Effect of air column in transport canisters on measured gas contents of coal

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Abstract

Canister desorption is a widely used technique to measure the gas content of coal. The gas content data, when normalized to volume/weight and multiplied by coal seam mass, is used to estimate the gas in place in an area around the cored hole. However, the gas content and the percentage of each constituent are likely to be influenced by trapped air in the canister at the time of the coal enclosure and subsequent sealing. Freshly-cored coal samples were collected from three mines, mining coal from Bulli seam, Sydney Basin. The studied underground mines were Appin West, West Cliff, and Tahmoor. The research programme, spanning for a period of four years, focused only on the influence of the trapped air in the canister on the coal gas percentage of each constituent. It was found that the percentage of each coal gas constituent was influenced by the trapped air in the canister space. The effect of trapped air was extended to the component percentage of the gases in the crushed coal samples, normally used for the estimation of Q3.

Keywords: *Air Column, Canister, Gas Contents, Coal.*

1. Introduction

Canister desorption is a widely used technique to measure the gas content of coal. The gas content data, when normalized to volume/weight and multiplied by coal seam mass, is used to estimate the gas in place in an area around the cored hole. However, the gas content and its components are likely to be influenced by the presence of trapped air column in the canister, particularly when the canister is not fully occupied by the coal column, and the trapped air, if not removed, is likely to be a concern.

Gas composition has been widely used to mean the percentage of each gas in a mixture of gas liberated from solid intact coal. This is not an appropriate phrase to be used when dealing with the gas content measurement using canisters. The use of the phrase "gas component percentage" is an acceptable terminology, as it refers to the percentage of each gas in the canister space, which may be influenced by the trapped contaminant air.

Three systems countering the influence of air column on the gas content of coal have been recognized in some gas processing laboratories, (a) by neutralising the canister air by flushing the air with helium gas; (b) by calculating the level of air components in the canister and then recalculating the gas content of the gas in the canister; and (c) by filling the air space with inert solid blocks and flushing out the rest of the remaining air with inert gas. Polymeric solid block rods are known to be used for canister's unoccupied space filling, as these rods do not react with coal gases. No consideration was given in this work on the issue of water vapour correction, as the objective of the paper was primarily for coal gas component percentage analysis and its variations with trapped air contaminants.

While all these techniques are used, however, no studies have previously been reported to scientifically examine the impact of the air trapped in canisters on the overall estimation of

(a) the gas content of coal (Qm), where Qm = Q1 +Q2 +Q3; (b) coal gas component percentages; and (c) component percentages of both Q2 and Q3. This paper reports the findings of the study, and demonstrates the importance of eliminating or flushing out air pockets in canister columns.

2. Measuremnt of gas content of coal

Measurement of the gas content of the coal samples involves three stages of Standards Australia (1999) [1]:

(i) Determining the gas lost from the coal sample during core sample recovery (Q1);

(ii) Measuring the gas desorbed from the coal sample, while sealed in a desorption canister (Q2);

(iii) Measuring the gas released from a coal sub-sample during crushing (Q3).

The gas content measured during the above-listed stages is added together to give the total measured gas content (Qm) as:

$$Qm = Q1 + Q2 + Q3 \qquad (1)$$

Qm represents the total volume of gas released per unit mass of coal when the ambient gas partial pressure is maintained at one atmosphere. Given the potential for variable temperature and atmospheric pressure conditions during the gas content measurement and differences in the mineral matter content of the coal samples, the results are typically normalized with Qm, being reported in NTP (20 OC and 101.325 kPa) and 10% non-coal matter (NCM) [1-2].

Two desorption methods are used in Australia, the fast and slow desorption ones, to directly measure the gas content of coal samples, as described in Australian Standard AS3980 (1999) [1]. Q1 is an estimated quantity of the gas component in coal; it is generally accepted to be the least accurate component of Qm [3-5]. The desorbed gas component (Q2) is a measure of the volume of gas released from a coal sample, whilst contained in a desorption canister. Duration of the Q2 test may be short in the case of a fast desorption method, less than one day or much longer in the case of slow desorption testing, not less than five days.

