2010

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Publication Details

This conference paper was originally published as Claassen, C and Beamish, B, Case study of ethane emissions at Mandalong Mine, in Aziz, N (ed), 10th Underground Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2010, 274-280.

CASE STUDY OF ETHANE EMISSIONS AT MANDALONG MINE

Cambridge Claassen[1] and Basil Beamish[2,3]

ABSTRACT: Gas chromatograph analysis of sealed goaf areas at Mandalong Mine show that ethane concentrations of 30 ppm are present in older areas and up to 225 ppm have been recorded in more recent areas. Such high levels of ethane would normally be considered an indication of spontaneous combustion for many mines. However, at Mandalong Mine despite these high ethane levels, no significant carbon monoxide is recorded, indicating that the ethane being measured is a result of gas desorption from the coal over time. Generally, there is a sympathetic evolution pattern between ethane and methane, with some areas of the mine being richer in ethane than others. This paper presents results from the mine showing trends in ethane emissions from the sealed longwall panels that have been extracted to date and discusses the implications of the historical goaf seal data for reviewing the existing TARP.

INTRODUCTION

Mandalong Mine is located 50 km south of Newcastle, New South Wales, Australia. The mine operates a 150 m wide retreat longwall system in the West Wallarah Seam of the Newcastle Coalfield. The seam varies in thickness from 3.5 to 6.5 m and has moderate gas content up to 6 m^3/t. The predominant seam gas constituent is methane, but ethane is also present as a subordinate component in appreciable amounts. In-seam gas drilling and drainage is applied to the seam to lower the gas content to sufficient levels to prevent statutory limits being exceeded in the mine general body gas make.

The presence of ethane at elevated levels has often been used as an indicator of coal self-heating in the underground environment. However, where ethane may be present as a seamgas constituent the use of ethane within the TARP system becomes more problematical and a considered approach is necessary to the interpretation of gas atmospheres under such circumstances. This paper presents a case history study of the work in progress at Mandalong Mine to resolve this issue.

GAS SAMPLING AND RESULTS SUMMARY

Summary of gas data

Gas chromatographic results of gasbag samples from sealed goaf areas at Mandalong Mine have been analysed graphically to determine and interpret trends in ethane emission data. The main goaf areas investigated to date are MG7, MG6, MG5, MG4, MG3, MG2 and MG1. Methane emission data have also been added to the same plots to establish any sympathetic relationships between the two gases. A summary of the long term averages for ethane, methane, carbon dioxide and oxygen is contained in Table 1. To standardise the interpretation of the results all values have been plotted on an air-free basis and outliers and erroneous data points have been excluded from the analysis. The oxygen values are also contained in Table 1 to show the efficiency of the goaf seals.

Sealed goaf trends

The ethane and methane emission trends for MG1 goaf are shown in Figure 1. The historical long term average for ethane is below 25 ppm (Table 1). However, for the past two to three months this has equilibrated at 30 ppm. Methane and ethane trends appear to be responding sympathetically. Oxygen remains below 5%, but the long term average shows a higher oxygen concentration on the Flank side of the goaf. The carbon dioxide is approximately 7% for both seals (Table 1). No carbon monoxide is present in the gasbag samples indicating the gas accumulation trends are controlled by seamgas desorption and not coal oxidation.

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Table 1 - Average gas results for maingate panel seals at Mandalong Mine

