# Design, Construction, and Assessment of Dry Coal Feeding in a High Pressure Oxy-coal System

44th International Technical Conference on Clean Energy

Sheraton Sand Key

June 16-21, 2019

For Energy and Environmental Solutions

REACTION ENGINEERING INTERNATIONAL
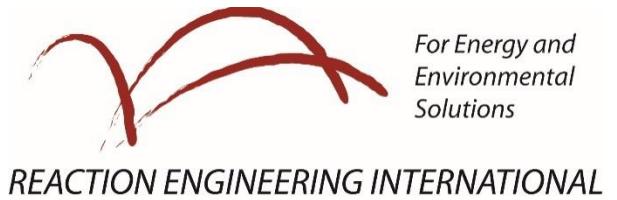
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Reaction Engineering International

Kevin Whitty, Jost O.L. Wendt, Xiaolong Li

University of Utah

DFHP Program

Enabling Technologies for Advanced Oxy-Coal Combustion Systems

- Dry feed firing systems for entrained flow, pressurized, oxy-coal combustors have not been well developed, although related technologies have been used

- Program will leverage high pressure research conducted in HTHP program

- Dry pressurized coal burner systems, will yield efficiency gains, improve flexibility and facilitate scale up

**Characterizing Impacts of Dry Coal Feeding in High Pressure Oxy-Coal Combustion Systems (DFHP)**
October, 2016 – September 2020

DFHP Technical Approach

| Design, construct and install pressurized dry feed system | Design, construct and install pressurized burner system | Conduct experiments at University of Utah's Entrained Flow Pressurized Reactor (EFPR) | Validate simulations of high pressure oxy-coal combustion | Economic analysis and full scale boiler scoping |

Gas Temperature (°F)

4500
3800
3100
2400
1700
1000
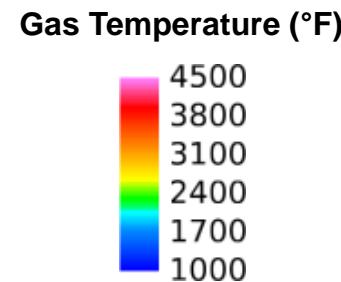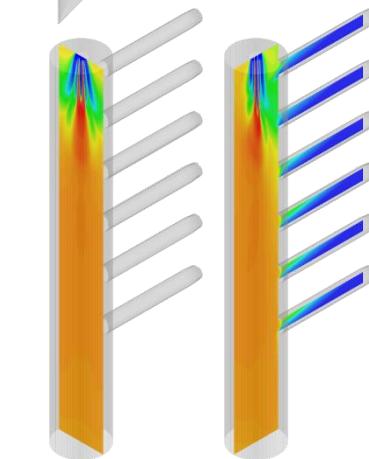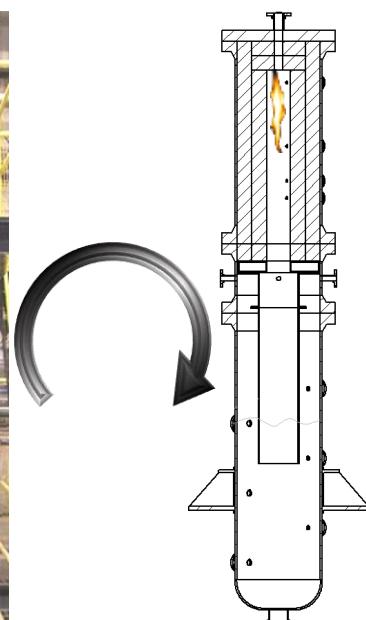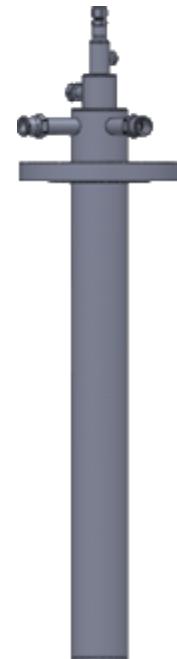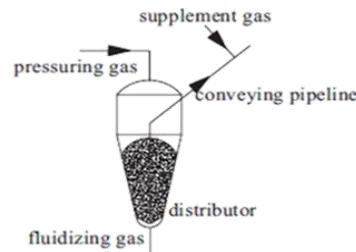
300 kW Entrained Flow Pressurized Reactor (EFPR)
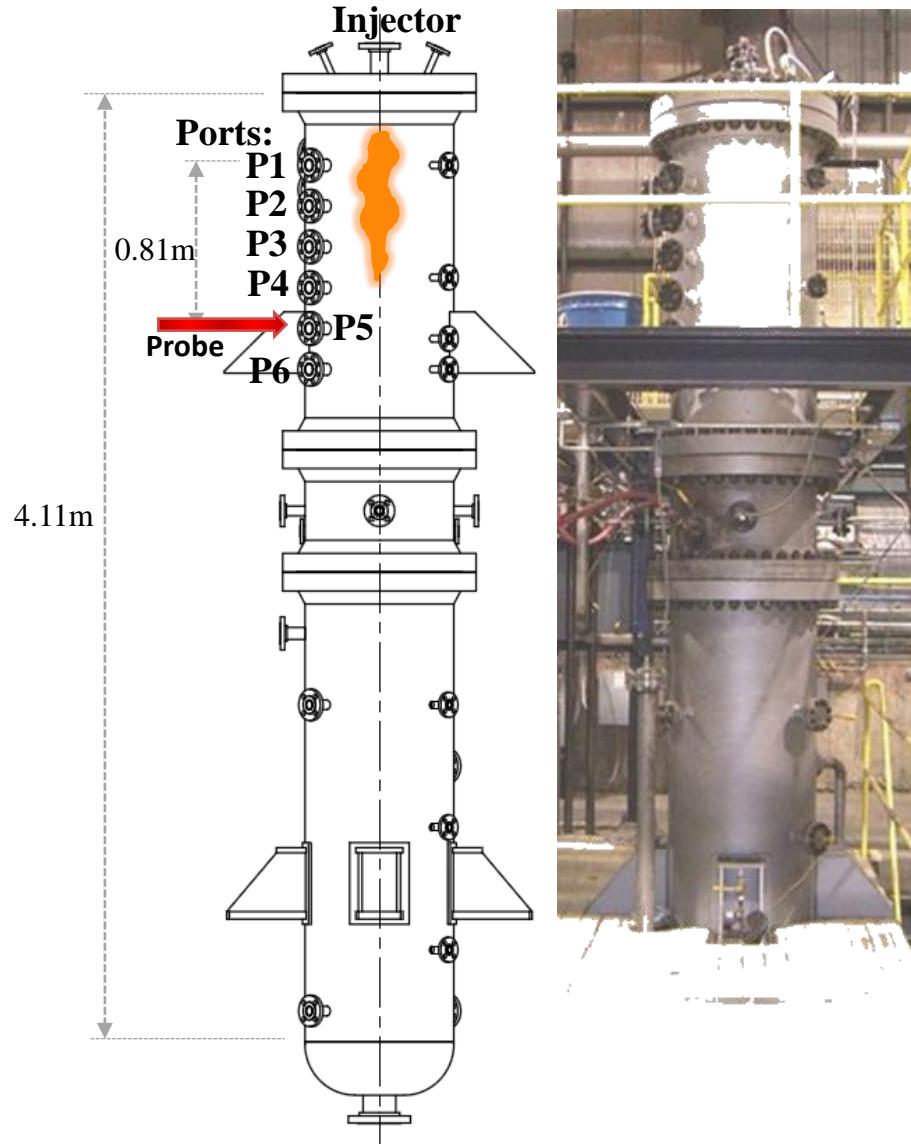
- Converted from an entrained flow gasifier
- 300 kW (rated) pilot scale
- Coal-water slurry feeding with pure O_2
- Down-fired, self-sustained and no external heating
- Operation pressure up to 30 bar

