PREDICTION OF REQUIRED VENTILATION LEVELS FOR LONGWALL MINING IN AUSTRALIAN GASSY COAL MINES

by

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ABSTRACT

The high gas emissions associated with :oal extraction at some Australian collieries ave provided a need to investigate the methods sed to predict these gas levels and the vent- lation requirements for gas dilution. It is enerally accepted that the introduction of ongwall extraction in particular is associated ith complex ventilation planning problems. hese problems are made much more severe when he colliery introducing longwalls is already acing high gas emissions even during the evelopment stages. A forecast of likely gas missions during the longwall mining process ndicated possible ventilation problems in aintaining the necessary ventilation levels o satisfy the statutory gas limitations for arious production rates.

Although there are sound principles used n world recognised methods of gas emission rediction a new approach developed from the indings of the Barbara Experimental Mine in oland appears most suitable for Australian onditions. This has been applied to an ustralian colliery preparing for longwall ining using statistical methods for air quantity on the basis of the results of gas content measurements. A better understanding of the ventilation requirements for all phases of longwall extraction, particularly goaf problems, has been achieved.

INTRODUCTION

The extraction of coal from seams at greater depth has presented the planning engineer with numerous problems. Of those, one of the most hazardous is the likely rate of gas emissions into the proposed workings so that provision for adequate ventilation and gas drainage can be made. At the same time, because there is a wide variation in the cost of planning, developing and equipping a gassy and non-gassy coal mine, it is essential that gas investigations be initiated as early as possible through the geological reconnaissance of the seams and intervening strata. Although it is recognised that initial gas content results are not always very accurate, they generally provide a reasonable indication of the gassiness levels required for the planning phase of the colliery. As the development of the mine progresses, it is recommendable to continue these gas investigations so that a more precise identification of gas problems be obtained, especially in the case where longwall mining is planned.

The prediction of the maximum gas emissions from proposed workings is generally obtained from the application of one or more of the world-wide recognised methods. The choice of method used depends on the prevailing local and geological

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ditions and the type of mining system adopt-

The techniques by which the gas quantities eased can be estimated to provide the nec- ary primary information for calculating both emission rates and ventilation requirements discussed.

In particular, the gassiness of coal ex- ction workings is calculated by the "simpli- d mining practice calculation method". This od takes into account only the gas liberated the mined coal and gas released into the wall workings through the fissures and ks which arise during mining from adjoining s subsequent to their destressing. Other ces of gas emission such as those arising the longwall face area and the ribsides of headings were not included in the calculat- because their relative quantities are idered to be small in comparison with the absolute gassiness. For various uction levels, an empirical determined tion between methane make and output is . For the purpose of assessing the applic- ity of this relation to Australian coal ng conditions and determining the approp- e ventilation levels, Macquarie Colliery, a pit in the process of introducing longwall ng has been chosen as a case study arzewski, Battino, 1982).

SYSTEMATIC STAGES OF GAS INVESTIGATIONS

During the exploration stage, very benefic- data can be gathered from surface boreholes led down to the working and adjoining seams. is stage the gas investigations should ise the determination of in-seam gas sures, working and adjoining seam gas nts as well as volatile matter, ash and ure contents of all relevant coal seam. e basis of these results, a classification e made of the gas conditions likely to be met at the start of the development phase and the appropriate mining system can be ascertained.

During the development stage more accurate data is necessary to verify the earlier results of gas investigations especially those pertaining to the working seam. These initial results are based on the testing of samples obtained from only a small number of exploration boreholes situated in various gas graphical locations within the colliery lease. In the majority of cases, wide variations in local gas characteristics are found.

These should be identified at regular intervals during the drivage of headings by measuring gas content from fresh face coal samples or by other methods. This will allow isolines of methane content to be established over the whole colliery holding and provide the basis for future planning requirements. Because the development phase in the Australian coal mining systems also involves coal production and hence gas liberation, the regular recording of ventilation readings and gas concentrations during the early mining stages yields a very useful guide to the eventual gas make during pillar or longwall extraction. In particular, variations in main fan suction, air quantities and changes in barometric pressure should be precisely monitored and their interdependence with the recorded gas emission should be established. From the collection of all results available during these two stages of gas investigations, world recognised methods of gas emission prediction can be applied and the appropriate ventilation levels required for gas dilution obtained. During the extraction stage, regular gas balances should be conducted in specific areas in order to:

(a) monitor local gas emissions in mine workings,
(b) verify the predicted levels of gas emissions, and
(c) adjust the predicted emissions for the

future mine workings.

