Case Study: Long Term Abandoned Mine Methane Recovery Operation in the U.S.

Methane to Markets Partnership-wide and Steering Committee Meeting, Monterrey, Mexico

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Presented by:
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Presentation Outline

• Project Background
• Field Operations
• Project Performance
• Estimating Reserves
• Lesson’s learned
Project Background

• First started by Illinois Methane in 2002 and was shutdown for financial reasons in 2004

• DTE Methane Resources purchased from Illinois Methane in 2004, modified the facilities, and restarted the project in March 2005
Project Background
83,000 acres

34 wells
Project Background

• The Mines
  – The mines in the project range in depth from approximately 100 to 200 meters.
  – All project mines are shaft mines and most are tightly sealed from the atmosphere.
  – Mine abandonment dates range from 1926 to 1996.
Project Background

• The Mines
  – The average gas composition is 72% methane, 20% nitrogen and 8% carbon dioxide.
  – The pressure in the mines prior to production ranged from 6.9 kpa to 106.2 kpa above atmospheric (1 psig to 15.4 psig) averaging 71.7 kpa (10.4 psig).
  – The average mined coal seam thickness is 2.5 meters (8.3 feet)
  – Some mines were found to be in pressure communication with each other
Project Background

• Risks
  – Mines are water flooded.
  – Low pressure (leakage or historical venting).
  – Well location (roof collapse or tight seals).
  – Air inflow (quality issue).
  – Recharge rate of methane limits production rate.
  – Drilling into coal pillars.
Arial Photo Overlay on Mine Map
Operations: Wells

- Metering runs consist of either venturi tubes or orifice runs
- Meters are read monthly
- Quarterly calibration checks
- Quarterly gas sampling
- Well headers to field stations are HDPE
Operations: Wells

• Drilled using truck-mounted rigs commonly used for coring of coal exploration wells
• Blowout preventers are necessary
• Casing program
  – 8-5/8” surface casing
  – 5-1/2” production casing cemented to surface
  – Case to within 50 feet of mine void
• Drill into mine with a 4-3/4” bit
Operations: Wells
Operations: Field Compressor Stations

- Wells connected to individual field stations via HDPE pipelines
- Standard infrastructure at each field station includes suction scrubber, compressor-gas engine skid, discharge scrubber, and metering
- Compression equipment comprises oil-flooded rotary screw compressors driven by gas engines operating on coal mine methane
Operations: Field Compressor Stations

- Gas compression capacities vary from 0.1MMSCFD to 1.7MMSCFD (40 to 400 BHP); six stations total
- Nominal design compressor operating range is -3 psig intake up to 170 psig discharge pressures
- Two full-time field operators
- Gas accumulator bottles are installed to obtain a weighted average gas composition
Field Compressor Station
Operations: Gathering Pipeline

• Twenty-nine (29) miles of 8-inch diameter carbon steel, internally coated pipeline
• Maximum operating pressure of 720 psig
• Capacity up to 14 MMSCFD
• Typical operating pressures range from 130 to 140 psig at the beginning of the pipeline to about 90 psig at the processing plant
• Quarterly Batch inhibition schedule for corrosion protection
Operations: Gas Processing Plant

- Inlet Gas Quality
  - Methane: 74%
  - Nitrogen: 18%
  - Carbon Dioxide: 8%
  - Oxygen: 0.1%
  - Hydrogen Sulfide: Trace to 5 ppmv
  - Heating Value (HHV): 750 Btu/scf
Operations: Gas Processing Plant

- Inlet Gas Volumes
  Design: 12.5 MMSCFD
  Current Rates: 4 to 6 MMSCFD
- Plant Design & Construction
  BCCK Engineering (Midland, TX)
- Four full-time Operators (24/7 coverage)
- One full-time Facility Manager
Project Performance

![Graph showing gas rate from Sep-02 to Feb-08]
Project Performance

Cumulative Gas, Mcf

9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000

Estimating Reserves

• Build a conceptual numerical model for Computational Fluid Dynamics simulation for each mine.

• Each model is based on:
  – Known information
  – Estimated information
Known Information

- Pressure in the void area
- Mine size
- Gas production and pressure history
Estimated information

- Volume of coal in contact with void based on stratigraphic column
- Permeability of coal and void
- Adsorption isotherm
- Sorption time
- Initial assumption that the mine is not flooded
Areal View of a Conceptual Abandoned Mine Model

![Diagram showing Areal View of a Conceptual Abandoned Mine Model with labels for Void, In-mine Coal, Well, and In Situ Coal.]}
Estimating Reserves

• Model calibration
  – The model’s gas production rate is forced to match actual data.
  – Flowing wellhead pressure is predicted by the model
  – The model’s permeability and volume parameters are modified within limits to match measured wellhead pressure data
Initial Pressure Match

SI Abandoned Mine Model Template
Mine 21

Model Gas Rate
Actual Gas Rate
Model Well Bottom-Hole Pressure
Actual Well Bottom-Hole Pressure

Gas Rate SC (m³/day)

Well Bottom-hole Pressure (kPa)

Time (Date)
Final Pressure Match

SI Abandoned Mine Model Template

Mine 21

- Model Gas Rate
- Actual Gas Rate
- Model Well Bottom-Hole Pressure
- Actual Well Bottom-Hole Pressure

Gas Rate SC (m³/day)

Well Bottom-hole Pressure (kPa)

Time (Date)
History Match After 5 Years

SI Abandoned Mine Model Template
Old_Ben_21

- Gas Rate SC_OBC_21_11-07.rtf
- Gas Rate SC_OBC_21-rate_11-07.thf
- Well Bottom-hole Pressure_OBC_21_11-07.rtf
- Well Bottom-hole Pressure_OBC_21-rate_11-07p.thf
## Expected Ultimate Recovery, Mcf

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<th>Oct 07</th>
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<td><strong>Total</strong></td>
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<td><strong>14,506,480</strong></td>
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Lessons Learned

• Adequate resource evaluation is essential to avoid over-sizing facilities
• All gas processing technologies should be considered
• Monitoring production volumes, wellhead pressures and gas composition is essential for reserves analysis
Lessons Learned

• Reservoir models need to be updated periodically to adequately account for long-term recharge rates

• Well location selection requires detailed evaluation of mine maps

• Performance risk based on flooding and/or compartmentalization needs to be taken into account
Thank you

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History Matching the Measured BHP by Varying the Permeability

Simple Abandoned Mine Model History Match

Low permeability

High permeability

- Simulated Gas Rate
- Calculated Bottom-hole Pressure
- Measured Bottom-hole Pressure
- Measured Gas Rate
- Calculated BHP with low permeability
- Calculated BHP with high permeability