Characterizing Impacts of Dry Coal Feeding in High Pressure Oxy-Coal Combustion Systems

Department of Energy under Cooperative Agreement No. DE-FE0029162

2018 NETL CO_2 Capture Technology Project Review Meeting

Omni William Penn Hotel; Pittsburgh, PA

August 14, 2018

Motivation

Relevance

- Fuel feeding and firing system flexibility are challenges for high pressure coal and biomass fed combustion and gasification equipment
  - Slurry-fed systems often have atomization and burnout problems exacerbated at high pressure
  - Slurry atomization processes may be difficult to scale up
- Dry feeding has the potential to yield efficiency gains, provide better control over flame aerodynamics, improve flexibility and facilitate scale up

Objective

Develop data and validate mechanisms describing heat transfer, ash deposition and corrosion in a high temperature, high pressure oxy-coal combustion system with dry coal feeding

Technical Approach

1. Design, construction and installation of a pressurized feeding system for dry pulverized coal in an entrained flow pressurized combustor
2. CFD-based guidance of burner design and pilot-scale operation of pressurized oxy-coal combustion with a dry feed system
3. Detailed measurements of heat flux and flame and material temperatures at high temperatures while firing at 300 kW and 17 bar
4. Ash aerosol measurements at 17 bar pressure experimental conditions to determine slagging and fouling propensity of the ash, and its deposition rates as a function of high pressure
5. Characterize corrosion propensity under high temperature and high pressure conditions using real time corrosion sensors
6. Refinement of CFD modeling tools to ensure accurate prediction of the impacts of high temperature and high pressure oxy-coal combustion on heat flux, ash deposition and corrosion in a commercial boiler implementation

Program Overview

Enabling Technologies for Advanced Oxy-Coal Combustion Systems

Characterizing Impacts of Dry Coal Feeding in High Pressure Oxy-Coal Combustion Systems (DFHP)

October 2016 – September 2019

REACTION ENGINEERING INTERNATIONAL

THE UNIVERSITY OF UTAH

SOUTHEAST UNIVERSITY 東南大學

EPRI

PRAXAIR

Program Elements

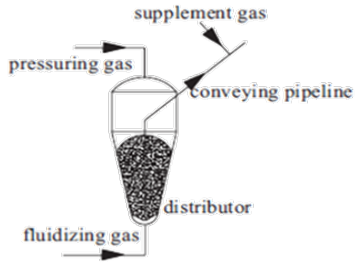
Design, construct and install pressurized dry feed system

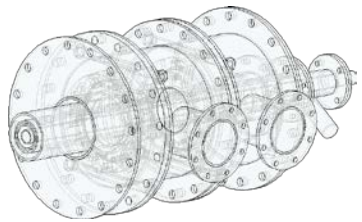
Design, construct and install pressurized burner system

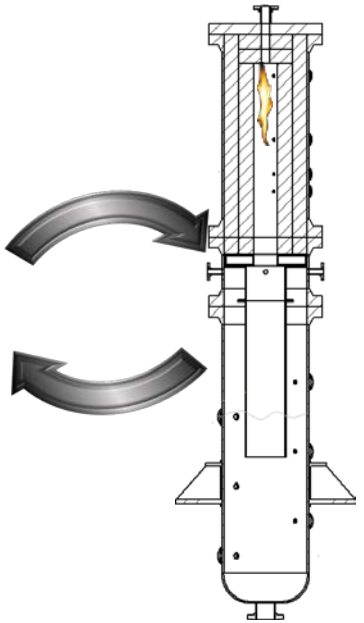
Conduct experiments at University of Utah's Entrained Flow Pressurized Reactor (EFPR)

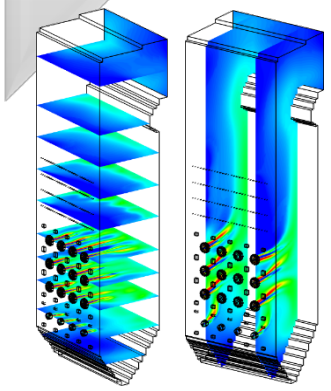
Validate simulations of high pressure oxy-coal combustion

Economic analysis and full scale boiler scoping









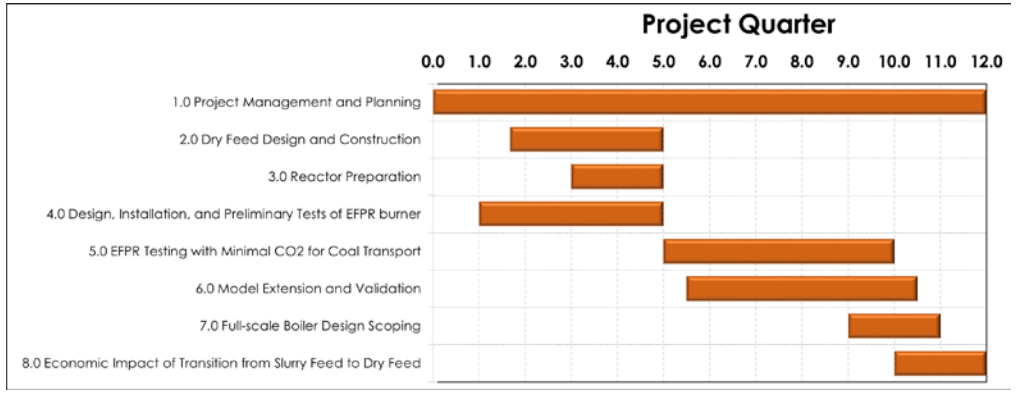
Program Organization

REACTION ENGINEERING INTERNATIONAL

- Program management
- Pressurized oxy-coal burner design
- CFD modeling of pilot-scale tests
- Development/refinement and validation of key mechanisms in CFD sub-models
- Conceptual design and simulation of multi-burner furnace at pressurized conditions
- Full scale boiler scoping and economic analysis

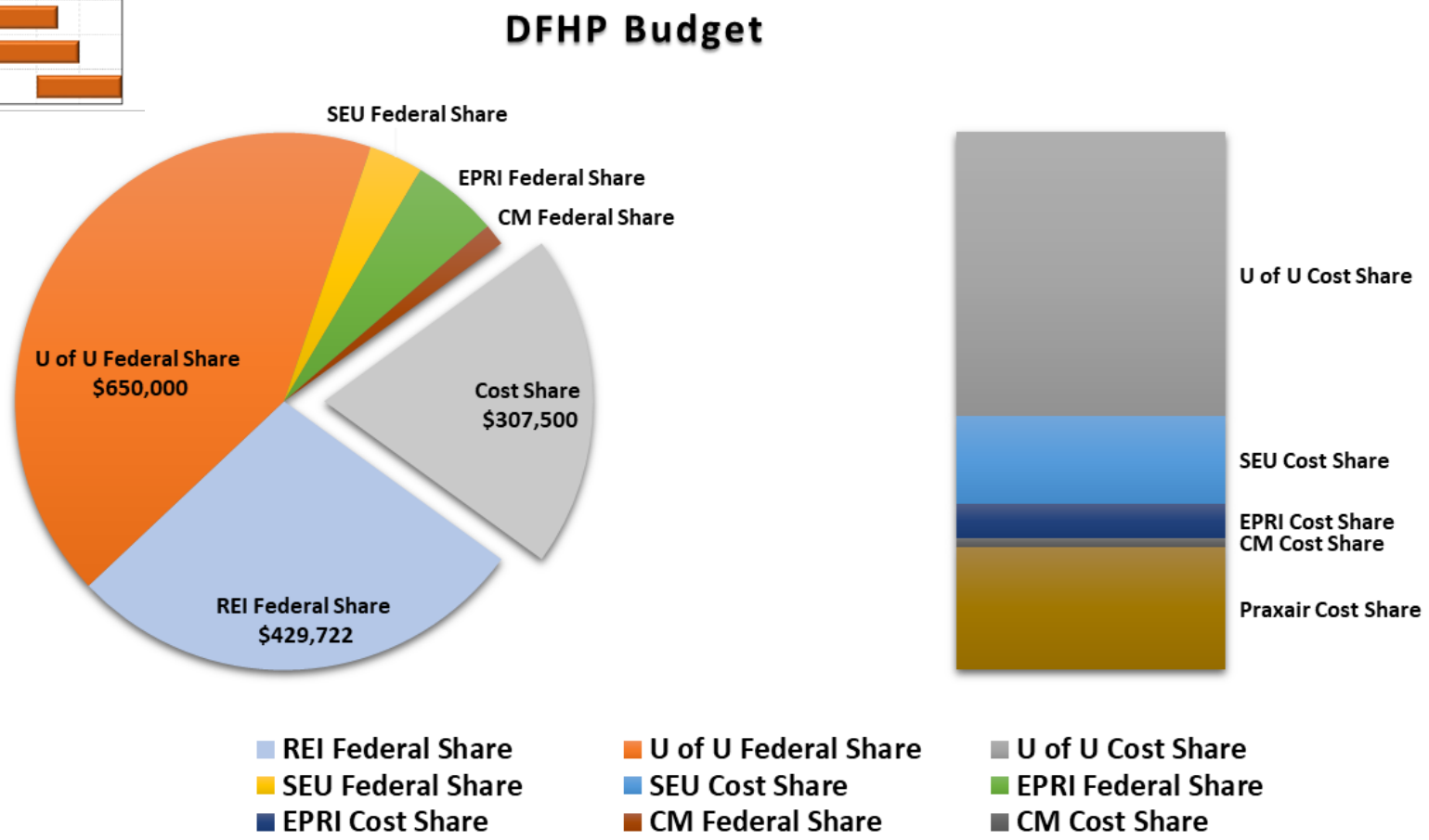
THE UNIVERSITY OF UTAH	SOUTHEAST UNIVERSITY		EPRI	PRAXAIR
• Responsible for installation and certification of the dry feeding system. • Operation of 300 kW Entrained Flow Pressurized Reactor (EFPR) • Gathering experimental data	• Design of dry feeding system, and construction of critical (internal) components • Consultation and advisory during startup and operation of EFPR	• Direction in construction of high pressure corrosion monitor design • Guidance of corrosion assessment of pressurized oxy-fuel combustion	• Supply power industry perspective and technical support • Design review and feedback on economic analysis and full scale boiler scoping	• Provide O_2 and CO_2 for multi-scale testing • Provide guidance on oxy-combustion testing • Serve as informal advisor

