

Computer Animation of Hot Spot Development in Bulk Coal as an Aid for Training Coal Miners

M Hancock¹, M S Kizil² and B B Beamish²

ABSTRACT

The processes that take place during the development of a heating are difficult to visualise. Bulk coal self-heating tests at The University of Queensland (UQ) using a two-metre column are providing graphic evidence of the stages that occur during a heating. Data obtained from these tests, both temperature and corresponding off-gas evolution can be transformed into what is effectively a video-replay of the heating event. This is achieved by loading both sets of data into a newly developed animation package called Hotspot. The resulting animation is ideal for spontaneous combustion training purposes as the viewer can readily identify the different hot spot stages and corresponding off-gas signatures. Colour coding of the coal temperature, as the hot spot forms, highlights its location in the coal pile and shows its ability to migrate upwind. An added benefit of the package is that once a mine has been tested in the UQ two-metre column, there is a permanent record of that particular coals performance for mine personnel to view.

INTRODUCTION

Self-heating leading to spontaneous combustion continues to pose a significant hazard during the mining of coal. A recent example of this is Southland Colliery in December 2003, where a heating progressed to ignition forcing the mine to be closed. Unfortunately, the heterogenous nature of coal and the contributing factors that control whether heat is gained or lost from the coal/oxygen system make it difficult to predict the onset of a heating with any confidence. In addition, it is difficult for mine personnel to visualise how a heating forms. Numerical models appear too complicated for most people and many of these are simplified to enable the complex equations involved to be solved.

It is important to gain an understanding of the nature of the progression of a heating in order to improve the effectiveness of preventive and control measures, including inertisation and emergency evacuation. By understanding the factors in heating progression, it is possible to estimate where an open fire may be initiated and predict the time until this is imminent.

Results from bulk coal testing at The University of Queensland's Spontaneous Combustion Testing Laboratory using a two-metre column (Figure 1) have demonstrated that heatings develop away from the edge and progress towards the oxygen rich side (Beamish *et al*, 2002). Monitoring of the off-gases produced by the coal heating provides a good indicator of when the development of an open fire is imminent.

The understanding of this migrating hot spot is relatively new and has potential to assist mine site and mines rescue personnel in better managing the risks of spontaneous combustion. An effective means to communicate the concepts and develop understanding is through visualisation of the hot spot development process.

A computer package was developed as a fourth year special topics in mining project to visualise temperature and gas data for The University of Queensland's two-metre column. The aim of the project was to develop a 3D model of the equipment, and then to create an animation that visualised the changes in

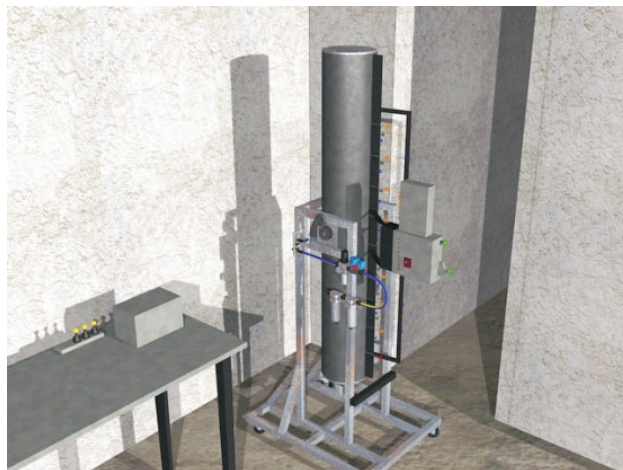


FIG 1 - The UQ two-metre column.

temperature and gas readings recorded from a column test over time. The package developed is called Hotspot and it helps the viewer to gain a better understanding of the way that a hot spot forms and migrates to become a major spontaneous combustion hazard. This paper presents the background to the operational inputs and outputs of the package as well as a series of snapshots from a test of a Bowen Basin bituminous coal.

THE HOTSPOT PACKAGE

The current version of Hotspot runs as a utility in the 3D Studio Max™ software environment. It uses the 3DSMAX architecture and the MAXScript programming language to create the visualisation animation. The utility loads the temperature and gas data from text files and performs a quick analysis. The results of the analysis may then be used to configure the visual environment by setting data ranges, selecting a time scale for the visualisation and setting other visualisation options. Once configuration is complete, the visualisation process may be executed. This produces an animated model in the 3D Studio MAX file format. This model can then be used to examine the data in real time, to render a distributable '.avi' movie file or to make still pictures at any point in the visualisation.

