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# COMMISSIONING ADIABATIC OVEN TESTING – AN INTER-LABORATORY COMPARISON

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**ABSTRACT:** Adiabatic oven testing for spontaneous combustion assessment has been a primary method used by the Australian and New Zealand coal industries for input to the development of Principal Hazard Management Plans for mining operations. Consistency of results is important to ensure that the ratings obtained are accurate and reliable for maintaining the integrity of the database used to compare between mines and for obtaining site specific relationships. This paper presents the results from commissioning tests of four new adiabatic ovens at two different laboratories, which show the high level of reproducibility and repeatability needed for confidence in planning of future mining operations. The results cover a range of coal self-heating rates to show the validity of the testing and the reliability of the adiabatic ovens.

## INTRODUCTION

Adiabatic oven testing has been used routinely by Australian and New Zealand coal mine operations since the early 1980's to rate the propensity of coal to spontaneously combust (Humphreys, Rowlands and Cudmore, 1981). The parameter obtained from these tests is known as the  $R_{70}$  initial self-heating rate and is simply a measure of the temperature rise rate of the coal as it reacts with oxygen under adiabatic conditions from a start temperature of 40 °C until it reaches 70 °C. The higher the  $R_{70}$  value the higher the intrinsic reactivity of the coal and therefore the more prone it is to spontaneous combustion.  $R_{70}$  values are strongly rank dependent (Beamish and Arisoy, 2008a,2008b; Beamish and Beamish, 2012), with low rank coals having high  $R_{70}$  values (up to 99 °C/h for lignite) and high rank coals having low  $R_{70}$  values (less than 0.5 °C/h for medium and low volatile bituminous coals). Other coal properties such as mineral matter and coal type (dull or bright) can also affect the  $R_{70}$  value (Beamish and Blazak, 2005; Beamish and Clarkson, 2006; Beamish and Sainsbury, 2008). To gain a proper perspective of the overall propensity of a particular coal for spontaneous combustion it is therefore important to obtain a reliable result for  $R_{70}$  as an input to management planning.

Unlike other coal quality tests, there are no established repeatability and reproducibility limits for  $R_{70}$  testing. This is partly due to the fact that the test is very specialised and only a limited number of laboratories are available to do the test and partly due to the fact that this would be a costly exercise in terms of time and resources. To date there has been no published inter-laboratory comparison of  $R_{70}$  results. This paper provides an insight into the reliability of the  $R_{70}$  test by presenting the results of inter-laboratory comparisons during the commissioning of four adiabatic ovens at two new laboratories. Results from a decommissioned third laboratory are used for comparison to validate a seamless transition for the coal industry into the future.

## ADIABATIC OVEN TESTING

### Laboratories and coal samples

Two new laboratories have recently been established in Australia (LAB A) and New Zealand (LAB B) to provide testing capabilities for spontaneous combustion assessment. At each laboratory, two adiabatic ovens have been commissioned and comparison of the test results from each laboratory has been performed to establish repeatability for the ovens and reproducibility between the laboratories. In addition, a comparison has also been possible with previous results from a decommissioned third laboratory (LAB C) using a stored (frozen) block of coal from one particular mine. Other comparisons with previous mine results are on-going as new testing is performed for compliance at existing mines.

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The samples used in this inter-laboratory comparison cover a range of reactive high volatile bituminous and sub-bituminous coals from several mining regions.

### R<sub>70</sub> self-heating test procedure

The R<sub>70</sub> testing procedure essentially involves drying a 150 g sample of <212 μm crushed coal at 110 °C under nitrogen for approximately 16 hours (Beamish, 2005). Whilst still under nitrogen, the coal is cooled to 40 °C before being transferred to an adiabatic oven. Once the coal temperature has equilibrated at 40 °C under a nitrogen flow in the adiabatic oven, oxygen is passed through the sample at 50 mL/min. A data logger records the temperature rise due to the self-heating of the coal. The time taken for the coal temperature to reach 70 °C is used to calculate the initial self-heating rate for the rise in temperature due to adiabatic oxidation. This is known as the R<sub>70</sub> index, which is in units of °C/h and is a good indicator of the intrinsic coal reactivity towards oxygen.

