAG unit run. The purpose of these was to verify the readings obtained on the real time and tube bundle systems to assist in making a decision on when each hatch could be closed. These portable gas detectors were operated by mines rescue trained personnel in the hatch closing team.

<u>Site Management of the GAG Unit</u>

It was recognised that running the GAG unit on site presented hazards which were not normally encountered at Crinum Mine. A risk assessment was carried out to determine and control the hazards on site introduced by the use of the GAG unit. All operational tasks relating to the GAG were managed by QMRS under QMRS procedures.

Controls which were in place included limited personnel on-site for the duration of the run. Any employees who were not directly related to the GAG run were not on-site or asked to stay within the administration area, and when entering the Crinum operational area, permission needed to be granted by the UMM. A final inspection of the Crinum North trench was completed by an ERZ Controller to ensure no unauthorised personnel were present. The GAG was being operated well away from the portal areas and the only personnel permitted to enter the portal areas were mines rescue trained personnel wearing compressed air breathing apparatus. A run sheet was developed for the day and was managed by the Underground Mine Manager.

<u>GAG Run</u>

QMRS commenced setting up on site on Monday the 7th and Tuesday the 8th of December 2015. The unit was test run in the afternoon of the 8th of December. The underground inertisation then started at 8.30am on Wednesday the 9th of December after ensuring all controls identified via risk assessment were in place. All ventilation was removed from the underground workings by turning off the maingate 23 A heading fan immediately prior to starting the GAG. The GAG unit then ran for 11 hours, injecting GAG product into the underground workings.

Initially when the GAG unit started injecting into the underground workings, the pressure relief valve on the inlet elbow allowed product to escape due to the pressure the GAG unit created. This was quickly resolved by placing heavy objects on the pressure relief valve.

The real time and tube bundle monitoring system was monitored closely in the control room by the control room operator. The first signs of the GAG product was detected by the tube bundle system at each end of the LW22 cross-drive at around 9.15am. This was expected as these locations were only 150m away from the injection point.

The first hatch expected to show GAG product showing was at the MG23 A heading seal hatch. As expected, this was first detected at the MG23 A heading hatch at 9:38am, when the oxygen levels showed signs of dropping. This location was closely monitored once the reduction in oxygen had been detected. Once the oxygen depletion was noticed, it took a further hour to reach 10% oxygen at this location. An oxygen level of around 9% was only able to be achieved before the decision was made to close the hatch around midday. Leaving the hatch open longer than necessary would allow further GAG product to escape from the underground workings, and the largest section of the mine was still yet to see significant oxygen depletion to allow ceasing the run. Figure 5 shows the real time gas monitoring results from this location.