Timeline and Budget

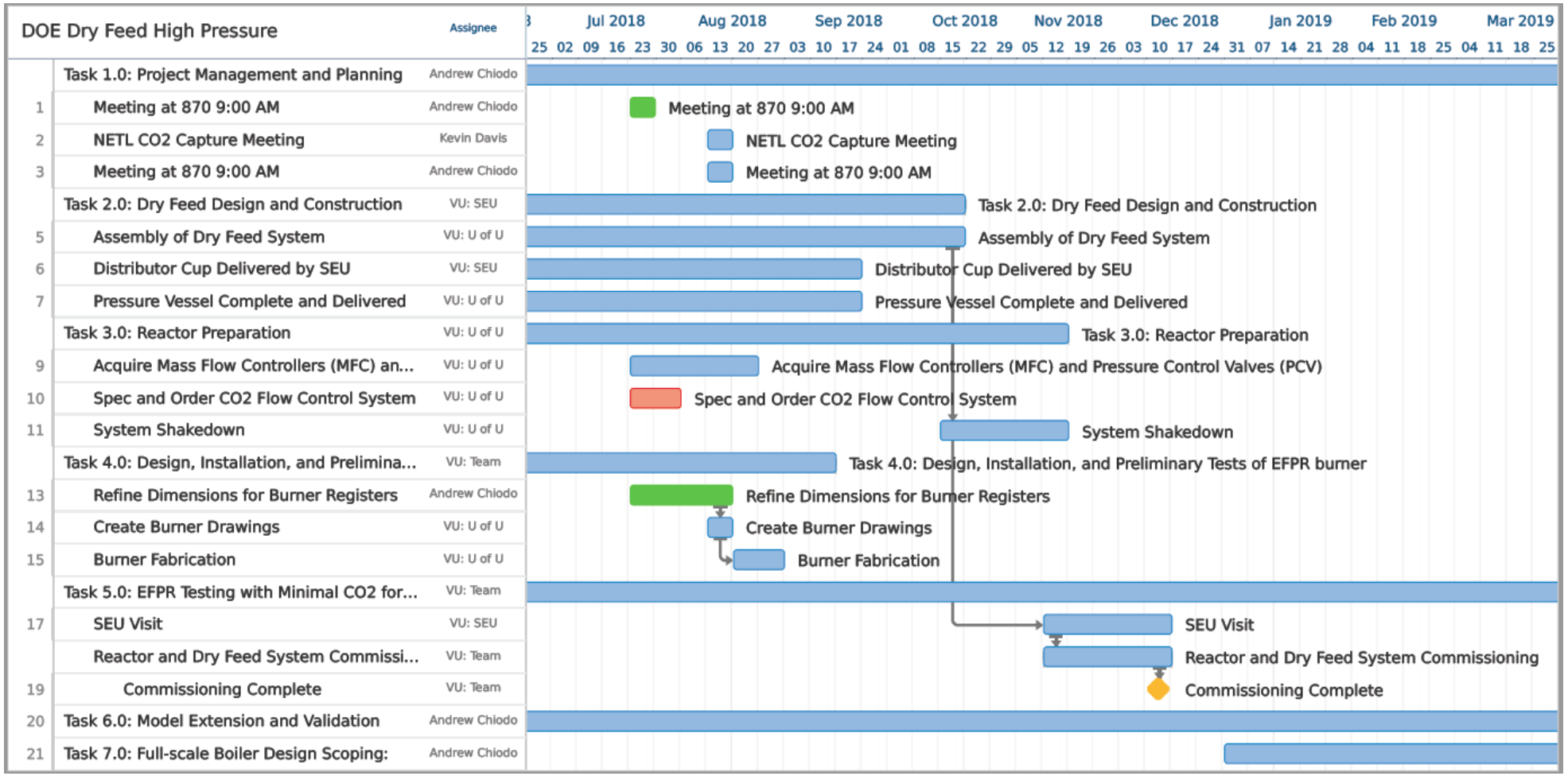


Total Budget
$1,537,220

Total Federal
$1,229,720

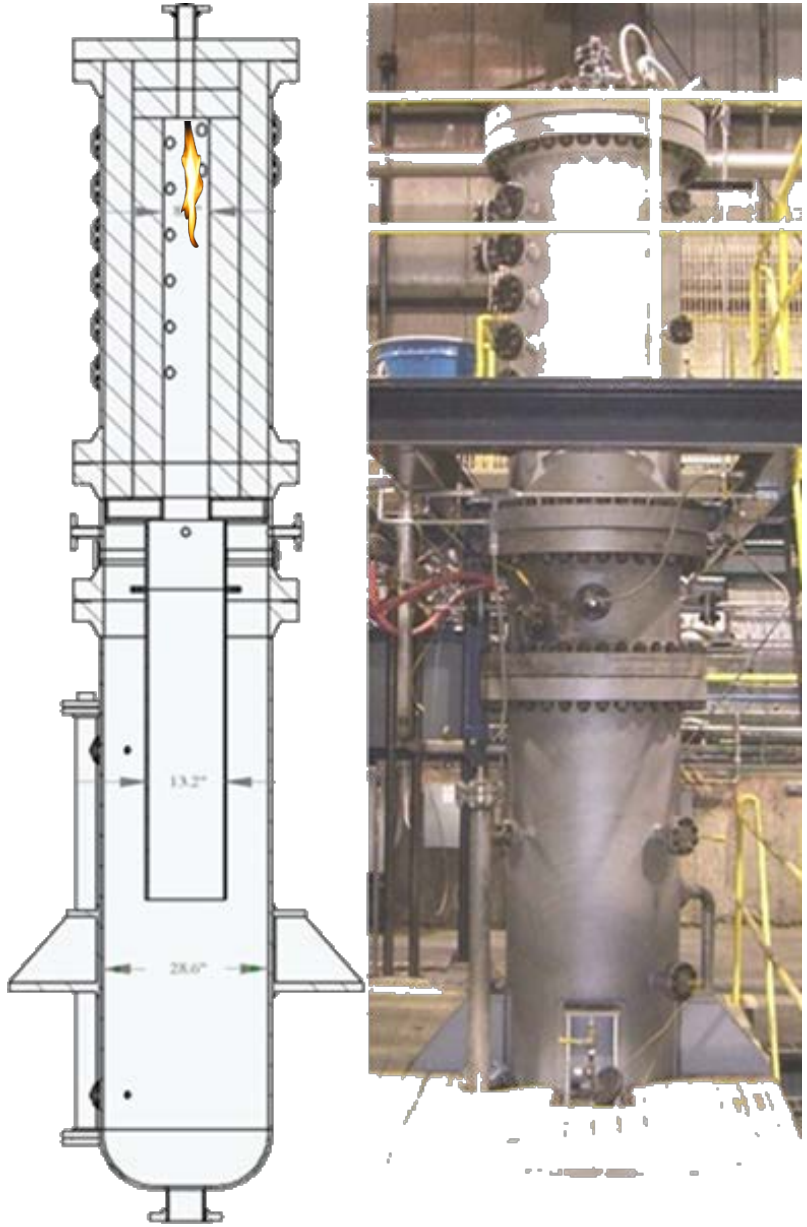


Schedule of Tasks: Q3 2018-Q2 2019



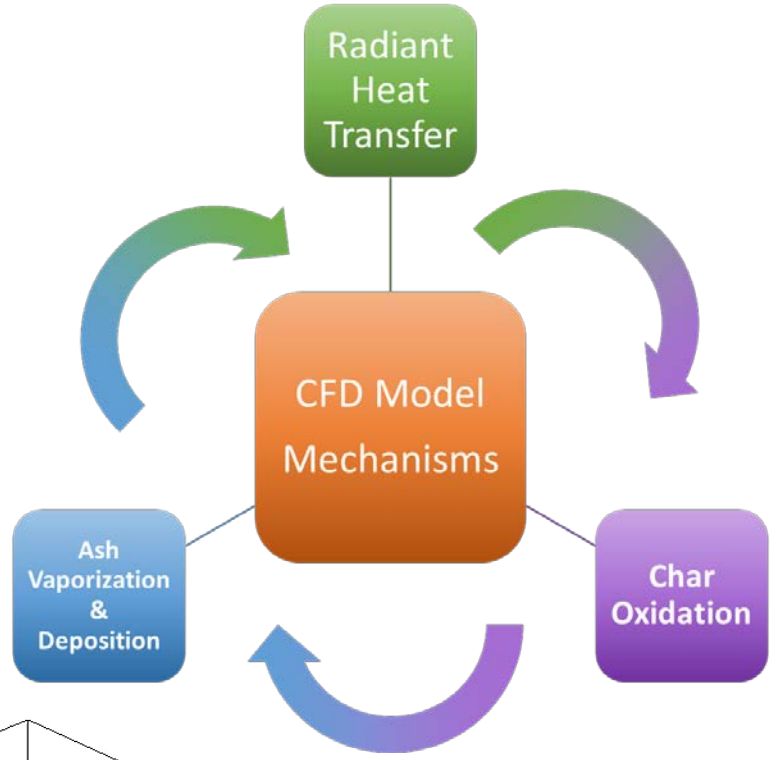
300 kW Entrained Flow Pressurized Reactor (EFPR)

