Atmospheric Iron-Based Coal Direct Chemical Looping Process for Power Production: Phase II

Pittsburgh, PA. August 12, 2016

Project Objectives

- **Phase I Project objectives: 2012 -2013**
  - Evaluate commercial viability of OSU's coal-direct chemical looping process for power production with CO_2 capture.
  - Perform a techno-economic evaluation of the commercial design.
- **Phase II Project Objectives: 2013-2017**
  - Conducting laboratory testing and small pilot-scale testing to reduce technology gaps identified in Phase I.
  - Update design and cost performance of the commercial 550 MWe CDCL power plant
  - Re-evaluate the CDCL technology and identify development pathway for commercialization in year 2025.

Project Participants

- **Federal Agencies:**
  - DOE/NETL

State Agency:

  - Ohio Development Service Agency

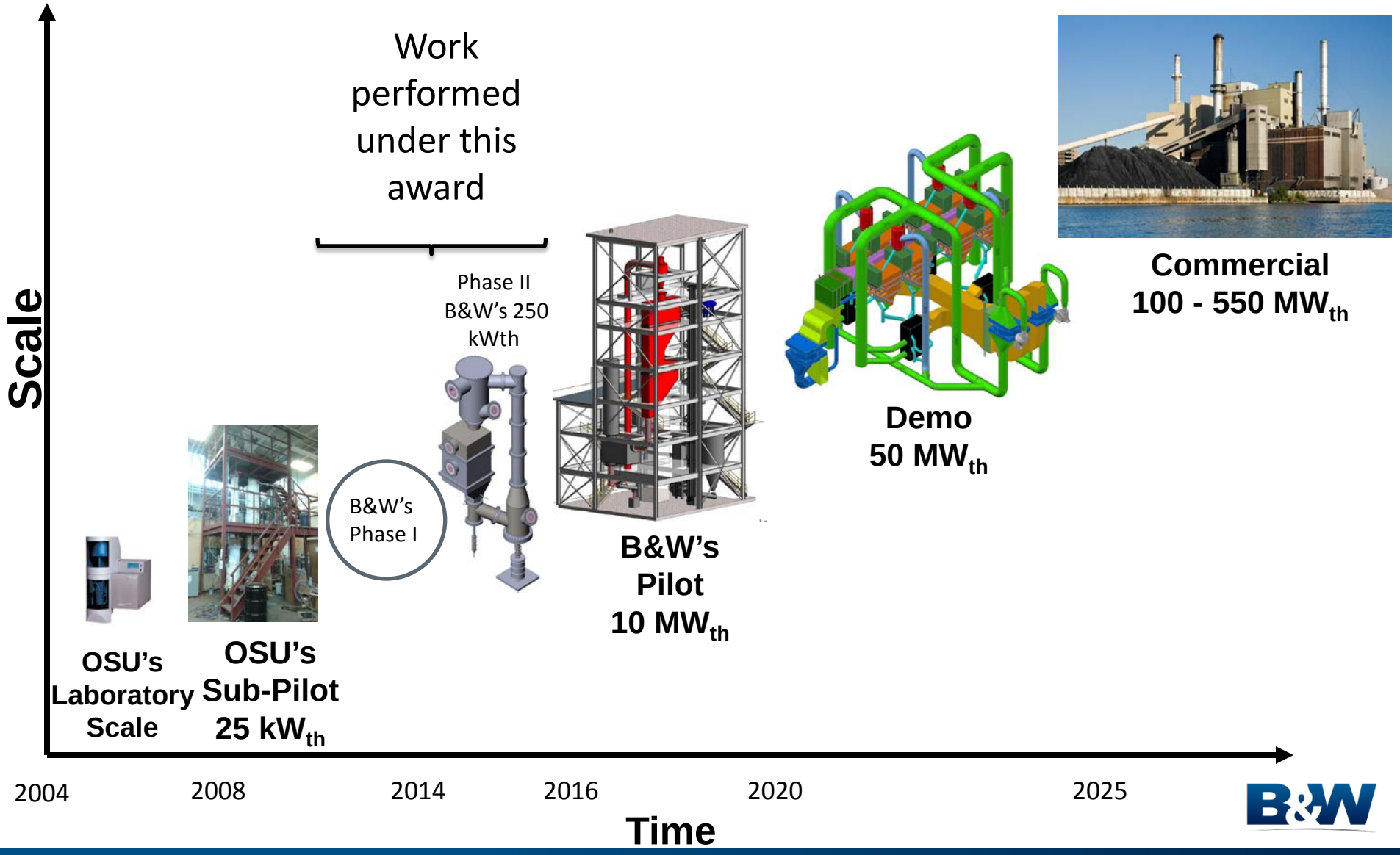
- **Project participants:**
  - The Babcock & Wilcox
  - The Ohio State University
  - Clear Skies Consulting

- **Industrial Review Committee:**
  - American Electric Power
  - Dayton Power & Light
  - Dover Light & Power
  - Duke Energy
  - First Energy
  - Consol Energy

Outline

- Commercialization Path
- Phase I: CDCL Concept and Techno-Economic Analysis
- Phase I: Technology Gaps
- Phase II-A: Laboratory Testing and Studies
- Phase II-B: 250 kWth Pilot Design and Construction
- Project Schedule
- Conclusions and Acknowledgments