Goaf seal	Ethane (ppm)	Methane (%)	Carbon Dioxide (%)	Oxygen (%)
FLANK 1HDG 0-1CT (8/01/08 – 12/10/09)	24 ± 7	46.73 ± 7.97	7.25 ± 0.30	3.93 ± 1.76
MG1 2HDG 1-2 CT (6/12/05 – 24/08/09)	22 ± 7	37.78 ± 9.05	6.94 ± 1.02	3.05 ± 1.72
MG1 1HDG 1-2CT (8/01/08 – 14/09/09)	26 ± 9	44.52 ± 6.80	6.79 ± 0.59	2.41 ± 0.78
MG2 2HDG 1-2 CT (2/06/06 – 22/09/09)	34 ± 5	46.16 ± 4.34	5.96 ± 0.78	2.75 ± 0.89
MG2 1HDG 1-2 CT (19/10/06 – 12/10/09)	32 ± 12	45.42 ± 8.82	6.34 ± 0.51	2.75 ± 1.19
MG3 2HDG 1-2 CT (22/11/06 – 7/10/09)	35 ± 10	43.64 ± 9.67	4.54 ± 1.54	3.93 ± 1.57
MG3 1HDG 1-2 CT (28/06/07 – 12/10/09)	52 ± 14	56.65 ± 8.02	5.10 ± 0.71	2.46 ± 1.04
MG4 2HDG 1-2 CT (15/05/09 – 7/10/09)	44 ± 6	52.09 ± 3.90	5.34 ± 0.20	1.76 ± 1.26
MG4 1HDG 1-2 CT (13/05/09 – 13/08/09)	82 ± 20	63.30 ± 4.29	2.99 ± 0.65	1.60 ± 0.76
MG5 2HDG 2-3 CT (8/04/09 – 8/08/09)	84 ± 14	59.88 ± 4.01	3.78 ± 0.43	1.60 ± 0.82
MG5 1HDG 2-3 CT (4/05/09 – 12/10/09)	217 ± 16	74.39 ± 3.15	1.99 ± 0.34	2.80 ± 1.27
MG6 2HDG 1-2 CT (11/04/09 – 11/10/09)	212 ± 7	74.26 ± 3.06	2.42 ± 0.41	2.47 ± 1.49
MG6 1HDG 1-2 CT (9/06/09 – 10/10/09)	216 ± 5	70.83 ± 1.59	1.65 ± 0.10	2.02 ± 1.36
MG7 2HDG 1-2 CT (12/06/09 – 7/10/09)	171 ± 4	63.13 ± 1.76	1.99 ± 0.09	2.54 ± 0.20

The ethane and methane emission trends for MG2 goaf are shown in Figure 2. The historical long term average for ethane is above 25 ppm (Table 1). However, for the past two to three months this has equilibrated at 40 ppm. Methane and ethane trends appear to be responding sympathetically. Oxygen remains below 5% and the carbon dioxide is between 6 and 7%. No carbon monoxide is present in the gasbag samples indicating the gas accumulation trends are controlled by seamgas desorption and not coal oxidation.

The ethane and methane emission trends for MG3 goaf are shown in Figure 3. The historical long term average for ethane is above 30 ppm (Table 1). However, for the past two to three months this has equilibrated at 40 ppm. Methane and ethane trends appear to be responding sympathetically. Oxygen remains below 5% and the carbon dioxide is currently at approximately 6%. No carbon monoxide is

present in the gasbag samples indicating the gas accumulation trends are controlled by seamgas desorption and not coal oxidation.

The ethane and methane emission trends for MG4 goaf are shown in Figure 4. The historical long term average for ethane is approximately 50 ppm (Table 1). However, this has recently risen to 60 ppm. Methane and ethane trends appear to be responding sympathetically. Oxygen remains below 5% and the carbon dioxide is between 5 and 6%. No carbon monoxide is present in the gasbag samples indicating the gas accumulation trends are controlled by seamgas desorption and not coal oxidation.

