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A new approach to the determination of methane content of coal seams

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Summary

An approach to the determination of methane content of coal seams is proposed. The method utilizes the transformed Airey's empirical equation on desorption of methane from coals. The methane content values estimated by this method correspond well with actual values from laboratory experiments. In the case of Indian coals, the applicability of the $\sqrt{t}$ relationship for the calculation of the gas lost from coal lumps during long periods of time loss appears to be limited due to poor agreement with the experimental values.

Keywords: Methane, Airey's desorption equation

Introduction

The importance of determining the methane content of coal in the seams being worked and also in the virgin coalbeds cannot be overemphasized in the assessment of the gassiness of seams. The 'Direct Method' of determination (Bertard *et al.*, 1970; Kissel *et al.*, 1973; McCulloch *et al.*, 1975; Diamond and Levine, 1981; Feng *et al.*, 1984) consists in the collection of coal samples from boreholes especially drilled for the purpose and estimation of the lost gas (Q_1), desorbed gas (Q_2) and the residual gas (Q_3). While Q_2 and Q_3 can be determined accurately in the laboratory after the coal samples are collected and sealed in the sample containers, to estimate Q_1 it is necessary to verify the applicability of the $\sqrt{t}$ relationship, $V \propto \sqrt{t}$, where V is the amount of methane desorbed in desorption time t, for different coals. This verification is particularly necessary for large sizes of coal core samples collected from exploration boreholes, as there is a significant loss of gas due to the time gap of a few hours between coring and securing the samples in containers.

This paper presents the details of laboratory experiments on the desorption of methane from some Indian coals to test the applicability of the $\sqrt{t}$ relationship on lump coals during long periods of time loss, and suggests a new approach to the determination of methane content of coals based on Airey's (1968) desorption equation.

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Theory

The empirical equation for desorption of methane from coal up to the size range of about 6–12 mm ($\frac{1}{4}$–$\frac{1}{2}$ in) has been proposed by Airey (1968) as

$$V_{(t)} = A\left[1 - e^{-(t/t_0)1/3}\right] \tag{1}$$

where $V_{(t)}$ is the amount of methane desorbed in time t, A is the initial methane content of the coal sample and t_0 is the time constant for desorption of 63% of the gas. A general exponential relation between $V_{(t)}$ and t has also been studied in depth (Bandyopadhyay *et al.*, 1974; Banerjee, 1982) and observed to hold good for desorption of methane from both moist and dry Indian coals at different temperatures, irrespective of their initial methane content.

In the transformed Airey's equation,

$$\log (A - V_{(t)}) = \log A - \frac{1}{2.303\ t_0^{0.33}}\ t^{0.33} \tag{2}$$

$\log (A - V_{(t)})$ has a linear relationship with $t^{0.33}$ and A, the methane content of the coal is determinable from the intercept.

Since $(A - V_{(t)})$ represents the amount of gas still remaining in the samples and may be accurately determined at different time intervals from the subsequent measurements of Q_2 and Q_3, the plot of $\log (A - V_{(t)})$ against $t^{0.33}$ has been used in this work for the estimation of the methane content of the coals. The desorption experiments have been carried out on coals of size fraction 5–8 mm and it is likely that they would also represent the emission characteristics of larger lumps since the spacing of fissuring network of the coals used in the experiments is less than 4 mm (Banerjee, 1982).

Experimental procedure

The experimental procedure comprised the measurement of the desorbed gas volumes with time from coal samples which were initially equilibrated with methane at a known pressure under isothermal conditions. Channel samples collected from the coal seams were brought to the laboratory in closed containers filled with nitrogen. They were crushed in a nitrogen atmosphere and samples of 5–8 mm size fraction of each coal were prepared using Indian Standard Sieves. A known weight of each sample was initially dried at 100° C for 1 h and then evacuated to 10^{-2} mm Hg for 24 h at 30° C. The samples were subsequently pressurized with methane at 0.6 MPa (6 atm) at 30° C in a pressure vessel for 15 days. The measurement of the desorbed gas volumes after release of the pressure was carried out at regular intervals for a period of about 2 days. The samples were subsequently transferred rapidly to the crusher vessel to estimate the residual gas in the usual way (Bertard *et al.*, 1970). All the gas volumes measured were computed to their corresponding STP (Standard Temperature and Pressure, i.e. 0°C and 760 mm Hg) equivalent. The details of the procedure and the analyses of the four coals (A, B, C and D) used in these experiments have been presented elsewhere (Banerjee, 1982).