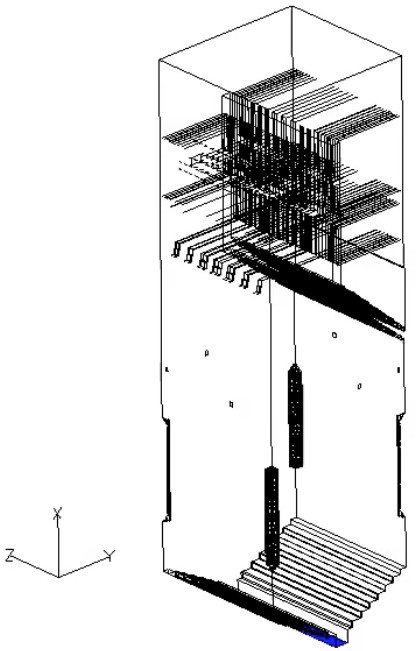
- Converted from entrained flow gasifier
- 300 kW (rated) pilot scale
- Max pressure 450 psi
- Coal-water slurry or dry feeding with pure O_2
- Down-fired, self-sustained and no external heating

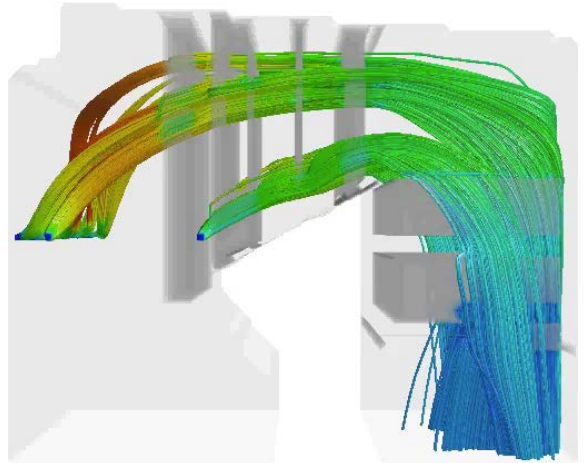


CFD Tools: GLACIER

- 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 NO_x, SO_x, CO, Hg and fine particles
- Continually evolving including recent developments for atmospheric pressure and pressurized oxy-coal applications