CRITERIA FOR USE OF GAS DRAINAGE

The number of Australian gassy collieries which have introduced gas drainage systems to date have not produced sufficient data to develop a set of numerical criteria which can be used to resolve the need for gas drainage. For instance, in Poland, on the basis of statistical data and for local conditions, degasification systems are applied for longwall mining systems with single heading development when the precalculated emission (absolute gassiness) surpassed 5.0 m^3/min in longwall workings or 2.5 m^3/min for a single heading (Lunarzewski, 1982).

At this stage of Australian coal mining, it is necessary to satisfy two basic conditions when contemplating the application of methane drainage:

(a) the predicted ventilation quantities available to dilute the gas emission rates to permissible levels are not adequate, either for physical or economic reasons, and
(b) the gas content and permeability of the coal seam or seams to be drained are sufficiently high as to permit effective drainage to take place.

For some gassy seams in Australian collieries the relevant macropermeability and measured desorbable gas values were determined and are shown in Table 1. For the specific purpose of establishing the criteria which influences the viability of a gas drainage system in gassy Australian coal mines it is advisable to determine statistically these relative gas macropermeability values of the working seam coal and to use them on a comparative basis for arriving at a decision. Other valuable information could be obtained from test holes drilled in the direction of the most likely source of gas prior to the start of longwall mining. The monitoring from these holes of such data as gas flowrates (both natural and with suction) and compositions especially at the moment where the longwall face passes the alignments of the holes is of critical importance.

ESTABLISHED METHODS OF GAS EMISSION PREDICTION

There are several world recognised methods of forecasting gas emissions into mine workings. The most widely used are the graphical techniques of Schulz, Stuffken, Winter and Patteisky, the mining statistical method, the procedure of the Soviet A.A. Skoczynski Mining Institute, the Coal European Committee method and the method developed at the Barbara Experimental Mine in Poland (Frycz, Kozlowski, 1979), (Dunmore, Creedy, 1980).

The Winter, Schulz, Stuffken and European Coal Committee methods have similar principles based on empirical graphs and rely on the relation between the percentage volatile matter and the methane content of coal seams (see Figure 1). The Barbara Experimental Mine technique uses the equation derived from statistical data obtained from direct underground investigations over long term periods. The major difference between all these methods is basically the effect of roof and floor relaxation over the rate of degassing (Figure 2). Furthermore, whereas the other methods use the direct distance between the working seam and adjacent seams, the Barbara Experimental Mine and Schulz methods use a stipulated distance which is relative to the longwall face length or height (Tarnowski, 1974).

Reduced distance in the roof for Schulz's method:

$$K = \frac{200d}{L}$$

TABLE 1

GAS MACROPERMEABILITY AND DESORBABLE GAS VALUES FOR SOME AUSTRALIAN GASSY SEAMS

Seam	Colliery	Depth (m)	Desorbable Gas (m^3/t)	Macropermeability using CH_4 (darcy x 10^{-3})	Macropermeability using CO_2 (darcy x 10^{-3})
Bulli	Appin	550	13.8	180	100
Bulli	Metropolitan	450	7.5	90	100
Bulli	Bulli	300	6.0	100	-
Gemini	Leichhardt	380	11.5	8	10
Borehole	John Darling	280	-	9	12
Wongawilli	Wongawilli	300	-	185	175
Castor	Cook	250	-	190	510
Dudley	Macquarie	280	3.0	50	-
Bulli	West Cliff	470	13.0	10 - 100	-

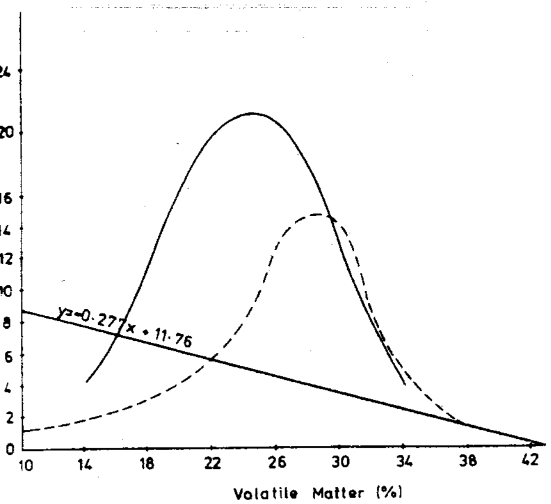

Fig. 1. Graph showing relation between volatile matter and gas content according to methods of Stuffken, Winter and Barbara Experimental Mine.

