

**Agglomeration and Defluidisation Behaviour of High-Sodium,
High-Sulphur South Australian Lignite under Fluidised Bed
Gasification Conditions**

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DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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LIST OF REFEREED PUBLICATIONS

McCullough, D.P., Mullinger, P.J., and Ashman, P.J., “The agglomeration behaviour of Lochiel coal during fluidised bed gasification,” *CHEMECA 2003*, 28th Sept.-1st Oct. (2003), Adelaide, South Australia.

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ABSTRACT

The accumulation in the atmosphere of man-made gaseous emissions, including CO₂, CH₄, and N₂O, are seen as a major contributor to climate change via global warming. Electricity generation is a major contributor to the production of these ‘Greenhouse Gases’ in Australia, mainly due to the reliance of the electricity industry on coal combustion. Vast reserves of lignite in South Eastern Australia ensure that coal will continue to be an important fuel for base load power generation for many years to come. Fluidised bed gasification is a process that has the potential to significantly reduce gaseous emissions from coal-based power generation. However, the ash-related problems of agglomeration and defluidisation may prevent the widespread commercialisation of such technology unless a control methodology for these problems can be developed.

An experimental program was developed for the current study to test the impact of agglomeration and defluidisation in a 77 mm spouted bed gasification reactor, utilising high-sodium, high-sulphur content lignite. Lignite from the Lochiel deposit in South Australia was used as the test coal. Gasification tests of 4 hour duration each were performed over a wide range of different operating parameters, including bed temperature (759 to 967°C), spouting velocity (0.50 to 0.68 m/s), air to fuel mass ratio (0.3 to 3.5), and steam to fuel mass ratio (0.4 to 10.5). The effect of steam content of the gasification environment on agglomeration and defluidisation was of particular interest. Steam content of the inlet fluidising gas was subsequently varied from 10 to 90 wt% over the range of experiments conducted. In addition, a limited number of tests were conducted in a 300 mm pilot-scale gasification reactor, which were designed to test the practicality of findings obtained from the spouted bed gasification tests.

Agglomeration and defluidisation in the pure char bed is governed by the ‘high temperature defluidisation limit’, which describes the increase in minimum fluidisation velocity with bed temperature beyond the temperature at which the ash begins to sinter. When operating at a superficial velocity below this limit, coating of solid mineral particles from the coal by molten ash phase creates particle growth. This particle growth eventually causes the bed to defluidise, resulting in a reduction of pressure drop from below the distributor to the freeboard. The temperature excursions that this creates results in an

increase of ash sintering, causing coalescence of ash particles into larger ash deposits that form at the walls of the bed. Lochiel coal demonstrated defluidisation behaviour at temperatures as low as approximately 860°C under atmospheric pressure conditions. At 8 bar pressure, defluidisation was observed in the temperature range of 800 to 850°C.

The high sodium content in Lochiel coal was found to result in the formation of the sodium disilicate-quartz eutectic (approximately 76 wt% SiO₂) in the steam gasification environment. This species has a eutectic melting point of approximately 790°C, which corresponded to the minimum defluidisation temperature encountered in a set of experiments operated with extreme steam content in the fluidising gas (i.e. approximately 90 wt% steam). This species was held primarily responsible for initiating molten ash formation during gasification, and this corresponds to findings from a previous fundamental study in the Cooperative Research Centre (CRC) for Clean Power from Lignite.

Agglomeration and defluidisation control methods for fluidised bed gasification of high-sodium coal were developed. Bed temperature is a key factor in the control of molten ash formation, and should be minimised to avoid formation of molten sodium silicate phases in the ash. A bed temperature of approximately 850°C at atmospheric pressure was suggested as the maximum temperature that a gasification reactor should be operated at when using high-sodium lignite. At higher pressures, this maximum temperature should be lowered further, as the sodium disilicate melting point decreases with increasing pressure. Under these conditions, maximum bed temperature should be maintained below approximately 800°C to avoid agglomeration and defluidisation. Use of steam in the gasification reactions should also be limited as much as possible, with the finding that the minimum temperature of agglomeration decreased with increasing steam content of the fluidising gas. A maximum steam to fuel ratio value of approximately 0.4 wt/wt at atmospheric conditions will limit the formation of low melting point sodium silicates. Additives high in calcium and magnesium, such as dolomite, can also be used to promote the formation of high melting point calcium and magnesium silicates in the ash.

The results of this study demonstrate that lignite containing high levels of sodium in the ash can be used effectively for commercial gasification operations, provided that the operating parameter limits described in the preceding paragraph are adhered to wherever

process considerations permit. This presents the opportunity for utilising lignite reserves in South Eastern Australia that are currently not viable for use in conventional combustion boiler systems due to the significant fouling that is incurred by these fuels. Recommendations for future study include conducting more extensive pilot scale trials, including an in-depth assessment of the use of additives for chemical control of molten ash formation, and the role of pressure in the formation of low melting point silicates. Other fuels, such as lignite from lower quality seams, and biomass, should also be investigated to determine the applicability of results from this study to different fuel types.

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