OUTBURST THRESHOLD LIMITS – CURRENT RESEARCH OUTCOMES

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ABSTRACT: Since outburst threshold limits were imposed on Bulli seam mines in 1994 the occurrence of coal and gas outburst incidents have virtually been eliminated from the Australian coal industry. With the reduction in incidents and therefore hazard to the industry there has been a corresponding drop in research effort in this area. Some mines have in recent years reviewed and raised threshold limit values and non-Bulli seam mines accept the method of threshold limit value determination introduced by GeoGAS, based upon the DRI900 concept.

Detailed analysis of gas desorption data from a variety of Australian coal mines, representing different coal seams with variable gas content, gas composition, rank, type, structure, etc., has been undertaken and the results indicate significant relationships which impact the accepted method of outburst threshold determination.

The relationships are discussed and a new method of determining outburst threshold limits, applicable to non-Bulli seam mines is presented.

INTRODUCTION

During an analysis of Bulli seam coal sample gas content data, as part of broader research into the factors that impact the drainage of gas from coal seams, several relationships were identified. These factors offered new insight into the nature of gas emission from coal and the method of determining outburst thresholds for non-Bulli seam mines (Black *et al.*, 2009). From the analysis of 930 samples it was found that gas composition had little impact on the relative proportion of the three components of total gas content, Q1, Q2 and Q3, and the relationship between total gas content and Q3 gas desorption rate index (DRI) was also virtually independent of gas content. The observed relationship was considered potentially significant given the use of DRI for the determination of outburst threshold limits applicable to non-Bulli seam mines. Additional data was sought to extend the data analysis to include additional Bulli seam and non-Bulli seam mines. The gas database was increased to 4,785 samples from eight mines representing the north-west and southern Sydney basin and the Bowen basin. From the complete dataset, DRI data was available for 3,824 samples. Using the new data the analysis was repeated and extended to further investigate the relationship between DRI and total gas content, the impact of gas composition and the potential impact on the method used to determine outburst threshold limits applicable to non-Bulli seam mines.

BACKGROUND

An assessment of the work undertaken by Lama (1995) that led to the recommendation of gas content outburst threshold limit values applicable to the Bulli coal seam has been presented previously (Black *et al.*, 2009). The gas content values nominated as threshold limit values were considered appropriate as no recorded outburst had occurred below this level. The Department of Mineral Resources applied a further factor of safety to the threshold limits and prescribed the limits to all mines operating in the Bulli seam (Clarke, 1994).

Williams and Weissman (1995) proposed the use of gas desorption rate to determine applicable outburst threshold limit values (TLV's) for mines operating in coal seams other than the Bulli seam. Underpinning this desorption rate proposal was an apparent relationship to the Bulli seam TLV's previously proposed by Lama, shown in Figure 1. The DRI is determined by measuring the volume of gas emitted from a 200 gram coal sample after crushing for 30 seconds and relating the result to the total gas content of the sample (Williams, 1997). The figure shows the distribution of gas emission volume relative to the total gas content of each sample which suggests that a CO₂ rich sample liberates gas at a faster rate than a CH₄ rich sample of similar total gas content. The data suggests a linear relationship between total gas content (m³/t) and desorbed gas volume (ml per 200g sample crushed for 30 secs) which may be represented by the equation, $Y = \alpha$. *X*, where *Y* is total gas content (m³/t), *X* is desorbed gas volume (ml) and α is variable being 0.01 for >90% CH₄ and 0.0067 for >90% CO₂.

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Based on the outburst TLV's of 9 m³/t and 6 m³/t, which correspond to gas compositions of 100% CH₄ and 100% CO₂ respectively, a common desorbed gas volume of 900 ml is liberated. Williams and Weissman (1995) concluded that subject to knowing the relationship between gas emission volume during Q3 testing and the total gas content an applicable outburst TLV is the gas content value corresponding to an emitted gas volume of 900 ml (DRI900).



Figure 1 - GeoGAS desorption rate (DRI900) relative to Lama's outburst threshold limit values



In the years since the introduction of the TLV's two Bulli seam mines, Tahmoor and West Cliff, have completed formal reviews of the outburst risk which, following implementing additional safety controls such as increased gas drainage drilling density and regular core sample analysis, led to increasing the TLV's. The original Bulli seam TLV's and revised Tahmoor and West Cliff TLV's are shown in Figures 2A and 2B respectively (Black *et al.*, 2009). The changes have effectively replaced the need for outburst mining procedures (bomb squad) with increased drilling, more frequent core sampling and restrictions on daily rate of advance. Where a core sample gas analysis result falls below the WCC-Level1 or Tahmoor-Unrestricted lines (Figure 2B) mining may proceed without the need for further control or restriction. Should the gas content result from core sample analysis increase above the lower TLV, then additional controls are required dependent upon the conditions encountered. For example, in the case of Tahmoor Colliery the TLV is lower when mining in close proximity to geological structures than in unstructured conditions. It is noted that since increasing the TLV's and maintaining the required additional controls neither mine has incurred an outburst event.

