

# **A View on Mine Gas Emission to 2005**

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## **Abstract**

Over the next 5 years, the proportion of longwall mining undertaken in mines requiring gas drainage, is likely to remain static in New South Wales, but increase four fold in Queensland. This paper looks at some of the challenges ahead and provides suggestions on what is required to make the most of the gas environment.

Coal mine, gas utilisation is seen as having potential to offset the cost of gas emission control. Increasing emphasis on greenhouse gas emissions adds impetus to the capture of coal seam CH<sub>4</sub>.

With the fast development rates required to sustain the planned high rates of longwall production (4 to 5 million tonnes/annum), long gateroads (3+ km) and especially in Queensland, thick coal seams (6 m), intake gas emission problems are likely to occur at surprisingly low gas contents (2 m<sup>3</sup>/t). Increased gate road lengths exacerbate the gas emission problem through lower volumetric efficiency of ventilating air.

A particular challenge is to find the optimum blend of gas control between ventilation and gas drainage, taking into account requirements for control of spontaneous combustion.

The trend toward increasing longwall face width will place additional load on the ventilation, drilling and gas extraction systems.

The outburst risk needs to be defined for all underground mining. It should proceed under the protection of an appropriate outburst management plan where gas contents are deemed sufficiently high.

The author is confident that profitable and safe mining of highly gassy deposits is achievable, provided the gas problems are addressed early enough and given due focus and priority.

## **Introduction**

Of the 32 currently operating longwall mines, there are 11 requiring gas drainage, 9 in New South Wales and 2 in Queensland. By 2005, the number of mines requiring gas drainage should increase to 18, 9 in New South Wales and 9 in Queensland, with a rise in the number of longwall mines to 39 (probably optimistic given the current industry climate).

The new longwall mines have targeted production rates double that being currently achieved. The faster rate of ground disturbance will release more gas per unit of time.

At a time of low demand and falling coal prices, the higher proportion of underground coal to be won from gassy mines presents considerable challenges for cost-effective mining – and opportunities in the area of coal mine gas utilisation.

This paper aims at providing a view on the challenges ahead and suggestions on what is required to make the most of the gas environment.

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## A View of Coal Mine Gas

Coal mine gas has historically been a cost impediment to a coal operation. In a time of falling coal prices, the additional cost of gas drainage, which can range between \$0.3/tonne to \$3/tonne of coal produced, impacts hard on the bottom line.

Can coal mine gas be turned from a liability to an asset? There is certainly a lot of work to do to identify the conditions that would permit this, but with underground mining rapidly becoming gassier, particularly in Queensland, it makes sense to endeavour to turn this liability into an asset, or to at least offset the cost of gas control.

Queensland has thick coal seams (commonly 6 m thick, but up to 11 m thick), with high gas contents (up to 14 m<sup>3</sup>/t)<sup>1</sup> and variable permeability. As gas reservoirs, they are quite large, and while the potential for high gas emission during mining is high, so too is the potential for gas recovery.

If the gas can be perceived as having value, this should act as a further incentive to improve mine safety, through more rigorous gas recovery efforts.

One of the main down sides to coal mine, seam gas is guarantee of supply. Gas supply is largely tied to mining. Difficulties in forecasting, arise from:

- Generation of mine plans of sufficient detail, that are able to look far enough ahead with reasonable certainty.
- Application of appropriate gas emission/extraction modelling to those plans.
- The realities of planned against actual progress, with allowance for major production disruptions.

In Queensland, there are number of relatively shallow mines (150 m – 300 m), where gas predrainage could be undertaken from surface borehole, cross measure to in-seam directional drilling. In divorcing gas production from the mine operation, costs can be kept down through wide spaced drilling and long lead times. Delays and inefficiencies caused by conflicting mining and drilling demands would be eliminated, and safety would be improved through less complex management. Gas supply would be far more uniform and predictable. The majority of gas may still be generated from goaf wells, in association with longwall extraction.

The impetus for mine gas utilisation should increase from pressures to reduce greenhouse gas emissions and the status of utilised coal seam gas as “green energy”.

