2012

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Publication Details

P. Mason, Challenges of gas monitoring and interpretation in underground coal mines following an emergency, 12th Coal Operators' Conference, University of Wollongong & The Australasian Institute of Mining and Metallurgy, 2012, 340-344.

CHALLENGES OF GAS MONITORING AND INTERPRETATION IN UNDERGROUND COAL MINES FOLLOWING AN EMERGENCY

Peter Mason

ABSTRACT: While modern coal mines are commonly equipped with a range of gas monitoring resources during normal operations, they are often lacking in their contingency planning when a mine loses communication with these systems following a major incident. Recent occurrences in underground coal mines in both Australia and overseas has highlighted the challenges in relation to effective atmospheric analysis and interpretation. This paper looks at the issues that face those involved, when not only the communication with existing gas monitoring systems has been affected, but the systems themselves have been destroyed.

INTRODUCTION

In discussing some of the challenges facing coal mines in relation to their gas monitoring and interpretation of data following an emergency, this paper will focus on those events that necessitate the evacuation of a mine as a result of heatings, fires and explosions. These are the occurrences that present the biggest challenges to ongoing gas monitoring at an affected mine.

While many modern coal mines would argue that they have effective atmospheric gas monitoring systems installed in their mines, few have adequate contingencies in place for the ongoing monitoring should a catastrophic event occur underground and these systems are destroyed. The lack of contingencies can severely impact on the effective management of an event as it is essential that representative and reliable data is available so that informed decisions can be made.

Speed of response is of the essence in these situations, particularly where workers may be trapped underground. The decisions in relation to evaluating the safety of the underground atmosphere are paramount if consideration is to be given to sending rescuers into a mine to assist in their escape.

GAS MONITORING

Typical gas monitoring systems

A range of different types of gas monitoring systems are used at underground coal mines. Aside from regulatory requirements, the selection, use, application and scope of these systems often depends on the individual mine and with regard to factors such as the seam gas content and propensity for oxidation of the coal seam. Typically one or more of the following are used:

- Telemetry fixed sensor system (sensors are located in situ underground – real time data);
- Tube bundle system (tubes are used to transport the underground atmosphere from selected locations to surface analysers – the lag time for sample retrieval is dependent on the length of tubes);
- Portable gas detection devices;
- Gas chromatographic system.

Telemetry fixed sensor systems are the most common type of gas monitoring system used by underground coal mines for atmospheric monitoring, providing real time data. Both telemetry and tube bundle systems are generally employed to monitor the same gases, namely oxygen, methane, carbon monoxide and carbon dioxide. With minimal restrictions in terms of the intrinsic safety, certifications, approvals, etc. for the analysers used for tube bundle systems (as they are generally located at the mine surface), a broader selection of analysers can be used for these systems.

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Portable gas detection devices are primarily used by mining personnel for routine inspections and personal monitoring while underground. A variety of multi sensor models are available for use by coal mines, but commonly measure the same gases as those monitored by the fixed and tube bundle systems.

Gas chromatographs have been used as an analytical tool for the analysis of underground coal mine atmospheres for over 30 years. However, analysis times for the earlier model chromatographic systems were generally too slow for the high volume sampling and analyses required during mine emergencies, lacked the desired sensitivity for critical gases and as a consequence were not widely considered as ideal for an on site gas monitoring system. The introduction of ultra fast micro gas chromatographs into the market has resulted in a wider acceptance and use of gas chromatographic systems at mine sites and they are now commonly used at mines in a number of mining regions. The ability of these systems to determine key gases such as hydrogen, carbon monoxide, ethylene, acetylene and ethane at parts per million levels is a significant advantage over other techniques.

System limitations post an event

While one or more of the above systems may provide adequate atmospheric gas monitoring during normal operations, the design and installation of telemetry and tube bundle type systems commonly do not take into account the issues that arise following a catastrophic event that results in loss of power underground and sealing of a mine. In these situations the likely damage to part or all of the underground gas monitoring components will render them ineffective following such an event. These systems are not generally designed to withstand the impact of significant heat, and in the case of the sensors that are utilised for telemetry fixed systems, their design ensures susceptibility to damage.

Even if underground power is able to be maintained and the integrity of the monitoring system has not been significantly compromised, other factors may also impact on the ability to manage an event using existing underground fixed sensor systems. The types of sensors used for these systems have a limited range of detection, can be cross sensitive to some products of combustion and may provide erroneous data regardless of the fact that they remain functioning.

While tube bundle analysers located on the surface would remain operational, the associated underground sample tubes, filters and other fittings are likely to have sustained damage. Depending on the severity of the event, it may take some time to determine which of the sample lines may have escaped damage and which are able to be used for sampling.

