Department of Natural Resources, Mines and Energy

Methane management in underground coal mines

Best practice and recommendations

June 2019

Queensland Government

SUMMARY

As Queensland underground coal mines have become deeper and longwall production rates have increased, mines are struggling to control the percentage of methane (CH_4) in the longwall return roadways tailgate.

Under the *Coal Mine Safety and Health Act 1999* and the Coal Mining Safety and Health Regulation 2017, if methane concentration is equal to or greater than 2.5% then the underground mine is dangerous and workers must be withdrawn from the mine. Methane is explosive between 5% and 15%.

The Mines Inspectorate recently completed a series of compliance audits and requested methane gas monitoring data from eight longwall mines so that a detailed analysis could be undertaken. The audits revealed that all mines' gas monitoring systems complied with the *Coal Mining Safety and Health Act 1999* but a review of gas data indicated that mines were not reporting all incidents over 2.5% methane. Modelling of the mines' ventilation and methane emissions has shown that in some cases explosive mixtures of methane could have been present in the atmosphere flowing into the longwall tailgate.

Following the issue of directives and substandard conditions and practice notices (SCPs), five mines introduced additional gas monitoring in the longwall tailgate interlocked to the longwall shearer so it automatically trips power to the shearer when methane reaches a certain level determined by a trigger action response plan (TARP).

Modelling of methane concentrations described in this document demonstrates how an increase in the general body concentrations in the longwall tailgate increases the risk profile of longwall operations. From this a mining operation can determine the applicability of this modelling to their operations and use this to determine the risk profile for their Longwall operations.

The Mines Inspectorate expects all underground coal mines to have effective gas monitoring systems with suitably placed methane detectors to prevent explosive accumulations of methane in areas where it could be ignited. Best practices and recommendations to achieve this are outlined in this document for mine operations to consider. At the time of writing this report, the Mines Inspectorate is also developing draft amendments to the regulation to prescribe minimum methane monitoring requirements, at all relevant locations in an underground coal mine.

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PURPOSE

The purpose of this document is to provide Queensland coal mines with information to consider when:

- determining location of additional monitor(s) that are interlinked to cut power to the longwall shearer which are critical controls for the management of risks from methane.
- determining suitable TARPs to prevent dangerous accumulations of methane in areas in the longwall tailgate where there are potential ignition risks.

This document does not cover the management of other gases which may be present in an underground coal mine.

BACKGROUND

In January 2017 the Mines Inspectorate became aware of issues relating to the management of methane in longwall coal mines. Coal mining operators were not controlling the methane levels in the longwall tailgate roadways. There were numerous occasions where the general body methane concentration met and exceeded 2.5%.

In February 2017 the Chief Inspector of Mines issued a letter to all underground site senior executives (SSEs) and underground mine managers (UMMs) advising them that if a roadway in a mine contains an atmosphere where the methane concentration is equal to or greater than 2.5% it is taken to be dangerous under section 366 of the Coal Mining Safety and Health Regulation 2017*.* If this occurs, coal mine workers must be withdrawn to a place of safety under section 273 of the *Coal Mining Safety and Health Act 1999.* As such, every occasion when methane is found in mine roadways required to be ventilated under regulation at a general body concentration of 2.5% or greater, must be reported as a high potential incident (HPI).

Investigations into these exceedances were undertaken at eight underground coal mines resulting in the issuing of directives and SCPs as well as the initiation of gas management audits focussed on methane management.

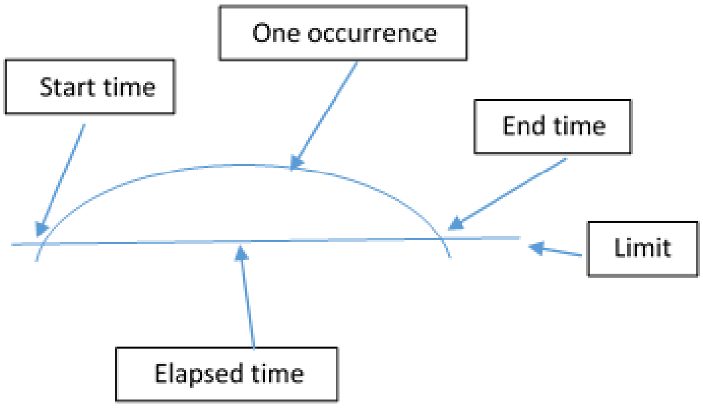
Operations at two sites were suspended due to the number of “dangerous” gas exceedances not being reported.