## ADIABATIC TESTING RESULTS AND DISCUSSION

### Oven repeatability and reproducibility tests at LAB A

The R<sub>70</sub> self-heating curves for a Newcastle high volatile bituminous coal are shown in Figure 1. These tests were conducted over consecutive days in the same oven. This comparison shows that Oven 1 at LAB A obtained R<sub>70</sub> values of 4.73 °C/h and 4.90 °C/h, indicating excellent repeatability that is well within the limits of ±5% reported by Beamish, Barakat and St George (2000). The same sequence of repeat testing was applied to an Australian and US sub-bituminous coal and the results are shown in Figures 2 and 3, which confirm the same excellent repeatability for the adiabatic oven testing of a higher reactivity coal. In addition, the R<sub>70</sub> value obtained by Oven 2 at LAB A for the US sub-bituminous coal (Figure 3) shows good reproducibility between the two different ovens.

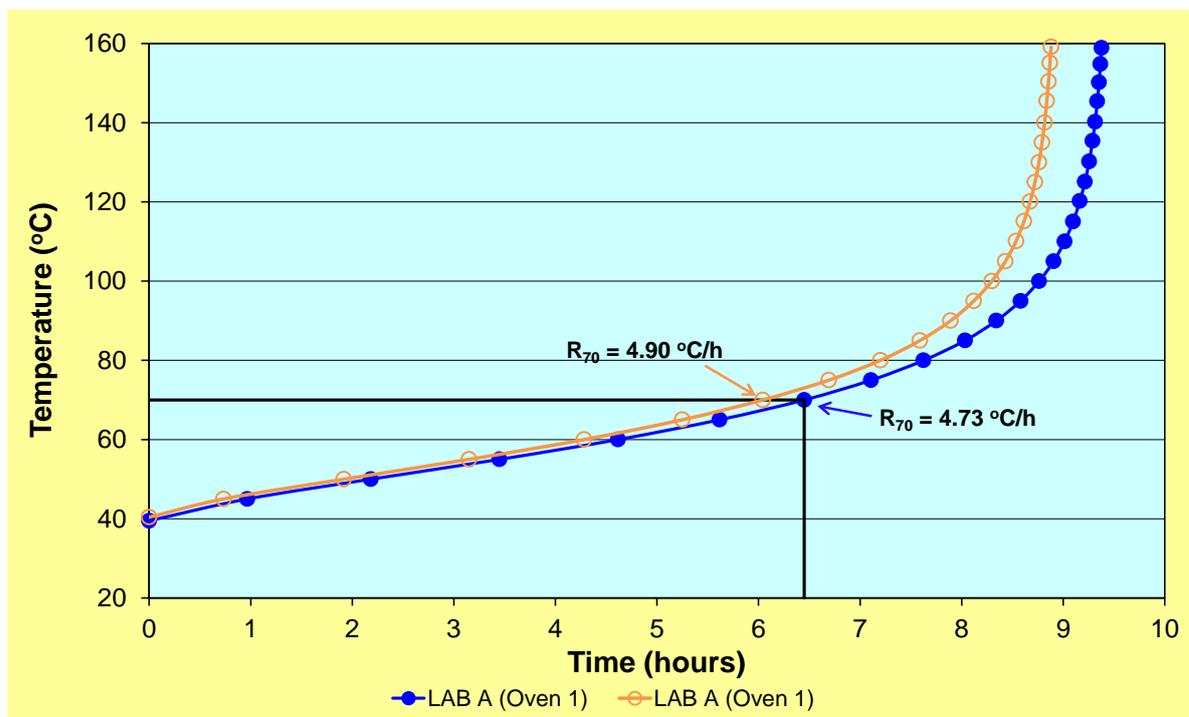


Figure 1 - Adiabatic self-heating curves for a Newcastle high volatile bituminous coal showing consistency of results between tests performed on consecutive days in oven 1 at LAB A

### Oven repeatability and reproducibility tests at LAB B

The R<sub>70</sub> self-heating curves for a New Zealand sub-bituminous coal are shown in Figure 4. The repeatability for Oven 1 and the repeatability for Oven 2 are almost identical for this highly reactive coal and both are within the limits of ±5% reported by Beamish, Barakat and St George (2000). The reproducibility between the two ovens is also very high as the average R<sub>70</sub> value for Oven 1 is

18.45 °C/h and for Oven 2 it is 17.98 °C/h. The  $R_{70}$  self-heating curves for a New Zealand high volatile bituminous coal are shown in Figure 5 for tests conducted in Oven 1 and Oven 2 at LAB B. Again there is good reproducibility between the two ovens.