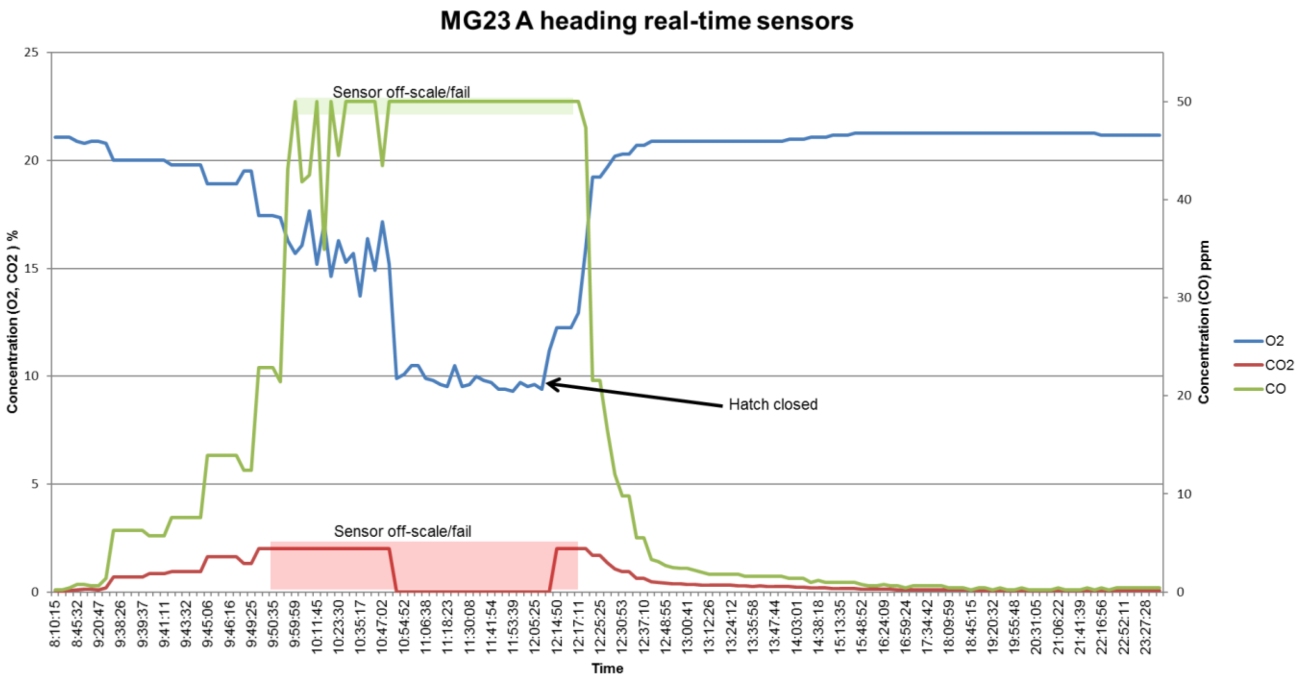

Figure 5 MG23 A Heading Real-Time Gas Sensor Results

Prior to closing of the MG23 A Heading hatch, GAG product was detected at MG24 B Heading by the real time sensors at this location at 10.20am. The tube bundle system confirmed this, also starting to detect an oxygen depletion at around this time. The oxygen depletion at this location was slow and was monitored for a number of hours before closing the hatch at 4.30pm when the oxygen concentration had reached 12%. Figure 6 shows the real time gas monitoring results from this location.