Commercialization Path



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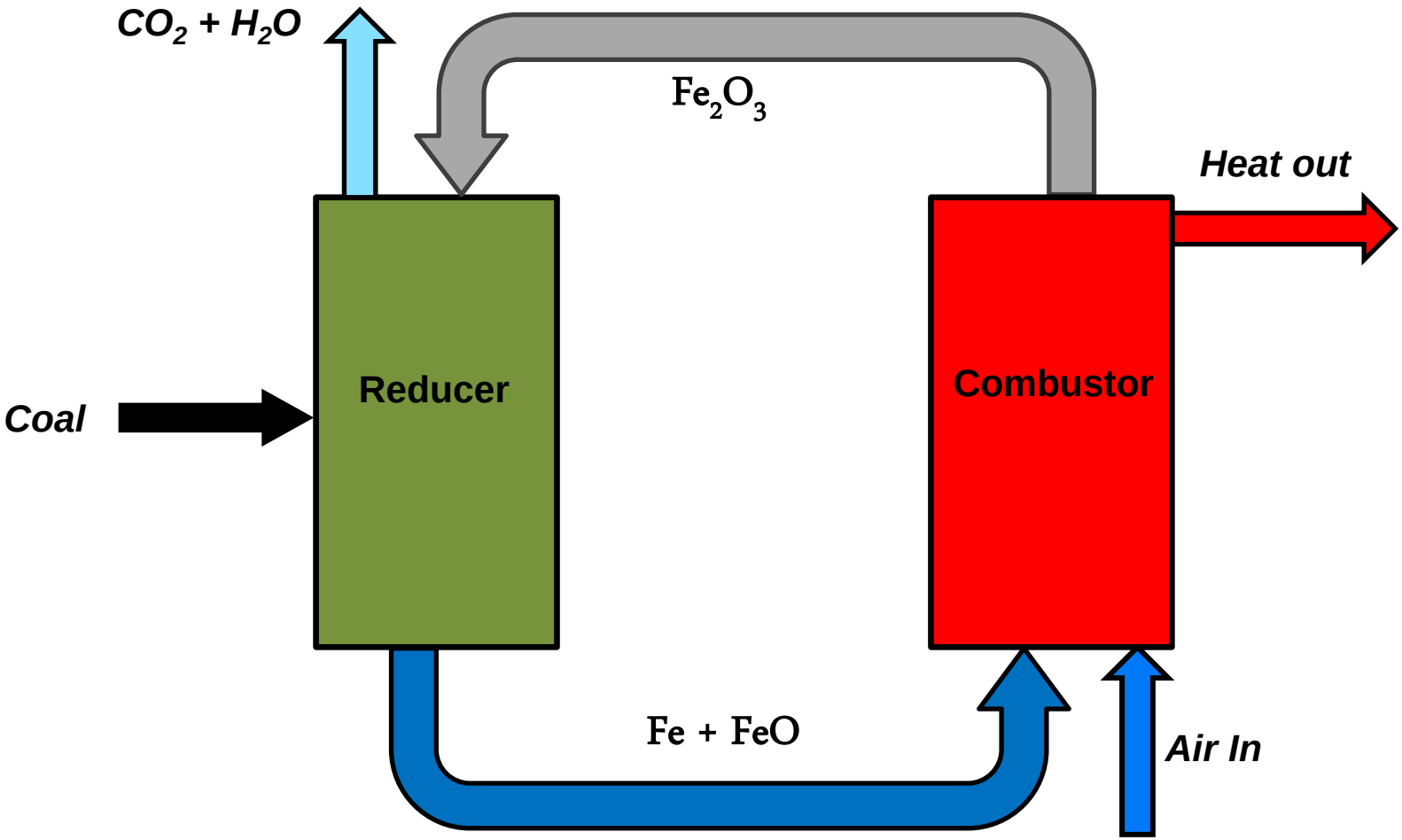
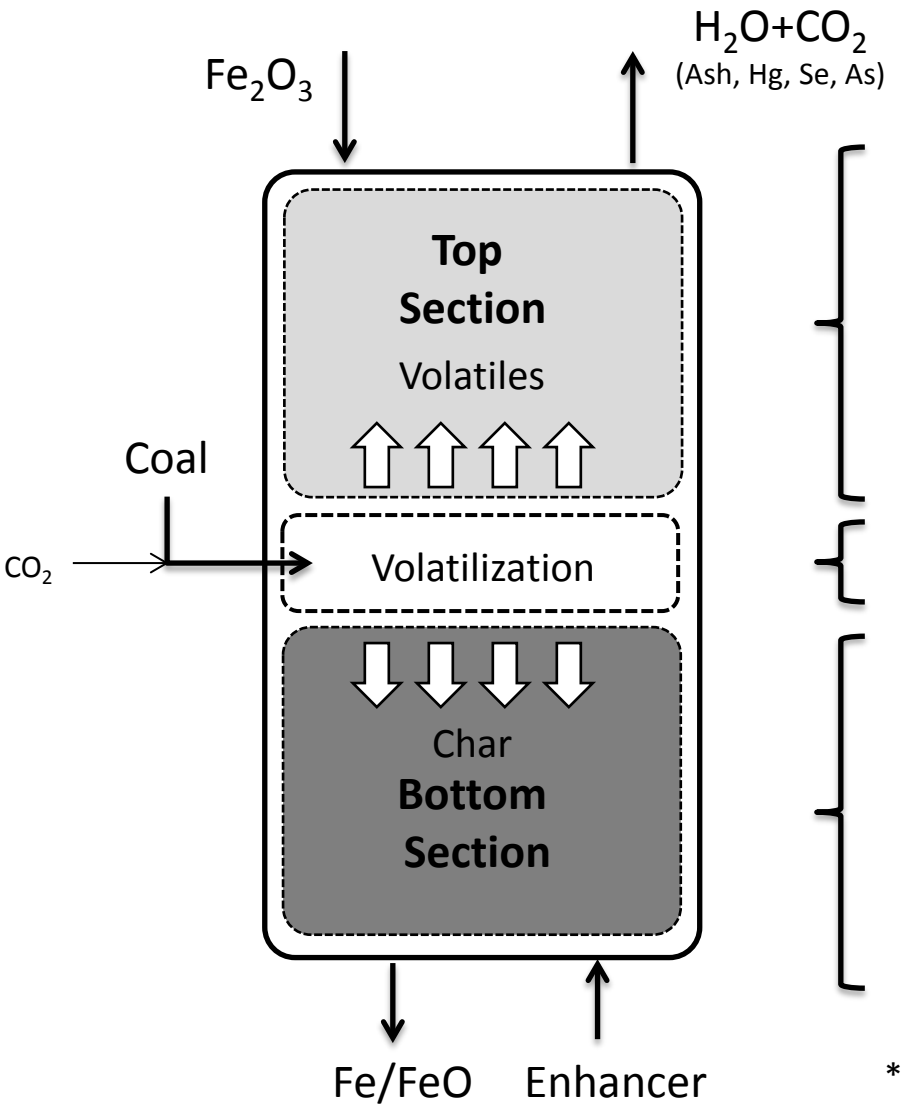
Chemical Looping Concept



CDCL Moving Bed Reactor Concept



Top Section*

$C_xH_y + Fe_2O_3 \rightarrow Fe + FeO + CO_2 + H_2O$

$CO + Fe_2O_3 \rightarrow Fe + FeO + CO_2$

$H_2 + Fe_2O_3 \rightarrow Fe + FeO + H_2O$

Coal Volatilization*

Coal $\rightarrow$ C + C_xH_y (Volatiles)