Conversion from Gasifier to Combustor
## *Hardware and Instrumentation*

Refractory overhaul

- UltraGreen SR
- Greentherm 28 LI Brick
- Insboard 2600
- Inswool Paper
- Steel Shell
- #36 Refractory Cement
- Inswool
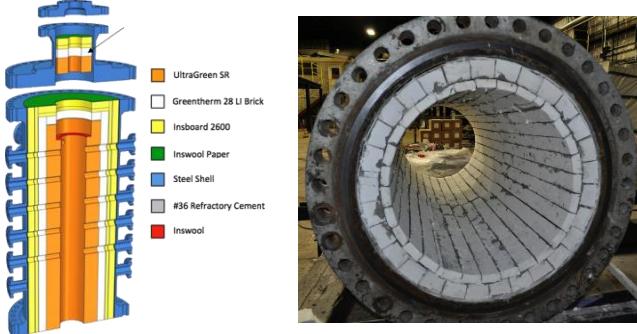
New top section
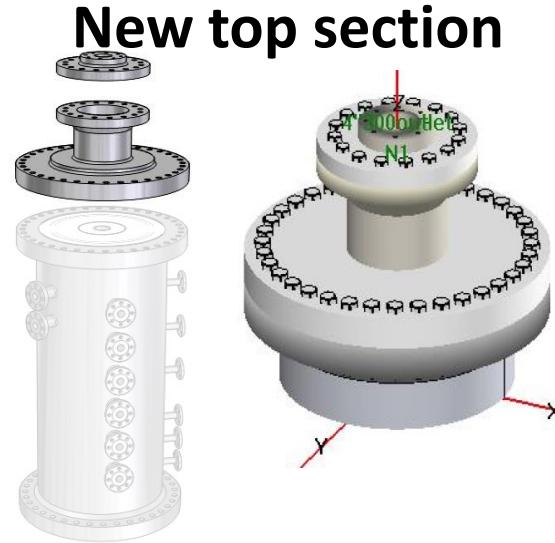
New burner
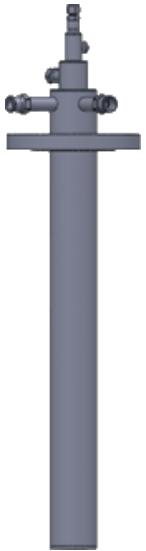
New radiometers & Multi-depth thermocouples

Flue Gas

B thermocouple

0.5"

2.5"

B thermocouple

R 4"

UltraGreen SR (castable)

R 8.25"
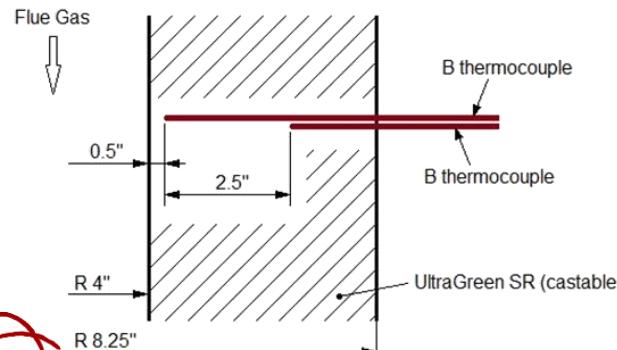
Particle sampling system designed and constructed

to air dilution then SMPS/APS and BLPI
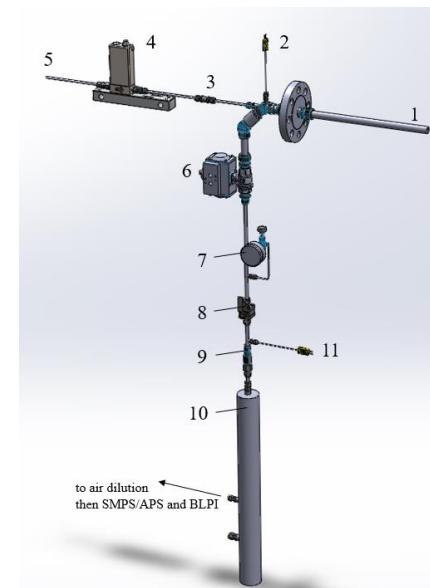
Corrosion probe designed and constructed

