Gasification Behaviour of Rhenish Lignite

Laboratory Characterisation

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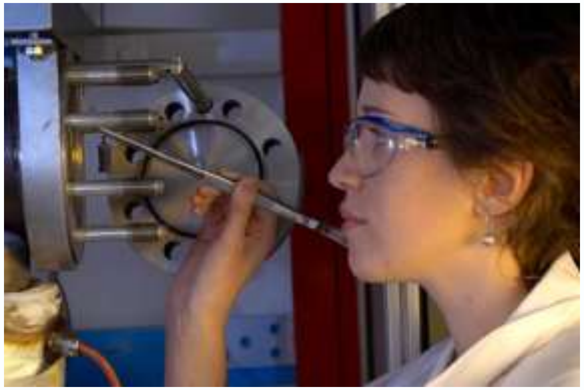
Background and Context

Entrained Flow Gasification of Lignite



Increasing interest in lignites as an energy source

- Inexpensive, abundant
- High reactivity, low ash

Challenges associated with thermal processing of lignites

- High moisture
- Low energy content
- Alkali and other corrosive inorganic species

Renewed interest in lignites for

- Upgrading for transportation, export etc
- Processing to high value products such as transport fuels

Joint research program between CSIRO and TU Bergakademie Freiberg

- Characterisation of gasification behaviour of Rhenish lignites for use in entrained flow and other gasification technologies

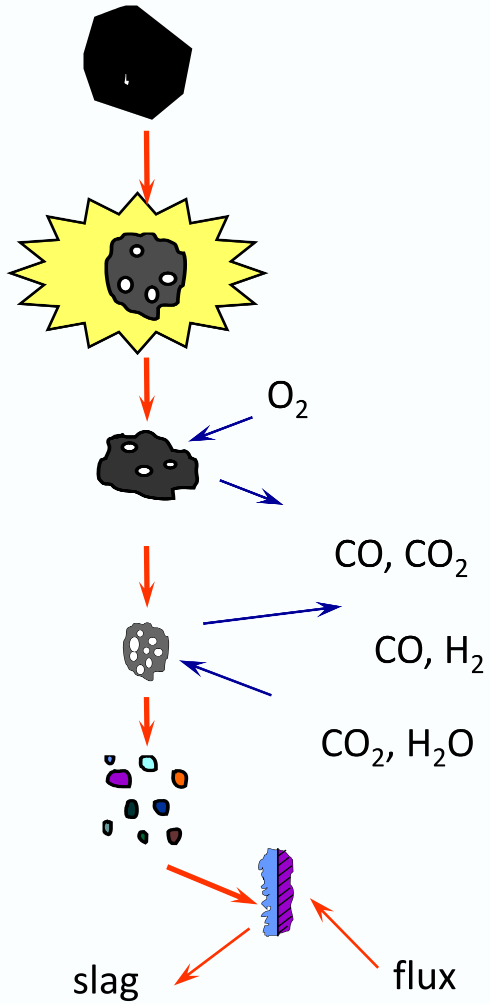
Background and Context

The Role of Laboratory Data in Understanding Fuel Performance

This work is part of a wider study into impacts of devolatilisation conditions on coal to char transformations

- Impacts of pressure, temperature and heating rates on
  - Volatile yields
  - Char surface area, structure and morphology
  - Char reactivity
- Wide range of coal types
  - Lignite to semi-anthracite
  - Caking and non-caking

A systematic study to provide the basis for developing relationships between coal and char properties under relevant gasification conditions.



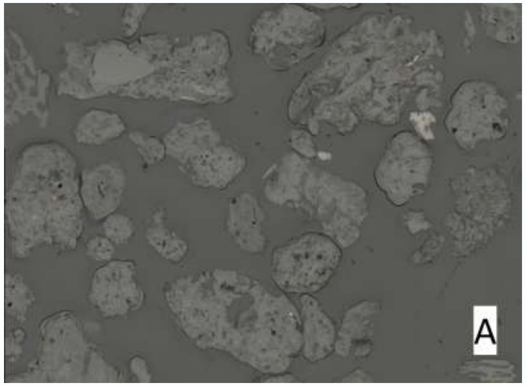
Coal Samples

	TUF102	TUF104
Size	-200+105 um	-180+45 um
PROXIMATE ANALYSIS (ad)		
Air Dried Moisture %	40.6	29.1
Ash %	5.1	6.8
Volatile Matter %	30.8	42.5
Fixed Carbon %	23.5	21.6
ULTIMATE ANALYSIS (d.a.f.)		
Carbon %	69.9	68.7
Hydrogen %	4.46	4.66
Nitrogen %	0.89	0.78
Sulfur %	0.46	0.76
Oxygen (By Difference) %	24.3	25.1
Calorific Value MJ/kg		17.10

