GAS CONTENT ESTIMATION USING INITIAL DESORPTION RATE

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ABSTRACT: The measurement of gas content plays an important role in mine safety and mine planning for coal and gas recovery. A number of methods exist to determine gas content; direct and indirect methods. The direct method of fast desorption test is the preferred method of gas content measurement. The indirect methods are based on either empirical correlations or laboratory derived sorption isotherms. Recent research has identified two new, semi-direct methods of estimating total gas content using early stage gas desorption rate measurement. Both techniques, if adopted, can provide operators with an indication of gas content and particularly whether the content is above or below the outburst threshold limit. A total of 930 samples, were analysed from two local mines, with known gas drainage problems and high degree of variability in both the *in situ* gas content and composition. Two specific aspects of the analysis included; the relationship of the three gas content components, Q1, Q2 and Q3, and the initial gas desorption rate relative to total gas content. Based on the relationship between desorption rate and total gas content, it was possible for minesite technical staff to provide operational personnel with an estimate of maximum expected total gas content from a particular core sample, based on the initial desorption rate value determined from $Q2_{field}$ measurement data collected by the drillers or site geologists.

INTRODUCTION

The measurement of gas content plays an important role in mine safety and mine planning as well as coalbed methane resource assessment and recovery operations. A number of methods are available to determine gas content, direct methods, which measure the volume of gas released from a coal sample sealed in a desorption canister, and indirect methods, which are based on either empirical correlations or laboratory derived sorption isotherms. In Australia the direct method, fast gas desorption test, is the preferred method of gas content measurement used to support the underground mining industry. The benefit of this method is the relatively short time required from core recovery to the reporting of gas content and composition. This is particularly important from the point of view of outburst risk management and control as it minimises the risk of production delays whilst awaiting confirmation that a particular mining area is 'below threshold' and therefore able to be authorised to resume mining. There are however a number of shortcomings with this technique, the most significant being the accurate estimation of the gas lost during the core recovery process.

Recent research involving the analysis of results from rapid desorption gas content measurement of coal samples recovered from underground drilling in two Bulli seam coal mines has identified two new, semi-direct methods of estimating total gas content from early stage gas desorption rate measurement. The use of these techniques to estimate total gas content, although not definitive, provide operators with an indication of gas content and particularly whether the content is (a) above threshold limit, in which case additional gas content reduction action must be taken; or (b) below threshold limit, in which case planning can commence for the continuation of production, pending the receipt of validated gas content measurement from the laboratory rapid desorption testing.

It is widely accepted that the direct method of gas content determination is the preferred method and provides a more accurate result when compared to indirect methods. The use of indirect methods such as sorption isotherms possess many inherent potential errors which include:

- available isotherm data not being representative of conditions at sample location due to change in coal characteristics and gas composition;
- laboratory procedures used to determine isotherm data not being representative of *in situ* conditions;
- inaccuracy in measuring gas pressure at sample location; and
- inability to determine the degree of saturation.

Although having the potential to produce a more accurate gas content measurement the direct methods also possess several areas where error may arise which include:

- inaccuracy in the estimation of the gas lost from the samples during sample recovery, prior to sealing of the sample in an air tight canister;
- inaccuracy in the field measurement of initial gas desorption rate;
- leakage of gas from the sealed canister;
- loss of gas due to dissolution when in contact with water;
- loss of gas whilst transferring sample from sealed canister for Q3 testing; and
- lack of control and inaccurate measurement of environmental conditions throughout the test.

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Since the development of the first method in France by Bertard, et al. (1970), a variety of direct gas content measurement techniques now exist:

a)   Bertard's method;
b)   US Bureau of Mines method;
c)   US Bureau of Mines modified method;
d)   Smith and Williams method;
e)   Decline curve methods;
f)   Gas Research Institute (GRI) method; and
g)   Australian Standards (AS3980-1999) method

The current direct method used in Australia was initially introduced in 1991 as a standard method of testing. This was revised and a new standard published in 1999. This standard (AS3980-1999) provides a guideline for both fast and slow desorption techniques. The fast desorption method is the most common method employed because of the significantly reduced time required to produce a result. Besides the test direction, there is a significant difference in the relative percentage of the Q1, Q2 and Q3 components of the total gas content of a particular coal sample.

Testing and analysis undertaken on a number of Bulli seam coal samples have shown the component percentages for fast desorption (Equation 1) and slow desorption (Equation 2).

$$\textbf{Total Gas Content}_{(Fast\ Desorption\ Method)} = (5-10\%)\textbf{Q1} + (12-17\%)\textbf{Q2} + (73-83\%)\textbf{Q3} \qquad (1)$$
$$\textbf{Total Gas Content}_{(Slow\ Desorption\ Method)} = (5-10\%)\textbf{Q1} + (75-90\%)\textbf{Q2} + (5-15\%)\textbf{Q3}* \qquad (2)$$

Q3$*$ in the slow desorption equation represents a true residual gas content which ranges between 0.7 and 1.0 m^3/t (CH$_4$) and 1.5-1.9 m^3/t (CO$_2$).