Hotspot currently visualises temperature readings from the eight thermocouples at the centre of the column (Figure 1), the levels of carbon monoxide, oxygen, hydrogen, methane, carbon dioxide, ethylene and ethane in the off-gas, and also the Graham's ratio of the off-gas stream. The visualisation allows for all this information to be seen together on one screen, changing over time. Used in this way, animation is a powerful and intuitive method of data visualisation for conveying data that spans time, indicates movement, or deals with multiple changing variables.

COAL SAMPLE AND UQ TWO-METRE COLUMN TEST PROCEDURE

Beamish *et al* (2002) describe the basic operation of the UQ two-metre column. The column has a 62 L capacity, which equates to 40 - 70 kg of coal depending upon the packing density

1. School of Engineering, The University of Queensland, Brisbane Qld 4072.

2. MAusIMM, School of Engineering, The University of Queensland, Brisbane Qld 4072.

used. The coal self-heating is monitored using eight evenly spaced thermocouples along the length of the column that are inserted into the centre of the coal at each location (Figure 1). Eight independent heaters correspond to each of these thermocouples and are set to switch off at 0.5°C below the coal temperature at each location so that heat losses are minimised and effectively semi-adiabatic conditions are maintained radially.

A sample of a Bowen Basin medium volatile bituminous coal was obtained from a larger batch of fresh run-of-mine (ROM) coal for testing in the UQ two-metre column. The coal particle size was kept below 150 mm, representing normal ROM coal and a size distribution of the sample was determined prior to loading into the column. The average particle size of the sample was 6.42 mm, based on the procedure described by Kunii and Levenspiel (1991) for estimating the surface-volume average particle size from the size distribution of the coal. Three subsamples were taken at this stage to obtain data on the as-received moisture of the coal.

The coal was loaded into the column with three 20 L plastic buckets. Once all the coal was in the column it was sealed and the heaters used to set the starting coal temperature of 25°C. This was achieved overnight. Air was then introduced to the coal at 0.5 L/min. A computer records all data at ten-minute increments. The column has several safety devices including computer-controlled trips on the external heaters and a temperature trip on the air inlet line. These were set to ensure maximum safety during operation of the column.

SNAPSHOTS OF A HEATING

A summary of the column test conditions is provided in Table 1. It must be remembered that the airflow used in this test is possibly an order of magnitude higher than that expected from air leakage, but it is still creates a low flow to mass ratio that would occur in a real heating.

TABLE 1

Parameters used for bulk coal self-heating test in the UQ two-metre column.

Sample mass	62.6 kg
Packing density	996 kg/m ³
Average particle size	6.42 mm
Initial moisture content	4.1%
Initial coal temperature	25 C
Airflow	0.5 L/min
Inlet air temperature	23 - 24°C

Snapshots from the Hotspot movie file of the test are presented for days six, 11, 13, 15, 16, 17, 18 and 19 in Figures 2 - 9 respectively. After the first six days the coal nearest the inlet has cooled to 23°C, while the coal approximately 1.5 m from the inlet has warmed up to 30°C (Figure 2). By day 11 the coal has warmed to almost 70°C at the same location and there is a noticeable increase in the Graham’s ratio, CO make and hydrogen evolution (Figure 3). A significant hot spot has formed by day 13, with the coal temperature reaching 130°C (Figure 4). By this stage ethylene is detected and the oxygen on the outlet begins to fall rapidly, due to the accelerated coal oxidation.

By day 15 the hot spot can be seen migrating towards the air source as the coal is now drier in this region and it is chasing the air to sustain the accelerated oxidation reaction (Figure 5). The gas levels are now increasing quite dramatically during this stage. By day 18 the hot spot has migrated to the bottom half of the column and also increased in size (Figure 8). By day 19 the hot spot has reached excessive temperatures (up to 270°C) and the test is terminated to prevent the coal reaching ignition.

