DETERMINATION OF GAS CONTENT OF COAL SEAMS

By
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ABSTRACT

A method for the determination of the gas content of coal seams is presented which improves upon existing methods. The method makes use of a gravitational technique for measurement of the gas desorbed. The amount of lost gas is estimated by determining an empirical relationship relating the desorption of gas with time for each sample separately. This is to replace the assumption that desorption follows a square root law with time. Laboratory investigations have been conducted which indicate that the square root desorption law does not hold good for carbon dioxide. Results of investigations on various factors influencing the technique are presented. It is shown that co-efficients of the empirical equation are dependent upon the elapsed time and the period of observation. Data about gas pressure measurements is presented and it is concluded that gas pressure can be approximated to 0.6 times the pressure below a column of water equal to the depth of cover. This estimate is good enough for adsorption tests to evaluate desorption co-efficients. The technique for repressurisation of the sample, along with the equipment required, is described.

INTRODUCTION

The determination of the gas content of coal seams is of fundamental importance in the planning of ventilation systems in coal mines. Its importance has increased very rapidly over the last 10 years, mainly due to developments in highly productive longwall equipment. Modern equipment capable of producing up to 1 000 tonnes per hour, requires that the environmental conditions, both gas and dust, be kept within specified limits.

The effect of specific methane emission (m^3/t) on the production potential of the working face is given in Fig. 1. It is obvious that in the planning of any operation in gassy mines, specific gas emissions for the area must be known in advance. For example, investigations on gas emission at West Cliff Colliery were conducted before the introduction of longwall mining. It was conlcuded that gas emission from the Bulli Seam must be reduced by at least 50%, if production of 6 000 - 7 000 tonnes per day is to be achieved.

Estimation of gas content is not only essential for ventilation, but also permits assessment of outbursts of gas and coal hazards in advance. It helps in the planning of suitable mining methods, selection of

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mining equipment and layout to combat these conditions. Gas content estimation, as one of the important parameters to be measured in the early stages of exploration, is becoming rapidly accepted.

METHODS OF ESTIMATING THE GAS CONTENT OF COAL SEAMS

Some of the earliest attempts to measure the gas content of coal were made by Graham, (1937-8), but intensive investigations really began in the mid-sixties with developments in the U.K., Germany, France, Belgium and the U.S.A.

Methods for the estimation of the gas content of coal seams can be grouped into two categories:

(i) Direct

(ii) Indirect

Direct methods are based upon extracting a coal sample, enclosing it in a sealed chamber and measuring the gas evolved from it. Indirect methods are based upon either gas adsorption characteristics of coal under given pressure and temperature conditions, or other empirical data obtained from existing mines which relate the gas content of coal to certain other related parameters. A summary of the various methods is given in Table 1.

DIRECT METHOD

This method was first developed on a scientific basis by CERCHER and has since been used in France, Belgium, Germany and the U.K.

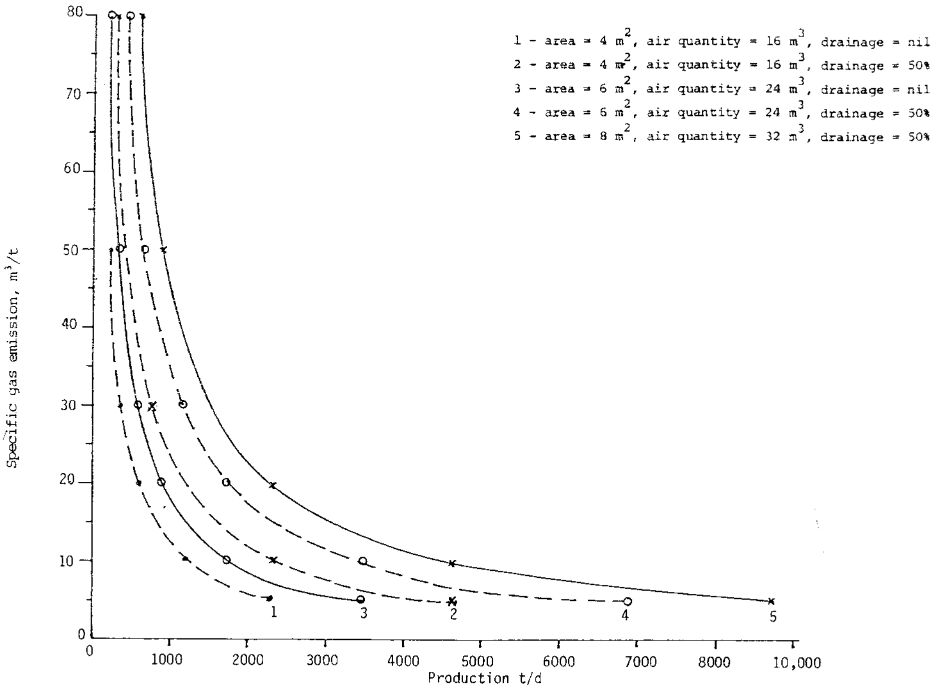

Fig. 1. Effect of specific gas emission on maximum production from a longwall face : Max. CH_4 concentration 1.25%; Coefficient of irregular emission 1.5.