Rhenish lignite

As-supplied sample prepared for use in laboratory facilities:

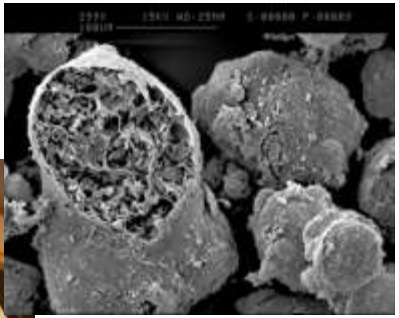
- -200+105 um for WMR testing
- -180+45 um for other work
  - Air classification led to some drying of product

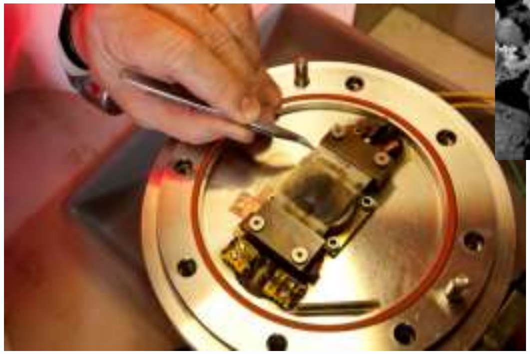


High Pressure Heated Grid Reactor

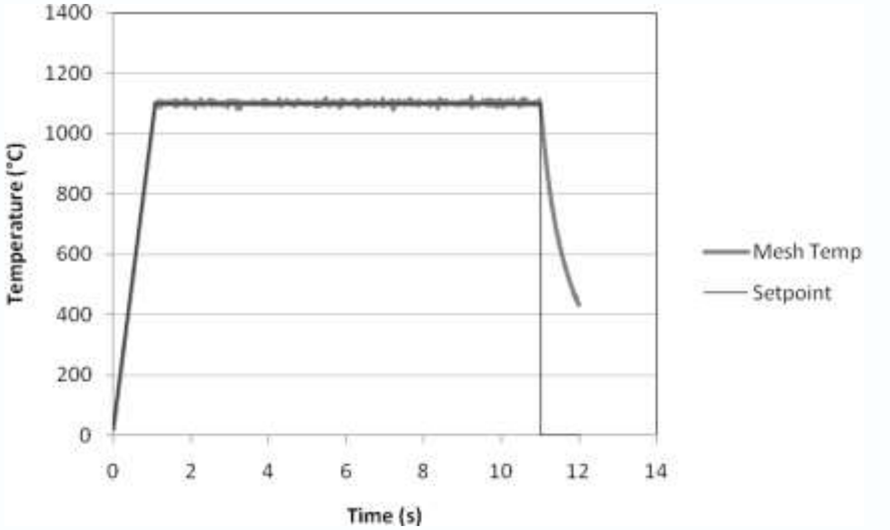
Bench scale heated grid (wire mesh) reactor.

- High pressures
  - Up to 30 bar
- High temperatures and heating rates
  - Up to 1100°C
  - Over 1000°C/s

