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UNDERGROUND COAL MINE GAS MONITORING EMERGENCY PREPARATION

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ABSTRACT: An emergency situation in an underground coal mine site is an unexpected and often dangerous event that can quickly escalate if immediate action is not undertaken. Emergency situations often occur at the worst possible time and have the potential for multiple loss of life, loss of equipment, loss of coal assets and major damage to a company's reputation. In an underground coal mine, an emergency situation involving a coal heating or small fire can quickly deteriorate into a large fire or worse a gas explosion. As the emergency situation unfolds, various activities will need to be undertaken that are not part of the normal work practices, for example gas sampling from a bore hole. The equipment required for bore hole sampling, may not be available onsite and the onsite personnel may not be familiar with its use. The aim of this paper is to provide a number of examples, from previous mine incidents to highlight some opportunities as to the emergency planning and preparation that can be implemented to improve the efficiency of the mines emergency response.

INTRODUCTION

When a high potential incident occurs in a coal mine, the situation can quickly spiral downward to cause multiple loss of life, loss of equipment, loss of coal assets and major damage to a company's reputation. Without wanting to state the obvious, a fire in a coal mine is very difficult to control as the fuel (coal) is abundant and changing the ventilation may endanger the underground mine workers.

A fire in an underground coal mine creates numerous problems –

1. The fire has plenty of fuel
2. The fire produces smoke, toxic gases and flammable gases
3. Gaining access to the fire may be restricted due to the underground workings
4. Coal is a good insulator so hot coal can readily reignite when exposed to ventilation
5. Using water on a hot fire can also produce flammable gases
6. The fire can be deep underground a long way from the surface
7. Gas monitoring of the fire may be restricted to monitoring at the ventilation shaft or portal.
8. The airflow may reverse and put flammable, fire produced gases, across the fire potentially resulting in an explosion.

It is very important to catch the fire event early so remedial actions can be taken and the fire can be put out with minimal investment in time and resources. Unfortunately, high potential events do occur and the mine has to manage the situation as it unfolds. There are various techniques that the mine can utilise in advance, to put the mine in a better position to manage a high potential incident.

LOCATION OF THE VENTILATION FANS AND PORTAL

The ventilation fans should be situated in an isolated location distant from the other mine infrastructure. Smoke from a fire will normally vent from the mine portal and/or ventilation fans. As the smoke, from an underground fire, may be toxic (high levels of CO) and potentially flammable, any infrastructure within a certain radius of the ventilation fan or portal will become an exclusion zone. Hence if the tube bundle shed, floxal /N_2 generators, air compressors, administration area, muster area, are in the exclusion zone, they will need to be evacuated and have the power isolated to prevent the risk of explosion. Obviously, the loss of critical infrastructure whilst trying to bring an

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emergency situation under control is an unwanted outcome. If the mine was to suffer an explosion underground then the Portal and ventilation shaft can become like a gun barrel Huntly West, Box Flat, and Moura No. 2) are examples. The control room at Huntly West looked down the portal and from an operational point of view, this was an advantage. Unfortunately, when the mine exploded, the control room (evacuated) was completely destroyed (Figure 1).

Figure 1: Huntly West portal

Having to relocate all of the mine personnel, during an emergency situation, is an unwanted layer of complexity that can be avoided by ensuring that the portal and ventilation fans are remote from the mines other infrastructure.

ROUTING OF SERVICES

It is recommended that the various services to an underground be supplied via different routes. For example, for a coal mine with a drift, it is convenient to route the power, water, compressed air, phone, Underground Intercom System (DAC), gas monitoring, down the drift. Unfortunately, if a fire was to occur in the drift, all the services in the roadway are going to be destroyed. Hence a fire, in the drift, can cause the loss of power, compressed air and phone, underground at the worst possible time. The Level 1 Emergency exercise at Cook Colliery was based on a fire at the bottom of the drift conveyor. As the conveyor was close to the surface infrastructure, many of the mines services were run down this drift including power, phone, DAC, compressed air, water, Tube bundle tubes and the realtime system. As the simulated fire gained in size, all of these services were destroyed, which impeded the mines response as the only communication with underground was via PED and the mines gas monitoring was offline. Hence, if the various services take different routes underground, i.e. via the drifts and bore holes the services damaged via a fire are limited.