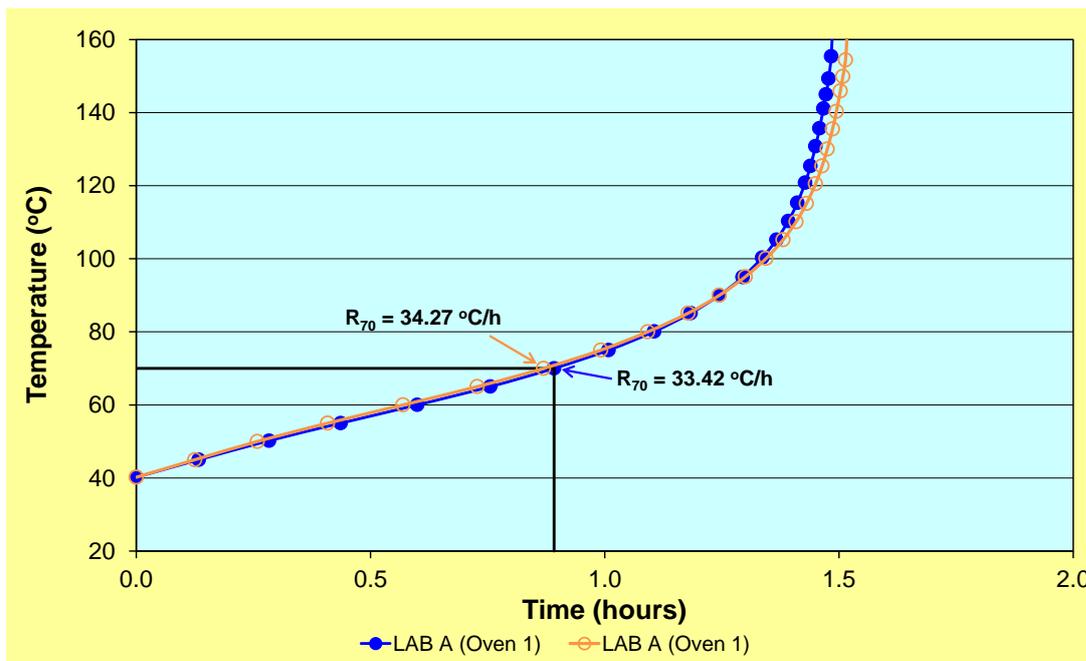


Figure 2 - Adiabatic self-heating curves for an Australian sub-bituminous coal showing consistency of results between tests performed in oven 1 at LAB A

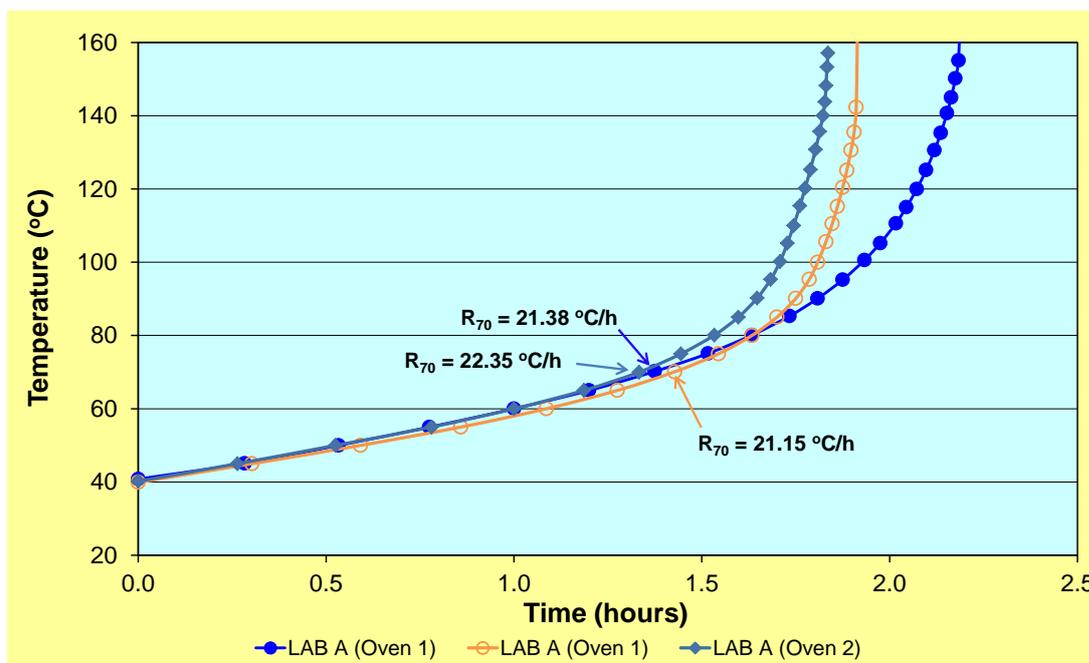


Figure 3 - Adiabatic self-heating curves for a US sub-bituminous coal showing consistency of results between tests performed on consecutive days in oven 1 at LAB A and a test in oven 2 at LAB A on the same coal