Pulverized Coal Feeder Design
Final design of fluidized feeder body
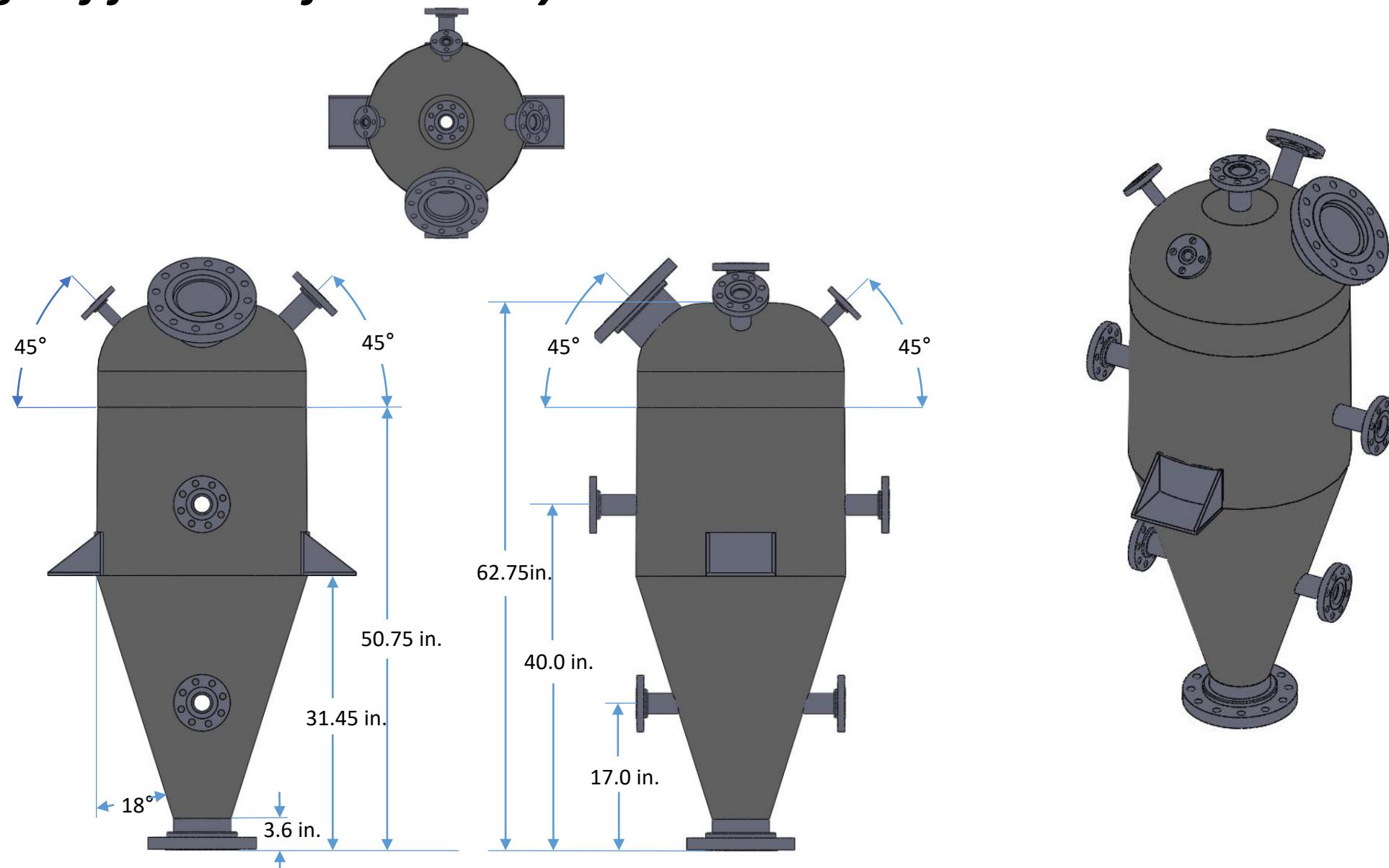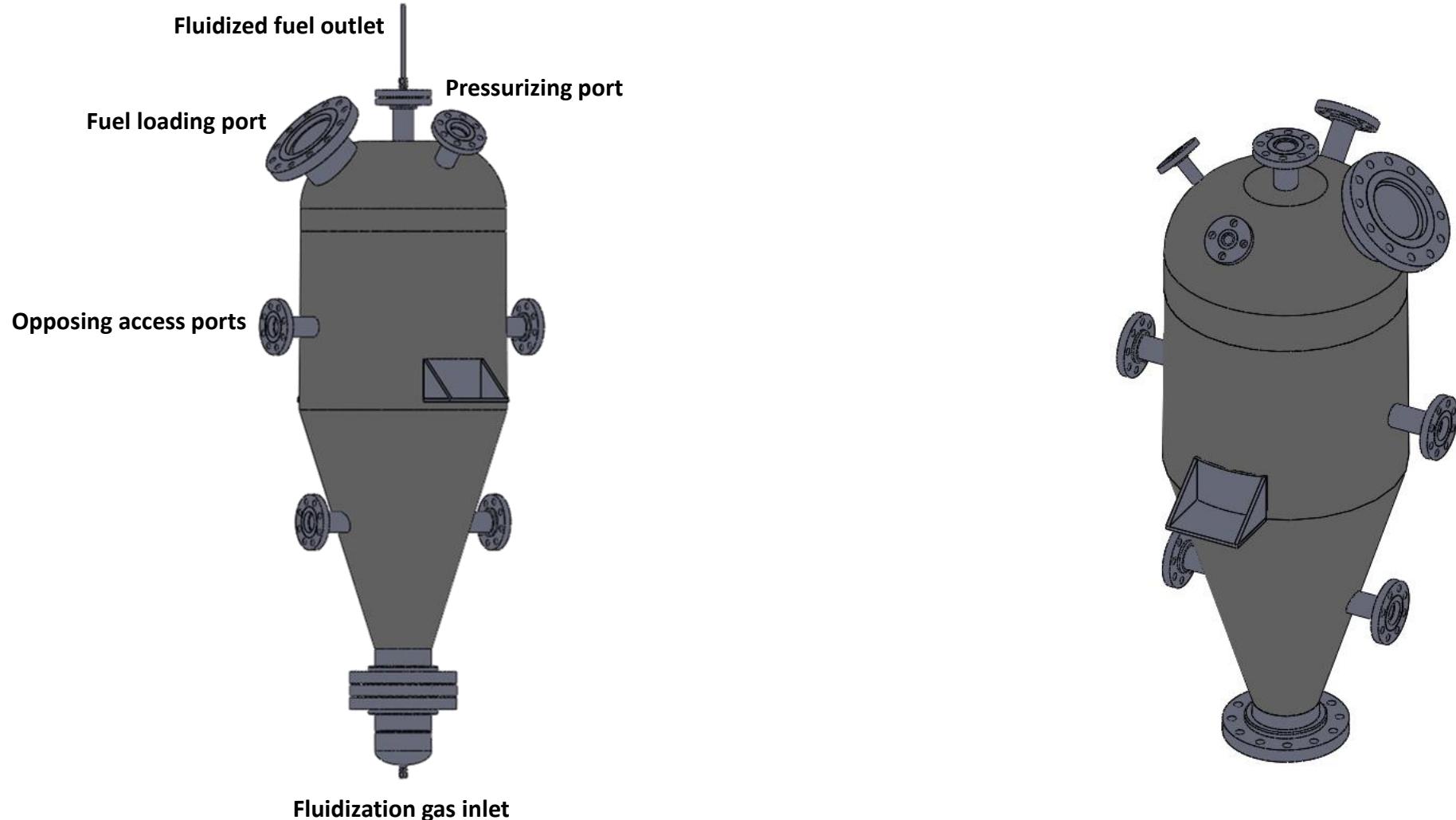
45°   45°

45°   45°

50.75 in.

62.75in.

40.0 in.

31.45 in.

18°   3.6 in.

17.0 in.

Pulverized Coal Feeder Design
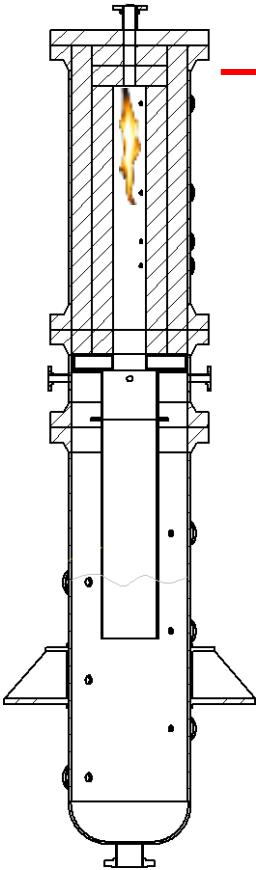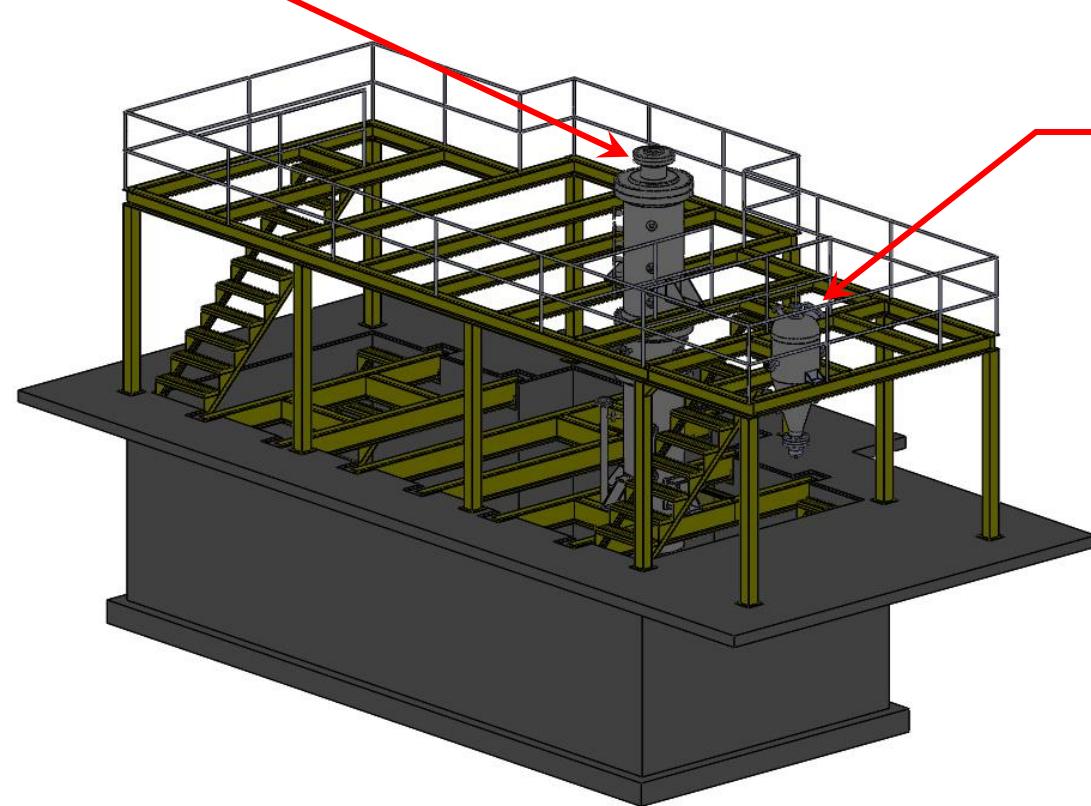
Fluidized fuel outlet

