Pre-Project Planning for a Flameless Pressurized Oxy-combustion (FPO) Pilot Plant

DOE National Energy Technology Laboratory
Project Number: DE-FE0027771
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Principal Investigator:
Joshua Schmitt

Project Team: SwRI, ITEA, EPRI, GE Global Research, Jacobs, PRA
Overview

• Project Summary
• Project Team
• Technology Premise and Background
• Project Goals
• Project Developments and Progress
Project Summary

• Part of DOE goal for advancing Transformational Coal Technologies

• Planning of a demonstration facility
  – Cycle analysis
  – Site Selection
  – Layout
  – Pre-FEED cost estimate

• Develop economic analysis and technology maturation pathway to commercialization
Project Team

Principal Investigator

Southwest Research Institute

Large Scope
- Itea
- Jacobs Engineering

Small Scope
- Electric Power Research Institute
  - GE Global Research
- Peter Reineck Associates
FPO Combustion

• Pressurized atmosphere of water and CO₂ under “volume expanded combustion” avoids traditional flame fronts
  – FPO combustion is more locally controllable with more uniform temperatures
  – Pressurized firing also improves cycle efficiency

• Conversion of carbon to CO₂ is over 99%
  – Almost zero carbon content in incombustible products
  – Traditional: flying and falling ash particles
  – FPO: slag with near-zero carbon content and tiny particulate

Traditional Combustion with Flame Front

Flameless Pressurized Combustion

Traditional Combustor Products: Particulate

FPO Combustor Products: Near-zero carbon, neutral slag
FPO Cycle

- Slurry of milled coal and water combusted under pressure
- Hot combustor gas is quenched through mixing
- Enters Once-Through Steam Generator (OTSG)
- A large percentage of combustion products are recycled
  - Some recycled flow used for quenching before OTSG
  - The remainder of recycled flow is mixed with pressurized oxygen and injected into the combustor
- New iteration of cycle splits before boiler and includes turbo-expander
Project Tasks and Goals

• Choose a location to host the pilot facility
  – Should already have coal receiving and handling infrastructure available
  – Must meet local regulatory requirements
• Design and layout a 50 MWth pilot facility
  – Includes engineering of coal slurrying, combustion loop, turbo-expander, and once-through steam generator
  – Generate cost estimates
• Create a testing program that addresses knowledge gaps and advances FPO technology readiness level
• Prove that FPO development path can meet DOE cost and emissions targets for transformational coal technologies with techno-economic assessment
Site Selection Progress

• Weighted criteria selection process
  – Availability of funding
  – Availability of staffing
  – Permitting process

• Narrowed down to a primary and secondary site
  – Primary: University of Wyoming Central Energy Plant (UW CEP)
  – Secondary: National Carbon Capture Center (NCCC)

• Focus shifted to layout and cost of pilot
UW CEP Proposed Site
UW CEP Permit Plan

• Provided documentation from UW
• Local Permits and Ordinances
  – State and local review
• Sound Issues
  – Need identified to keep below a threshold “hospital-grade acoustical design”
• Air Quality and Emissions
  – Possibly tied in with UW CEP existing Title V permit
  – Possibility of waiver
• Water Permits
  – No requirement for zero liquid discharge
  – Polish plant water products for reuse to minimize usage and cost
• NEPA Study
  – Goal of a Categorical Exclusion or Environmental Assessment with a Finding of no Significant Impact
PFD Development

- PFD for identification of major components and streams
  - Establishing a naming and tagging convention
  - Showing system interconnection/balance of plant
  - Identifying key streams and figures of merit
  - Showing scope breaks for project management
  - Showing material selection for components and streams
Component Specification

- Based on the “super-compliance” PRB coal published by NETL
- Heat and mass balance in Aspen Plus
- Combustion gas characterization from ITEA testing and custom codes
- Specification of major components
  - Combustor
  - OTSG
  - Turbo-expander
  - Water pumps
  - Economizers
  - Feedwater heaters
  - Water vapor condenser
  - Flue-gas desulfurization (FGD) scrubber

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<th>Coal name</th>
<th>PRB Wyodak/Anderson Rochelle Coal Co. Subbituminous C</th>
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<th>Coal seam nomenclature</th>
<th>Mine</th>
<th>ASTM D388 Rank</th>
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<th>As-Received</th>
<th>Dry</th>
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<td>Volatile Matter</td>
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<td>Ash</td>
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<td>Fixed Carbon</td>
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<td>Total</td>
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<th>Ultimate Analysis³</th>
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<tr>
<td>Carbon</td>
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<td>Hydrogen</td>
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<td>Chlorine</td>
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<tr>
<td>Ash</td>
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<tr>
<td>Moisture</td>
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<td>Oxygen</td>
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<th>Heating Value²,⁵</th>
<th>As-Received (Reported)</th>
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<td>LHV (Btu/lb)</td>
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<td>HHV (kJ/kg)</td>
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<td>LHV (kJ/kg)</td>
<td>18,738</td>
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Combustor Design

- **Vertical design**
  - Evolution from the horizontal combustor in the 5 MWth pilot
  - Close to design of ITEA 15MWth commercial plant
  - Refractory lined

- **Expanded volume cone**
  - Gas and slurry injected at top
  - Temperature and velocity tuned with CFD
  - Cone reaches to the bottom of the combustor before traveling back up the sides to the exit

- Flue gas quenching occurs at exit
Once-Through Steam Generator (OTSG)

- Banks of finned tubes contained in a pressure vessel
  - Square duct supported and inserted into a circular pressure vessel
  - Between duct and pressure vessel is pressurized with cooler gas from the recycle blower
- Modular tube bank design can include multiple reheat
  - Banks can be assembled in different orders that optimize gas temperature profile
  - Fast startup and shutdown improves flexibility
- Size can improve ease of manufacturing and cost
  - Design of each OTSG could be kept small enough for off-site fabrication and transport
  - Multiple OTSG units may be needed, depending on plant scale
FPO 50 MW Loop Layout

- ITEA design
- Batching of quenched slag at bottom of elevated combustor
- OTSG horizontal for minimal support
- Refractory lining for combustor/pipe sections at 1380°C
- Footprint for layout in overall facility
Preliminary Test Plan

• Test plan being developed to target areas of risk and advance TRL of FPO
• Includes multiple phases of testing that mitigate risk
  – Subscale slurrying and firing trials
  – Cold commissioning of the 50MWth plant
  – Hot commissioning and shakedown
  – Steady-state, flexibility, and dynamic load testing
  – Inspection outages
  – Performance testing on-design
  – Off-design condition testing
ITEA study with ENEL showed that cost greatly increases above 500MWth boiler.

To achieve 500MWe output, modular approach needed.

FPO loops would include combustor, OTSG, turbo-expander.

All other elements would be consolidated into single packages:
- Steam power
- Flue gas treatment
- Heat recovery package
- Carbon capture
Thank You