ACARP Project C14011

Hydraulic Fracturing for Gas Recovery and Its Impact on Subsequent Coal Mining

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Overview

• Objective / Outcomes
• Background to Project
• Approach
• Review of Experience in USA & Australia
• Numerical Modelling Results
• Issues Identified in Risk Review
• Findings and Recommendations
Objective

To understand the effect that seam gas stimulation, particularly full-scale hydraulic fracture stimulation treatments, has on the future mineability of coal seams.
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Outcomes

No significant impacts noted in USA or Australia
Record keeping necessary to determine where holes are and the completion and abandonment details need to be controlled
Background

• Queensland Petroleum and Gas Bill
  – Includes policy and regulations controlling the interaction between Coal Bed Methane (CBM) operators and underground coal mining companies in areas where there may be potential for overlapping operations.
  – Queensland Resource Council (QRC) had opportunity to review this bill.

• QRC was concerned that production hydraulic fracturing routinely used by CBM operators has the potential to affect the roof and floor stability in future underground operations.

• This ACARP Project was initiated to investigate the potential impacts of hydraulic fracture stimulation on the subsequent safe and efficient mining of the coal.
Approach

• Review experience to date of mined through hydraulic fractures in USA and Australia

• Use hydraulic fracturing models and geomechanical models of strata behaviour to determine the nature and significance of potential impacts

• Identify and assess the potential impacts through a risk review process

• Recommend strategies to manage and further investigate potential impacts
Hydraulic fracturing uses a pressurised fluid to generate a single, essentially circular / planar fracture (in an ideal uniform stressfield).
Sand propping involves placing a graded sand in the fracture so that when the pressure is released, the fracture closes imperfectly and provides a drainage path to enhance gas drainage and overcome borehole damage.
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Current CBM Areas in USA
(from Energy Information Administration, Dept of Energy, US Govt)
# Review US Experience

<table>
<thead>
<tr>
<th>Type of mine</th>
<th>Production (metric tonnes)</th>
<th>Number of mines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground (active) mines - total</td>
<td>320.05 Mt*</td>
<td>580***</td>
</tr>
<tr>
<td>Surface (active) mines - total</td>
<td>651.25 Mt**</td>
<td>714 ***</td>
</tr>
</tbody>
</table>

Sources: *UNFCCC (2005a); **Schwochow (1997); ***GeoHive (2004)

<table>
<thead>
<tr>
<th>Mine Name</th>
<th>Mine Location</th>
<th>Total Emissions Avoided 2003</th>
<th>Methane Use Option</th>
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</thead>
<tbody>
<tr>
<td>Blue Creek No. 4, 5, 7</td>
<td>Alabama</td>
<td>232 MM m³ (3.31 MMTCO₂)</td>
<td>Pipeline Sales</td>
</tr>
<tr>
<td>Oak Grove</td>
<td>Alabama</td>
<td>42.7 MM m³ (0.61 MMTCO₂)</td>
<td>Pipeline Sales</td>
</tr>
<tr>
<td>Shoal Creek</td>
<td>Alabama</td>
<td>10.3 MM m³ (0.15 MMTCO₂)</td>
<td>Pipeline Sales</td>
</tr>
<tr>
<td>Mine X*</td>
<td>Colorado</td>
<td>0.40 MM m³ (0.01 MMTCO₂)</td>
<td>Mine Heating</td>
</tr>
<tr>
<td>San Juan</td>
<td>New Mexico</td>
<td>0.40 MM m³ (0.01 MMTCO₂)</td>
<td>Pipeline Sales</td>
</tr>
<tr>
<td>Blacksville No. 1</td>
<td>Pennsylvania</td>
<td>34.0 MM m³ (0.48 MMTCO₂)</td>
<td>Pipeline Sales</td>
</tr>
<tr>
<td>Buchanan No. 1 VP #8</td>
<td>Virginia</td>
<td>785 MM m³ (11.2 MMTCO₂)</td>
<td>Pipeline Sales, On-Site Use, Power Generation</td>
</tr>
<tr>
<td>Federal No. 2</td>
<td>West Virginia</td>
<td>8.5 MM m³ (0.12 MMTCO₂)</td>
<td>Pipeline Sales</td>
</tr>
<tr>
<td>US Steel No. 50</td>
<td>West Virginia</td>
<td>15.7 MM m³ (0.22 MMTCO₂)</td>
<td>Pipeline Sales</td>
</tr>
</tbody>
</table>

*Mine X has requested that they remain anonymous at this time. Source: USEPA (2004a)
Current US Fracturing Practice

- Foam based fluids - 70% $N_2$ and 8 cp linear gel base.
- Pumped at 35 bpm with 20/40 and 16/30 mesh sand. Place 3,000 to 5,000 lbs per net foot of seam.
- 5 stages per well with 2 to 3 seams per stage.
- Some slick water treatments at 30 bpm also done.
- Some cross-linked gels
Abandonment Strategies

- Case across mineable seams using fibreglass casing

- Re-enter well and cut steel casing ahead of mining so that it can be extracted underground. Alternatively, can mill casing completely out

- Cement plugs are typically 15-50m length above and below seams

- Not practical to mill casing ahead of mining because there are too many seams that aren’t mined and not necessary if hole passes through a pillar
Fracturing and Mining

- CONSOL have mined 400 to 600 hydraulic fractures out of a total of 1900. They documented first 200 or so internally until they decided there was no issue.

