Technology Development for a Pressurized Dry Feed Oxy-Coal Reactor

DE-FE0029157 – 2018 Program Update

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Project Overview

- 3-yr program, Oct 2016 – Sep 2019
- $1.41 M total; DOE $1.1M, Recipient $310K

Team Member	Role
BYU	Management, design, construction, measurements, technology development
CPFD Software	Barracuda software support
Reaction Engineering International	CFD modeling

POC Combustion Challenges

- Pressurized Oxy-Coal (POC) Combustion Advantages
  - Latent heat recoverable, enhanced heat transfer – *improved cycle efficiency*
  - Reduced equipment size – *capital cost reductions*
  - No air in-leakage – *increased CO_2 purity*
- R&D Challenges
  - *Combustor/burner design*
  - *Solid fuel feeding*
  - Emissions control
  - *Heat recovery and integration*

Source: DOE Office of Fossil Energy: Advanced Combustion Systems Program
J. Rockey, September 20, 2016

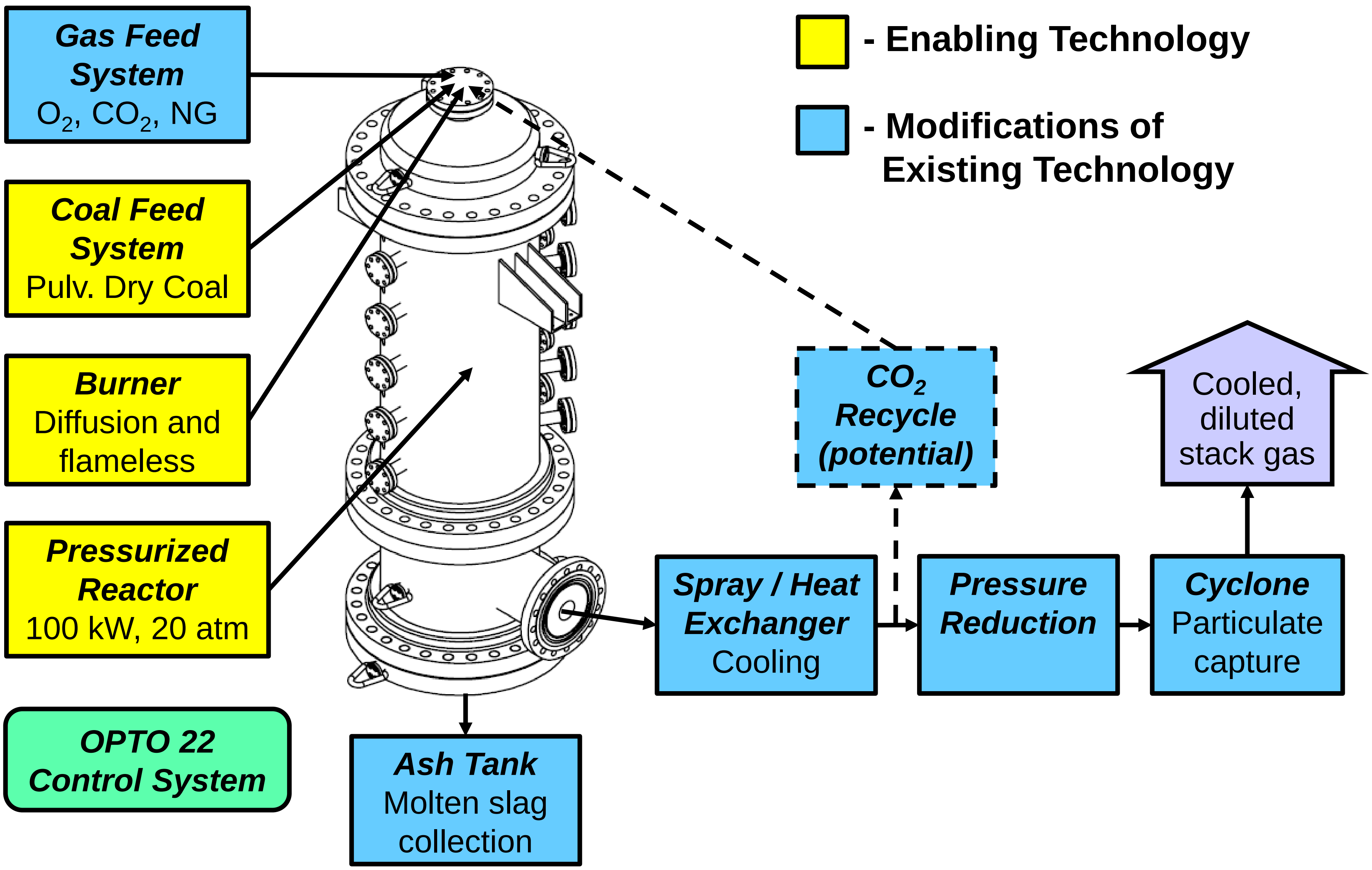
Project Objective

- Develop technologies and data to enable design and operation of full-scale pressurized oxy-coal (POC) combustor
  - 100 kW 20-atm pressurized oxy-coal reactor
  - Scalable pressurized dry coal feed system
  - Scalable O_2-CO_2-coal burners/firing systems for diffusion flame and flameless combustion
  - Measurement data
  - Mechanistic-based hybrid process model to guide reactor scale-up and plant integration

