U.S. EPA Coalbed Methane OUTREACH PROGRAM www.epa.gov/cmop

Ventilation Air Methane (VAM) Utilization Technologies

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Why is VAM Mitigation Important?

Methane, the principal component of natural gas, is often present in deep coal seams and is a safety hazard to miners because it is explosive in concentrations ranging from 5 to 15 percent in air. Therefore, gassy underground coal mines employ large-scale ventilation systems. These systems dilute methane released into the mine workings as coal is extracted and remove the gas from the mine, thereby maintaining safe working conditions. In-mine methane concentrations must be maintained well below the lower explosive limit, so ventilation air exhausts carry only very dilute concentrations of methane (typically less than 1 percent and often less than 0.5 percent). However, because flow rates are so high, ventilation air methane (VAM) constitutes the largest source of methane emissions at most mines. VAM exhausts not only waste a clean energy resource but also contribute significantly to global greenhouse gas emissions. Methane has a global warming potential 23 times that of carbon dioxide, so successfully deploying technologies to convert VAM into useful forms of energy (such as electricity and heat) can result in very substantial greenhouse gas emission reductions.

Ventilation exhaust (evasé) (Photo courtesy of H. Lee Schultz)

Utilization Technologies: VAM as Supplemental Fuel

Internal Combustion Engines/Turbines/Boilers: Some technologies for beneficially using the energy content of ventilation air exhausts are currently available, while others are in the development and demonstration phase. One existing approach is quite straightforward and entails using VAM as *combustion air,* thereby supplying ancillary fuel to internal combustion (IC) engines, turbines, or industrial and utility boilers. Such VAM use in IC engines running on drained coal mine methane has been well demonstrated. The Appin Colliery in New South Wales, Australia implemented a project employing 54 VAM/coal mine methane driven internal combustion engines to power generators that produced 55.6 MW of electricity for the mine. Although using ventilation exhaust as combustion air in large utility or industrial boilers has been demonstrated on a pilot scale at the Vales Point Power Station in Australia, this option is limited by the need to site the facility near the mine. In contrast, IC engines and turbines are readily deployable at remote locations.

Appin power plant (Photo courtesy of EDL)

In addition, EESTech Inc. acquired the rights to an innovative rotary

Available and Developing Options for VAM Utilization

- VAM used as a supplemental fuel (i.e., combustion air)
  - Internal combustion engines
  - Turbines
  - Utility or industrial boilers
  - Hybrid rotary kiln/gas turbine
- VAM used as the principal fuel
  - Flow-reversal oxidizers, with or without energy recovery
    - Thermal
    - Catalytic
  - Gas turbines—microturbines (e.g., 30 kW) and full sized turbines (>0.5 MW)

kiln system that burns waste coal with ventilation air methane or drained coal mine methane. In this application, VAM again is a supplemental fuel. The mixed fuel is combusted in the kiln, and the exhaust gases pass through a specially designed air-to-air heat exchanger. The heated clean air then powers a turbine to produce electricity. The waste coal feed can be adjusted in response to variations in VAM flow or concentration, allowing for a constant energy feed to the turbine for electricity generation. By combusting waste coal and VAM, this technology offers the ability to mitigate methane emissions while also reducing acid runoff from (and spontaneous combustion of) waste coal piles. The technology was developed jointly by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Liquatech Turbine Company Pty., and a 1.2 MW pilot plant was constructed at CSIRO's Queensland Centre for Advanced Technologies. EESTech is standardizing designs for 10 MW and 30 MW systems and is actively commercializing the technology in China and India. Because it avoids the water requirements of steam-cycle power generation, the hybrid coal and gas turbine is appropriate for remote locations where waste coal and methane are available but water is scarce.

Hybrid waste coal/VAM rotary kiln (Photo courtesy of ComEnergy)

Utilization Technologies: VAM as Primary Fuel

Flow-reversal Oxidizers: Both thermal and catalytic systems are commercially available and capable of oxidizing VAM. When VAM enters an oxidizer, the gas encounters a bed of heat exchange material that has been preheated to the oxidation temperature of methane (1000° C). The VAM oxidizes and releases heat, which in turn maintains the temperature of the heat transfer material at or above 1000° C, thereby sustaining the auto-oxidation process without requiring additional fuel input. Valves and dampers repeatedly reverse the flow of incoming VAM to keep the hot zone in the center of the oxidizer. Catalytic and thermal systems both operate on this principal, although catalysts allow the reaction to occur at lower temperatures. When VAM concentrations are high enough, thermal oxidizers can provide excess heat energy for uses such as electricity generation.