The crushed gas component (Q3) is a measure of the gas liberated from a coal sample following crushing. Following completion of the desorbed gas test, the coal core is removed and a representative sub-sample is collected and sealed into a crushing or grinding mill. Following crushing, volume of the gas liberated from the coal sample is measured using a water column similar to that used in the desorbed gas measurement.

In the fast desorption testing, where the desorption time is less than five days and typically less than one day, Q3 represents a large percentage of Qm. In the slow desorption time lasting over a period of time equal to or greater than five days, Q3 is quite low, and represents the residual gas content of the sample. The residual gas content is the volume of gas per unit mass of coal that is naturally retained within the coal and not readily released from an intact sample. The residual gas content also represents the portion of Qm that will not be liberated into the mine atmosphere from mined or intact coal (Diamond and Schatzel 1998).

Residual gas content is also an important consideration in the evaluation of coalbed methane gas recovery potential, as it represents the portion of Qm that will not readily flow to gas drainage boreholes [4]. Gas Chromatography (GC) is used to analyse the gas component percentages in coal.

3. Experimental study

The influence of the contaminant air trapped in the canister on gas component percentages of a coal column contained was studied experimentally. Fixed lengths of freshly-drilled coal core samples were inserted into different length canisters. Two sets of three canisters, 350 mm, 800 mm, and 1000 mm in length, were used, which allowed analysis of the samples with reduced air columns contained in their respective canisters. No attempt was made to determine the true gas content of coal in this particular study, as the objective was to examine the changes in the gas mixture component percentage caused by the presence of mine air trapped in the canister. The procedure adopted consisted of:

1) Studying the effect of varying air columns in transport canisters on the coal gas component percentage;

2) Elimination of the presence of air trapped in canisters by either flushing out the trapped air with inert helium gas or filling the unoccupied canister space with polymer rods plus helium gas to completely expel air out of the transport canister.

Freshly-cored coal samples, 45 mm in diameter, were obtained from three mines, mining coal from the Bulli Seam of the Sydney Basin. The mines were Tahmoor, Appin West, and West Cliff. The 300-mm long coal samples, once cored, were inserted and sealed in different length canisters. The loaded canisters were taken to the gas laboratories of both UOW and Illawarra

Coal- South 32 at Cordeaux Colliery, respectively. All the three mines are known to have high levels of mine gases, with varied mixture gas component percentages, ranging from 90% methane to 90% carbon dioxide [6]. The duration of the study was prolonged to over four years, and thus the sample collection for this study was varied over that period of the study.

The locations of the cores collected from the three mines were:

Tahmoor Mine: Coal Core samples were collected from Panel 810, maingate A at about 5 m away from the intersection between 47 and 48, as shown in Figure 1a. Three canisters were used for sample collection with the shortest canister having an internal space length of 350 mm, 55 mm ID.

West Cliff Mine: Core collections occurred in two different time frames, in 2011 and later in 2014. The samples collected in 2014 were drilled in Panel 516-38.5-1/1, shown in Figure 1b; the borehole direction was 45.5o, making it perpendicular to the cleat. The samples were retrieved from the drilled hole at a depth of 350 m.

Appin West Mine: Four sets of samples were taken from Appin West Mine. The sample sets one and two were extracted from a drill hole located in the panel 705 maingate, 8 Cut Through (C/T). Sample set one was first drilled at a depth of 20 m before the hole was continued to a depth of 41 m, and the core was excavated for sample set two. Samples for sample sets three and four were also cut from 705 maingate, from A heading at 21 C/T. The drilling direction was 15o to the cleat. For sample set three, the cores were retrieved from a depth of 60.5 m, while the set four samples were drilled from a depth of 80 m. The collection of samples from Appin West mine was confined to one period of samples collected in 2011.