RESULTS AND DISCUSSION

Data was sourced from eight separate coal mines representing a broad range of conditions and coal properties, such as variable gas content, gas composition, rank and coal type, permeability, etc. Of the eight mines, DRI data was available for six. Figure 3A presents the DRI and total gas content values for each of the 3,824 samples. The results are significant showing a strong relationship between the two values which is given by

Total Gas Content $(m^3/t) = 0.008. DRI (ml)$ (1)

Equation 1 holds for each of the six individual mine datasets which, given the range of conditions present at each location, suggests that the relationship between total gas content and DRI is independent of coal mine conditions, particularly gas composition. These results differ from those presented by Williams and Weissman (Figure 1), which indicate that for a given total gas content the DRI of a CO_2 rich sample is 50% greater than that of CH_4 rich sample.

The relationship between total gas content and the Q3 gas content component was also investigated. Figure 3B shows the relationship between total gas content and the estimated total volume of gas liberated during Q3 testing. The results indicate reasonable correlation but the relationship is not as strong as for DRI. The estimated gas volume liberated during Q3 testing is determined by multiplying the reported Q3 gas content (m^3/t i.e. ml/g) by the standard sub-sample mass which is 200 grams in the case of non-GeoGAS laboratories and GeoGAS laboratories to the end of 2007 and 150 grams for GeoGAS laboratories from the start of 2008 to present (Williams and Weissman, 1995, Williams, 1997 and Neilsen *pers. comm.*, 2009).

Considering the relationship between DRI and total Q3 gas volume similar values are expected, particularly in the case of low total gas content samples, where the residual gas content is not expected to be high and the bulk of the gas present within the sample will be released rapidly, within the first 30 seconds of crushing. Under normal circumstances the volume of gas liberated within the first 30 seconds of crushing (DRI) is not expected to exceed the total volume of gas released during the complete Q3 test.



Figure 3A – GeoGAS desorption rate index (DRI) relative to total gas content Figure 3B – Estimated Q3 desorbed gas volume relative to total gas content

Figures 4A and 4B show the distribution of the DRI:Q3 volume ratio relative to each of Q3 and total gas content. For the majority of data the DRI:Q3 volume ratio ranges between 50% and 200%, indicating that the DRI gas volume could be as little as half to as much as double the volume of gas estimated to have been liberated during the complete Q3 test. Some data fall outside this range and are considered likely to be the results of erroneous data. This result was not expected and various reasons for the difference were investigated.



Figure 4A – DRI:Q3 volume ratio relative to Q3 gas content

Figure 4B - DRI:Q3 volume ratio relative to total gas content

The possible use of non-standard coal sub-sample mass by the laboratory during Q3 testing would affect the estimated Q3 gas volume which in turn impacts the DRI:Q3 volume ratio, resulting in an over or under-statement of the estimated Q3 gas emission volume. However for the sub-sample mass to effect the ratio to this extent the mass would have to also range from half to double the laboratory standard.

The method used to determine DRI and the impact of gas content and gas emission rate of the coal sample was also considered to impact the DRI:Q3 volume ratio. Figure 5A shows the results of gas volume liberated during Q3 testing for three separate coal sample conditions, representing high, medium and low gas content with corresponding high, medium and low gas emission rates. As noted by Williams (1997), the total time that the coal sub-sample is crushed during Q3 testing is 7 minutes (540 seconds). This same test period has been used in the examples illustrated in Figure 5A.

Figure 5B shows the same three gas emission profiles as Figure 5A however the x axis has been changed to reflect the square root of elapsed time. A similar method is used in determining the Q1 lost gas component, as explained in AS3980:1999, which presents the emission curve in a more linear trend.

Although the details of the DRI are considered by GeoGAS to be proprietary (Neilsen *pers. comm.*, 2009) and the exact details of the calculation are confidential, equation 2 is considered by the authors to represent a credible method for determining DRI.

$$DRI (ml) = \frac{Q_{3i}}{t_i} t_f(2)$$

where: $t_i = 5.5 (\sqrt{30 \ secs})$

 $t_f = 23.2 (\sqrt{540 \text{ secs}} \text{ i.e. square root of 7 minute total test duration}); and$

 Q_{3i} = volume of gas liberated (ml) during the initial 30 seconds of crushing.





Figure 5B - Q3 gas content relative to square root of time and DRI relative to Q3 for samples of high, medium and low gas content and gas emission rate

Figure 5B illustrates the application of equation 2 in determining the DRI gas content/gas volume through extrapolating the gas volume (Q_{3i}) liberated at time $(t_i) = 5.5 \text{ secs} (\sqrt{30 \text{ secs}})$ out to time $(t_f) = 23.2 \text{ secs} (\sqrt{540 \text{ secs}})$, which represents the full 7 minute crushing period of the Q3 test (Williams, 1997).