The results of gas content testing on coal core samples obtained from underground to inseam drilling were provided by two collieries operating in the Bulli seam. The large number of samples, 516 from Mine A and 414 from Mine B, were considered to be highly representative of conditions present in the mine given the core sample locations covered a large area both across and along multiple longwall blocks. Throughout both of these large areas there is a high degree of variability in both the *in situ* gas content and gas composition. During the analysis of these two separate datasets a number of relationships and similarities became evident. Two specific aspects of the analysis presented include the relationship to total gas content of both the three gas content components, and the initial gas desorption rate. The impact of seam gas composition is also discussed.

GAS CONTENT DETERMINED FROM Q1 MEASUREMENT

Analysis gas content test results was undertaken with particular emphasis on determining whether a relationship existed between the three components which make up total gas content. Using the samples from both Mine A and B, the analysis identified that each of the three gas content components, Q1, Q2 and Q3, represent a relatively consistent percentage of the total gas content, particularly below a total gas content of 6-8 m^3/t. It was observed that above 8-10 m^3/t there was an increase in the data scatter away from the mean with a general increase in the percentage of gas liberated during the early stages of desorption (i.e. Q1+Q2), increasing relative to the decreasing Q3. Figure 1 shows the volume of gas released for each of Q1, Q2 and Q3 relative to the total content of each sample analysed for both Mines. The increased scatter above 10 m^3/t is clearly evident in both datasets. In order to reduce the impact of the high degree of scatter, the data with total gas content less than 10 m^3/t have been averaged and trend lines generated.
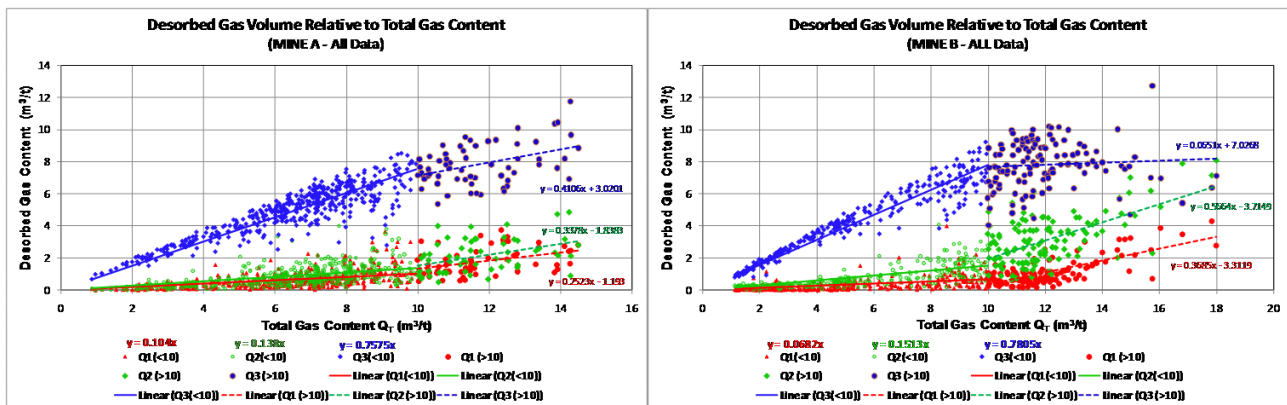

Figure 1A: Gas content component volumes measured determined during fast desorption testing (Mine A)

Figure 1B: Gas content component volumes measured determined during fast desorption testing (Mine B)

In the case of Mine A, Q1 represents 10.4% of Q$_T$, Q2 is 13.8% Q$_T$ and Q3 is 75.8% Q$_T$. In the case of Mine B, Q1 represents 6.8% of Q$_T$, Q2 is 15.1% Q$_T$ and Q3 is 79.0% Q$_T$. In both cases, and with Q$_T$ above 10 m^3/t, there is a significant increase in the rate of early stage desorption with high gas volumes liberated during Q1 and Q2 with a

corresponding reduction in Q3 emission. The relative component percentages of total gas content are summarised in Table 1.

Table 1: Relative gas content component percentages of total gas content

Average Component Percentage of Total Gas Content	MINE A	MINE B	Diff (%Q_T)
Q1 (% of Q_T)	10.40	6.82	3.58
Q2 (% of Q_T)	13.80	15.13	1.33
Q3 (% of Q_T)	75.80	78.05	2.25

Using the observed relationship, it is possible for minesite technical staff to estimate the expected average total gas content for a particular core sample, based on the Q1 component value determined from $Q2_{field}$ measurement data collected by the drillers or a site geologist.