Project Technology

- BYU POC Technology Advantages
  - Pressurized dry coal feed
  - Flameless combustion
  - Fast-running scaling and integration model
- BYU POC Technology Challenges
  - Feed system – CO_2-coal ratio, steadiness
  - Firing system – flame control with low momentum
  - Slagging

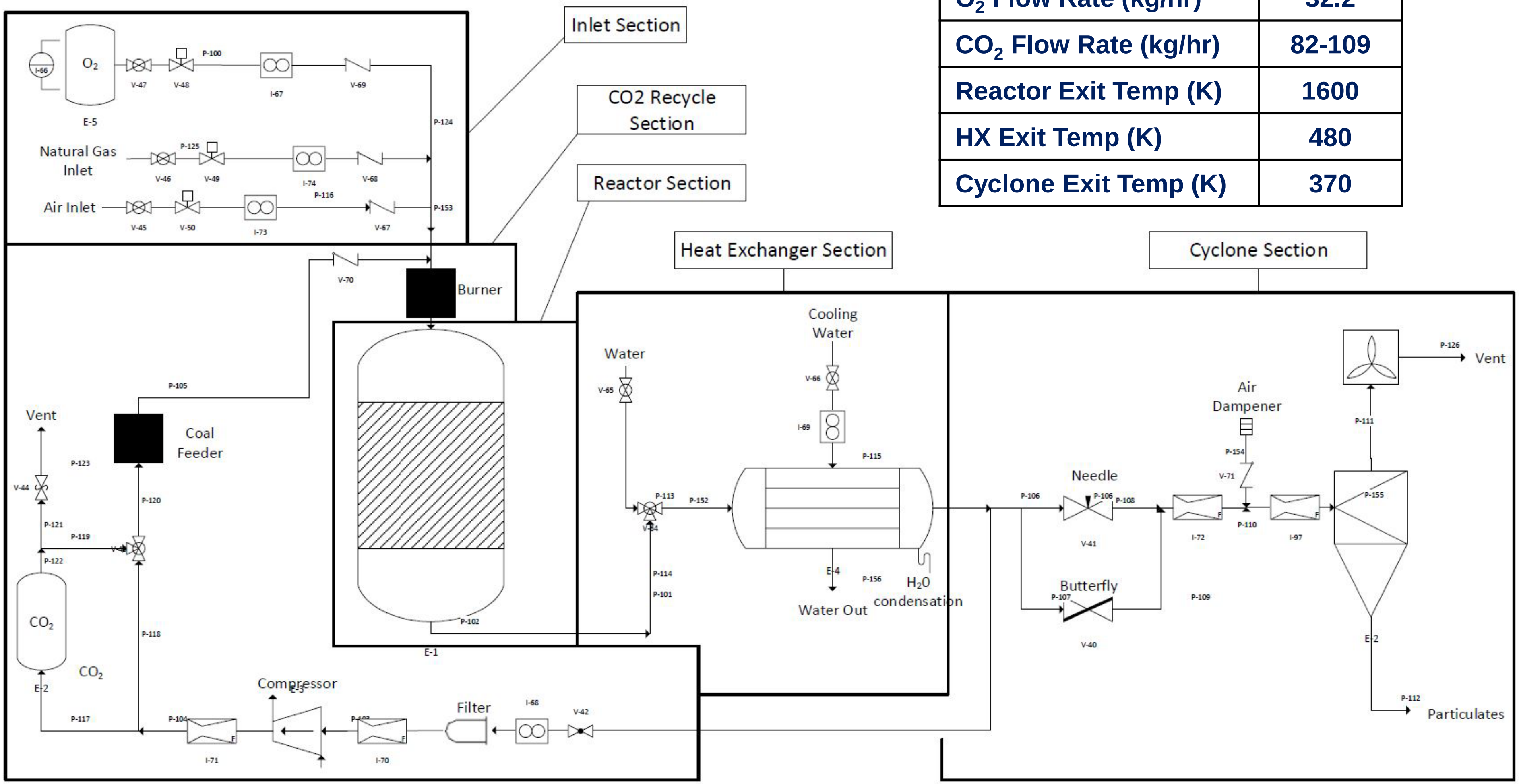
POC System Overview



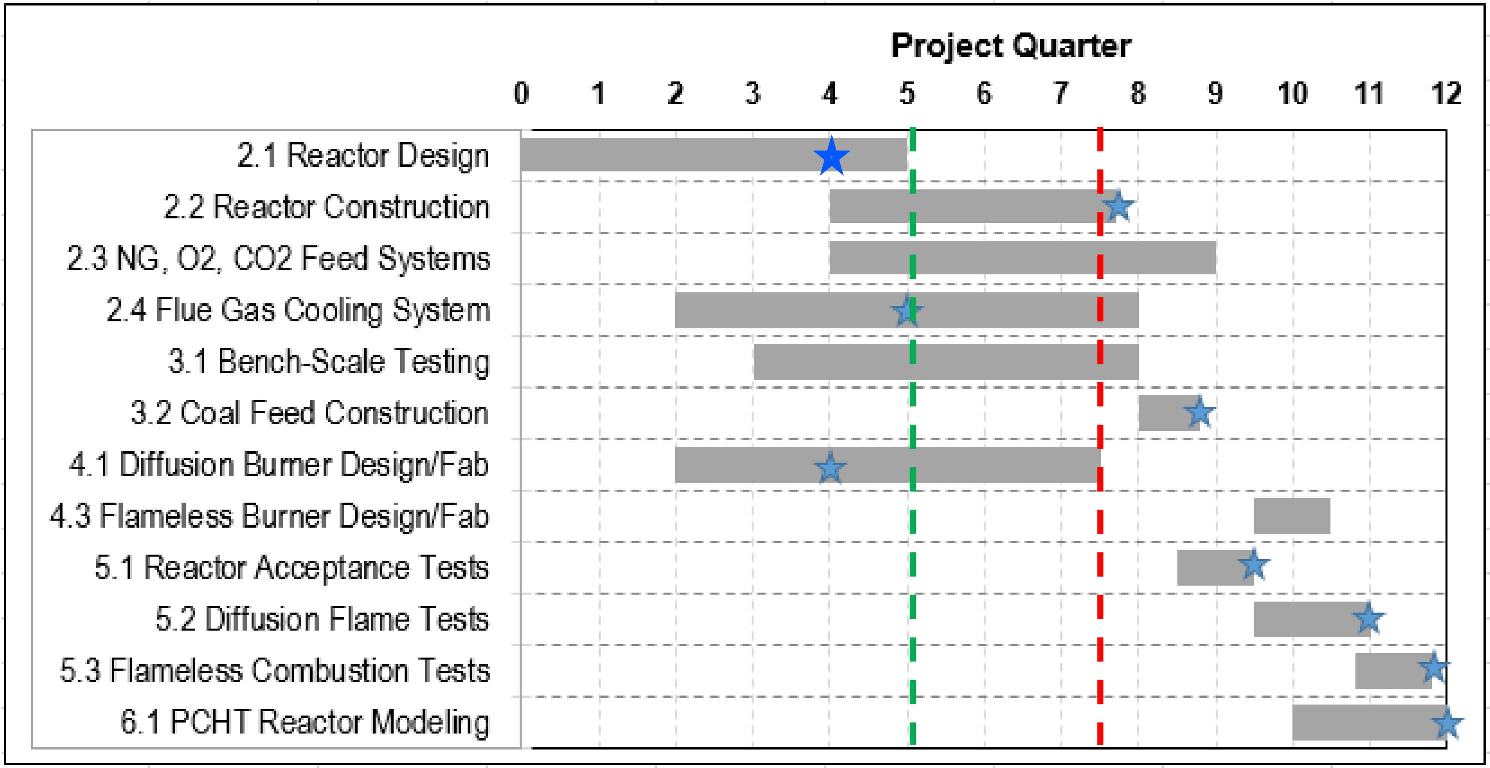
POC System P&ID

Process Conditions

Coal Flow Rate (kg/hr)	**13.6**
O_2 Flow Rate (kg/hr)	**32.2**
CO_2 Flow Rate (kg/hr)	**82-109**
Reactor Exit Temp (K)	**1600**
HX Exit Temp (K)	**480**
