the Energy to Lead

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

gti

Project Overview

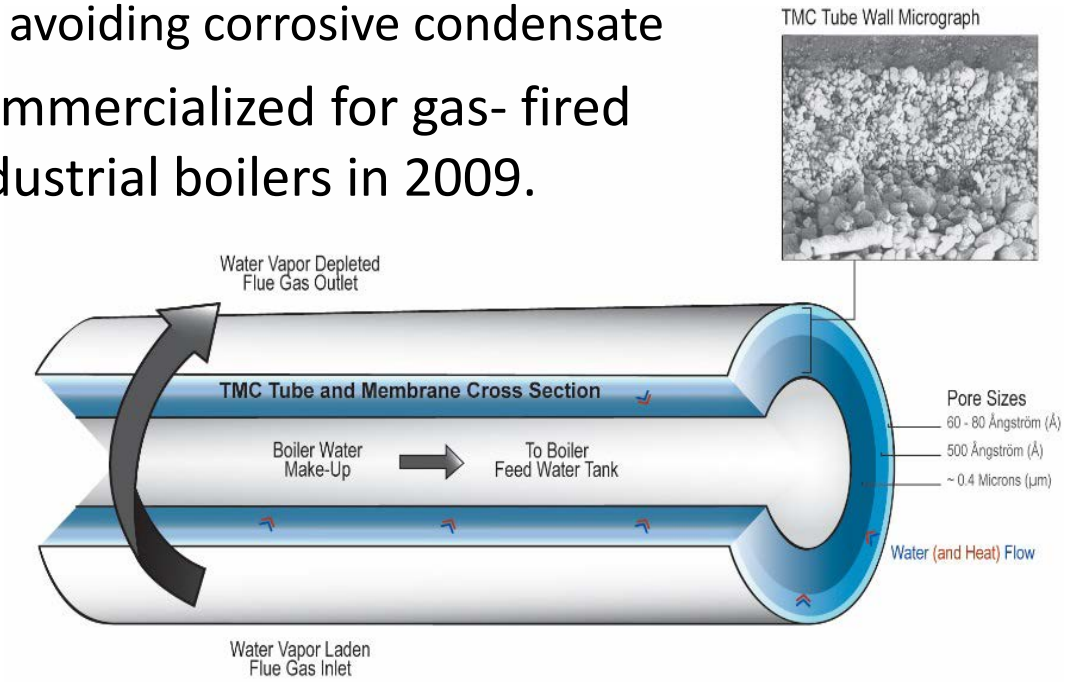
- Funding: $2,648,945
  - DOE = $1,999,795. Cost share = $649,150 (24.5%)
- Performance Period:
  - Sep 1 2015 – Aug 31 2018
- Participants:
  - Gas Technology Institute (lead)
  - Media & Process Technology
  - Florida International University
  - SmartBurn LLC

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
- Commercialized for gas- fired industrial boilers in 2009.