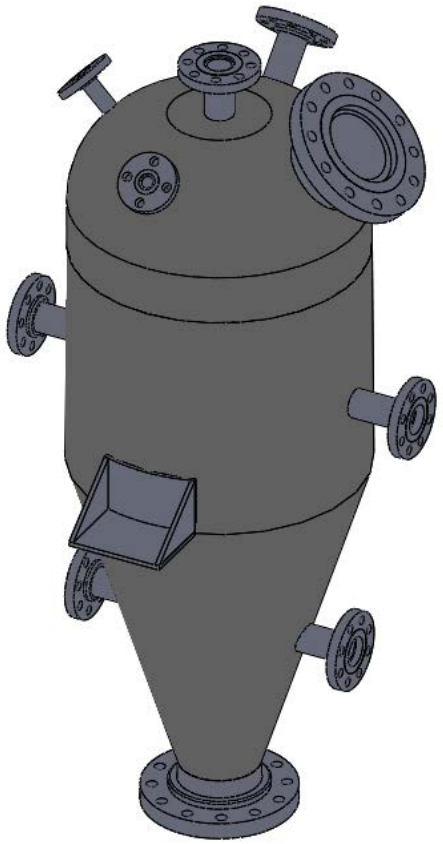


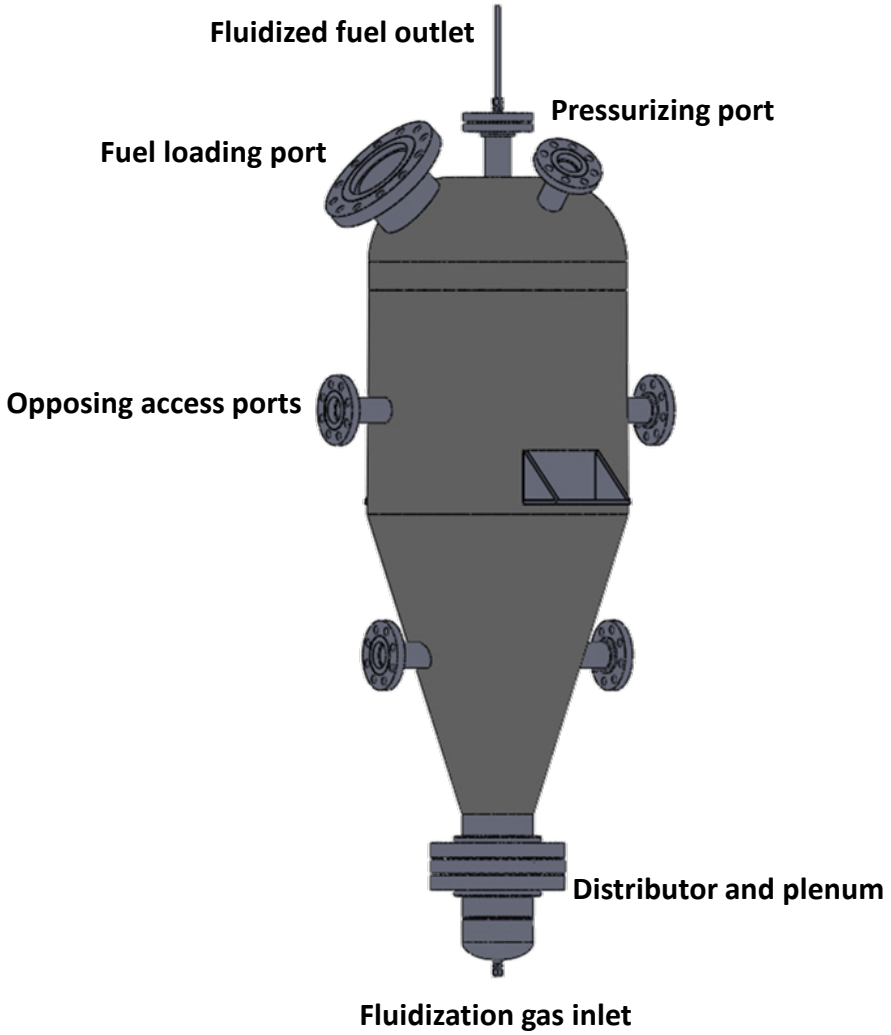




Pulverized Coal Feeder Design

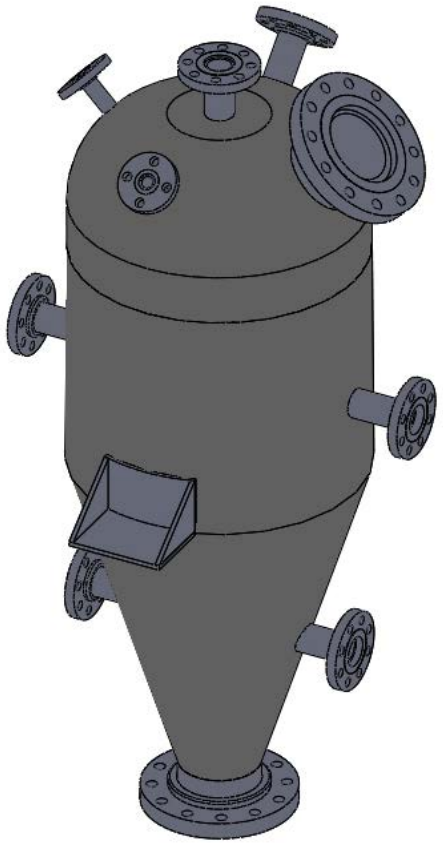
Integration with EFPR

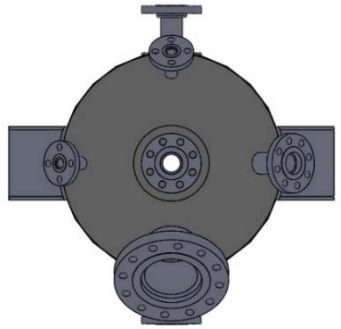


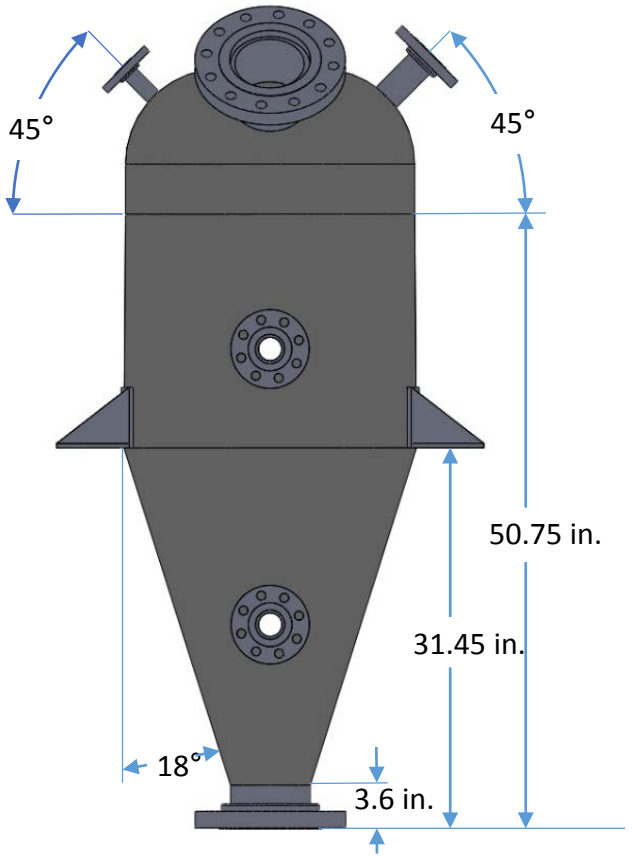


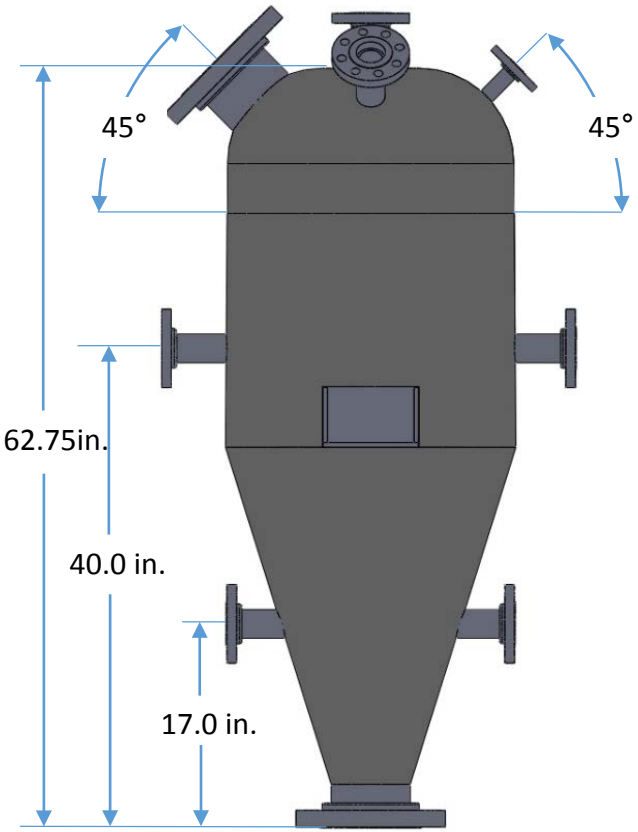
Pulverized Coal Feeder Design

Final design of fluidized feeder body