In this work, the field results were confined to two mines, West Cliff and Tahmoor, and additional tests were made in the laboratory on the coal samples subjected to gas saturation using the indirect absorption method [6].
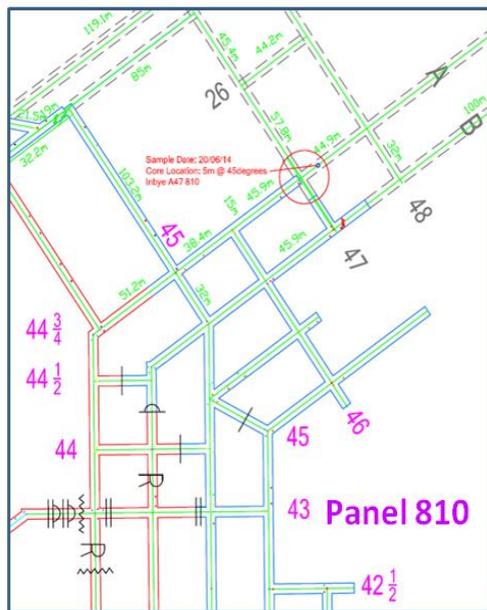

Figure 1a. Tahmoor Mine coal core sample location.
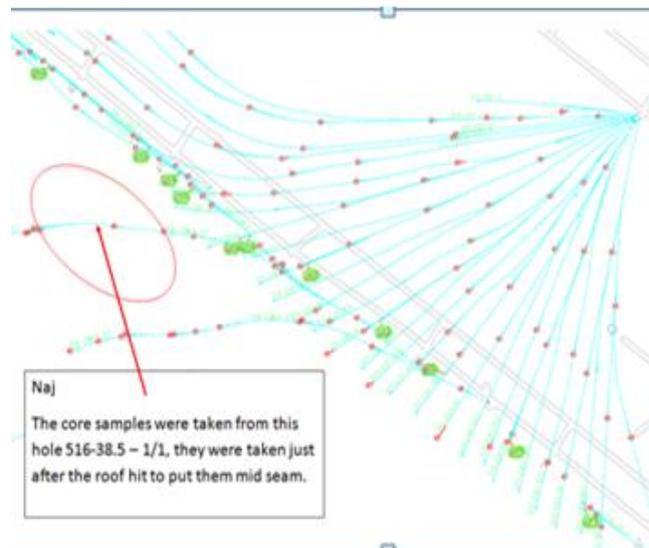
Figure 1b. West Cliff Mine coal sample location.

4. Results and discussion
4.1. Transport of coal in air-trapped canister
Figure 2 shows the three typical canisters used for collecting equal-length coal core samples. The coal samples were collected in canisters, and transported to the laboratory for gas mixture component percentage analysis. Samples of canister gas were extracted from each canister and fed to the GC. Three canisters of different lengths were used. They were 350 mm, 800 mm, and 1100 mm long. All canisters contained trapped mine air when sealed. Changes in the gas components were examined for both $Q2$ and $Q3$ of Qm.

Figure 2. Coal transport canisters of varying lengths.

Following the tests in each canister for changes in gas component percentages (canister gas composition) from extracted gasses released in the canister, the coal samples were removed from the canisters and crushed down to 200 mm. The released gas from crushed coal was collected and fed to the GC to determine the gas component percentages in the Q3 stage. Table 1 lists the analysis results of some relevant gas constituent components contained in three different-length canisters from West Cliff Colliery, and both the Q2 and Q3 levels. Figures 3 and 4 show the bar charts for gas at both the Q2 and Q3 stages, respectively. The following were found:

a) There was a clear variation in the gas component percentages contained in different canister lengths.

b) The oxygen and nitrogen levels were dependent on the quantity of trapped contaminant air in the canister.

c) The gas released from West Cliff Mine was rich in methane.

d) As expected, the variation in the gas mixture component percentages was consistent with the gas content of the coal in the panel, where coal was cored. The CH4 level recorded was higher in the shortest canister with less trapped mine air. The methane component of the mixed gas reduced with increased air column. Changes in the CO2 percentage were opposite to those for CH4.

Table 2 and Figures 5 and 6 shows the results obtained from Tahmoor Mine. Figure 7 shows the canisters with equal lengths of coal, and Figure 8 shows the procedure used for removing gas from the canister for GC analysis. The study found:

a) There were variations in the gas component percentages in different canister lengths and canister air volume;

b) The of O2 and N2 levels were higher in canisters with a large quantity of trapped air and in comparison with the smaller shorter length canisters with relatively less trapped air;

c) Gas component percentages of coal from Tahmoor Mine were relatively rich in CO2, and poor in CH4.