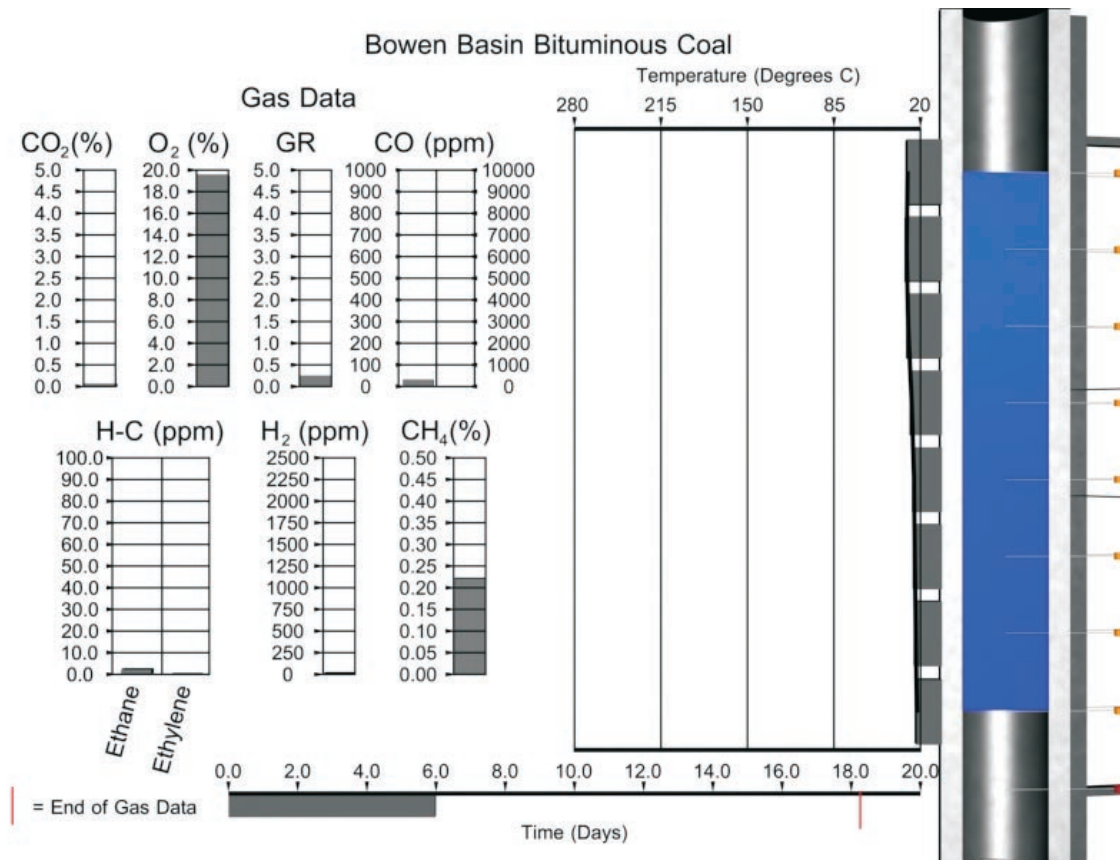


FIG 2 - Bowen Basin bituminous coal, day 6.

