Beyond TARPS - the need for supporting systems

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Abstract:

Much emphasis has been placed on the correct use of Trigger Action Response Plans, especially for underground coal mines. However, it is clear that TARPS are being used beyond their original purpose. TARPS have a place in the management of risk but are not the sole catalyst for reaction to potentially adverse situations. This paper will illustrate the need for ancillary activities to the support TARPS and to allow them to be what was intended - a minimum response to adverse conditions preventing harm to miners. Spontaneous combustion TARPS will be used as a case study. For TARPS to be effective they must be simple, robust and be capable of being applied at all times without resorting to specialist equipment, techniques or external expertise. These should be available and utilised in addition to the TARP process. Case studies will be presented that illustrate this. TARPS cannot hope to cover all situations.

Introduction:

Trigger Action Response Plans (TARPS) first entered the Queensland lexicon in 1998 with the release of the Approved Standard for Mine Safety Management Systems, issued under the Coal Mining Act 1925 (QDME,1998). This approved standard was not reissued when the legislation was revised in 1999. Recognised Standard 08 - Conduct of mine emergency exercises (DNRME,2018), does mention TARPS with reference to withdrawal of persons. Instead, the legislation in Queensland makes repeated reference to gas alarm levels. TARPS are required in NSW under the Code of Practice – Safety management systems in mines, issued under the Workplace Health and Safety (Mines) Legislation (TINSW,2015). The focus of the Action Response Plans (Triggers) (section 6) was on the prevention and mitigation of spontaneous combustion (not surprising as there had been a wealth of activity post the Moura No.2 mine disaster in 1994). Section 4 goes into detail about the processes required to predict and prevent spontaneous combustion. The standard required:
"*In particular the mine should have documented evaluation/decision processes for the following*:

- *"The setting of trigger levels or conditions for spontaneous combustion indicators in use at the mine and which result in the activation of pre-determined decision processes and actions;*
- *The development and implementation of pre-determined responses action plans to defined triggers indicative of spontaneous combustion*;…….
- *These documented evaluations/decision processes should identify who should be involved in each process, who has authority for the decisions(s) and the criteria to which the decisions are to be made. All evaluation/decision processes should be supported by action plans which are implemented as a result of decisions and which are documented as internal standards at the mine"*

The action plans were to include withdrawal of persons, instigating a control group, and sealing under duress.

Since that time there have been no fatalities in Queensland or NSW mines due to spontaneous combustion though there have been many major incidents (eg North Goonyela, 2018, various incidents at Dartbrook and Newstan in 2005).

The use of TARPS has spread beyond spontaneous combustion to other principal/major hazards as well as personal safety issues and even beyond the mining industry – for example Orange Sky (Orange Sky, 2023) have a TARP for dealing with aggression on shift.

Most recently the Board of Inquiry (BOI) review of the incidents at Grosvenor Coal Mine in 2020 (BOI,2021) found that :

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The TARPs in place for spontaneous combustion in the active goaf and the goaf wells, as at 6 May 2020, were unlikely to provide a timely warning of a small but intense heating in the goaf. Products of such a heating are likely to report to the goaf stream and/or the goaf wells.

The BOI made a number of recommendations relating to TARPS relating to :

- TARP triggers for spontaneous combustion in the active goaf with respect to the goaf stream,
- TARPs for goaf wells and include a requirement for the taking of regular bag samples under 'Normal' TARP conditions.
- Coal mines include the carbon monoxide (CO) reporting to the goaf wells with that measured in the longwall return when calculating the total CO Make for the active goaf.
- Resources Safety & Health Queensland takes steps, through the consultative process provided by the Coal Mining Safety and Health Advisory Committee, to ensure that a Recognised standard based on best practice is developed for the monitoring and control of spontaneous combustion in underground coal mines.

Understanding of the complexities of spontaneous combustion has improved since 1998 and mine environment monitoring systems have undergone major improvements. Sometimes this causes its own problems – for example the significant improvement in the capacity to detect ethylene has spawned a major debate over its use a trigger in TARPS, both in terms of trigger values and whether or not its use adds any value to TARPS (RSHQ, 2022, Zaidi et al, 2016, and Cliff, 2022). When attempting to deal with these complexities it is important that any TARP process is supported by a range of activities. The limitations of the TARP process have been known for over 10 years (Cliff, 2009). This paper outlines some of these support activities.

