TOWARDS A RELIABLE GAS EMISSION PREDICTION METHOD FOR AUSTRALIAN LONGWALL MINING

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ABSTRACT

Although there are sound principles used in the world recognised methods of gas emission prediction, results based on these methods applied to several Australian longwall extractions have yielded unacceptably high discrepancies. With the development of mining in new seams and at higher rates of extraction, the need has grown for a methodical approach to predicting emission levels specifically for local Australian mining conditions. Such an approach is developed from results of recorded emission readings during longwall mining at Appin and Pacific Collieries over the past 6 years.

INTRODUCTION

In order to maintain methane concentrations within the specified statutory levels, the mine planning engineer must ensure adequate air quantities are supplied to the workings and, if necessary, make provision for methane drainage systems. However, with the progressive deepening of mining and the introduction of longwall extraction to improve economic levels, gas emission problems have markedly increased. Considerable assistance to the solution of these problems could be achieved at the planning stage with the development of a reliable method of methane emission prediction specifically for Australian longwall mining conditions. In view of the fact that a significant proportion of mine operating costs is associated with its ventilation and gas drainage systems, it is essential that the requirements of these systems be calculated as accurately as possible at the planning stage.

AVAILABLE WORLD RECOGNISED METHODS

The techniques which are available for calculating the methane flow into coal mine workings have been under study by research organisations from Belgium, France, FGE, Poland, UK, USA and USSR. However, the underlying basic parameters which need to be determined for the application of each of the existing methods are essentially the same, namely:

1. the stratigraphy above and below the worked seam
2. the desorbable gas content of the worked coal seam and adjacent seams and strata
3. the zone of influence of and degree of gas emission from the roof and floor strata and from adjoining coal seams.

The accurate determination of the gas content of the sources of gas emission has a major role in the eventual precision of the gas emission predictions. A number of methods of gas content determination are available (Dunmore, 1979) but these are normally classified under two groups: direct method and indirect methods.

The direct method involves the development of a gas desorption - time curve from fresh coal lump samples collected from the working face; the volume of gas "lost" prior to sealing the sample in the desorption vessel is calculated by extrapolation of the initial linear part of the desorption - time curve and residual gas sorbed by the coal after direct desorption is determined by crushing in a ball mill.

Indirect methods make use of "scorption isotherms" - laboratory determined gas content/pressure curves - and the gas pressure in the coal seam which is measured in-situ. The difficulty with this method is that the gas pressure measurement requires a perfect seal (leakage-free) around the borehole. In addition, the hydraulic effect of strata water has a marked influence on the in-situ moisture content of the coal which in turn affects its methane sorption capacity.

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At Broken Hill Proprietary Co. Ltd and Australian Coal Industry Research Laboratories, a modified version of the USM direct method of gas content measurement is used. This method is still under review and is the basis for a new Australian Standard dealing with the gas content of coals. It is believed that this method is reliable, less costly and more practical for mine personnel. In addition, the modified method has also made it possible to gain valuable gas content information from coal borecores from surface exploration wells (Battino and Doyle, 1983) and from all the intersected seams by each borehole. The ability to gather this data is essential for accurate gas emission prediction ahead of a mining development.

The major difference between the various methods of methane emission prediction rests with the actual curve used to establish the contribution of gas emissions from sources above and below the workings. Curves showing the % contribution to gas emission by adjacent seams as a function of distance from the worked seam, according to various world authorities are presented in Fig. 1. The variations in these graphs are a direct result of the physical models on which each of these is based. Stoffken, Koppe and CERCIAR curves are based on residual gas measurements. The Barbara Experimental Mine method has been used in Poland after experimental tests against other methods and using practically developed relations between gasiness and coal production. Lidin, Guntner and Winter curves consider emission from rectangular blocks of strata above and below the workings, extending up in the roof and down in the floor to a level where the emission contribution is zero.

The Airey theory considers the solid coal in a seam as an assemblage of lumps of broken coal, the dimension of these lumps varying in accordance with their distance from the working face (Airey, 1971). As coal extraction proceeds, the increased load on the strata induces fractures which define the coal lumps. As the maximum stress in the front abutment zone is approached, an increase in induced fracturing results thereby reducing the lump size. The importance of Airey's theory is that the gas emission rate is dependent on the dimension of the coal lumps expressed as a function of the longwall advance rate and time.

![Graphs showing the % contribution to gas emission by adjacent seams as a function of distance from the worked seam.](image)

**Fig. 1** - Seam gas emission contribution (%) as a function of adjacent seams according to world authorities (after Dunmore, 1979).
In 1982, five of the above methods were used (Lunarzewski and Battino, 1983) to establish gas emission predictions during longwall extraction of the Elara block at Pacific Colliery. Whilst the gas emission levels experienced at the start of longwall mining were statutorily acceptable, large errors (more than 100%) in predicted emission levels were recorded as the extraction progressed. This necessitated immediate reassessment of both the gas volumes generated and the necessary air quantities for dilution to statutory limits. This demonstrated that the world recognised methods of gas emission predictions cannot be readily and adequately adapted to Australian longwall mining conditions, and that a new method is required for use in Australia, which is based on local mining geological and gassy characteristics.

