A Comparison of Coalbed Methane Drilling Practices in the Southern Shanxi Province, China, through Advanced Reservoir Modeling

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Overview

- EPA Methane to Markets Project
- Current status of CBM production in China
- CBM potential in China
- Basic CBM modeling parameters and assumptions
- Inputs for modeled CBM reservoir
- Results
EPA Methane to Markets Project
Best Practices for Mine Degasification

- **Marshall Miller and Associates** - Detailed Feasibility Study Template and Reserve Analysis for CBM Field in Southern Shanxi Province, China
- **Virginia Tech** - Modeling Simulations, Comparisons of Various Degasification Practices
Coal Basins and Resources in China

China’s Coal Reserves

<table>
<thead>
<tr>
<th>Type</th>
<th>Reserve (Bt)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown Coal</td>
<td>658 Bt</td>
<td>13%</td>
</tr>
<tr>
<td>Bituminous</td>
<td>3,794 Bt</td>
<td>75%</td>
</tr>
<tr>
<td>Anthracite</td>
<td>607 Bt</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Total Reserve</strong></td>
<td><strong>5,059 Bt</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: Overview of China’s Coal Resources – 1996 (Bt: Billion Tonnes)
China Coal Statistics

- Energy consumption satisfied by coal
- ~30,000 existing coal mines (fully mechanized to hand-loading). Some estimates are >50,000 mines
- Reported employment >6 million
- Average miner produces ~325 tonnes/year
- Coal production
  - 2003: 1.7 billion tonnes
  - 2004: 2.0 billion tonnes
  - 2005: 2.2 billion tonnes
  - 2006: 2.3 billion tonnes
  - 2009: 2.6 billion tonnes
China Coal Statistics

- Official reported fatalities in:
  - 2003 = 6,700
  - 2004 = 6,000
  - 2005 = 5,500
  - 2006 = 4,700
  - 2007 = 3,800

- Reportedly China can safely produce 1.2 billion tonnes/year.

- Remaining 0.8 billion tonnes generated from small, unregulated mines and overproduction at large, undercapitalized mines.
China Coal Statistics

• Majority of Chinese mining accidents related to methane explosions
  – Reported ~30% to 40% of deaths from CH₄ explosions

• Low permeability and high rank coals

• ~ 1/3 of Chinese mines develop coal with gas contents exceeding 300 ft³/tonne

• Chinese need western degas technology
  – In-mine drainage
  – Surface drilling (both vertical and slant)
China’s Coalbed Methane Production

Billion cubic meters

Actual
Projected
U.S. Coalbed Methane Production
1989 - 2007

Billion cubic meters

Source: E.I.A., Office of Oil and Gas • Annual Report
Natural Gas Production: US vs. China

Current Annual Production:

- US: 550 Billion m³
- China: 50 Billion m³

CBM: ~50 Billion M³
Comparison of 4 CBM Basins:
Central Appalachian Basin, Black Warrior Basin, and San Juan Basin (U.S.A.), and Qinshui (China)
Cleat Development Comparison

Typical Anthracite (U.S.)

Note: Absence of Cleats

Jincheng No. 3 Seam

Note: Favorable Cleat Development
MLD Well Drilling
Modeled Wellbore Orientations
Modeling Governing Equations

- Langmuir Isotherm Relationship
  \[ V(p) = \frac{V_L P}{P_L + P} \]

- Fick’s Law of Diffusion
  \[ q_m = \frac{V_m}{\tau} [V - V(p)] \]

- Darcy’s Law
  \[ q_s = -\frac{k}{\mu} \text{grad}(P) \]
## Modeling Inputs

<table>
<thead>
<tr>
<th>Input Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Water Saturation</td>
<td>100%</td>
</tr>
<tr>
<td>Initial Reservoir Pressure</td>
<td>550 psi</td>
</tr>
<tr>
<td>Initial Gas Content</td>
<td>500 cubic feet per ton</td>
</tr>
<tr>
<td>Cleat Porosity</td>
<td>3%</td>
</tr>
<tr>
<td>Cleat Spacing</td>
<td>2 inches</td>
</tr>
<tr>
<td>X Direction Permeability</td>
<td>3 md</td>
</tr>
<tr>
<td>Y Direction Permeability</td>
<td>1 md</td>
</tr>
<tr>
<td>Z Direction Permeability</td>
<td>3 md</td>
</tr>
<tr>
<td>Langmuir Pressure</td>
<td>290 psi</td>
</tr>
<tr>
<td>Langmuir Volume</td>
<td>1000 cubic feet per ton</td>
</tr>
</tbody>
</table>
Modeling Calibration

• Assumes all wells (vertical and multilateral) can produce 250 barrels of water per day

• Once operating pressures reach atmospheric pressure, water production is reduced to maintain atmospheric operating pressure

• Skin Factors
  – Vertical Fracture Wells: -3.0
  – Multilateral Horizontal: +0.5
Daily Total Production Comparison - MLD Without Vertical Support

Graph showing the comparison of daily total production over time (years) with a logarithmic scale for gas production (mcf/d). The graph indicates a decreasing trend in production over time, with a sharp initial peak followed by a gradual decline.
Daily Total Production Comparison – System of MLD and Vertical Support
Analysis of Vertical Support Wells

- Multilateral Wells Produce Large Volumes of Gas Without the Use of Vertical Support Wells
  - MLD Peak Rate—2.4 MMcfd
  - Vertical Peak Rate—50 Mcfd
- Vertical Support Wells Provide Negligible Additional CBM Production
  - Gas Drained by Vertical Support Wells is Easily Drained by MLD
- Economically, the Capital Expenditures from Vertical Support Wells Could be Better Used to Drill More Densely Spaced Multilateral Wells and/or Additional MLD Wells
Comparison of Recovery (2.0 md)

2.0 md, 600-ft spacing, 3 years

2.0 md, 200-ft spacing, 3 years
Comparison of Recovery (0.2 md)

0.2 md, 600-ft spacing, 3 years

0.2 md, 200-ft spacing, 3 years
Conclusions

• Vertical Support Wells Do Not Provide Sufficient Additional Production Compared to Closely Spaced Laterals
• Closely Spaced Laterals are Crucial for Optimal Recovery When Degasification Time is Short and/or Reservoir Permeability is Low
• Required Capital to Drill Additional Laterals is Low Relative to Other Capital
• In Gassy Reservoirs, Effective Pre-Mining Degasification Lowers Carbon Footprint and Improves Mine Safety
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