Subsequently eight underground coal mines were required to provide their real-time gas monitoring data to the Mines Inspectorate for the period 2016 to 2018 for analysis.

Definition of methane incident

For the purposes of the detailed analysis a ‘methane incident’ was defined as follows:

FIGURE 1: METHANE INCIDENT DEFINITION



Exceedance elapsed time was the period above the limit of 2.5% methane

LONGWALL METHANE ANALYSIS

The analysis of methane monitoring data from all underground coal mines with longwall operations from July 2016 to June 2018 has revealed that exceedances of general body methane concentrations occurred in six of the eight mines, with **all six** failing to report some of these exceedances to the Inspectorate.

Results of the detailed analysis of four coal mines having a large number of incidents are shown below. These mines are referred to as Mines A, B, E and F.

Mine A

- There were 264 independent methane exceedance incidents.
- In some, more than one gas detector exceeded 2.5%.
- **Only 22 of these were reported to the Inspectorate**
- One occurrence lasted 600 minutes.
- There were 69 days without methane monitoring data from the tailgate detectors.
- Methane levels above 2.5% were recorded over a total of 318 hours.
- Methane levels above 2.0% were recorded a total of 517 times, over a total of 1,559 hours (65 days).

Mine B

- There were 72 independent gas exceedance incidents (greater than or equal to 2.5%) in the roadway. In some, more than one gas detector exceeded 2.5%.
- **Only 15 of these were reported to the Inspectorate**
- One occurrence lasted 157 minutes.
- Methane levels above 2.5% were recorded over a total of 14 hours.
- Methane levels above 2.0% were recorded a total of 355 times, over a total of 198 hours.
- Many of these incidents correlated directly with the diurnal variation of the barometer and were predictable.

Mine E

- There were 135 independent gas exceedance incidents (greater than or equal to 2.5%) in the roadway. In some incidents, more than one gas sensor exceeded 2.5%.
- **Only 44 of these were reported to the Inspectorate**
- One occurrence lasted 530 minutes.
- Methane levels above 2.5% were recorded over a total of 78 hours.
- Methane levels above 2.0% were recorded a total of 603 times, over a total of 82430 hours (576 days).

Mine F

- There were 263 independent gas exceedance incidents (greater than or equal to 2.5%) in the roadway) plus another eight reported incidents without supported data. In some incidents, more than one gas sensor exceeded 2.5%.

- **Only 34 of these were reported to the Inspectorate**
- One occurrence lasted 423 minutes.
- Methane levels above 2.5% were recorded over a total of 83.1 hours.
- Methane levels above 2.0% were recorded a total of 822 times, over a total 1008 hours (42 days).

A summary of the results and analysis from all the underground mines is shown in Table 1.

Note that as the data recording frequency (time interval between samples) for monitoring the longwall return atmosphere was not consistent, in some cases there may be more exceedances than are actually recorded.

TABLE 1: SUMMARY OF TAILGATE METHANE MONITORING DATA - ALL QUEENSLAND UNDERGROUND LONGWALL MINES BETWEEN 1/7/16 AND 30/6/18

Mine	Exceedances reported	Exceedances not reported	Elapsed time at or exceeding 2.5 % (Hours)	Elapsed time at or exceeding 2.0 % (Hours)	Methane recording frequency
A	22	242	318	1559	5 minutes
B	15	57	14	198	10 seconds
C	7	13	10	28	Variable store time step, 1 minute above 2.5%, 12 minutes below 2.5%
D	4	1	<1	2	Variable store time step, 20 seconds above 2.5%, others between 1 to 10 minutes
E	44	91	78	1374	10 minutes
F	34	229	83	1008	5 minutes from July 2016 to April 2017; 30 seconds from May 2017 to June 2018
G	0	0		0	Variable store time step, 1 minute above 2.5%, 6 minutes below 2.5%
H	0	0		0	Variable store time step, 1 minute above 2.5%, 12 minutes below 2.5%

Five of the six underground mines issued with directives have implemented additional risk controls by placing an additional methane monitor in the longwall tailgate return airway within 400 metres of the longwall face. This additional monitor operates with specific TARPs for the purpose of controlling the longwall operation to avoid incidents of general body methane concentrations equal to or greater than 2.5% in the tailgate.

