2009

Times to Ignition Analysis of New South Wales

J. Sargeant
University of New South Wales

B. Beamish
University of Queensland

D. Chalmers
University of New South Wales

Publication Details

This conference paper was originally published as Sargeant, J, Beamish, B & Chalmers, D, Times to Ignition Analysis of New South Wales, in Aziz, N (ed), Coal 2009: Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2009, 254-358.

TIMES TO IGNITION ANALYSIS OF NEW SOUTH WALES

Joel Sargeant[1], Basil Beamish[2] and Duncan Chalmers[1]

ABSTRACT: The 'times to ignition' theory has had limited use in the coal industry and virtually no use within Australia. The concept was originally applied to a range of Scottish coals to assess their spontaneous combustion propensity during transport in a 3x3m shipping hold. This paper presents results from an investigation into the application of the times to ignition (t_{ad}) concept to a range of New South Wales coals using data obtained from adiabatic oven self-heating tests. There is a strong association between t_{ad} and the R_{70} self-heating rate of a coal. The geographical location of the coal has a dramatic effect on the t_{ad} value as the initial coal temperature significantly changes the results by varying degrees.

INTRODUCTION

The coal mining industry will always be faced with the potential of a spontaneous combustion event, whether it is in an underground environment, in a coal stockpile, or during coal transport. There are many methods used for assessing the propensity of coal to spontaneously combust. One of the more common ones used in Australia is the adiabatic oven self-heating test (Humphreys, Rowlands and Cudmore, 1981; Beamish, Barakat and St George, 2000). Data obtained from this test is also amenable to reaction kinetic analysis, particularly once the coal temperature exceeds 70ºC. Parameters obtained from this analysis can be used as input to a 'times to ignition' concept proposed by Jones (2000) for assessing the risk of spontaneous combustion.

Adiabatic self-heating data was selected from the University of Queensland's Spontaneous Combustion Testing Laboratory database for analysis. This data consisted of seven samples from four New South Wales coalfields with ash contents in the range of 8-12%.

This paper presents the results of times to ignition analysis of these samples and shows the significance reaction kinetics has on spontaneous combustion behaviour.

TIMES TO INGITION BACKGROUND

The original times to ignition concept was derived by Boddington, Feng and Gray (1983), with the purpose of providing an analytical treatment for systems with distributed temperatures in which heat-transport is controlled by conduction. More recently, Jones (2000) used the concept in the calculation of coal transport ignition times. Equation (1) shows the expression used to calculate the times to ignition (t_{ad}):

$$t_{ad} = (RT_R^2/E) \times (c/QA) \times \exp\{E/RT_R\} \quad \text{(seconds)} \qquad (1)$$

where the times to ignition, t_{ad} is in seconds (s) of a reactant of specification A (pre-exponential factor) and E (activation energy) at initial temperature T_R, and c is the specific heat, Q is the heat of reaction and R the Universal gas constant. The expression QA/c can be obtained directly from the test data.

TIMES TO INGITION CALCULATIONS

Test data

Adiabatic oven self-heating test results were obtained on pulverised dry coal from a start temperature of 40ºC. The test procedure used is adequately described by Beamish (2005). All data was stored in an Excel spreadsheet for further analysis.

[1] *The University of New South Wales, School of Mining Engineering, UNSW Sydney*
[2] *The University of Queensland, School of Engineering, Brisbane QLD*

Times to ignition data analysis

Jones *et al.* (1996, 1998) used the Arrhenius equation for obtaining kinetic parameters from oxidation of Scottish bituminous coals. Under adiabatic conditions this equation can be expressed as:

$$\ln [dT/dt] = \ln (QA/c) - (E/RT) \qquad (2)$$

A plot of ln [dT/dt] versus 1/T will produce a straight line of slope –(E/R) and intercept of ln (QA/c). An example of this plot for one of the samples tested from the Gunnedah Coalfield is shown in Figure 1. Jones (2000) also showed that under adiabatic conditions a "times to ignition" value can be obtained from some initial temperature (T_R) if E/R (slope from Figure 1) and QA/c (y-intercept from Figure 1) are known for a particular sample and the values substituted into Equation (1).

