Enabling Staged Pressurized Oxy-Combustion: Improving Flexibility and Performance at a Reduced Cost

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Introduction

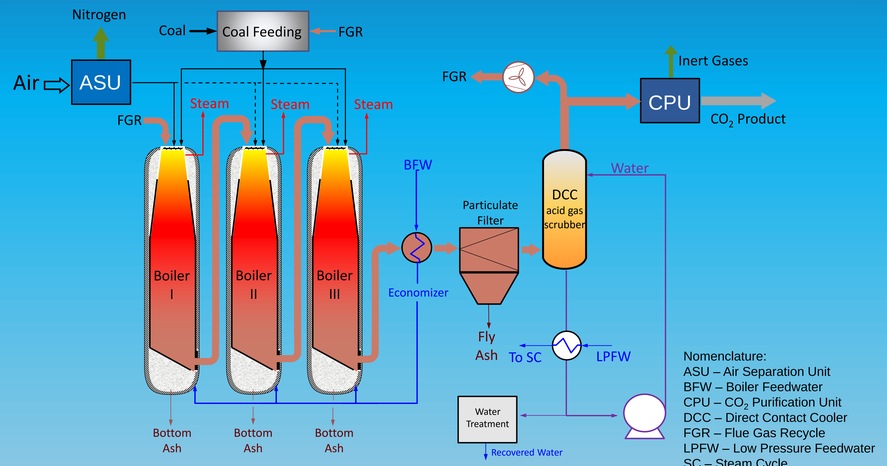
Coal-fired power plants need to reduce emissions of criteria pollutants and CO_2, particularly after the COP21 pledges to reduce greenhouse gas emissions made in late 2015 by 196 countries. Existing technologies for carbon capture and storage (CCS) are expensive and energy intensive; thus, second-generation technologies that can capture CO_2 and reduce other emissions to near-zero values at lower cost and energy penalty are critical to ensuring cleaner coal power generation can contribute to a low-cost, stable, and reliable future energy mix.

Future coal generation will need to operate in a very flexible manner due to increasing levels of non-dispatchable renewable energy in the power system. SPOC, developed at Washington University in St. Louis, is a candidate technology for this purpose. This project aims to investigate this potential by supporting a boiler OEM in conducting a full review of the technology.

Objectives

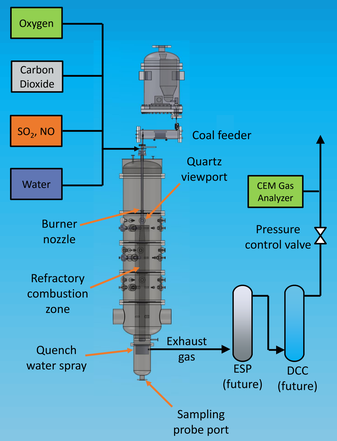
1. **Develop a conceptual SPOC design to deliver flexible and efficient steam generation**
2. **Test part-load combustion in the 0.1 MW_{th} pressurized oxy-combustion facility**
3. **Demonstrate the SPOC burner and confirm heat release profiles**

Staged Pressurized Oxy-Combustion Process



Nomenclature:
ASU – Air Separation Unit
BFW – Boiler Feedwater
CPU – CO_2 Purification Unit
DCC – Direct Contact Cooler
FGR – Flue Gas Recycle
LPFW – Low Pressure Feedwater
SC – Steam Cycle

0.1 MWth Pressurized Oxy-Combustion Facility



Project Tasks

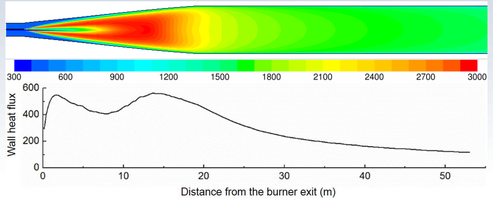
- **OEM Review of SPOC Technology**
- **Conceptual Design of Flexible, Full Scale System – 550MWe**
- **Turndown Performance and Flexible Oxygen Supply**
- **Part-Load Combustion Characteristics**
- **Techno-Economic Analysis for comparison with NETL baseline cases**

Flexible Oxygen Supply

- **Pressurized oxygen supply to SPOC**
- **Use of liquid and/or gaseous oxygen storage**
- **ASU process changes to deliver flexibility**

Furnace Heat Flux Assessment

- **Down-fired boiler configuration to prevent bottom ash hitting the burner**
- **Axial flow with low mixing**
  - **Avoids flame impingement**
  - **Long combustion zone for distributed heat release**
  - **Minimized ash deposition (near-zero radial velocity)**
- **Diverging section to minimize the effect of buoyancy**
- **Wall heat flux controlled to acceptable level by radiative trapping**



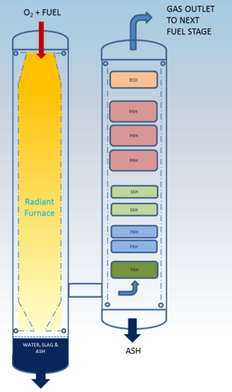
Temperature distribution (K) and wall heat flux (kW/m²) of Stage 1

Conceptual Boiler Design

Two-pass concept design investigated.

Optimized cross-sectional areas possible for combustion stage and heat recovery stage.

Targeted heat release between stages.



Combustion Testing

- **Stage 1 combustion testing with at reduced firing and full firing**
- **Long and straight flames obtained with high stoichiometric ratio**
- **No flame impingement and minimal particle deposition**

Acknowledgments

U.S. Dept. of Energy Award FE0029087

Air Liquide creative oxygen
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