Support activities:

The complexity of using gas concentrations as indicating of spontaneous combustion or the development of spontaneous combustion has long been recognised as difficult (see for example Cliff et al, 2018 and NSWRR, 2021). For example: the rate at which an indicator gas is produced is governed by the coal temperature, the amount of coal involved and the supply of oxygen. The last factor also causes dilution.

At Moura No. 2 in 1994 prior to the incident CO in ppm was used as an indicator of coal oxidation and after 512 panel was sealed the CO concentration was monitored automatically via the tube bundle system. The system regularly alarmed over the period following sealing, but as the concentrations were not beyond those seen previously no concern appears to have been raised. As the figures below indicate however the rate of rise was much quicker than previously seen (24 hours vs 10 days to reach 160 ppm)). Similarly had Graham's ratio been being tracked in the control room then values above normal would have been observed.

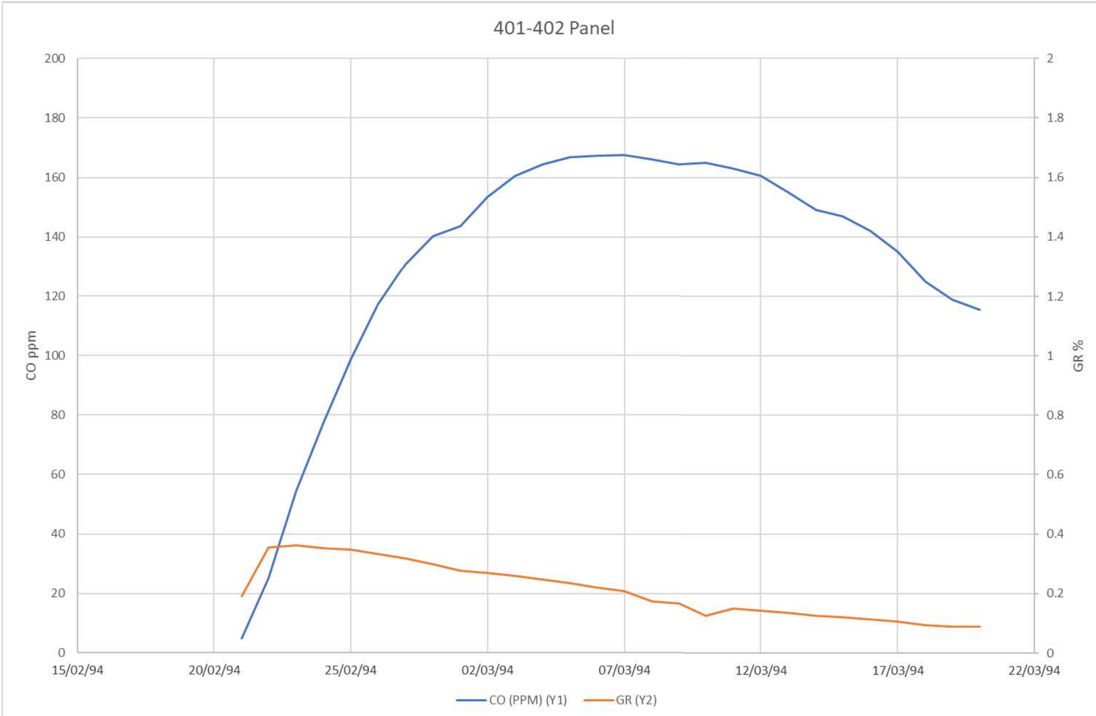

Figure 1. 401-402 Panel CO and Graham's ratio at Moura No.2 mine.