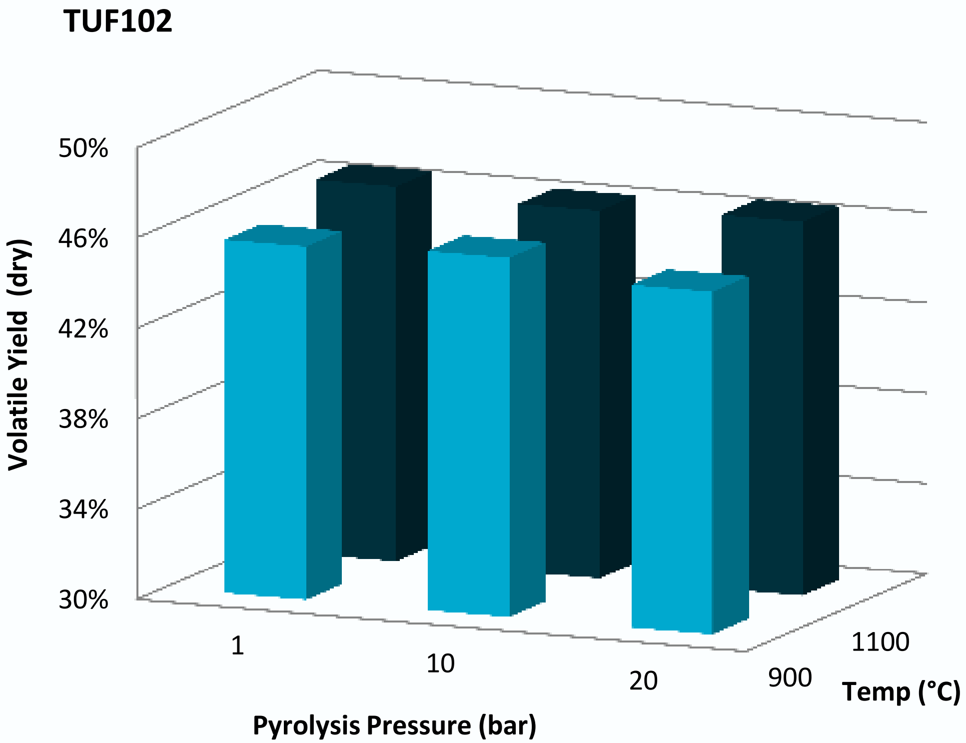




Allows systematic studies of impacts of temperature, pressure, and heating rate on volatile yields and char structures



High Pressure Volatile Yields
Rhenish Lignite



Dry VM for this coal is 51.9%

- VY are consistently less than this at 1000°C/s and 10s hold

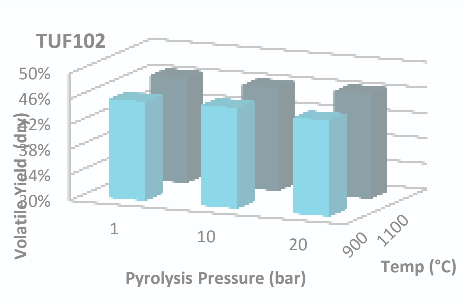
Temperature and pressure have limited impact

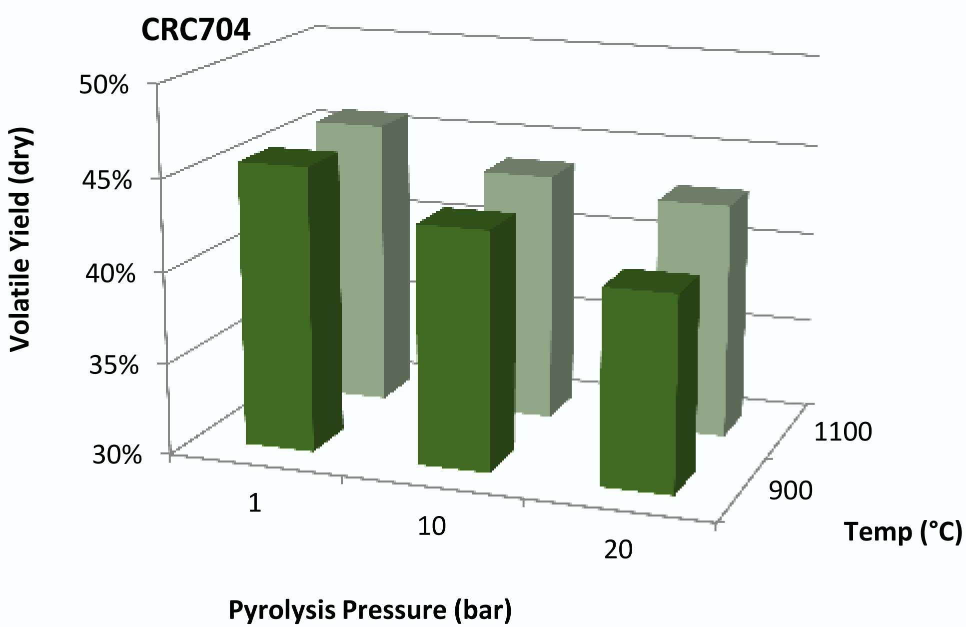
- Somewhat inconsistent with expectations based on high rank coal experience

Hold time more significant for this sample?