Cyclone Exit Temp (K)	**370**

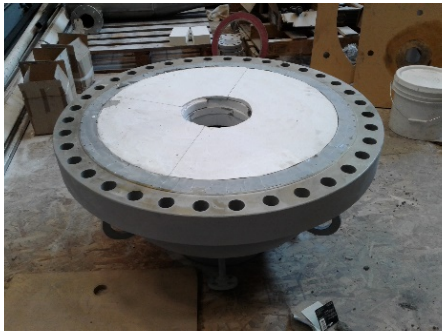


Project Schedule and Milestones



- New Building Delays
  - Occupancy 1/18 vs 8/17
  - Structural steel
  - Gas feeds, electrical

Reactor Construction



Reactor Construction

Reactor Systems

Controls P&ID elements
Mass flow controllers
Flow sensors
Pressure sensors
Thermocouples
Radiometers

Shell pass: 6’ long, 5.76” ID
20 atm gas, 1260 K → 480 K
25 two-pass tubes, 0.245” ID
80 psi water, 300 K → 330 K

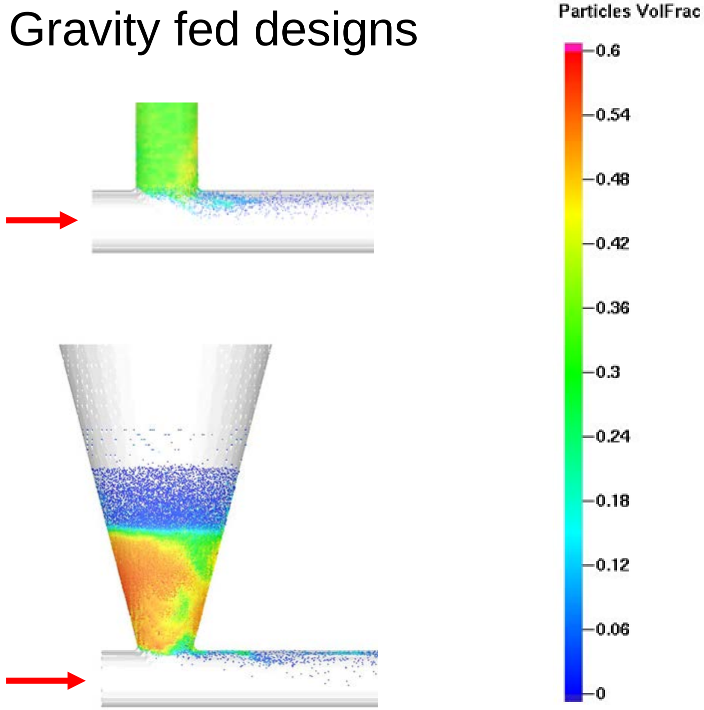
~170 SCFM (1 atm flue gas + dilution air)