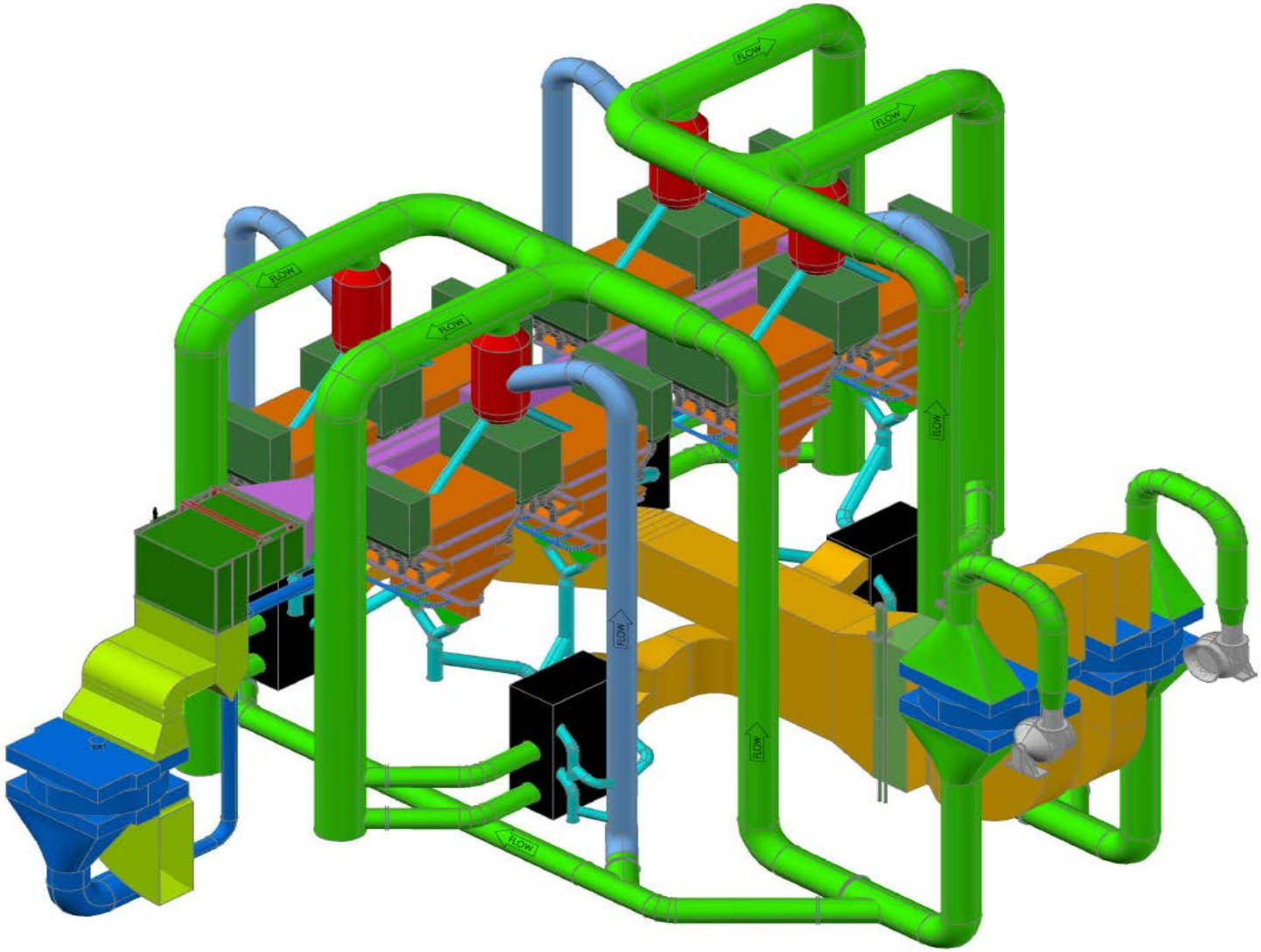
Bottom Section*

$C + CO_2 \rightarrow 2\ CO$

$2\ CO + Fe_2O_3 \rightarrow Fe + FeO + 2\ CO_2$

* Reactions not balanced

CDCL Commercial Plant Design and Engineering



CDCL Technology Comparison

	Base Plant	MEA Plant	CDCL Plant
Coal Feed, kg/h	185,759	256,652	205,358
CO_2 Emissions, kg/MWh_{net}	801	111	31
CO_2 Capture Efficiency, %	0	90	96.5
Net Power Output, MW_e	550	550	550
Net Plant HHV Heat Rate, kJ/kWh (Btu/kWh)	9,165 (8,687)	12,663 (12,002)	10,084 (9,558)
Net Plant HHV Efficiency, %	39.3	28.5	35.6
Cost of Electricity, $/MWh	80.96	132.56	102.67
Increase in Cost of Electricity, %	-	63.7	26.8

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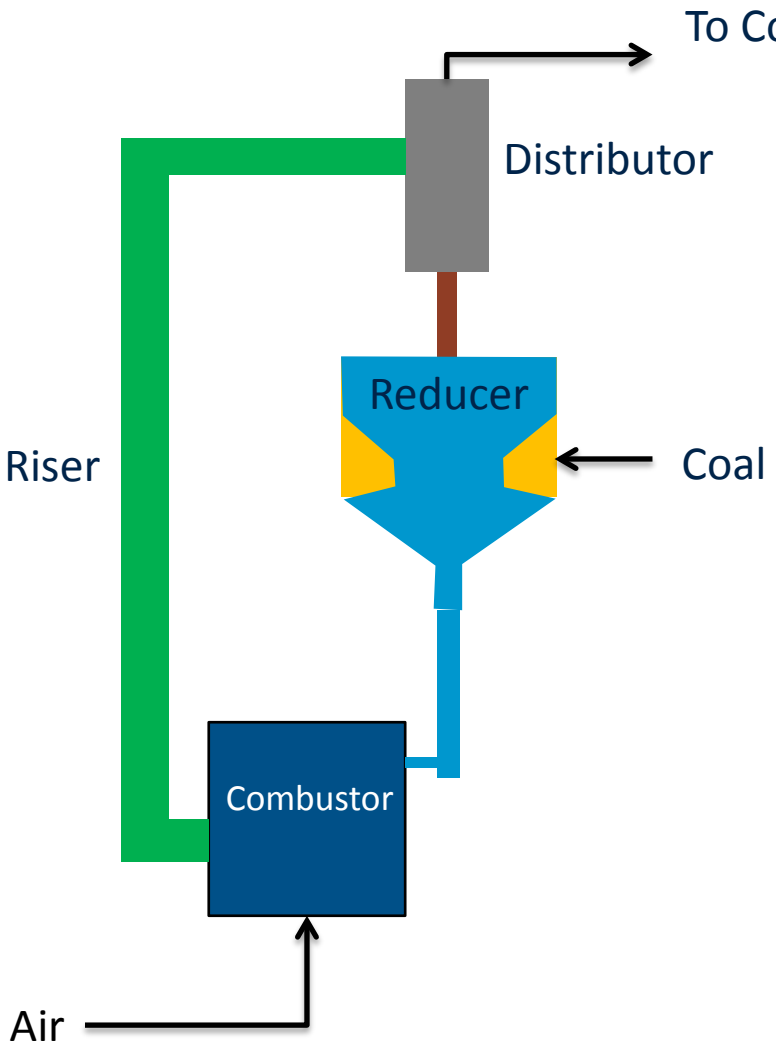
Technology Gap Analysis



Reducer

- Coal Injection and distribution
- Char residence time
- Ash Separation
- Enhancer Gas
- Fate of alkali & Agglomeration
- Fate of S, Hg, and N