Stipulated distance for Barbara Experimental Mine Method:

$$K' = \frac{l}{h}$$

where
- d = distance of the overlying seam from the mined seam, (m)
- L = length of planned longwall, (m)
- l = real distance between the seams, (m)
- h = height of longwall in the mined seam multiplied by coefficient of the compressibility of stowage (for caving, coefficient = 1)

In all cases however, the gassiness of the mined seam was calculated from the following formula:

$$Q_T = W_M + Q_1 + Q_2 \; m^3CH_4/t \qquad (1)$$

where
- Q_T = total methane emission, m^3CH_4/t
- W_M = methane content in mined seam, m^3CH_4/t a.f.d.

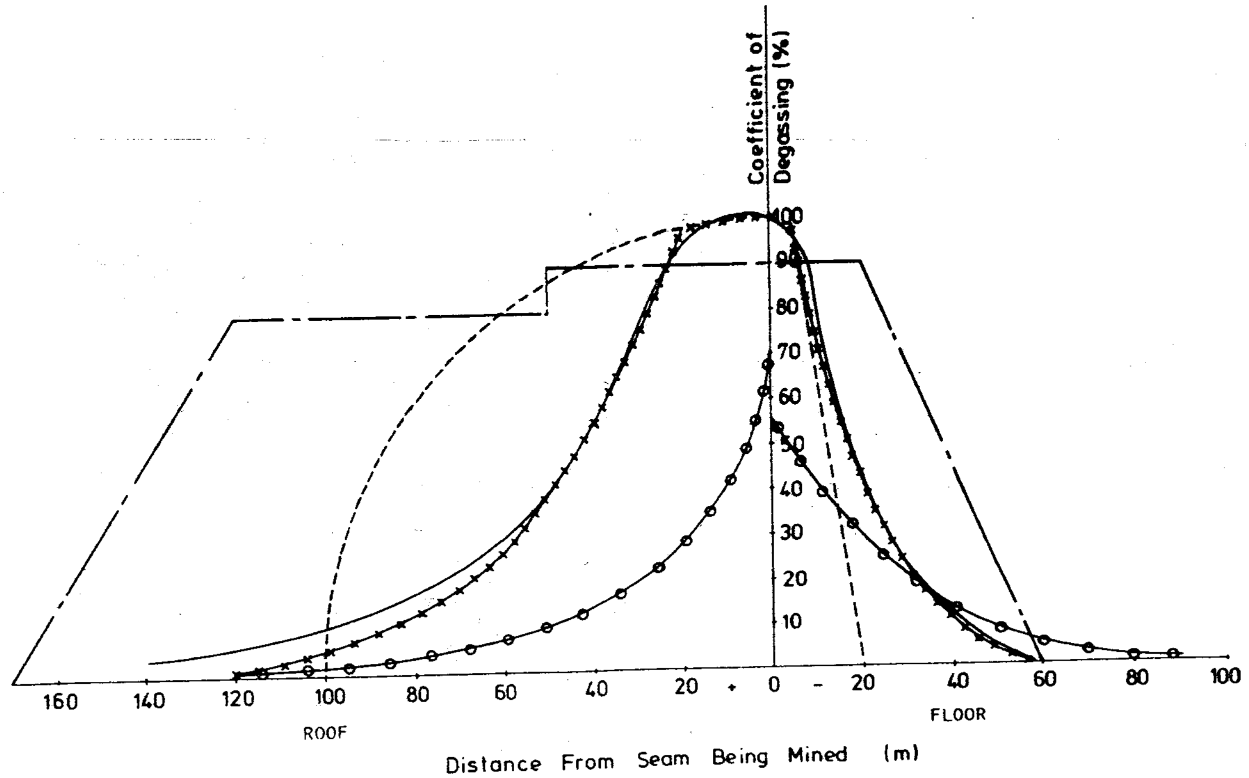

Fig. 2. Graph showing effects of roof and roof relaxation on the rate of degassing according to Shultz, Winter, Stuffken, Barbara Experimental Mine and Europe Coal Committee

Q_1 = methane emission from overlying seams, m^3CH_4/t

Q_2 = methane emission from underlying seams, m^3CH_4/t

The parameters Q_1 and Q_2 are the amounts of methane coming from the adjoining seams per ton output in the mined seam and are calculated from the equation:

$$Q_{1,2} = \Sigma \frac{m_A \times W_A \times n_A}{100\ m_M} \quad m^3CH_4/t \qquad (2)$$

where m_A = thickness of investigated adjacent seams (m)

W_A = methane content of investigated adjacent seams (m^3/t a.f.d.)

n_A = degassing coefficient of investigated adjacent seams (%)

m_M = thickness of mined seams (m)

The accuracy of the calculated values for Q_1 and Q_2 depends significantly on the degree of precision with which the geological data was gathered and on the number of borehole logs available for analysis in the vicinity of the proposed longwall area.