Neither these monitors nor their alarm or trip levels are currently specified in the legislation. Mines A, E, and Mine F had these monitors installed, however they did not experience a reduction in exceedances during the data review period after corrective actions had been implemented. At the time of writing this report the Mines Inspectorate is finalising proposed amendments to the legislation to clarify and confirm minimum methane monitoring requirements, for all the relevant locations in the return airway from a Longwall face.

METHANE MONITORING AUDITS

As a result of the methane exceedances the Mines Inspectorate issued several directives and SCPs, and initiated gas management audits focused on methane management.

These audits found that:

- The installation of the gas monitoring equipment was in compliance with the Coal Mining Safety and Health Regulation 2017.
- Five mines introduced additional gas monitoring in the longwall tailgate.
- The additional monitor was at a distance of not greater than 400 metres outbye of the longwall face. The monitor was interlocked to the longwall shearer so that it automatically tripped electric power to the shearer when the methane reached a certain level determined by a TARP but not greater than 2.5%.
- Some mines interlocked the methane monitor, located at the start of the longwall block in the return ventilation split, to the shearer. This monitor tripped power to the shearer when the methane concentration in the longwall return ventilation split reached a certain level determined by a TARP but not greater than 2.5%.
- Two mines reduced the trip level for power to the shearer to 2%. This significantly reduced the number of trips due to exceeding 2.5% methane in the tailgate.
- Mine sites failed to report an HPI when the tailgate monitor detected a general body methane concentration of 2.5%. Mines have started to understand that this is an HPI.
- The risk associated with an increase in methane concentrations in the longwall tailgate had not been adequately assessed by the mines.

  The initial approach was that mines did not consider the methane in the longwall tailgate return roadway made it a dangerous place according to the relevant legislation. There was discussion on whether this should be considered an HPI as there are no people present in the tailgate during production, however, further analysis of the hazard has highlighted the scenarios that a dangerous place is potentially present, and also that explosive mixtures of methane could be present.