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<sup>1</sup> Reference to “gas content” refers to Total Desorbable Gas Content calculated to 20 °C and 101.3 kPa absolute.

The following statement is from Carothers (1998). “Methane is a potent greenhouse gas, approximately 21 times more effective than carbon dioxide in causing global warming over a 100 year time frame... In US mines, mine ventilation air liberates around 73% of the coal seam methane... As gas drainage systems are implemented, the ‘vented to drained’ ratio will decrease, but the absolute volumes of vented methane will continue to be substantial”.

Processes are being developed to fully combust the methane component of vented mine gas (“The Vocsidizer Process”, “Catalytic Flow Reversal Reactor”, Carothers, 1998, “carburetted gas turbine”, Wal Hammond of EDL - *pers comm*).

With a rapidly growing interest in the gas being exhausted from a coal mine, it is becoming clear that mines will need to more positively address their gas emission from all sources. Greater efforts will need to be placed on prediction of gas makes (both vented and drained), that can take into account the inherent uncertainty in the assessment (probabilistic modelling). Based on this modelling, financial models and engineering designs would be undertaken.

The resulting infrastructure would be hard to justify as an additional cost in meeting environmental constraints alone. The ideal solution is to structure the operation to generate net income from the gas. To minimise variability of supply and infrastructure costs, it makes sense for a group of coal mines to utilise a central facility.

To work toward this, a change in mindset is required, to view gas along side coal as a resource. In mine planning and feasibility studies, costed options for its utilisation would be an automatic part of the venture. This change in mindset is beginning to happen.

It follows that in some deposits, gas recovery will be much more “economical” than others, according to their basic gas reservoir characteristics.

## Some Basic Gas Terms

Gas content is widely regarded as the most important measure in defining basic gas properties. The majority of tests in coal mining applications are carried out using the fast desorption method. Desorption rate measurements (GeoGAS’s Desorption Rate Index or DRI) and gas composition, are also determined during this test.

Gas content values in isolation, often provide misleading indications of potential gas emission conditions. It is measured in units of  $\text{m}^3/\text{t}$ , ie  $\text{m}^3$  of gas per tonne of material. Defining the material can be a significant source of error, especially in vertical borehole, surface exploration cores. How are mixtures of stone and coal treated? At what point is carbonaceous rock, deemed to not contain gas?

It is a more useful measure to define gas content in terms of a unit volume of material. Ie gas content ( $\text{m}^3 \text{ gas}/\text{m}^3 \text{ material}$ ) = gas content ( $\text{m}^3 \text{ gas}/\text{t material}$ ) \* density ( $\text{t}/\text{m}^3$ ).

Multiplying this result by the seam thickness gives a clearer indication of the gas reservoir size for both coal mining applications and gas utilisation. Gas content units become  $\text{m}^3 \text{ gas}/\text{m}^2$  of seam floor area.

The gas content expressed in  $\text{m}^3/\text{t}$ ,  $\text{m}^3/\text{m}^3$  or  $\text{m}^3/\text{m}^2$  is a static measure. It gives little insight into how fast, and how much of the gas will be released, which is important for coal mining, environmental assessments and gas utilisation. These processes are determined by the complex interaction of:

- *Gas desorption rate* – the rate at which gas desorbs from the coal matrix.
- *Permeability* – a measure of the ease with which the gas will move through the fracture network.
- *Water saturation* - reduces permeability to gas, retarding gas migration.
- *Gas sorption properties* – the relationship between gas pressure and the corresponding equilibrium gas content of the coal.
- *Pore pressure* – the overall fluid pressure magnitude.

Taking these parameters into account, including gas content and composition, requires use of a gas reservoir simulation program, such as SIMED II and proprietary modelling tools.

## Gas Problems

### Compliance and Related Issues

Gas problems centre on the need for statutory compliance with gas concentrations, and nullifying outburst potential and face ignitions (Table 1). Gas concentrations are prescribed according to Queensland and New South Wales legislation.