CHOOSING THE MOST SUITABLE METHOD

On the basis of the values of Q_T determined from equation (1) for each borehole characteristic, the rates of gas emission can be computed for a maximum level of production of 500 t/day for all methods. This peak level of production has been chosen because, in this low range, the gas emission varied linearly with production. For output in excess of 500 t/day, the absolute gassiness increases with output growth but this increase is proportional to the square root of output (see Figure 3). The empirical formula relating these two parameters is one derived from long term investigations at the Barbara Experimental mine in Poland (Myszor, 1974). This equation has the general form:

$$Q_p = k\,(\sqrt{P} + C)\ m^3/min \qquad (3)$$

where Q_p = total methane emission rate (m^3/min)
P = production rate (t/day)
k, C = coefficients of proportionality dependent on local gas, geological and mining conditions

On the basis of the most accurate local geological information from boreholes situated as close as possible to the proposed longwall area, calculations can be carried out to determine the appropriate values of Q_1 and Q_2.

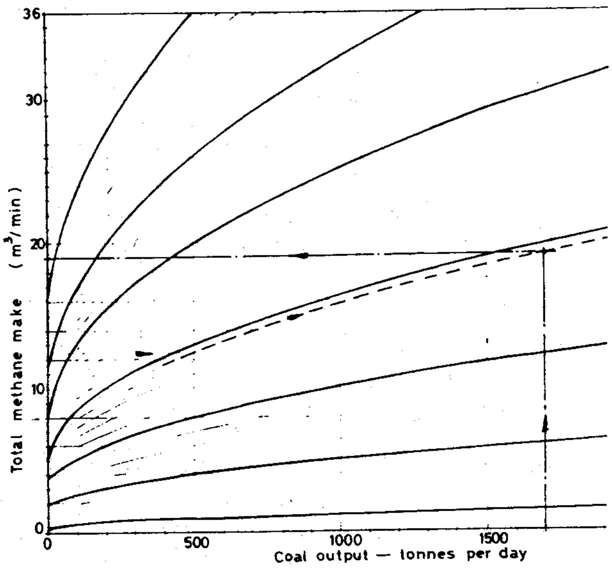

Fig. 3. Relation between coal output and total methane make (longwalls with caving)

Another criterion which is commonly used to arrive at the most applicable prediction method is the long term monitoring of gas make (absolute gassiness) for the whole of the colliery workings as well as for individual panels. This should be carried out as early as possible during development. First stage criterion can be chosen by comparison of the results from equation (1) for various methods and absolute gassiness (gas make) for developments and the whole of the colliery.

The second stage (during longwall mining) is as an examination of the accuracy of predicted data and statistical material and should be collected for more precise determination of the most suitable method.

APPLICATION OF CHOSEN METHOD TO A SPECIFIC TEST CASE - MACQUARIE COLLIERY

As the deepest of the BHP Collieries in the Newcastle region and having already faced certain specific ventilation problems associated mainly with gassy and geological conditions, Macquarie Colliery was chosen as a test case for gas emission prediction. The colliery, which has been working the Dudley Seam of average thickness 2.1 m, at a depth of approximately 280 m, has been developing its first longwall block as shown in Figure 4. The geology of the strata in the immediate area of Longwall 1 is reasonably complex and variable with five coal seams in the first 100 m directly above the working seam and two other coal seams underlying it. A section was prepared from geological borelog data to illustrate the stratigraphic variations in the proximity of the No. 1 longwall block (see Figure 5). In turn, the location of these boreholes relative to the longwall have been noted in Figure 4. With such a large number of coal seams lying in the close proximity of the working seam and on the basis of gas make results achieved during panel developments,