Table 1. Methods of estimation of gas content of coal seams

Method	Requirements	Methods of interpretation	Accuracy	Country	Method of measurement	Applicability
DIRECT	Cores	Requires knowledge of gas emission laws.	Depending upon time lost, core quality and applicability of gas emission laws. ± 50% → ± 20%	U.K. U.S.A. Australia	Volumetric gas emission at atmospheric pressure followed by crushing.	Good from surface boreholes and doubtful from underground boreholes, fractured cores etc. Degree of fracturing influences results.
DIRECT	Sampling of fractions.	Empirical	?	Poland	Volumetric gas emission.	Existing mines.
Indirect Statistical	Lumps of coal	Statistical analysis of gas content of lumps.	± 20%, statistically measured values from face samples are consistently higher.	U.K.	Sample (30-40 mm size), collection at the face and estimation of gas contents.	For seams under mining, face sampling, applicability to highly variable and high rank coals not proved.
Indirect Adsorption isotherms	Pressure measurement and sampling.	Direct reading for adsorption isotherms.	Depending upon pressure measurements and sampling. ~ 10-20%.	Poland USSR Australia Germany	Volumetric techniques and gravimetric techniques.	For seams under mining and seams lying above or below.
Indirect Chemical analysis	Proximate analysis of coal.	Empirical	~ 30-100%	USSR U.S.A. Poland	Chemical analysis	New and existing mines.
Indirect	Exhaust Ventilation sampling	Subtraction techniques	± 20%	Australia	CH_4 or CO_2 gas analysis (%).	Existing mines.
Indirect	Sampling of exhaust mine air	Empirical	± 50%	Germany U.S.A.	Volumetric gas emission.	Existing mines - general make of gas.

The original method consists of sampling coal seams by drilling and enclosing the cuttings in a container as soon as possible from which the gas content Q_2 is measured volumetrically (Bertard et al., 1970; Belin, 1971).

The sample is then crushed in a sealed chamber and additional gas evolved (Q_3) is measured. Crushing is done at atmospheric pressure (Germany, France, Belgium, Poland and the U.S.A.), or at zero partial pressure (U.K.). The amount of gas lost during extraction and transfer (Q_1) is calculated using the relationship

$$Q_1 = K(t)^n \qquad (1)$$

The value of n is either calculated from desorption data or assumed. The French (Bertard et. al., 1970) and the U.S.A. investigators (Kissel et. al., 1973) believe this to be 0.5; U.K. (Airey, 1968), believe that its value varies between 0.25 - 0.3, and Germans, between 0.3 and 0.35. The error in the value of Q_1, however, by using n = 0.3 instead of 0.5 will be almost 100%. The total gas content is then given by

$$Q = Q_1 + Q_2 + Q_3 \ m^3/t \qquad (2)$$

Certain modifications of the direct method have been tried. These include sealing of the sample in situ (Ettinger et al., 1958; Lidin et al., 1965), and sealing of the core barrel (Tarnowski, 1960). Some investigators believe that the methods of direct determination are not accurate enough to warrant the calculation of lost gas and instead assume this quantity to be 10% of (Q_2+Q_3).

The size and shape of the sample is an important consideration in the direct method and it is here that conflicting views exist. The authors believe that it is imperative to obtain full cores to determine accurately the gas content. The French (CERCHER) believe that it is sufficient to obtain cuttings of 2mm size and above with a total mass of 10g. In the U.K., a sample of 30g is supposed to be sufficient to give the required accuracy.

INDIRECT METHOD

The indirect method has many variations. These include:

(a) adsorption techniques where adsorption isotherms are obtained in the laboratory and pressure measurements are done in the field, and

(b) empirical techniques based on estimation of the gas content from certain indirect measurements where the correlation has already been established between these indirect measurements and the gas content of a coal seam or an area.

Measurement of pressure in the field presents problems in highly porous seams where the pressure gradients are low and the length to which holes must be drilled is long, particularly when measurement is done from underground. Sealing of holes, length of seals and measurement time are some of the problems that need to be satisfactorily overcome before these measurements can be made. Methods are available to solve these problems, and appropriate answers have been found and tried with success.

A number of indirect methods exist and have been used to estimate the gas content of coal seams. These include exhaust ventilation sampling (Lama, 1980); sampling from ribsides (Tarnowski, 1972); use of empirical data relating the gas emitted into ventilating air and the gas content of the coal (Noak, 1976); proximate analysis and gas adsorption correlation (Ettinger et al., 1958; Kim, 1977).

DIRECT METHOD USING GRAVITATIONAL TECHNIQUES

While conducting tests using the conventional direct method, as developed by Bertard (1970) and modified by USBM, it was realised that large errors resulted in the estimation of the gas content of coal seams because of the following factors:

(i) The emission of gas from coal samples is sensitive to changes in pressure. The use of large sized sample containers to accommodate the full length of the core requires large capacity measuring cylinders. This results in subjecting the coal sample to a sudden vacuum as the sample container is connected to the measuring cylinder.

(ii) When the gas content of a coal seam is large the measuring cylinder needs to be replaced frequently. During this stage, there is a build up of pressure (above atmospheric pressure) which causes a change in the condition of gas emission from the sample (slowing down of the gas emission rate).