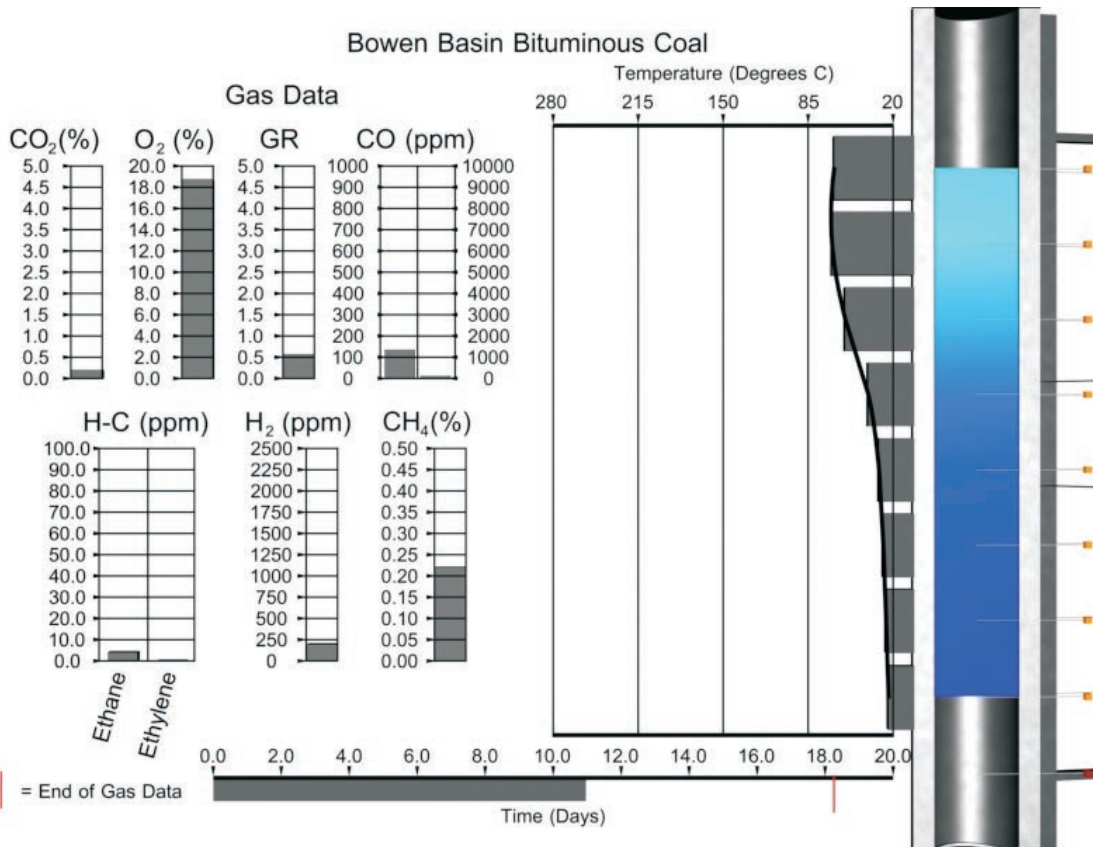


FIG 3 - Bowen Basin bituminous coal, day 11.

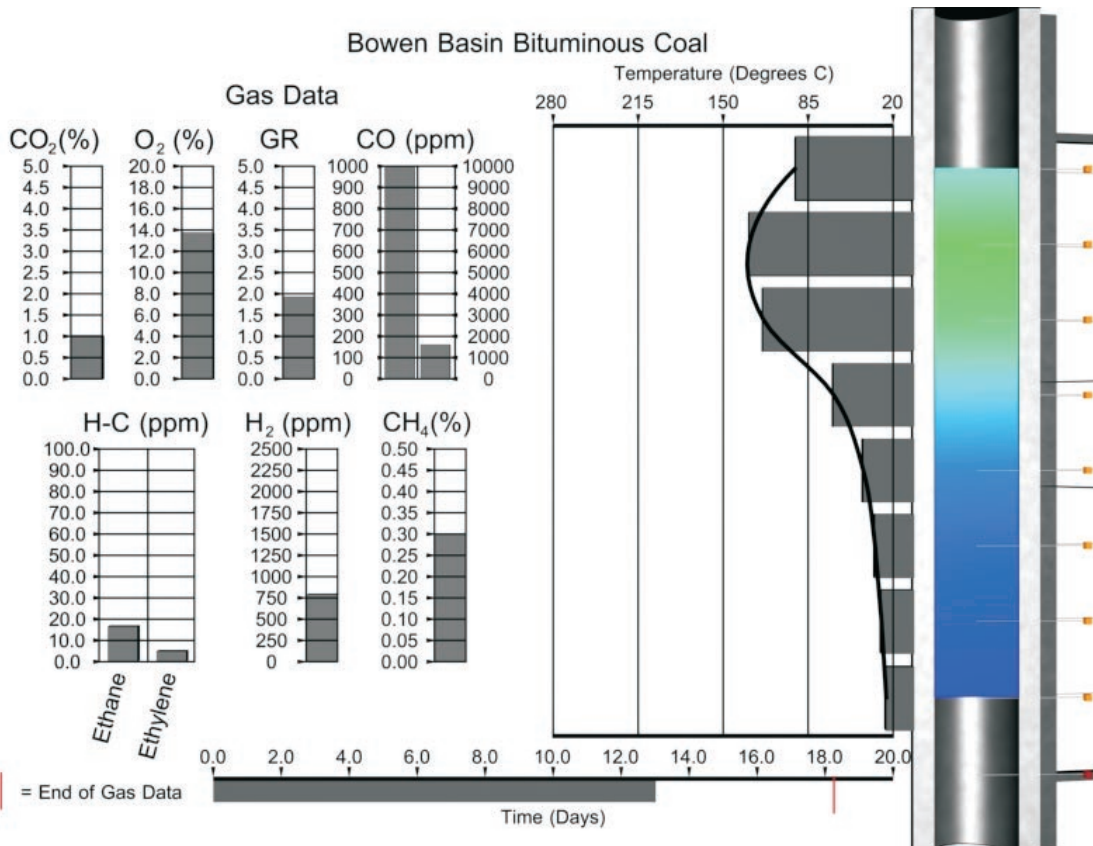


FIG 4 - Bowen Basin bituminous coal, day 13.