Results and discussion

Table 1 shows the desorbed volumes of gases against time for the coals A, B, C and D which were initially charged with methane at a pressure of 0.6 MPa at 30° C for 15 days. The table also indicates the total methane content of the samples including the volumes of gases desorbed from the samples crushed to − 8 mesh Indian Standard Sieve Designation (0.075 mm).

Table 1. Cumulative desorbed volumes and total methane content of the samples.

	Cumulative desorbed volumes with time (ml g^{-1})							Residual gas (ml g^{-1})	Total methane content (ml g^{-1})
Coal sample	2 h	4 h	6 h	8 h	24 h	28 h	32 h		
A	1.88	2.24	2.47	2.63	3.21	3.28	3.35	0.98	4.33
B	1.47	1.72	1.90	2.06	2.53	2.61	2.69	1.66	4.35
C	1.07	1.27	1.45	1.57	2.05	2.14	2.19	1.12	3.31
D	1.31	1.69	1.95	2.11	2.76	2.89	2.95	2.63	5.58

To demonstrate the independence of initial time loss during measurements, the desorption data have been presented with time loss of 2 h for coal samples A and C, and 4 h for coal samples B and D. From the gas volumes measured subsequently, the plots of log $(A - V_{(t)})$ against $t^{0.33}$ are shown in Fig. 1 for coals A and B, and in Fig. 2 for coals C and D. Figs 3 and 4 show the plots of lost gas according to the $\sqrt{t}$ relationship in the usual way (Kissel *et al.*, 1973) for samples A and B, and samples C and D, respectively. Methane content values as obtained directly from the intercepts in Figs 1 and 2 are shown in Table 2 along with the actual values as experimentally determined. The table also includes the methane content values computed by taking the lost gas into account by the application of the $\sqrt{t}$ relationship as obtained from Figs 3 and 4. It may be observed from the table that the application of the $\sqrt{t}$ relationship gives lower values than the actual methane content of the samples.

Figure 5 shows an illustration of the use of the method on a coal core sample (coal S) collected at a depth of 344.75–344.80 m from an exploration borehole in a virgin area in Jharia coalfield in

Table 2. Results of methane content determination by different methods.

		Methane content (ml g^{-1})			
		From $\sqrt{t}$ relationship			
Coal sample	Experimental value	Lost gas (Q_1)	(Q_2+Q_3)	Total gas	Proposed method
A	4.33	0.92	2.45	3.37	4.57
B	4.35	0.80	2.63	3.43	4.07
C	3.31	0.50	2.24	2.74	3.63
D	5.58	1.07	3.89	4.96	5.75

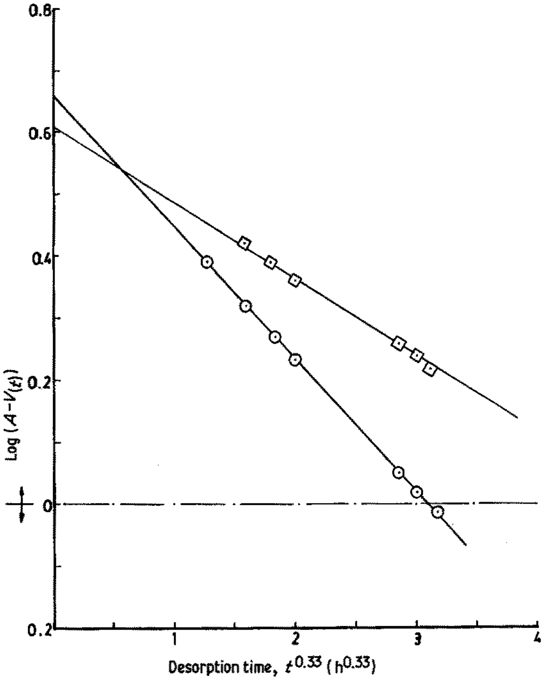

Fig. 1. Desorption plots for coals ⊙, A and ⊡, B.