Bore holes

Gas monitoring is essential to the management and resolution of emergency situations such as a fire underground. Once the gas levels underground reach the levels prescribed in legislation, the power has to be turned off to prevent the risk of an explosion. Hence the realtime monitoring will stop operation several hours, after the power is turned off and the Uninterruptible Power Supply (UPS) batteries run out of power. After the power is turned off the only monitoring available will be via the tube bundle system and bag sampling via the portal, ventilation fans and any bore holes. If the tube bundle system is monitoring locations around the fire, it would be a significant advantage. However, additional gas monitoring locations are normally required to gain a greater understanding of the fire event and additional bore holes take time to drill.

It would be an advantage to have boreholes predrilled at various strategic locations ready for gas monitoring should an emergency event occur. The boreholes do not need to be very large as they only need to have a tube to sample the underground atmosphere. These locations should be identified as areas of high risk.

The delays created by sourcing and transporting drill rigs to site in addition to actually drilling the bore holes can be quite long. The borehole delays only allow the situation to potentially deteriorate further. If the emergency monitoring bore holes were drilled as part of the development, the mine would be better placed to respond to a future emergency situation. Pike River mine is located under mountainous terrain in a national park in New Zealand. After the mine explosion on 19 November 2010, the only monitoring that could be undertaken was from the portal and ventilation shaft. Bore holes needed to be drilled to gain more information regarding the gas atmosphere underground, but unfortunately, due to the mountainous terrain, the drill rigs had to be disassembled, flown to site by helicopter and then assembled prior to the start of drilling (Figure 2).

Figure 2: Drill rig at Pike River

At Carborough Downs where in 2012, spontaneous combustion in the longwall panel required extra bore holes to be drilled. As this was approximately at the peak of the mining boom, sourcing drill rigs was more difficult and expensive.

Borehole Sampling Equipment

Once an explosion or fire has occurred, gas monitoring is essential to the response and potential rescue of trapped mine workers. The process of collecting gas samples can be potentially hazardous if the correct equipment is not available or an incorrect methodology is applied. For example, collecting a gas sample from a ventilation shaft after an explosion could expose the mine worker to toxic levels of CO and the risk of another explosion. Hence consideration needs to be given to installing an explosion proof tube for remotely monitoring the gas from the ventilation shaft. A 12.5 mm (1/2”) stainless tube encased in concrete which is sampling the ventilation shaft about 5 m from the surface would allow for the collection of the explosion’s afterdamp or fire’s smoke when the mine is breathing out. The ventilation shaft tube would need to run to an area outside the exclusion zone and the majority of the run could be carried out in normal tube bundle tube.

In order to draw a gas sample though the tube, it would require a gas sampling kit (pump and bag filling equipment). The equipment required to draw a sample from a ventilation shaft or bore hole consists of a small diaphragm pump and various valves to fill a gas bag. Most mine sites do not have this equipment or even the parts required to build one in an emergency situation. A case in point is Pike River, where in order to sample the ventilation shaft, after the explosion, a stomach pump from an attending ambulance had to be used. Hence, having a bore hole sampling kit available would have made the sampling of the ventilation shaft a lot faster and with reduces risk. Of course, training in the use of the Bore Hole Sampling Kit is a core requirement as is the maintenance of the equipment.

If the bore hole is not fully lined, then a tube will need to be lowered into the mine. With mines approaching 300m in depth, the process of lowering a 12.5 mm (½") tube can be quite involved as the tube gets very heavy and beyond a certain length, the tube will start to stretch hence will require a catenary cable for support. In addition, the mine environment could be very hot (melting the tube) and hence the last few meters may need to be stainless steel to survive. The last two meters will need to have a piccolo arrangement, so a cross section of gases, from the underground environment, is drawn to the surface for analysis. The process of lowering this arrangement down a bore hole is not a simple exercise and requires a tested procedure, risk assessment, training and the equipment to safely lower the tubes without risk to the mines personnel.