**Reproducibility between LAB A and LAB B**

$R_{70}$  test results for US sub-bituminous coal sample tested at both LAB A and LAB B are shown in Figure 6. There is excellent reproducibility between the  $R_{70}$  values obtained, which indicates that the sample preparation procedures as well as the oven performance at each laboratory are working very effectively.

Consequently, there is a considerable degree of confidence in comparing results between these two laboratories.

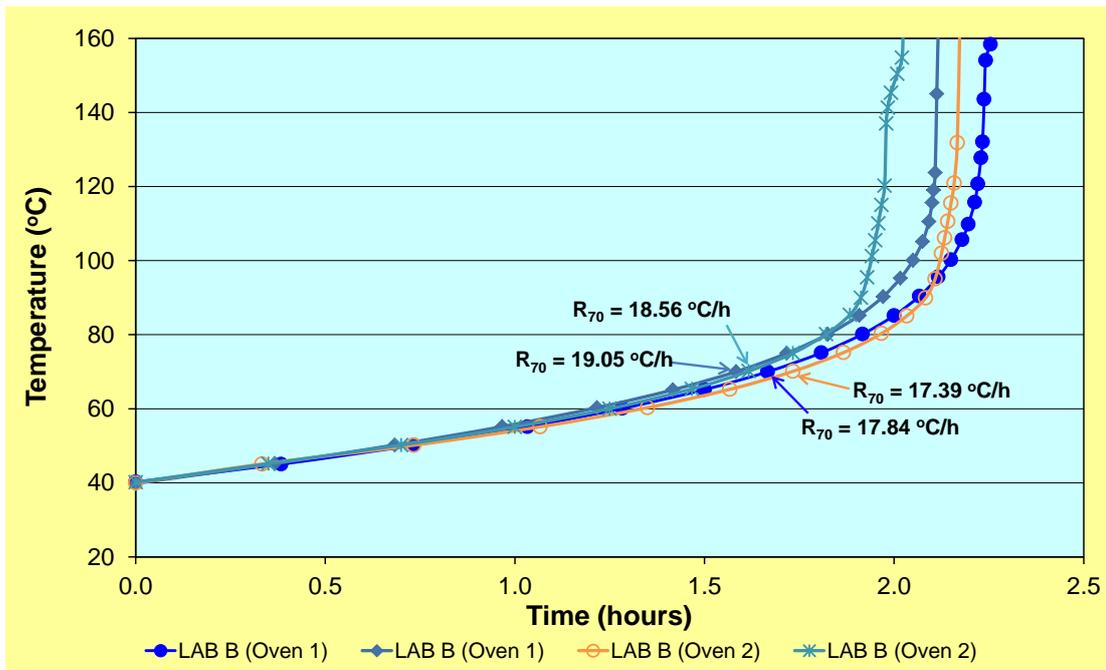


Figure 4 - Adiabatic self-heating curves for a New Zealand sub-bituminous coal showing consistency of results between ovens