(iii) When cores are fractured, loss of gas in the initial stages is very high and it is advisable to close the valve of the sample container immediately on enclosing the sample. The time elapsed between the start of measuring gas (first reading) and enclosure of the sample results in a build up of positive pressure invalidating the method of analysis.

(iv) Automation of the gas measuring system is very difficult and costly.

To overcome these difficulties, the gas emission measurement technique has been modified and a new method has been used where, instead of volumetric measurements, gravimetric techniques are adopted to measure the gas emission of a sample.

The equipment used in the method is shown in Fig. 2. It consists of a sample container, a mercury seal, an electronic digital balance and a digital recorder (not shown in the figure). In case of a high moisture content of the sample (wet drilling) a moisture absorbing attachment is connected to the sampling tube.

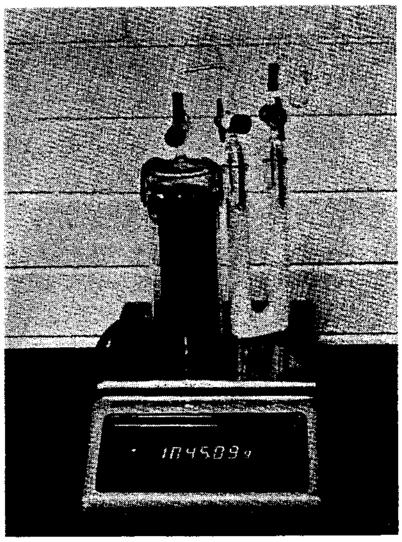

Fig. 2 Gravimetric gas adsorption cell with moisture adsorber

The accuracy of the system depends upon the balance. For coal samples up to 1.5kg weight capacity the accuracy in measurement is 1.5cc for CH_4 and 0.5cc for CO_2. For samples greater than 1.5kg weight, the accuracy drops because of balance limitations and is approximately 15cc for CH_4 and 5cc for CO_2. The accuracy in gas measurement in cc/g is better than 0.007cc/g for CH_4 and 0.0025cc/g for CO_2.

The method of measurement of the gas content is as follows:

(i) Transfer the coal sample into the pre-cleaned and pre-weighed sample container as soon as possible.

(ii) Record the change in weight every 30 seconds in the beginning with the time between readings extending to several hours at later stages.

(iii) Continue gas emission tests until the rate of gas emission drops to less than 0.1cc/g/day, then transfer the sample to an adsorption bomb.

(iv) Pressurise the adsorption bomb containing the sample to a pre-determined pressure until equilibrium is obtained, as determined by the change in weight not exceeding 0.01cc/g/day. The method of pressurisation is described in the following section. The sample is then allowed to desorb at constant temperature and the desorption rate is measured, starting within 45 seconds. The desorption data is interpolated to obtain the value of n (Eq.7) using the least square method by using data for different time intervals (60-500s; 60-1000s and 500-1000s, etc.) depending on the expected time lost in field sampling. The field curve is superimposed on the laboratory obtained curve and the value of n is obtained by matching the field curve with the laboratory curve. This value is then used in calculating the lost gas.

REPRESSURISATION OF COAL SAMPLES

The coal samples are carefully removed from the sample containers and placed into the adsorption bomb. The schematic of the apparatus is given in Fig. 3 and is shown in Fig. 4.

The equipment consists of a gas supply cylinder which is connected to a manifold through a storage reservoir and a pressure regulating valve. The manifold has six independently controlled outlets to which sample containers are attached using flexible nylon hoses and high pressure quick attach fittings. The manifold is attached to a vacuum pump with a facility to monitor both pressure and vacuum in the manifold, and to the sample containers. Pressure release valves are incorporated to release pressure in the manifold line on any of the sample containers independently.

Sample containers (sample bombs) have isolation valves mounted on them and are placed in a temperature controlled water bath surrounded by a copper sleeve. The copper sleeve permits good thermal conductivity without wetting the bomb surface.

The system is designed so that gas adsorption tests can be conducted up to 7000 kPa gas pressure and at temperatures from -10°C to 40°C. All tests are conducted at the temperature measured in the coal seam.

Before starting tests, sample bombs are calibrated to determine the gas holding capacity of the bombs individually. The bombs are weighed when fully evacuated. They are then pressurised to equilibrium at a defined temperature and re-weighed to determine the gas capacity of the bombs. Calibration curves are obtained for each bomb.

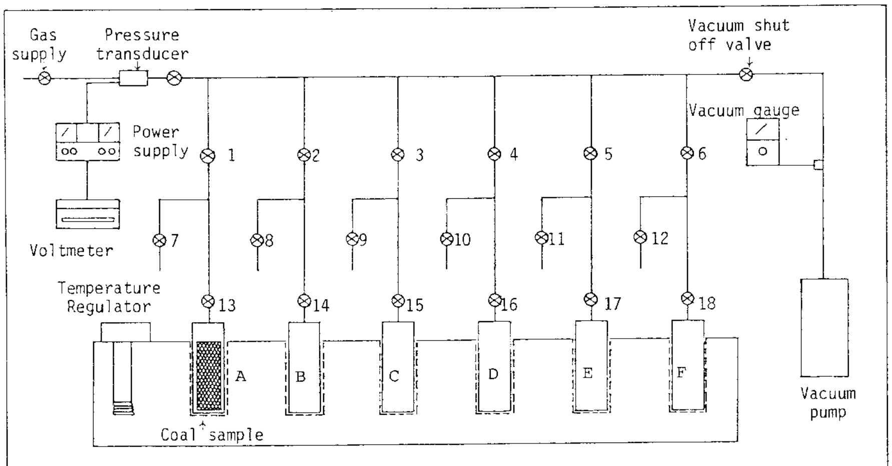

Fig. 3. High pressure adsorption system. 1-6 Primary supply system; 7-12 Pressure release valves; 13-18 Isolation valves; A-F Sample bombs