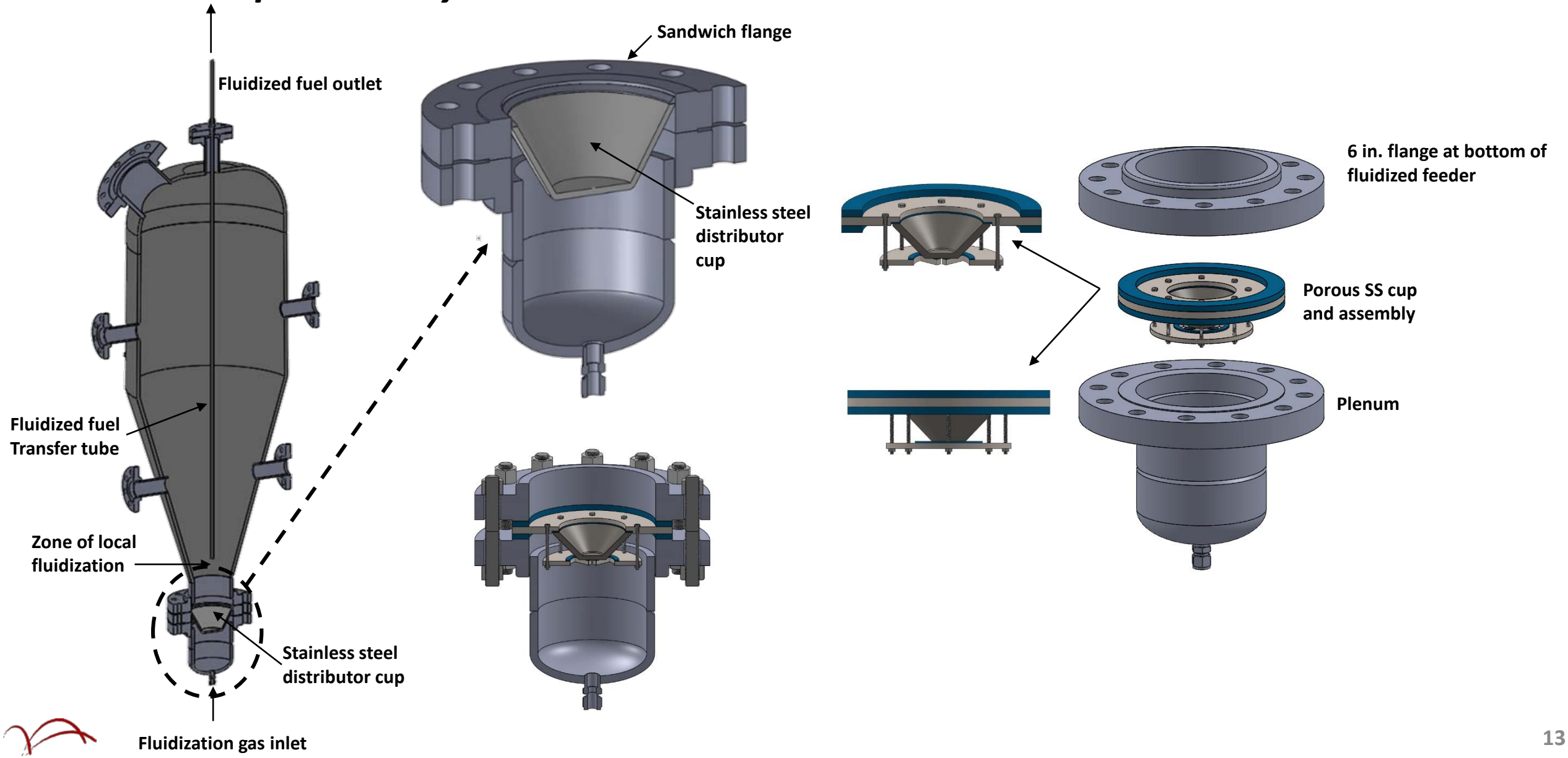


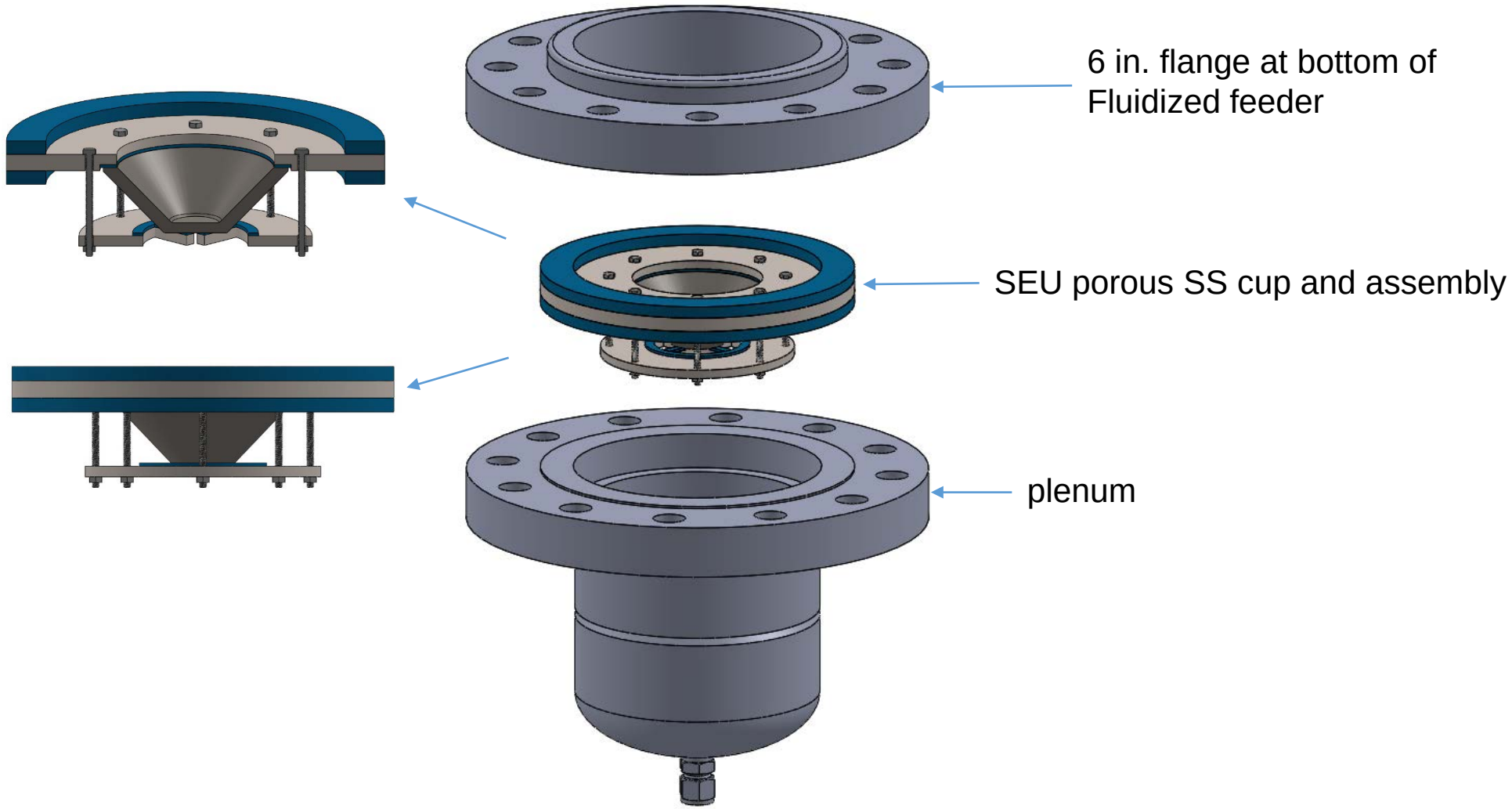




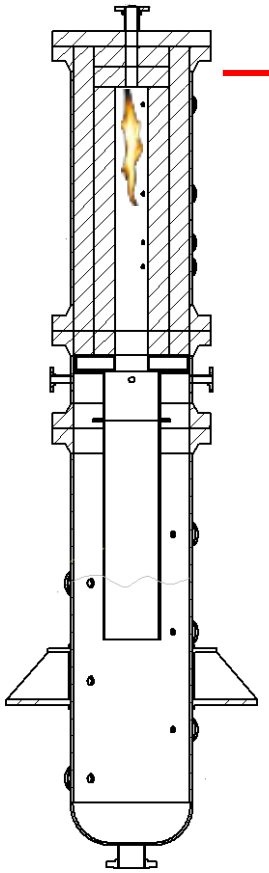
Pulverized Coal Feeder Design

Distributor cup assembly

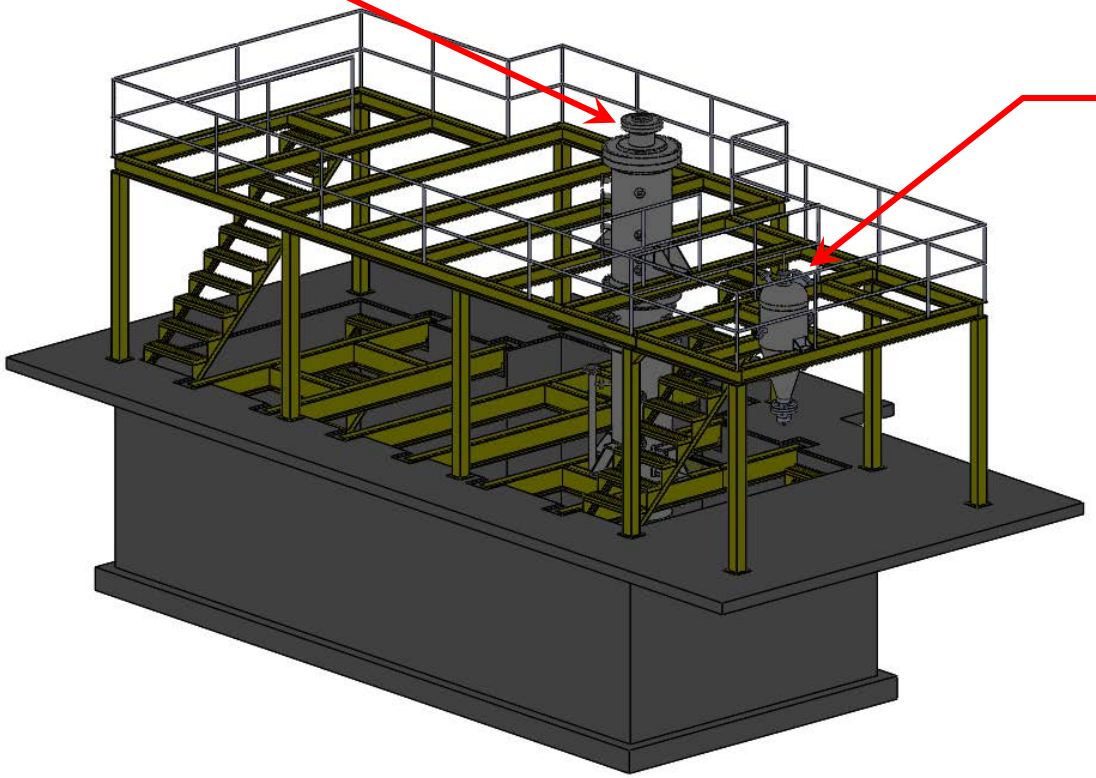



6 in. flange at bottom of
Fluidized feeder
SEU porous SS cup and assembly
plenum

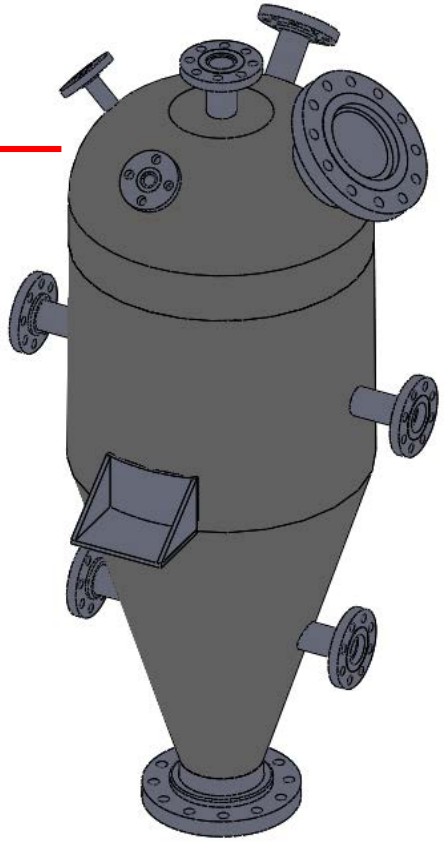
Pulverized Coal Feeder Design & Construction