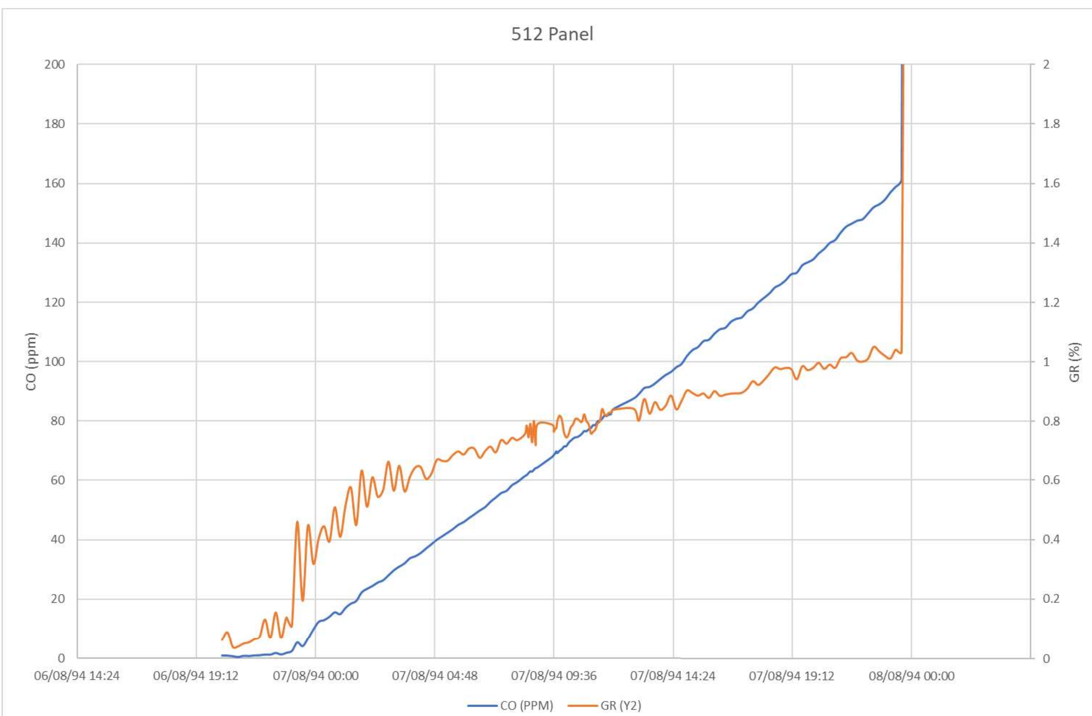

Figure 2. 512 panel CO and Graham's ratio at Moura No. 2 Mine

TARP trigger levels are typically identified as: normal, abnormal, more abnormal and evacuate. At each level numeric values for the indicators are specified.

Limits to normality are specified from past experience at the mine where there is no evidence of elevated temperature coal oxidation. Evacuation triggers are based upon the risk of a fire or explosion occurring. The level in the middle usually functions to try to identify worsening conditions but not yet potentially life threatening.

The indicators commonly used include:

In the panel return: CO make – note Division 2 section 353 (CMSHR 2017) specifies monitoring requirements from a contamination perspective, Division 1 section 222 requires monitoring of CH_4, CO, CO_2 and O_2 in each return split and the calculation of Graham's ratio, the CO to CO_2 ratio and explosibility. Given the high ventilation quantities in modern longwall mines the ratios are often not able to be calculated reliably as the samples are too close to fresh air and subject to a high noise to signal ratio for the oxygen deficiency.

In the goafstream: CO concentration and airfree, ethylene concentration, Graham's ratio, CO to CO_2 ratio.

In a seal: often as per the goafstream with the addition of oxygen concentration in the deep goaf to indicate potential leakage through seals.

The evacuation point is usually linked to the estimation that the coal temperature is at or above 100 $^{\circ}$C, as laboratory experiments both large and small scale have shown that once the coal temperature exceeds the boiling point of water the rate of reaction increases rapidly. Small scale laboratory tests have been used to indicate what ratios such as Graham's ratio or the CO to CO_2 ratio will be at this temperature. It is not possible to identify what the concentration based indicators would be at this temperature for the reasons outlined previously – principally dilution and mass of coal involved. For these concentration based triggers, experience at the mine tends to be applied using a multiplier to the value determined as the limit to normality – between 3 and 10 times.

Small scale laboratory testing of gas evolution due to oxidation of coal provides much useful information but is inherently of limited applicability. There is for example no standard approved test, currently there are at least three different testing regimes in use, giving different concentration vs coal temperature curves (see for example, Beamish et al, 2015, Wieckowski et al, 2018 and Cliff et al 2000).

Beyond TARPS:

TARP triggers are inherently numerical values and should be regarded as the minimum points at which action should be taken. TARP triggers need to be simple, and absolute, for them to be applied by miners, deputies and control room operators. Automatic monitoring systems can be programmed to alarm based upon these measurements.

One key parameter that cannot easily be monitored automatically nor have trigger values set is the rate of change of the indicators mentioned above. The example from Moura No. 2 cited above is an excellent demonstration of how while the actual concentration of CO was not of concern, had someone been monitoring the rate of increase then action may have been taken. Similarly, much of the debate over the usefulness of ethylene and what the presence of sub ppm concentrations of ethylene indicate can be resolved simply by monitoring whether or not there is any trend in concentration over time. With the detection sensitivity of modern GC's many thick seam longwall mines are routinely detecting up to 0.3 ppm of ethylene in goaf samples, without any other indicator of elevated temperature coal oxidation. If there is no indication of increasing ethylene concentration over time, nor of any other indicator, thus it is logical to assume that there is no elevated temperature coal oxidation occurring. This is supported by recent laboratory gas evolution studies demonstrating the generation of ethylene from coal oxidation at temperatures of 40 °C and below.