High Pressure Volatile Yields

Compared with a Sub-bituminous coal





Compared with results from an Australian sub-bituminous coal (dry VM 45.6%)

- 1 bar yields are similar to proximate analyses, as expected
- Increasing temperature increases VY
- Increasing pressure decreases VY

These are results consistent with our understanding of bituminous coals

Char Reactivity

Fixed Bed and TGA Reaction Systems

Fixed Bed Reactor

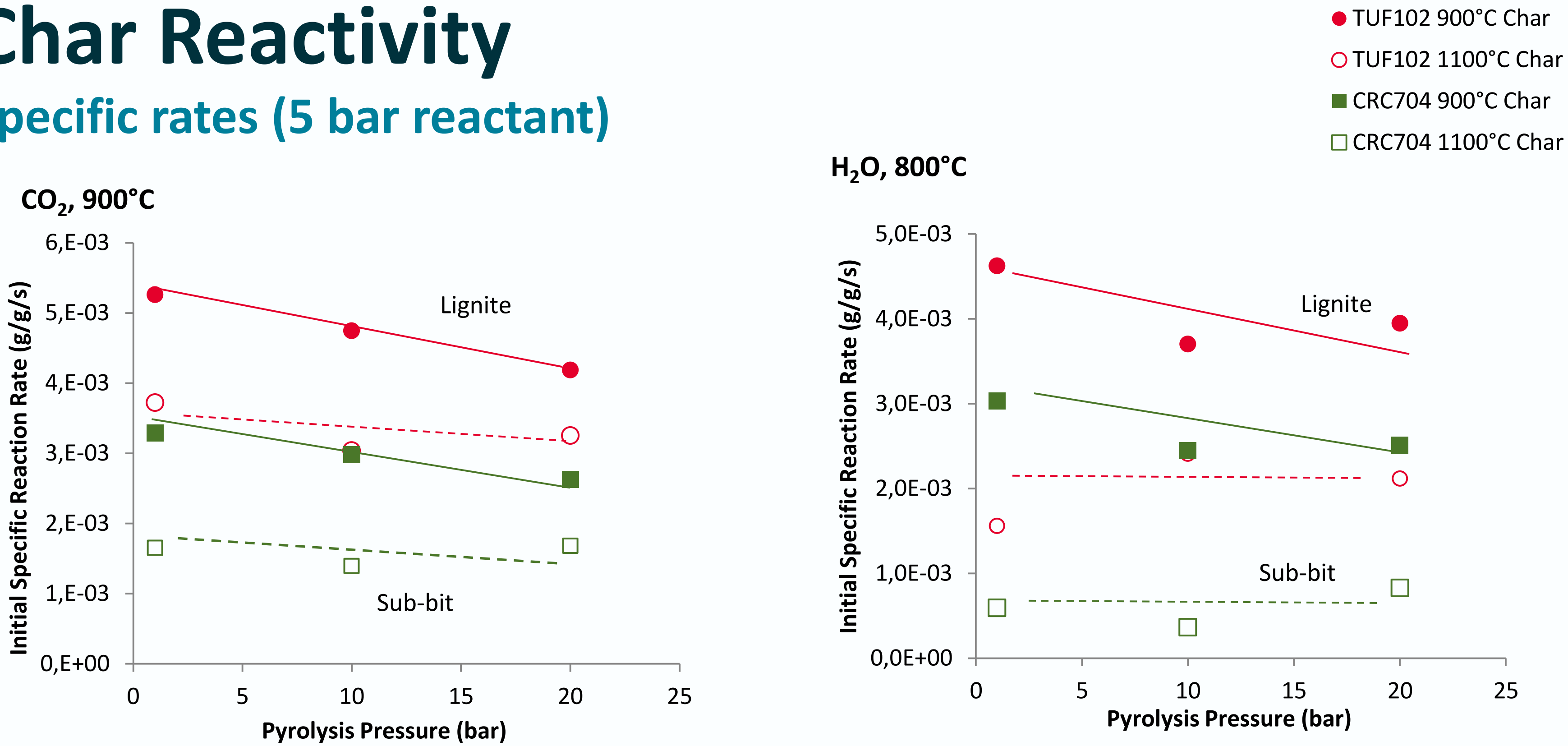
- Detailed studies of the fundamentals of surface reactions
- Reaction kinetics, mechanisms, etc.

