Flue Gas Water Vapor Latent Heat Recovery for Pressurized Oxy-Combustion

Project DE-FE0025350
NETL Program Manager: Steve Markovich

Project Manager:
Dexin Wang – Institute Engineer
Gas Technology Institute
Project Overview

- **Funding:** $2,648,945
  - DOE = $1,999,795. Cost share = $649,150 (24.5%)

- **Performance Period:**
  - Sep 1 2015 – Aug 31 2018

- **Participants:**
  - Gas Technology Institute (lead)
  - Media & Process Technology
  - Florida International University
  - SmartBurn LLC
Project Overview

- Overall Project Objectives
  - Facilitate energy and water recovery to improve the efficiency of pressurized oxy-coal power boilers
  - Design, build, and test a high-pressure modular version of the Transport Membrane Condenser (TMC) at pilot scale to evaluate its performance and analyze the results for future commercial-scale power plants.
Technology Background

- GTI developed Transport Membrane Condenser (TMC) technology
- Nanoporous ceramic membrane selectively recovers water vapor and latent heat from natural gas combustion flue gases
  - Increases boiler efficiency and saves water, avoiding corrosive condensate
Technology Background

- Non-boiler industrial applications (e.g., commercial laundry)
- Existing power plants (slipstream from coal-fired power boiler)
Technology Application for Pressurized Oxy-Coal boiler

**ADVANTAGES**

- Latent heat recovery can boost power generation efficiency of pressurized oxy-coal boiler by up to 14%
- TMC can recover clean water from flue gas equal to 2.0% of steam demand
- No boiler modifications required
- Reduced dew point of flue gas

**CHALLENGES**

- Durability of TMC in flue gas with coal-derived contaminants (particulates, SO$_2$, and NO$_x$)
- Integrity of ceramic multi-tube sealing in pressurized TMC operation
- Controllability and performance
Approach/Scope

- **Experimental design**
  - Single TMC membrane bundle housed in a pressure vessel, connected in parallel and/or series

- **Work plan**
  - Develop and build high-pressure modular version of the TMC
  - Install TMC skid at GTI’s Flex Fuel Gasification Facility
  - Gasify PRB coal, combust and condition syngas to simulate exhaust from pressurized slurry-fed oxy-coal combustion with FGD at 1-3 MW\text{th} scale
  - Test TMC unit in different configurations

- **Success criteria**
  - TMC performance conforms to model predictions
  - TMC meets expectations for controllability and durability
Progress & Current Status

Task 2: Process Modeling and Design Evaluation

- Task 2.1: Process Modeling for System Design and Operation
  - Model for commercial reference case is a 550-MWe slurry feed oxy-coal boiler using PRB coal with 50% moisture
  - Flue gas is recirculated from downstream of FGD
Progress & Current Status

Task 2: Process Modeling and Design Evaluation

- Task 2.1: Process Modeling for System Design and Operation
  - Developed and updated model for 2.7-MWth pilot simulation of commercial case, actual flue gas going to the TMC equivalent to 1.24MWth coal boiler flue gas
  - Coal is gasified, syngas filtered, and slipstream combusted with oxygen, CO₂, water, and steam to obtain conditioned flue gas for TMC testing
  - Portion of TMC water is recycled and cooled to simulate plant water supply
Progress & current status
Task 2: Process Modeling and Design Evaluation

- Task 2.2: CFD Simulation to Define TMC Design Parameters
  - Single TMC module CFD study for different tube arrangement effect
  - Baffle effect has been studied, and the 3-baffle configuration shows optimum heat and mass transfer
Progress & current status

Task 2: Process Modeling and Design Evaluation

- Task 2.2: CFD Simulation to Define TMC Design Parameters
  - 6 TMC modules arranged into different series and parallel configurations based on flue gas flow
    - 3x2 (3 in series, 2 parallel sets)
    - 2x3 (2 in series, 3 parallel sets)
Progress & current status

Task 3.1: Spaced tube bundles design, fabrication, and testing

Completed Pilot Scale TMC Membrane Bundle Fabrication

✓ Completed preparation of seven pilot scale TMC membrane bundles
✓ Dual ended potting successfully demonstrated in thermal cycling to 200°C
✓ Potting based upon high performance glass reinforced epoxy

TMC Bundle Fabrication Layout
(4” OD x 36” Length; ca. 90 Tubes)

Finished TMC Bundles

Teflon Baffles for Shell Side Gas Flow Distribution
Progress & current status
Task 3.2: High-Pressure Bundle Housing Design, Fabrication, and Testing

Completed Fabrication of the TMC Housing
✓ Seven pilot scale TMC membrane housings were fabricated and tested
✓ Membranes and modules tested to 200°C and 200 psig.

Fully Assemble TMC Module

Bundle Installed in Module
Progress & current status

Task 3.2: High-Pressure Bundle Housing Design, Fabrication, and Testing

Bundle Test Rig and Oven
Progress & Current Status
Task 3.3: TMC Test System Configuration and Control Design

- Two configurations can be easily changed online for pilot testing.
Progress & Current Status
Task 3.3: TMC Test System Configuration and Control Design
Progress & Current Status
Task 4: Pressurized Oxy-Coal Pilot System Test Preparation

Pilot plant complex
Gasifier
Progress & Current Status

Task 4: Pressurized Oxy-Coal Pilot System Test Preparation

Task 4.2: Test system modifications
- Completed coal feeding lift line modification
- Completed syngas burner fabrication
- Now testing the burner before it is integrated into existing tar reformer vessel
Progress & Current Status
Task 5.1: TMC Test Skid Installation and System Configuration
Progress & Current Status

Task 5.1: TMC Test Skid Installation and System Configuration
Progress & Current Status

Task 5.1: TMC Test Skid Installation and System Configuration
## Progress & Current Status

### Schedule Update

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Plan

To Date
Plans for Next Step
Testing, development, commercialization

- Test, analysis, and CFD simulation
  - We plan to test each of two TMC configurations for at least 24 hours at steady state conditions
  - Key variables will be TMC inlet water flow rate and temperature
  - Test results will be used to validate CFD modeling, which can then be applied to evaluate more configurations and operating modes

- Scale up and integration evaluation for commercial scale plant
  - Performance and Cost optimization for membrane module manufacture, TMC system design, and control;
  - Commercial plant integration study to achieve the best economy for shorter payback period.
Thanks!

Questions?