- JW Resources have mined about 250 fracs out of 500 total

- Oak Grove have mined about 200 wells with fracs

- Consol believe northern West Virginia cannot be fractured. NIOSH strongly disagree with this and cite Emerald mine experience
Australian Experience

• Have mined 9+ large hydraulic fractures in coal, only one of which was full scale (ECC90)
• Two fractures in 1981 at Appin were not found on mining
• Nine recent fractures are well documented
• ECC90 was 27bpm crosslinked gel frac
• 624 small sand propped fractures placed in LW9 at Dartbrook (in 2002) and later mined
Hydraulic fractures can be complex in geometry with multiple branches and both horizontal and vertical parts.

Mapped section through hydraulic fracture in well ECC90 at Central Colliery.
ECC90 was treated using a borate crosslinked gel at 27 bpm

A large horizontal fracture was created with an underlying vertical branch
Hydraulic fracture in roof rock near borehole ECC 87
Dartbrook Mine.

Hydraulic fracture in roof of A heading shortly after mining through DDH 139.
Summary of Experience

• USA experience of CBM mine throughs
  – CONSOL mined 400-600 of 1900 fracs in Central & Northern Appalachian without negative impacts
  – Some 450 out of 750 fracs in the Black Warrior Basin have been mined through without impact
  – No significant effects on the stability of underground coal operations from production hydraulic fracturing
  – Effective strategies/regulations in place to solve conflicts at least at a state level
  – Coal operators are actively encouraging CBM especially where they have a commercial interest in it
Summary of Experience

- Australian experience of CBM mine throughs
  - Limited to mine throughs of only a few full scale fractures (Jeffrey et al., 1992) and several hundred small-scale hydraulic fractures mined in both Queensland and NSW, mainly at Dartbrook.
  - No significant effects although some drying out of coal noted at Dartbrook because of the effectiveness of drainage
Material Property Comparison

Comparison of Rock Properties and E/UCS Plot

Emerald Mine, Northern Appalachian, USA
Hawkesbury Sandstone, Robson (1978)
Medium Grained Sandstone (circle denotes average)
Fine Grained Sandstone
Siltstone
Mudstone
Laminate
Bowen Basin SCT Reports ACA1966 and ACA2170

Sandstone (Deere & Miller, 1966)
Shale (Deere & Miller, 1966)
In Situ Stress Comparison

Depth vs Tectonic Stress Factor

Tectonic Stress Factor (TSF)

Depth (m)

Pittsburgh seam  PA *  T Fracs

Blue Creek / Mary Lee  JWR Alabama  #

Vertical fracs

* interbedded coal roof
# variable
Strength Properties of Pittsburgh Seam

Near Seam section “similar” to Australia
T shaped Fracture

40 m

Coal
Stone band
40 m

250 m
Pore Water Pressure During Gas Production
Gas Content after Production

Rock  No Gas

Drained seam zone

Rock  No Gas
Stress Changes due to Gas Desorption Volumetric Strain

- Methane and CO2 behave similar.
- CO2 has higher stress drop above approx 12 m3 conc.
Simulated Effects of T shaped Fracture System

**Normal Section**

**Disturbed Section**

*Horizontal Stress in Coal seam reduced by 2 MPa.*
Stress and Deformation Characteristics

Stability range for a thick coal section under Normal and Disturbed conditions

- Normal Ground conditions
- Disturbed Ground conditions

Secondary Cables typically required.

Disturbed Ground Weaker

BUT.....
Comparison of Normal and Post Fracture Stability

Stability range for a thick coal section under normal and post hydraulic fracture conditions

Post-Frac ground more stable due to reduced horizontal stress
Summary of Modelling Outcomes

- Fractures have minor mechanical impact that is expected to be within the range of general experience based on structured and unstructured ground conditions.

- Increased gas capture and reduced horizontal stresses associated with shrinkage more than offsets any mechanical impacts of fractures.
Issues Identified in Risk Review

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- Impacts associated with uneven stress distribution after gas drainage
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- Mining into foreign objects such as casing
- Chemical contamination of seam from fracing fluids
- Unsealed holes and impacts on ventilation
- Impacts on structural integrity of coal and roof strata
- Impacts associated with uneven stress distribution after gas drainage
- Various other minor issues that are within the range of normal mining experience
Findings and Recommendations

- Sand propped hydraulic fracturing and coal mining can (and do in the USA) successfully co-exist
- Key requirements for this are that government or other agency should maintain in perpetuity a record of where holes are located, and their completion, production and abandonment details for the benefit of future coal mining
- Holes do not need to be reamed out at coal seams ahead of coal mining but should be able to be reamed out if required
Findings and Recommendations

- Mechanical impacts of the fractures are minor and have not been reported to be an issue in any of the fracs that have been mined through in the USA or Australia.
- Ventilation impacts are insignificant if holes are cemented above and below seam at abandonment.
- Gas drainage is an advantage and improves mining conditions and reduces the potential for outburst or other gas related issues.
Findings and Recommendations

• Chemicals used in fraccing are generally of no significance for future mining

• Commercial conflict may exist over historical rights to drain and utilise coal, but this is something that legislation can obviate

• Sand-propped hydraulic fracturing ahead of coal mining is generally beneficial to coal operations, particularly if the locations of holes is known and they have been abandoned so that re-entry is possible
Acknowledgements

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