Self-heating incubation behaviour of New Zealand lignite

Basil Beamish\textsuperscript{1}, Tana Levi\textsuperscript{2}, Andy Gunson\textsuperscript{3} and Rod Brown\textsuperscript{2}

\textsuperscript{1}B3 Mining Services Pty Ltd \\
basil@b3miningservices.com

\textsuperscript{2}CRL Energy Ltd \\
T.Levi@crl.co.nz \\
R.Brown@crl.co.nz

\textsuperscript{3}GXSim Ltd \\
andy@gxsim.co.nz
Presentation outline

• The spontaneous combustion incubation process
• Lignite coal quality characteristics
• Adiabatic testing procedures and results for New Zealand lignite samples
• Additional examples of reactive pyrite and ageing effects on lignite self-heating balance
• Conclusions
Sponcom process for coal

Coal + O₂ \rightarrow CO, CO₂, and H₂O + HEAT

Intrinsic and extrinsic factors determine reaction rate

Inconvection

Balanced determines development of event

Conduction

Evaporation

Incubation period is the time taken for coal to reach thermal runaway with given intrinsic and extrinsic factors.

- Oxidation rate approximately doubles for each 10 °C rise in temperature, once the coal temperature reaches thermal runaway
- Coal is a good insulator and can retain heat for years
- Coal can retain elevated activity for years
- Incubation periods can range from weeks to years
- Never use incubation period to avoid controls

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## Coal quality data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture (%, ar)</th>
<th>Ash (% db)</th>
<th>Volatile Matter (% dmmf)</th>
<th>Calorific value (Btu/lb, mmmf)</th>
<th>ASTM rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite 1</td>
<td>47.2</td>
<td>6.4</td>
<td>62.2</td>
<td>7464</td>
<td>LigA</td>
</tr>
<tr>
<td>Lignite 2</td>
<td>45.2</td>
<td>6.6</td>
<td>55.2</td>
<td>7553</td>
<td>LigA</td>
</tr>
<tr>
<td>Lignite 3</td>
<td>46.0</td>
<td>6.8</td>
<td>56.3</td>
<td>7092</td>
<td>LigA</td>
</tr>
<tr>
<td>Lignite 4</td>
<td>38.7</td>
<td>7.6</td>
<td>55.6</td>
<td>6847</td>
<td>LigA</td>
</tr>
</tbody>
</table>
Suggate rank plot of New Zealand lignite samples

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R$_{70}$ Test procedure
(Beamish and Arisoy, 2008)

- 150 g coal crushed to <212 micron
- Dried under nitrogen at 110°C for at least 16h, then cooled to 40°C
- Transferred to thermos and stabilised under nitrogen in adiabatic oven at 40°C ± 0.2°C
- Flow switched to oxygen at 50 mL/min
- Temperature change recorded by computer
- R$_{70}$ values determined as the average self-heating rate from 40°C to 70°C, expressed in °C/h
- Measures low temperature intrinsic reactivity
Adiabatic $R_{70}$ self-heating curve for a high volatile bituminous coal

$R_{70} = 6.51 \, ^\circ C/h$
$R_{70}$ self-heating relationship with ash content and coal rank
Incubation testing procedure
(Beamish and Beamish, 2011)

• Tested with as-received moisture content
• Larger sample mass than R_{70} testing
• Lower oxygen flow rate than R_{70} testing
• High mass to flow rate ratio more indicative of reality
• Test provides quantification of initial coal self-heating from low ambient temperatures where moisture effects can have a strong moderating influence
• Minimum incubation period benchmarked against coals with known self-heating histories
Adiabatic incubation test results for New Zealand lignite samples
R₇₀ self-heating relationship with ash content and coal rank

Ash content (% db)

Northern BB1
Northern BB2
Central BB1
Central BB2
Central BB3
Southern BB
Clermont
Callide
Powder River
San Juan
Spring Creek
Indonesian
AUS Raw lignite
AUS Pyritic lignite
AUS Pyritic shale

R₇₀ (°C/h, db)

Extremely High
Ultra High
Very High
High
Medium
Low - Medium
Low
Pyrite nodules present in lignite samples
Pyritised twig fragments present in lignite samples
Adiabatic incubation test results for Australian lignite samples

New Zealand Lignite

AUS Fresh Lignite

AUS Pyritic Lignite

AUS Pyritic Lignite (some nodules removed)

M = 32.5%
TS = 9.17%
TOC = 11.45%

M = 39.0%
TS = 4.22%
TOC = 12.87%

M = 21.0%
TS = 11.03%
TOC = 18.95%

M = 45.2%
TS = 0.45%
TOC = 22.7%
R_{70} self-heating relationship with ageing

\[ y = -2.5365\ln(x) + 7.8516 \]

R² = 0.9995

Ageing (weeks)

R_{70} (°C/h, db)

Extremely High
Ultra High
Very High
High
Medium

AUS lignite
Adiabatic incubation test results for aged Australian lignite samples

- NZ Lignite (47.2%M)
- AUS Lig (45.2%M)
- AUS Lig (1wk 26.7%M)
- AUS Lig (4wk 11.3%M)
Conclusions

• Lignite spontaneous combustion is controlled by the interaction between its extremely high intrinsic reactivity and the liberation and evaporation of its high moisture content when freshly mined.

• Storing and rehandling can tip the balance in favour of heat gain due to reduced moisture content resulting in thermal runaway.

• Longer term ageing can tip the balance in favour of no thermal runaway due to loss of intrinsic reactivity.

• The presence of reactive pyrite can act as an accelerant to the self-heating process.
Questions?