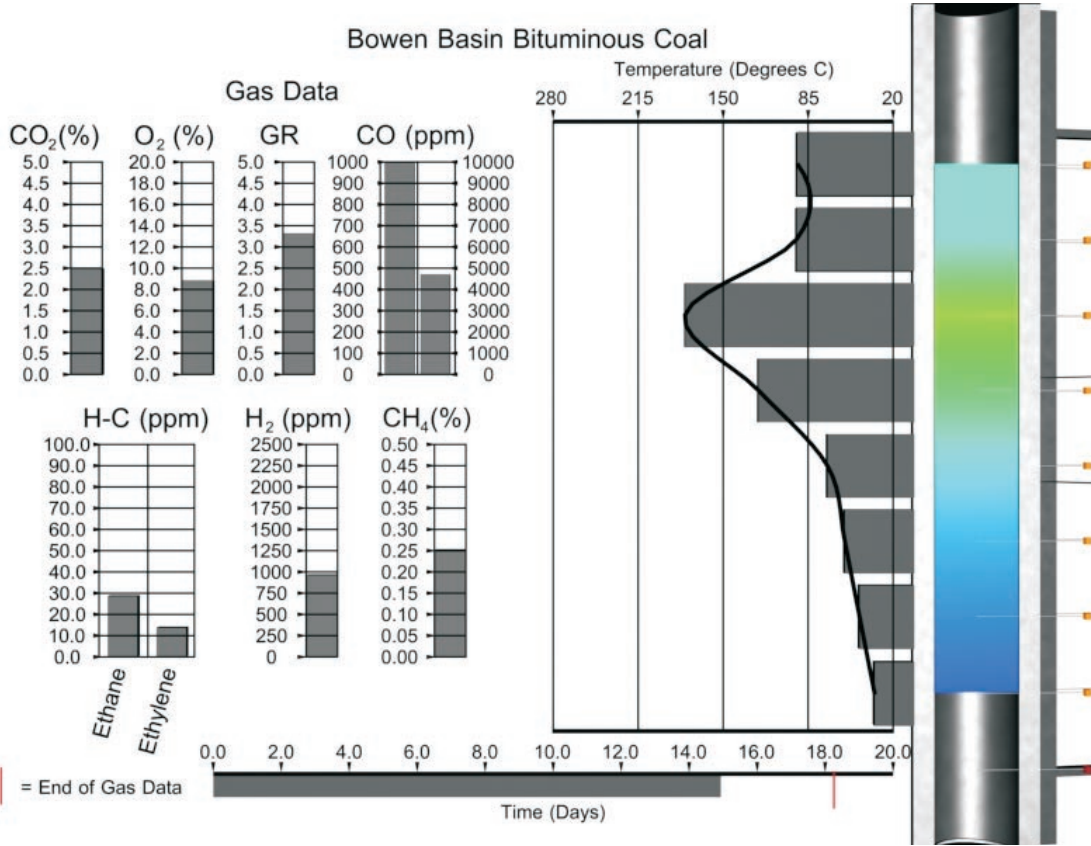


FIG 5 - Bowen Basin bituminous coal, day 15.