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

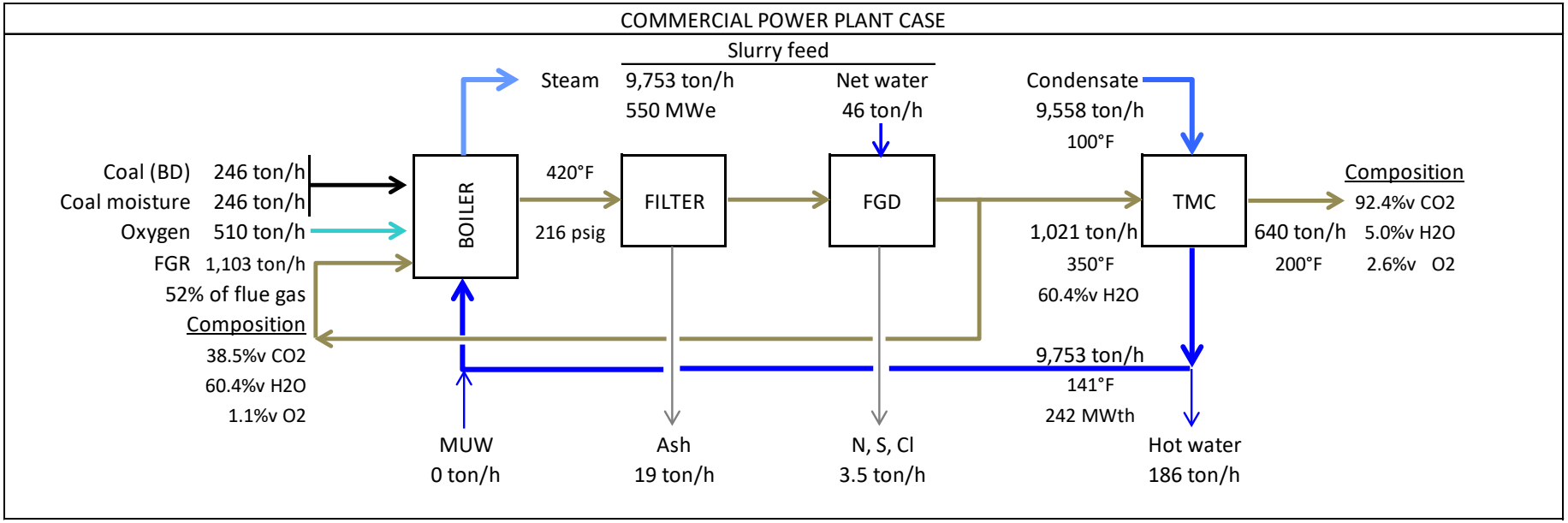
Approach/Scope

- 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_{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

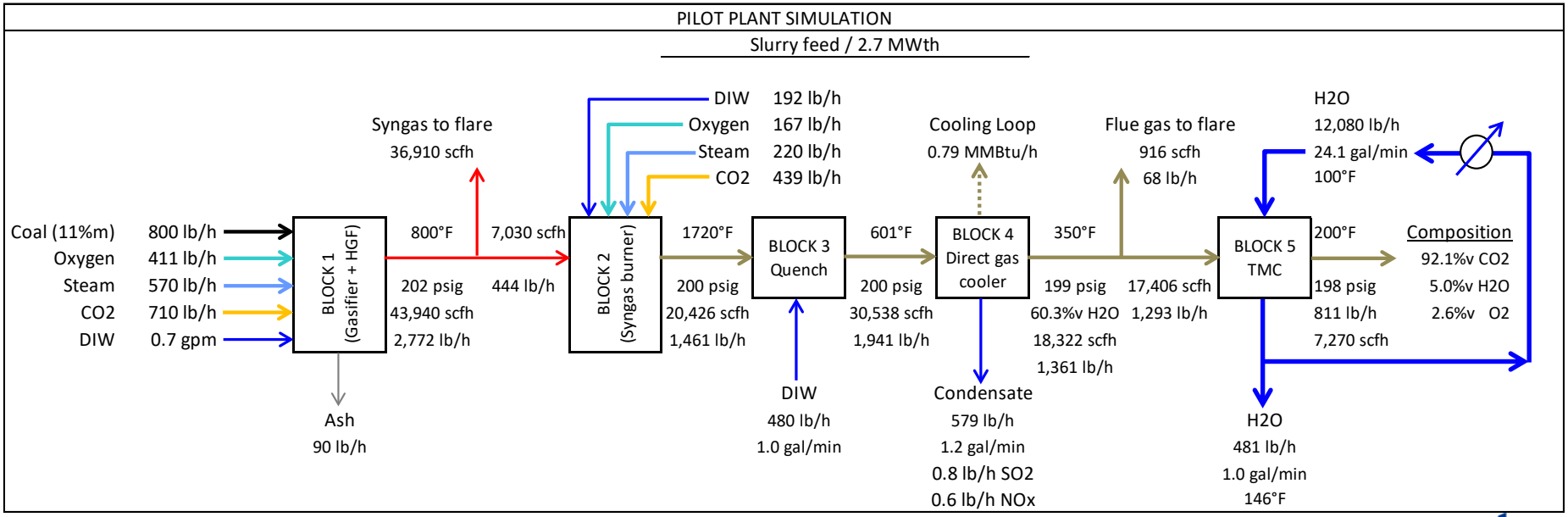
- Task 2.1: Process Modeling for System Design and Operation
  - Model for commercial reference case is a 550-MW_e slurry feed oxy-coal boiler using PRB coal with 50% moisture
  - Flue gas is recirculated from downstream of FGD



Progress & Current Status

Task 2: Process Modeling and Design Evaluation

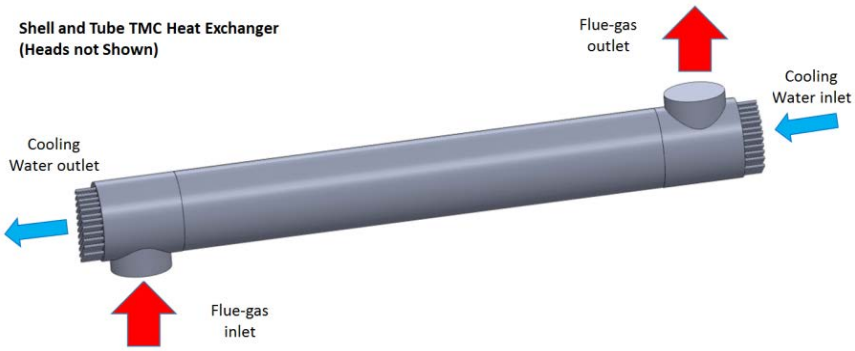
- Task 2.1: Process Modeling for System Design and Operation
  - Developed and updated model for 2.7-MW_{th} pilot simulation of commercial case, actual flue gas going to the TMC equivalent to 1.24MWth coal boiler flue gas
  - Coal is gasified, syngas filtered, and slipstream combusted with oxygen, CO_2, water, and steam to obtain conditioned flue gas for TMC testing
  - Portion of TMC water is recycled and cooled to simulate plant water supply