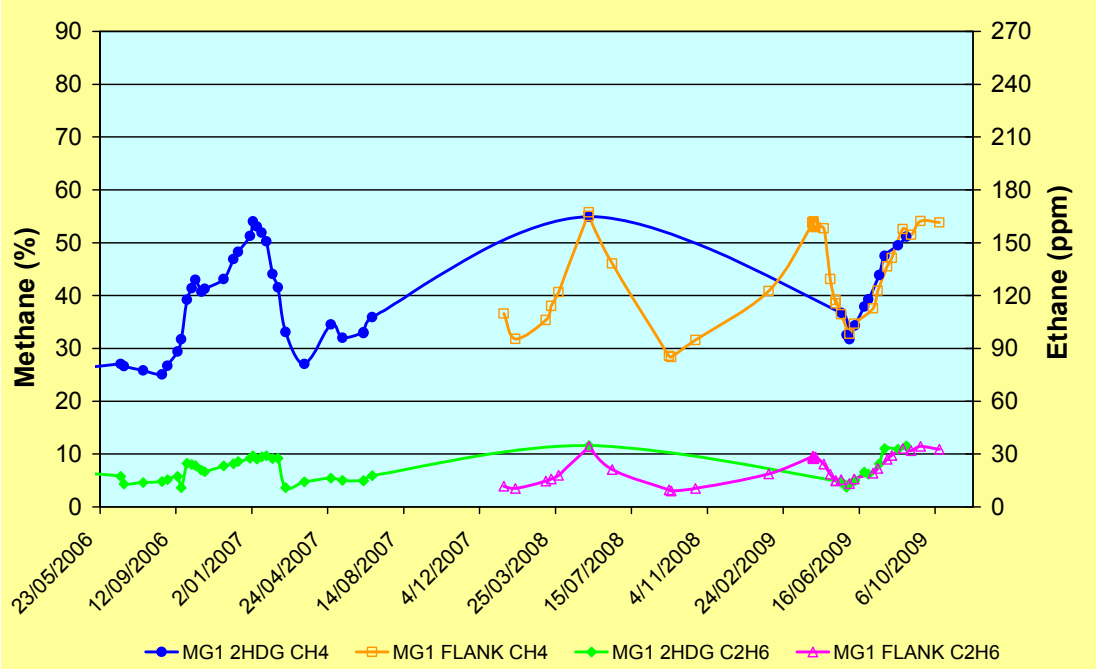

Figure 1- Ethane and methane emission data from MG1 goaf

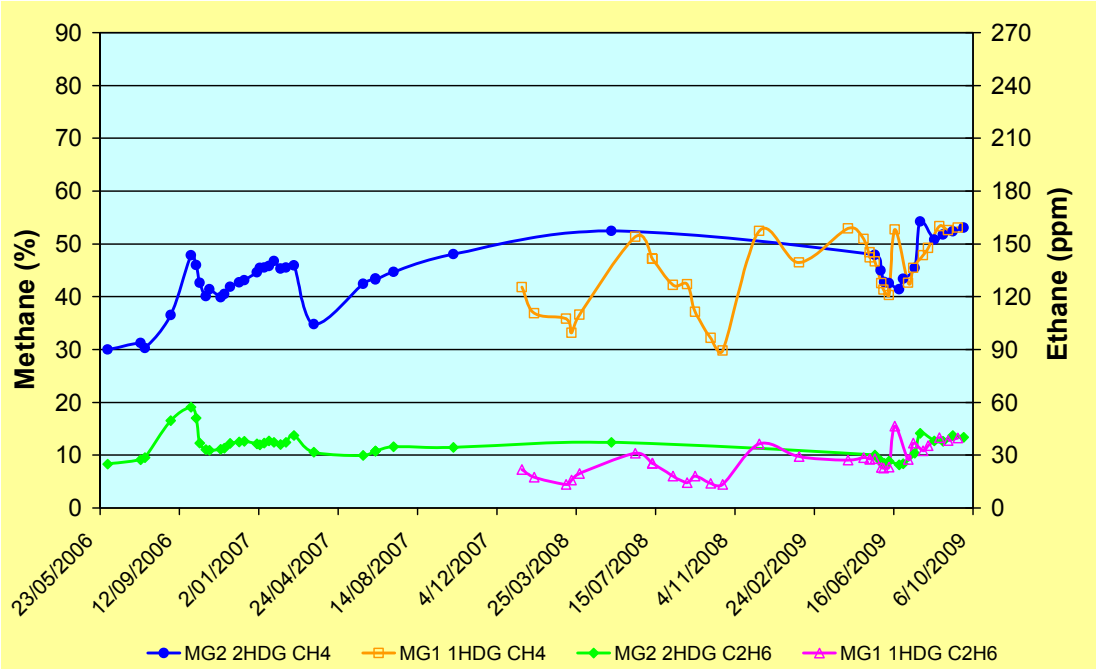

Figure 2- Ethane and methane emission data from MG2 goaf

The ethane and methane emission trends for MG5 goaf are shown in Figure 5. The historical long term average for ethane is approximately 80 ppm (Table 1). However, MG5 2HDG seal has recently risen to 100 ppm. Methane and ethane trends appear to be responding sympathetically. Oxygen remains well

below 5% and the carbon dioxide is between 3 and 4%. No carbon monoxide is present in the gasbag samples indicating the gas accumulation trends are controlled by seamgas desorption and not coal oxidation.