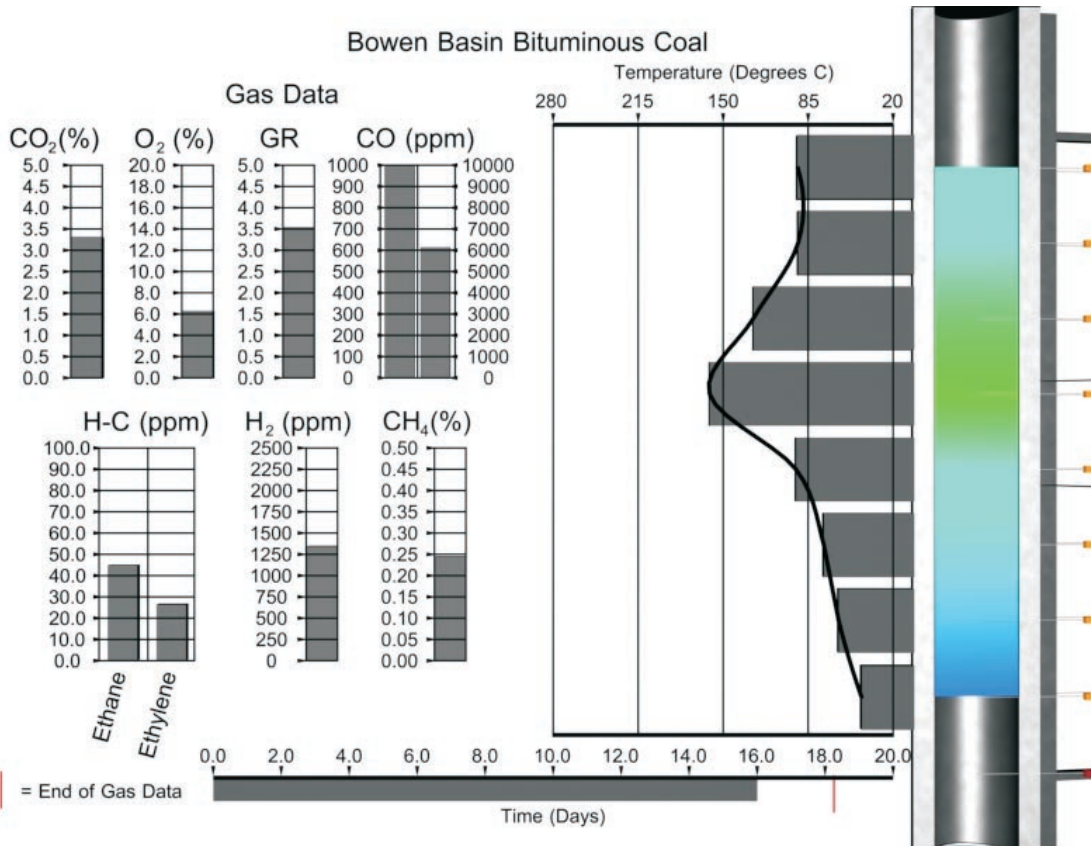


FIG 6 - Bowen Basin bituminous coal, day 16.