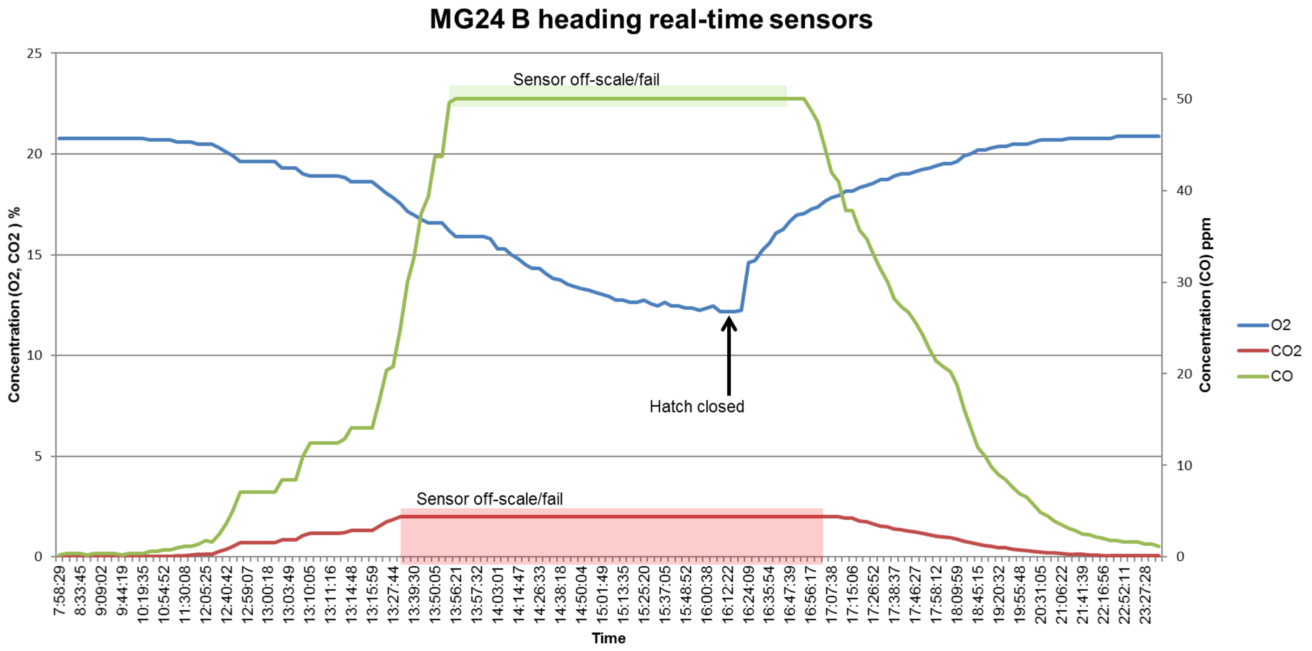

Figure 6 MG24 B Heading Real-Time Gas Sensor Results

The last hatch to detect GAG product and be closed was the MG22 A Heading hatch. This was expected due to the volume of roadways the product had to migrate through prior to reaching the hatch. Oxygen depletion was detected at this location at 11.40am by the real time sensors. The tube bundle in this location, was able to detect an oxygen depletion first, at 10.50am. This hatch was the last to be closed, and was not closed until 7.30pm in the evening after the GAG had begun to shut down. The oxygen level at this time was approximately 10%. This hatch was unable to be closed prior to this as QMRS advised the backpressure on the GAG was already high. Closing the hatch would only increase this and affect the operation of the GAG unit. A decision was made late in the day to continue running the unit until 7.30pm. This decision was made as personnel had been on site for some time, and were reaching the allowed time on-site as per the fatigue management policy. As previously discussed, ceasing the operation without an inert atmosphere did not pose a risk of flammable gas accumulation due to the benign atmosphere at Crinum North. Figure 7 shows the real time gas monitoring results at this location.

On the day of the GAG run, no hatch location was able to achieve the target of 8% oxygen before closing the hatch. A number of tube bundle locations underground within the area to be sealed showed under 8% oxygen on the tube bundle system. These locations were predominantly closer to the GAG injection site and open roadways with no regulators close to the tube bundle point.

Carbon monoxide levels underground reached a maximum of 200ppm, and carbon dioxide levels underground reached a maximum of 9% during the operation of the GAG.

The output oxygen concentration of the GAG unit during the run was around 4.5% oxygen. It is believed that the 8% target at the hatches were unable to be achieved due to a mixing effect with the existing underground atmosphere rather than a full displacement of the underground atmosphere.

Real time sensor results were confirmed by the use of the portable gas detectors, with no notable variation between the two monitoring methods.