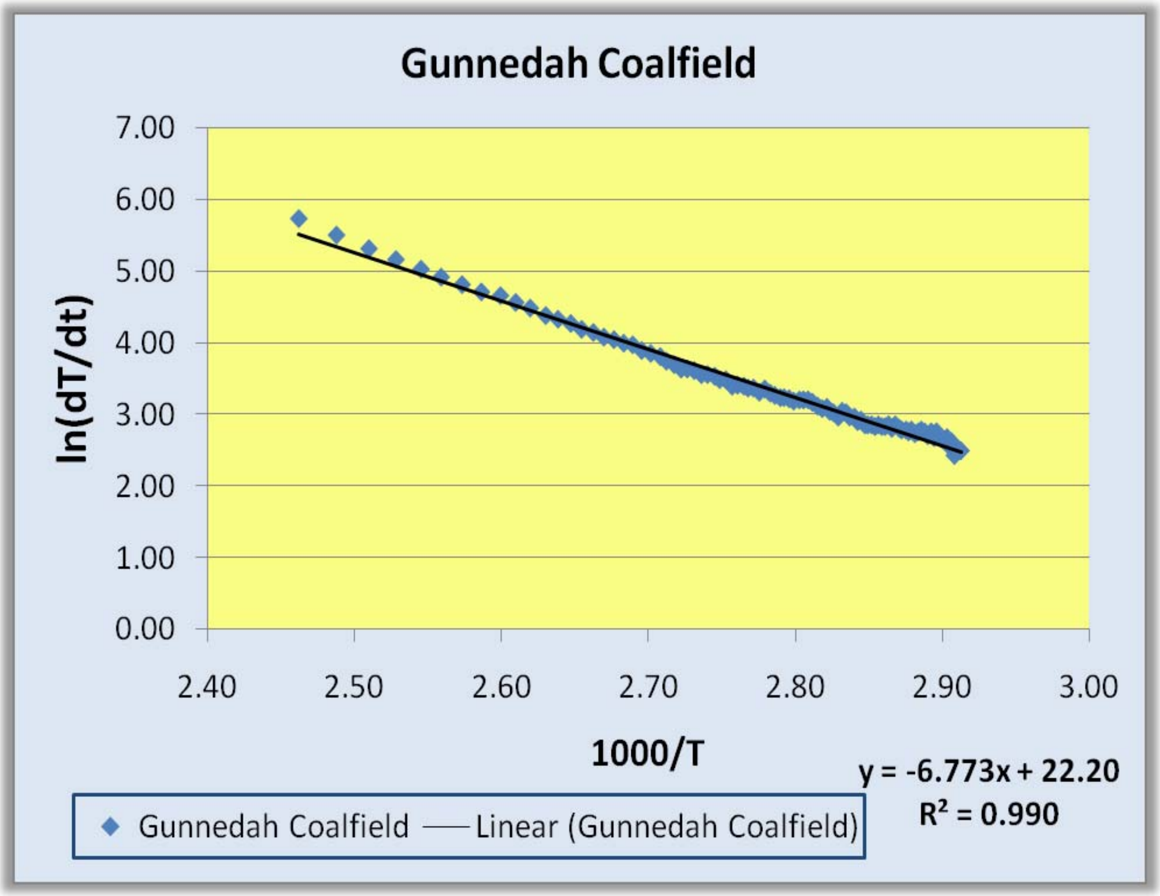

Figure 1 - Example of Arrhenius plot for adiabatic self-heating results from a sample of Gunnedah coal

RESULTS OF TIMES TO IGNITION ANALYSIS AND DISCUSSION

Variation in times to ignition

The range of t_{ad} values is shown in Table 1. The Southern Coalfield sample has a t_{ad} value of 57 days compared with 0.92 days for the Gunnedah Coalfield sample. It is interesting to note that the Southern Coalfield sample is a high rank coking coal, whereas the Gunnedah Coalfield sample is a lower rank steaming coal. Both coal rank (Beamish, 2005) and coal type (Beamish and Clarkson, 2006) have previously been linked to differences in spontaneous combustion propensity. It must also be remembered that these samples have been tested in a completely dry state and the influence of moisture in the coal on the kinetics of the oxidation reaction have not been taken into consideration. Further work is in progress on this effect as it is known to have a major impact in terms of delaying thermal runaway.