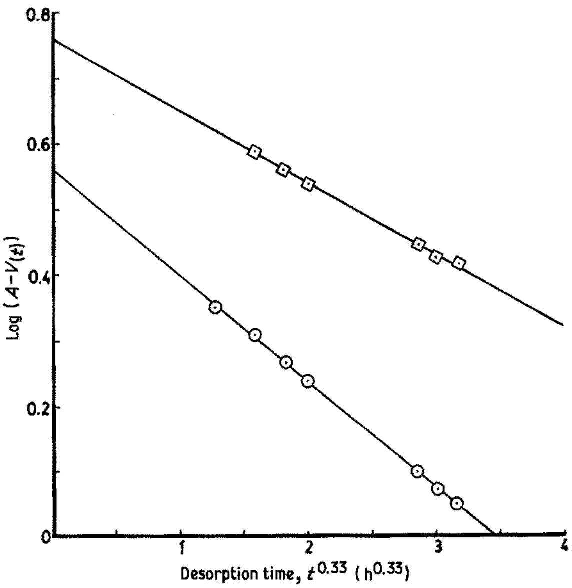

Fig. 2. Desorption plots for coals ⊙, C and ⊡, D.

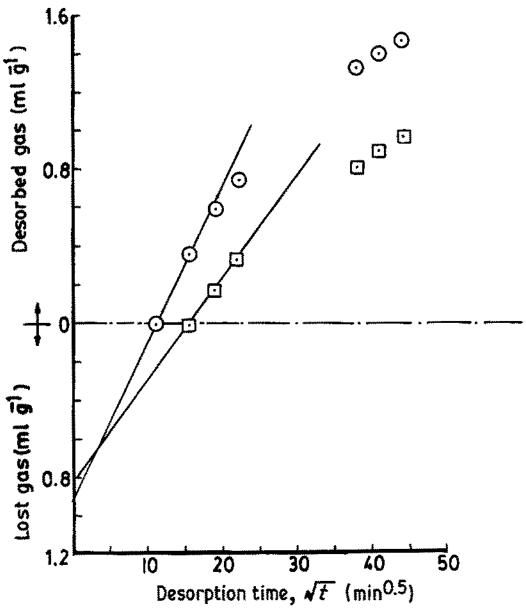

Fig. 3. Lost gas graph for coals ⊙, A and ⊡, B.

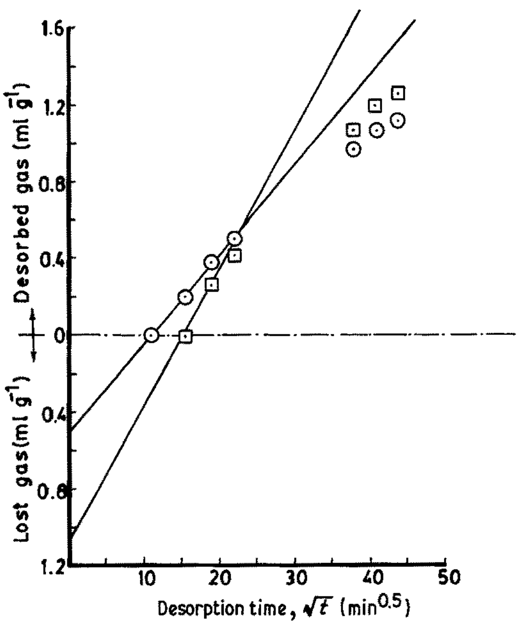

Fig. 4. Lost gas graphs for coals ⊙, C and ⊡, D.

