Ventilation Air Methane (VAM) Utilization Technologies

August 2016

U.S. EPA Coalbed Methane Outreach Program

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. Gassy underground coal mines employ large-scale ventilation systems to move fresh air into the mine. 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 contain very dilute concentrations of methane (typically less than 1 percent and often less than 0.5 percent). However, because mine exhaust flow rates are so high, ventilation air methane (VAM) constitutes the largest source of methane emissions at most mines.

Emissions of VAM waste a clean energy resource and contribute significant global greenhouse gas emissions. Methane is a potent greenhouse gas with a global warming potential more than 25 times that of carbon dioxide. Deploying technologies that destroy VAM emissions or convert VAM into useful forms of energy (such as electricity and heat) can yield substantial greenhouse gas emission reductions.

Technologies Using VAM as Primary Fuel

Regenerative Oxidation and Catalytic Oxidation: Regenerative Thermal Oxidation (RTO) is the only commercially operational technology capable of using VAM as a primary fuel at methane concentrations below 1.5 percent. RTO and Regenerative Catalytic Oxidation (RCO) have long been used as odor and pollution abatement equipment in manufacturing, printing and other industries, and have now been successfully adapted to oxidize methane in mine ventilation air. Demonstrations of RTO and RCO VAM abatement occurred in the 1990's and early 2000's, with implementation of the first commercial VAM RTO project in 2007. In total, at least six commercial RTO projects have operated in Australia, China, and the United States.

Available and Developing Options for VAM Utilization

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

How does an RTO destroy VAM? Ducts direct a slip stream of exhaust air from the fan to the oxidizer. Air velocity is maintained in the ducting by use of a fan that creates vacuum pressure. This provides a steady flow of mine ventilation air into the oxidizer, and also ensures that there is not back pressure on the shaft fan. When entering an RTO, gas encounters a bed or column of heat exchange material, usually ceramic media that has been preheated to an oxidation temperature of methane (1000° C). The VAM enters the oxidation chamber where it is oxidized and releases heat, which is absorbed by the second bed or column of heat exchange material, heating the bed to 1000° C. This heat sustains 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 are intended to allow the reaction to occur at lower temperatures and also with reduced pressure drop across the bed of heat exchange material. When VAM concentrations are high enough, thermal oxidizers can provide excess heat energy for uses such as shaft heating and electricity generation. Examples of commercial VAM RTO projects include the West Cliff Colliery in New South Wales, Australia, Verdeo McElroy VAM Abatement Project at the Marshall County Mine in West Virginia, and the Gaohe Mine in China.

***Verdeo McElroy VAM Abatement Project, Marshall County Mine, West Virginia,* USA (courtesy of Sindicatum Sustainable Resources)**

In addition to being the world's first commercial VAM project in 2007, the West Cliff Ventilation Air Methane Project (WestVAMP) developed by BHP Billiton, was also the world's first commercial-scale VAM-to-power project. The plant consists of a VOCSIDIZER™ RTO manufactured by B&W MEGTEC Systems and a 6 MW power plant using a steam turbine generator.

Fortman Clean Energy Technology Ltd VAM Abatement Project, Gaohe Mine, Shanxi Province, China (courtesy of Dürr Systems)

The Verdeo McElroy VAM Abatement Project at the Marshall County Mine in West Virginia commenced operation in May 2012. Sindicatum Sustainable Resources developed the destruction-only project, which consists of 3 RTOs manufactured by Dürr Systems. Each RTO has a capacity of 53,330 cfm for a total plant throughput capacity of 160,000 cfm (75 Nm^3/s), which is 80 percent of the shaft flow.

As of 2016, the world's largest operating VAM destruction project is at the Gaohe Mine in China. Developed by Fortman Clean Energy Technology Ltd. of China, the project's total throughput capacity is 700,000 cfm (300 Nm^3/s) utilizing 12 RTOs manufactured by Dürr. Heat produced by the oxidation process is routed to a steam boiler which generates sufficient steam for a 30-MW power plant. In addition to the Gaohe Mine project, China has hosted several other projects including one at the Datong Mine in Chongqing, which featured six MEGTEC Vocsidizers for a total throughput capacity of 210,000 cfm (104 Nm^3/s).