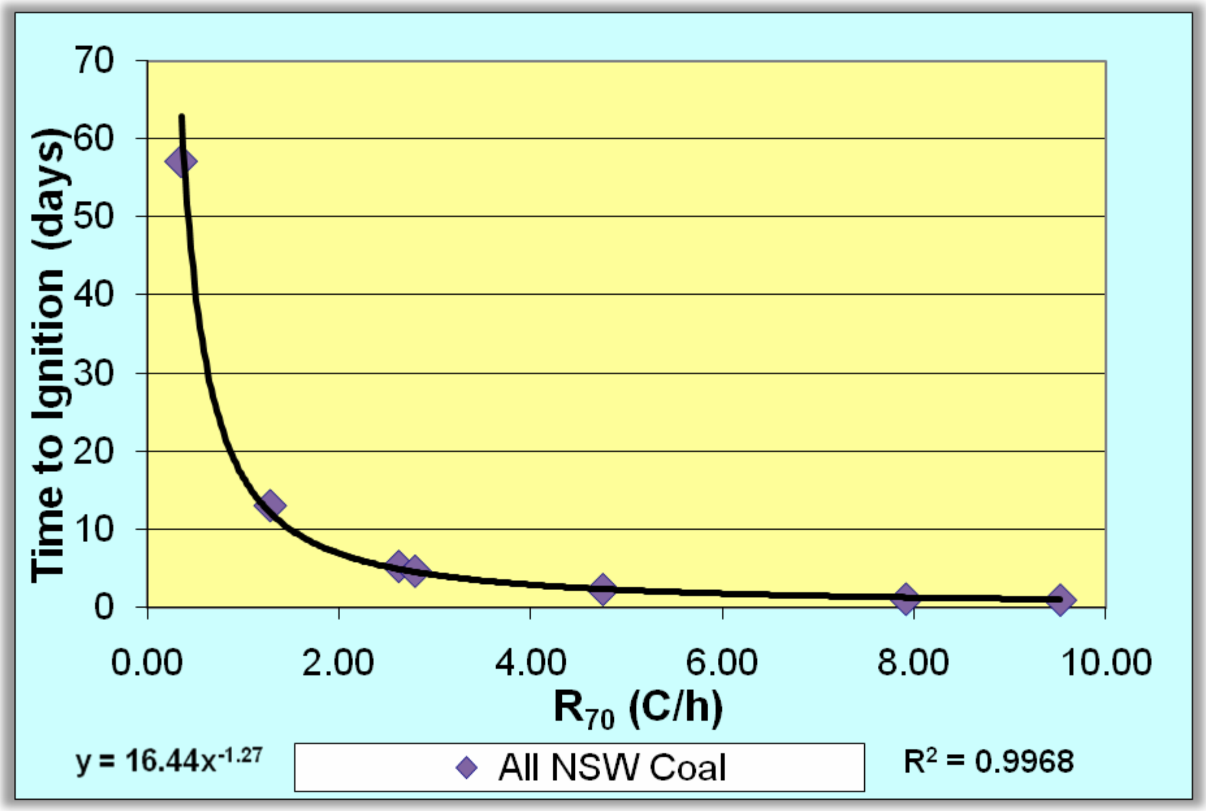

Figure 2 - relationship between t_{ad} and r_{70} self-heating rate

There is a strong non-linear relationship between t_{ad} and R_{70} self-heating rate (Figure 2). This is somewhat surprising as the t_{ad} calculations are based on the portion of the adiabatic self-heating curve above 70°C and the R_{70} value is obtained from the 40-70°C portion of the curve.