CURRENT INVESTIGATIONS

(a) Basis for Analysis

The approach taken for the study and development of gas emission prediction for Australian longwall mining conditions has been to record and evaluate data of gas emission levels, production rates and barometric changes in two separate mining areas of the Sydney Basin. These are the Illawarra Region and the Newcastle Coalfield.

The geological characteristics of these two areas are distinctly different. In the Illawarra Region, the worked Bulli seam is at approximately 500 m depth and gas contributions are, in the main, only from underlying seams. In the Newcastle Coalfield, gas sources include the worked seams, at approximately 300 m depth, as well as coalbeds predominantly in the roof and some in the floor (Fig. 2). Results have shown that the highest contribution of the gas emissions has occurred from the adjacent seams. These distinctive features have been responsible for both the levels of gas emissions recorded and the ultimate method of gas emission prediction selected (Lunarzewski, 1987).

The mines which have been selected to typify the two areas under consideration are Appin and Pacific Collieries. Appin Colliery has been extracting Bulli seam coal using the retreating longwall system since 1970. The 3 m worked seam has a gas content of 15 to 15 cu m/tonne, and a gas composition of 96% CH₄. Peak daily production levels in excess of 15 000 tonnes from one operating longwall have been recorded. Total absolute gassiness levels from longwall extraction have been of the order of 1 500 1/s.

During longwall extraction at both these mines, regular monitoring of gas data was undertaken. The work included gas balance surveys, gas drainage measurements, seam gas content testing, coal production records and barometric changes (Lunarzewski, Kerkhoff and Clark, 1985-1987). The most significant analysis study dealt with the relationship between total absolute gassiness, time and coal production levels. The total absolute gassiness was calculated as the sum of the ventilation...
gassiness and the methane volumes extracted by the gas drainage systems on the basis of a 7 day cycle. The gassiness on any given day was assumed to pertain to the coal production of the previous day. The basis for the weekly cycle analysis in absolute gassiness has been selected because of the established trend in changes of gas emission with time.

(b) Gas emission results

In order to typify the variations in gas emission levels with longwall production and time in both areas under study, the absolute total gassiness has been plotted as a function of coal output for several operating longwalls at Pacific and Appin Collieries. Although analyses were undertaken on all available results, the graphs selected for presentation herein were those relating to the extraction of longwalls Nos 9 and 14 at Appin Colliery and Longwall No. 5 at Pacific Colliery. The specific reasons for which these longwall results were chosen are

1. the locations of the Appin No. 9 and Pacific No. 5 Longwall blocks are such that they both have established caving characteristics after the extraction of a number of previous adjacent longwalls,

2. changes in weekly coal production from these 2 blocks were not dramatic and enabled meaningful analyses to be conducted between the 2 areas,

3. both longwalls were extracted under the protection of gas drainage systems, and

4. the No. 14 Longwall block emission results have been included to exemplify the gassy conditions during extraction of a first longwall block in a new area of the mine.

The graphs showing the variation in absolute gassiness with coal production and time for Appin Longwall No. 9 and Pacific Longwall No. 5 are presented in Figs 3 and 4 respectively.

Fig. 3 - Variation of absolute gassiness with coal production and time for Appin Longwall No. 9

Fig. 4 - Absolute gassiness - coal production curve for Pacific Longwall No. 5

The specific emission ($m^3 CH_4$/tonne of coal mined) was plotted as a function of weekly coal production for Appin Longwalls Nos 9 and 14 and Pacific Longwall No. 5. These are shown in Figs 5, 6 and 7 respectively.
Fig. 5 - Specific gas emission/weekly production curve for Appin Longwall No. 9

Fig. 6 - Specific gas emission/weekly production curve for Appin Longwall No. 14

Fig. 7 - Specific gas emission/weekly production curve for Pacific Longwall No. 5

The effect of variations in barometric pressure changes on the recorded methane concentrations in longwall returns during the extraction of the Pacific No. 5 longwall block is graphically presented in Fig. 8.

Fig. 8 - Variations in methane levels with barometric pressure at Pacific Longwall No. 5

**ANALYSIS OF RESULTS**

(a) Absolute gassiness

Examination of the results shown in Figs 3 and 4 indicate a very close correlation between total absolute gassiness, coal output and time. In both cases, there is a time delay in the expected rise in the level of total absolute gassiness at the start of each longwall extraction. This is attributed to the time required for the complete formation of the goaf area. Subsequent to this initial behaviour in
the total gassiness curve, the recorded gas emission levels appear to stabilise within a certain range of values; this range depends on the local stratigraphy and is proportional to the gas content of the seams contributing to the gassiness experienced during mining.

The above observations are specifically demonstrated by the range of values plotted in Figs 3 and 4. For the Appin Longwall No. 9 extraction, where the seam gas content is of the order of 15 cu. m/tonne, the average level of total absolute gassiness was 1.5 million m$^3$ of CH$_4$. For the Pacific Longwall No. 5 extraction, where the seam gas content is of the order of 5 cu. m/tonne, the mean total gassiness level was approximately 500 000 cu. m CH$_4$. In addition to the seam gas content factor, other elements such as coal output, production delays, strata behaviour and support characteristics and barometric changes contribute to the varying levels of gas emissions.