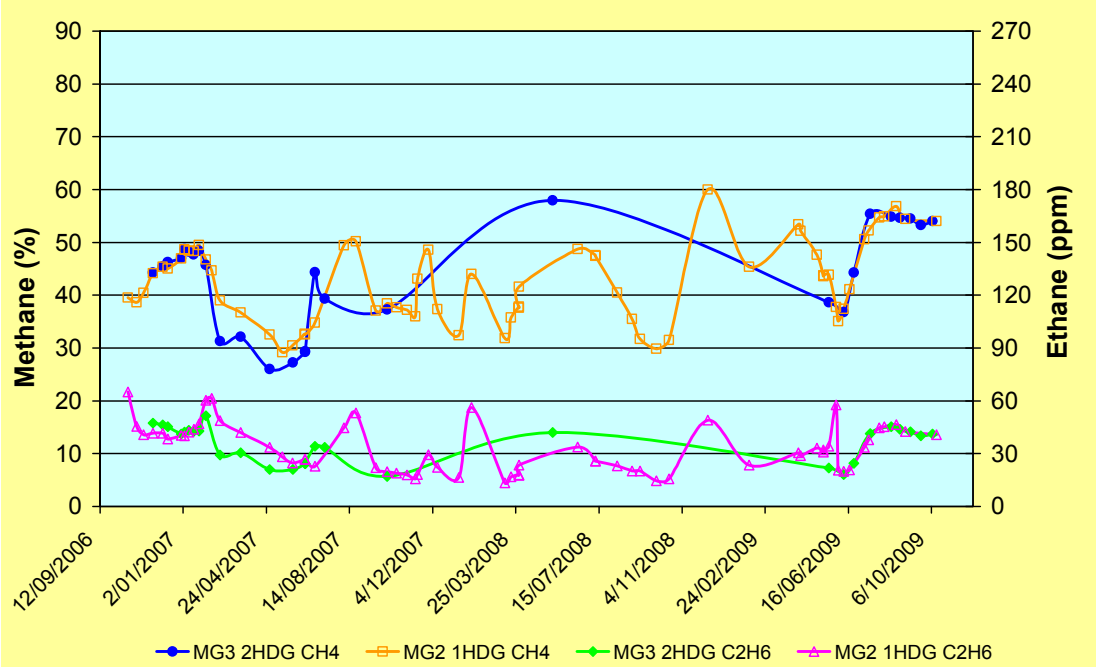

Figure 3- Ethane and methane emission data from MG3 goaf

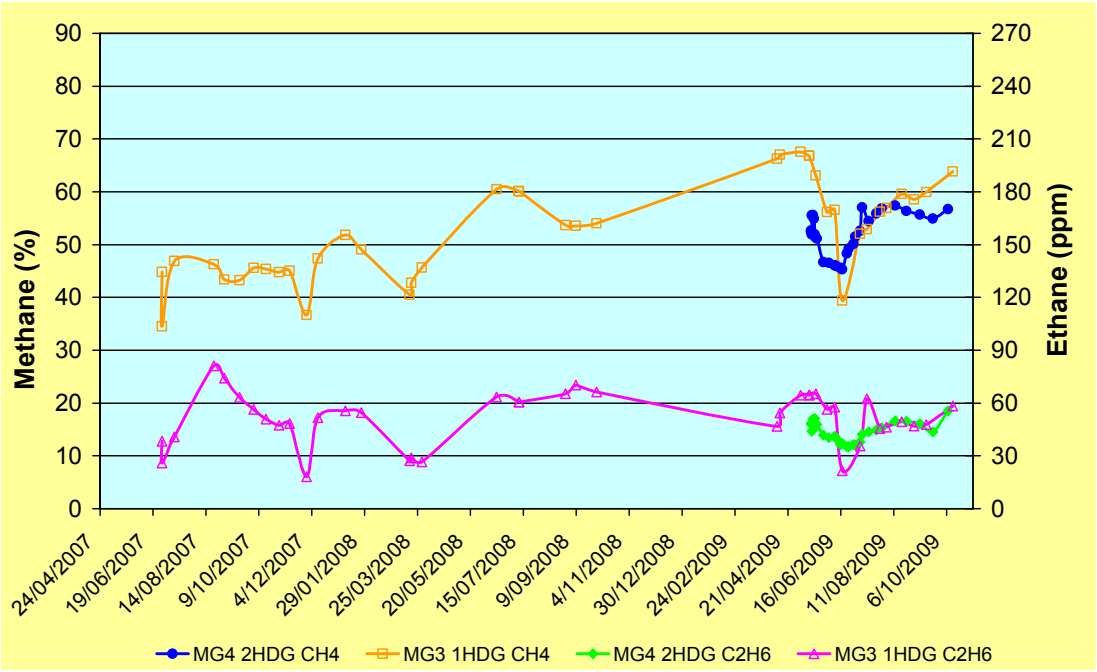

Figure 4- Ethane and methane emission data from MG4 goaf

The ethane and methane emission trends for MG 6 goaf are shown in Figure 6. The historical long term average for ethane is between 210 and 220 ppm (Table 1). However, MG 5 1HDG seal has recently risen to over 250 ppm, but the latest gasbag sample shows the values returning to the long term average (Figure 6). Methane and ethane trends do not appear to be responding sympathetically. Oxygen remains below 5% and the carbon dioxide is between 2 and 3%. No carbon monoxide is present in the gasbag samples indicating the gas accumulation trends are controlled by seamgas desorption and not coal oxidation.