Further investigation was undertaken to determine the extent of any impact which gas composition may have on the observed relationship. The datasets from each mine were divided into subsets comprising all samples with gas compositions greater than 80% CH_4 and greater than 80% CO_2. A total of 305 samples were analysed in the case of Mine A and 297 in the case of Mine B.

A comparison of the component relationships for each mine, shown in Figure 2, indicates that gas composition has little impact on the relative percentage of the gas component volumes released during gas content measurement using the fast desorption method. In the case of Mine A (Figure 2A), although the relative percentage of total gas content of each of the three components is virtually independent of gas composition the average result for the two gas composition datasets indicates that the desorbed Q1 and Q2 components are marginally higher for the high CH_4 samples and lower Q3 component than the high CO_2 samples. Although quite small, the relative difference in component percentage of total gas content between the two gas composition datasets for Mine B (Figure 2B) does indicate a greater difference than was observed for Mine A. In the case of Mine B the desorbed Q1 and Q2 components are greater for the high CO_2 samples with the Q3 component being less for the high CO_2 samples than for the high CH_4 samples.
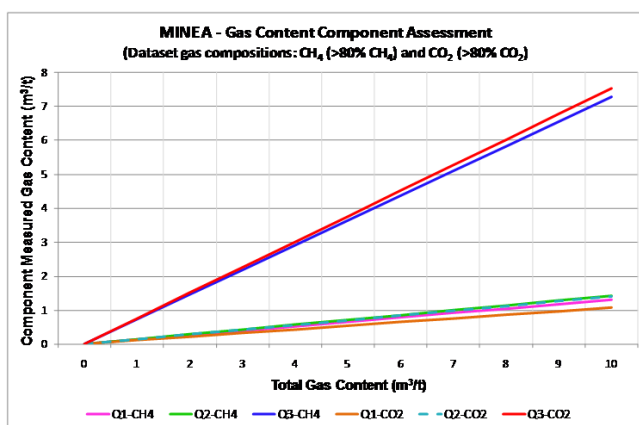

Figure 2A: Impact of gas composition on gas content component volumes (Mine A)
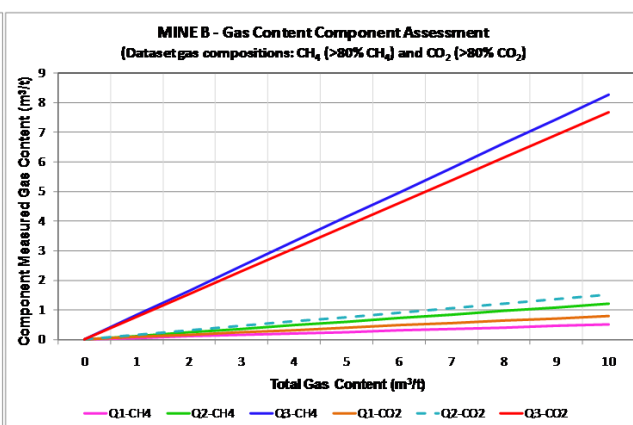
Figure 2B: Impact of gas composition on gas content component volumes (Mine B)

GAS CONTENT DETERMINED FROM INITIAL DESORPTION RATE

The analysis of the data from the two mines was extended to include the initial desorption rate with particular assessment of the desorption rate relative to the total gas content of the samples from each mine. The data obtained from each mine is illustrated in Figure 3. The data indicates quite a high degree of scatter which can occur for various reasons including:

- Where a sample is highly fractured an increased gas emission is likely to occur early in the desorption process resulting in increased desorption rate relative to total gas content;
- Where a core sample remains intact a reduced gas emission is likely to occur early in the desorption process resulting in decreased desorption relative to total gas content; and
- Where leakage of gas from the desorption canister has occurred between sealing in the field and laboratory testing the total measured gas content will be low relative to the initial desorption rate.

With the exception of leakage, scatter among the results is expected given the lack of control on the condition of the recovered core. The impact of leakage can be minimised through equipment design, maintenance and operator training.

Interestingly, all data points lie below an observed maximum envelope. A projected log relationship through the identified maximum total gas content values for each of the two data set, as shown on the two graphs, clearly indicate that the envelope line represents the maximum gas content value expected for a given desorption rate value.

Figure 4 shows the maximum gas content / desorption rate curves for both mines. It can be seen that the two curves are very similar in shape with the Mine B curve indicating a slightly higher total gas content than Mine A for a given desorption rate value.