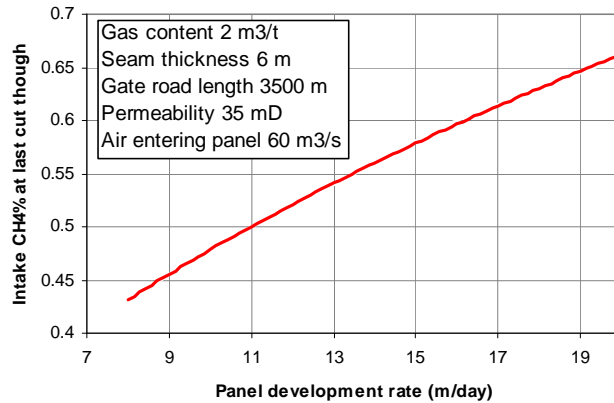
**Table 1 Gas Problems and Legislation Compliance**

<b>Problem/Area</b>	<b>Compliance</b>
Intake to last open cut through	0.25% CH <sub>4</sub>
Face area, with electrical power	1.25% CH <sub>4</sub>
Panel returns	2% CH <sub>4</sub> (NSW no non IS electrical power), 1.25% CH <sub>4</sub> (Diesel equipment, warning 1.0%).
CO <sub>2</sub> all areas	0.5% CO <sub>2</sub> (Qld), 1.25% CO <sub>2</sub> (NSW)
H <sub>2</sub> S all areas	10 ppm H <sub>2</sub> S
Outbursts	Mine specific gas content threshold limits. Ranges 7 to 9.5 m <sup>3</sup> /t CH <sub>4</sub> and 6 m <sup>3</sup> /t CO <sub>2</sub> .
Sudden gas releases in the face area (eg longwall floor breaks)	No mining until CH <sub>4</sub> < 1.25%.
Face ignitions	Mine specific control and alleviation

Mines operating in conditions deemed liable to outburst, do so according to an outburst management plan, an important part of which stipulates the gas content threshold value above which normal mining cannot proceed. Face ignitions are exacerbated by high gas emission (eg “blowers”) in regions of high permeability. An approach has been to apply gas drainage to achieve a target gas content limit (eg South Bulga Colliery).

Compliance with the intake 0.25% CH<sub>4</sub> becomes increasingly difficult as gate roads are lengthened and panel development rates<sup>2</sup> increase. Difficulties in compliance can be realised in gas contents as low as 2 m<sup>3</sup>/t CH<sub>4</sub>, in combination with high permeability, long gateroads and relatively thick coal seams (Figure 1).

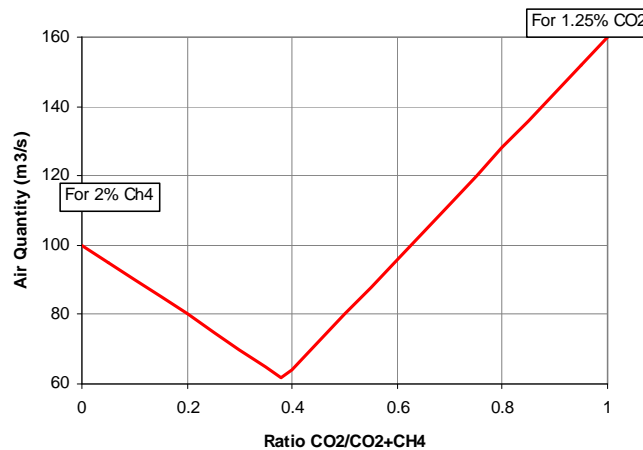
Figure 1 Effect of Panel Advance Rate on Intake CH<sub>4</sub>%



Power trips on the continuous miner are exacerbated by high intake emissions. In a CO<sub>2</sub> environment, intake concentrations are allowed to be much higher than for CH<sub>4</sub>, resulting in a greater likelihood of exceeding permitted CO<sub>2</sub> concentrations in the face area.

Compliance with 1.25% in the longwall return is particularly difficult for CO<sub>2</sub>. Similar difficulties apply for CH<sub>4</sub> in mines where return roadways used for diesel vehicle access, are restricted to 1.25% CH<sub>4</sub>.