Other manufacturers of VAM RTOs include the following:

- Biothermica, a Canadian air pollution control equipment supplier, manufactures an RTO called the VAMOX™. A VAMOX™ unit was fully operational at the Blue Creek No. 4 mine in Brookwood, Alabama USA from 2009 through 2012. The project employed a single unit capable of handling 30,000 cfm or 14 Nm^3/s. The project was the first to operate at an active underground coal mine in the United States, and the success of the demonstration led Biothermica to design a much larger RTO capable of handling 140,000 cfm.
- Gulf Coast Environmental Systems, LLC, supplies the CH4 RTO™
- HEL East Ltd. of the United Kingdom, which has tested a commercial-scale unit at an operating coal mine

Biothermica VAMOX™, Blue Creek Mine #4 Mine, Alabama, USA (courtesy of Biothermica Technologies Inc.)

Catalytic technology for VAM abatement operates in a manner similar to RTOs but employs catalysts that enable it to operate at lower temperatures. The catalysts are placed with the heat exchange media in the bed increasing the total column of material. Although this lowered the oxidation temperature compared to a similar-sized RTO in early trials, it also resulted in lower VAM throughput and, thus, reduced revenue potential. However, research and development have continued to address these issues, and commercial deployment of RCOs is expected in the near future.

- Canada's CANMET Energy and Technology Centre developed a prototype catalytic VAM RCO called the CH4MIN™ using a proprietary catalyst. Following bench scale and field demonstrations by CANMET, Sindicatum Sustainable Resources licensed the CH4MIN™ technology since 2007, and from 2008-2009, built and successfully tested a 15 Nm^3/s commercial-scale CH4MIN™ in a laboratory setting.
- In 2015, Johnson Matthey, a United Kingdom-based global chemical manufacturer, introduced a new catalytic system, COMET™, developed in collaboration with Anglo Coal to address VAM emissions. COMET™ is a "once through" system where the VAM stream is passed through a heat exchanger to raise the temperature of the gas to the desired inlet temperature and then passed through the oxidation reactor containing the oxidation catalyst. Johnson Matthey and Anglo Coal successfully tested the COMET™ system at an operating mine in Australia on VAM concentrations ranging from 0.1-0.8 percent CH_4.

Lean-fuel Turbines: Generation of electricity from VAM requires a rich and consistent CH_4 stream. For most shafts, this will require the addition of supplemental fuel such as drained gas that can be blended with VAM to increase the methane concentration to approximately 1 percent methane.

Ener-Core Powerstation EC250 (courtesy of Ener-Core, Inc.)

Lean-fuel gas turbines using VAM as the primary fuel are close to commercial deployment.

- The Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia has developed a lean-fuel gas turbine, the VAMCAT™, which employs a catalytic combustor to run on VAM concentrations. CSIRO created a 25kWe power generator demonstration unit and trialed it at an underground coal mine of the Huainan Coal Mining Group in China in November 2011. The demonstration unit operated at a CH_4 concentration of 0.8 percent.
- Ener-Core produces the Powerstation EC250 which uses a Flexturbine microturbine to produce power directly from VAM. The operating range is from 100% to as low as 1.5% CH_4. The system can run directly on low pressure, low quality gases including VAM. A Power Oxidizer replaces the combustor, producing the heat to drive the turbine. With low-Btu fuels including VAM, the fuel is aspirated with air prior to the inlet and oxidation, eliminating external compression and accepting low pressure gas. Ener-Core also makes the Power Oxidizer 2 MW power station using a Dress-Rand turbine.

Technologies Using VAM as Supplemental Fuel

Some technologies capable of using the energy content of ventilation air exhausts as a supplemental fuel in internal combustion engines, turbines, or industrial boilers are currently available.