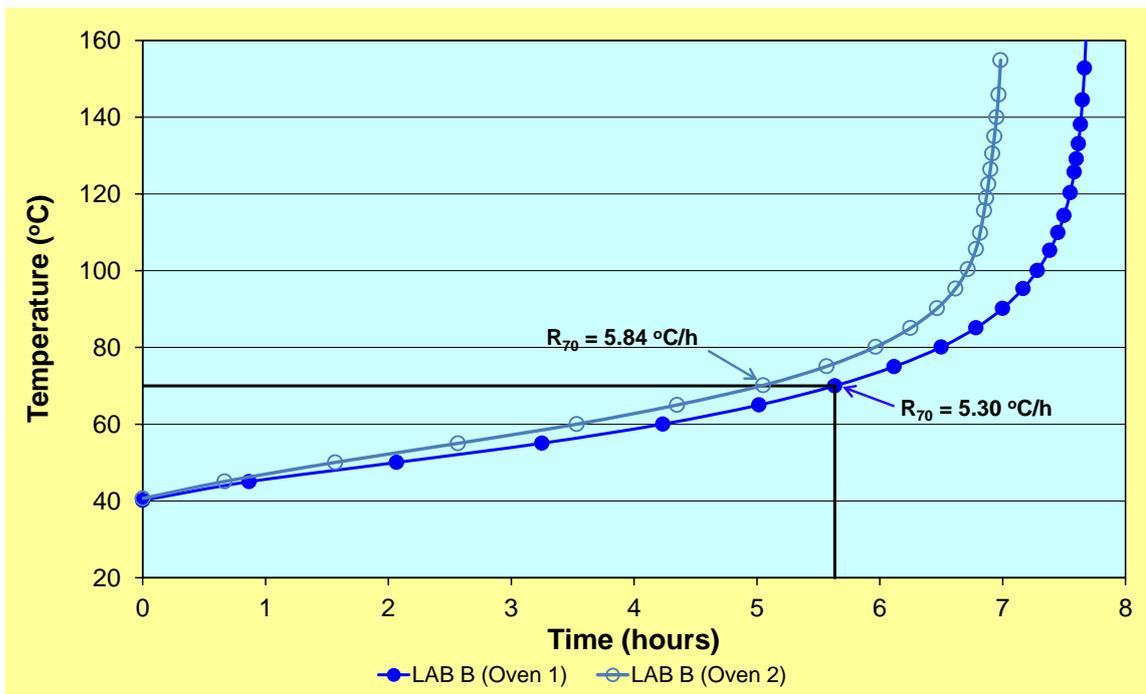


Figure 5 - Adiabatic self-heating curves for a New Zealand high volatile bituminous coal showing consistency of results between ovens

**Comparison between results from LAB A and previous results from LAB C**

The block of Newcastle high volatile bituminous coal tested at LAB A in 2013 was also tested at LAB C in 2007. Figure 7 shows that the self-heating test results overlap, indicating excellent reproducibility between these two laboratories. These results provide on-going confidence in the continuity of spontaneous combustion assessment at the mine extracting this particular coal. Test results from other

mines previously tested at LAB C are also showing good overlap with results from LAB A, thus maintaining the integrity of the large database across a range of mining operations around the world.