Pressurizing port

Fuel loading port

Opposing access ports

Fluidization gas inlet

Pulverized Coal Feeder Design & Construction


Dry feed system pressure vessel

Entrained flow pressurized reactor
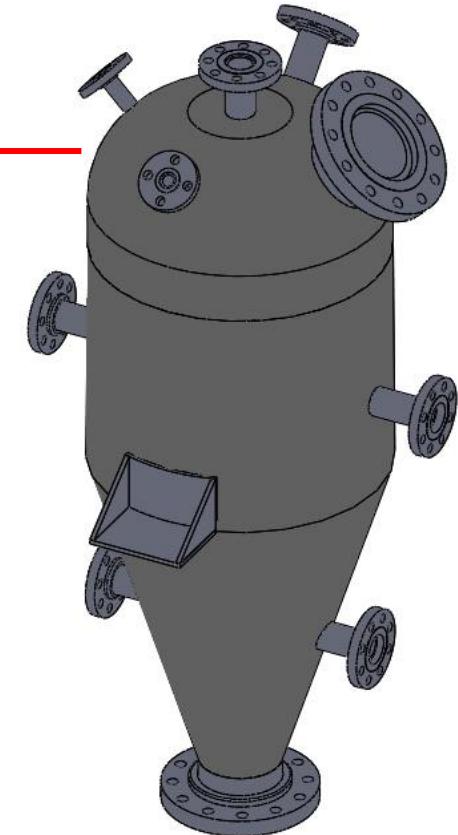
Pulverized Coal Feeder Design & Construction

Dry feed system pressure vessel
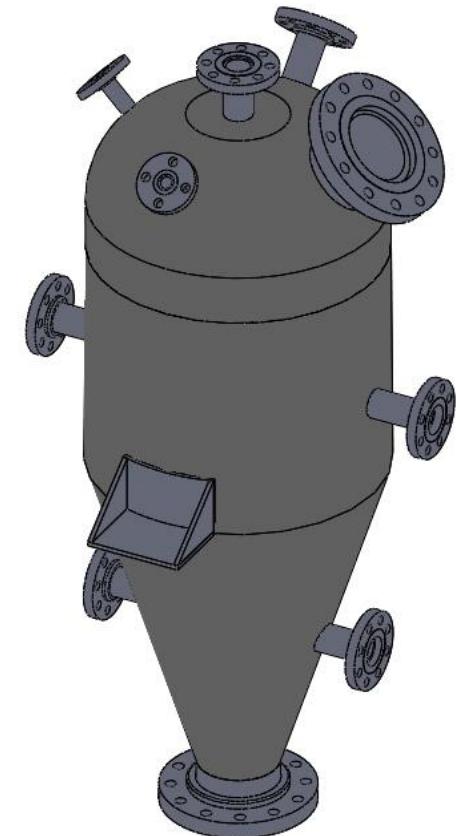
CFD Tools: GLACIER

- REI's in-house CFD software
- Developed specifically for application to solid fuel fired furnaces and boilers
- 3D, steady-state, turbulent flows
- Coupling between turbulent fluid mechanics, radiative and convective heat transfer, homogeneous and heterogeneous reactions
- Statistical description of particles including particle dispersion
- Pollutant formation kinetics for NOx, SOx, CO, Hg and fine particles
- Continually evolving including recent developments for atmospheric pressure and pressurized oxy-coal applications

Radiant Heat Transfer

CFD Model Mechanisms

Ash Vaporization & Deposition

Char Oxidation
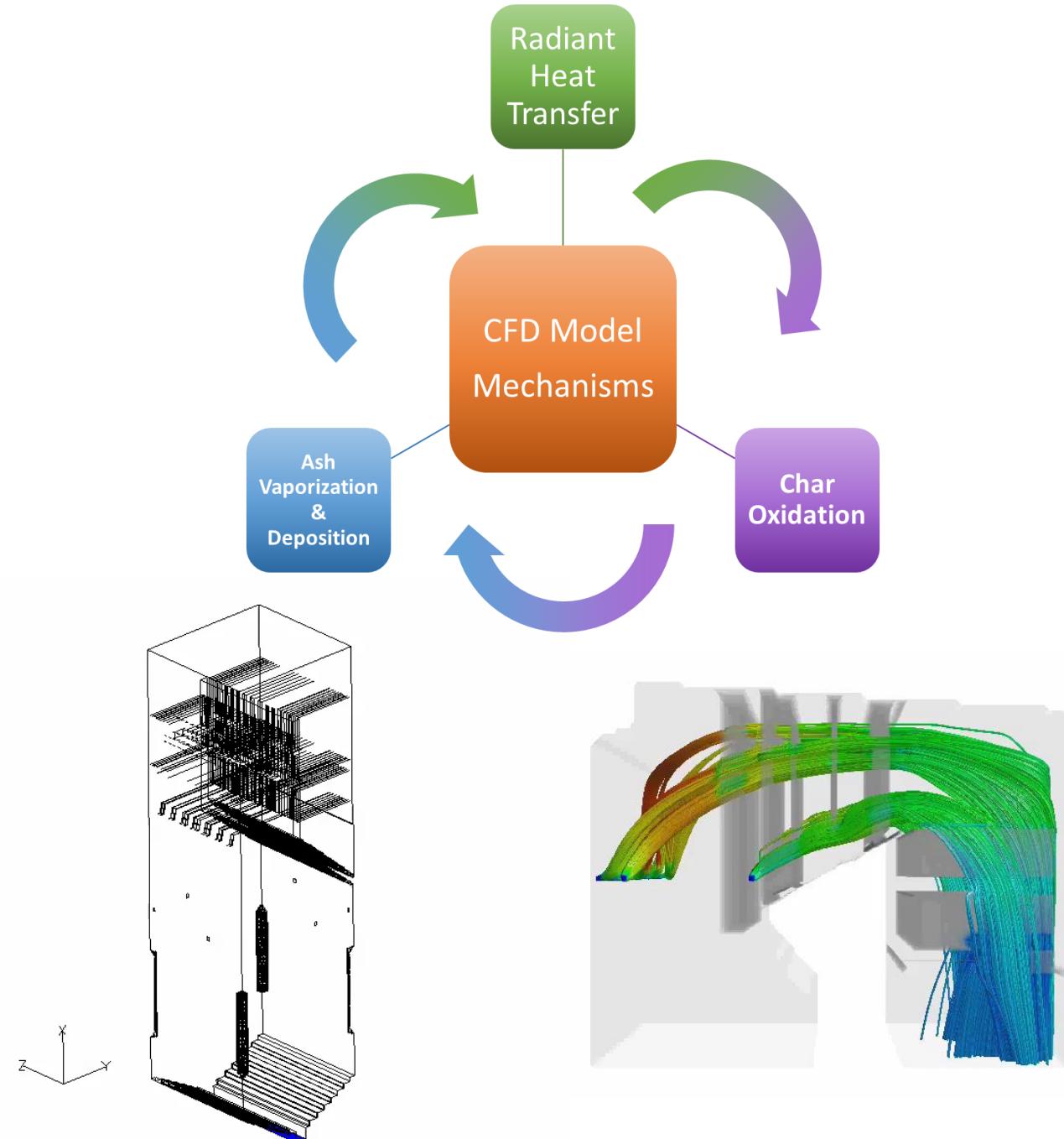
EFPR Dry Pulverized Coal Burner Design Concepts
CFD Model Predicted Gas Temperature Profiles

Gas Temperature (°F)