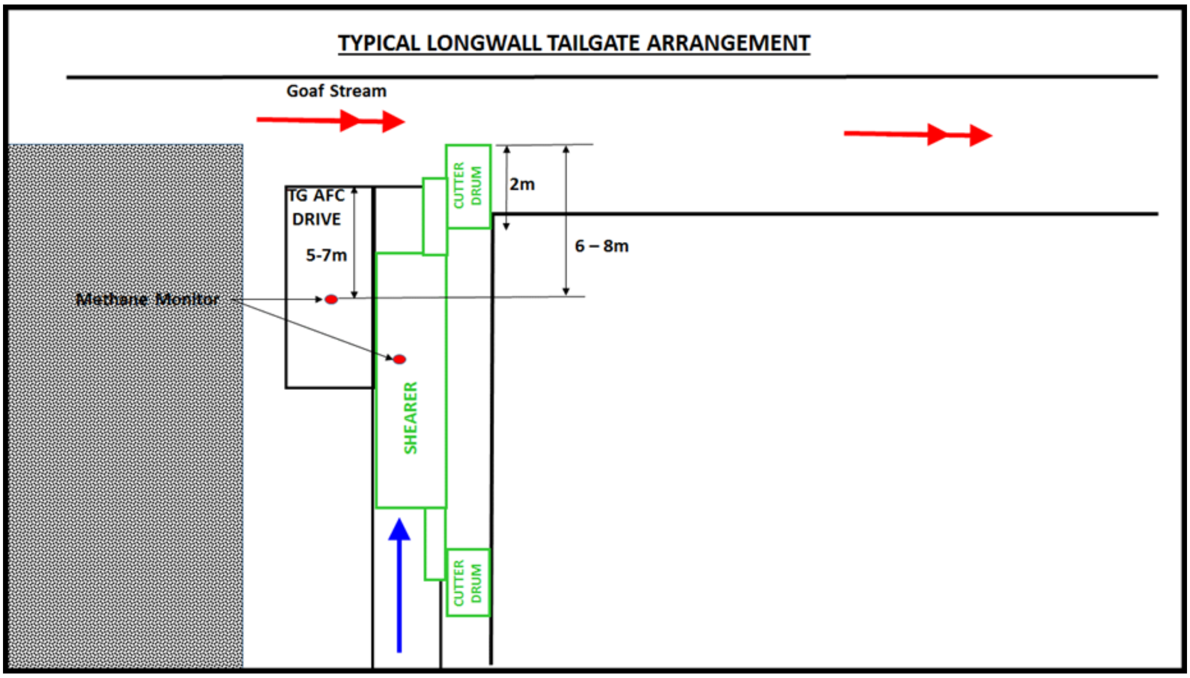
MODELLING OF METHANE CONCENTRATION

On numerous occasions around the world methane has ignited when the shearer has been cutting into the tailgate. This occurred in the 2010 Upper Big Branch mining disaster resulting in a methane and coal dust explosion which killed 29 coal mine workers.

The increase in the general body concentrations in the longwall tailgate increases the risk profile of longwall operations. The following modelling has been undertaken to evaluate the risk.

Figure 2 shows a sketch of a typical layout at the tailgate end of a longwall face.