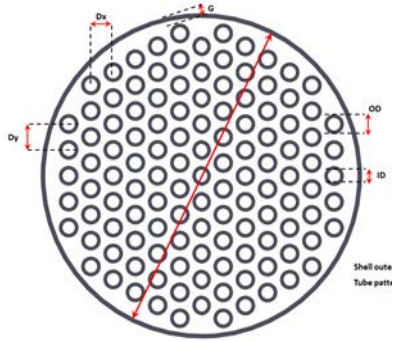


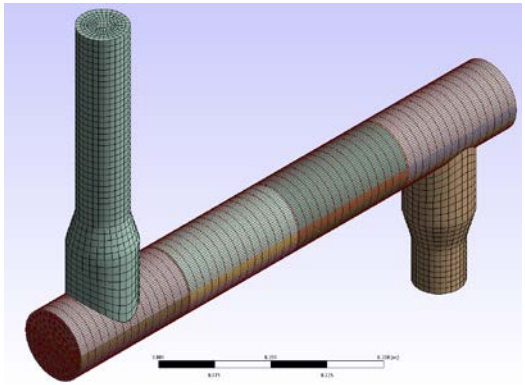
Progress & current status

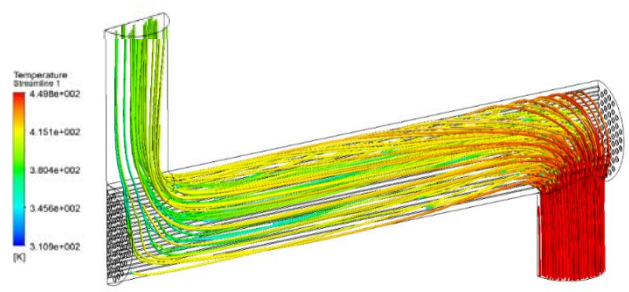
Task 2: Process Modeling and Design Evaluation