4500
3800
3100
2400
1700
1000
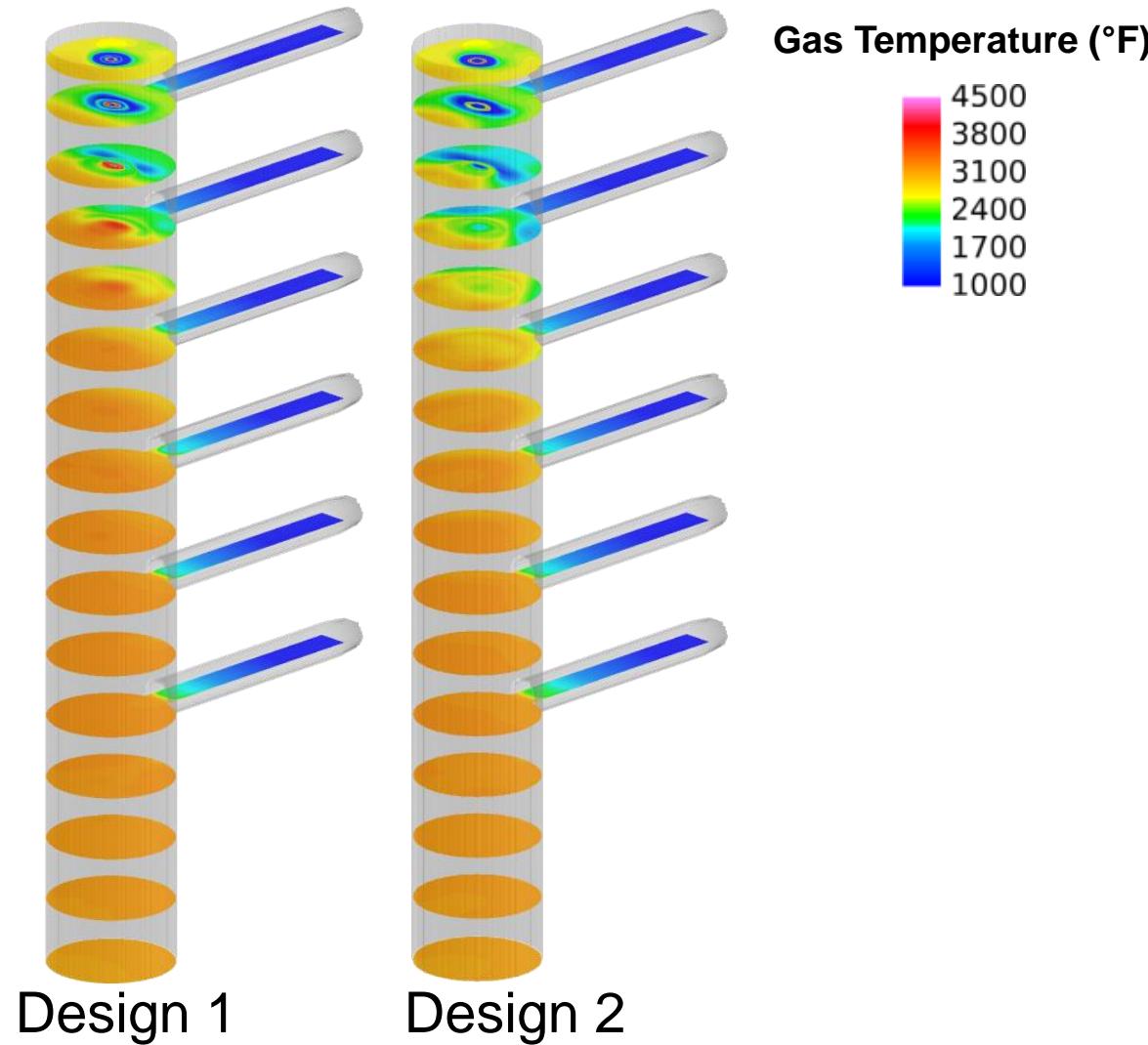
Design 1   Design 2

CFD Model Predictions
Gas Temperature Profiles

Gas Temperature (°F)