Low particle loading

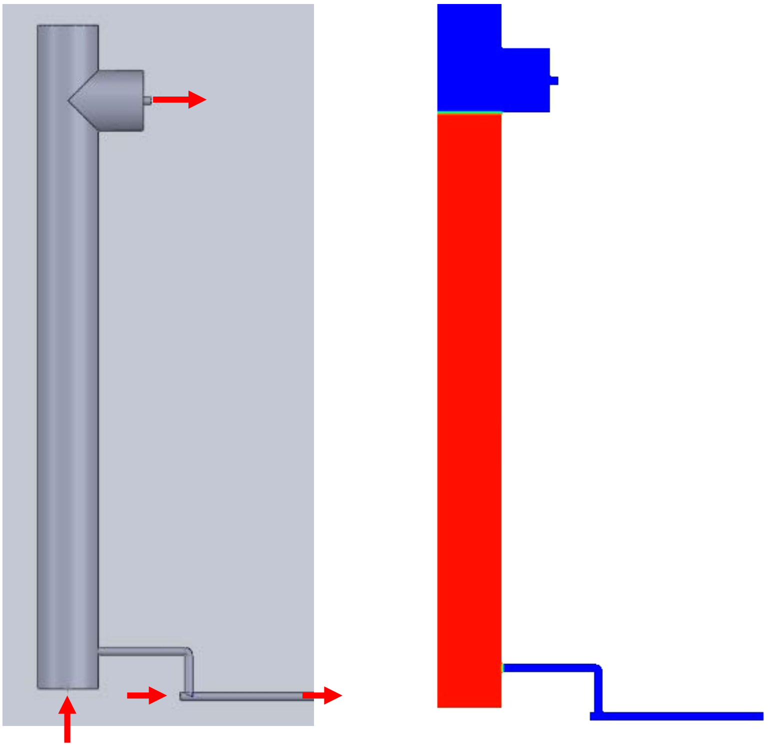
Coal Feed System Modeling

- Transport 13.6 kg/hr (~30 lb/hr) coal with CO_2 at 20 atm
- Steady coal flow at burner
- Control fluidization and dilution independently