One existing technology application entails using VAM as combustion air, supplying ancillary fuel to internal combustion (IC) engines, turbines, or industrial and utility boilers. Using VAM as combustion air in IC engines whose primary fuel is drained coal mine methane has been well demonstrated. For example, 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. 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. Using VAM for combustion air is limited by geographic constraints: the facility must be sited near the mine.

Another approach to using VAM as a supplemental fuel involves an innovative rotary kiln system that burns waste coal with ventilation air methane or drained coal mine methane. 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 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 CSIRO and Liquatech Turbine Company Pty., and a 1.2 MW pilot plant was constructed at CSIRO's Queensland Centre for Advanced Technologies. EESTech Inc. acquired the rights to the technology and is standardizing designs for 10 MW and 30 MW systems while 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.

For More Information…

To obtain more information about emerging VAM mitigation technologies, contact:

Babcock & Wilcox MEGTEC (B&W MEGTEC)
Theros Svenssons Gata 10 SE-417 55Gothenburg, Sweden 41755
Ken Zak, Vice President
Phone: 46 (0)31 65 78 19
E-Mail: KZak@megtec.com
http://www.megtec.com/

Biothermica Technologies Inc.
426, rue Sherbrooke Est
Montréal, Québec H2L 1J6 Dominique Kay, Director of R&D
Phone: (514) 488-3881
E-mail:
dominique.kay@biothermica.com
http://www.biothermica.com/content/coal-mine-methane

CANMET
1615 Lionel-Boulet Boulevard P.O. Box 4800 Varennes, Quebec, Canada J3X 1S6
Eric Soucy, Director, Industrial Systems Optimization Group
Phone: (450) 652-4299
E-mail: eric.soucy@nrcan.gc.ca
http://www.nrcan.gc.ca/energy/

Commonwealth Scientific and Industrial Research Organisation
PO Box 883 Kenmore, Queensland, Australia 4069
Dr. Su Shi, Project Leader
Phone: 61-7-3327 4679
E-mail: shi.su@csiro.au
http://www.csiro.au

Dürr
40600 Plymouth Road Plymouth, MI 48170 USA
Jason Schroeder, Director
Phone: +1 734-254-2443
E-mail:
jason.schroeder@durrusa.com
www.durr-cleantechnology.com
www.durr.com

EESTech
Ground Floor, Engineering House
447 Upper Edward Street Brisbane, Queensland, Australia 4000
Ian Hutcheson, CFO
Phone: 61-7-3832-9883
E-mail:
ihutcheson@eestechinc.com
http://www.eestechinc.com/index.php?page=16

Ener-Core, Inc.
9400 Toledo Way Irvine, CA 92618
Mark Owen, Director of Sales
Phone: (949) 616-3300
Fax: (949) 616-3399
E-Mail: info@ener-core.com
http://ener-core.com/

Fortman (Beijing) Clean Energy Technology Ltd.
Steven Wan, Ph.D., CEO
E-Mail:
steven@fortmanenergy.com

Gulf Coast Environmental Systems, LLC
18150 Interstate 45 North
Willis, TX 77318
Chad Clark, Technical Director
Phone: (773) 572-5992
Email: cclark@gcesystems.com
http://www.gcesystems.com

HEL East Ltd.
Randall Way, Retford
Nottinghamshire, UK
Neil Butler
Design Engineer and Project Technical Development
Phone: +44(0)1777712764
E-mail: nbutler@hel-east.com
http://www.hel-east.com/

Johnson Matthey Process Technologies
Paddington, 10 Eastbourne Terrace London, W2 6LG, UK
Ian Mitchell
Phone: +44 (0)20 7957 4120
E-mail:
ian.mitchell@matthey.com
http://www.jmprotech.com/

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

Coalbed Methane Outreach Program
U.S. Environmental Protection Agency
Washington, DC

Felicia Ruiz
Phone: + 1 (202) 343-9129
E-mail: ruiz.felicia@epa.gov

Website: www.epa.gov/cmop

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