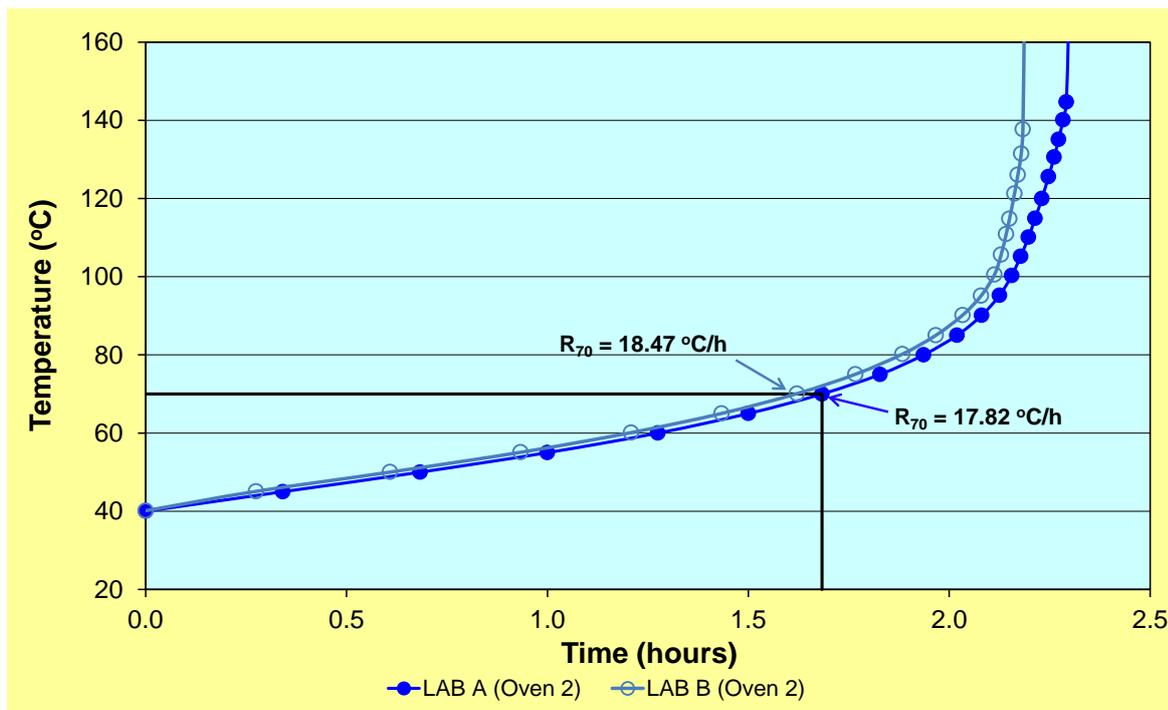


Figure 6 - Adiabatic self-heating curves for a US sub-bituminous coal showing reproducibility between LAB A and LAB B

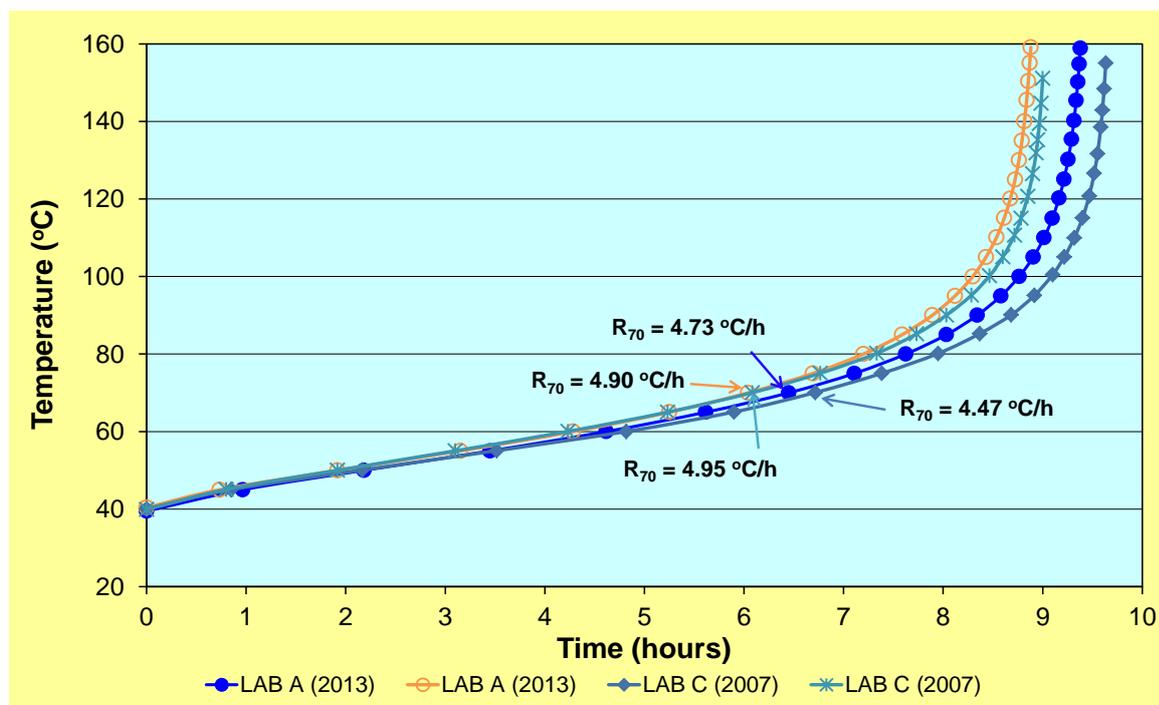


Figure 7 - Adiabatic self-heating curves for a Newcastle high volatile bituminous coal showing continuity of results over a long period of time

### CONCLUSIONS

The coal mining industry expects reliable and accurate results to be available for spontaneous combustion assessment as an input to the development of an appropriate Principal Hazard

Management Plan. No published data exists to establish the reproducibility of  $R_{70}$  self-heating rates between laboratories. As part of the due diligence process in establishing two new laboratories an inter-laboratory comparison has been performed that shows the high degree of repeatability and reproducibility that can be obtained for this parameter. The results obtained provide the industry with confidence when comparing results across mining operations and also in terms of establishing site specific relationships that can be used for developing a hazard map model. Comparison of results with a laboratory that is no longer in operation shows a good degree of consistency that provides continuity for future mining operations.

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