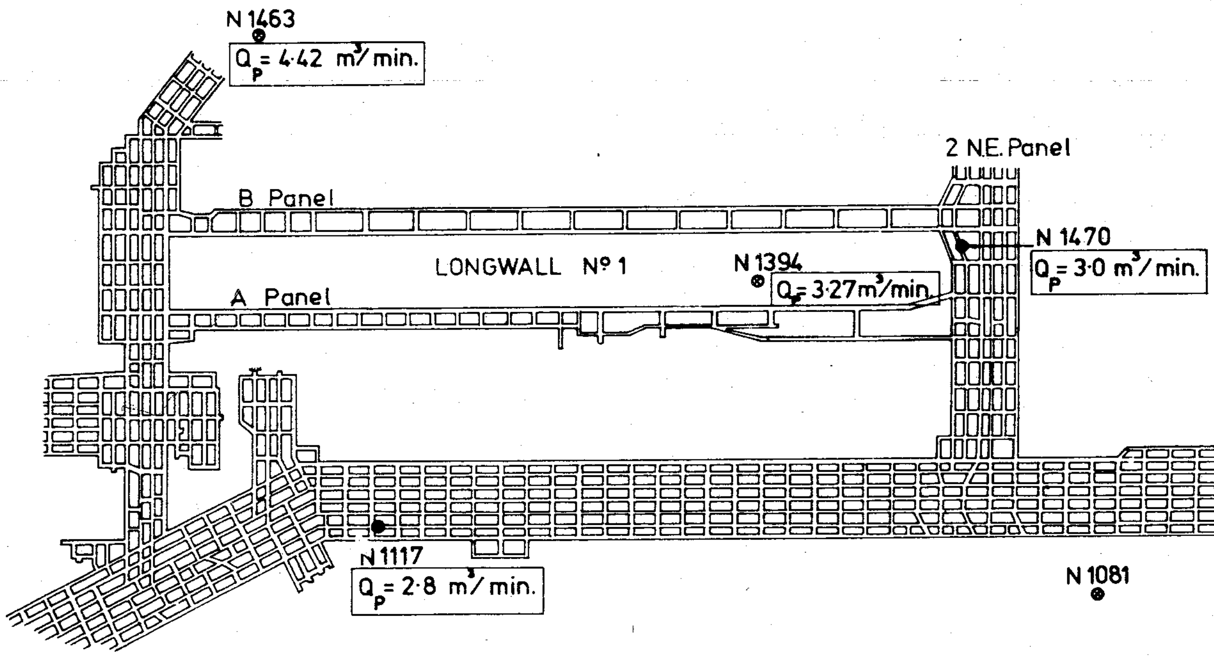

Fig. 4. Plan showing No. 1 Longwall Block at Macquarie Colliery together with the positions of five analysed geological bores in the vicinity of the block. The predicted gas emissions (Q_p) shown were calculated for a coal output of 500 tonnes/day.

it was reasonable to expect a fairly significant contribution of gas emissions from these seams into the working seam especially as strata relaxation took place during longwall mining.

In order to determine the likely methane emission and accumulation during the mining of the No. 1 longwall block, a fairly involved data gathering program was implemented. A study was made of all appropriate information available to date which included detailed plans of the workings around the No. 1 longwall block, geological sections in the immediate vicinity of the proposed longwall extraction area, chemical analyses from working and adjacent coal seams, ventilation and gas make measurements in working panels as well as from the upcast shaft and gas content and macropermeability calculations at specific points of the No. 1 longwall. More specifically, in order to obtain the most up-to-date information on certain measurements, the gas make was measured and compared for production and idle periods during the 4 calendar months immediately preceding the mining of the No. 1 longwall. These measurements indicated that the gas emission rate for an average pit production of 1500 t/day was approximately 3 m^3/min greater than for idle periods. On a panel level, it was found that for an average production of 350 t/day, the gas emission rate was in the vicinity of 4.3 m^3/min.

As the calculations of prediction relied significantly on local geological information, relevant parameters were obtained from the