Tube bundle gas bag collection

One of the advantages of a tube bundle system is the ability to actually collect a sample from underground for analysis with a gas chromatograph. In order to actually collect a sample via the tube bundle system requires gas bags and personnel trained in the process. If the correct methodology for gas bag sampling is not followed, it is very easy to introduce some sample from a previous tube or contaminate the bag with fresh air. Having a ready supply of gas bags and personnel trained in the use of collecting samples would be essential to gaining a good picture of the gases underground early in the incident. A careful and considered gas chromatograph run by a highly trained operator and then interpreted by a technical expert are quickly undone if the quality of the gas bag collection is substandard.

HAZARDS CREATED DUE TO THE EMERGENCY

As an emergency situation is an unexpected event, many people are performing work outside their normal area of expertise. For example, mine workers may be charged with collecting borehole samples. Without a procedure, risk assessment or a trained supervisor, the workers may be exposed to hazards that they do not recognise. One potential hazard is the exhaust of the Bore Sampling Kit i.e. toxic and/or flammable gas. Hence the operators may be exposed to toxic/flammable gas and when the Bore Hole Sampling Kit is situated next to the generator, the hazards increase further (flammable gas being ignited by the hot exhaust of the generator.

When the first emergency bore hole was completed for Pike River, an improvised bore sampling kit was constructed and transported to the bore site. The bore sampling kit's exhaust line was not unrolled (information tag instructions not followed) and pumps exhaust was venting next to the portable generator. As the underground atmosphere was found to by approximately 95% CH_4, the potential for an explosion was present. Hence, it would be an advantage to have procedures and risk assessments for the expected tasks that would need to be undertaken if there was an emergency onsite in order to prevent personnel being exposed to risk.

Fatigue management is an area where procedures and risk assessments are very relevant as the emergency event may continue for weeks or more. The standard fatigue management system may need to be modified to take into account the emergency situation but the underlying hazards of sleep deprivation remain. In addition, it would be an advantage if the Risk Assessments for various emergency situations were competed and updated on a regular basis so these can be used as a backbone for a future real emergency. By having a backbone risk assessment, it could be updated to reflect the actual event and hopefully speed up the deployment of mines rescue, ventilation changes.

Gas monitoring infrastructure

The gas monitoring in an underground coal mine is constantly changing to suit the current mining conditions. However, the gas monitoring needs to be in front of the mining conditions and the industry is very good in being proactive on this front. However, there have been occasions where the gas monitoring has not been in place to suit the mining conditions. Hence, prior to a goaf being formed, the tube bundle system needs to be in place and operational in order to detect the start of spontaneous combustion in the remaining crushed coal.

If the mine doesn't have a tube bundle system and there is an incident underground or the fans trip and the mine gases out, the power to the realtime system will need to be turned off, leaving the gas monitoring to the Tube Bundle system. Hence it would be of value to have tubes located in strategic locations underground to ensure that regardless of the power state underground, the gas monitoring of important locations underground can continue. Areas additional to those required by the legislation should be identified as part of the development of the mines principal hazard management plans

Explosion protected gas monitoring

The explosion at Pike River rendered the realtime gas monitoring nonoperational. With the force of the explosion, the realtime system was damaged and no longer reported the gas readings to the control room.

However, it has been found that a gas detector survived the blast in the ventilation shaft. The blast destroyed the fan housing, but the gas detector survived and when tested continued to work normally (the gas detector was badly burned but otherwise operational). Hence, there is scope to make the realtime system explosion resistance by shielding the gas detectors from the full force of an explosion down the roadway. The realtime cables, phone cables and tube bundle tubes need to installed with blast protection in mind i.e. tied at smaller regular intervals and installed where some protection is afforded. With regards to the tube bundle systems and explosions, it has been found (Brady,*et al*, 2015) that ½" tubes have a higher survivability that 16 mm (5/8") due to the 12.5 mm (½") tubes being more robust i.e. more difficult to kink. A mine that has an explosion protected gas monitoring system would be better placed to rescue trapped miners and recover the mine. A more robust system would also sufferer less damage from every day incidents as well.