Gravity fed designs

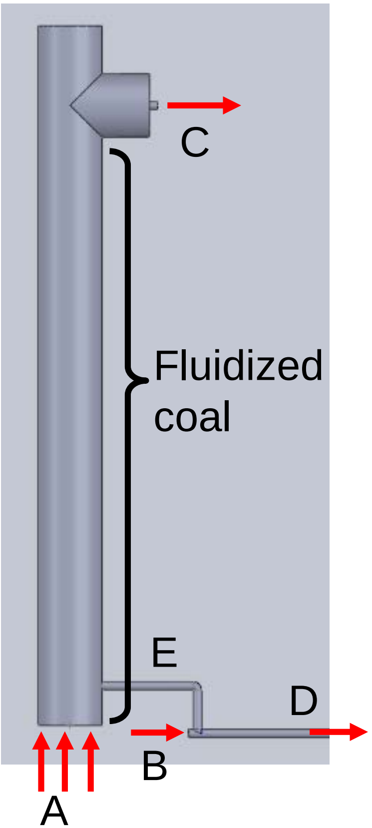


Fluidized designs

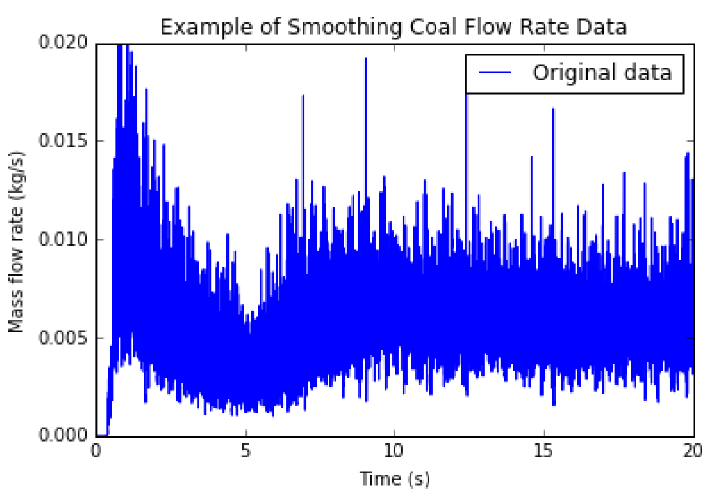


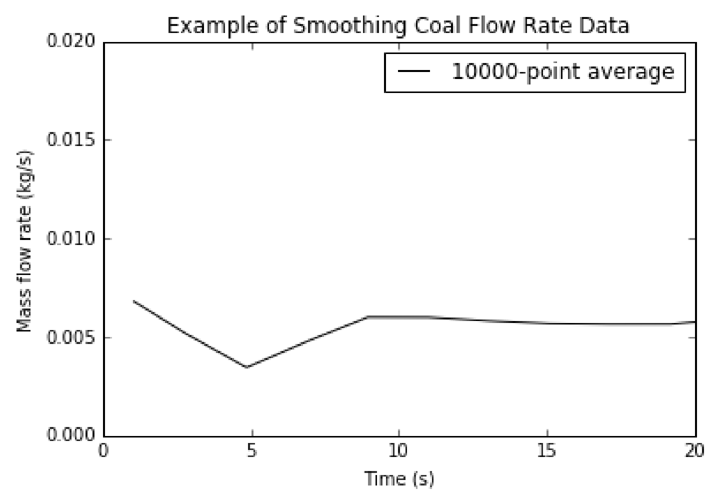
CFD images from CPFD Barracuda VR

Coal Feed System Modeling



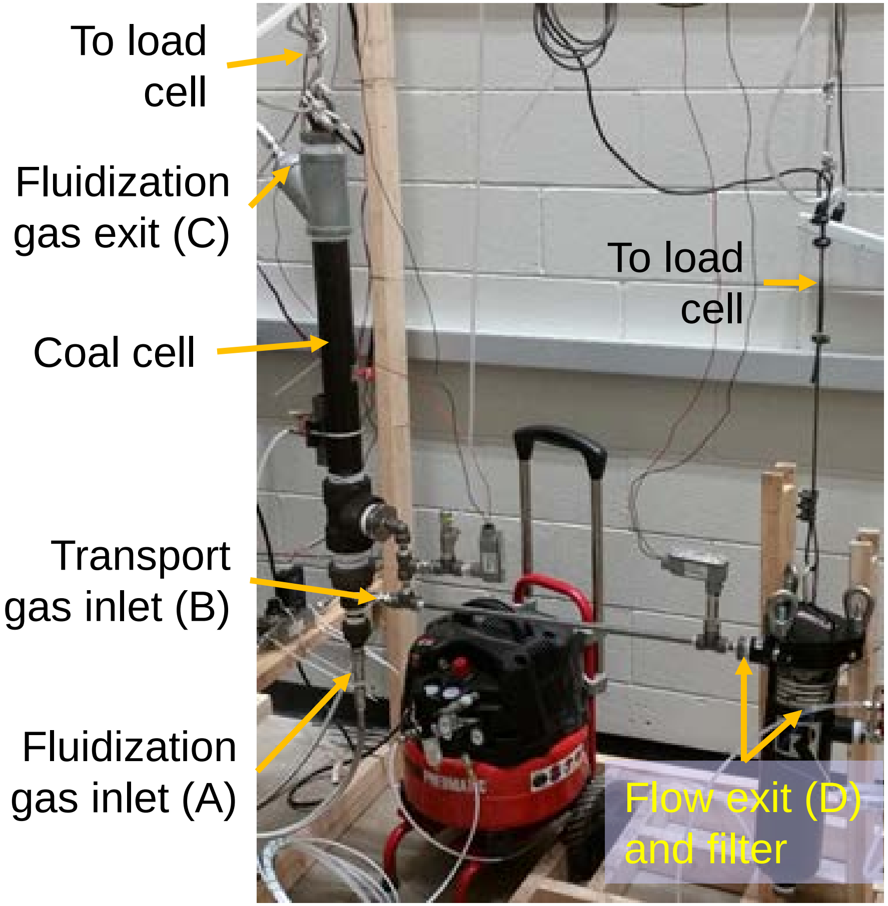
Inlet A	Outlet C	Outlet E	Inlet B	Outlet D	
CO_2 Fluidization Flow (g/s)	CO_2 Flow Through Vent (g/s)	CO_2 Flow Exiting Hopper (g/s)	CO_2 Dilution Flow (g/s)	Coal Flow at Exit (g/s)	Exit Coal to CO_2 Ratio
0.384	**0.034**	**0.350**	**3.350**	**5.757**	1.625
0.850	**0.500**	0.350	3.350	**4.933**	1.384
0.500	**0.150**	0.350	3.234	**5.712**	1.669
0.384	0.034	0.350	**6.700**	**5.985**	**0.869**
0.734	0.034	**0.700**	3.000	**10.588**	3.103
1.200	**0.500**	0.700	3.000	**11.130**	3.276