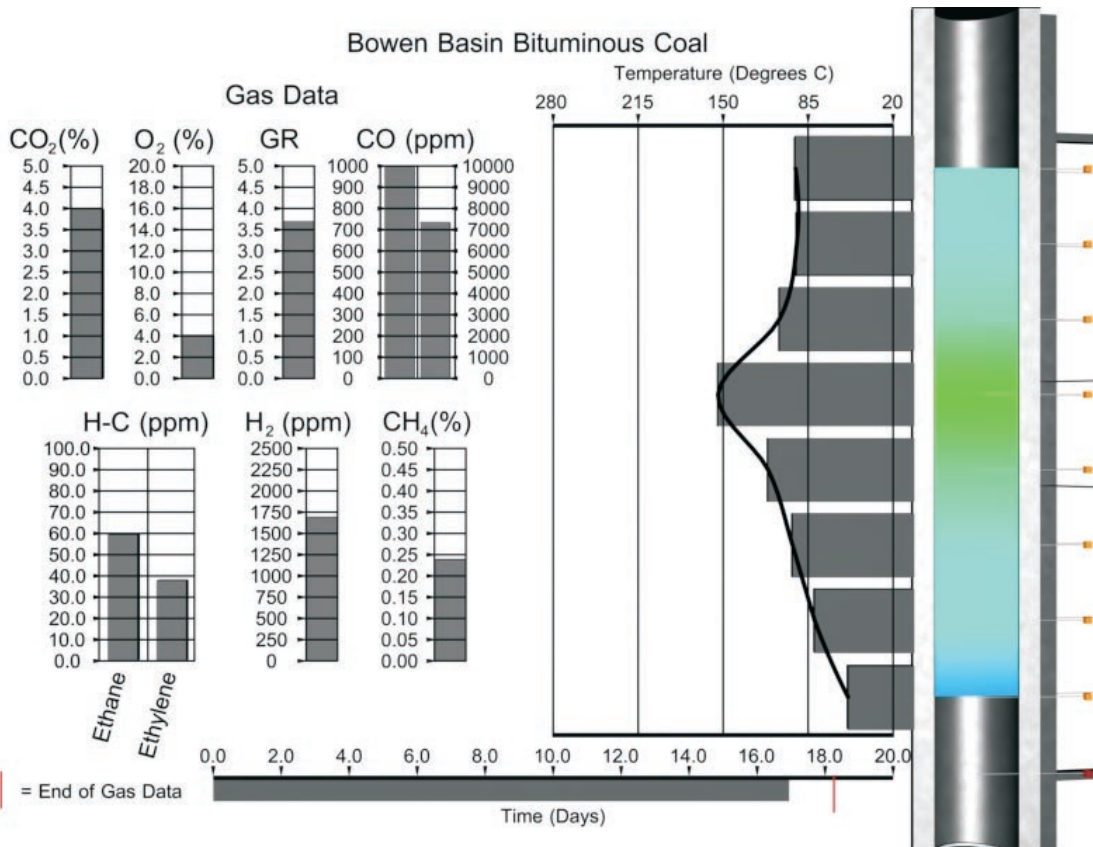


FIG 7 - Bowen Basin bituminous coal, day 17.

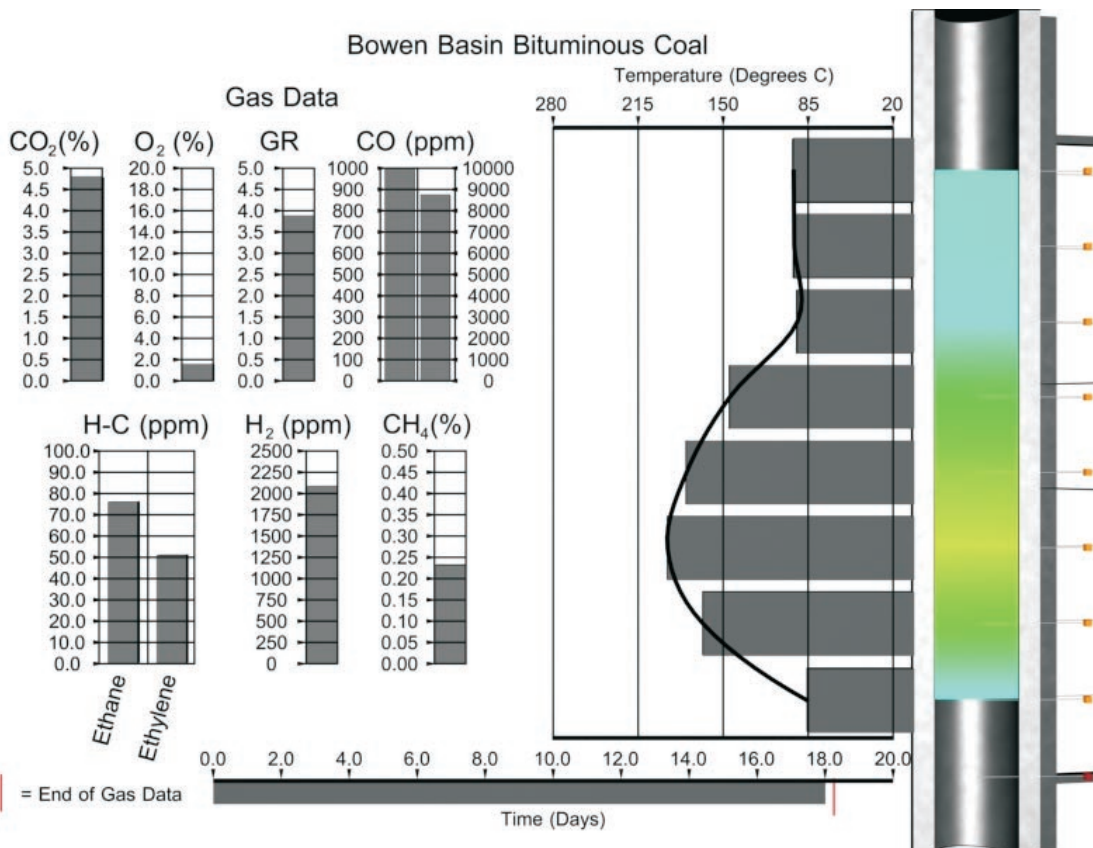


FIG 8 - Bowen Basin bituminous coal, day 18.