Using this observed relationship between desorption rate and total gas content minesite technical staff are able to estimate the maximum expected total gas content for a particular core sample using the initial desorption rate value, determined from $Q2_{field}$ measurement data collected by the drillers or a site geologist.
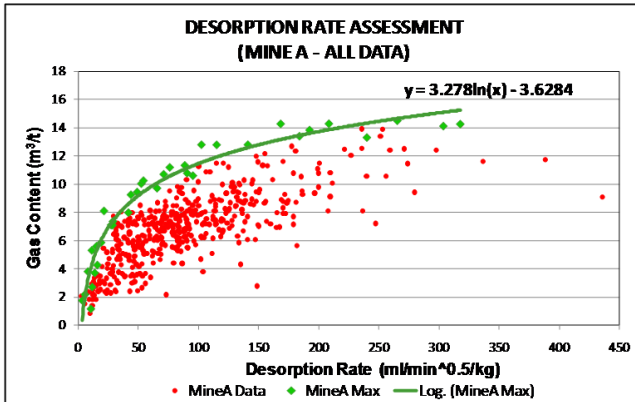

Figure 3A: Initial desorption rate measurement relative to total core sample gas content (Mine A)
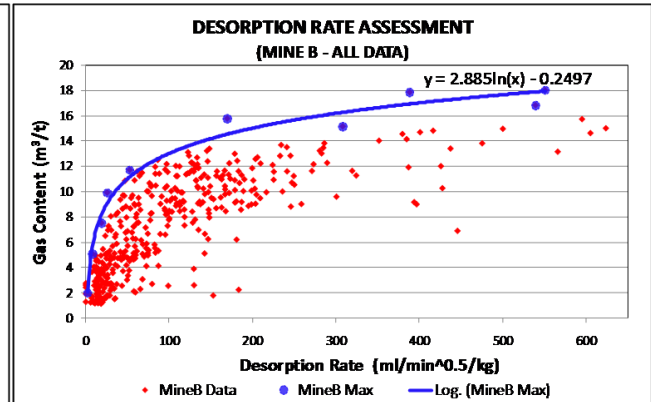
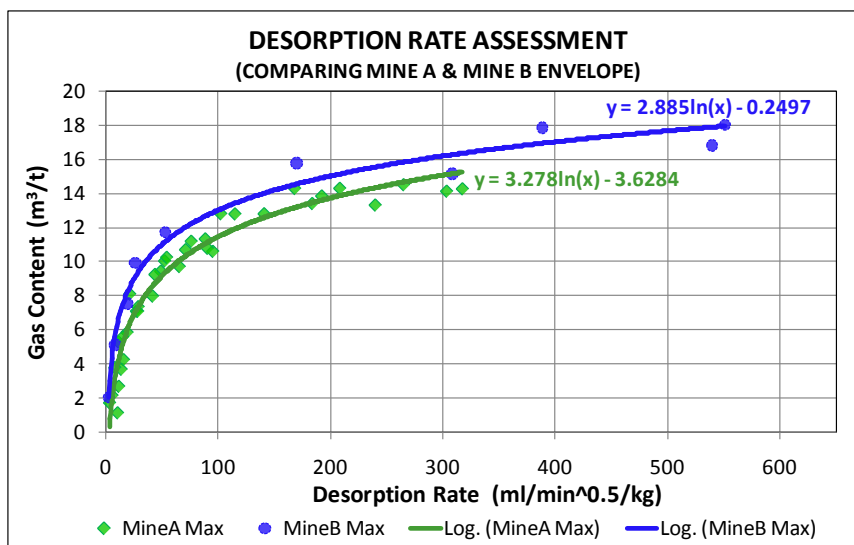**Figure 3B: Initial desorption rate measurement relative to total core sample gas content (Mine B)**

Figure 4: Determination of maximum total gas content based on initial desorption rate measurement

CONCLUSIONS

Using the fast desorption method of determining the gas content of coal based on AS3980-1999, a number of important relationships have been identified, which have the potential to assist mine operators in the rapid estimation of the gas content of a given sample literally while the sample is in transit to the laboratory for testing.

A relationship was identified which demonstrated, for gas content values below 10 m^3/t, that each of Q1, Q2 and Q3 maintained a consistent percentage relative to the total gas content. The composition of the gas within the sample had very little impact on this relationship. Thus it can be concluded that during fast desorption testing, the percentage of the desorbed gas components relative to total gas content will remain reasonably consistent and this relationship is maintained independent of gas composition.

There was increased scatter of the desorbed gas component values above 10 m^3/t, with the scatter being more pronounced in the case of Mine B. This scatter indicates that a greater percentage of total gas content is released during

early stage desorption in those samples with high total gas content. This trend was unexpected and should be further through extending the analysis to include additional Bulli seam and non-Bulli seam mines.

Further analysis of the initial gas desorption rate relative to the total gas content identified a maximum total gas content envelope which represents the maximum gas content for a given sample desorption rate.

ACKNOWLEDGEMENTS

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