4500
3800
3100
2400
1700
1000
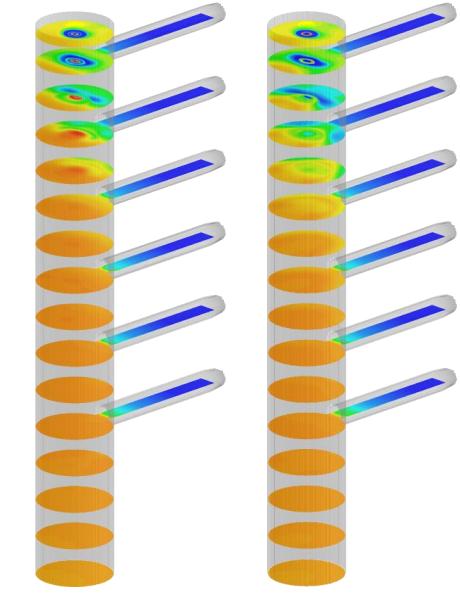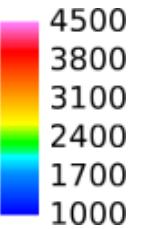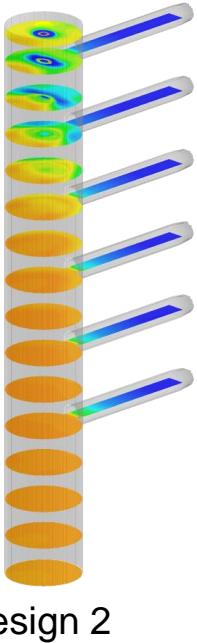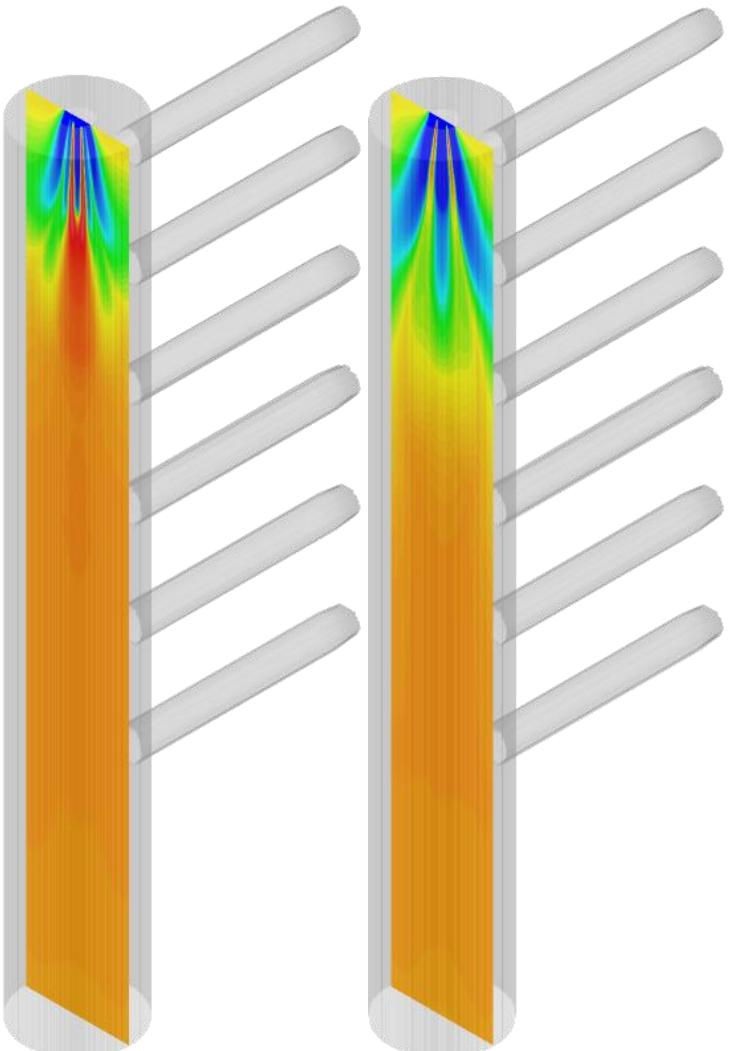
Design 1   Design 2
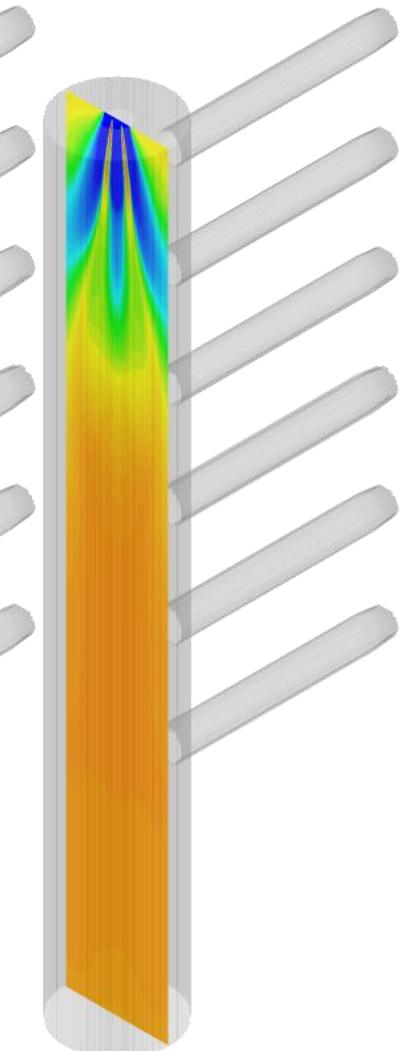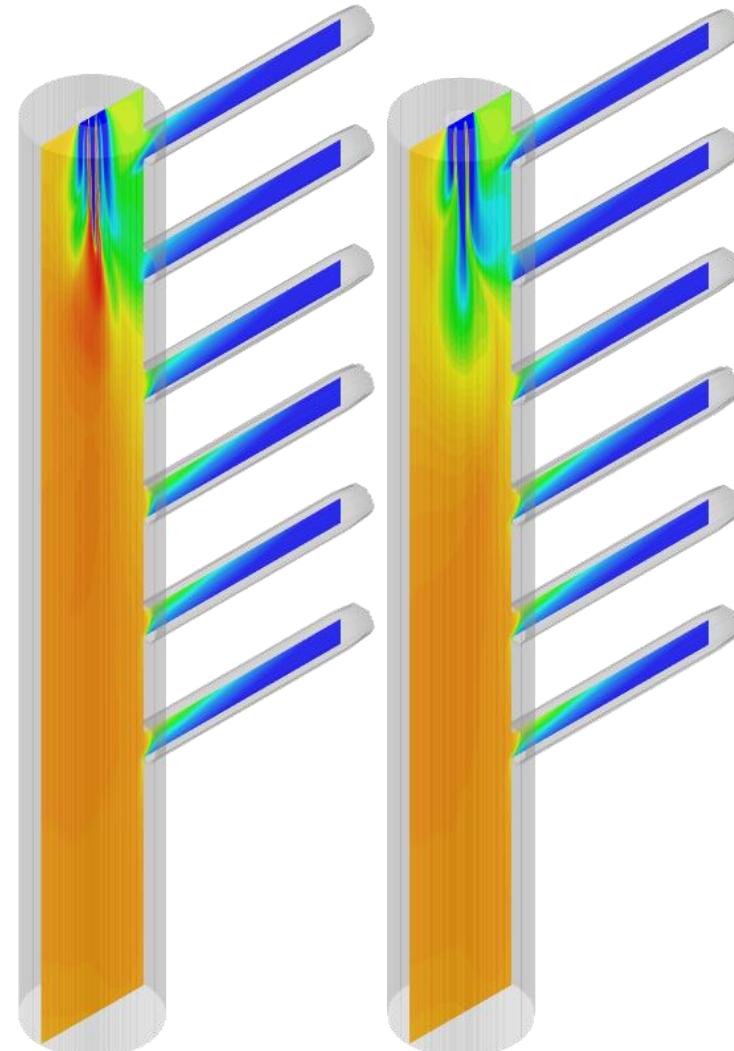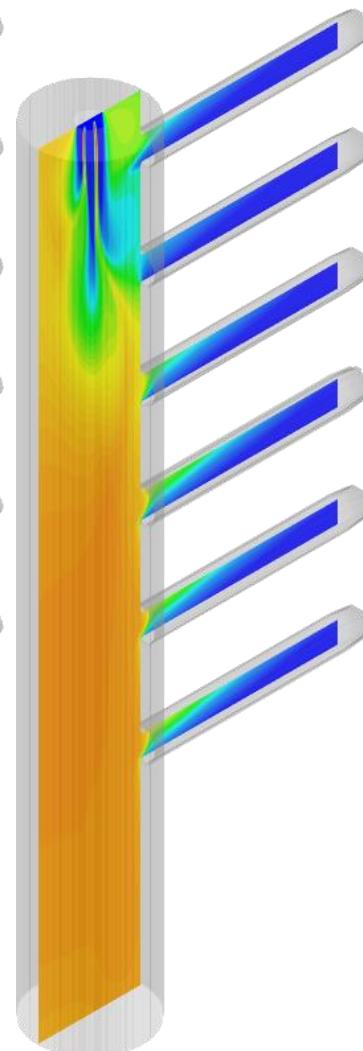
Design 1   Design 2   Design 1   Design 2