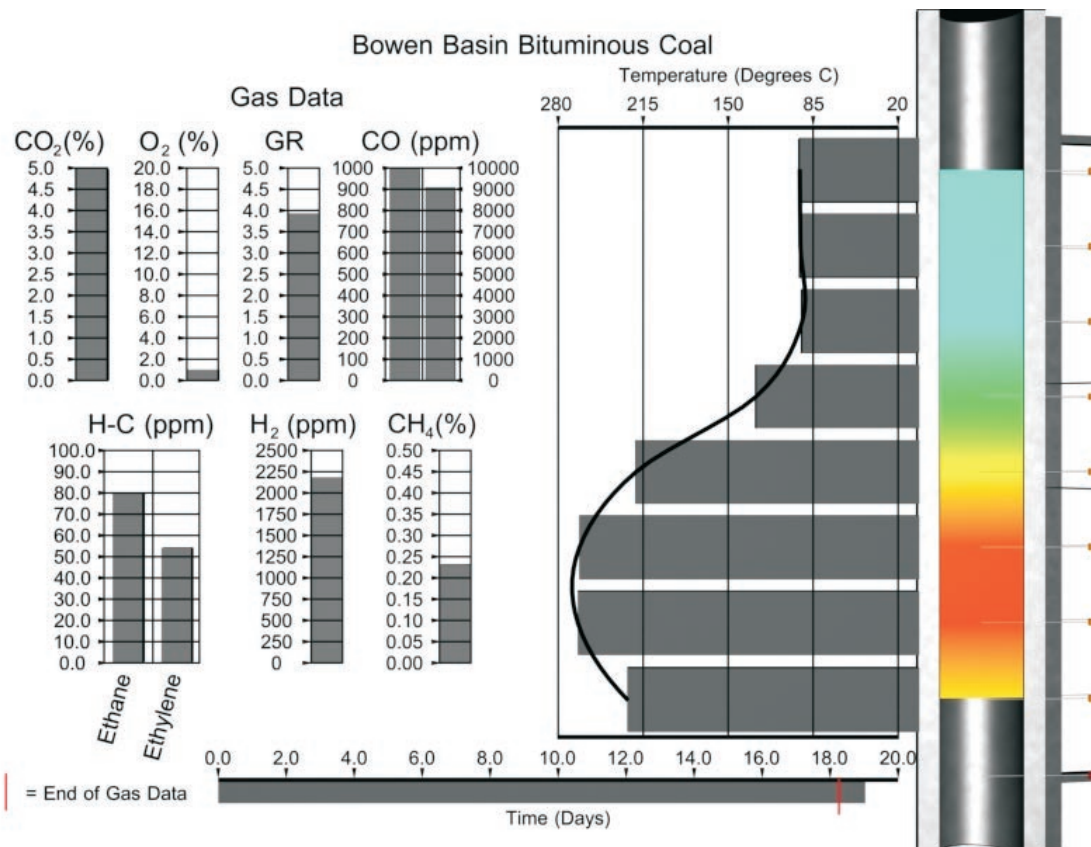


FIG 9 - Bowen Basin bituminous coal, day 19.

The results obtained from this UQ two-metre column test are completely consistent with the moist coal models published by Schmal, Duyzer and van Heuven (1985), Arisoy and Akgun (1994), Portola (1996), Monazam, Shadle and Shamsi (1998) and Akgun and Essenhigh (2001). The development stages of the hot spot, including the migration towards the air source, must be considered by mining personnel when assessing the risk of spontaneous combustion. By using the Hotspot package combined with individual testing of coal from each mine a better understanding of the spontaneous combustion risk can be obtained.

CONCLUSIONS

For the first time it is now possible to show mine personnel the stages that are associated with the development of a heating. Hot spot formation is not one continuous temperature increase, nor is it a stationary phenomenon. This feature of a heating is clearly shown in the results from bulk coal self-heating when they are loaded into the computer animation package Hotspot. This new development in spontaneous combustion visualisation provides a powerful training tool for mine personnel that can be tailored to show features relevant to the coal being mined. To achieve this, the coal must of course be tested in the UQ two-metre column using test conditions similar to that likely to be experienced at the mine. With the advances in computer visualisation technology it is envisaged that further enhancements of the Hotspot package will be possible in the near future that will provide even more benefit to the coal industry through

competency training for recognition of relevant gas sampling frequency and analysis to track hot spot development. In this manner simulation exercises can be produced to assist with advanced learning.

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