Table 1. West Cliff Mine gas percentage components at both Q2 and Q3 Stages.

Q2 LAB (May 30-2014)				Q3 May 2015			
Gas	**Gas (%)**			**Gas**	**Gas (%)**		
	350mm	**800 mm**	**1000 mm**		**350 mm**	**800 mm**	**1000 mm**
CO2	4.73	3.79	4.49	**CO2**	1.85	1.50	1.41
N2	19.60	36.54	48.85	**N2**	45.79	48.77	50.73
CH4	71.63	52.37	37.84	**CH4**	39.4586	35.60	33.23
O2	4.00	6.37	7.74	**O2**	11.3338	12.35	12.91
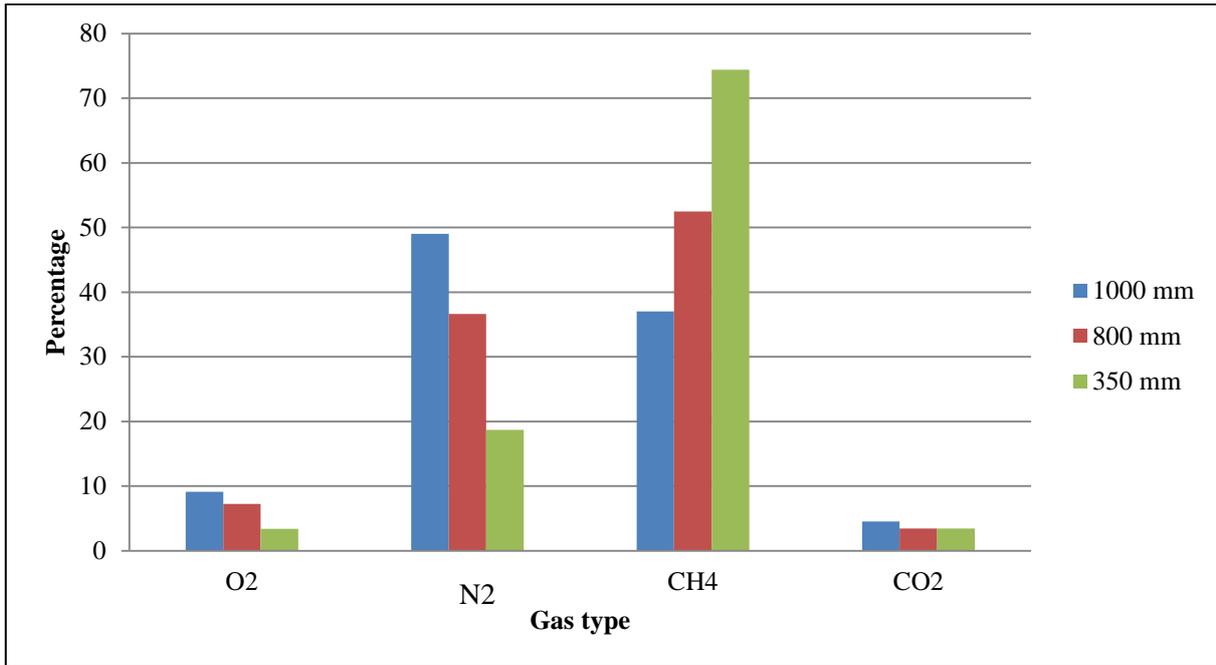
Figure 3. West Cliff Mine Q2 stage gas component in percentage in coal in different length canisters.
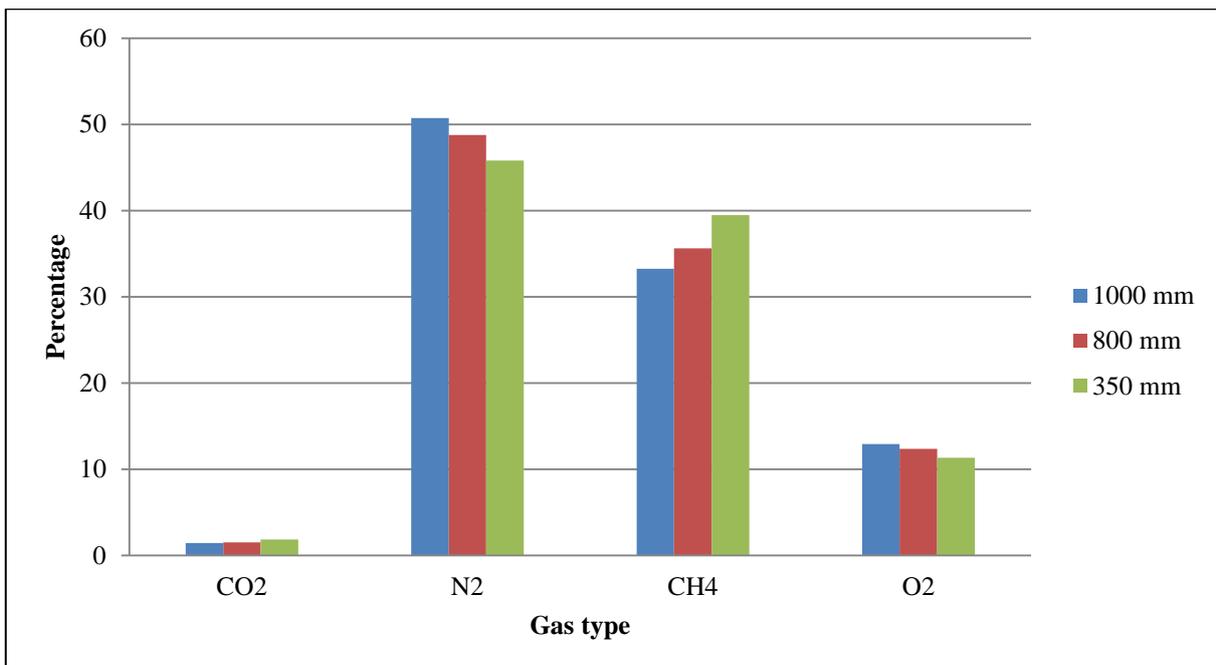

