ARPA-E REMEDY Project DE-FOA-0002504-1557: Catalytic Oxidation of Ventilation Air Methane

PI: Joseph M. Fedeyko – Johnson Matthey Inc.

Team Members: Oak Ridge National Laboratory
CONSOL Energy Inc.

Project Vision

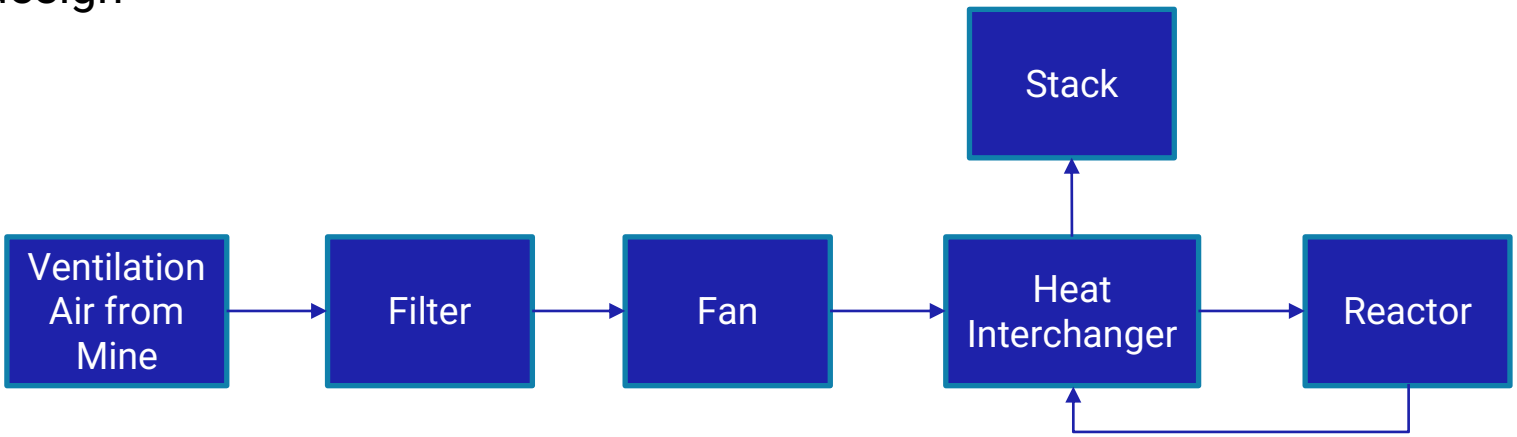
To demonstrate a low-cost solution to achieve above 99.5% methane conversion efficiency at temperatures below 600 ℃ to abate Ventilation Air Methane (VAM) from underground coal mines with methane concentration in the range of 0.1-1.6%, which represents nearly all VAM sources in the US

Total Project Cost:	$5.4M
Length	36 mo.

The Concept

The project builds on the COMET™ design previously demonstrated at lab scale by JM

Key features:
Low temperature and high conversion operation in once through simple unit design



Project Goals:

- Maintain key features with reduced precious metal cost contribution ~ 75%
- Field Test Unit scaled down from commercial scale
- One year durability test on Field Test Unit

The Team

- PI: Joseph M. Fedeyko
- Project Manager: Yuliana Lugo-Jose
  - Methane oxidation catalyst development
  - Catalytic Oxidation of METhane (COMET™) system design and validation

- Co-PI: Hai-Ying Chen
  - Catalyst characterization and model development

- Co-PI: Jacqueline M. Fidler
  - Field testing site selection
  - Field testing unit installation and validation
  - One-year field durability testing

Project Plan

Major milestones (budget period 1)

Project Start Date: 5/23/2022

MS		JM	Consol	ORNL	1	2	3	4	5	6	7	8	9	10	11	12
1.5	Gas composition/mine site selection		Lead				M1									M2
1.3	Catalyst Characterization			Lead						M1						M2
1.4	System Design	Lead	Lead							M1						M2
1.2	Development of methane oxidation catalyst	Lead											M1			M2
1.5	Site permitting		Lead													M1
1.6	T2M and Stage 1 project review	Lead	Lead	Lead												M1
1.6	Go/no Go decision	Lead	Lead	Lead												M1

Quarterly report	Timeline
1	October 30th
2	January 30th
3	April 30th
4	July 30th

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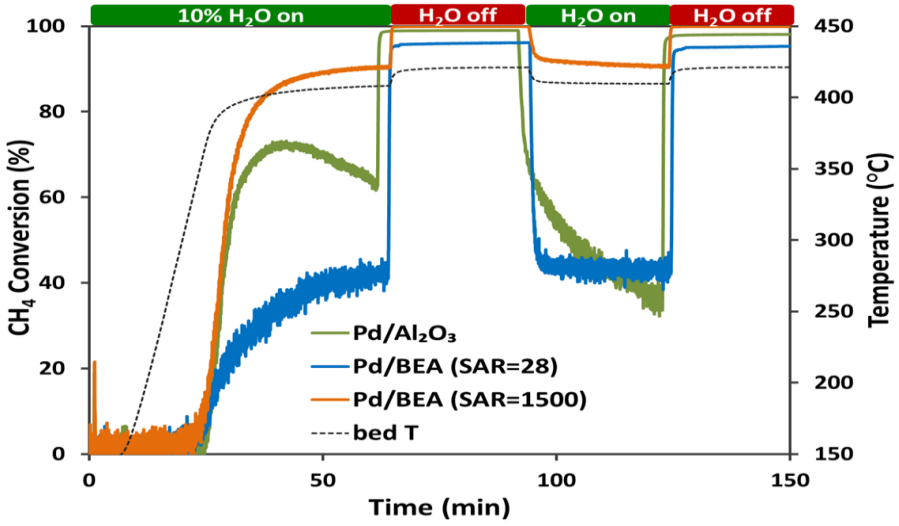
CHANGING WHAT'S POSSIBLE