- 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

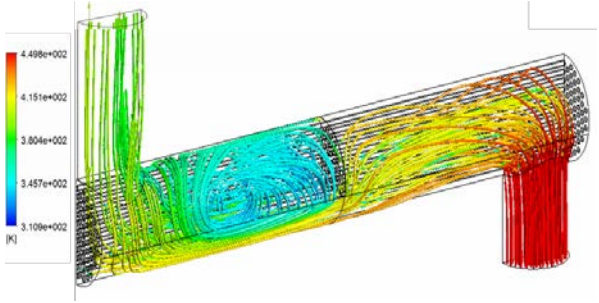




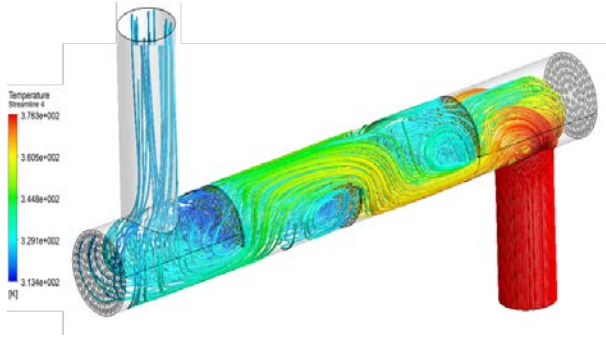




No-baffle configuration



1-baffle configuration

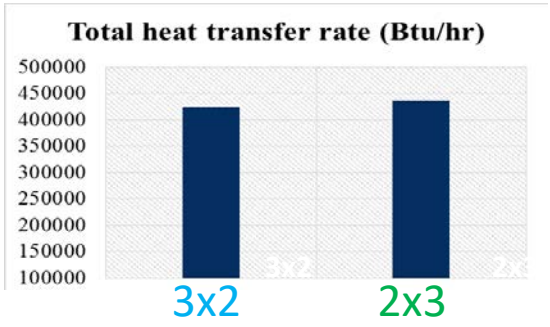


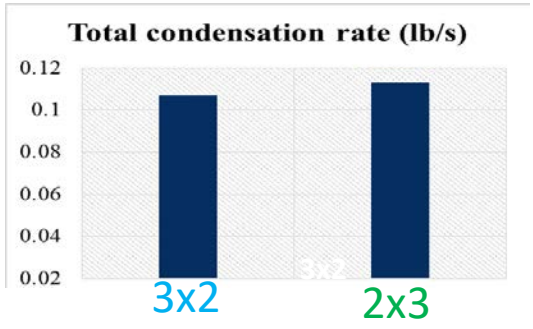
3-baffle configuration

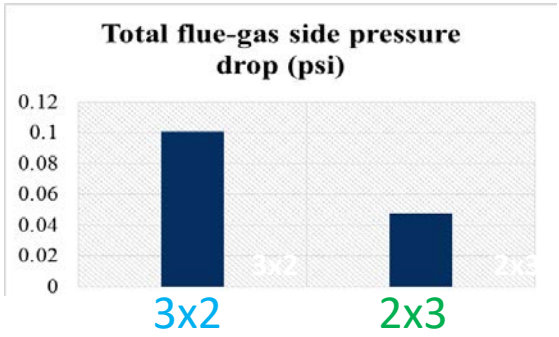
Progress & current status

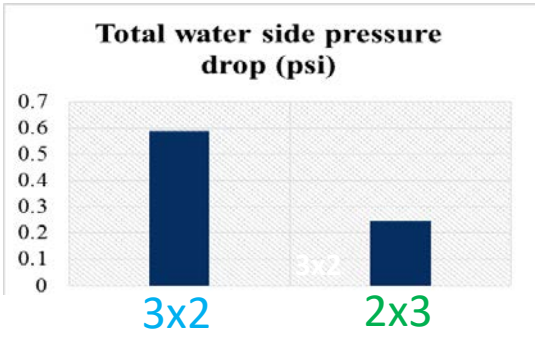
Task 2: Process Modeling and Design Evaluation

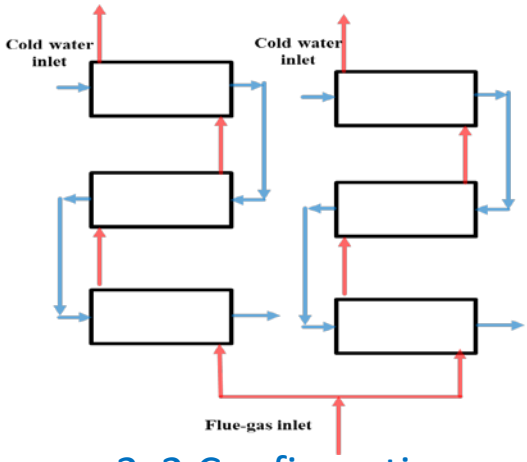
- Task 2.2: CFD Simulation to Define TMC Design Parameters
  - 6 TMC modules arranged into different series and parallel configurations based on flue gas flow
    - 3x2 (3 in series, 2 parallel sets)
    - 2x3 (2 in series, 3 parallel sets)



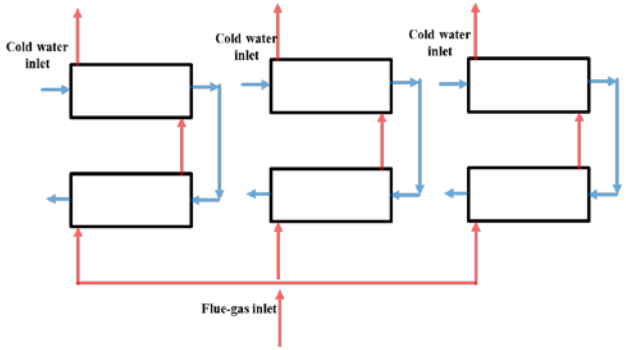








3x2 Configuration



2x3 Configuration

Progress & current status

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

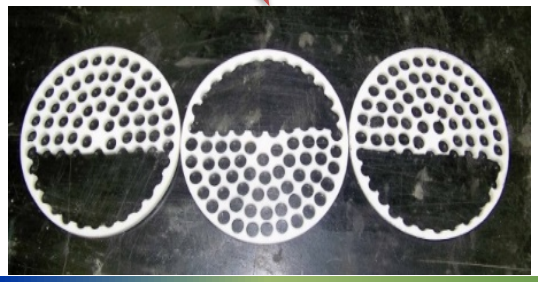
Completed Pilot Scale TMC Membrane Bundle Fabrication

