Variability of Coal Seam Parameters as They Impact on Outbursts

ACARP Project C11030
CSIRO Petroleum

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Context of the Outburst Problem

- Safety is paramount – must maintain or improve
- Economic pressure to increase development rates
- New mines are approaching outburst conditions
- Every mine has its own conditions
- Variability of conditions within mines
- Existing controls may be conservatively uniform
- Potential to further optimise outburst management
Interactive factors in outburst mechanisms

- **Gas**: content, composition, pressure, diffusion, desorption, permeability, relative permeability
- **Stress**: pre-mining, mining induced, effective stress, coal yield
- **Strength**: structure, scale effects, porosity (energy storage)
- **Time**: drainage rates, development rates, desorption rates, pore-pressure gradients

Diagram showing the interplay between gas, stress, strength, and time.
Influence of gas pressure gradient on outburst initiation

Field measurements by Wood and Hanes, 1982
Impact of gas composition and drainage on pressure gradient
After initiation – dynamic evolution model

- Gas desorption
- Coal deformation and failure
- Coal fragmentation
- Gas dynamics and transport of outburst coal
- Integrated model (initiation + evolution)
Dynamic evolution model

weak coal

strong coal

XVEL:
-0.348625
-0.73025
-1.11187
-1.4935
-1.87512
-2.25675
-2.63837
-3.02
-3.40162
-3.78325
-4.16487
-4.5465
-4.92812
-5.30975
-5.69137

XVEL:
-0.109188
-0.278375
-0.447563
-0.61675
-0.785938
-0.955125
-1.12431
-1.2935
-1.46269
-1.63188
-1.80106
-1.97025
-2.13944
-2.30863
## Seeking options for expanded criteria – taking a mechanistic view

<table>
<thead>
<tr>
<th>Stage of evolution</th>
<th>Driving force</th>
<th>Resisted by</th>
<th>Important variables</th>
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</table>
| Initiation         | Quasi-static pressure gradient within intact and yielding coal | Tensile and compressive strength | • Reservoir pressure  
|                    |               |             | • **Permeability**  
|                    |               |             | • Isotherm           
|                    |               |             | • Composition        |
| Post-initiation dynamic | Dynamic energy release of compressed gas in rapidly fragmenting coal | Remnant strength  
|                    |               | Fracture toughness | • Isotherm  
|                    |               |             | • **Composition**    
|                    |               |             | • Desorp. rate       
|                    |               |             | • Diffusion rate     
|                    |               |             | • Strain rate        
|                    |               |             | • Particle size      |
Elements of current project

- Statistical model of spatial variability
  - measure permeability and strength
- Sensitivity to variability
  - apply quantitative models
- Input to risk analysis
  - integrate with outburst risk management
Measured variability of permeability and porosity
Measuring variability of permeability and strength
Strength measurement on site
- rapid, portable
- assess spatial variability
Core Permeability

Measurement of permeability under simulated *in situ* stress
Well Test Schematic

7 in-seam holes @ 2m spacing, 35m depth from rib, 9 interference tests

Plus

Pair of in-seam holes, upper and lower, vertical perm. component
Well test equipment developed for this project

System schematic

Inflatable packers
Well test hydraulic equipment

IS approved hydraulic power pack

Fluid injection pump

Packer inflation pumps
Coal pre-saturation
- objective is single-phase flow conditions during well tests

\[ \text{Kh} = 0.1 \text{md}, \quad \text{Kv} = 0.01 \text{md} \]
\[ \Delta p = 0.5 \text{MPa}, \quad t = 7 \text{ days} \]

\[ \text{Kh} = 0.1 \text{md}, \quad \text{Kv} = 0.01 \text{md} \]
\[ \Delta p = 0.5 \text{MPa}, \quad t = 14 \text{ days} \]
Well test simulations: long horizontal well in extensive medium and layer of finite thickness

Extensive medium

Finite thickness
Well test simulation: short horizontal well in layer of finite thickness

Pore pressure contours@ 1000s injection

Well pressure vs log (t/t₀)
SUMMARY

**General**

- There is scope to refine and expand the threshold criteria, incrementally
- Safety is paramount
- Quantitative models have been developed (ACARP C6024 and C9023)
- Better understanding of CO2 in coal is required (ACARP C13012, current)
- Permeability and strength have potential for expanding the criteria
- Methods to account for spatial variability of data are needed
SUMMARY

Current stage, ACARP C11030
- Measurement of permeability and strength at field and laboratory scale

Near future
- Spatial variability analysis
- Quantitative modelling of sensitivity to variability

Longer term
- Application to outburst risk assessment and management