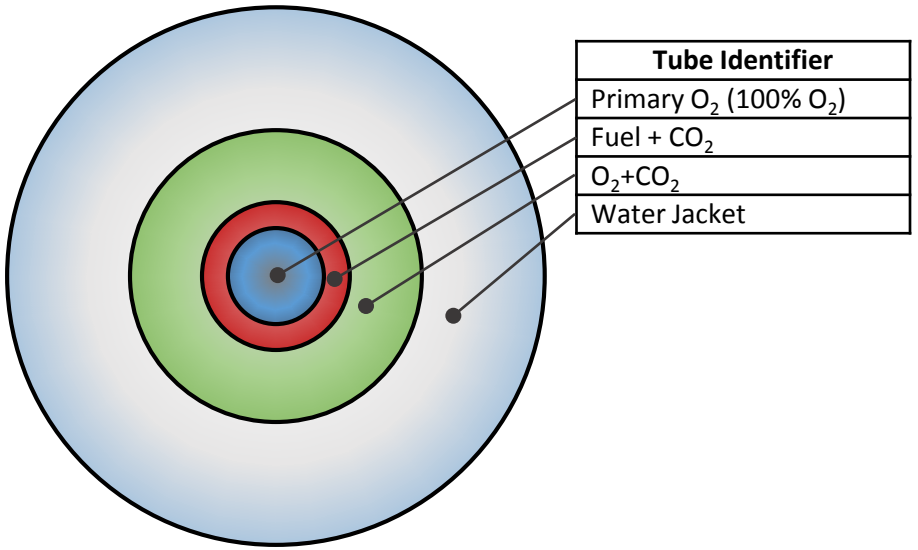
Entrained flow pressurized reactor



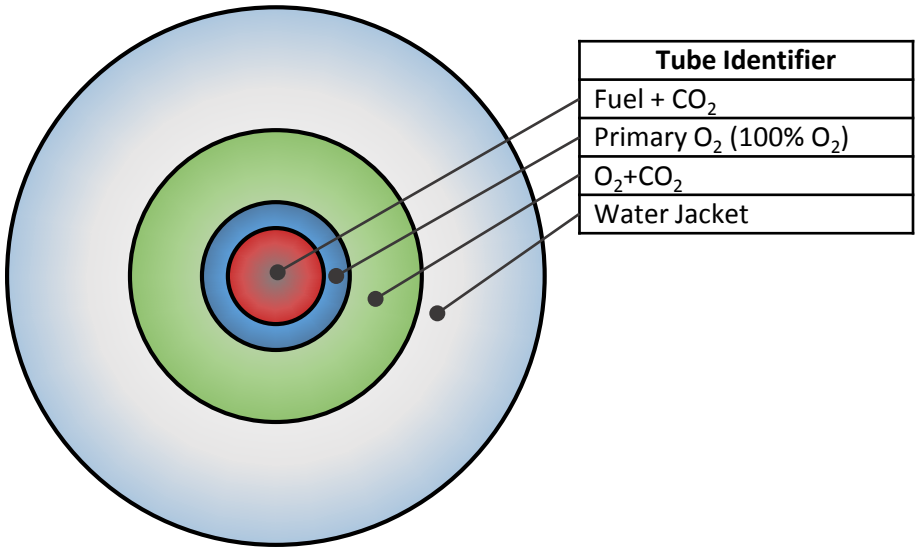
Dry feed system pressure vessel



EFPR Dry Pulverized Coal Burner Design Concepts



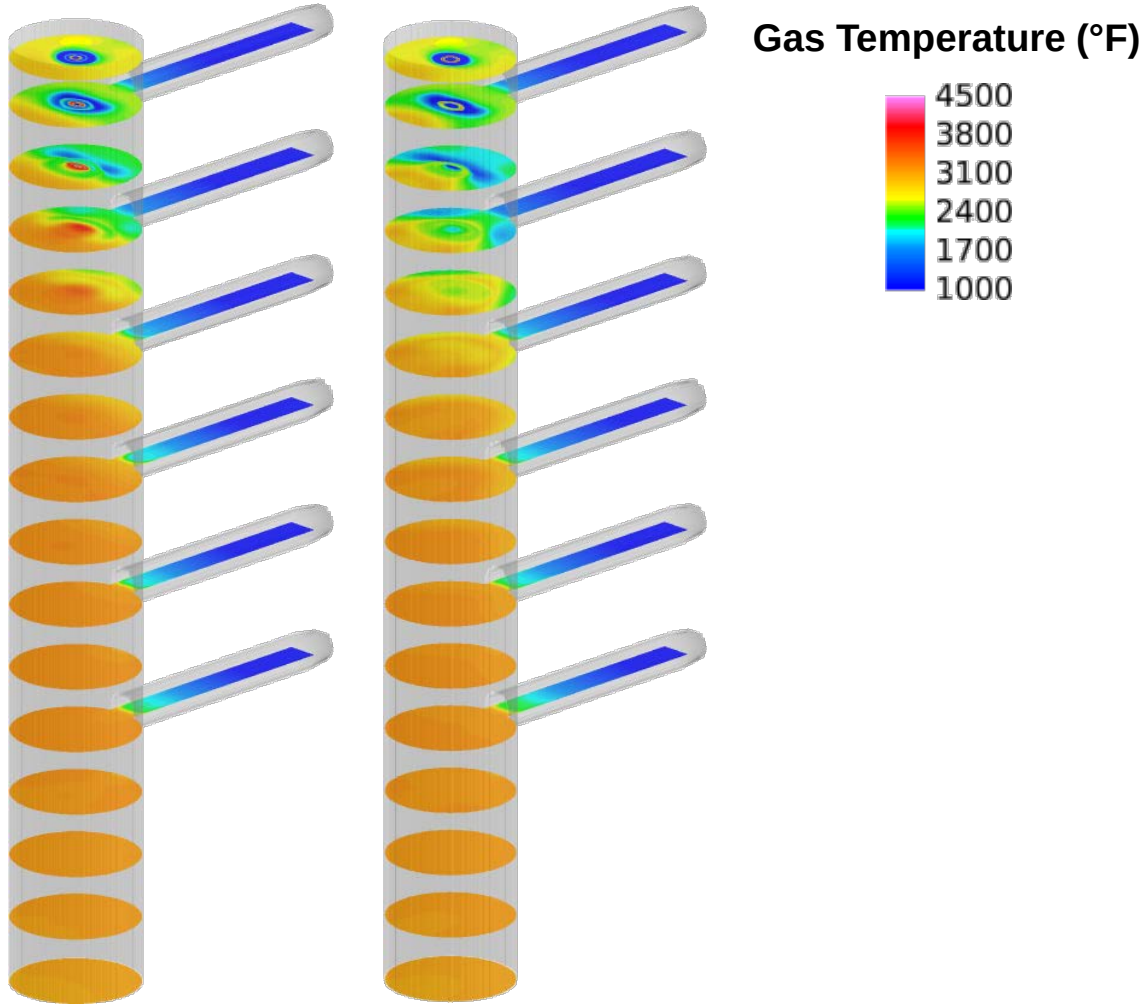
Design 1



Design 2

CFD Model Predictions

Gas Temperature Profiles

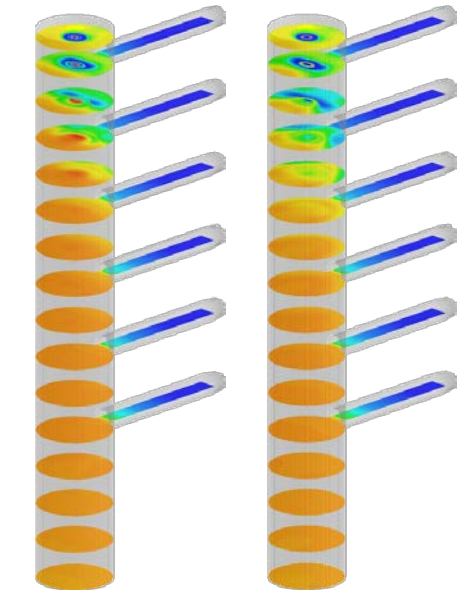


Design 1
Peak = 5088°F

Design 2
Peak = 4605°F

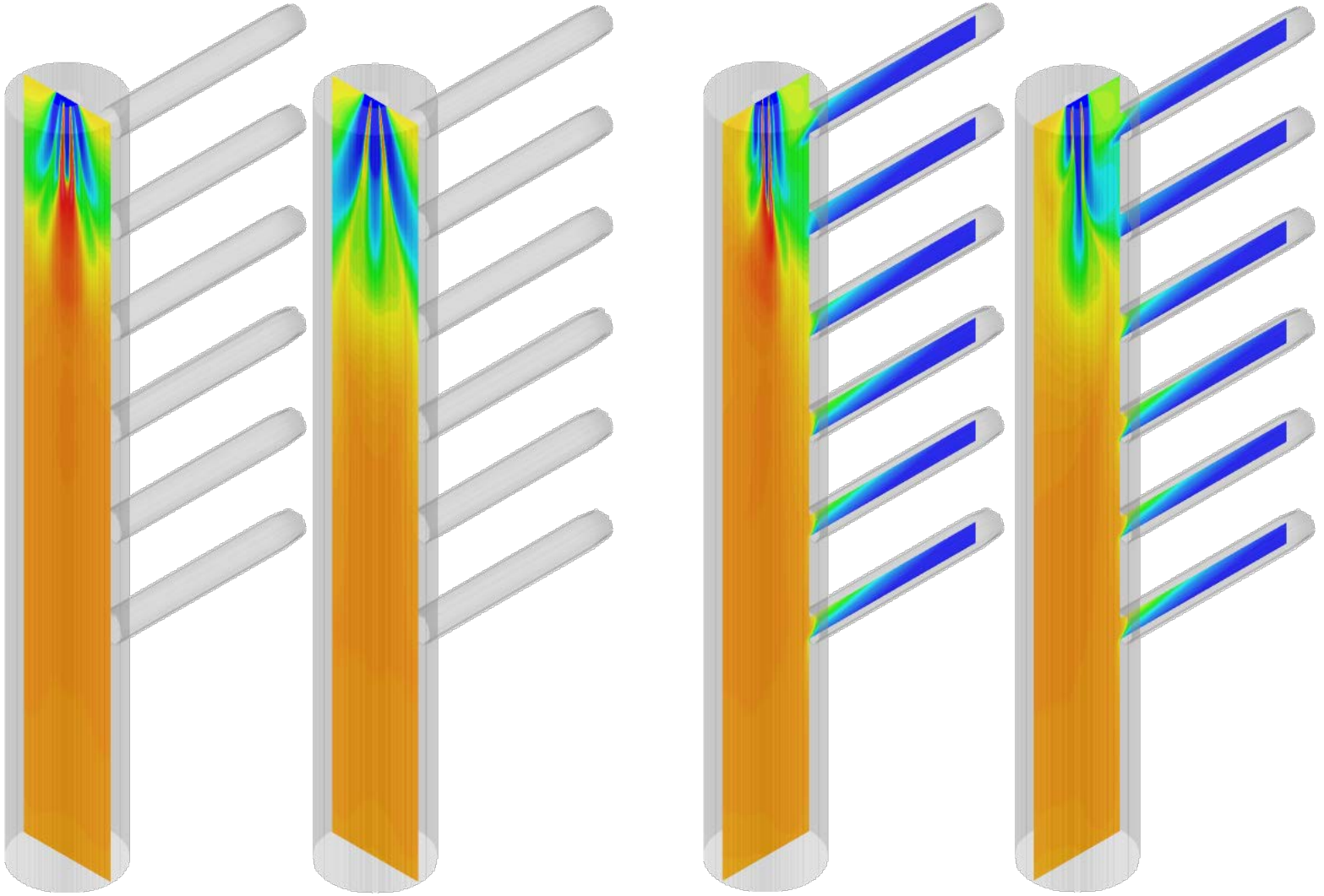
CFD Model Predictions

Gas Temperature Profiles



Design 1 Design 2

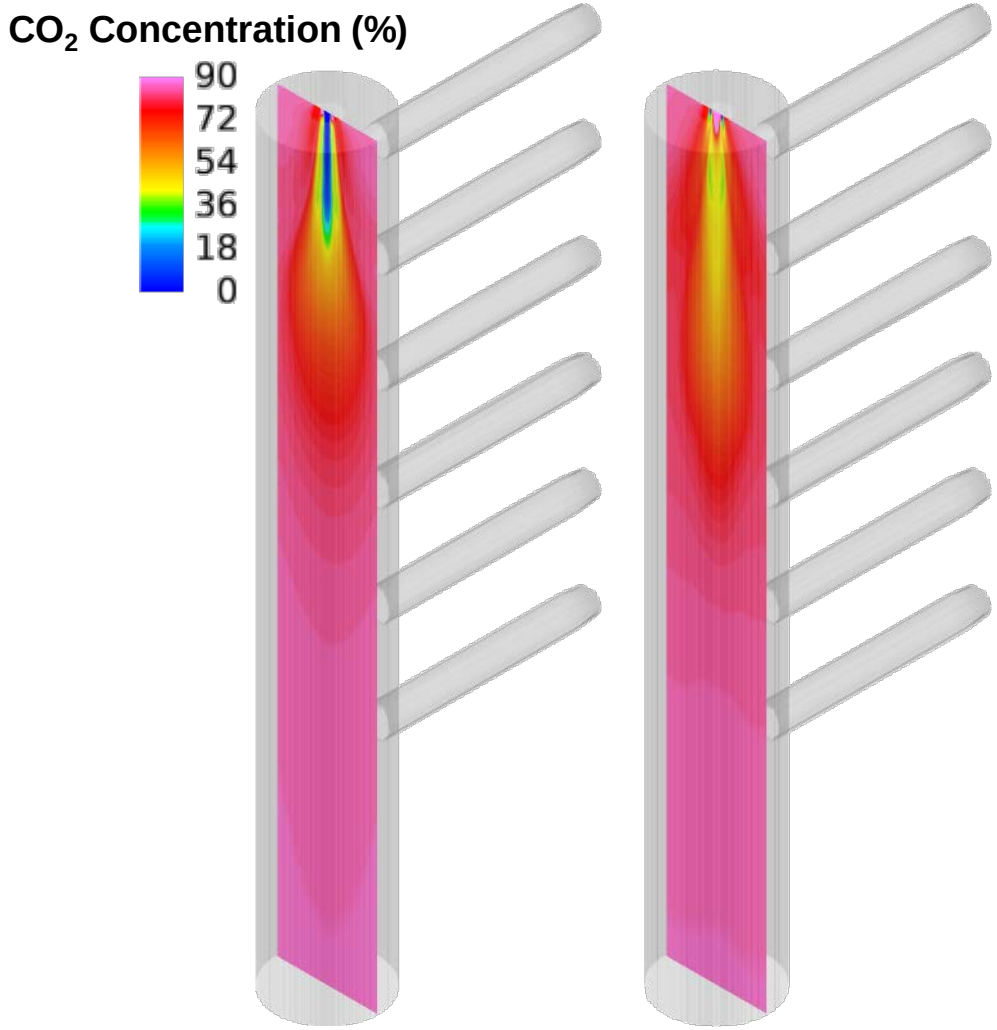
Peak = 5088 °F Peak = 4605 °F

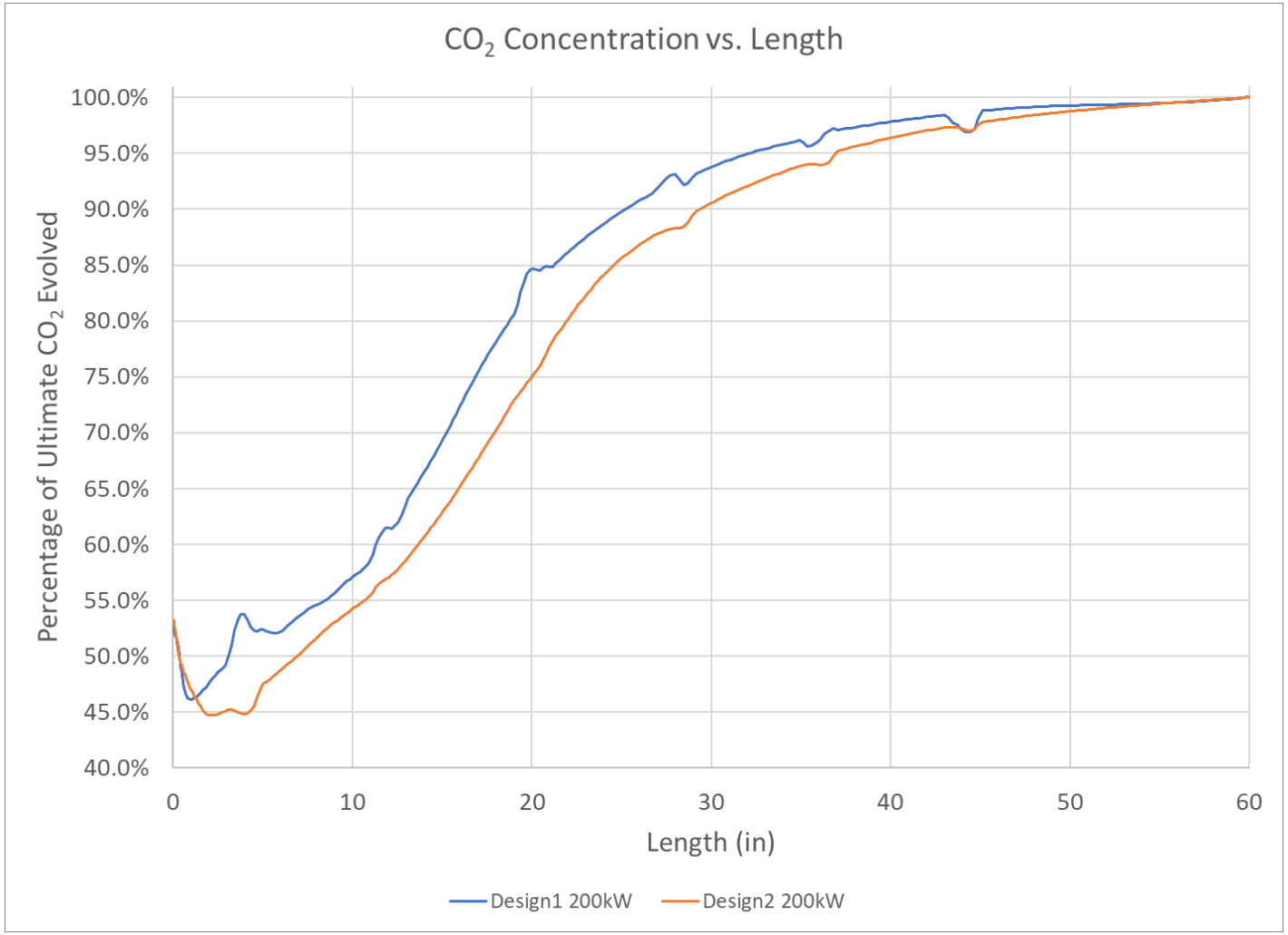