- ✓ 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



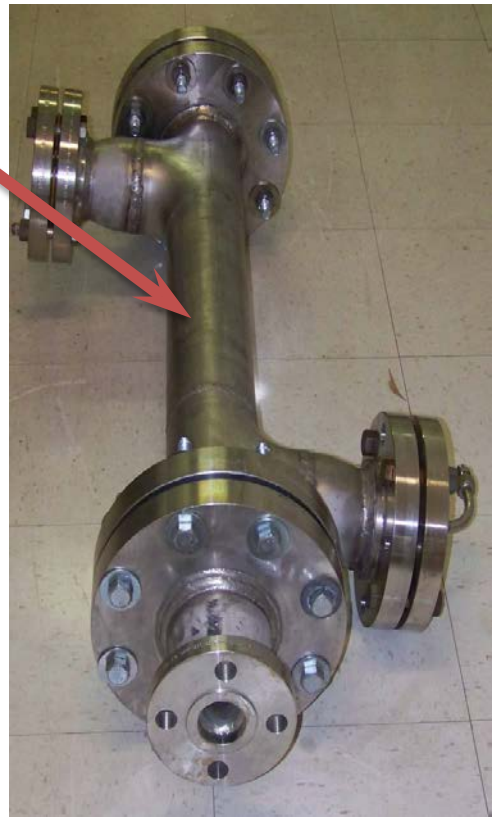
Progress & current status

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

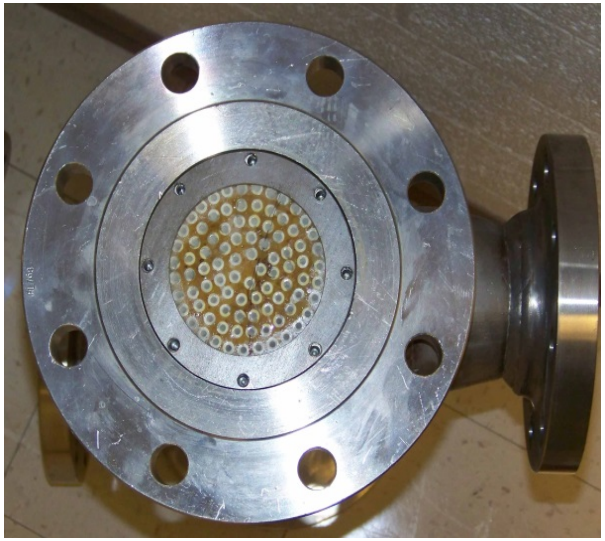
Completed Fabrication of the TMC Housing