These curves show very clearly that for methane the ideal gas equation is acceptable at pressures up to 4000 kPa, but for carbon dioxide the ideal gas equation is not acceptable at pressures beyond 1100 kPa.

The bomb containing the sample is pressurised to a given pressure. Change in weight is monitored until equilibrium is reached. The increase in weight gives the amount of gas adsorbed in coal plus the amount of gas present in the empty space of the bomb.

Let the weight of the bomb = W_1 (g)

Weight of the sample and bomb = W_2 (g)

Weight of the sample in the bomb = $W_2 - W_1$ (g)

Weight of bomb and sample when saturated with gas at pressure 'P_1' = W_3 (g)

Density of gas at NTP = ρ_g (cc/g)

Volume of gas (free and adsorbed at NTP) in the bomb = $\left\{\left[\frac{W_3 - W_2}{\rho_g}\right]\right\}$

Density of coal (Helium density) = ρ_c (cc/g)

Volume of coal in the bomb = $\left(\frac{W_2 - W_1}{\rho_c}\right)$

Let the volume of bomb (at NTP) = V_o (cc)

Free volume of bomb not occupied by coal

$$= \left\{\left[V_o - \frac{W_2 - W_1}{\rho_c}\right]\right\}$$

Volume of gas (at NPT) contained in bomb at pressure 'P_1' as obtained from calibration curve = V_1

Free gas volume present in bomb at pressure 'P_1' with coal sample contained in it

$$= \frac{V_1}{V_o}\left[V_o - \frac{W_2 - W_1}{\rho_c}\right]$$

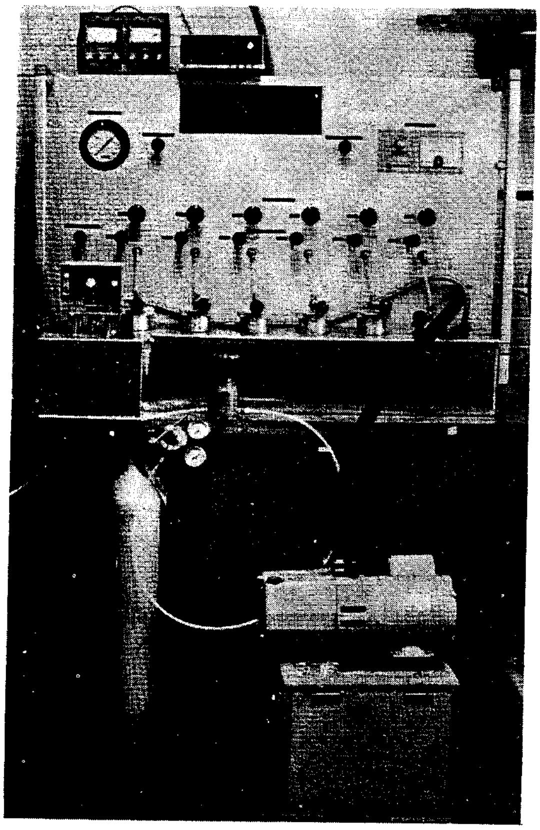

Fig. 4 High Pressure gas adsorption/desorption system

Therefore volume of gas adsorbed in coal (at NTP)

$$= \left[\frac{W_3 - W_1}{\rho_g}\right] - \frac{V_1}{V_0}\left[V_0 - \frac{W_2 - W_1}{\rho_c}\right]$$

The gas pressure in the sample is then released. Tests have indicated that the gas pressure in the bomb reaches equilibrium within 5-45 seconds after opening the valve, depending upon the gas pressure and sample volume. The change in weight of the sample is monitored and the amount of gas released per gram of coal is calculated. A typical desorption curve is given in Fig. 5.

Though the first reading is taken after about 45 seconds, the amount of gas released in the first 45 seconds can be calculated by knowing the total amount of gas adsorbed and subtracting from it the amount of gas present at the time of the first reading. This permits the complete desorption curve for the sample to be obtained.