Combustor

- In-bed Heat exchanger

Operation

- Start up, shut down, turn down

Particles

- Attrition
- Reactivity
- Deactivation

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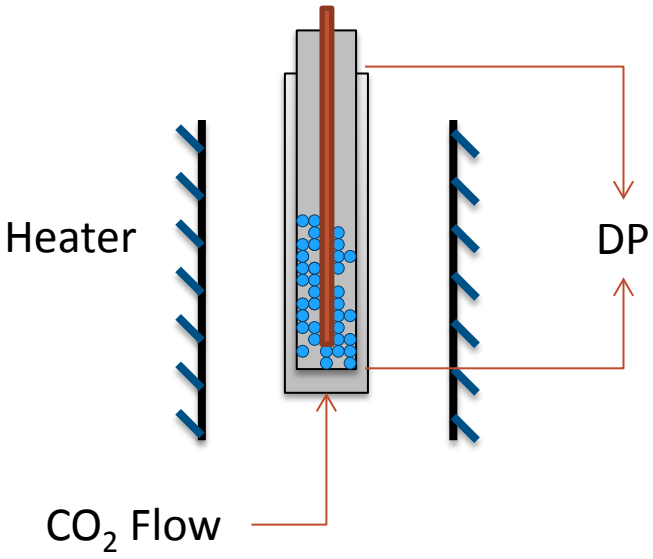
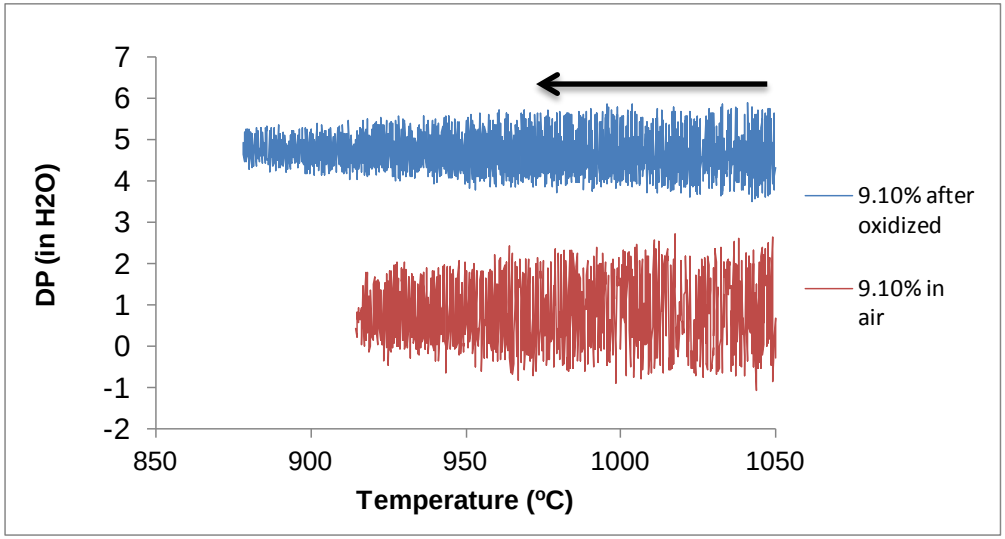
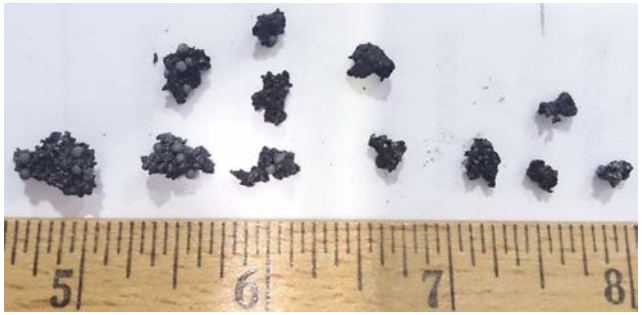
Alkaline Agglomeration Test

Alkaline injection test inn BFB



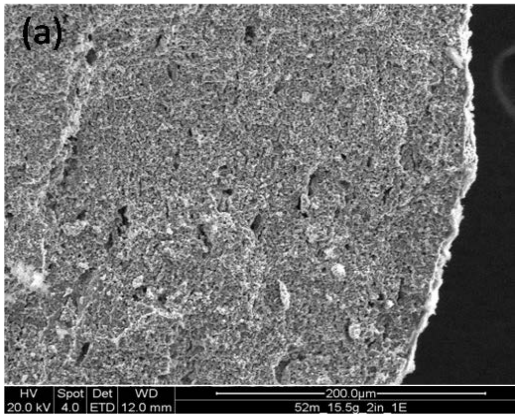




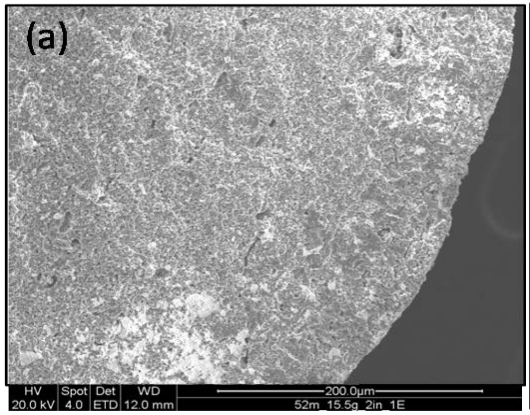
Particles aglomerate at very high alkaline content :

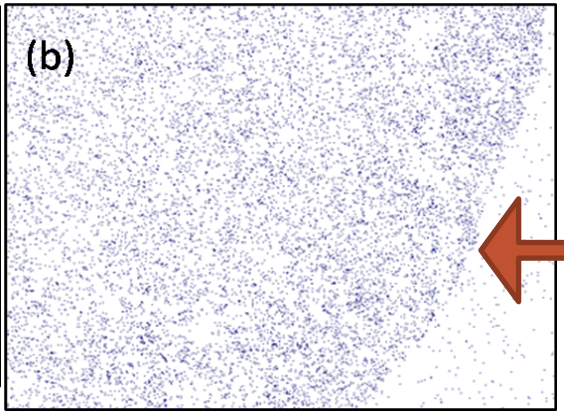
~9.1wt.%

Paraticle Regeneration



Agglomerated particles





Regenerated particles

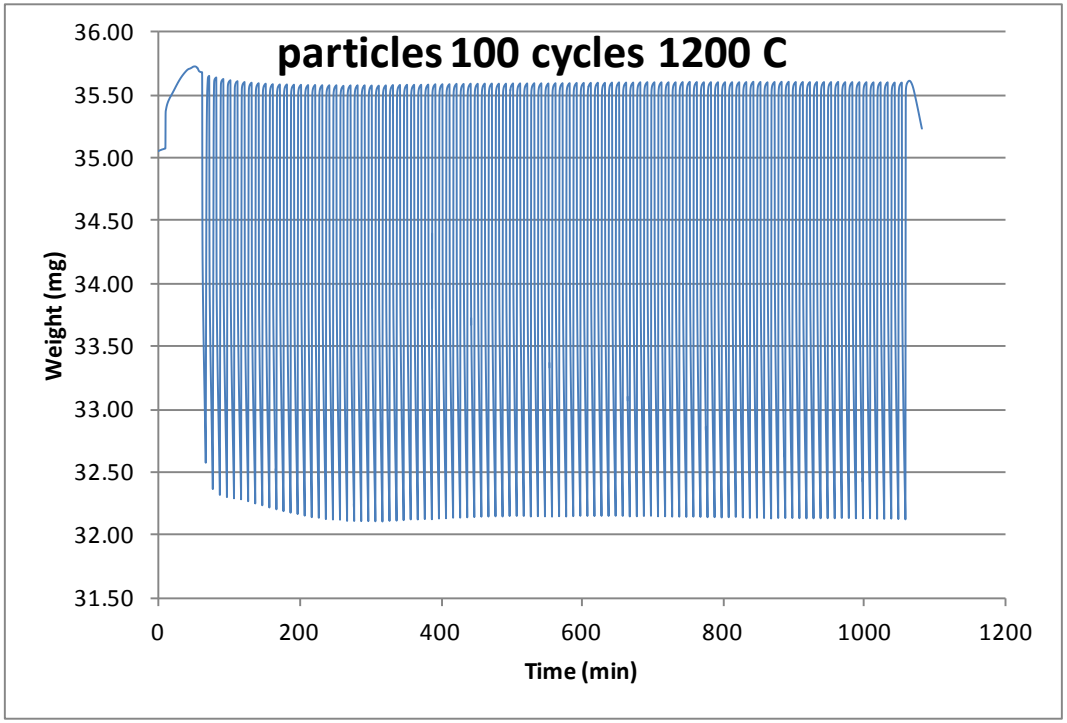
Agglomerated particle caused by alkaline can be regenerated in the combustor.