- ✓ 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



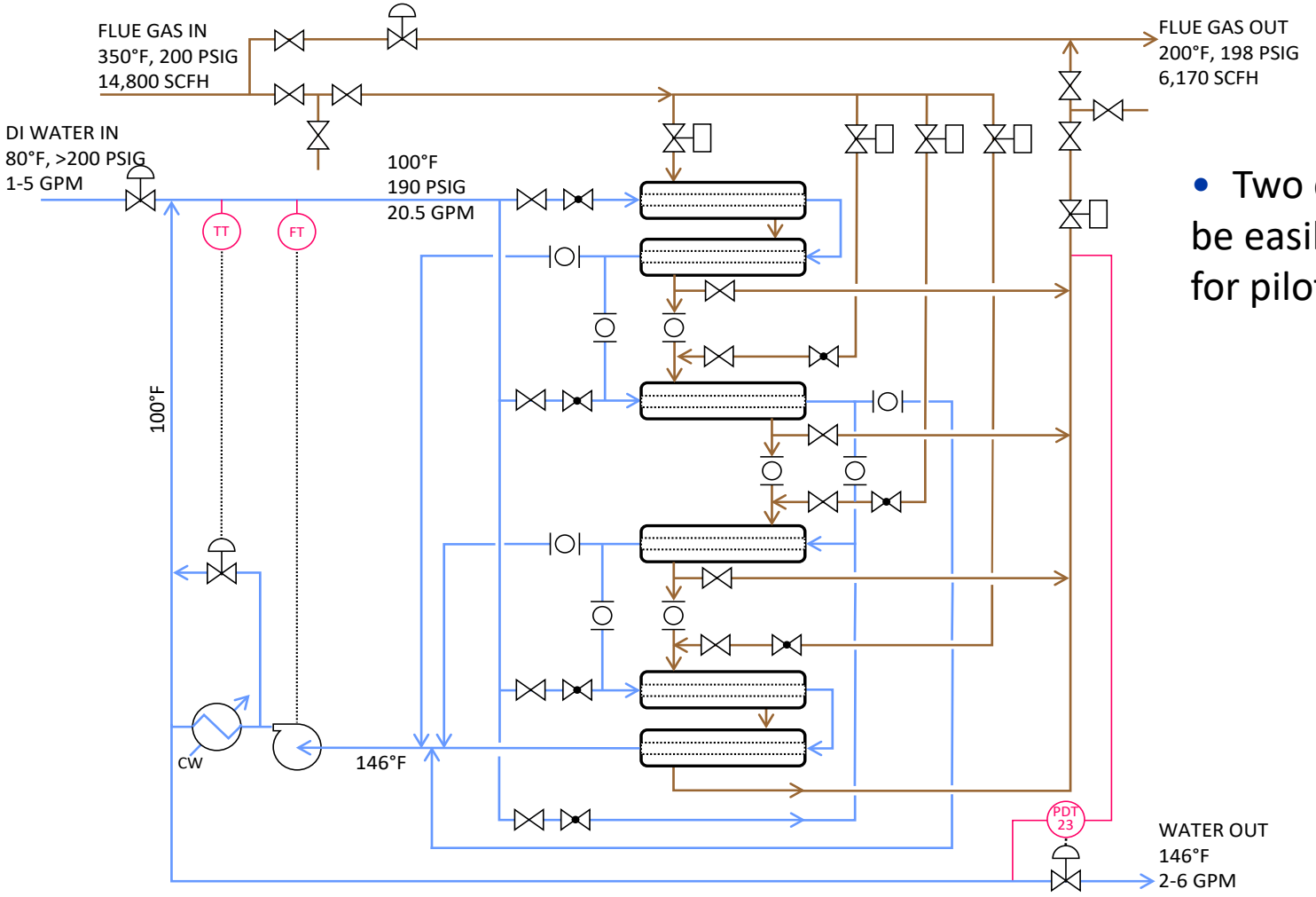
Progress & current status

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

Bundle Test Rig and Oven

Progress & Current Status

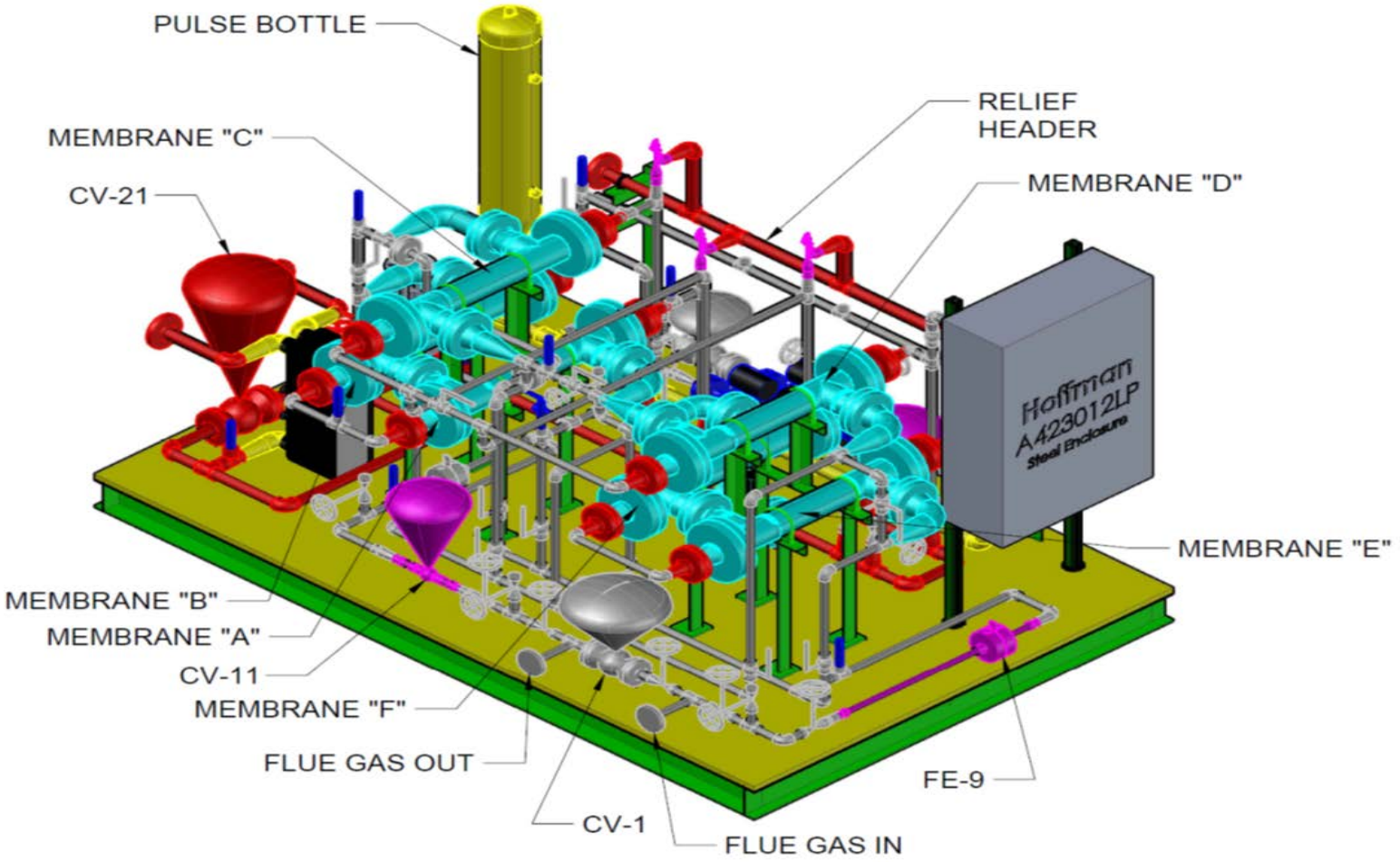
Task 3.3: TMC Test System Configuration and Control Design