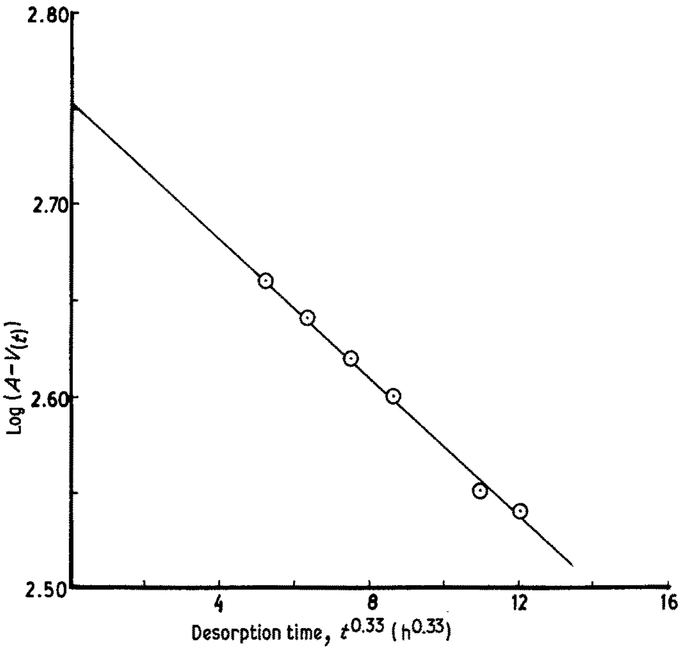

Fig. 5. Desorption plot for coal S.

India. The core sample was put in the sample container after an initial time loss of 90 min. The lost gas time was calculated following the method of Diamond and Levine (1981). The sum of the desorbed and the residual gas measured subsequently at different time intervals is plotted in a similar fashion, and the intercept shows the initial methane content of the sample as 568.8 ml in the 166 g of the core sample collected – a methane content of 3.43 ml g^{-1}. The lost gas as in the $\sqrt{t}$ relationship shown in Fig. 6 is estimated to be 63 ml, which in addition to the desorbed gas volume of 137.3 ml measured during the period of 1.5–31.5 h after collecting the sample and the residual gas volume of 346.7 ml, showed the total methane content as 547.0 ml which is equivalent to 3.30 ml g^{-1}. The methane content obtained by the proposed method is higher than that obtained by the $\sqrt{t}$ relationship and it conforms with the experimental observations.

It is therefore evident that the method can also be applied to coal cores from exploration boreholes for the determination of their methane content. However it may be pointed out that the accuracy of the determination of methane content would depend on the compatibility of the desorption data with the empirical equation. Harpalani *et al.* (1986) have recognized variable values of the index of t for different time ranges for desorption from coal powders. The actual desorption characteristics of coal within the seam may differ widely from those of powdered coals, since coal *in situ* is in a relatively unbroken condition where the resistance to gas flow is fairly high. The experiments on coal lumps of greater than fissuring network size would probably represent the desorption process from coal seams. These seams may be considered to be composed of small discrete lumps or blocks, because of the intensifying crack structure

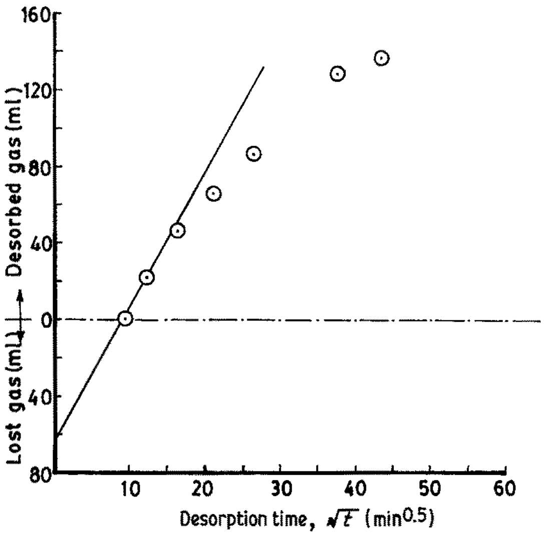

Fig. 6. Lost gas graph for coal S.

induced due to increased stress in the strata caused by mining. Therefore, the empirical equation with 0.33 as the exponent of t which has been found to conform well with the experimental observation gives a better estimate of the methane content for practical usage in the cases of Indian coals.

Conclusion

The applicability of the $\sqrt{t}$ relationship for the calculation of the lost gas from coal lumps at long periods of time loss appears to be limited due to poor agreement with the actual values in the cases of Indian coals. A better estimate of methane content may be obtained by the method based on Airey's desorption equation. This method does not require any additional measurement to those used for the calculation of the lost gas by the $\sqrt{t}$ relationship, and it can be completed within 2 days of collection of the samples.

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