Thermogravimetric Analyser (TGA)

- Pressures of 1-50 atm, temperatures up to 1000°C
- Accurate control of a range of reaction gas mixtures
  - He, N_2, CO_2, O_2, H_2O, CO, H_2
- Provides reaction rates as a function of burnoff at a specified temperature and pressure
  - Detailed information on kinetics of complex char gasification reactions at high pressure

Char Reactivity

Specific rates (5 bar reactant)



Lignite more reactive than a highly-reactive sub-bituminous coal char

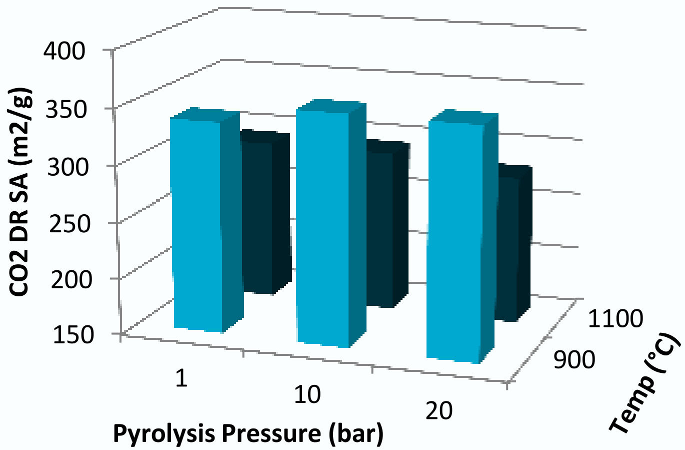
High T chars (1100°C) less reactive than low T chars (900°C)

Reactivity of chars made at 1100°C less affected by devolatilisation pressure than those made at 900°C

Surface Areas

CO_2 adsorption

TUF102



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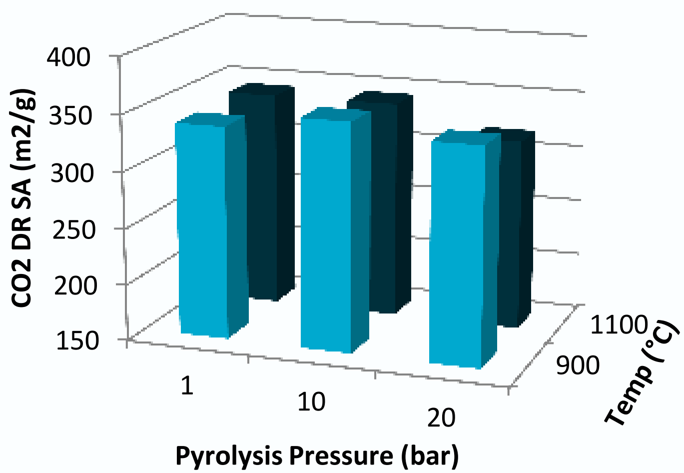