- Two configurations can be easily changed online for pilot testing

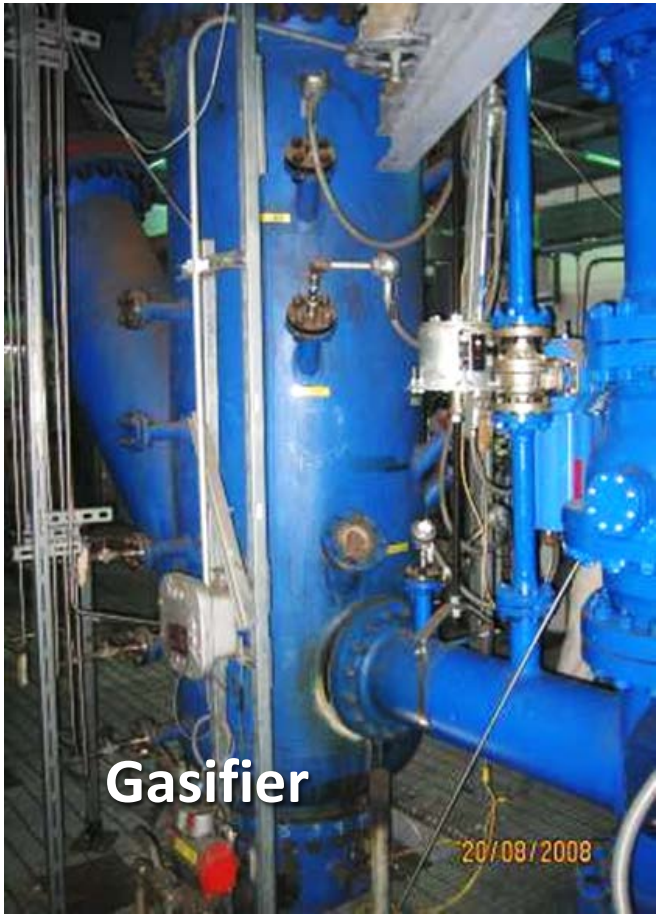
Progress & Current Status

Task 3.3: TMC Test System Configuration and Control Design



Progress & Current Status

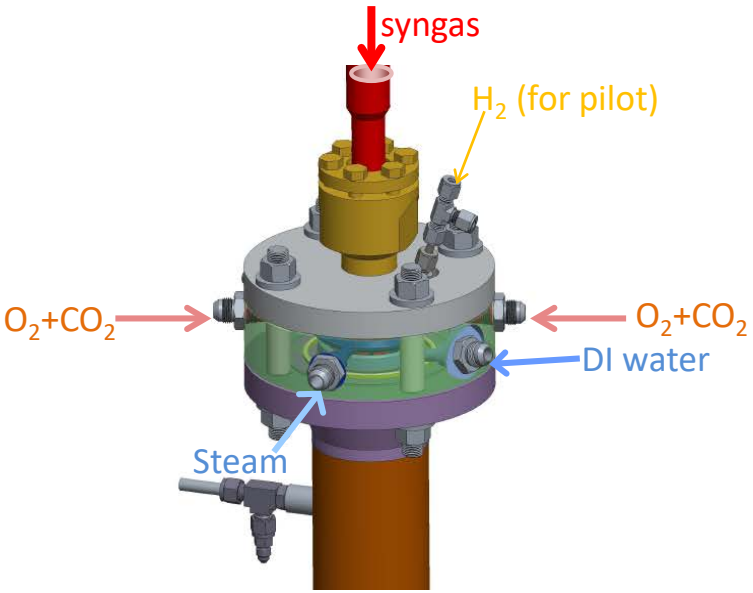
Task 4: Pressurized Oxy-Coal Pilot System Test Preparation

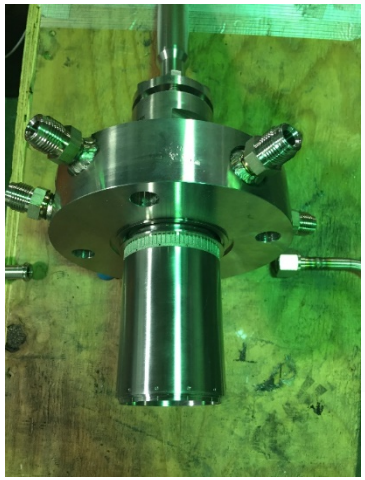


Progress & Current Status

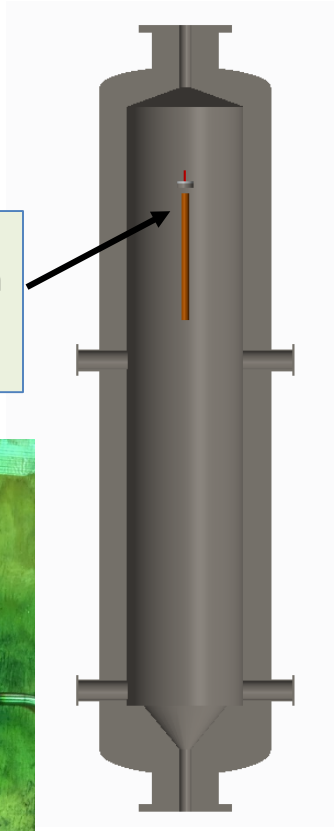
Task 4: Pressurized Oxy-Coal Pilot System Test Preparation