In theory it may be possible to program modern mine monitoring systems to track rates of change. For gas chromatography samples this would require major upgrades to existing software or exporting to a third party data analysis package, hardly suitable for a TARP process. A question that cannot easily be answered is what is an acceptable rate of change?.

To get around these problems it is important that the official TARP process is supported by comprehensive regular trending of the key parameters at each monitoring location. Experienced personnel will quickly identify any abnormality. They are then able to evaluate the potential causes of the abnormal trend, eg is it due to changes in the mining method, ventilation quantities, ventilation circuit, etc. This scrutiny doe not replace the TARP process rather it provides additional information to assist in the detection of abnormality and the evaluation of any risk this behaviour may pose. It can also avoid costly false alarms.

Such trending also allows for the different phases of the mining operation to be scrutinised without generating multiple TARPS. For example, the goaf atmosphere behind the longwall during start up before the first proper goaf forms can be very different to the deep goaf after mining has retreated further. Also as many mines have different zones in their goafs – the “air wash” zone and deep goaf, and the transition between the two, it is easy to monitor for the expected behaviour without codifying it into a TARP, which could be quite cumbersome. Figure 3 below shows the observed variation in CO in the return vs longwall chainage for a thick seam mine. The associated CO make would have been up to 100 l/min initially with no indication of spontaneous combustion. The second peak was associated with an identified spontaneous combustion event resulting in the application of inert gas to remove oxygen from the goaf.

In addition such trending can overcome issues with the accuracy or relevance of some indicators where the mine atmosphere reacting with the coal is not fresh air and thus the assumed initial oxygen to nitrogen value is inaccurate leading to underestimating the ratio values.

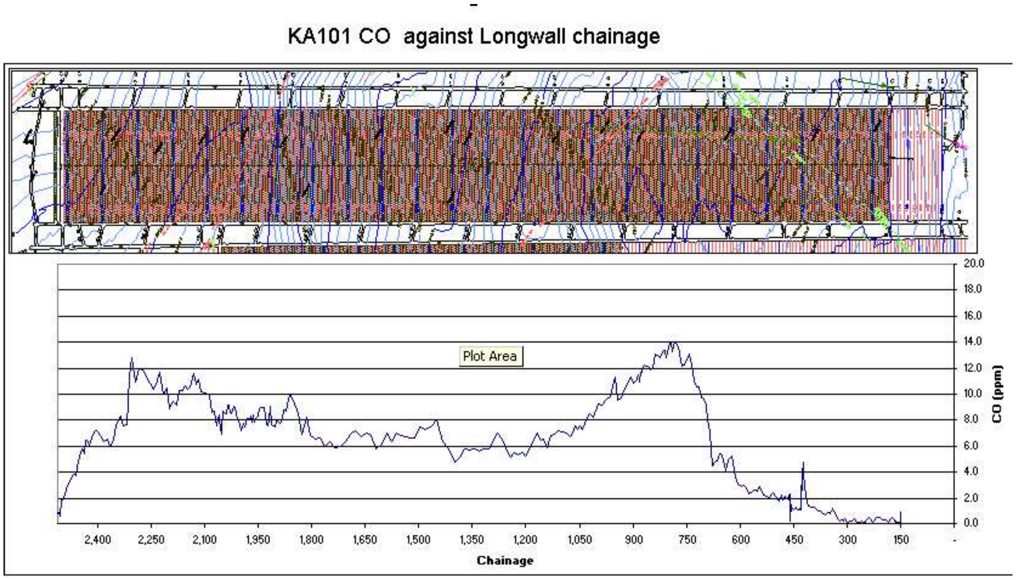

Figure 3. CO concentration vs longwall retreat for a thick seam mine.

Figure 4 below illustrates how support analysis of samples, not easily possible within the routine TARP process, can identify an abnormality. In this case for a monitoring location within a sealed area, the true value for the CO to CO2 ratio was masked by the presence of a CO2 seam gas. After the CO2 concentration was adjusted for the seam gas contribution the revised ratio clearly indicated elevated temperature oxidation.