Figure 4. West Cliff Mine Q3 component percentage analysis from different canisters.

Table 2. Component percentage analysis for Q2 and Q3 - Tahmoor Mine.

| Q2 (Tahmoor - UOW)				Q3 (Tahmoor - UOW)			
Gas	Component percentage (% mol)			Gas	Component percentage (% mol)		
	350 mm	800 mm	1000 mm		350 mm	800 mm	1000 mm
CO2	0.34	13.35	23.03	CO2	25.50	22.87	13.52
N2	77.56	72.1	61.19	N2	55.58	58.09	64.99
CH4	0	0.9	2.86	CH4	3.35	2.86	3.34
O2	21.21	12.8	12.21	O2	14.40	15.05	17.03
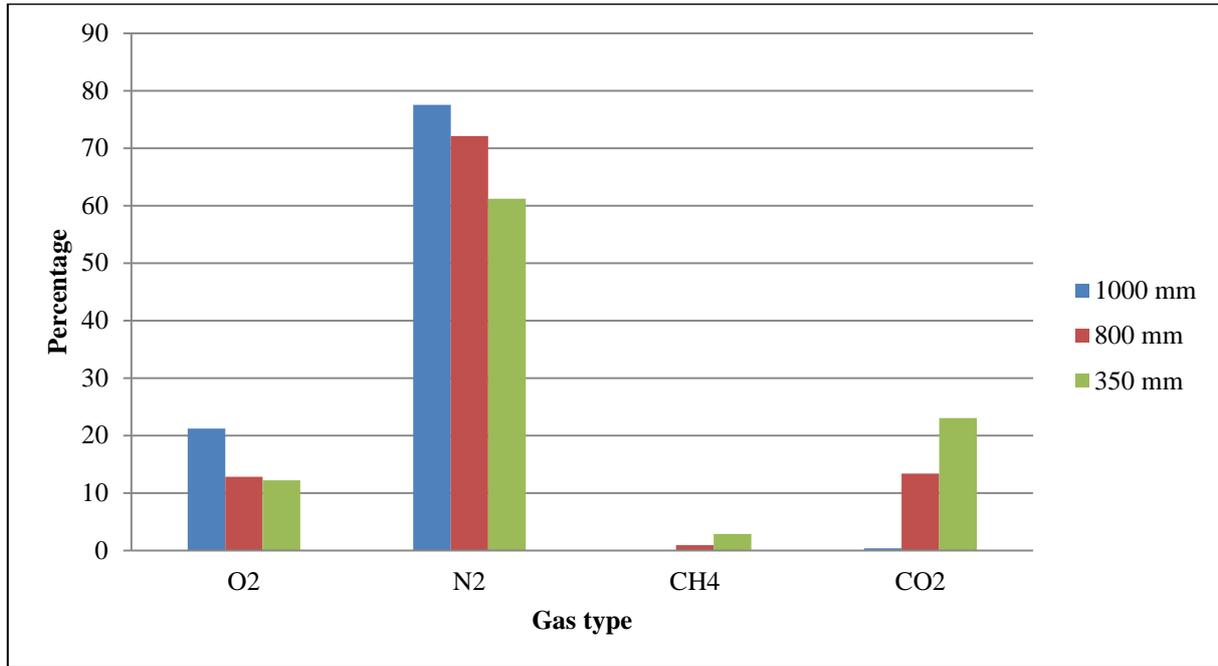
Figure 5. Tahmoor Mine Q2 gas component percentage analysis from different canisters.
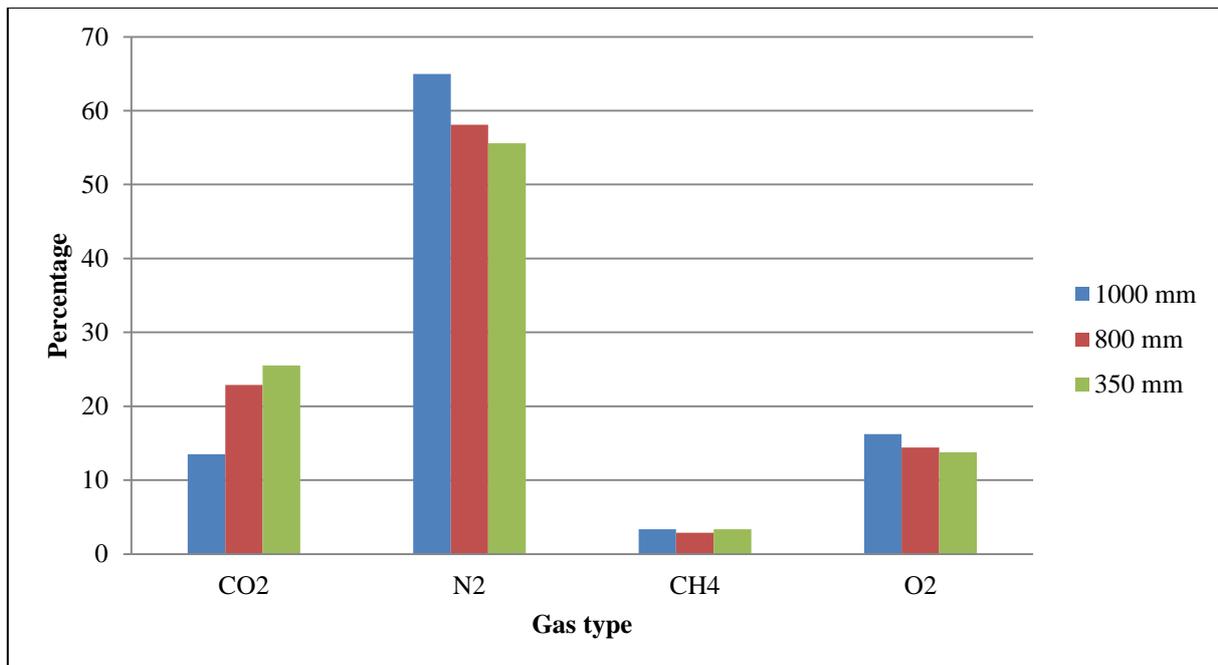

Figure 6. Tahmoor Q3 component percentage analysis from different canisters.