The ethane and methane emission trends for MG 7 goaf are shown in Figure 7. Since the end of July 2009 the average for ethane from MG 6 1HDG seal has been between 210 and 220 ppm (Table 1). However, MG 7 2HDG seal is currently averaging just over 170 ppm. Methane and ethane trends do not appear to be responding sympathetically. Oxygen remains below 5% and the carbon dioxide is between 1 and 2%. No carbon monoxide is present in the gasbag samples indicating the gas accumulation trends are controlled by seamgas desorption and not coal oxidation.

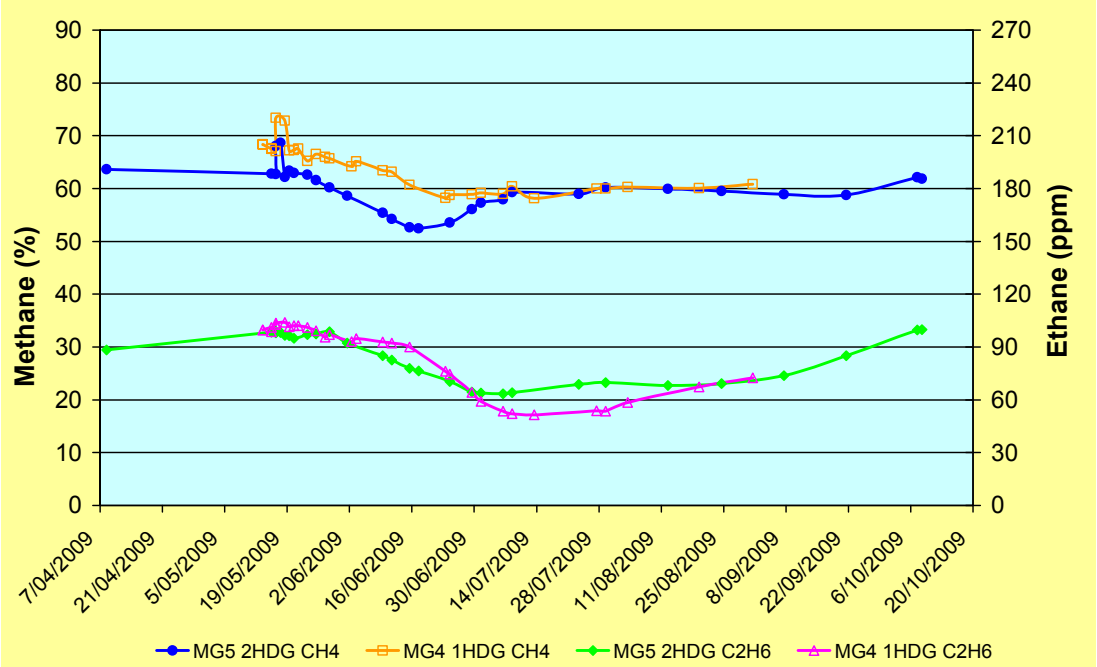

Figure 5- Ethane and methane emission data from MG5 goaf

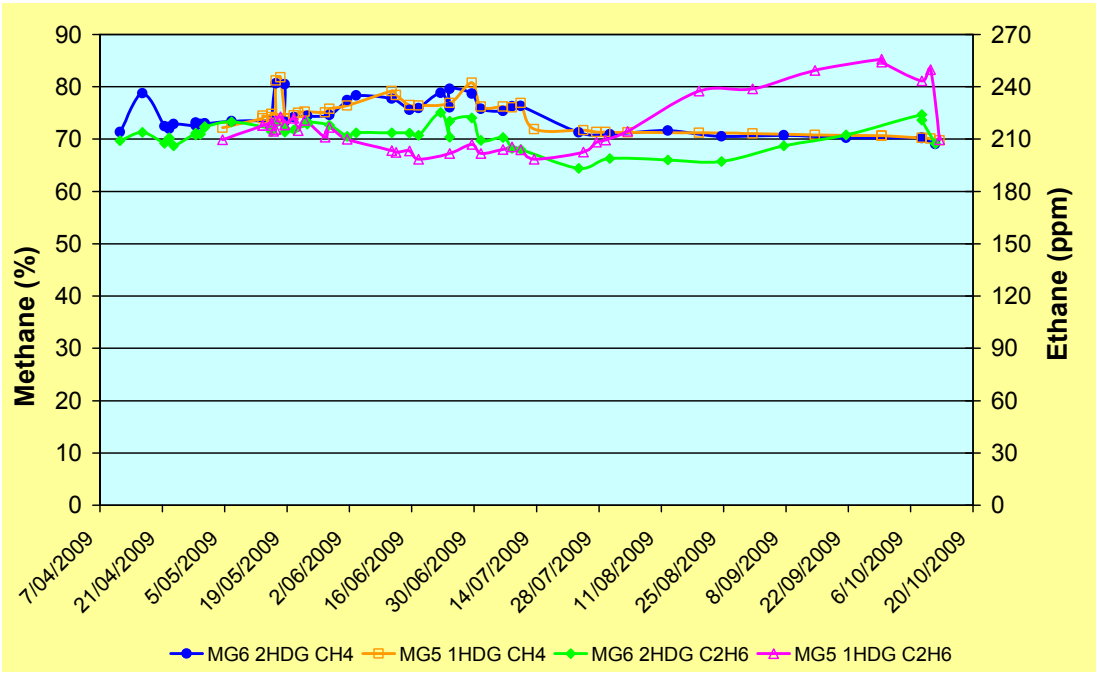

Figure 6- Ethane and methane emission data from MG6 goaf

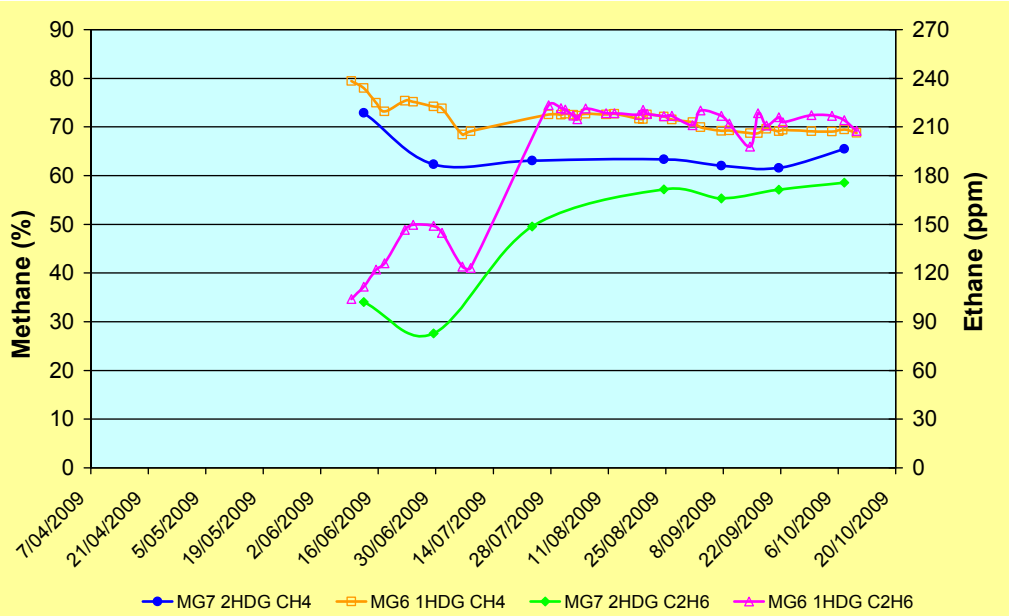

Figure 7- Ethane and methane emission data from MG7 goaf

DISCUSSION OF SPONTANEOUS COMBUSTION TARP FOR SEALED GOAF

Current spontaneous combustion TARP for sealed goaf

The current spontaneous combustion TARP for sealed goaf is shown in Table 2. This appears to be overly complex, but at the time it was originally developed the TARP was meant to cover all perceived combinations that may represent an event at the mine. The high level of ethane used to set the normal TARP level has been based on the recognition that ethane would be present even under normal circumstances due to its presence as seamgas. However, as the mine has progressed it has become apparent that this level does not capture the nature of the ethane emission in the goaf and recent goaf seals are now reaching the trigger purely on the seamgas desorption response with no other signs of oxidation products. Conversely, the fact that no carbon monoxide is being detected in the sealed goaf suggests that the LEVEL 1 trigger for carbon monoxide is set far too high and by the time this is reached a serious event would more than likely be underway. Therefore, based on the historical sealed goaf gas trends a simpler and logical TARP can be developed.