Particle Characterization

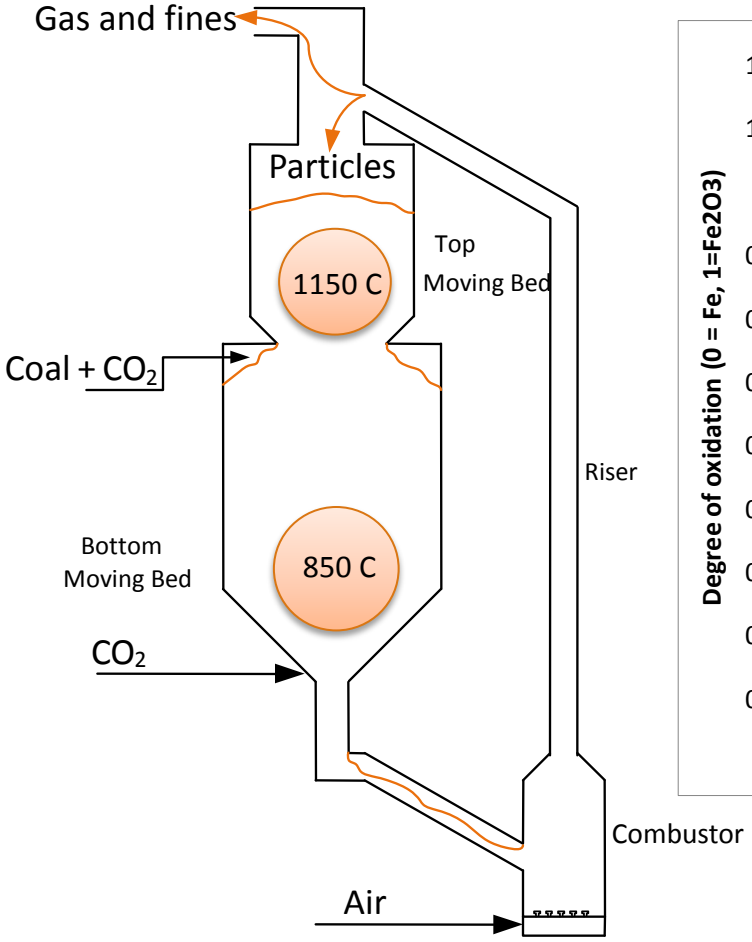
Photograph of TGA Analyzer

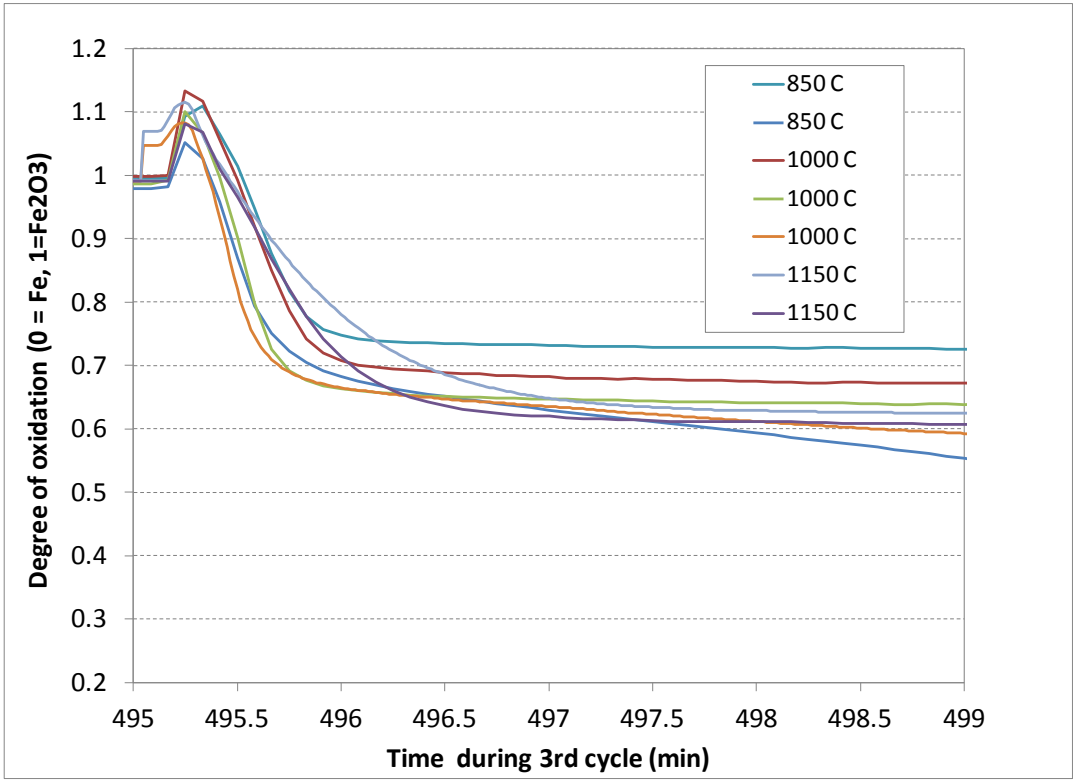
Gas Delivery System

Recyclability Test

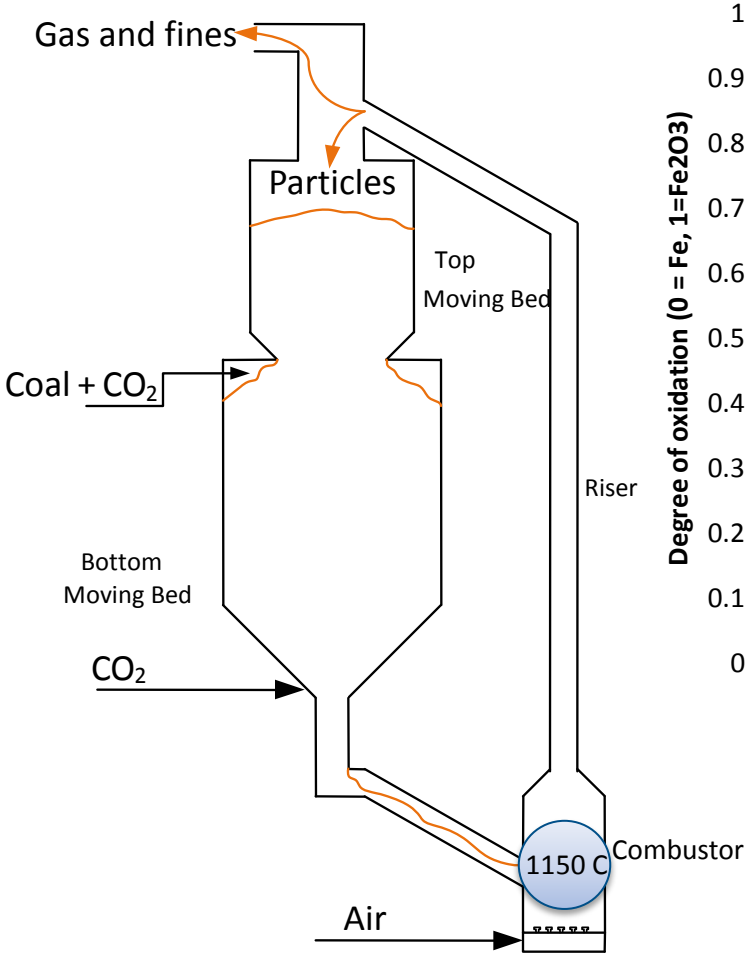


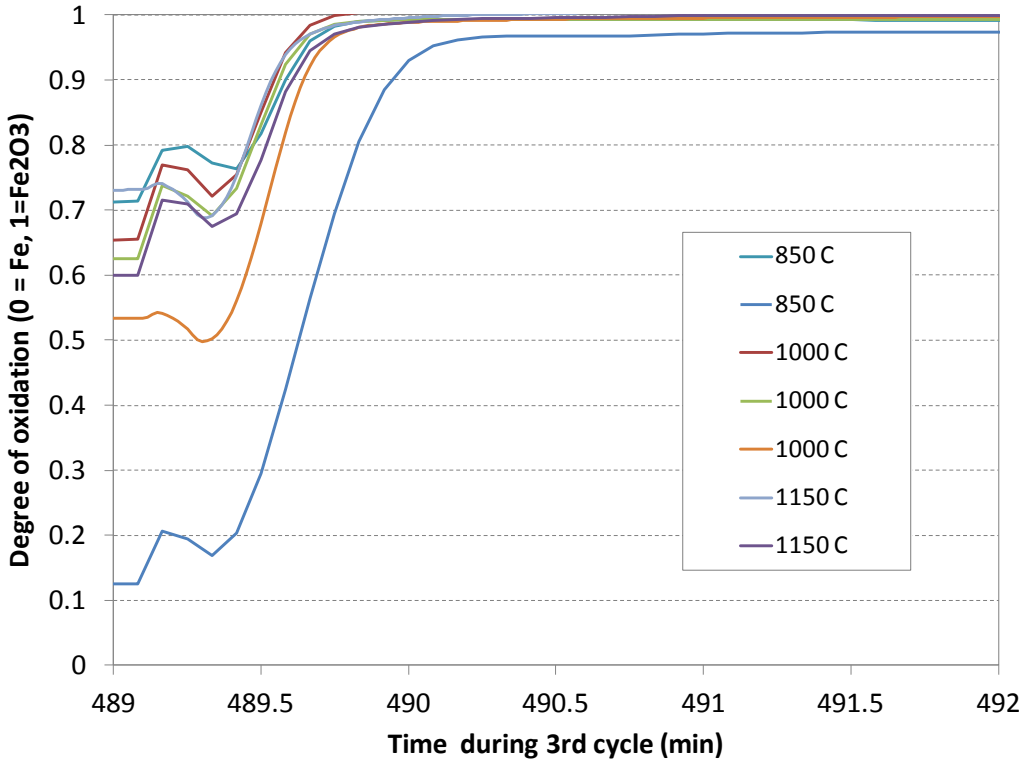
Particle Reduction Studies