FIGURE 2: TYPICAL LONGWALL TAILGATE ARRANGEMENT

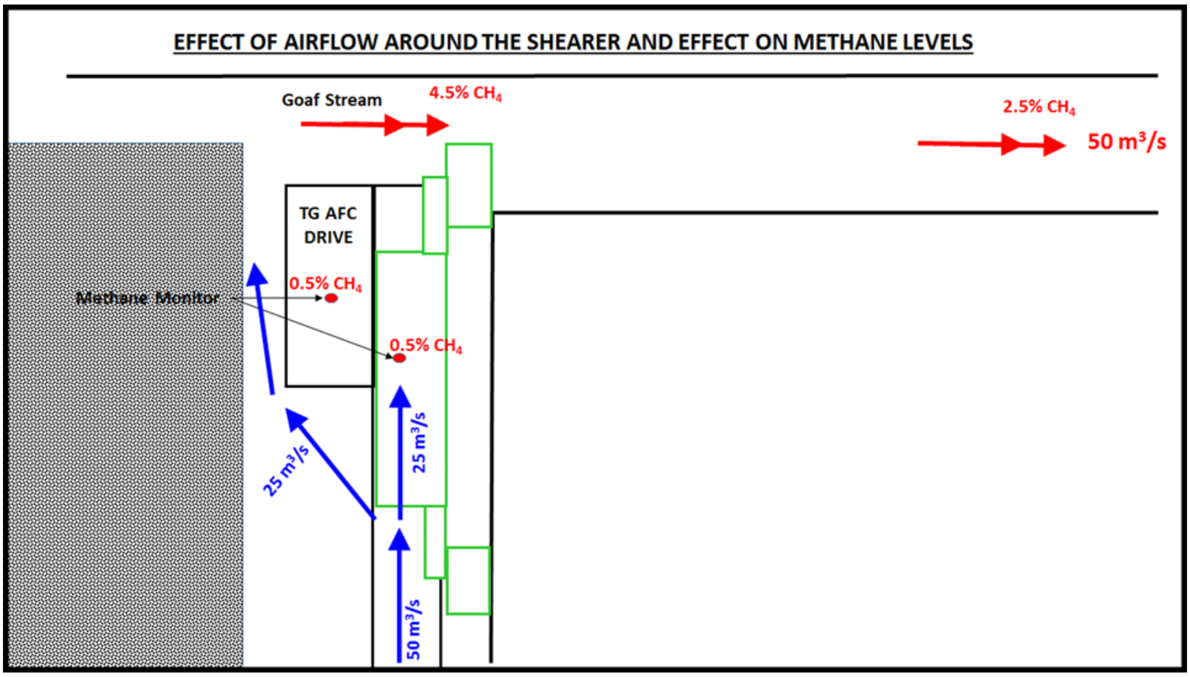


The methane monitor required by section 244(1)(b) of the Coal Mining Safety and Health Regulation 2017 at the intersection of the longwall face and return roadway, is fitted near the tailgate armoured flexible conveyor (TG AFC) motor under the carport (a protective canopy around the TG AFC motor and gearbox). Figure 2 shows that the TG AFC monitor can be up to 8.0 metres away from the cutter picks at the TG side of the cutting drum.

Due to obstruction by the body of the shearer, air is deflected around the shearer and behind the shields, flushing out goaf gases. This has been seen on coal mines gas monitoring systems with a gradual increase in methane levels at the TG end as the shearer progresses towards the tailgate. If the shearer is left at the TG end, the methane levels settle back down to more ambient conditions as equilibrium with the goaf gases is reached.

Figure 3 shows the possible ventilation arrangement when the shearer is in the TG end of the face with a total face ventilation quantity of 50 m^3/s. Monitoring results from mines show that, when high levels of methane are present in the tailgate, the TG drive monitor may remain at around 0.5%.

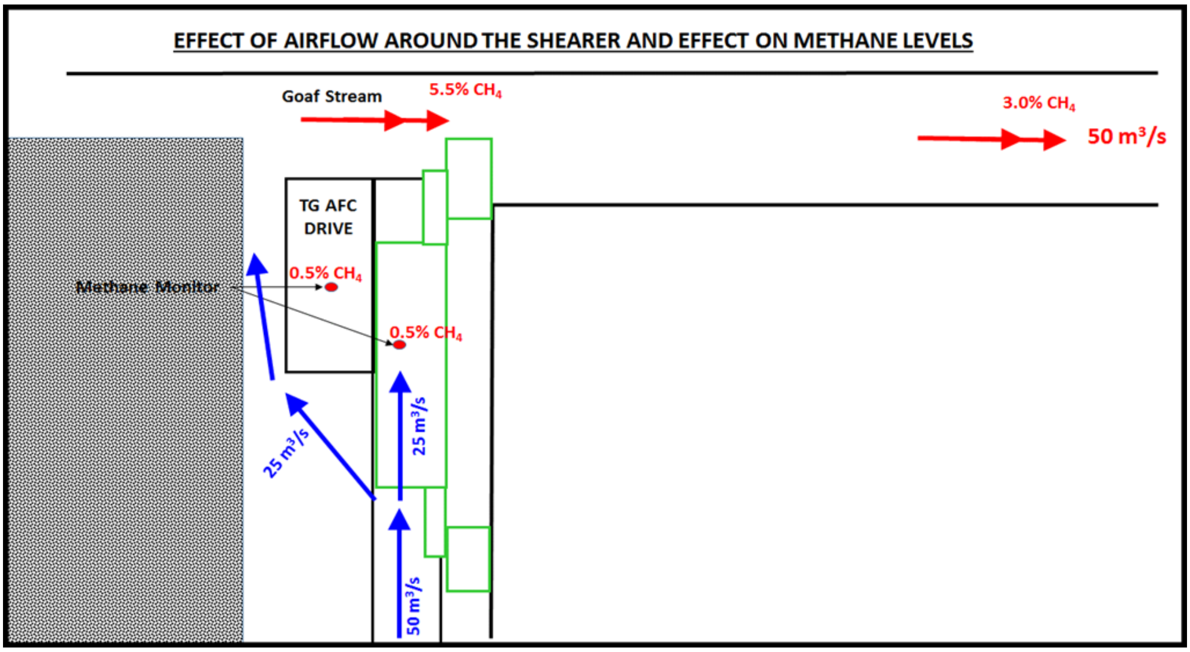
FIGURE 3: LONGWALL TAILGATE VENTILATION ARRANGEMENT



Modelling shows that if there is a 2.5% general body concentration of methane in the longwall tailgate roadway then there could be an **average** of 4.5% methane in the airway adjacent to the longwall face of the tailgate operations. The gas distribution in this area is not homogenous and there is usually a part of this area where the true 'goaf stream' exists (usually evident by increased temperature and humidity and high methane levels associated with lower oxygen levels).