Controlling the Rate of Heat Release
Tracking CO₂ Formation in the Furnace

CO₂ Concentration (%)
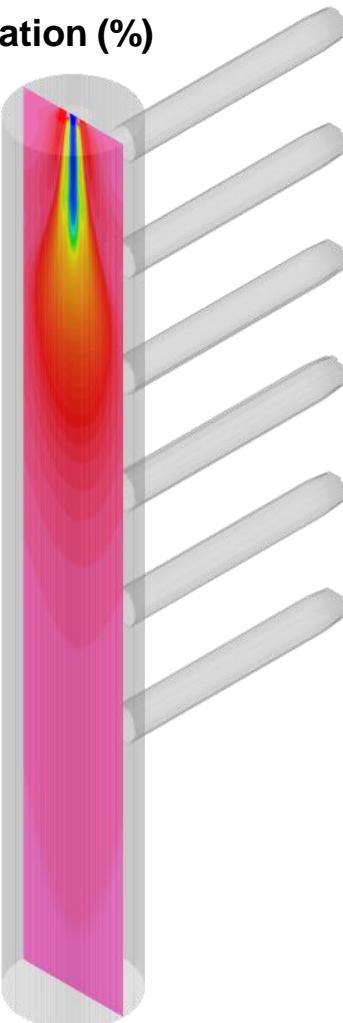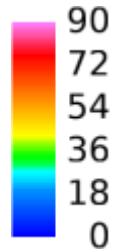
Design 1   Design 2
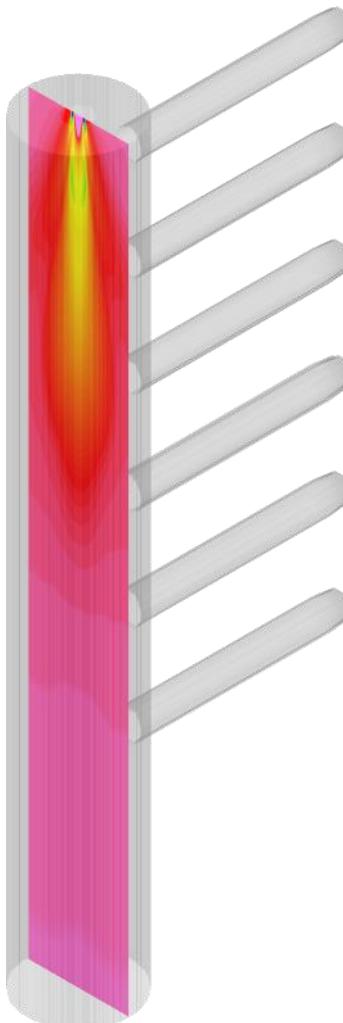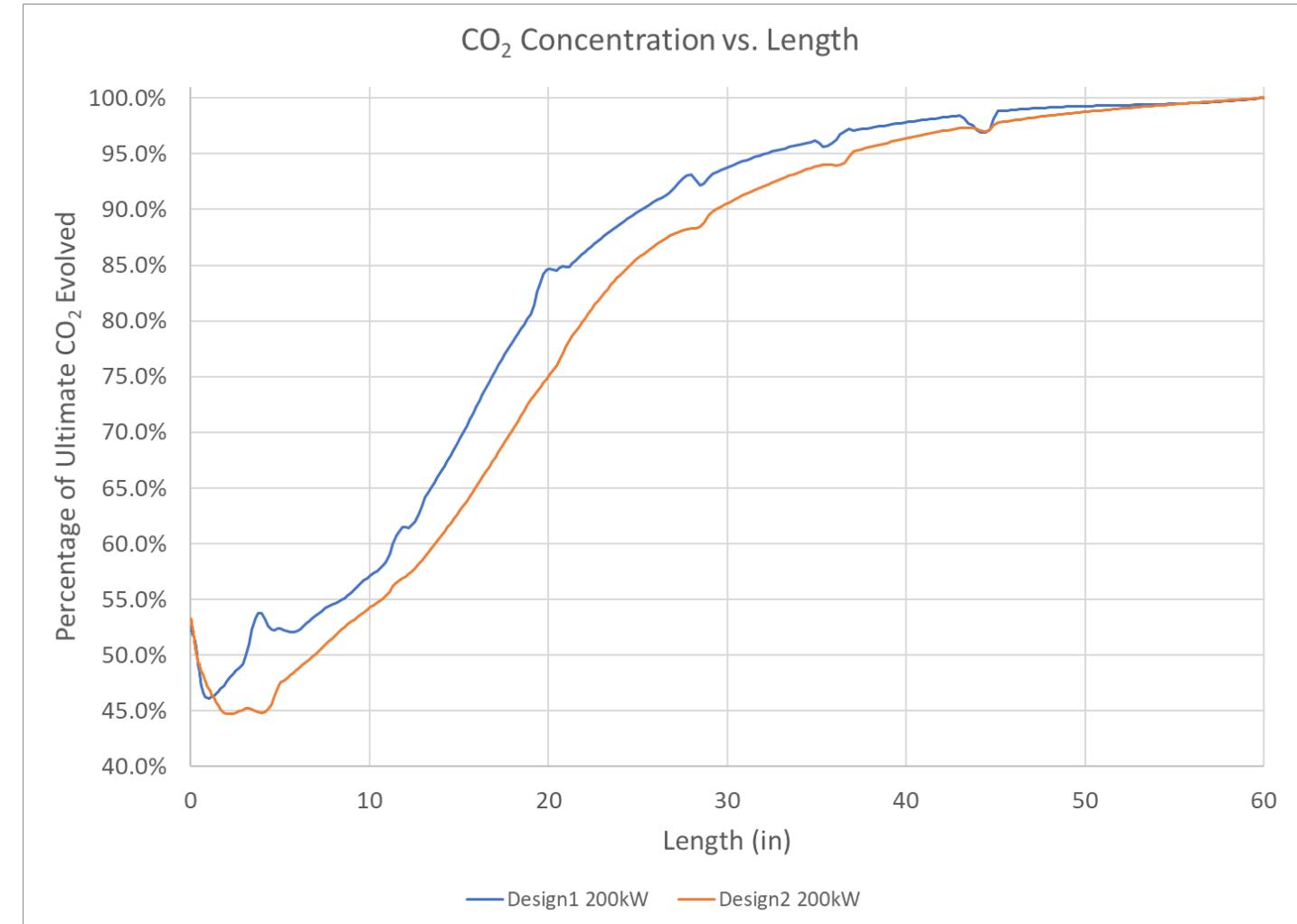
CFD Model Predictions
Radiant Flux Distribution


Design 1   Design 2

Incident Heat Flux
(Btu/h·ft²)

325000
260000
195000
130000
65000
0

Design 1   Design 2
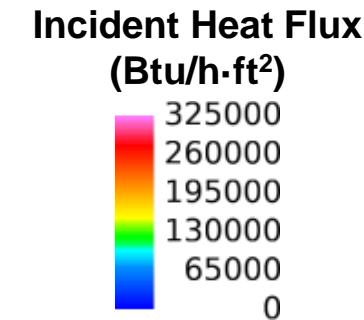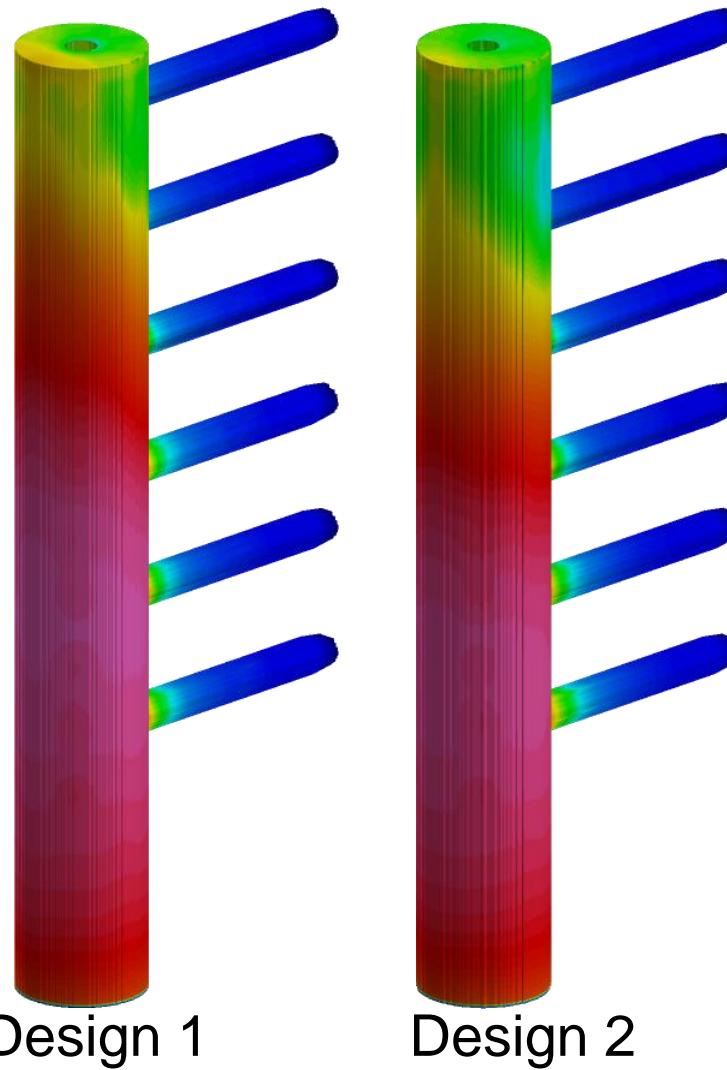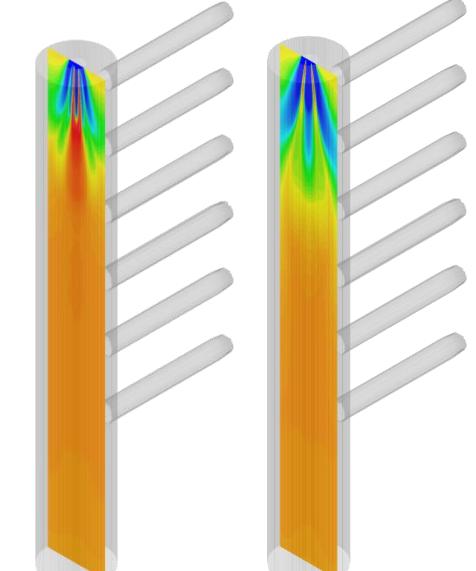
EFPR Dry Pulverized Coal Burner Design Concepts