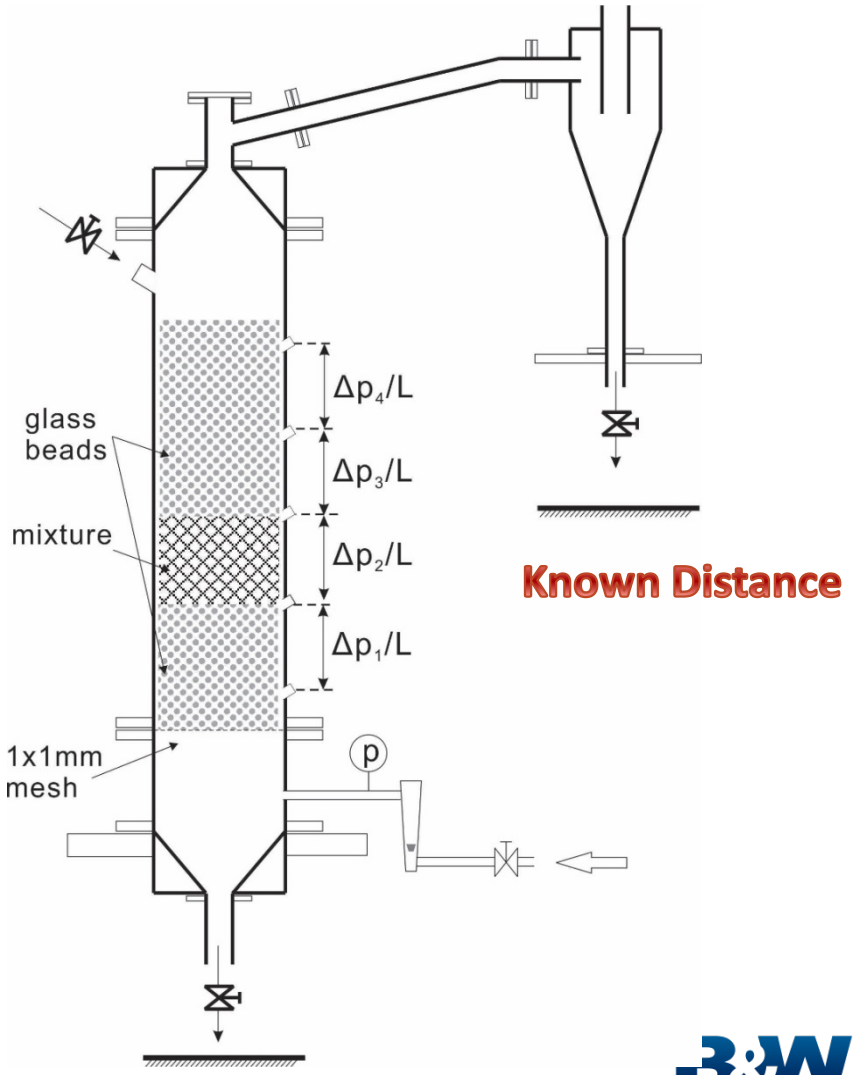


Particle Oxidation Studies

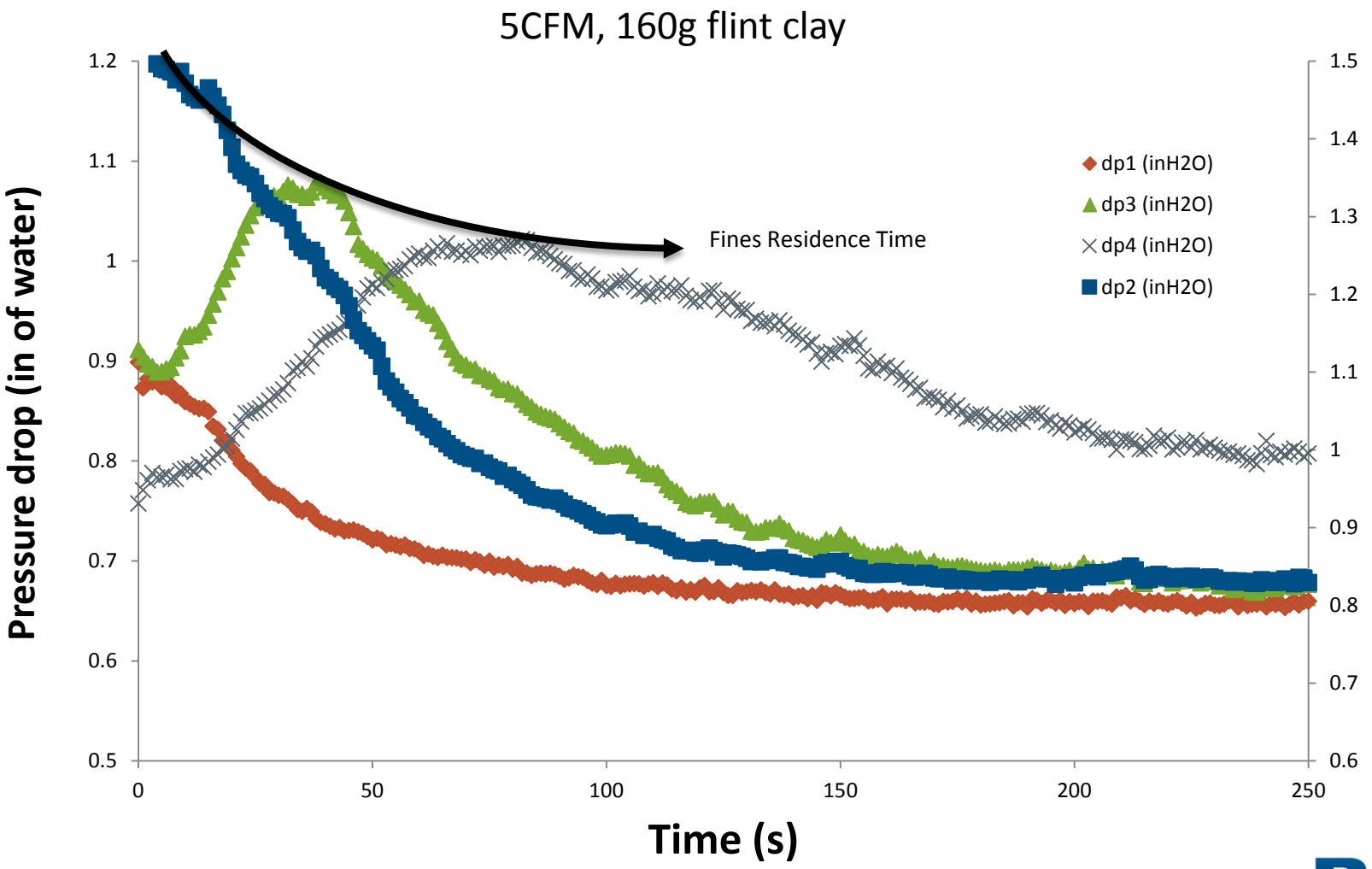




Coal Flow Model Tests: Fines entrainment



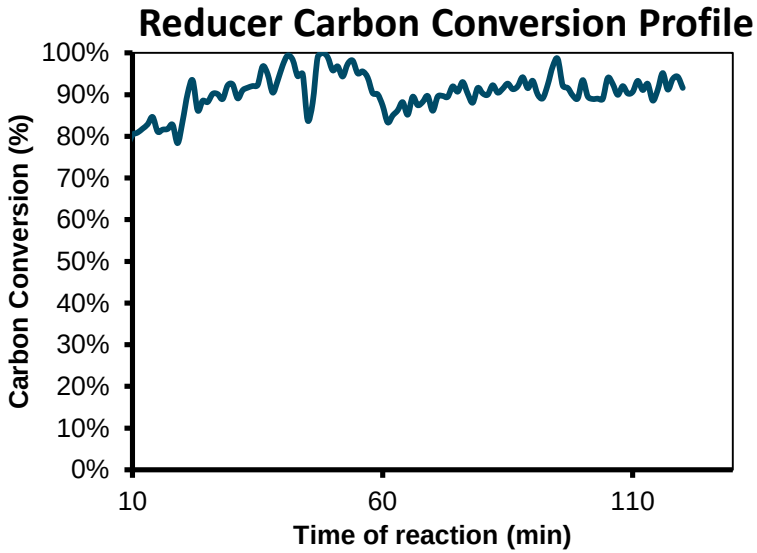
Char & Ash Residence Time in Moving Bed

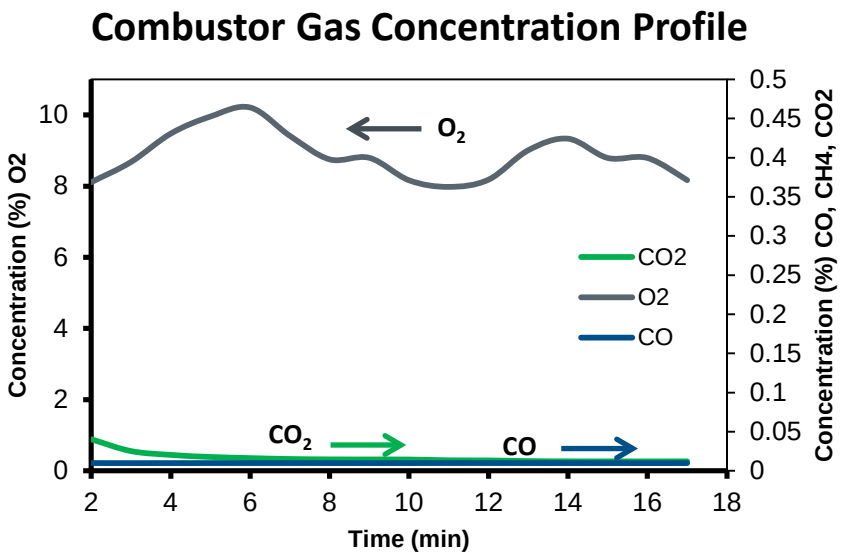