Table 2 - Calculated t_{ad} values by NSW coalfield

Location	T_{ad} (days)	R_{70}	Ash % db
Southern Coalfield	57.15	0.35	9.7
Hunter Coalfield 1	13.03	1.28	10.1
Newcastle Coalfield	5.24	2.62	9.3
Hunter Coalfield 2	2.27	4.75	10.9
Hunter Coalfield 3	1.03	7.91	11.8
Gunnedah Coalfield	0.92	9.52	8.1
Newcastle 1	4.63	2.79	11.6

Effect of start temperature on times to ignition

The t_{ad} start temperature has a large impact on the resultant time to ignition, which is shown in Figure 3. The value of 25°C used for NSW conditions was compared to 40°C, to replicate Queensland conditions and outline the difference a simple change in temperature has on t_{ad}. The Southern Coalfield sample t_{ad} value reduces from 57 days to approximately 17 days. It is clear from Figure 3 that a coal mined in New South Wales may not create a spontaneous combustion issue, but the same coal mined in Queensland would create a problem.

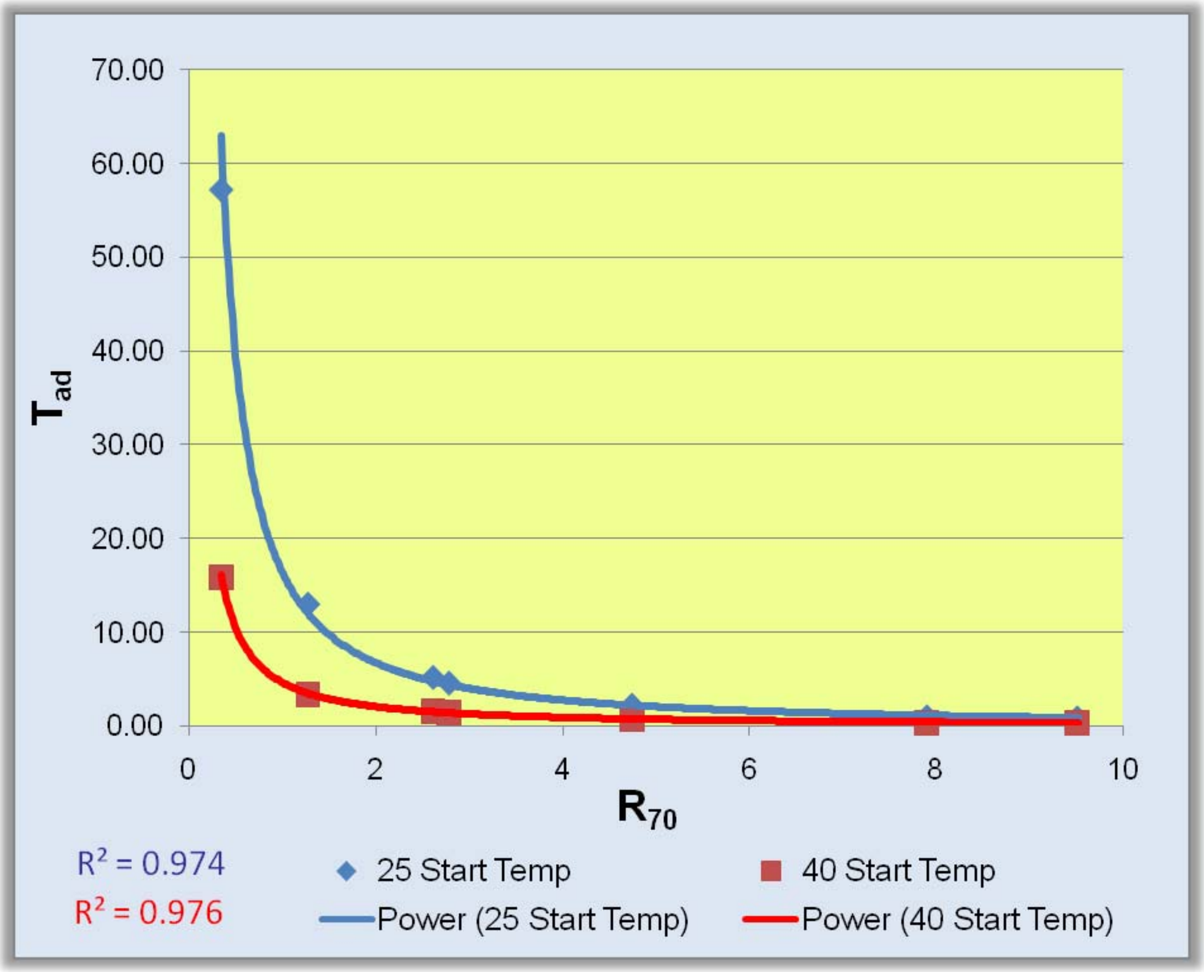

Figure 3 - Comparison of start temperature effect on t_{ad} values

CONCLUSIONS

The times to ignition (t_{ad}) concept has been applied to New South Wales coals using data obtained from adiabatic oven testing. Generally, high rank coking coals have the highest t_{ad} values and lower rank steaming coals have the lowest t_{ad} values. This is due to the significant difference in activation energy required for the oxidation reaction to take place in each of these coal types. There is a strong non-linear relationship between the times to ignition and R_{70} self-heating rate obtained from the same test data. More importantly the time to ignition analysis emphasises the importance of the coal start temperature on the time to ignition due to the exponential effect of the Arrhenius kinetics of the oxidation reaction, whereby as the temperature increases the rate of reaction increases. Therefore it is crucial that mines obtain coal temperature data to be input to any spontaneous combustion propensity assessment.