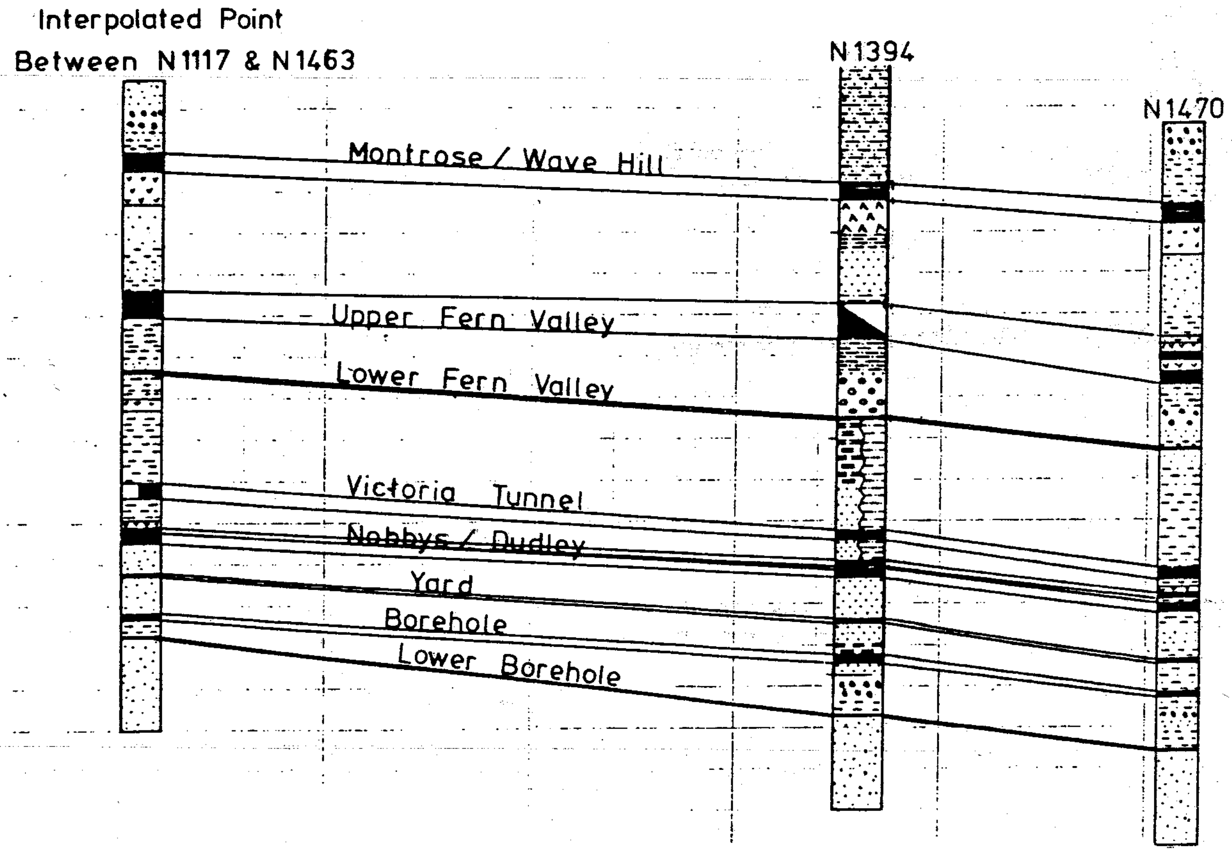

Fig. 5. Geological borelog section in the vicinity of the No.1 Longwall Block, Macquarie Colliery

closest surface boreholes to the No. 1 longwall block (Figure 5). From five such boreholes, the two most suitable were found to be N1463 and N1394. For these two boreholes, five different world recognised methods of prediction were applied to estimate the methane emissions during longwall mining (see Table 2). The results indicate that the emission rates forecast by the methods of Winter, Schulz and Stuffken are very similar (within 5% difference). However, the emission rates calculated by the Barbara Experimental Mine and European Coal Committee methods are markedly higher and differ by up to 35%. These variations apply to both geological boreholes chosen. In order to plan for the worst situation, it has been decided to work with the emission rates obtained from borehole N1463. Furthermore, as the first 3 methods of prediction yielded very similar results, and the other two methods likewise, the mean gas emission rates have been computed on the basis of only two groups (refer to Table 2). The predicted variations in methane emissions with different production levels computed for the first group of methods used are presented in Table 3. It can be clearly seen that even using predictive methods with totally different bases, the calculated gas emission rates at 10,000 tons/day are still within a 25% variations.

It should be pointed out that all the above calculations were made on the assumption that Macquarie Colliery will continue to develop 2 panels of 2 headings and 1 panel of 6 headings with an average daily production of 1500 tons

TABLE 2

Methane Emission Rates Based on 500 t/day Production at Macquarie Colliery for Different Methods of Prediction

Borehole	N1463		N1394	
Method of Prediction	Methane emission rates in m^3/min			
	On basis of individual method	On basis of group of methods	On basis of individual method	On basis of group of methods
Winter	4.42	4.34	3.27	3.31
Schulz	4.20		3.45	
Stuffken	4.38		3.22	
Barbara Experimental Mine	5.25	6.00	4.06	4.40
Europe Coal Committee	6.70		4.73	

even after the introduction of longwall mining.

The results presented in Table 3 are divided in such a way as to predict the required ventilation levels separately for longwall mining and for the whole mine workings. The dilution levels of 1.25% to 2.25% CH_4 were computed on the basis of permissible methane percentages in the ventilation current while the 0.5% CH_4 values were included for upcast shaft ventilation requirements. All given values in the table were calculated for the worst gas conditions associated with mining; for instance, the irregularity coefficients of 1.5 and 1.65, were adopted assuming the greatest variations in barometric pressure and mining conditions. It is expected however, that these ventilation levels will not always be required.

Examination of the gas emission rates obtained by the five different predicting methods reveals that variations of 5 to 40% can be expected. The European Coal Committee method alone, is known to have variations of 50 to 100%. However, based on the limited data available to date, the calculations presented in Table 3 are considered reasonably reliable for Macquarie Colliery conditions.