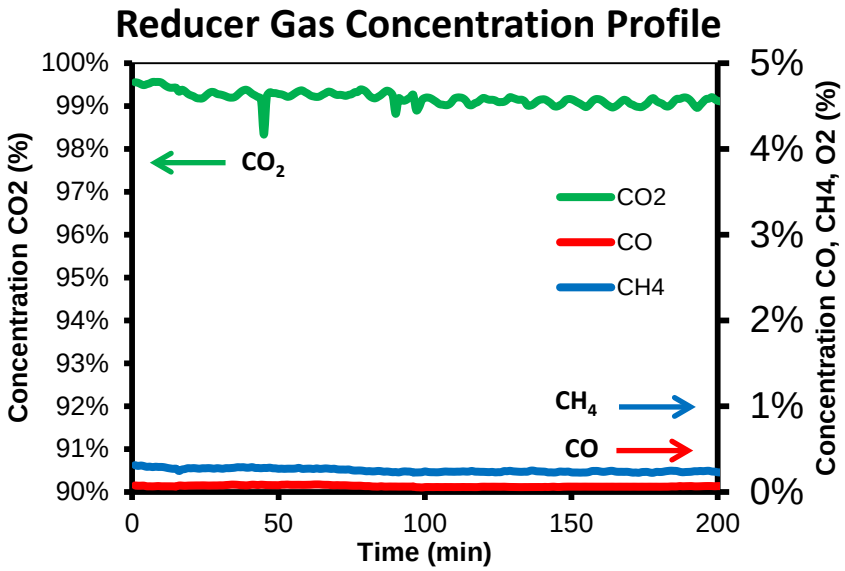
25 kW_{th} Sub-Pilot Demonstration

- > 800 hours of operational experience
- > 200 hours continuous successful operation
- Smooth solids circulation
- Complete ash separation in reducer.
- Achieve nearly pure CO_2 from reducer outlet
- 17 test campaigns completed