Although more common for the underground gas monitoring components to be damaged and rendered inoperable following a heating, fire or explosion, there have also been instances where surface equipment has also been damaged. Figure 1 shows photographs of damage to tube bundle system sample pumps following the surface ignition of methane that was being sampled from an underground sealed area and also the pumps as they appeared prior to the damage.

Figure 1 - An example of damage to a tube bundle pump system located on the surface

Gas monitoring post an event

Following a major event that has resulted in the sealing of a mine and loss of power, the mine will be restricted to using surface analysers for its ongoing gas monitoring requirements. These may include a gas chromatograph if available, and tube bundle system analysers for mines who have an existing system installed.

A typical tube bundle system would normally be configured at a mine site to monitor specific gases such as oxygen, methane, carbon dioxide and carbon monoxide. However, they are not able to accurately determine key gases such as hydrogen, ethylene, acetylene and other gaseous products of combustion. The determination of these gases is essential for effective decision making in relation to the management of an event. The most effective method for these determinations is by gas chromatography

Access to a gas chromatographic system is essential for mines with coal seams that have a high propensity for oxidation. Modern ultra fast micro gas chromatographs are able to provide accurate atmospheric analysis for the common coal mine gases (eg. oxygen, nitrogen, methane, ethane and carbon dioxide) and also for essential products of combustion (eg. hydrogen, carbon monoxide, ethylene and acetylene). A complete analysis for all components can be achieved in two to three minutes. These analysers have been successfully installed and used at coal mines for many years. While a mine may not utilise this type of system on site during normal operations, it should have a process in place for access to the technology from an external provider if required. Figure 2 shows a typical ultra fast gas chromatograph installed and operated by a mine at their site.

Figure 2 - A typical ultra fast gas chromatograph installation

Coordination of post event monitoring resources is also an important consideration. There may be external providers assisting a mine in delivering analytical support services and therefore the roles and responsibilities for all those involved needs to be clearly defined. Commonly in the early stages of a major occurrence, there is a period where those responsible are still establishing what resources remain available for use and what additional resources are required for the ongoing incident management. Time is a key factor in this process. Early decision making can significantly impact on the final outcome of the situation, and prevent a further escalation.

Sampling considerations post an event

The importance of a well coordinated gas sampling program cannot be understated. The interpretation resulting from the analysis of the samples collected will be a critical element in the decision making process that will follow. Sampling locations should be valid and sufficient in number to be representative of the area required to be monitored.

While the ideal situation would be to have fire and explosion proof gas sampling lines installed in a mine during the development process, it is not common for these contingencies to be put in place. Generally existing tube bundle sample lines (for mines that have these systems installed), or surface boreholes are the only available options for remote sampling of the underground atmosphere. As indicated previously, if a heating, fire or explosion occurs underground, it is often difficult to determine the extent of damage to the tube bundle sample lines and therefore the integrity of the data in relation to those sample locations. Existing borehole sampling may then be the only option.

Remote sites and adverse terrains pose their own problems for sampling. In these situations not only can the logistics for the collection and transportation of samples raise difficulties, but the establishment of new sample locations can also pose problems. If all underground monitoring components have been destroyed, then a site will have to rely on the existing surface boreholes in order to obtain gas samples. Depending on the mine and the location of these boreholes, they may not be adequate in providing a representative overview of what is occurring underground. The drilling of additional boreholes to provide the sampling coverage required may also be difficult in these situations and take some time for completion.

Ideally all sample boreholes should be cased, capped and sampled when breathing out. Down borehole sample tubes should be used to ensure that a representative sample is collected from the specific location required. Samplers should be trained and ensure that gas lines and sample containers are sufficiently purged prior to taking gas samples. All relevant details in relation to the samples should be recorded, e.g. sample location, type of sample, date, time, whether the sample point is breathing in/ out and any other relevant information. Recommended standards or guidelines in relation to gas sampling should be adhered to (Queensland Mines and Energy, 2009). Sample collection must be consistent to ensure meaningful comparison of the analytical data collected.

If surface boreholes are used for sample collection, and if distances between the borehole locations are such that it is possible to run some or all sample lines back to a central analyser system, then continuous sampling and data collection from all these sites is possible. Suitable gas sample pumping systems would be required to achieve this outcome. Apart from the ability to monitor and collect gas data continuously and provide as close as possible to real time trending, it significantly reduces the requirement to manually collect and transport samples.

Consideration must also be given to the safety of the gas samplers. Both terrain and sample locations need to be considered. If potentially flammable atmospheres are being sampled, then the risk of ignition at both the surface sample point and underground atmosphere must be considered. Sufficient care must be taken to ensure samples are collected in a safe manner. If samples are being collected from boreholes, this may require the sample tubes to extend a safe distance from the actual borehole.