The gas emission rates and ventilation requirements stipulated are believed to be applicable for the start of the No. 1 Longwall block. As the extraction of the block progresses, investigations show that there should be a decrease of approximately 25% in the gas emission levels. This estimation is based on the absolute gassiness levels predicted for different locations around the No. 1 longwall block (see Figure 5).

TABLE 3

Prediction of Gas Emission Levels and Ventilation Requirements for Different Outputs at Macquarie Colliery for methods of Winter, Schulz and Stuffken

	LONGWALL MINING			ALL UNDERGROUND WORKINGS			
Coal Output (tonnes/day)	Gas Emission Calculated (m^3/min)	Gas Emission Including Irregularity Co-efficient* (m^3/min)	Air Quantity Necessary for Dilution for 1.25% CH_4 (m^3/sec)	Total Gas Emission Calculated (m^3/min)***	Total Gas Emission Including Irregularity Coeff.(m^3/min)	Air Quantity Required For Dilution to 2.25% CH_4 (m^3/sec)	Air Quantity Required For Dilution to 0.5% CH_4 (m^3/sec)
1	1	3=2 x coeff.	4=3 x coeff.	5=2 + coeff.	6=5 x coeff.	7=6 x coeff.	8=6 x coeff.
1000	5.45	8.18	10.91	49.45	81.59	60.44	271.97
2000	7.02	10.53	14.04	51.45	84.89	62.88	282.97
3000	8.23	12.35	16.47	52.23	86.18	63.84	287.27
4000	9.25	13.88	18.51	53.25	87.86	65.08	292.87
5000	10.15	15.23	20.31	54.15	89.35	66.19	297.84
6000	10.96	16.44	21.92	54.96	54.96	67.17	302.27
7000	11.70	17.55	23.40	55.70	91.91	68.08	306.37
8000	12.40	18.60	27.74	56.40	93.06	68.93	310.20
9000	13.05	19.58	26.93	57.05	94.13	69.73	313.77
10000	13.67	20.51	27.28	57.67	95.16	70.49	317.20

* Irregularity Coefficient = 1.5 due to changes in barometric pressure and mining conditions for longwall

** Irregularity Coefficient = 1.65 due to changes in barometric pressure and mining conditions for whole of pit

*** These values include longwall gas emission and all developing panels gas emission (ribside and extraction) for development, 1500 t/d average production was assumed and average methane emission 44 m^3/min

These levels of gassiness indicate that gas emission rates rise for current workings from 2.8 m^3/min to 4.4 m^3/min in a Northerly direction and decrease from 4.4 to 3.0 m^3/min in the direction of the No. 1 longwall extraction. It should be emphasised that these results were based on the data from only four available boreholes in the vicinity of the longwall block. For more accurate predictions, as many boreholes as possible should be used and much more numerous and frequent local observations should be made in order to define the specific METHANE ISOLINES in the required region of investigation as well as for future longwall emission prediction.

GAS PROBLEMS IN LONGWALL GOAVES

The emission of gas into longwall goaves from adjacent seams in the roof and/or floor of the working seam is a slow and long-term process which depends on geological, gassy and mining conditions. This process can take only several months or as much as a few years. Over this entire period, however, the goaf gas provides a continuous source of emission which increases significantly with the number of extracted longwall blocks. The major problem to date has been the necessity to maintain the gas composition at any point in the goaf area within safety limits. In general practice around the world, it is established that the goaf gas composition has to be greater than 30% CH_4.

In Australia, where the mining system used incorporates multiple heading development, bleeder systems and high main fan suction, a specific sealing system should be adopted especially in gate roads connecting to the main intake and return roadways, to minimise goaf gas leakage. In the cutthroughs on the maingate and tailgate sides of longwall blocks prepared for extraction, marked improvements in sealing can also be achieved.

Experience with European coal mining conditions, has shown that the most appropriate method of sealing for gas in goaves has been the erection of double brick stoppings with sand dust and cement filling in the intermediate space or with pressure chambers (see Figure 6). One significant feature of this type of stopping is the erection of the brickwalls into the roof, floor and ribsides by insets to the depth of solid strata. This effective method of sealing also permits the introduction of gas drainage from behind the stoppings, if required (Linton, 1977). Furthermore, effective sealing is of great importance in the control and regulation of goaf gas as well as in the verification of the predicted gas emission during longwall mining.

