Best Practices in CMM Project Development

Workshop on Promoting Coal Mine Methane (CMM) for Energy, Safety and the Environment: Legislation and Project Development in Kazakhstan

25 September 2015
Astana, Kazakhstan

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Presentation Outline

- What is good safety practice?
- Review of methane drainage systems
- Integrating coal mine methane (CMM) capture and utilization
- CMM utilization
- Ventilation air methane (VAM) utilization
- Best practices case study
- Conclusions
- Discussion
What is Good Safety Practice?

Avoid explosive gas mixture

- Rapidly dilute explosive mixtures to safe concentrations
- Maximize methane drainage to minimize high gas concentrations in mine airways

Why employ best practice

- Mine safety
- Asset protection
- Coal Production
- Energy Recovery
- Environmental Protection
UNECE Best Practice Guidance on Effective Drainage and Use In Coal Mines

- High level principals-based guidance
- Target audience - government and corporate decision-makers
- Adopted by the UNECE in 2010
- Recommended for worldwide application by UN Economic and Social Counsel (ECOSOC) in 2011
- Supports development of safer and more effective practices
- Includes real world case studies
- Available in 7 languages including Russian
- Currently revising and 2nd edition expected to be released in 2016.
- Complements existing legal and regulatory frameworks
Flexible Nature of Guidance

- Engineering Judgement
- Corporate Strategy
- UNECE Best Practice Guidance
- Performance-based Regulatory Development
- Prescription-based Regulatory Development
Stakeholders Critical to Achieve Best Practice

Best Practices

- Mine Staff
- Mine Company Management
- Mine Management
- CMM Project Developer
- Mineral Rights Holder
- Mine Safety Regulatory Authority
- Environmental Regulatory Authority
- Company Shareholders
Key Tenets for Best Practices

- Prediction of underground gas release
- Efficient mine ventilation
- Effective gas drainage
- Optimal use of drained gas (CMM) and ventilation air methane (VAM) for near-zero emission coal mining
- Management and staff education and training
- Reinvestment in mine and gas operations
# Methane Drainage Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
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</table>
| Conventional Vertical Unstimulated Pre-Drainage | • Simple  
• Does not interfere with mining operation                                  | • Perform poorly in low permeability                                          |
| Surface Vertical Hydraulic Fracture Pre-Drainage | • Multi-seam completions  
• High recovery efficiency of 40-70%                                             | • Limited effectiveness in complex geology  
• Large footprint                                                              |
| Surface Directionally Drilled Pre-Drainage   | • High recovery efficiency, up to 90%  
• Smaller footprint than vertical wells  
• No hydraulic fracturing                                                        | • Expensive  
• Can be difficult to steer in complex geology                                |
| In-Mine Short Hole                       | • Simple – use non-steerable rotary drills  
• Relatively inexpensive                                                        | • Requires access to galleries  
• Drainage efficiency is limited by very short drainage period                 |
| In-Mine Long-Hole Directionally Drilled Borehole | • Up to 1 year in advance of mining  
• Up to 50% recovery efficiencies                                                | • Requires access to galleries  
• Lower drainage efficiency than surface pre-drainage                          |
| Drainage Galleries                       | • Lower cost and widely used  
• Does not require boreholes                                                      | • Inflexible to change during mining  
• Can be inefficient                                                            |
| Cross Measure Boreholes                  | • Practicable for deep coal seems  
• Effective in low permeability                                                   | • High capture efficiencies difficult to sustain                               |
| Surface Gob Vent Boreholes               | • Very effective for shallower coal seams  
• Lower drilling cost than pre-drainage                                            | • CH4 concentration declines rapidly  
• Challenging in mountainous terrain                                             |
Integrated CMM Capture and Utilization at an Operating Mine
Coal Mine Methane (CMM) Value Chain

**METHANE EXTRACTION AND RECOVERY**
- Vertical Degasification Wells
- In Mine Well
- Gob Wells

**GATHERING, COMPRESSION, AND PROCESSING**
- Compression
- Dehydration
- Gas Processing
- Power/Heat Generation
- Sales Metering

**METHANE TO MARKETS**
- Regional and Export Gas Sales
- Power Generation
- Chemical Feedstock
- Methanol Production Plant
- Transportation Fuel
- Compressed Natural Gas Refueling Station