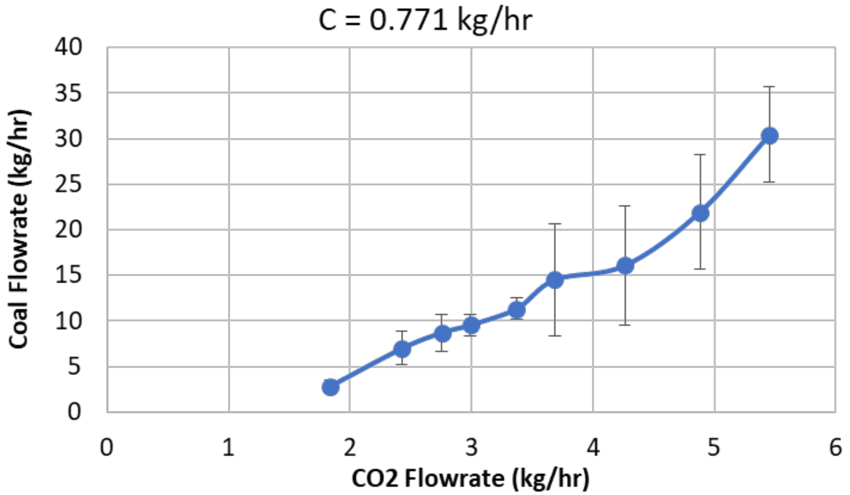


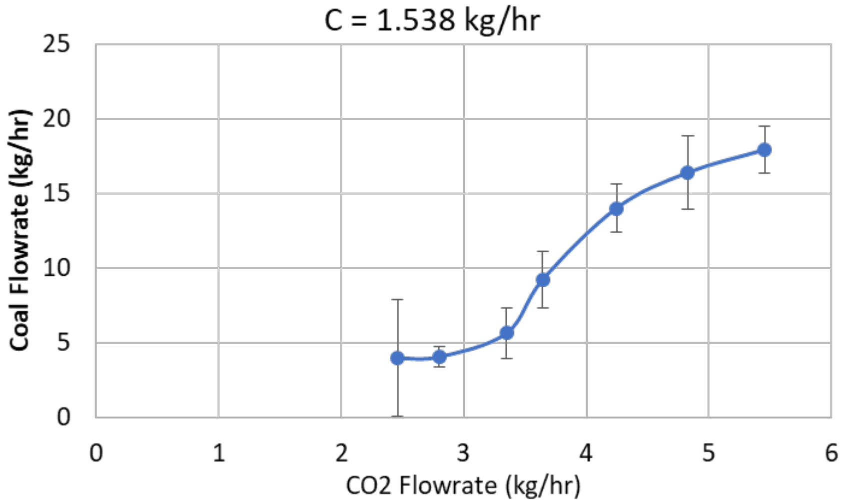


Coal Feed System Testing

- Bench-scale apparatus (pipe ID similar to actual)