CONCLUSIONS

The planning and development of a gassy coal mine depends substantially on the recognition of geological and gassy conditions. The prediction of gas emission levels and required air quantities for dilution to permissible limits should be started as early as possible in the

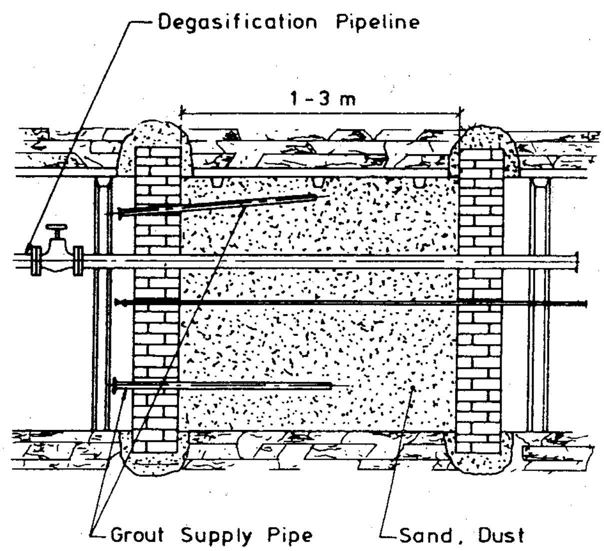

Fig. 6. Typical double stopping used in gassy mines operating Longwall systems

life of the colliery. The accuracy of the predictions depends equally on the precision of geological reconnaissance, the choice of the most appropriate method of prediction and the number and magnitude of the available gas statistical data. The initial predictions of gas emissions during the planning phase should be adjusted and corrected during the development and subsequently, the extraction stages.

Although world-wide recognised methods of gas emission prediction can be adapted to Australian longwall mining conditions, the chosen method found to be most appropriate can be further refined by careful analysis of the available data collected prior to, during and after extraction. For initial gas emission predictions and for collieries with outputs in excess of 500 tonnes/day, it is proposed that the equation relating gas emission to the square roof of output be used. It appears to be the most appropriate relation for the test case studied although confirmation of the predicted gas emission levels has yet to be achieved.

In order to maintain the goaf gas concentration within safety limits, it is strongly recommended to erect adequate sealing systems especially in gate roads connecting to the main intake and return roadways of longwalls.

The implementation of gas drainage systems at present in Australia can generally be based on the following criteria:

(a) the inability of the available air quantities to dilute the predicted gas emissions to permissible limits, either for physical or economic reasons,

(b) the gas content of the coal seam or seams to be drained are sufficiently high,

(c) the gas macropermeability of the coal seam or seams is relatively high for pre-drainage, and

(d) gas flowrates under suction from test holes drilled to the appropriate draining sites should be significantly greater than those under free flow conditions.

ACKNOWLEDGEMENTS

The investigations relating to Macquarie Colliery were carried out by The Broken Hill Proprietary Company Limited. Some results of investigations from the Barbara Experimental Mine as well as the Task Force of the Minister's for Mining Plenipotentiary for Methane Drainage in Poland were used. The views expressed are those of the authors, and not necessarily those of the Companies.

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G. CROFT (Gunnedah Collieries): With reference to Figure 3, it is proposed that there is a linear relationship between the variables - however it does not appear to be so from inspection of the graph. What is the reason for this discrepancy?

S. BATTINO (BHP Collieries Research): To derive those curves a lot of field data was gathered and all of that data was based on experiences of 500 tonnes per day up. All these curves were drawn from actual field points. When trying to fit the field points to the curves it was found that, in fact, it obeys the square root law, it was not a linear relation. That is why to complete the graph it was completed on a curve. But really up to 500 tonnes its quite safe to assume a linear relation, but definitely above 500 tonnes the square root law must be used.

B. HAM (MIM Holdings Ltd.): In exploration, would gas flow rates be measured or would the gas bombs be used? There is a radius of influence of gas drainage from mining; what findings have been made on this subject, and how should it be pursued?

S. BATTINO: In reply to the first question; yes, but both should be measured really. A try should be made to measure the 'gas content', not really gas content, but better the desorbable gas from the bomb as well as flow rates from the holes. In the paper it was stated that not enough has been done and really both should be done - as much data of that nature should be gathered as possible to be able to get an accurate prediction. Regarding the radius of effectiveness - yes, some tests have been done in BHP Collieries on radius of effectiveness but it varies so widely even within the colliery so much so that it is not reliable to give a value as a general figure. Intra-pit it varies, let alone inter-pit, it's just too hard to put a figure on it, but definitely that's something else that should be examined and that of course would have a very significant influence on the in-situ permeability. And there is need for knowledge of permeability also, hence that permeability test should be done as well.