In the final section of the gassiness - time curve, there is a distinct increase in gas emission levels over those experienced in the earlier phases. This is explained in terms of the increasing strata relaxation effects and the accompanying gas volumes released cumulatively from the progressive goaf formation. The gas emission levels encountered during the extraction of this portion of the longwall are generally the highest and could potentially create very hazardous conditions. Any gas emission predictions should therefore aim to overcome the highest level of gassiness which could be experienced during the longwall extraction under study.

(b) Specific gas emission

The specific gas emission is a parameter which has been used world-wide as a guide for relating the gas volumes released per tonne of coal mined for a range of longwall coal production levels. As the total gassiness of a longwall area is a finite quantity, the effect of coal extraction is such that gas levels emitted per tonne mined progressively and markedly decrease as production levels increase.

With reference to Figs 5, 6 and 7, the geometry of the specific emission/weekly production curves is a logarithmic function which asymptotes at very high production levels. The value of this asymptote is 35 m$^3$ CH$_4$/tonne for the Appin Longwall No. 9, 20 m$^3$ CH$_4$/tonne for the Appin Longwall No. 14 and 17 m$^3$ CH$_4$/tonne for the Pacific No. 5 Longwall block. The magnitudes of these values can be interpreted in terms of the relative location of longwall extraction and seam gas content of the working environment.

The upper region of the curves at low weekly longwall production levels, however, requires more careful interpretation. By definition of the logarithmic function, this curve would reach an upper limit which is totally unrealistic. For practical purposes, it would be advisable to restrict the lower limit of the production range to a level which permits interpretation. On the basis of the results obtained for Appin and Pacific Collieries, this lower production limit was selected at 10 000 and 5 000 tonnes/week respectively.

(c) Effects of barometric changes

During the extraction of the No. 5 Longwall block at Pacific Colliery, the effect of variations in barometric pressure over the methane concentrations in the longwall returns was examined and is shown graphically in Fig. 8. As expected the typical pattern encountered was characterised by rising CH$_4$ levels during periods of pressure drops, and for several longwalls, this effect was observed to contribute up to 15% in total absolute gassiness changes. However, attention is drawn to the fact that the methane level variations were not uniquely attributable to the barometric changes but to simultaneous effects of coal production rates, strata behaviour and ventilation conditions.

PROPOSED CURRENT PRACTICE FOR EMISSION PRODUCTION

Experience with gas emission predictions for several longwall extractions in different districts in Australia has led to the conclusion that there is no direct and readily applicable method already developed overseas which will yield the required result. Long term investigations have been undertaken by Dr. Lunarszewski to develop a technique specifically suitable for Australian conditions. Extensive analyses and adjustments of the results yielded the following findings:
For mining areas where the floor gas emissions are the predominant contributors, the strata relaxation behaviour as stipulated by the curves developed by Koppe (Fig. 1) appears to be most compatible. In cases where roof gas sources contribute significantly to the total absolute gassiness, the theory of strata relaxation based on the triangular geometry developed by Lehmann and used by Flugge (Fig. 1) is most adaptable.

These two theories were tested in a number of gas emission prediction studies in association with a newly established angle of caving of 65°-70° in the Newcastle Coalfield (Lunarzewski and Larkeings, 1986) and close correlation was achieved with actually measured emission rates. A similar approach was used to predict gas emission levels for longwall extractions in the Illawarra region (Battino, 1986-7) and the results to date are satisfactory.

The relation between total absolute gassiness (Q) and longwall production (P) used for these predictions was:

\[ Q = a(P^2 + b), \]

where a and b are coefficients dependent on local gas conditions; and

\[ Q = \text{total gassiness, } m^3/\text{week} \]

\[ P = \text{production level which is a function of the total weekly production, tonne/week.} \]

The values of a, b and P have been statistically determined from data obtained during operating longwall extraction.

CONCLUSIONS

The continuing acquisition of gas emission data and statistical analyses relating to several longwall operations in Australia have made it possible to achieve a much improved level of understanding when predicting the total absolute gassiness during a longwall extraction. Having established the deficiencies of the overseas methods in achieving reliable, reproducible and accurate results in Australia, a new approach based on the development of a technology specifically applicable to the Australian mining, geological and gassy environment was adopted.

This technology was established after careful analysis and fine tuning of available data recorded prior, during and subsequent to longwall extraction. Consideration of the major contributing factors to the total absolute gassiness has led to this proposed method of dealing with the forecasting of gas emission levels in Australia. In particular, the magnitude of the longwall caving angle was determined as 65° to 70° together with the establishing of the pattern of the total absolute gassiness - longwall coal production curve. Although this approach is considered appropriate for present face technology, it is envisaged that the progressive improvement in longwall mining systems will need simultaneous enhancement in the technique of gas emission prediction.

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REFERENCES