SMOKE HAZARD MANAGEMENT

Coal smoke can be high in CO, CO2 and particulate matter which reduces air quality and can be detrimental to people with pre-existing heart or lung conditions. As the smoke from the Hazelwood mine fire forced the town of Morwell to eventually evacuate the children, elderly and people with pre-existing medical conditions, the handling of the hazards created by the smoke has been the subject of much debate. In addition, the gas sampling of a coal fire can expose the mine worker to a range of chemicals and gases not usually found in the work place including H_2S and tar. At low levels H_2S is very easily detected (smells like rotten eggs) but at higher levels the olfactory nerve is overwhelmed and after a few inhalations, the sense of smell disappears which exposes the mine worker to high levels of H_2S without their knowledge. Procedures based on risk assessments are advised prior to mine workers being in the vicinity of the mine smoke to ensure that exposure in minimised. The sampling equipment used to monitor the underground fire or explosion will collect the by-products of burning coal. BTEX (Benzene, Toluene, Ethylbenzene and Xylenes) can be found in the tar residue and these chemicals are toxic. Risk assessments on the handling and disposal of equipment contaminated by the mines exhaust would be advisable to reduce harm to the mine workers and the environment.

Efficiency of the emergency response

By having the gas sampling equipment and knowledge on how to take gas samples onsite, time and resources are saved and these can be put toward managing the incident instead. If the risk assessments and general procedures have been prepared earlier, a lot of the ground work that needs to be done prior to an activity is already partly completed so more efficient sealing, firefighting and inerting, work can be undertaken.

Data exchange

During various incidents, the sharing of gas monitoring and other data is a priority so people can work in parallel to analyse/resolve the current situation. Naturally, the various parties will all have their preferred analytical software i.e. Segas Professional, SMARTMATE and Spreadsheets.

As there are many different types of gas monitoring systems and they each have their own data format, in an emergency situation the gas monitoring data will need to be periodically (typically at the end of each shift) converted from the native data type into a common format for each of the various parties to analyse. The fast data conversion and it’s uploading to the various parties is an important aspect of the emergency response. It would be a step forward, if there was a standardised gas sample format that each of the various gas monitoring systems could export their data into. A standardised gas sample format would reduce data handling errors, scaling errors and conversion errors, and speed up the generation of reports for third parties.

The Emergency Management System software used by the mine to store the events, actions, tasks, data, etc relating to the incident would be improved by having a regularly updated summary of the important information. The running summary would allow the mine worker, coming onto shift, to quickly see an overview of incident and its current status. The information and directions handed over at the end of shift, if misunderstood, can quickly lead to undesired events, hence an easily assessable running summary could reduce potential misunderstandings and well as keep everyone up to date on the incident.

CONCLUSION

High potential incidents in underground coal mine are an ever present risk in the industry. However, the mine can be better prepared to take control of the situation earlier by having some of elements of the mine designed with consideration of emergency situations, having some emergency equipment onsite and training as below -

1. Locate the portal and ventilation fans some distance from the mine’s other surface infrastructure, so in the event of a major incident, the mine can avoid isolating surface equipment or evacuate mine workers.
2. Ensure that bore holes are drilled at various strategic locations ready for emergency gas monitoring.
3. Have the equipment and expertise on site to sample the emergency bore holes.
4. Ensure that the response the emergency incident doesn’t expose workers to unforeseen hazards.
5. Ensuring the gas monitoring not only meets the requirements of “peace time” mining but also monitors other strategic locations from an emergency event perspective.
6. Install critical infrastructure with a view to protect it from blast damage i.e. hardened gas monitoring systems, phones, DACs, etc. monitoring system and phones may be possible.

The speed of response is critical to bringing the emergency situation under control and the deployment of mines rescue to find trapped mine workers. As mines rescue cannot be deployed until it can be assessed as safe to go underground, the ability to collect gas samples, quickly share the information and update risk assessments all help to reduce this delay.

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