High Pressure Aerosol Sampling System
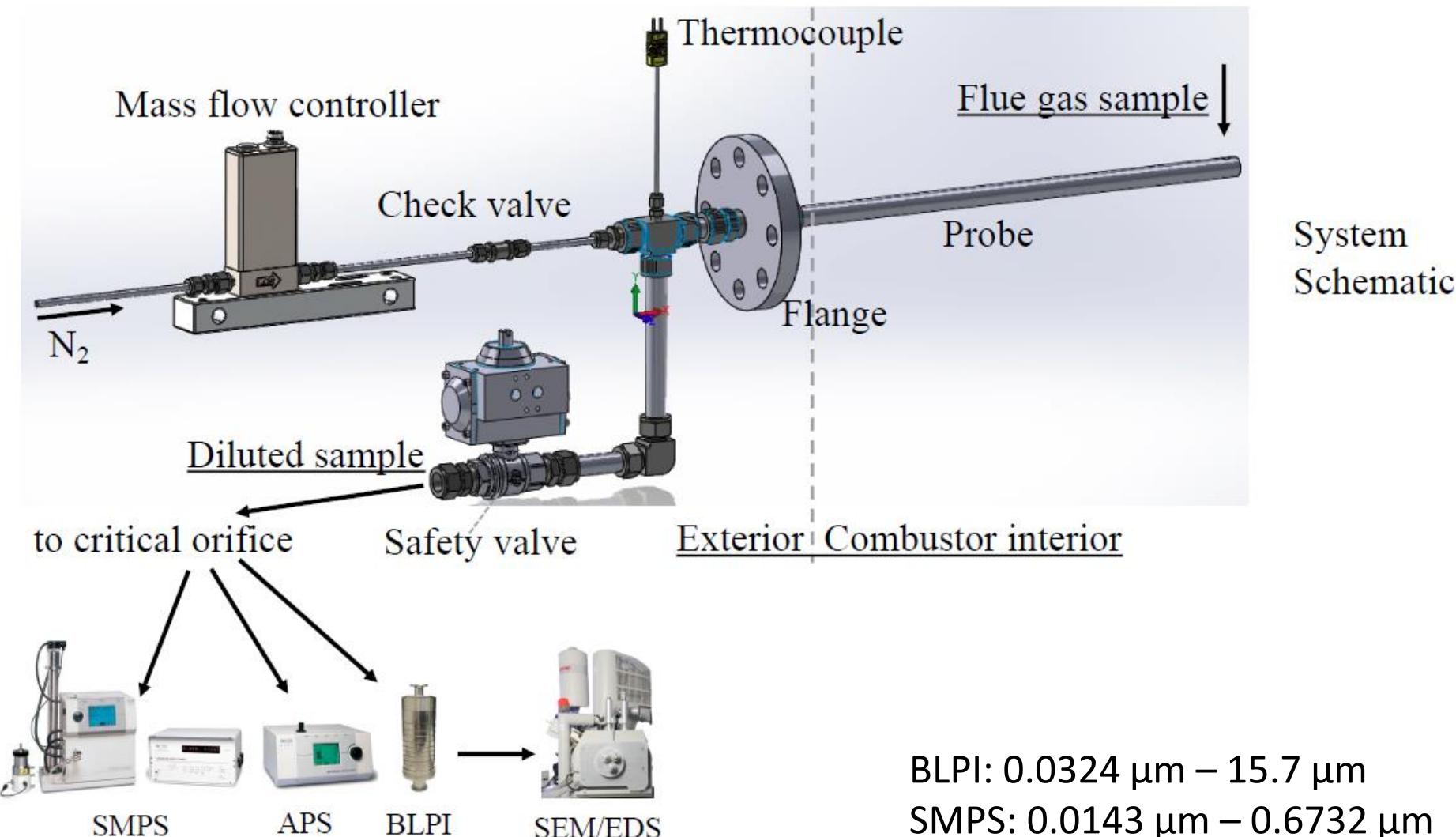
BLPI: 0.0324 μm – 15.7 μm
SMPS: 0.0143 μm – 0.6732 μm
APS: 0.532 μm – 20 μm
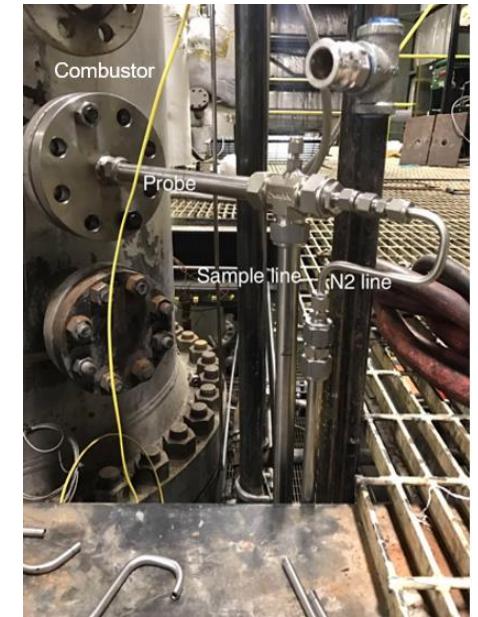
EFPR Corrosion Propensity Characterization

Probe
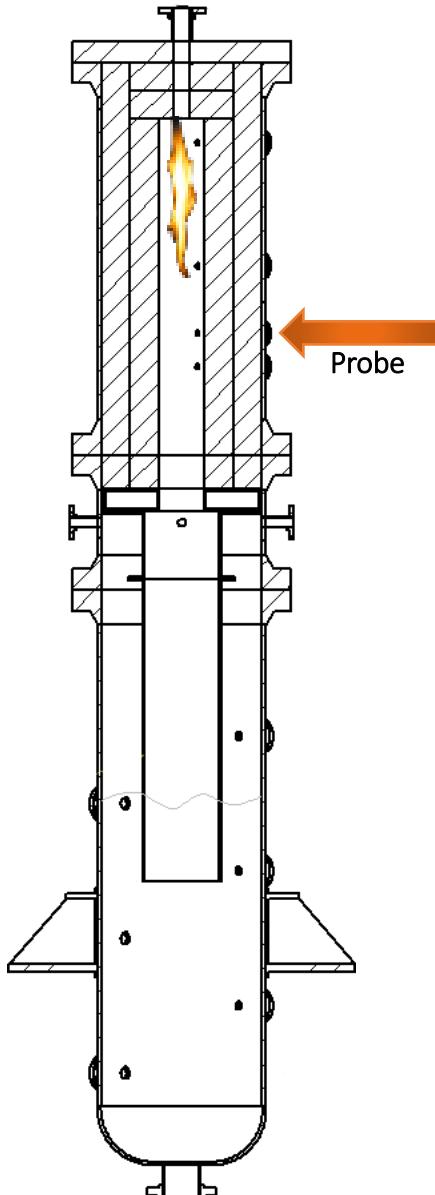
- Three alloys of interest
- T22, P91, and 347H
- T22: Low carbon, low chromium alloy commonly used in sub-critical boilers
- P91: Commonly used in supercritical boilers
- 347H: Advanced high-Ni, high-Cr alloy targeted for advanced power plants
- The corrosion studies will primarily focus on the extremes, T22 and 347H, with some limited data from P91

Summary

- Design and fabrication of dry feeding system completed and integration with EFPR in process
- CFD-guided design of burner for the EFPR with dry feeding completed and burner fabricated and tested
- Advanced aerosol characterization in EFPR successfully applied in coal slurry-fed operation and readied for dry-fed experiments
- Design and fabrication of corrosion monitoring equipment for use in the EFPR completed
- Integration of dry feeder with high pressure EFPR and subsequent shakedown testing scheduled for July

Acknowledgment & Disclaimer