ACKNOWLEDGEMENTS

The authors would like to thank UniQuest Pty Limited for granting permission to publish this paper and Mining Education Australia for supporting the collaboration between The University of Queensland and The University of New South Wales to work on this project.

REFERENCES

Beamish, B B, 2005. Comparison of the R_{70} self-heating rate of New Zealand and Australian coals to Suggate rank parameter, *International Journal of Coal Geology*, 64(1-2), pp139-144.

Beamish, B and Clarkson, F, 2006. Self-heating rates of Sydney Basin coals – The emerging picture, in *Proceeding of the 36th Sydney Basin Symposum*, pp. 1-8, University of Wollongong.

Beamish, B B, Barakat, M A and St George, J D, 2000. Adiabatic testing procedures for determining the self-heating propensity of coal and sample ageing effects, *Thermochimica Acta*, 362 (1-2), pp79-87.

Boddington, T, Feng, G-C and Gray, P, 1983. Thermal Explosion and times-to-ignition in systems with distributed temperatures. I. Reactant Consumption Ignored, paper presented to Proceedings of the Royal Society of London A, Mathematical and Physical Sciences.

Humphreys, D, Rowlands, D and Cudmore, J F, 1981. Spontaneous combustion of some Queensland coals, in *Proceedings of Ignitions, Explosions and Fires in Coal Mines Symposium*, pp5-1 - 5-19, The AusIMM Illawarra Branch.

Jones, J C, 2000. On the role of times to ignition in the thermal safety of transportation of bituminous coals, *Fuel*, 79, pp1561-1562.

Jones, J C, Chiz, P S, Koh, R, and Matthew, J, 1996. Kinetic parameters of oxidation of bituminous coals from heat-release rate measurements, *Fuel*, 75, pp1755-57.

Jones, J C, Henderson, K P, Littlefair, J and Rennie S, 1998. Kinetic parameters of oxidation of coals by heat-release measurement and their relevance to self-heating tests, *Fuel*, 77, pp 19-22.R P, 2000.