Figure 7. Equal coal column lengths inserted in canisters.

Figure 8. Gas transferred from canister to bags.

4.2. Air-free canisters

In this part of the study, as no freshly-drilled coal core samples were forthcoming from the local mines, it was decided to simulate the gas component percentage study in the laboratory by the indirect absorption method. 50-mm diameter coal samples were cored out of freshly-dug coal lumps, and brought to the laboratory from the mine. The cored coal samples were cut into 100-mm long samples, loaded individually into the sorption pressure vessel "bombs", and charged with methane gas to a pressure of 2000 kPa. The gas pressure was maintained constant until saturation. The gas saturated bombs were then opened, and coal samples were readily transferred to two 800-mm long canisters (canisters A and B). Each canister was loaded with three 100-mm long core samples (total length of 300 mm), as shown in Figure 9. The first canister (Canister A) was sealed with normal atmospheric air trapped in the empty space. In the second canister (Canister B), 100-mm long 50-mm diameter polymer rods, as shown in Figure 9b, were inserted to fill the unoccupied space above the coal column. Canister B was next flushed with the gas to expel air, and then sealed. Table 3 shows the component percentages in the two canisters with and without trapped air.

After two weeks, the samples of gas were extracted from the canisters and analyzed for gas component percentage. Figure 10 shows the component percentage results from the two canisters charged with CH4 gas. As it can be seen in Table 3 and bar charts in Figure 10, there were variations between methane concentrations in the two canisters at both the Q2 and Q3 stages. This exercise clearly demonstrated that the trapped air in the canister unoccupied space had an influence on the gas component percentage similar to that

obtained from the cored coal samples directly drilled from the coal seam.

It is clear from all the tests reported in this paper that the changes in the gas mixture component concentrations show that as the air column is increased, there would be a decrease in the CH_4 and CO_2 percentage volume/volume (%v/v) ratio, while O_2 and N_2 would show an increase in the %v/v ratio. These variations were clearly depicted in Tables 1 and 2, respectively, at the Q_2 percentage gas mixture component analysis stages. More significantly, the air column in the canister will have an effect on the gas component percentages due to the much lower partial pressures of the seam gas in the canisters with trapped air column during desorption.


Figure 9a. Canisters A and B.
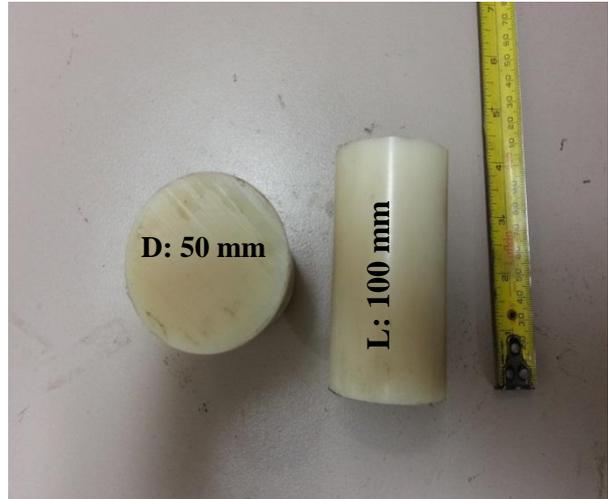
Figure 9b. Resin rods placed in canister A.

Table 3. Gas component percentage in two canisters with and without trapped air.

