Key Outcomes of VAM Abatement Demo Project at Walter Energy’s Mine in Alabama

U.S. Coal Mine Methane Conference
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Agenda

- Biothermica
- Challenges of VAM Application
- Vamox® Demo Project (JWR, Alabama, USA)
  - Review
  - Key Outcomes including process simulator
- Large Scale Vamox® Unit
- Moving Forward
Biothermica
Who we are

- Private Canadian group founded in 1987.
- Fully integrated carbon project developer.
  - Managing all aspects of its carbon and energy projects.
Transactions exceeding $US 100 million in turn-key projects, including...

- $US 45 million as equity sponsor.
  - Landfill gas collection and power generation systems.
- $US 50 million in carbon credit transactions.
  - Kyoto and voluntary carbon markets.
Landfill Gas Projects

Gazmont 25 MW Power Plant
Montreal landfill (Canada)
2 billion kWh of electricity since 1996

El Salvador CDM Project
Nejapa landfill
215,000 carbon credits over 2006-2008
Major interest in project sold in 2008
Industrial Emissions Control
BIOTOX® Technology

- **Regenerative Thermal Oxidation (RTO).**
- **Expertise → Non-conventional emissions.**
  - Involving corrosive and/or Condensable Organic Compounds (COCs).
- **10 patents**

- Food industry - COC emissions
  - Presque Isle, Maine, USA
  - 100,000 cfm

- Asphalt Shingles - COC emissions
  - Joliette, Quebec, USA
  - 35,000 cfm
VAM Project Development
Natural Evolution

RTO Technology

Landfill Methane Carbon Project Experience
VAM Abatement: More challenging than it looks!
Challenges:

- **at HIGH %CH4:**
  - Prevent $T^\circ$ peak to compromise the integrity of the system.

- **at LOW %CH4:**
  - Maintain RTO in operation without supplemental energy input (e.g. propane).
- Bleeder shafts are typically operational 3-7 years.
- System must be easily movable!
Stringent Safety Requirements

- Each project must be approved by MSHA.
Safety features are required to prevent a deflagration and flashback to the mine.
Features Required to Prevent Deflagation

- System MUST be designed to prevent VAM exceeding 2% from reaching RTO.
  - This safety limit is much below Lower Explosive Limit (LEL 5%).

- Many preventative measures required, including:
  - Fast CH4 Detectors
  - Fast Isolation Dampers
  - Safety Dilution Capacity
Biothermica has adapted its RTO technology (Biotox®) specifically for VAM abatement.
1st Vamox® Demo Project

- Walter energy, No. 4 Mine (shaft 4-9), Brookwood, AL.
- 2009 to 2013.
- 1st VAM oxidation project at active U.S. Coal mine.
- Financed by Biothermica, 100% equity.
- Registered with the Climate Action Reserve (CAR).
Demo Vamox® Specs

- 2 ceramic bed RTO.
- Nominal Capacity → 30,000 cfm.
  - Capture ~10% of VAM flow discharged by the ventilation shaft.
- %CH4 Range → 0.3% - 1.2%.
  - Dilution with fresh air if required.
- Footprint → 1,400 ft² (40’X35’)

[Image of equipment and diagram]
80,766 CRTs (Emission Reductions)

>27,000 hours of operation

92.7%* Availability Rate

*Excluding external events such as CH4 concentration below min. threshold or electricity supply outages
Key Demo Project Outcome: Process Simulator

- **Simulator** is a reliable tool used to...
  - Guide large scale’s design
  - Develop control strategies
  - Predict performance
Simulator Overview: Key Calculation

- Methane oxidation reaction rate ($k_r$)

![Reaction diagram](image)

- Calculated based on Arrhenius Law

$$k_r = A \times \exp \left( -\frac{E}{RT} \right)$$

Where

- $A = \text{experimental constant} \ (\text{s}^{-1})$;
- $E = \text{energy of activation} \ (\text{exp. constant}) \ (\text{cal/mol})$;
- $R = \text{Gas constant} \ (1.987 \ \text{cal/mol/K})$;
- $T = \text{absolute temperature} \ (\text{K})$. 
Simulator Overview: Key Calculation

Methane Oxidation Rate vs Temperature
Simulator Overview: Key Calculation

- **Heat Exchange Rate** between gas and ceramic:

  - Many inputs involved...
    - Ceramic’s characteristics (specific surface area, heat capacity, ...).
    - Gas properties (heat capacity, density, ...)
    - Gas velocity.

- Retained model provides an excellent fit with process data over a wide range of conditions.
- **Pressure drop** through the system

- Many theoretical models tested (i.e. Ergun Equation)

\[
\frac{\Delta P}{H_{layer}} = 150 \left( \frac{\mu v_0}{D_p^2} \right) \frac{(1 - \varepsilon)^2}{\varepsilon^3} + 1.75 \left( \frac{\rho v_0^2}{D_p} \right) \frac{(1 - \varepsilon)}{\varepsilon^3}
\]

- Once again, excellent fit with process data over a wide range of conditions.
Simulator Overview: Key Results

- Temperature profile in ceramic beds

![Diagram showing temperature profiles for BED#1 and BED#2](image-url)
Simulator Overview: Key Results

- **Temperature profile at stack**

![Outlet Temperature graph](graph.png)

- Temperature (°C)
- Time (sec)
Flow & Power Consumption (fan’s performance)
- The fan flow curve provided by manufacturer is used by the simulator to determine the equilibrium flow.
Other Key Demo Project’s Technical Outcomes

- Identification of a ceramic media adapted for this stringent application.
- Optimization of control strategy.
  - Auto-adjustment of operating conditions based on methane concentration to maximize performance.
The experience gained from the Demo project has led to the design of a Large Scale Vamox® system.
Specs - Large Scale Vamox®

- 2 ceramic beds.
- Nominal Capacity → 140,000 cfm.
- %CH4 Range → 0.3% - 1.2%
  - Dilution with fresh air if required.
- Footprint → 5,000 ft² (~50’X~100’).
- System fully instrumented for safety, process control and credit monitoring purposes.
- Self-Diagnostic of system’s performance.
- Designed for facilitated relocation.
Moving Forward

- Finalizing the planning of the next Vamox® project at Walter energy (Brookwood, AL) to connect 2 large scale units on a bleeder shaft.
- Expected credits production: ~400,000 CCOs/year.
- Project to be registered under the new ARB’s MMC Protocol.
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Operating Principle
Start-up
Operating Principle
Cycle 1
Operating Principle

Cycle 2