DESORPTION OF GAS FROM COAL

To calculate the amount of gas present in a coal sample and particularly the lost gas, it is essential to understand the mechanism of adsorption and desorption of gas from coal. A number of studies have been conducted which model gas emission as flow or diffusion. In the absence of knowledge of the various parameters involved such as permeability, diffusion, particle diameter and shape, total quantity of gas present and initial pressure, the use of theoretical formulations is not very useful in calculating desorption of gas from coal under field conditions. Certain empirical formulations, based on simplified relationships, are more useful. These are as follows (Lama, 1981):

$$Q_t = A\sqrt[3]{t} \tag{3}$$

$$Q_t = A\sqrt[2]{t} \tag{4}$$

$$\frac{Q_t}{Q_\infty} = \frac{12}{d}\sqrt{\frac{Dt}{\pi}} \tag{5}$$

$$\frac{Q_t}{Q_\infty} = \left[1 - e^{-\left(\frac{t}{T}\right)^n}\right] \tag{6}$$

$$Q_t = Q\left(\frac{t}{T}\right)^n \tag{7}$$

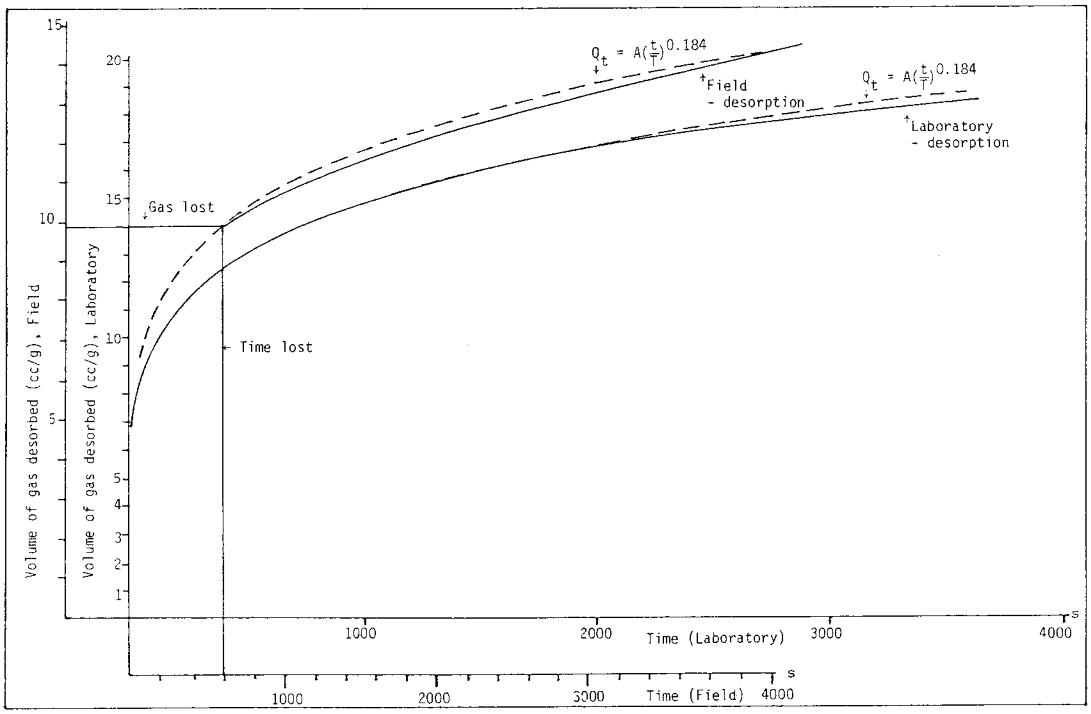

Fig. 5. Results of laboratory and field desorption tests and the use of laboratory determined coefficient n to estimate lost gas. (Sample No. 12, gas CO_2, lost time 600 seconds).

Where:

Q_∞ = gas desorbed cc/g at time
Q_t = gas desorbed cc/g in time t,
Q = gas present cc/g immediately before desorption,
A = constant,
t = time seconds,
d = equivalent particle diameter,
D = coefficient of diffusion, cm^2/s
T = constant

To estimate lost gas it is essential to know the law that a given coal would follow to permit interpolation of the curve.

The method adopted by USBM assumed a square root law (Eq.4). This law was tested under laboratory conditions and it was found that calculating lost gas using this method would be seriously in error.

Table 2 shows the results of calculation of lost gas from the two commonly used equations. These results show that the use of the square root law to calculate lost gas gives consistently low values. It is therefore suggested that instead of the square root law, the modified Eq.7 be used.

Table 2 Comparison of actual and calculated lost gas (laboratory investigation, dry sample, CO_2)

Sample no.	Measured gas lost (cc/g)	Calculated lost gas (cc/g) Eq. 7	Calculated lost gas (cc/g) Eq. 4
1	8.48	8.48	2.71
2	27.72	27.72	0.27
3	14.03	14.02	2.27
4	5.42	5.86	3.26
5	6.90	7.19	4.34
6	6.55	8.05	10.15
7	13.40	13.50	1.84
8	10.51	10.45	1.26
9	6.75	6.56	1.95
10	9.26	9.25	1.61
11	10.50	10.45	0.76
12	6.85	6.84	2.28
13	8.48	8.44	0.29
14	10.40	10.28	1.43
15	13.07	13.07	0.27
16	13.94	13.95	0.30
17	14.14	-	0.10

CALCULATION OF THE VALUE OF THE COEFFICIENT n

The value of the coefficient n (Eq.7) is calculated by using the desorption data. The results have shown that the value of n to fit the curve is not constant, but depends upon which section of the curve is taken. The values of n as obtained at various test intervals are given in Table 3. The value of coefficient n is variable but it usually decreases with increase in the elapsed time from the start of desorption and the value of T increases. The relationship of (n/T) as a function of elapsed time is given in Fig. 6. It is therefore not possible to assume any value of n, but it has to be determined for the sample under investigation and the elapsed time.