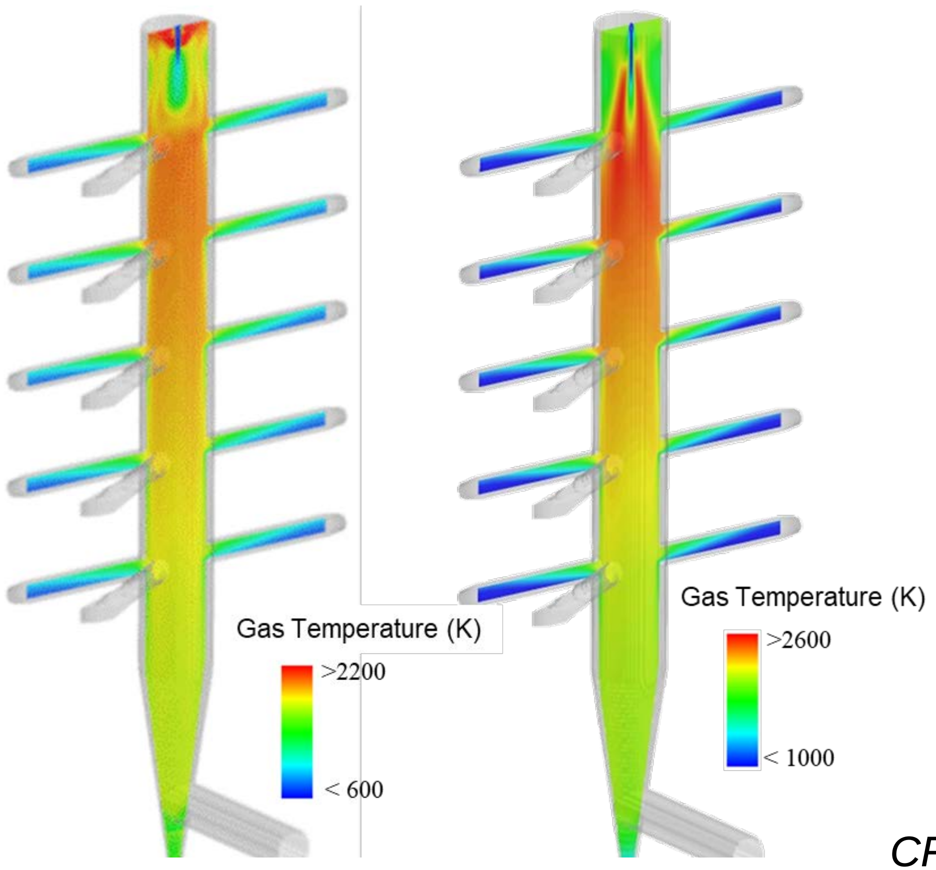


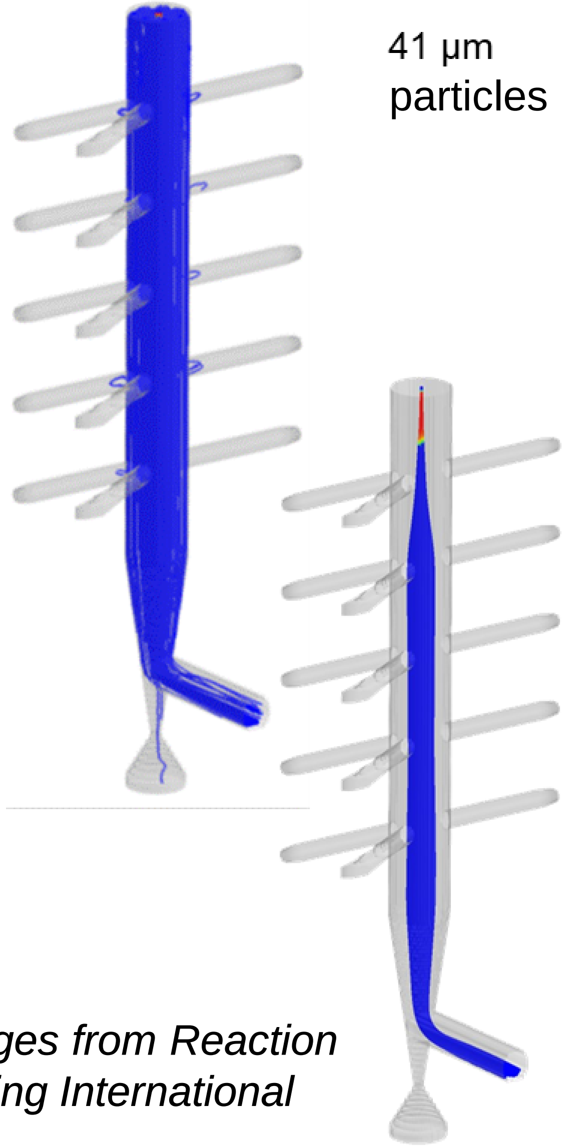




Burner CFD Predictions

- Design impacts flame shape

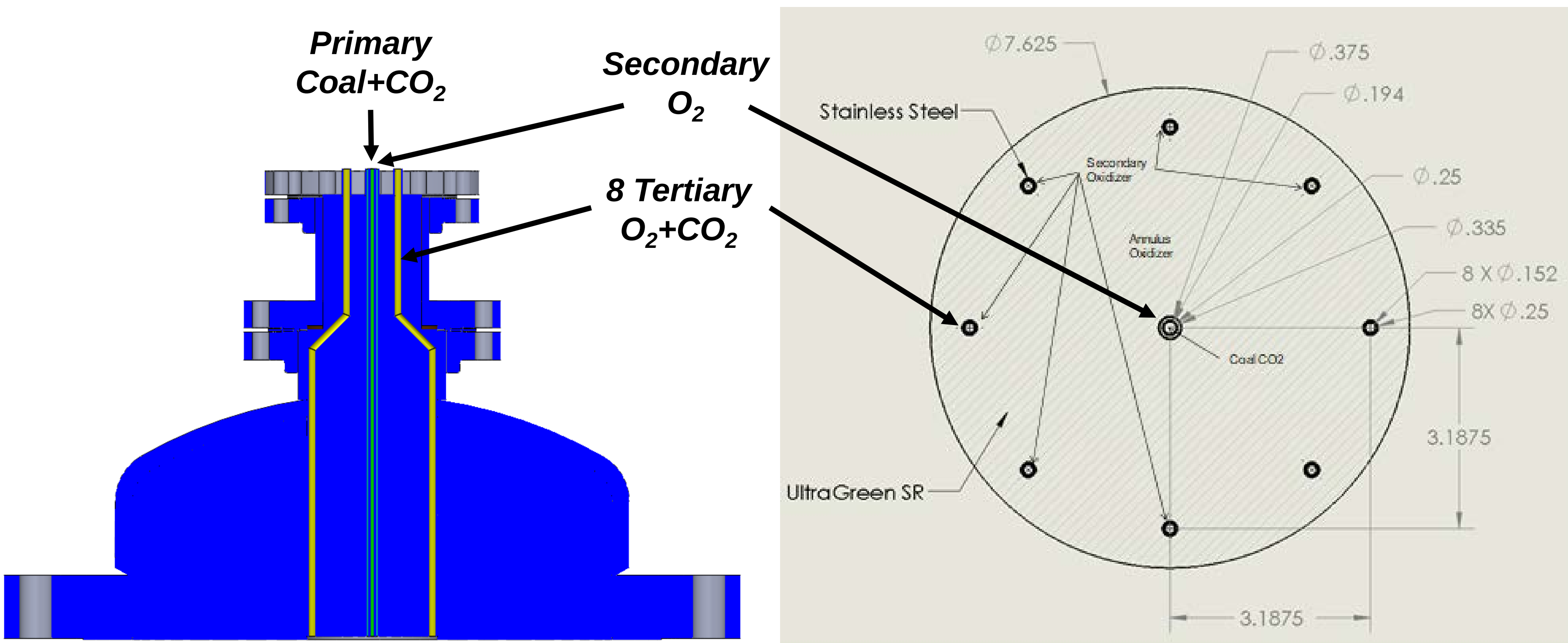




CFD Images from Reaction Engineering International

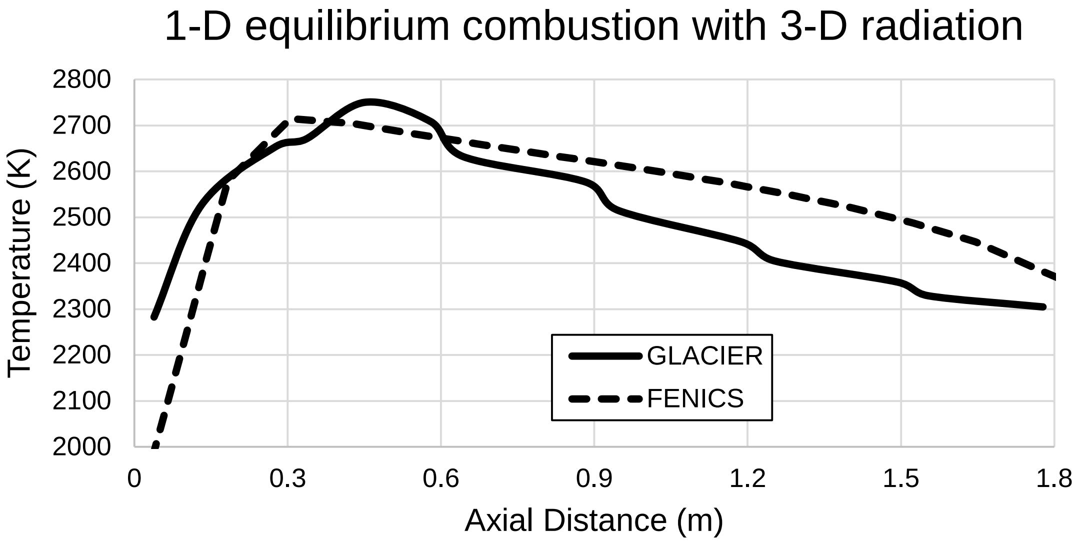
Burner Design

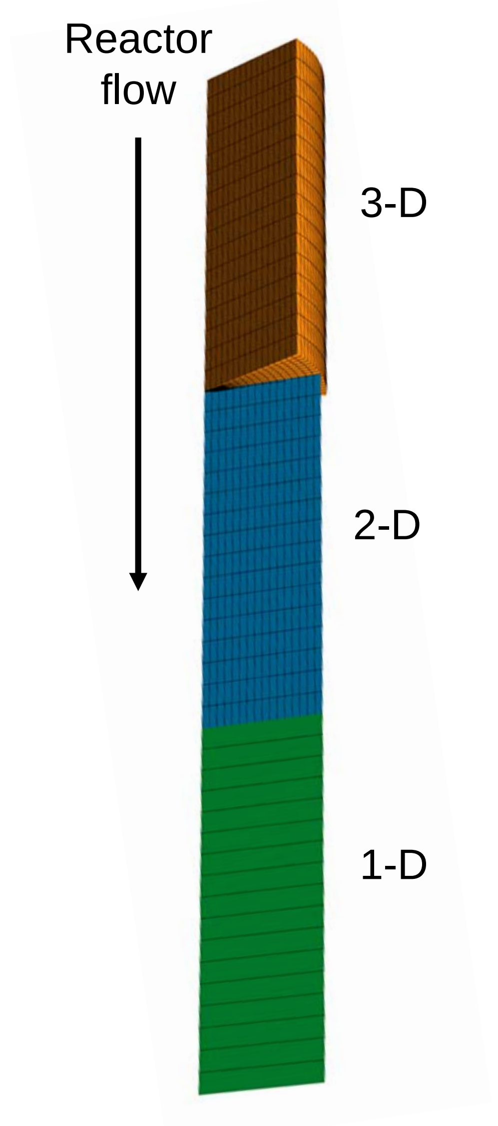
- Diffusion flame burner
- Challenge with jet momentum (~4.9 m/s velocity at 20 atm)



PCHT Modeling Tool

- Fast-running hybrid process model
  - Flow, gas and particle reactions, radiation
  - Scale-up and integration to plant models
- Based on adaptive dimensionality
  - Progressive reduction in dimensionality based on gradients





Remaining Key Tasks

- System integration
- Hazard and operability study
- Reactor acceptance tests
- Diffusion flame burner measurements
  - Wall temperatures, heat fluxes (TC)
  - Radiation intensity (NA radiometer, FTIR)
  - Gas and particle temperature (FTIR)
  - Exit properties, slagging state
- Flameless burner design and measurements
- PCHT model development, comparisons, scaling

Status Summary

- Some building delays but no technology show stoppers
- Deliverables on track and in budget
  - 100 kW 20-atm pressurized oxy-coal reactor
  - Scalable pressurized dry coal feed system
  - O_2-CO_2-coal firing systems for traditional and flameless combustion
  - Measurement data
  - Mechanistic-based process model for scale-up and integration

Potential Next Projects

- Scale-up and commercialization of high pressure dry feed system
- Detailed design of heat transfer surfaces in full-scale reactor
- Further development of traditional and flameless firing systems
- Gas chemistry kinetics for sulfur and nitrogen species at pressure (with Chalmers University)
- CO_2 clean up and compression system (with KITECH and Chalmers)
- Ash management in high temperature pressurized system
- POC integration and cycle efficiency optimization at full-scale

Acknowledgment/Disclaimer

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