This end-use is currently being employed at the West Cliff Colliery in New South Wales, Australia. The West Cliff Ventilation Air Methane Project (WestVAMP) is the world's first commercial-scale VAM-to-power project. Building upon earlier demonstrations of VAM oxidation and steam generation in the UK and Australia, WestVAMP started operation in September 2007 and is producing 6 MW of power for use by the mine. It employs a thermal flow-reversal oxidizer, the VOCSIDIZER™, manufactured by MEGTEC Systems. Another project deploying the VOCSIDIZER™ is in the planning stages at the Datong coal mine in China's Chongqing municipality. This will be the largest VAM oxidation project in the world to mitigate methane emissions and generate thermal energy.

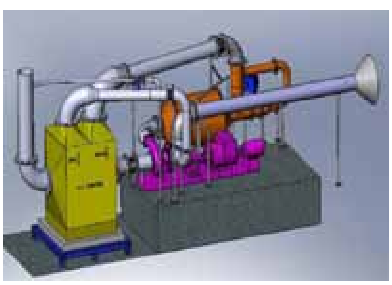
WestVAMP (Photo courtesy of MEGTEC)

Biothermica, a Canadian air pollution control equipment supplier, offers a VAM oxidizer called the VAMOX™. A VAMOX™ unit has been deployed in a successful demonstration program at the Jim Walters Resources mine in Brookwood, Alabama since March 2009. The project is the first to operate at an active underground coal mine in the United States.

Three other oxidizer manufacturers have recently entered the VAM market. Gulf Coast Environmental Systems, LLC provides a thermal flow-reversal oxidizer, the CH4 RTO (regenerative thermal oxidizer), that uses a shipping container as the oxidizer shell, thereby reducing manufacturing costs. China's Shengdong Group is offering a VAM oxidizer that has been field tested for energy recovery (i.e., steam production) at two Chinese mines (Bingchang mine in Shanxi province and Pingmei mine in Henan province). Dürr Environmental and Energy Systems manufactures both traditional oxidizers and the Ecopure® RL rotary RTO, which avoids the use of poppet valves and dampers by employing a single rotary valve to control the flow-reversal process. Finally, Canada's CANMET Energy and Technology Centre developed a prototype catalytic VAM oxidizer called the CH4MIN.

VAMOX™ Project (Photo courtesy of Biothermica)

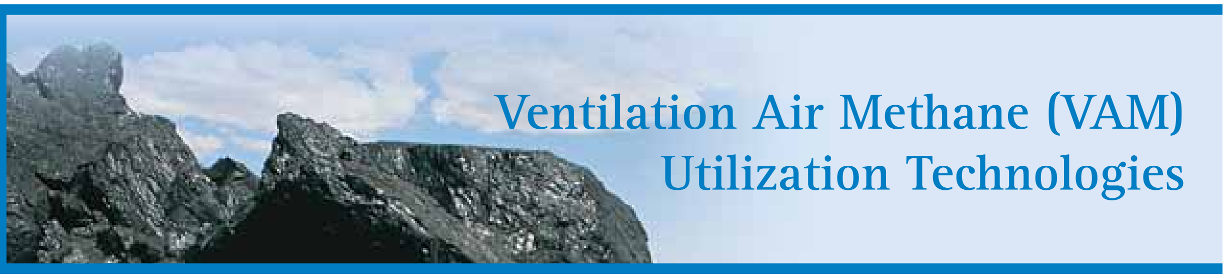
Lean-fuel Gas Turbines: CSIRO developed a lean-fuel gas turbine, the VAMCAT, that employs a catalytic combustor to run on VAM concentrations in the 1 percent range. In most field applications, this technology will require the availability of supplemental fuel (e.g., drained coal mine methane) that can be blended in to increase the methane concentration entering the turbine to approximately 1 percent methane.



VAMCAT schematic (Image courtesy of CSIRO)

In cooperation with Capstone Turbines, FlexEnergy offers a lean-fuel microturbine (Flex-Microturbine™) that is capable of using methane concentrations as low as 1.5 percent for its principal fuel. The system accepts fuel at atmospheric pressure and, by employing catalytic combustion, is able to operate with very low NO_x emissions (below 0.1 ppm). The units can generate up to 30 kW of electrical power each and, in proof-of-concept testing, were shown to achieve nearly full power running on fuels equivalent to <2 percent methane. A FlexEnergy turbine has been installed at the DCOR oilfield near Santa Barbara, California, to consume oilfield gas at concentrations ranging from 1.5 to 4.2 percent, and another is running on coal process waste gas at the Western Research Institute in Laramie, Wyoming. Although no VAM field testing has been performed to date, the system would be applicable to settings where blending gas is available in quantities adequate to raise methane concentrations in the mine exhaust up to the operating concentration of 1.5 percent.

Flex-Microturbine™ (Photo courtesy of Flexenergy)



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Contact EPA's Coalbed Methane Outreach Program for more information about this and other profitable uses for coal mine methane:

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The mention of products or services in this case study does not constitute an endorsement by EPA.