Increasing temperatures

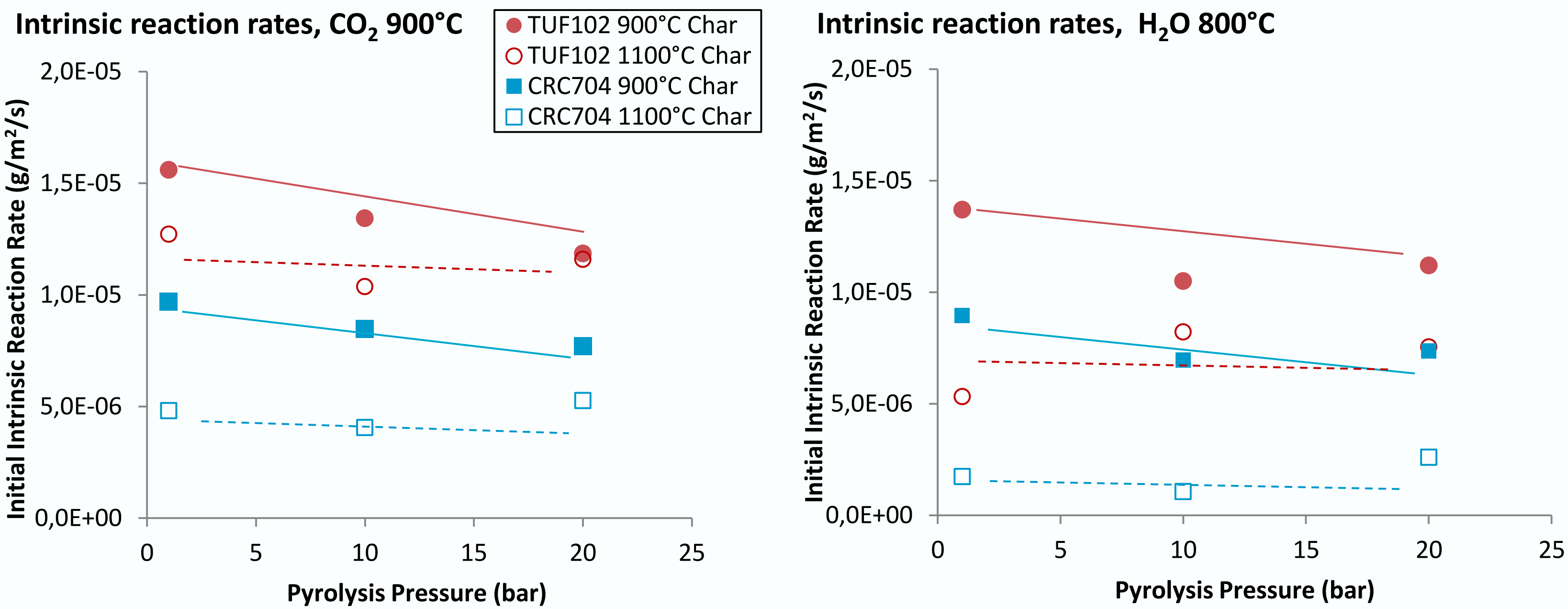
- generally decrease the SA of the char formed
- More pronounced effect for lignite

Pressure effects

- Slight at 900°C
- More pronounced at higher temperature
  - (previous work has been focussed exclusively on higher temperature behaviour)
- Coal specific effects?

Char Reactivity

Intrinsic Rates (5 bar reactant)

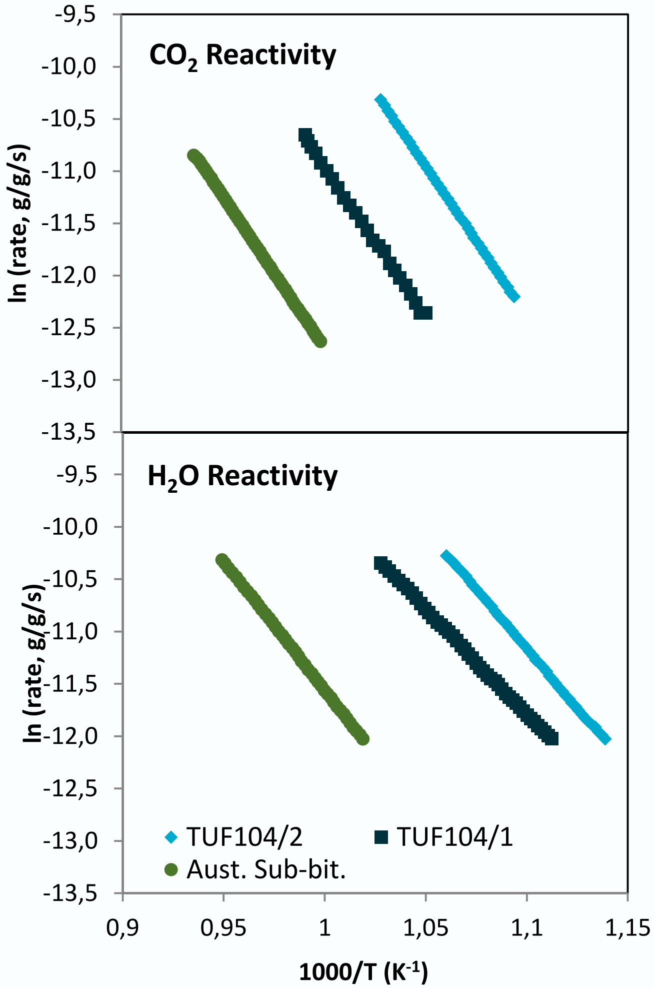


Accounting for effects of SA removes some effects of devolatilisation pressure

- At 1100°C this is more apparent, and consistent with previous work
- At 900°C there is some considerable effect of devolatilisation pressure on *intrinsic* reaction rates.
  - This temperature effect may be important in generating a wider, more applicable model of the coal-to-char process.