Figure 4 shows the difference in the above situation when there is 3.0% methane general body concentration in the tailgate roadway.

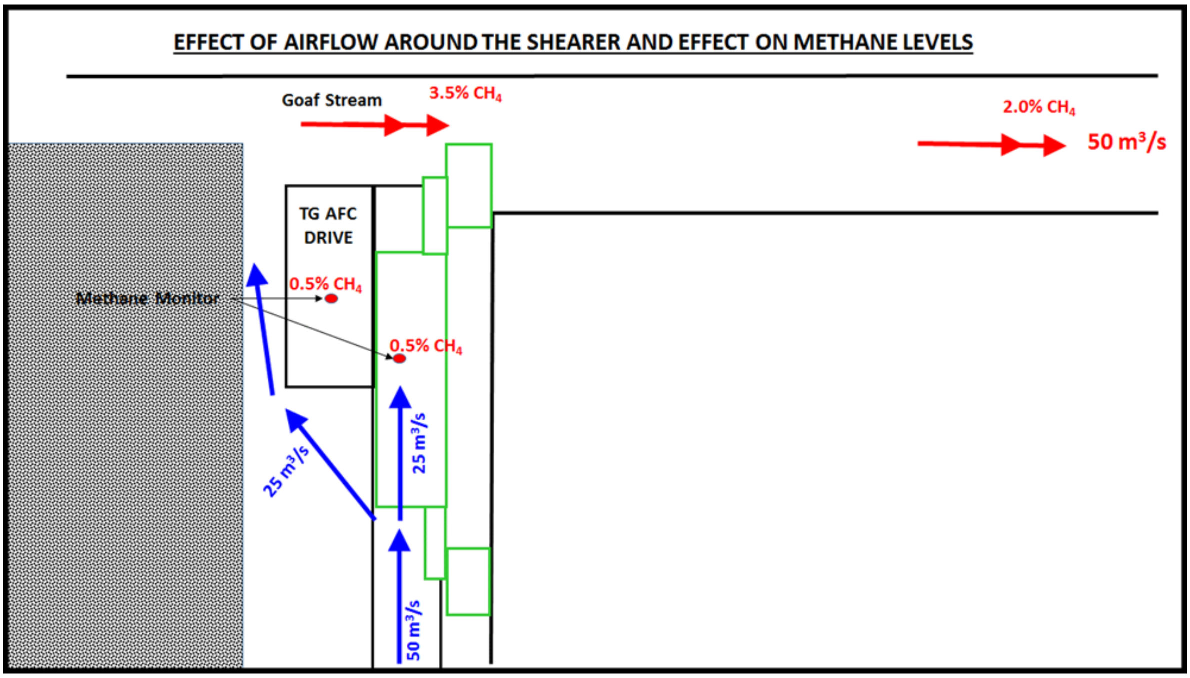
FIGURE 4: LONGWALL TAILGATE VENTILATION ARRANGEMENT 3.0% METHANE IN TG



As can be seen, the presence outbye of a 3.0% general body methane concentration in the longwall tailgate roadway means that the **average** methane concentration in the airway adjacent to the longwall face of the tailgate operations could be as high as **5.5%**. As this is not homogenous, parts of this roadway will have a methane concentration below 5% while in other parts the methane concentration could be well above 5%. Methane is explosive between 5 and 15%.

As can be seen from Figure 5, when there is a methane concentration of 2.0% in the longwall face of the tailgate roadway, the average methane concentration in the airway adjacent to the longwall tailgate operations drops to 3.5% which is below the explosive limit.