It is possible that the values of n and T are dependent upon pressure. Some initial studies have shown that its value is not very much affected by the initial pressure within limits (5). The best method would be to determine the gas pressure in situ. In the absence of this data an estimate can be made from the depth parameters. Some data obtained from Australia and overseas countries is given in Table 4. This table indicates that except for special circumstances (close to outcrops, highly faulted and folded areas), pressure could be taken as 0.6 - 0.7 of the pressure at the base of a column of water equal to the depth of cover. This gives a reasonable estimate of the pressure and permits calculation of the coefficients n and T.

CASE STUDY

Coal samples were obtained from surface drill cores. The gas composition was analysed and it consisted mainly of carbon dioxide. The lost time was estimated using the following relationship:

Lost Time = (Time core in sample container
- Time core on the surface)
+ 0.4 ×
(Time core on surface - Time core extraction started)

From fixed desorption measurements the amount of gas desorbed cc/g is calculated and is plotted. The best desorption relationship is given by Eq.7. Therefore,

$$Q_t = A\left(\frac{t}{T}\right)^n$$

The lost gas (Qo) is desorbed during the lost times (to).

$$Q_0 = A\left(\frac{t_o}{T}\right)^n \qquad (8)$$

Table 3 Values of coefficients n and T for coal samples, gas CH_4, Middle Gooonyella seam

Sample no.	Time interval used to compute (s)	Computed value of coefficients		Coefficient of correlation (r)	$(\frac{n}{T}) \times 10^{-5}$
		(n)	(T)		
3	41 - 341	0.337	4325	0.997	7.79
	341 - 641	0.256	9821	1.000	2.61
	641 - 941	0.228	13789	1.000	1.65
	941 - 1241	0.249	11138	0.999	2.24
	1241 - 1901	0.223	14081	0.998	1.58
	1901 - 2501	0.206	17043	0.998	1.21
4	340 - 640	0.224	9560	0.998	2.34
	640 - 940	0.211	11400	0.999	1.85
	940 - 1240	0.195	13534	0.995	1.44
	1240 - 1540	0.206	12067	0.995	1.71
	1540 - 1900	0.203	12814	0.994	1.58
	1900 - 2500	0.184	15558	0.999	1.18
5	35 - 335	0.323	3114	0.988	10.37
	335 - 635	0.224	9567	0.999	2.34
	635 - 935	0.205	12705	0.999	1.61
	935 - 1235	0.194	14826	0.999	1.31
	1235 - 1835	0.204	12985	0.999	1.57
	1835 - 2435	0.150	26230	0.997	0.57
6	45 - 345	0.307	4093	0.993	7.5
	345 - 645	0.228	10284	0.998	2.22
	645 - 945	0.232	10023	0.999	2.31
	945 - 1245	0.208	12877	0.999	1.62
	1245 - 1605	0.203	13750	0.990	1.48
	1605 - 1965	0.210	12698	0.997	1.65
	1965 - 2645	0.210	13817	0.999	1.52

Table 4 Gas pressure in relation to depth in Australian and overseas coal mines

Colliery (coal seam)	Gas	Depth (m)	Gas pressure (kPa)	$\frac{\text{Gas pressure}}{\text{Hydrostatic head}}$
AUSTRALIA				
West Cliff (Bulli Seam)	CH_4	480	3000	0.60
Appin (Bulli Seam)	CH_4	520	4200	0.77
Leichhardt (Gemini Seam)	CH_4	400	3640	0.91
Collinsville (Bowen Seam)	CO_2	280	1500	0.54
Metropolitan (Bulli Seam)	CO_2	610	3000	0.49
U.S.A.				
(Pocahontas 1403 Coal Bed)	CH_4	600	4330	0.72
(Pittsburgh Coal Seam)	CH_4	252	1360	0.54
Beatrix Colliery	CH_4	470	4000	0.85

Note: Hydrostatic head is taken as equal to depth without accounting for depth of water table.