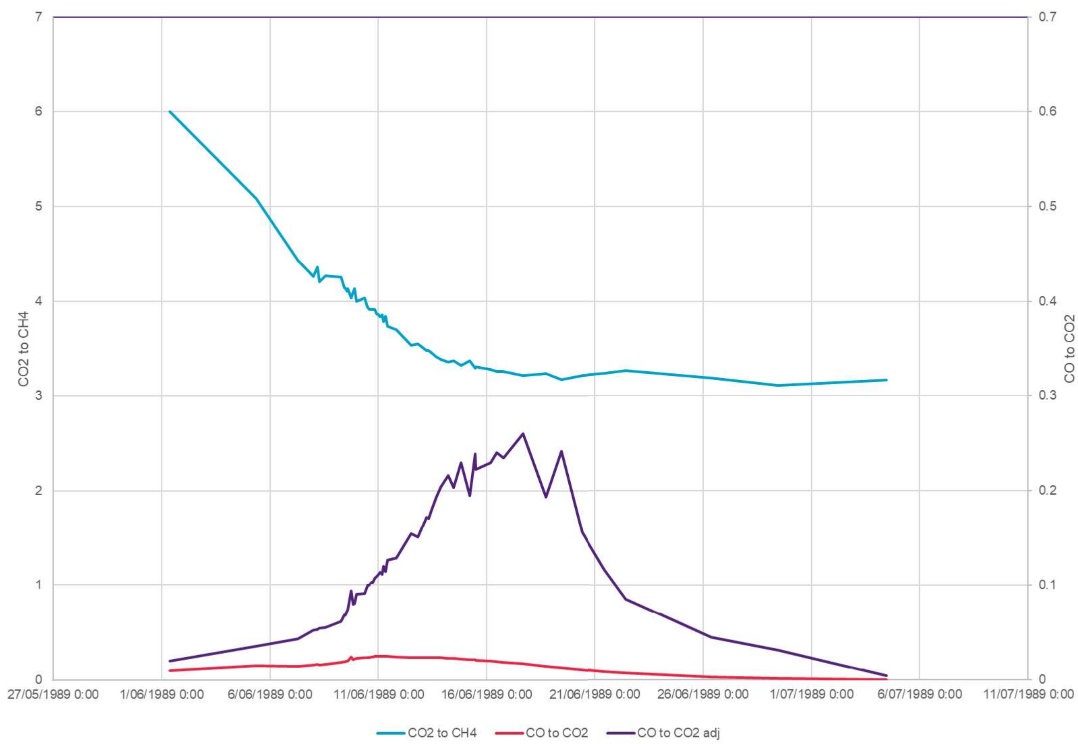

Figure 4. CO to CO2 ratio before and after allowing for seam gas.

Trending and analysis can also compensate for the effects of inertisation on gas concentrations and ratios, which many mines now routinely use during longwall take off and panel sealing. Inertisation can dilute gas concentrations and cause significant underestimation of derived ratio indicators. It can also mask monitoring by being a blocking agent preventing the goaf atmosphere from reporting to a monitoring point. Allowing for these factors would be difficult to do automatically.

External scrutiny of data can also quickly identify the impact of the change in barometric pressure.

Another activity that an experienced person can undertake outside the formal TARP process is the comparison of data between monitoring locations in order to identify anomalies for further investigation. For example when monitoring goaf seals behind the longwall in the active longwall, one would expect to see a trend in decreasing oxygen concentration, increasing CH4 and CO2 due to seam gas, and increasing CO and CO2 up to a point where oxidation ceases. Any deviation in this behaviour should trigger investigation.

The example below relates to an investigation of the cause of an observed oxidation event as per figure 5. Normally at this mine the oxygen concentration would reduce with distance from the face, however in this case it actually increased for the first 400 m of goaf and then reduced, indicating a leaking seal.