INTERPRETATION OF THE DATA

Essential to the effective interpretation of the analytical data is the integrity of the information provided to those interpreting the results. While absolute accuracy is desired, it is not always possible to achieve in the initial period following a major occurrence. While modern analysers such as ultra fast micro gas chromatographs and other quality analytical systems are able to provide consistent and reliable analytical data in laboratory environments, commonly these devices are used in temporary make shift situations at mine sites during the early stages following an emergency, where the operating environment is not always ideal. Attention to routine maintenance and regular calibration of the on site systems is therefore essential in these circumstances to ensure the provision of consistent and reliable data.

When interpreting the data in relation to an event such as a heating, fire or explosion, explosibility of the atmospheres being sampled must be calculated, trended and graphically displayed. Regardless of what method is used for this purpose, expertise is required in reviewing the data to ensure other parameters that may affect the explosibility of the atmosphere being monitored are taken into consideration. These include not only the levels of flammable gases present, but also the impact of the ingress of air and known or suspected sources of ignition.

Although reviewing the raw analytical data is essential, trending of it in conjunction with relevant ratios and indices provides a better indication of what is happening in the underground environment. While there are a variety of ratios and indices that have been developed to assist in the interpretation of gas data produced by heatings, fires and explosions, relatively few have stood the test of time and used on a consistent basis. These have been well documented (MDG 1006 Technical Reference, 2011; David, *et al.*, 1996; David, *et al.*, 1998; Mine Rescue Board NSW, 1998), with the following to have shown to be of consistent value over a long period:

- Graham's ratio;
- CO/CO_2 ratio;
- CO make;
- Jones-Trickett's ratio;

- Young's ratio;
- H_2/CO ratio;
- Air free calculation.

As the ratios used for heatings and fires are a generally a measure of the conversion efficiency of oxygen to the products of combustion, it is not necessary to calculate and trend significant numbers of these deficiency ratios as the data will simply show the same trends.

Ratios such as Graham's, CO/CO_2, Jones-Trickett's, H_2/CO are useful tools for interpretation as an increase in these ratios normally indicates an increase in temperature. However, if a mine is sealed, it is likely that the site will deploy some form of inertisation to manage the situation. If this occurs then care must be taken when reviewing the gas data as some of the common ratios used for interpretation and prediction will be compromised by the addition of the inerting gases into the underground environment.

This situation raises additional complications when more than one type of inerting system is deployed. Inertisation systems such as membrane nitrogen generators (commonly called "Floxyl" systems), vaporising liquid nitrogen systems and pressure swing absorption systems (PSA) all essentially produce high purity nitrogen as the inerting product. Other systems such as the Gorniczy Agregat Gasniczy (GAG) jet engine and the Tomlinson boiler also produce a relatively high purity nitrogen product, but also produce up to 15% carbon dioxide. While the analytical data will show the presence of these inerting systems, and therefore their effectiveness, their use then negates the application of ratios that contain these gases in the calculations.

Although commonly used, care should be exercised when using air free calculation of the raw analytical data for interpretation purposes. Whilst successfully used for many years to compensate for the ingress and expulsion of air from behind seals and boreholes that may mask increases/ decreases for other gases being monitored, it can provide erroneous estimates of residual gases in atmospheres close to fresh air. While a useful tool, it should be used by experienced personnel.

During a major occurrence there can be significant external pressure on those reviewing and interpreting the data to provide comment and advice in a timely manner. This may come from sources such as mine owners, governments, media, mine workers, families and others. A simple approach is often the most effective in the decision making process, with those placed this position of responsibility ensuring that the task at hand is not influenced by these external pressures. Clear and concise comment in relation to the findings is essential.

CONCLUSIONS

While some aspects of the challenges of gas monitoring and interpretation in underground coal mines following an emergency have been discussed in this paper, the topic is significant and only a brief overview has been provided. It would be an ideal situation if increased diligence in safe mining practices resulted in such papers being viewed as pure discussion. Unfortunately this is not likely to be the case in the near future, and the need for increased expertise in this field is an essential component of underground coal mining.

REFERENCES

Cliff, D, Rowlands, D and Sleeman, J, 1996. *Simtars - Spontaneous Combustions in Australian Coal Mines Book*.

Cliff, D, Gollege, P, Rowlands, D and Sleeman, J, 1998. *Simtars - Mine Fires in Australian Coal Mines Book*.

MDG 1006 Technical Reference, 2011. Technical Reference for Spontaneous Combustion Management Guideline, Produced by Mine Safety Operations Branch Industry and Investment NSW.

Mine Rescue Board NSW, 1998. *Emergency Preparedness and Mines Rescue Book*.

Queensland Mines and Energy - Recognised Standard 09, 2009. *The Monitoring of Sealed Areas*, Version 1, 5th November 2009.