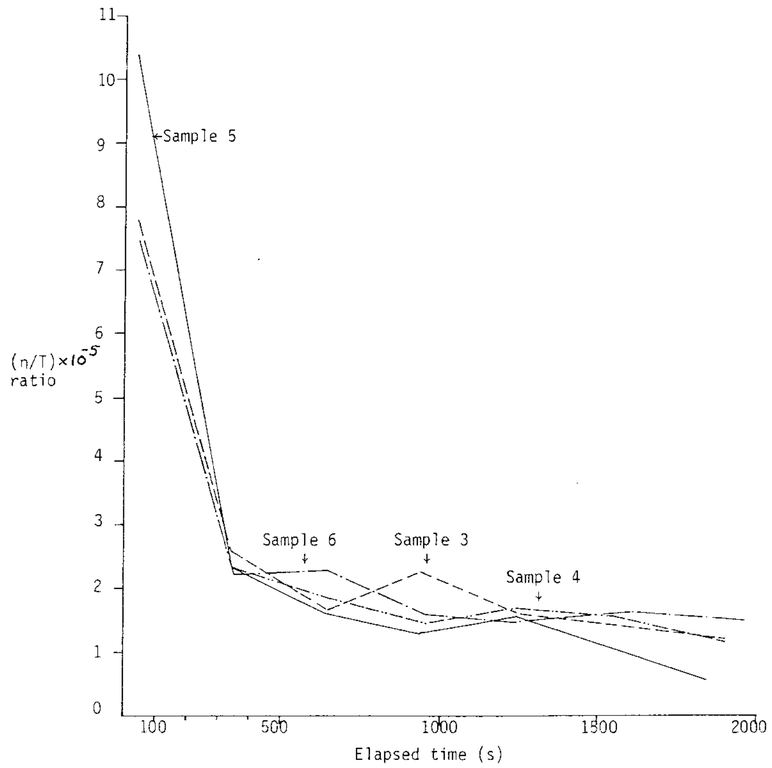

Fig. 6. Values of coefficient (n/T) as a function of elapsed time.

Table 5 Calculation of lost gas using the Eq. $Qt=A(t/T)^n$

$\left\{ \begin{matrix} t_o = 900 \\ n = 0.293 \end{matrix} \right\}$

Desorption TIME s	VOLUME DESORBED	$\ell n(Q_t)$ Y	$(t_o)^n$	$(t+t_o)^n - t_o^n$	$\ell n\left[(t+t_o)^n - t_o^n\right]$ X
60	0.085	-2.464	7.338	0.140	-1.966
120	0.181	-1.711		0.274	-1.294
180	0.250	-1.387		0.403	-0.910
240	0.319	-1.143		0.526	-0.642
300	0.420	-0.867		0.645	-0.438
360	0.497	-0.699		0.760	-0.274
420	0.572	-0.559		0.871	-0.138
480	0.638	-0.449		0.979	-0.021

Therefore the real amount of gas desorbed

$$Q_t + Q_o = A\left(\frac{t+t_o}{T}\right)^n$$

Taking logs

$$\ln(Q_t) = \ln\left(\frac{A}{T^n}\right) + \ln\left[(t+t_o)^n - t_o^n\right]$$

A plot of $\ln(Q_t)$ against $\ln\left[t+t_o)-t_o^n\right]$

should be a straight line relationship with slope approaching 45^o. The intercept gives the value of $\ln\left(\frac{A}{T^n}\right)$.

The amount of gas lost (Q_o) can be calculated by introducing the value of t_o into Eq.8. The total gas desorbed is then calculated by adding the gas lost to the gas desorbed from actual measurements. Table 5 gives details of calculations. Fig. 5 gives results of actual measurements and the desorption tests conducted on field samples. The close approximation of the curve obtained from calculated values of n based on laboratory tests for the assumed time to those based on field investigations is acceptable. The field and calculated desorption curves in the region of lost time lie very close to each other.

CONCLUSIONS

The gravimetric method of measuring gas desorbed from coal samples, both in the field and in the laboratory, is superior to the volumetric method commonly used. It has also been shown that the square root law of estimation of the gas lost during field estimations does not hold good, as determined under laboratory conditions. The most suitable empirical relation is given by Eq. 7. The coefficients n and T are dependent upon the time elapsed from start of desorption. These can be determined reasonably accurately by repressurising the sample and measuring the gas desorbed over a short period of estimated time lost.

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DISCUSSION

R.J. WILLIAMS (Collinsville Coal Company Ltd.): It is suggested that the lost gas calculations or the lost gas determination from the laboratory method described may be substantially over what really is the case. It was indicated that the zero time is at the point when the coal is cut at the bottom of the hole and under those conditions there is a hydrostatic head of water on top of the coal. As well the core being cut is confined ultimately by the triple tube core barrel so there is the point of deciding when to make that zero time. It could be that only when it is out of the triple tube core barrel, the desorption rate is similar to what has been done in the laboratory. Up until that time there is resistance to flow due to confinement and to the core barrel. Up until that time a much lower desorption rate occurs so it could be that the true lost gas value is somewhere between what has been calculated and what the U.S.B.M. shows.

R. LAMA (Kembla Coal and Coke Pty. Ltd.): What has been shown basically is the technique. The question of time, when does the first desorption start will depend upon how the drilling is done and what the local conditions are. Yes it is true, the time is estimated. For example, in the paper, the lost time has been estimated from the time pulling out that core is started to the time it reaches the surface but multiplied by the factor of 0.4. That is the lost time which has been taken as if the hole is full of water. It is assumed that the gas pressure is only about 0.6 of the vertical depth. It is not assumed that the gas starts liberating from the sample immediately on starting to pull the sample out, but it starts liberating only if it has reached a certain amount of depth where the gas pressure in the coal sample is equal to the hydrostatic head of water in that particular hole. The figure shown had two scales, one laboratory and one field. The reason behind that was that knowing very well that pressure might influence, the samples were subjected to higher pressure in the laboratory. Using the data even from very high pressures and correlating it with the field data, it was still found that the correlation is pretty good. The factor n is not influenced by the pressure. The factor obtained in the laboratory could be used to transfer the data to the field conditions although the laboratory pressure conditions are quite different than the field conditions.