200-hour Sub-Pilot Continuous CDCL Demonstration







- **Sample Data: PRB Process Performance**
- Continuous steady carbon conversion from reducer throughout all solid fuel loading (5- 25kWth)
- <0.25% CO and CH_4 in reducer outlet = full fuel conversion to CO_2/H_2O
- <0.1% CO and CO_2 in combustor = negligible carbon carry over, nearly 100% carbon capture

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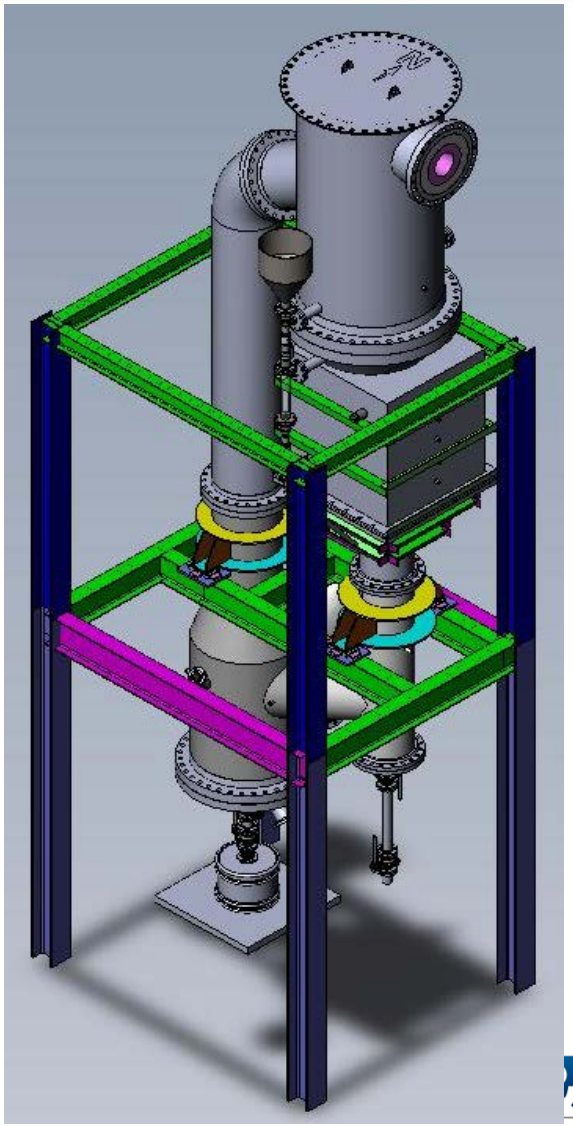
Pilot Unit Design

Physical Specifications
- Materials: Refractory lined Carbon Steel
- Overall Height: 32 ft
- Footprint = 20’ x 20’

Process Specifications
- Thermal rating: 250 kWth
- Coal Feed Rate: 70 lb/hr
- Coal size: Pulverized coal
- Max Operating Temperature: 2012 ^{o}F
- Oxygen Carrier: Iron based
- Reducer : Counter-current moving bed
- Combustor : Bubbling bed
- Particle tranport: Pneumatic

Oxygen Carrier Specifications
- Active metal: Iron based
- Size: 1.5 mm



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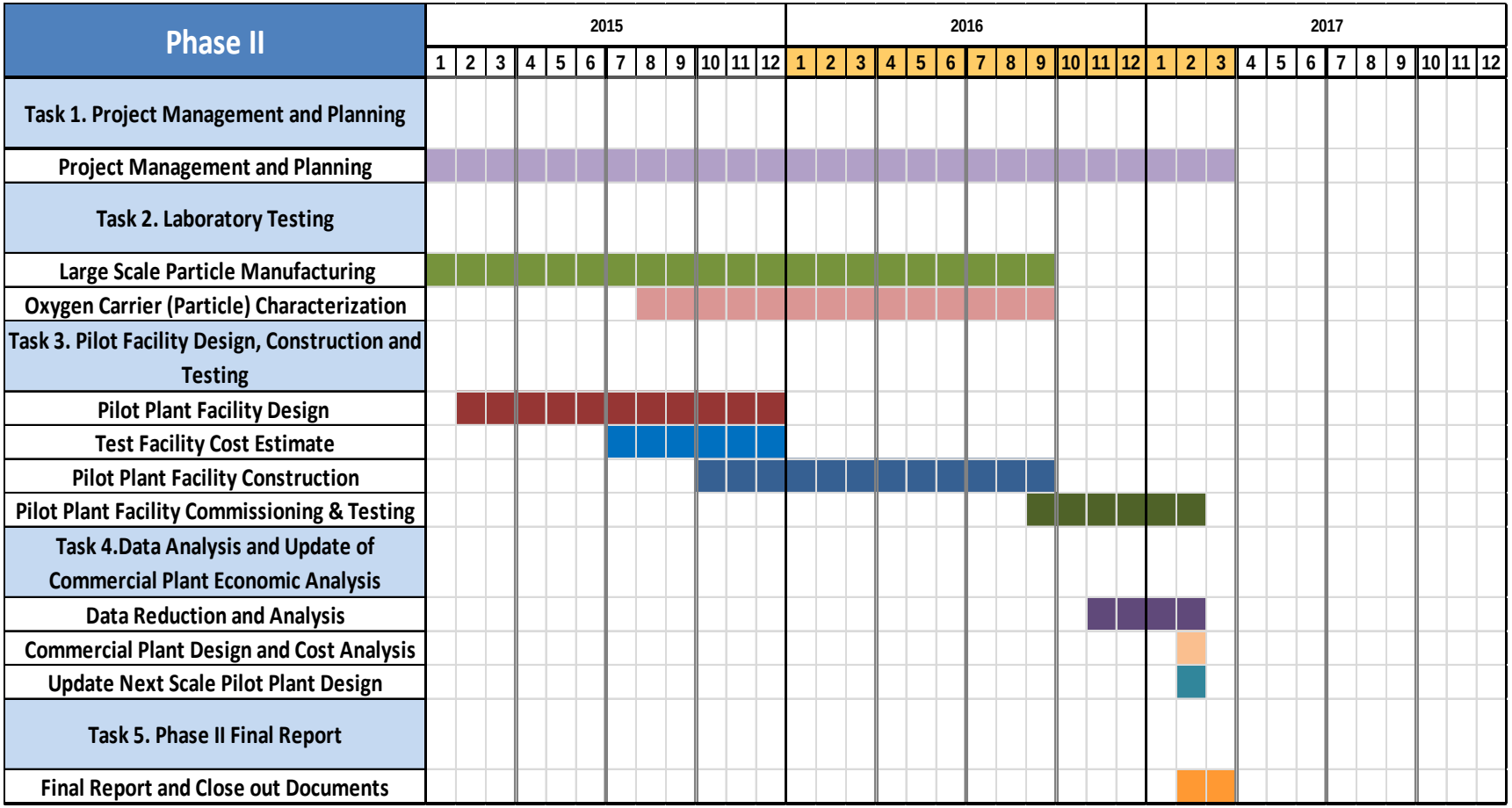

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Conclusions

- CDCL offers a cost-effective alternative for coal-based power generation with carbon capture
- The commercial CDCL modular design is ideal for commercial deployment of the technology
- Cold flow model and laboratory testing is confirming assumptions and design features of the 250 kWth pilot unit and the commercial design
- The design of 250 kWth pilot plant has been completed, the unit is under construction and we are moving soon towards the comissioning and testing phase

Acknowledgments

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