Figure 2 Air Quantity Required to Dilute 2000 l/s Mixture of CO<sub>2</sub> and CH<sub>4</sub>



An advantage of having a mixed CO<sub>2</sub>/CH<sub>4</sub> gas concentration is the ability to dilute more gas with the same quantity of air. For a situation permitting up to 2% CH<sub>4</sub> and 1.25% CO<sub>2</sub> in the returns, the optimum gas mixture is 38% CO<sub>2</sub> and 62% CH<sub>4</sub>. For the example in Figure 2, just over 60 m<sup>3</sup>/s of air is needed to dilute 2000 l/s of this gas mixture. With increasing quantities of CO<sub>2</sub>, the required air quantity increases at a rate of around 15

<sup>2</sup> The net rate of panel advance, inclusive of the normal stoppages during the mining sequence.



outburst prone (Williams, 1997).

For similar gas contents and compositions, different rates of gas desorption between mining areas are evident, probably reflecting differences in the level of microfracturing, coal type and rank. On the basis of gas desorption rate, Bowen Basin coals are on the whole, more outburst prone than Sydney Basin coals. Whereas gas content threshold levels for high CH<sub>4</sub> coals in the South Coast are around 9.5 m<sup>3</sup>/t, in some parts of the Bowen Basin, threshold levels have been set at 7 m<sup>3</sup>/t, based on the DRI (Figure 4).

### Longwall Extraction

Longwall gas emission is set to increase with the trend toward mining wider faces and the correspondingly more extensive strata relaxation zone. Control of spontaneous combustion necessitates minimisation of ventilation pressures across goafs. In the thick seam deposits, “U” ventilation systems are required to minimise pressure differences. The non-spontaneous combustion prone mines of the South Coast of NSW utilise “Z” ventilation systems or modified “U” and bleeder systems. Compared to these, “U” only ventilation (or dominant “U” with a minor bleed) necessitates all (or the great majority) of the goaf gas generated being handled in the “U” return. This reduces the scope of ventilation to handle this gas, especially where the “U” return gas concentration is limited by the need for diesel vehicle access.

Surface based, post drainage, goaf holes are the preferred means of collecting the excess gas. For spontaneous combustion control, it is important to maintain a high gas purity, so location and operation of the boreholes becomes an important feature. The goal is to establish the correct balance of maintaining a high gas concentration in the goaf, a low return airway gas concentration, and high purity goaf gas extraction.

### Control

Gas dilution with mine ventilation air is the first option in gas emission control. Available air quantities are limited to acceptable pressure differentials in respect of spontaneous combustion and volumetric efficiency, fan power requirements and roadway air velocities.

A “law of diminishing returns” applies, where for each additional 10 m<sup>3</sup>/s delivered, the effect on gas dilution is proportionally less (Figure 5), with an increasing rate of growth of ventilating pressures (Figure 6).

Deciding upon the balance between gas drainage and ventilation is particularly

Figure 5 Diminishing Return on Gas Concentration for Incremental Increases in Air Quantity

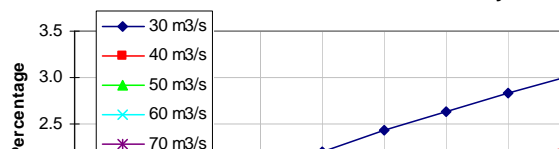
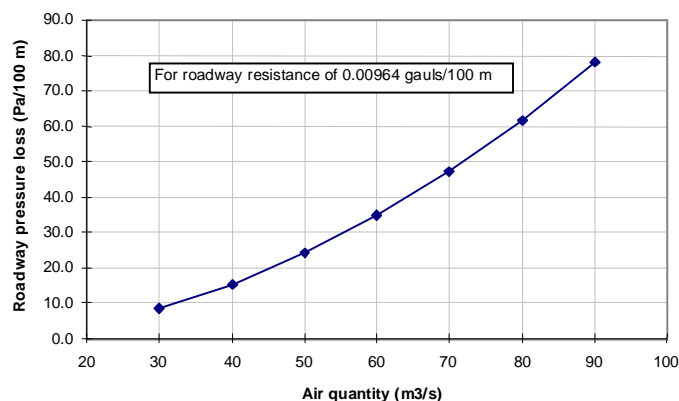


Figure 6 Increasing Pressure Loss With Air Quantity



interesting. The problem is most complex in Queensland, where mines develop from conditions of high permeability, low gas content and low mine resistance to conditions of increasing gas content, reducing permeability (Figure 3) and increasing mine resistance.