*High Quality Methane (90%+ CH₄)*
*Low/Medium Quality Methane (30% 70% CH₄)*
## Methane Drainage Use and Destruction Technology Options

<table>
<thead>
<tr>
<th>Technology</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Natural Gas Pipeline Sales</td>
<td>• Requires consistently high gas quality to meet pipeline specifications.</td>
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<tr>
<td>Power Generation</td>
<td>• Small IC engines (500kW-3 MW) are most common because they can handle lower CH4 concentrations down to 25% CH4</td>
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<td>• Containerized modular construction allows for cost effective operation. Most popular use outside the US.</td>
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<tr>
<td>Vehicle Fuel – CNG/LNG</td>
<td>• LNG/CNG can be used for mine vehicles or external markets</td>
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<tr>
<td></td>
<td>• Requires very pure CH4 stream - expensive options</td>
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<tr>
<td>Boiler Fuel</td>
<td>• Not technologically complex and can use mine gas with 30% CH4 concentration.</td>
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<td></td>
<td>• Very common use – usually involves conversion of a coal-fired boiler</td>
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<tr>
<td>Direct Heating</td>
<td>• Use in industrial burners or industrial flares</td>
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<tr>
<td></td>
<td>• Primary use is mine shaft heating in winter or in manufacturing</td>
</tr>
<tr>
<td>Flaring</td>
<td>• Used for stranded gas with no market, as an interim GHG destruction option, or to destroy excess GHGs in an integrated CMM project.</td>
</tr>
<tr>
<td>Other uses</td>
<td>• CMM has been used in methanol production, glass making, steel manufacturing, desalination plants, green houses, and coal drying.</td>
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Methane Drainage Key Points

- Technologies to use or destroy CMM are the same as those that use natural gas.

- End use is determined by many factors:
  - Gas quality (CH₄ %)
  - Gas quantity (4.2 m³/min CH₄ = 1 MW)
  - Access to markets
  - Infrastructure
  - Financial position
  - Staff capacity
  - Mining company priorities
  - Government policy priorities
Methane Drainage Key Points

- Projects often include a portfolio of technologies to maximize gas use.
- When deciding what technology to use:
  - Power, flaring, boilers, and vacuum pumps require minimal gas treatment
  - LNG, CNG, and pipeline sales require expensive gas treatment
- In order to implement a successful methane drainage project:
  - Improve gas availability (gas quantity and quality) and maintain CH4 concentrations above the explosive range
  - Size plant properly- 80% of average gas flow
  - Flare gas when not used rather than venting
  - Regular maintenance and overhaul are required to keep the plant operating
Ventilation Air Methane (VAM) Abatement Technology

- Regenerative Thermal Oxidizer (RTO) technology has become standard through successful demonstration in Australia, China, and U.S.
- Currently 2 VAM projects operating in U.S., 1 in Australia, with 1 in under development in China

- Other technologies are in development and close to commercialization
  - Regenerative Catalytic Oxidation
  - Lean-burn turbines
  - Monolithic reactors
  - Rotary kilns
Commercial VAM Projects

Marshall County Mine, West Virginia, USA
- Mine formerly owned by CONSOL and project began under CONSOL
- Mine purchased by Murray Energy in December 2013
- VAM project financed and developed by Sindicatum Sustainable Resources
- 3 2-can RTOs from Durr
- Capacity = 160,000 cfm
- Emission reductions = 197,411 tCO2e

Gaohe Mine, Shanxi Province, China
- Owned by Shanxi LuAn Group
- In development
- 12 RTOs + steam turbine
- Will rely solely on power sales revenue
- Full capacity will be 700,000 cfm and utilize RTOs
- Using drained gas to enrich VAM to 1% CH₄

VAM RTO Manufacturers
- MEGTEC
- Biothermica
- Durr
- HEL-East Ltd
- Gulf Coast Environmental
- Shendong (China)
VAM Best Practices

- VAM projects are a significant investment – requires careful planning before development and considerable oversight after operations begin.
- Understand the methane resource, mine plan, and mine ventilation plan including gas drainage.
- Design should be based on air flow and CH4% data obtained from regular sampling and analysis or preferably continuous emissions monitoring systems.
- Most projects will be destruction-only. Success is almost entirely dependent on carbon markets.
- Some potential for power generation with consistent flow and high VAM concentration (0.90% CH4 or greater).