As shown, the gas content and emission rate does affect the DRI value and the relative difference between the two values. In this example the DRI value (dashed line) relative to the Q3 gas volume (solid line) for the high, medium and low gas content/gas emission rate samples is 124%, 99% and 42%, respectively.

Alternatively, projecting a line of best fit through each of the three Q3 emissions curves and recording the total Q3 gas emission / gas content at the completion of the 7 minute test period may also provide a DRI value for each case. Using this method the difference between DRI and Q3 gas volume is reduced with the difference between the high, medium and low gas content/gas emission rate samples being 115%, 111% and 98%, respectively.

Figure 6 shows the impact of gas composition on the relationship between total gas content and DRI. Although the slope of the CO_2 dataset is adversely impacted by scatter there is little difference between the average of both the CH_4 and

 CO_2 datasets. In this case the results of testing and analysis of 3573 indicates that gas composition has little impact on the average relationship between DRI and total gas content.

The fact that several Bulli seam mines are now safely operating at threshold levels greater than those presented by Lama and prescribed to industry by the Department of Mineral Resources, combined with the results presented in Figure 6 may have a potentially significant impact upon the widely accepted method for determining outburst thresholds applicable to non-Bulli seam coal mines.

Figure 7A shows the relationship between DRI and total gas content, presented by Williams and Weissman (1995), for each of CH_4 and CO_2 whereby the outburst TLV's applicable at that time correspond to a DRI value of 900. Given the demonstrated ability of Bulli seam mines to safely operate at increased TLV's, e.g. 12 m³/t for CH_4 and 8 m³/t for CO_2 , a DRI value of 1200 may be a more suitable value for use in determining TLV's for non-Bulli seam mines.

This analysis of DRI and Q3 gas emission data from eight separate mines has however demonstrated that gas composition has little impact on the relationship between DRI and total gas content. Therefore a single line, shown in Figure 7B, represents the common relationship between DRI and total gas content which is seemingly applicable to all Australian coal mine conditions. Given this standard relationship an outburst threshold gas content value proven effective in the Bulli seam also applies to non-Bulli seam mines. For example if a TLV of 8 m³/t is proven for CO₂ rich Bulli seam conditions the DRI is 1000 and this gas content is applicable to all non-Bulli seam mines as a TLV for CO₂ rich conditions. Likewise if a TLV of 10 m³/t is proven for CH₄ rich Bulli seam conditions the DRI is 1200 and this gas content is applicable to all non-Bulli seam mines as a TLV for CH₄ rich conditions.



Figure 6 – Assessment of gas composition affects on DRI relative to total gas content of 3573 samples from six mines compared to Williams & Weissman (1995) data

It is understood that the gas content at the sites where outbursts occurred in the CH_4 rich conditions at both Central and North Goonyella Collieries in 2001 was above the current 12 m³/t Bulli seam CH_4 TLV. If confirmed this supports the proposed direct transferability of the Bulli seam TLVs. Assessment of the conditions present at outburst sites in other Queensland mines to confirm gas content and composition above the Bulli seam TLVs would further validate the proposed relationship.

Having analysed such a large data set it has been possible to better understand the relationship between DRI and total gas content, and the use of this relationship to determine appropriate outburst TLVs for non-Bulli seam mines. For the reasons discussed above the use of DRI900 as the basis for determining outburst TLVs is no longer considered valid, as the method produces overly conservative results. Therefore TLVs applicable to the Goonyella Middle seam and German Creek seam (Middlemount/Tieri) of 7.0 m³/t and 7.7 m³/t respectively (Williams, 2002) are considered to be lower than necessary and may be increased without creating an adverse outburst risk. Whilst in relatively benign conditions overly conservative TLVs have no impact upon mine operations. However with increased depth and gas content, the mine

operators may be forced into unnecessarily onerous gas content reduction programs in order to avoid production delays and potential loss of reserves.



Figure 7A: Impact of increased outburst TLV gas content values on DRI value used to determine TLV applicable to non-Bulli seam mines – based on Williams & Weissman (1995) proposal



1400

1600

1800

CONCLUSIONS

An extensive analysis of gas analysis data from some 4700 coal samples representing eight separate Australian coal mine conditions has been undertaken. The method of determining outburst threshold limit values applicable to non-Bulli seam mines, proposed by Williams and Weissman (1995) was reviewed. Based on recent Bulli seam experience it is suggested that the DRI value of 900 (DRI900) is no longer applicable and 1200 (DRI1200) may be a more appropriate value to use in non-Bulli seam outburst threshold limit determination.

Further analysis of the DRI and total gas content data has confirmed the existence of a standard relationship which appears to be independent of location and site conditions. This relationship provides the basis for an alternate theory for determining outburst TLV's applicable to Australian coal mine conditions. It is therefore suggested that a TLV applicable to the Bulli seam is also directly applicable to non-Bulli seam coal mine conditions.

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