An iterative approach is required, where the costs of applying gas drainage are weighed against the costs of ventilation and vice versa. Inherent in these costs is uncertainty, mostly applied to gas predrainage. As the mine deepens, increasing drainage time and/or decreasing hole spacings are required to effect pre drainage in a reduced permeability environment.

In outbursting environments, there are no ventilation options to alleviate the condition – the gas content has to be reduced to below the gas content threshold, regardless of the need for gas emission control. In the thicker Queensland seams, with relatively high permeabilities at shallow depths, gas emission problems invariably present themselves in gas content environments lower than the outburst threshold limit. In this environment, the drilling required for gas emission control also serves the outburst problem – essentially at no additional cost for drilling.

The most cost effective method of gas drainage is post drainage through vertical goaf wells, with estimates of one third the cost per unit of gas recovery, compared to in-seam pre drainage. Because drilling options between pre and post drainage rarely present themselves, there is normally no alternative to application of the more expensive pre drainage drilling.

Given the level of uncertainty in gas emission assessment, a sensible strategy is to predrain as much of the gas possible, then relax the amount of drilling as knowledge is built up about the drilling and gas drainage conditions. (eg Dartbrook Mine has made enormous strides in gas emission cost control and effectiveness, building upon the early experiences around Longwall 1).

## Conclusions

The magnitude of gas emission problems will vary greatly according to the mining and geological circumstances. Gas drainage control options will range from low cost rib capture systems to control intake emission in high permeability coal, to comprehensive predrainage and post drainage systems.

The author believes there is considerable extra scope to manage these problems and reduce their cost to acceptable levels. It requires early action in recognition and assessment and finally resolve in implementation. The greatest danger in the current climate of cost control is for mines not to devote adequate resources through a lack of appreciation of the problem – then “hit the wall” when gas problems become overwhelming.

It is important to show that gas problems are solvable. Dartbrook Mine is easily the most gassy mine in Australia, and will probably remain so for a long time to come. That they have been able to mine safely, with high productivity and handle large volumes of gas, is a credit to their management and people involved. They show what can be done.

Mine gas utilisation has the potential to offset the cost of gas emission control, and even result in a net profit on gas control expenditure. Consideration should be given to reassessing mine planning to optimise the balance between mining and gas utilisation requirements.

Sharing of gas utilisation infrastructure costs on an inter-company basis should result in cost minimisation and provide a greater level of supply security.

Gas pre drainage not tied to mining operations is attractive to both miners and gas utilisation engineers alike. There is scope for a number of the relatively shallow mines (7 in all) to undertake surface based, cross measure to in-seam, long-hole directional drilling. They could pool resources and get a trial going (eg via a syndicated AMIRA project).

At the exploration and mine feasibility stage, there is good awareness and support within the industry for assessment of inherent gas conditions and of the effects of gas on mining and mine safety. The challenge is presented to groups such as the CSIRO and GeoGAS to continue to devise methods of assessment appropriate to the conditions and in collaboration with mining companies and other suppliers, to engineer more appropriate solutions.

For operating mines, there is considerable scope for improvement in the monitoring of gas emission and gas drainage as a basis for improved understanding and design. On this important point, operators need to be convinced to devote resources to this in the current, difficult economic times. The incentive should increase if the gas has its own commercial worth.

The potential for outbursting in Queensland mines will increase considerably. In response to the Leichhardt Colliery fatalities in 1978, the “Coordinating Committee on Outburst Related Research” was set up in Queensland, but that committee was dissolved in the 1980’s. There is currently no industry body looking at the problem. Do we need to wait for the next fatality?

The author is confident that profitable and safe mining of highly gassy deposits is achievable, provided the gas problems are addressed early enough and give due focus and priority.

## References

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