Table 2 - Current Mandalong Mine spontaneous combustion TARP for sealed goaf

Normal	LEVEL 1	LEVEL 2	LEVEL 3
CO <20 ppm CO_2 <10% H_2 <30 ppm Ethane <200 ppm CH_4 >15%, O_2 <10%	CO > 20 ppm and O2 >10% **OR** CO_2 > 10% and O2 >10% **OR** H_2 > 30 ppm and O_2 > 10% **OR** Ethylene <5 ppm	CO > 50 ppm (and upward trend doubling or more over previous 24 hours) and O2>10% **OR** CO_2 > 15% and O2>10% **OR** H_2 > 50 ppm and O_2 > 10% **OR** Ethylene >5 ppm **OR** Temp >50°, seal sweating, heat haze, tarry smell	CO >200 ppm and upward trend doubling or more over previous 24 hrs **OR** CO_2 >20% **OR** CO >200 ppm (and upward trend doubling or more over previous 24 hrs and H_2 >100 ppm **OR** Ethylene >10 ppm (and rising) **OR** Smoke or open flame

Modified spontaneous combustion TARP for sealed goaf

A modified spontaneous combustion TARP for sealed goaf is shown in Table 3. This TARP is much simpler than the existing one and the levels have been set to match the historical data of the first seven longwall panels. The major elements of the TARP are as follows:

- Values for carbon monoxide, carbon dioxide, ethane and ethylene are on an air-free basis.
- Generally <2% O_2 indicates no potential to lead to a serious rise in temperature for any coal as the rate of oxidation is too low, but Mandalong historical data would suggest this value is 5% O_2 due to the low reactivity of the coal.
- At NORMAL level ethane, carbon dioxide, methane and hydrogen are monitored to interpret the state of the goaf with respect to seamgas desorption.
- LEVEL 1 historical averages can be calculated automatically in SMARTMATE and an Excel macro can be added to automatically alarm at the appropriate trigger level. In addition, the historical average for ethane and carbon dioxide should be reviewed at the fortnightly ventilation meeting. By doing this the ethane and carbon dioxide historical averages and standard deviation (SD) information can be provided to mine personnel as a fortnightly update.
- At LEVEL 2 ethane, carbon dioxide and hydrogen values would have increased substantially above the historical average for the goaf.
- The progression from one level to the next takes into consideration the doubling effect of accelerated coal self-heating.
- To confirm an alarm requires repeatable results from an additional two gasbag samples taken from the same location within two hours.

Table 3 - Modified Mandalong Mine spontaneous combustion TARP for sealed goaf

Normal	LEVEL 1	LEVEL 2	LEVEL 3
CO <5 ppm **OR** O_2 <5% **AND** CH4 >15%	CO ≥5 ppm **AND** O_2 ≥5% **OR** Ethane >2SDs above that particular goaf seal historical average **AND** CO ≥2ppm **OR** CO_2 >2SDs above that particular goaf seal historical average **AND** CO ≥2 ppm **OR** Ethylene 1 ppm	CO ≥10 ppm **OR** Ethylene ≥2 ppm **OR** Temp >50°, seal sweating, heat haze, tarry smell	CO ≥20 ppm **OR** Ethylene ≥4 ppm **OR** Smoke or open flame

CONCLUSIONS

Ethane emissions into the sealed goaf areas of Mandalong Mine have been reviewed in conjunction with other gas data. As a result it is clear that more recent areas of the mine are subject to higher concentrations of ethane from seamgas desorption. This phenomenon has prompted a review of the existing spontaneous combustion TARP levels, which appear to be quite complex and may well result in an underestimation of the development of a heating in the sealed goaf. Consequently, a modified TARP is proposed that can be validated against the historical goaf seal gas data from the first seven longwall panels. A similar procedure is being investigated for other areas of the mine.

ACKNOWLEDGEMENTS

The authors would like to thank Centennial Coal and in particular Mandalong Mine for their continued encouragement to review the existing mine data.