Design 1 Design 2 Design 1 Design 2

Controlling the Rate of Heat Release

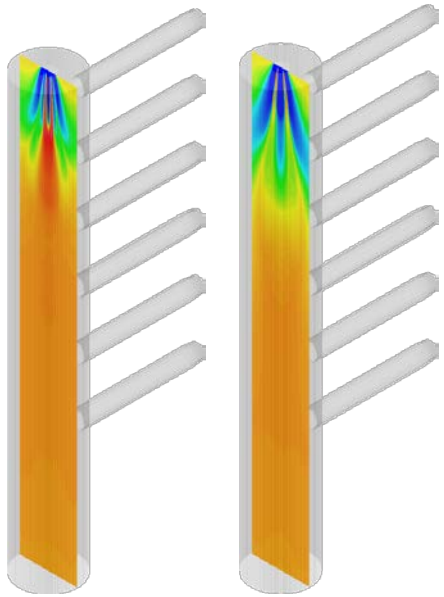
Tracking CO_2 Formation in the Furnace



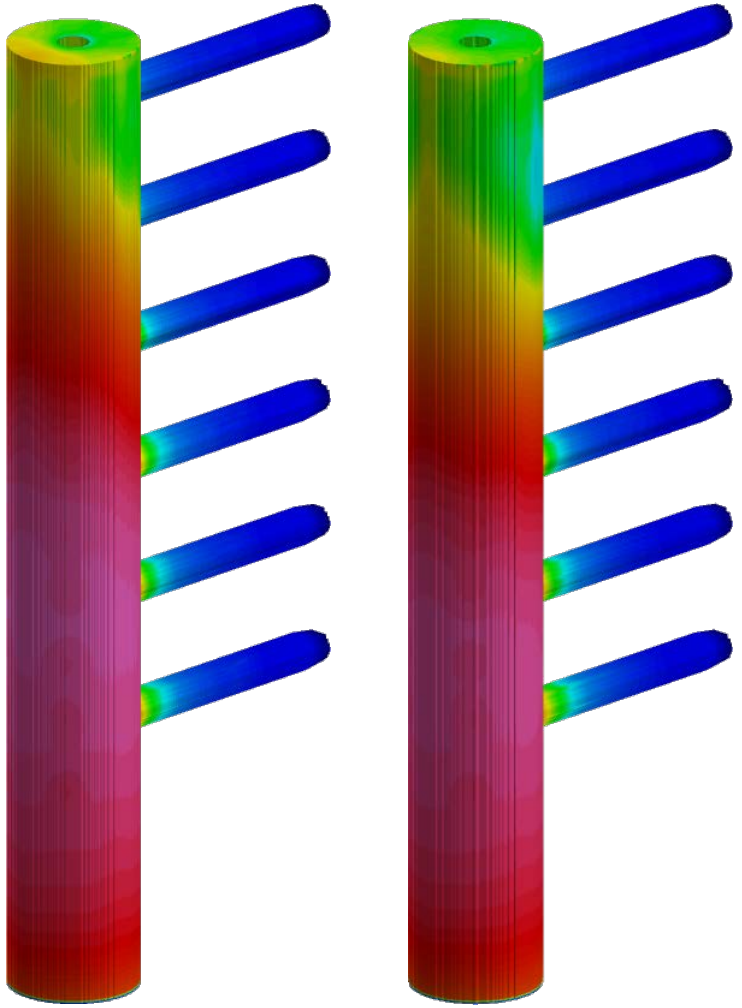


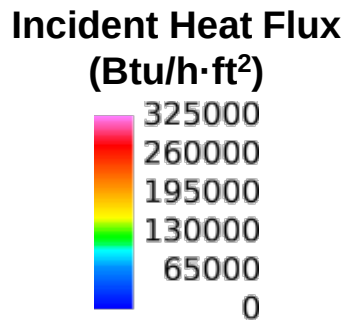
CFD Model Predictions

Radiant Flux Distribution



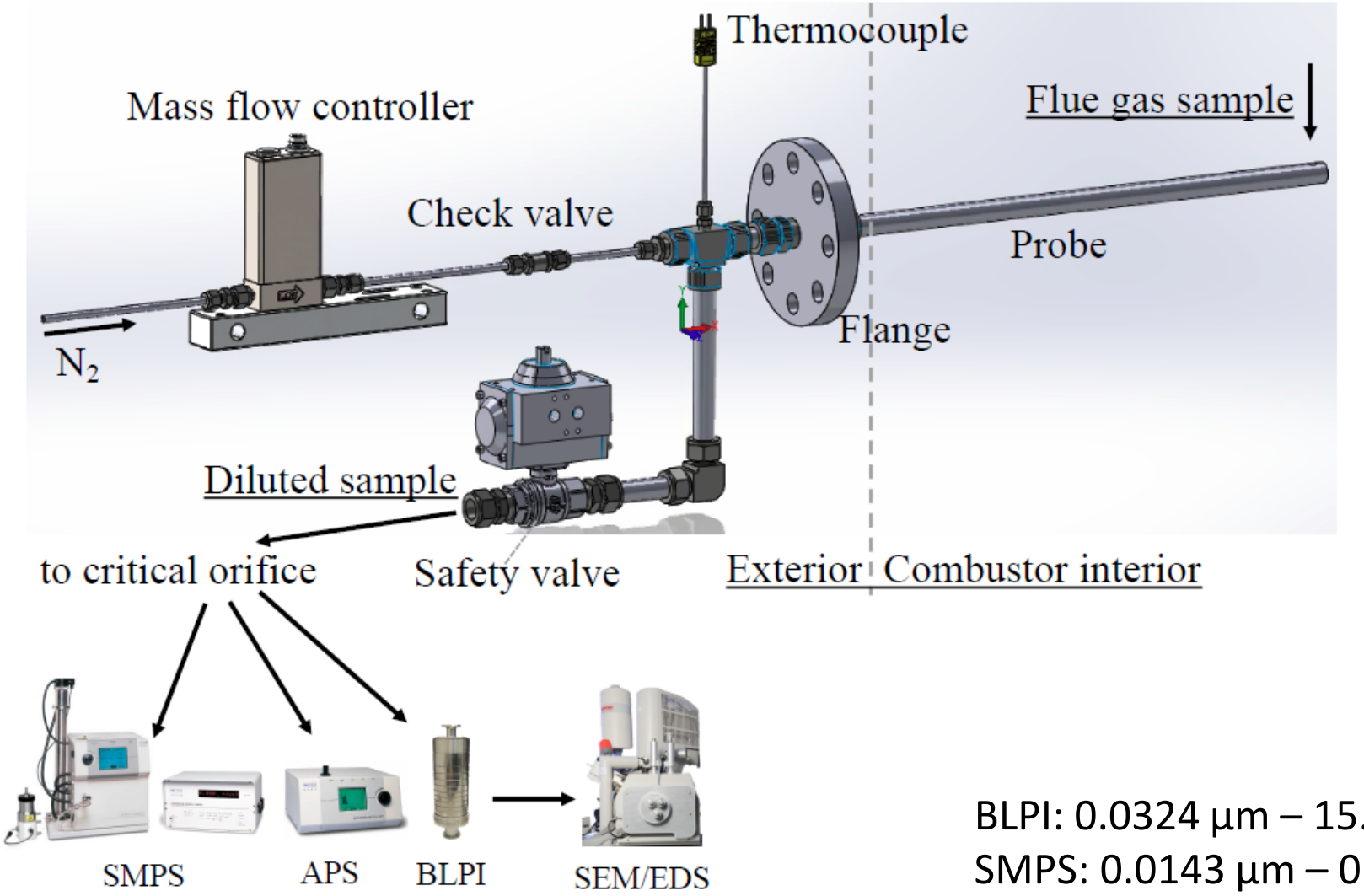
Design 1 Design 2



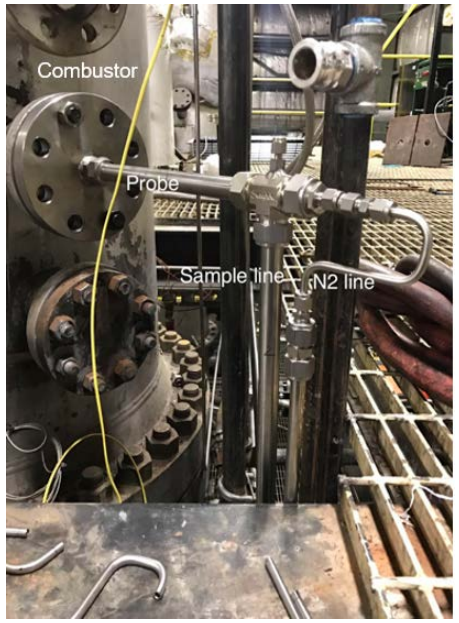


Design 1 Design 2

High Pressure Aerosol Sampling System

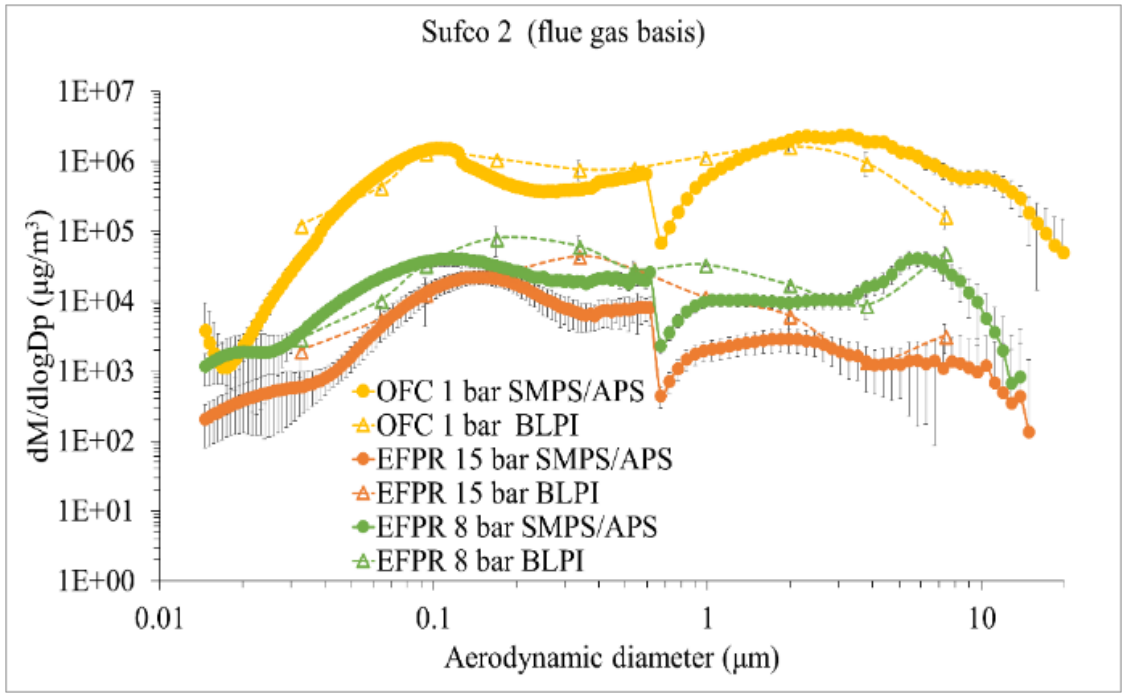


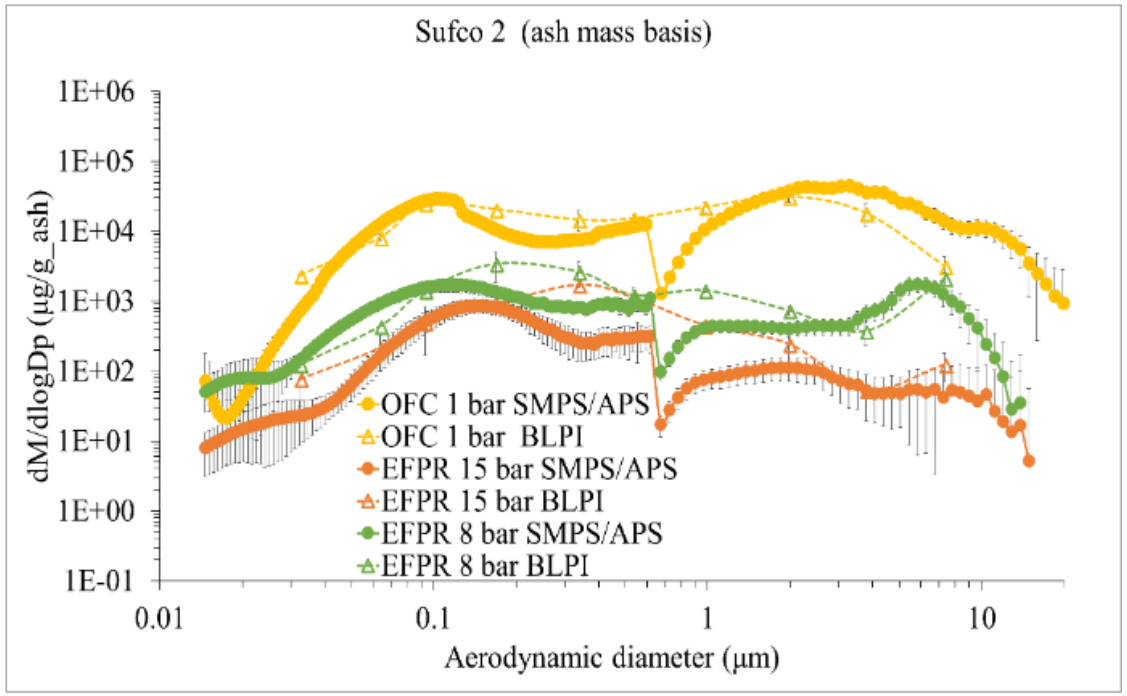
System Schematic



BLPI: 0.0324 µm – 15.7 µm
SMPS: 0.0143 µm – 0.6732 µm
APS: 0.532 µm – 20 µm

Effect of Pressure on Ash Aerosol Particle Size Distributions





Summary

- Design of dry feeding system for integration with EFPR completed and in fabrication
- CFD-guided design of burner for the EFPR with dry feeding has been completed and drawings are being finalized
- Testing of equipment for advanced aerosol characterization in EFPR completed
- Design of corrosion monitoring equipment for use in the EFPR underway
- Integration of dry feeder with high pressure entrained flow reactor and subsequent shakedown testing scheduled for October

Acknowledgment

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