| Sample A	%	Sample B	%
Oxygen	13	Oxygen	5.81
Nitrogen	61.7	Nitrogen	33.8
Methane	23.5	Methane	50
Carbon dioxide	0.95	Carbon dioxide	0.9
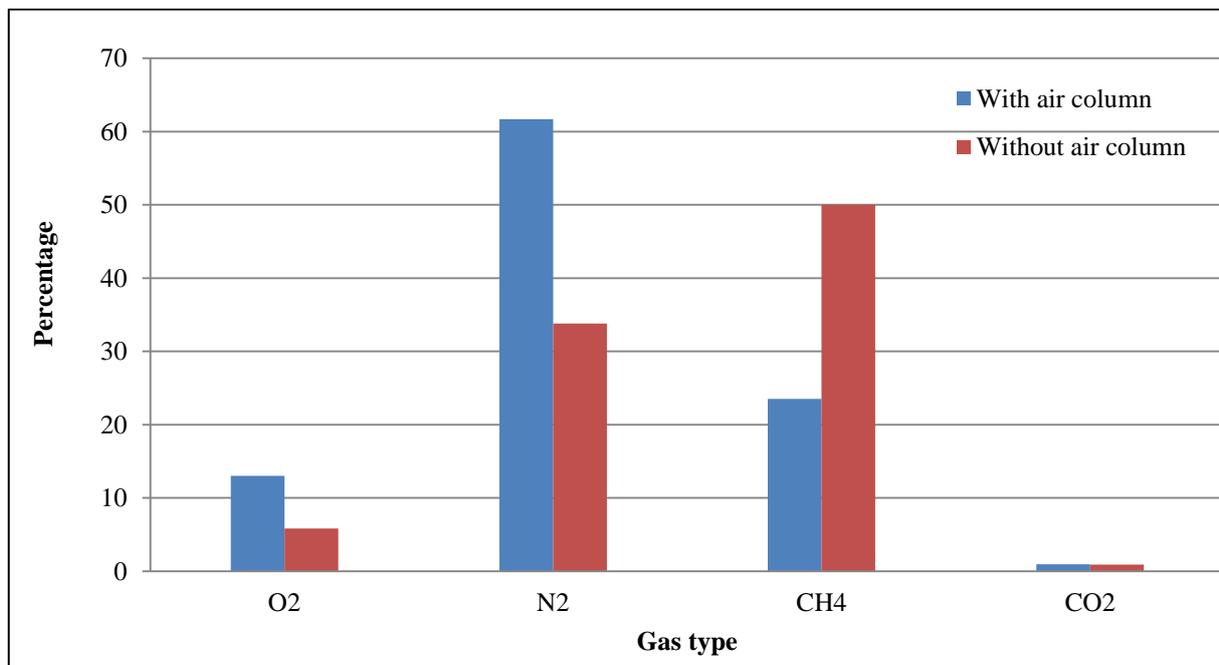
Figure 10. Component percentage with and without trapped air in canisters.

5. Conclusions

The presence of mine air in the transport canister is an issue that may influence the gas content determination of the coal seam. This is particularly important when the transport canisters are not fully loaded with coal. The impact of the air column appears to influence the released gas component percentages at both the Q2 and Q3 stages of Qm. Thus it is important to address the issue of the trapped contaminant air when canisters are partially filled with coal cores. Possible ways of removing contaminant air include filling the void with inert material like polymer rods, to be flushed with helium gas or flush the canister with the gas altogether. The alternative will be to use the %O2 to determine the air-free gas percentage components. More significantly, the air column length in the canister will have a decreasing effect on the gas mixture component percentages due to the much lower partial pressures of the coal gas in the canister during desorption.

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بررسی تأثیر ستون هوای مخزن انتقال در میزان گاز محتوی اندازه‌گیری شده زغال‌سنگ

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چکیده:

مخزن انتقال روشی است که برای اندازه‌گیری گاز محتوی زغال‌سنگ به طور گسترده‌ای استفاده می‌شود. داده‌های گاز محتوی برای تعیین نسبت حجـم بـه وزن و مقدار گاز موجود در لایه‌های زغال‌سنگ توسط مغزه‌های حفاری استفاده می‌شود. میزان گاز محتوی و درصد هر یک از اجـزا تشـکیل‌دهنـده متأثر از هـوای قـرار گرفته در مخزن انتقال زغال‌سنگ هستند. در این تحقیق، نمونه‌های زغال‌سنگ تازه حفاری شـده از سـه معـدن Appin West، West Cliff و Tahmoor از سیدنی جمع‌آوری شدند. در نهایت نتایج حاصل از این تحقیق نشان داد که درصد محتویات گاز محتوی نمونه‌های زغال‌سنگ متأثر از هوای ذخیره شده در مخـزن انتقال بودند.

کلمات کلیدی: ستون هوا، مخزن انتقال نمونه زغال‌سنگ، گاز محتوی، زغال‌سنگ.