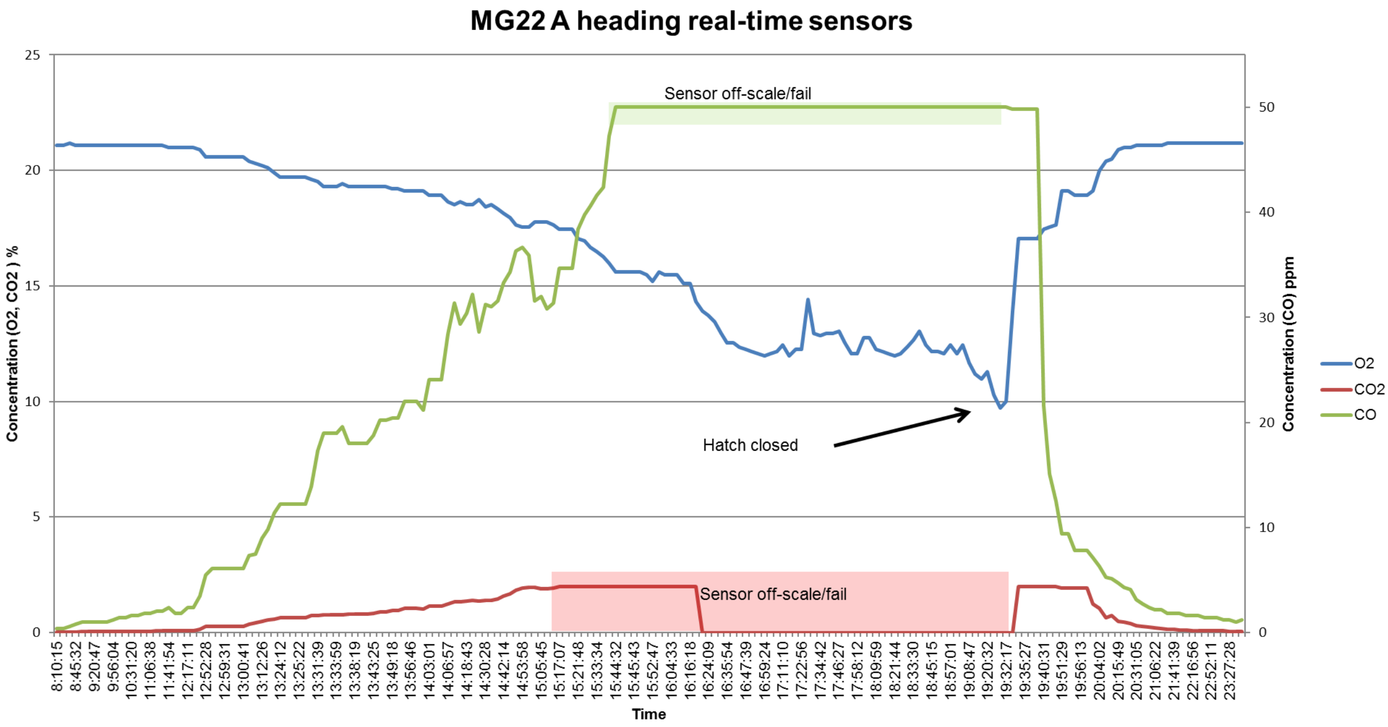

Figure 7 MG22 A Heading Real-Time Sensor Results

Final sealing of Crinum North Mine was completed on the following day, of which the final step was to backfill the GAG borehole used for the injection point.

Results of GAG Run

Gas monitoring via tube bundle of the underground workings continued until the 15th of December following the GAG run. Bag samples were taken from portal locations as per the sealing management plan, to confirm tube bundle readings and for early detection of flammable gases or heatings.

Carbon monoxide and carbon dioxide levels underground started depleting following the GAG run. Some locations showed small increases following the GAG run, however this continued for only the remainder of the 9th of December. This was a good indication that there was no cause for concern over potential heatings within the sealed area.

Gas monitoring results obtained from the MG22 A heading portal had variability in which was believed due to the barometric pressure across this seal, however the oxygen continued with an overall downward trend. The MG24 B heading portal results showed high oxygen levels for 4 days, followed by a sudden drop to below 8% oxygen which were unable to be explained. MG23 A heading showed a continual depletion of oxygen, with under 8% oxygen achieved on the 12th of December via the tube bundle results. Seals were inspected following final sealing with no leaking or damaged seals found.

Tube bundle monitoring in the area of the mine sealed during stage 1 of sealing was enabled following the GAG run. Ongoing monitoring in the days following the GAG run showed that oxygen levels also depleted in this area of the mine during the GAG run, which allowed this area to be classified as stable and inert. This area was unable to be declared stable and inert prior to the GAG run.

By the 15th of December, all tube bundle locations underground showed oxygen levels of 8% or below. The only exception was one tube bundle line showing variations consistent with barometric pressure changes, therefore was suspected to be leaking and providing inaccurate data. The underground atmosphere at Crinum North was declared inert, and tube bundle monitoring ceased on this day. Bag sampling from seal sites continued whilst demobilisation work was occurring in the Crinum North trench in close proximity to portal seals, with the purpose of early detection of flammable atmospheres.

Conclusions

The operation of the GAG unit was successful in assisting the inertisation of the underground atmosphere at Crinum North. It accelerated the process which would have taken up to 6 months, to only 6 days. It also assisted already sealed areas in reducing oxygen levels, showing that a direct path through the workings is not necessarily required.

This use of the GAG was also able to show that the use of a borehole for GAG inertisation was successful. The use of the inlet elbow minimised leakage into the underground workings. It also enabled the inertisation to be undertaken well away from other mine openings which may present a hazard to operators, particularly where flammable gases are present underground. The success of using a borehole was also due to its location, being central to the mine workings.

The real time gas monitors appeared to recover quickly. Whilst the carbon dioxide and carbon monoxide sensors went off scale during the GAG run, they recovered when fresh air was returned to the sensors. All gas monitoring methods used provided results with no noticeable variation.

Sufficient ventilation was produced by the GAG unit to enable the flow of GAG product underground. The use of an auxiliary or main fan in conjunction with the GAG was investigated prior to the run, however the use of a fan would likely dilute the GAG product and decrease the effectiveness of the assisted inertisation.

Recommendations for Further Work

- In depth modelling and reconciliation of the GAG unit to allow predictions of inertisation in planned or emergency situations.
- Consideration of placement of GAG docking stations or injection locations for effectiveness; i.e. place central to mine workings or areas of elevated risk such as active longwalls.
- Installation of sensors on the collar of GAG inlet during use to allow for flow approximation at the injection point.
- Improvements to GAG docking stations to minimise leakage, particularly where backpressure relief valves are installed.
- Combination the GAG and other inertisation methods to shorten the inertisation time required, the GAG was able to significantly reduce oxygen levels in a short time frame however did not reach the target.
- Test the effect of GAG product against products such as Carbofil or Rocsil to provide a better understanding of emergency sealing situations.

References

Watkinson, M, Lidell, K, Muller, S, Hanrahan, C 2015,Lessons from the Operational Use of the Gag Jet Engine at Mine Sites, 15th Coal Operators Conference, University of Woollongong