VAM abatement is essential for near-zero emissions coal mining!
Case Study: Duerping Coal Mine, China

- Owned by Xishan Coal & Electricity Co Ltd, a subsidiary of Shanxi Coking Coal Ltd (Jiaomei Group)
- Xishan Coal Field near Taiyuan City
- 1,600m above sea level
- Metallurgical coal mine
- Production capacity = 5 Mtpa
- 700 Mt reserves
- 50 year life
- Relative emissions = 17.7 m3/t (567 ft3/st)
- CH4 emissions increasing as mine goes deeper and production increases
- Drainage system before project
  - in place prior to project development
  - Prior CH4 concentrations: 25-30%
  - Drainage efficiency = 15%
- No CMM utilization prior to the CMM utilization project
Near Zero Emission Mining for the Duerping Mine CMM Project:

- Maximise gas drainage capture
- Optimise utilisation of the drained coal mine methane (CMM)
- Thermal destruction of surplus CMM
- Destruction of the methane in the ventilation air (VAM)
- Exploit waste heat

A holistic approach to mine safety, energy production & environmental protection
Approach for the Duerping Mine CMM Project*: Steps 1 and 2

**Step 1: Determine Gas Availability**
- Confirmed gas content data, structure of the coal matrix and permeability of the coals
- Modeled CH4 liberation rates

**Step 2: Improve Gas Quality & Quantity**
- Enhanced methane purity
  - Improved borehole sealing (2-stage)
  - Regulated Suction
- Raised gas capture
  - Increase orifice - plate size in the choke
  - Improved borehole design and pattern
  - Controlled extraction from sealed areas

*Acknowledgment to Sindicatum Sustainable Resources and Xishan Coal & Electricity Co.
Step 3: CMM Utilization System Design

- CMM power plant includes:
  - Power generation - 12 MW
  - 5000 m$^3$ per hour enclosed flare
  - Closed loop oil-based heat recovery system
  - Passive vent
  - Minimal gas processing: dewater with knock-out pot and chiller and use 2-stage dust control

- Employed a conservative approach for power plant design
  - Sized project at 80% of the average CH$_4$ flow
  - Assume 80-85% availability for gas engines

- Focus first on utilization of gas drainage
- VAM destruction was secondary objective
Step 4: CMM Plant Operation

- After start-up, implemented best practices to maintain plant operations
  - Training for mine and SSR staff
  - Team to worked with the mine staff to maintain gas availability.
  - Telemetry to monitor operations remotely.
  - Regular walk-throughs and scheduled maintenance including

- Operational monitoring
  - Constant observation to ensure project is operating as planned
  - Alarms and notice system alert staff to problems

Duerping Phases 1&2
Power Plant & Flare Performance

CERs Requested vs Total

- CERs Requested
- Total

Periods:
- 2/09-6/09
- 6/09-10/09
- 10/09-4/10
- 4/10-10/10
- 10/10-3/11
- 3/11-10/11
- 10/11-8/12
- 9/12-12/12
- 1/13-2/14

Total CERs

450,000 CERs Requested

1,600,000 CERs Requested per 150,000 Period
Step 5: VAM Plant

- **Preparation**
  - Installed continuous emissions monitoring system for 3 years recording CH4% data every 15 minutes
  - Regular air flow data at the fan provided by mine staff

- **Contracted with manufacturer in 2011**
  - One 35 m$^3$/sec RTO
  - One 20 m$^3$/sec RCO
  - Plant is destruction only

- **Project registered as CDM project in November 2011**
- **Construction in 2012/2013**
- **Plant is currently idled due to low CDM prices**
Conclusions

- Every project is unique – tailor each project to the operations, mine gas characteristics, regulatory framework, and market conditions
- Be open to employing a portfolio of methane capture and use technologies to achieve near-zero emissions mining
- Project success will be enhanced by
  - Excellent communication among stakeholders
  - Thorough preparation and planning
  - Conservative approach – it is easier and more cost-effective to scale up than scale down.
- But be prepared to still face range of issues throughout project development, construction and operation
  - Gas quality and quantity
  - Mechanical issues
  - Changes in mine operations
  - Changes in market conditions
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