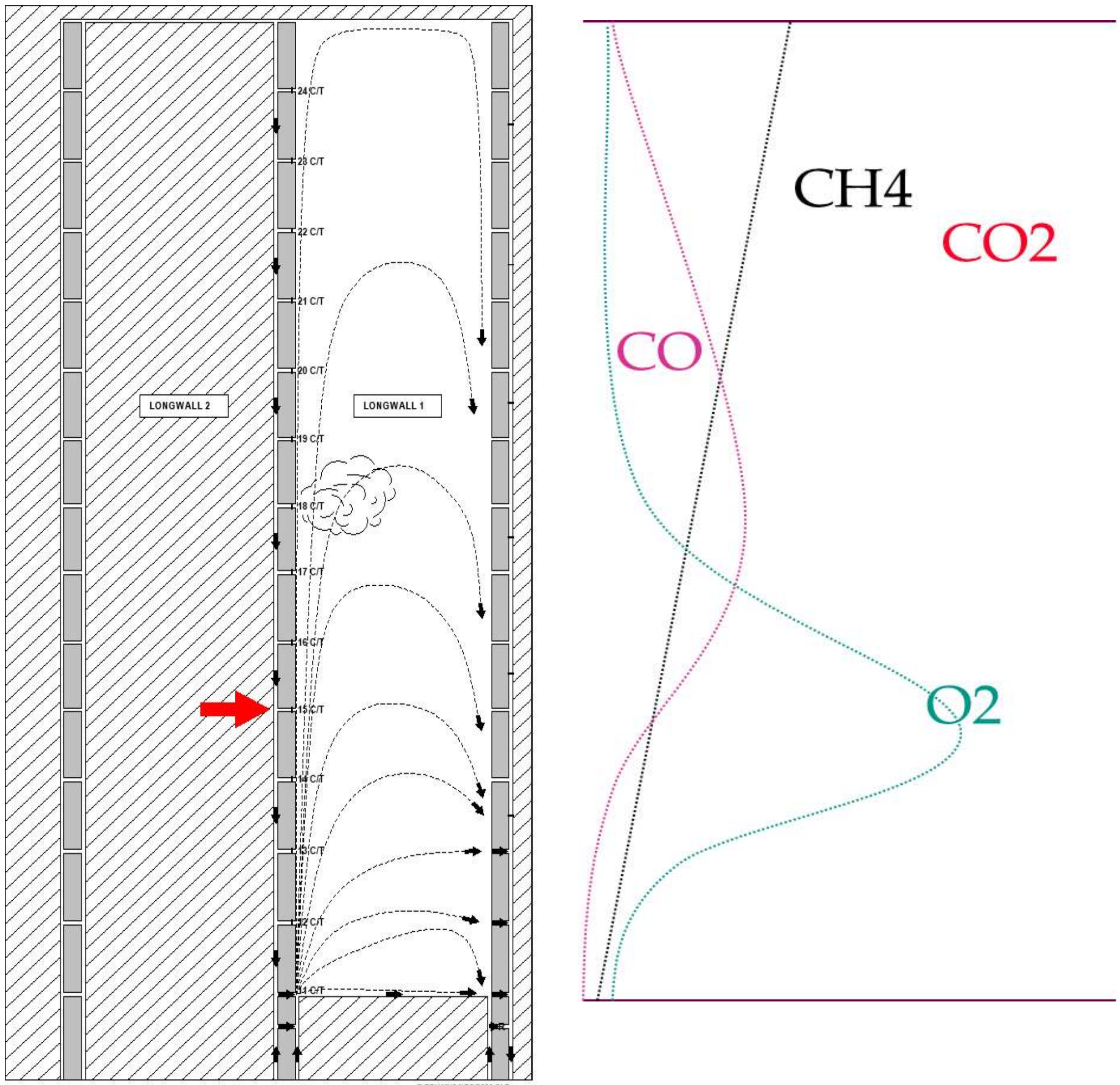

Figure 5. Observed oxidation event at 18 ct due to air leakage through seal at 15 ct.

Other activities that support the early detection of abnormality include monitoring pressure differentials and goaf temperatures. In these cases, it is difficult to identify absolute trigger points, as these could vary with location and mining conditions, etc. It would be easier to identify abnormal values by a person experienced in scrutinising such data.

The routine monitoring of mine environment data can also identify potential issues with baseline drift and calibration for individual gases that may render the automatic alarming inaccurate.

Conclusions:

In summary, Trigger Action Response Plans form an essential part of the risk management process for principal hazards and can be validly applied in other areas. However, by their very nature of being simple, automatic, and robust, they are limited in their capacity to cover all situations. They need to be supported by comprehensive data collection, reporting and analysis systems that can identify changes from normal that would not otherwise be detected and also can confirm or negate potential adverse situations based upon past experience at the mine. This analysis should only be undertaken by personnel experienced in interpreting such data and familiar with the expected mine atmosphere behaviours at that mine. These systems can also assist in managing situations where it is difficult to apply the simple logic of TARPS such as during inertisation.

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