R. KING (U.S. Bureau of Mines): Concerning the dry sample which was used. Could not the over-estimation of the laboratory versus the lost gas be due to the fact that the sample was dry? The same problem is experienced with isotherms. With a dried isotherm sample the theoretical maximum gas storage is much higher than what it is in reality because the moisture and the gas are both trying to share the same home. Has this factor been addressed in this over-estimation?

R. LAMA: Yes, the effect of moisture on the adsorption of gas in the sample is very large. The figures vary from anything from 10-15 per cent. The question arises is, that the sample would not dry if the sample is subjected as early as possible to the laboratory conditions. It is not necessary to evacuate the sample. Normal absorption tests are done where all the gas is first evacuated and then gas is pumped in it. The field samples are not evacuated. Neither are the samples evacuated in the laboratory tests. They are kept as they are, and that is true, though a certain amount of water still gets out from the coal sample. But the question is that it is not an attempt to determine the amount of gas which is present in the coal seam from indirect method using sorption, it is an attempt to determine the value of the parameter n. Results show that higher pressure adsorption puts in more gas (with or without water). The amount of gas though put into the sample is larger, but the value of n does not change. German investigations using this formulation do show that even the value of n is more or less independent of the grain size of the particles. Therefore it is believed that though this is a bit more time consuming technique, the limitation of the amount of gas lost is far better. The determination of gas lost is far more accurate.

I. GRAY (Australian Coal Industry Research Laboratories): Actually there seems to be a varying boundary condition as the sample is raised. The sample is cored and then raised up the borehole and the hydrostatic head over the sample is changing entirely during that period. If the empirical 0.4 is correct then that is fine, but it must be empirically done. The second thing is that in working in combination with Collinsville Coal Company, A.C.I.R.L. found that comparisons of field tests at Collinsville Coal using their desorption and back analysis procedure gave a very close correspondence indeed, which gives some faith in the method. It is a log-time back analysis, taking into account when desorption would commence and field values measured underground using pressure and sorption curves. If it is to be researched further, possibly that means going into the realms of simulators and multi phase flow, but possibly it is not worth it if a reasonable comparison can be obtained which appears to be the case with this particular mine.

R. LAMA: The comments made were not on use of some sort of quadratic equations to fit desorption of gas from the coal sample as used by Collinsville. The comments were made on the standard methods which have been accepted world wide for estimating the lost gas. It is possible that the quadratic equation can be fitted in to the data and pretty close values may be obtained. After all that is a question of curve fitting. The aim was to design the system so that with values of coefficients determined under similar conditions on the same coal sample, an interpolation could then be made.

That seems more scientific rather than trying to fit a quadratic equation. I do say, no attempt was made to use any quadratic equations. The number of constants that would be involved and have to be determined would be so many. It seems better to use a simpler formulation.

W. HIGHTON (National Coal Board, U.K.): Looking mainly to the benefits that have to be obtained from this research work it must be agreed that it is worthless doing research if there is not some production benefit. The requirement was mentioned for a 50% capture by methane drainage to maintain acceptable levels. Does this mean for the working seam or for the total gas emission from the strata above and below the working seam?

N.C.B. experience has been that only 3 to 5% of the gas from the working seam is captured by a cross measure methane drainage system. Tracer gases were used to conduct these trials. Finally, apart from using the prediction work in headings, what is the real value of determining the total gas emission from longwall districts. N.C.B. experience up to now has been that there has been an error of as much as 2 to 1 in the predicted figures. It was found that predictions are more reliable when based on past experience.

R. LAMA: That is a very interesting question. In referring to the amount of coal which can be produced from a longwall face, only the gas contained in the coal seam, not of the surrounding strata was taken into consideration. Also the assumption in the paper was based on some of the observations from driving of headings, that possibly 30-40% of gas is liberated in the district. Maybe up to 50%. The assumption was made that only 50% of the gas contained in the coal seam would be liberated at the return end of the longwall face. It is agreed, it is very hard to determine the total amount of gas that would be liberated in a district, whether it is longwall mining or bord and pillar development. The experience with some calculations for Westcliff Colliery, was that they were wrong between 100 and 150%. The thing which will help to understand will be having such theoretical models, or using different types of formulation for different types of models and identifying which model possibly gives results which are closer to what are observed in practice. The calculations cannot be done purely on any mathematical or any hypothetical model without confronting those calculations with actual measurements. The difficulty arises when there are no data, particularly in some of the cases where there is no experience of what will happen. In such cases there is no other option except to go to some of those models. In the paper by Marshall, Lama and Tomlinson (to follow) some data will be presented in which some 12 different methods are used. These methods have been used overseas to calculate the amount of gas that will be liberated in a longwall operation. It is found that values could be anything from x to 5x. It is very good for people in Europe, having had an experience. West Cliff has used the method that people use in Germany, the U.K., France, Poland, Russia and Belgium. Using these methods and adapting them to West Cliff conditions, the amount of gas emissions arrived at are so large that these are sometimes incomprehensible. Once these methods are used and confronted with actual measurements, probably a better answer to this problem of gas emission will be obtained.