Intrinsic Gasification Kinetics

Reactivity to CO_2 and H_2O using Reference Chars



Activation energies (kJ/mol)

	TUF104/1 (1100°C char)	TUF104/2 (900° char)	Aus sub bit (1100°C char)	Aus sub bit (900°C char)
H_2O	166.5	188.6	229.0	205.1
CO_2	238.9	238.3	234.7	240.6

Surface areas (m^2/g)

Sample	Conditions	CO_2 (DR)	N_2 (BET)
TUF104/1 (1100°C)	Unreacted	185.1	223.4
	CO2 (X=10%)	178.7	280.0
	H2O (X=10%)	179.1	312.6
TUF104/2 (900°C)	Unreacted	210.7	228.6
	CO2 (X=15%)	202.6	320.0
	H2O (X=15%)	196.0	320.8

Ongoing Work

Entrained Flow Gasification Behaviour

Brings together our laboratory-based understanding

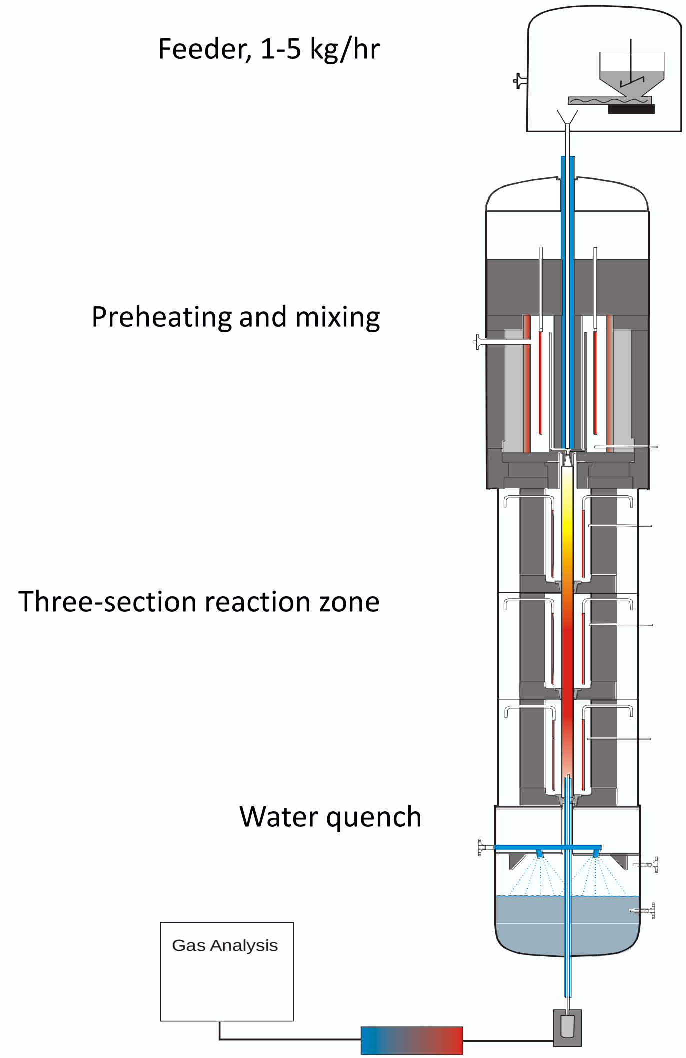
- Volatile yields
- Char reactivity

Gives us an indication of the conversion behaviour under entrained-flow conditions

- Char porosity and morphology
- Complex gas environments

Generates important reaction conditions:

- 20 bar
- Fast heating rate, 1400°C
- Realistic O:C stoichiometries and evolving gas composition



Thank you

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