FIGURE 5: LONGWALL TAILGATE VENTILATION ARRANGEMENT 2.0% METHANE IN TG



There will be operational differences in the layouts shown above when, for example, due to creep or the alignment of the maingate (MG) and TG roadways, the tailgate end of the AFC could be significantly closer to the chain pillar rib line.

The position of the shearer when cutting into the tailgate is potentially the location of the highest risk of an ignition of methane in the longwall. There could be sparks from the shearer picks contacting any steel or incendive material, such as steel pipes or pipe hangers left in the goaf area as the longwall retreats. There is also the risk of tramp steel left in the tailgate area from secondary support operations or other work previously conducted in the TG roadway.

The most recent ignition in a longwall in Queensland occurred when the shearer was in the position similar to that shown in Figure 2. However, at the time of the incident the shearer drums were not operating and the ignition source most likely occurred at the tailgate AFC where the chain contacts the strippers as it comes over the sprocket.

HIERARCHY OF CONTROLS

The hierarchy of controls model should be used in the risk management process. Measures towards the top of the pyramid are the most effective and provide the highest level of protection.

BEST PRACTICE AND RECOMMENDATIONS

The relevant standard[1] and legislation[2] must be complied as a minimum, however, in addition, operations using the hierarchy of controls should consider the following.

Engineering controls	❖ Consider including additional mining engineering controls to reduce the potential reservoir of methane in the longwall goaf or in the underlying and overlying seams e.g. pre-drainage and/or goaf drainage
Trigger action response plans	❖ Consider the modelling of methane concentrations described in this document which shows that, in a typical layout, a methane concentration of 2.5% in the longwall tailgate roadway will result in a dangerous level of methane in the airway adjacent to longwall tailgate operations. ❖ Consider introducing additional gas monitoring in the longwall tailgate, within 400 metres outbye of the longwall face interlocked to the longwall shearer so that it automatically trips power to the shearer and the AFC when the methane concentration reaches 2.0%. ❖ Consider interlocking the gas monitor at the return of the ventilation split to the longwall shearer so that it automatically trips power to the shearer and the AFC when the methane concentration reaches 2.0%. ❖ Consider the impacts of lag times and calibration tolerances that can affect the accuracy and trip time for any methane monitors. ❖ Consider ventilation velocity and impacts from adjacent goaf and rib emissions with different concentrations for inbye and outbye sensors. ❖ The gas monitoring system must be capable of recognising static data issues and raising an alarm.
Gas monitoring system	❖ Underground gas monitoring system data should be readily available at all times in a format that is recoverable to demonstrate continuous monitoring of the mine atmosphere has been undertaken to ensure dangerous conditions are not present.

[1] Australian and New Zealand standard, AS/NZS 2290.3:2018, *Electrical equipment for coal mines – Introduction, inspection and maintenance, Part 3: Gas detecting and monitoring equipment*

[2] *Coal Mine Safety and Health Act 1999* and Coal Mining Safety and Health Regulation 2017

Tube bundle detectors	❖ Due to the inherent lag time, these systems can only be used to verify normal background levels and should not be used for identifying peak levels. ❖ Where possible the tubes should be run in return roadways to reduce condensation which can lead to accumulations of water blocking the tube. Suitably placed self-draining water traps need to be placed to remove these accumulations.
Real time and transportable detectors	❖ Real time detectors should be installed on a suitable plate and hanger with the wire harness clamped to the plate to prevent movement. ❖ The detector should be mounted on the downstream side to prevent ingress of dirt and moisture. ❖ The detector should be at a height and position in the roadway that enables it to adequately measure the gas of interest. Blockages of the gas path can lead to serious issues with the T_{90}* response time of the detector. In roadways with high velocities and total mixing this may not be an issue. Installation standards need to be developed that cover the purpose of the gas monitoring required. ❖ Access to the detector will be required for maintenance purposes. The installation should be designed to allow easy access for calibration and detector change out. Where easy access is not possible a suitable means of access to the detector needs to be available (i.e. portable work platform, not a ladder). ** The time it takes for a detector to register 90% of the change in gas levels*
Maintenance of detectors	❖ Maintenance of detectors should be in accordance with original equipment manufacturers (OEM) procedures and the relevant standard.