- 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





Burner placement in tar reformer vessel



Progress & Current Status

Task 5.1: TMC Test Skid Installation and System Configuration

Progress & Current Status

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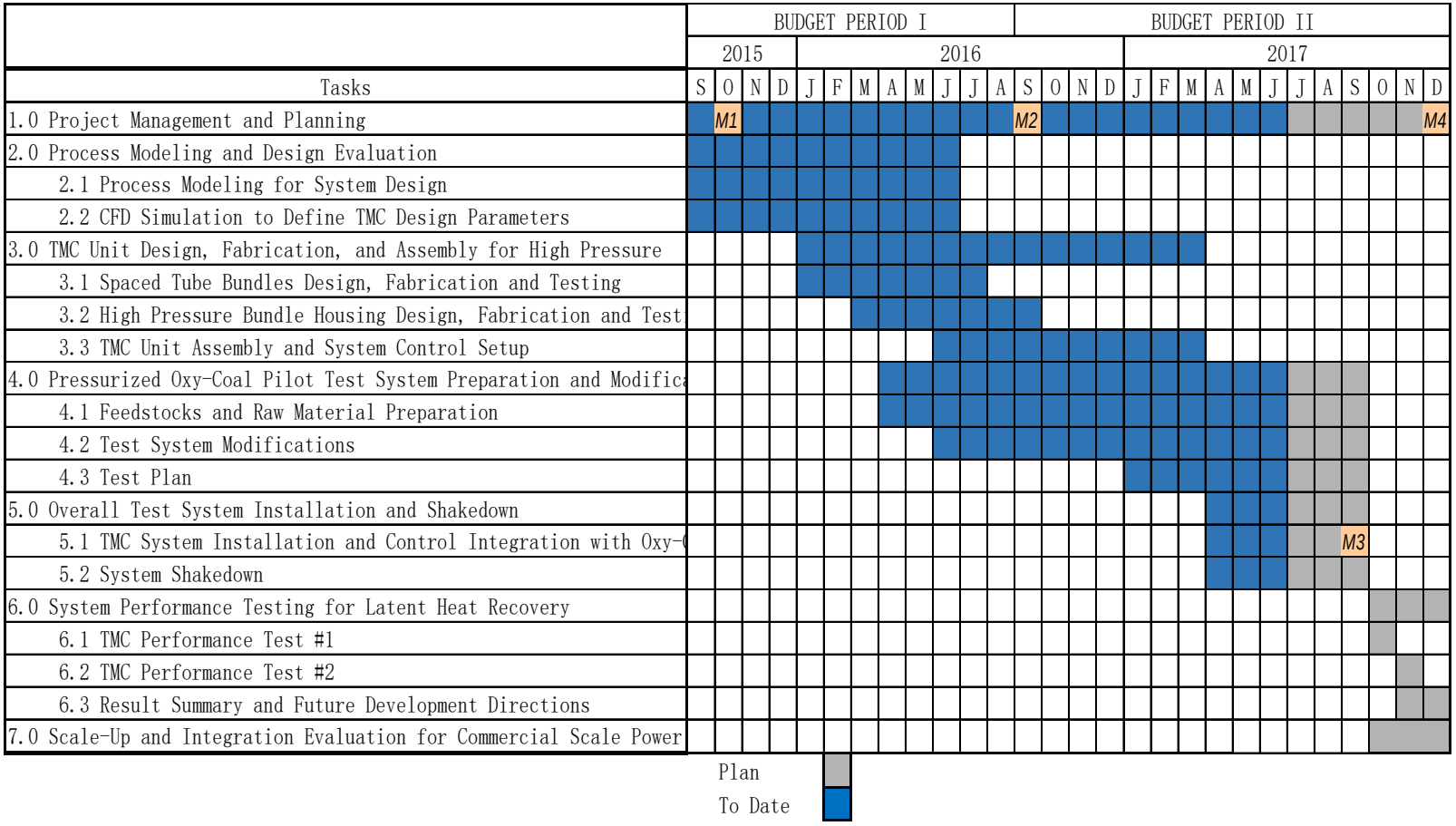
Progress & Current Status

Schedule Update



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?