Preliminary Results

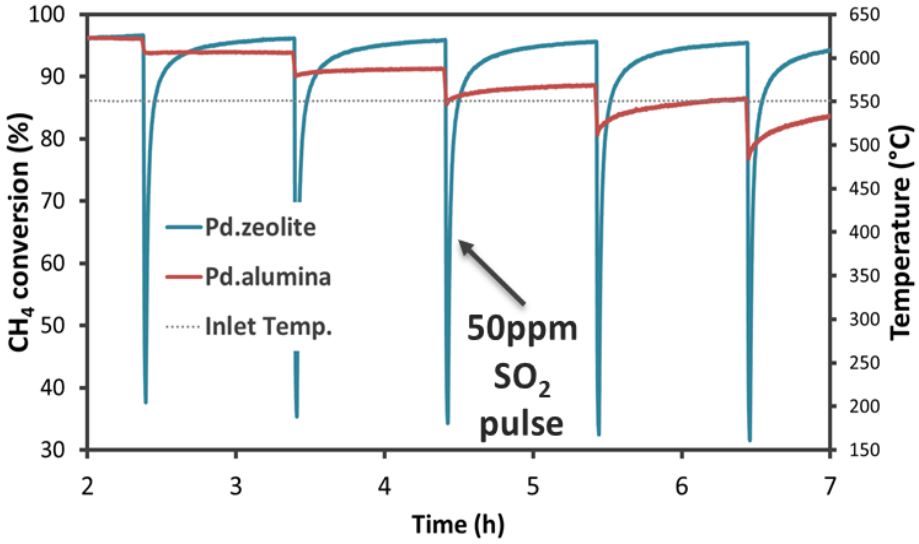
- Using JM extensive expertise in methane oxidation
- A series of potential support materials have been identified and are being evaluated for water tolerance and sulfur resistance, the key factors for methane oxidation performance

Impact of Water



Methane oxidation on Pd/Al_2O_3 and Pd/BEA catalysts: Effects of H_2O on CH_4 conversion (4000 ppm CH_4, 120 ppm C_2H_6, 1000 ppm CO, 500 ppm NO, 6.5% CO_2, 0 or 11% H_2O, 12% O_2, balance N_2, SV = 1000 L $gcat.^{-1}h^{-1}$

Impact of Sulfur



Impact of sulfur on the methane oxidation activity of Pd/Al_2O_3 and Pd/zeolite, (4000 ppm CH_4, 120 ppm C_2H_6, 1000 ppm CO, 500 ppm NO, 6.5% CO_2, 11% H_2O, 12%O_2, 0 or 50 ppm SO_2, balance N_2, SV =1000 L $gcat^{-1}$ h^{-1}, Temp = 550 °C).

Reference: Lu, J., et al. Siliceous Zeolite-supported Palladium Catalysts for Methane Oxidation. in North American Catalysis Society Meeting 2017. 2017.

Site Selection Criteria

First task after kick-off was to identify sites and evaluate key aspects

Activities includes:

- Potential sites for test unit in Green County, PA
- A matrix for site selection was developed
  - Methane content (applicability and range)
  - Construction and Operability of unit(s)
  - Site Access, Space Availability and Communications
  - Mine Scheduling/Timing
  - Security
- 3 potential sites were ranked in order of suitability
- Gas monitoring equipment has been selected and will be purchased, tested and installed

Challenges and Risks

Main challenges and risks

- Inability to reduce PGM cost contribution ~ 75%
- Lack of tolerance to other poisons and long-term durability
- Inaccurate characterization of VAM flow rates and composition
- Inability to secure all regulatory approvals
- Unexpected changes to mine timing, permitting, etc
- Inability to fabricate the field test unit in a timely manner
- Other: Lack of market, regulatory uncertainty, inability to identify T2M

Summary

- The team: Johnson Matthey, ORNL and CONSOL Energy

- The goal of the project is to:
  - Demonstrate a low-cost catalyst and system to achieve above 99.5% methane conversion efficiency at temperatures below 600 ℃
  - Design and commercialize the system
  - Generate a one-year durability assessment

- If successful, initial full-size systems will be designed, fabricated, and installed through a collaboration of the project team.
  - Subsequent marketing will be led by JM
  - With JM providing catalysts, catalyst services and licensing of the system.
  - JM will collaborate with 3rd party engineering company for detail engineering and construction