Commercialization of the Iron-Based Coal Direct Chemical Looping Process for Power Production with In Situ Carbon Dioxide Capture

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Project Participants

- Federal Agencies:
  - DOE/NETL
- State Agency
  - Ohio Development Services Agency
- Industry & University
  - The Babcock & Wilcox Company (B&W)
  - The Ohio State University (OSU)
  - Clear Skies Consulting
  - Johnson Matthey (JM)
  - EPRI
  - Dover Light & Power
  - Nexant
  - American Electric Power
  - Dayton Power & Light
  - Duke Energy
  - First Energy
  - CONSOL Energy

Project Overview

NETL Pilot PHASE I

Year: 2012-2013

- Design of 550 MWe commercial CDCL power plant
- Techno-economic analysis
- Technology gap analysis

NETL Pilot PHASE II -A

Year: 2013-2015

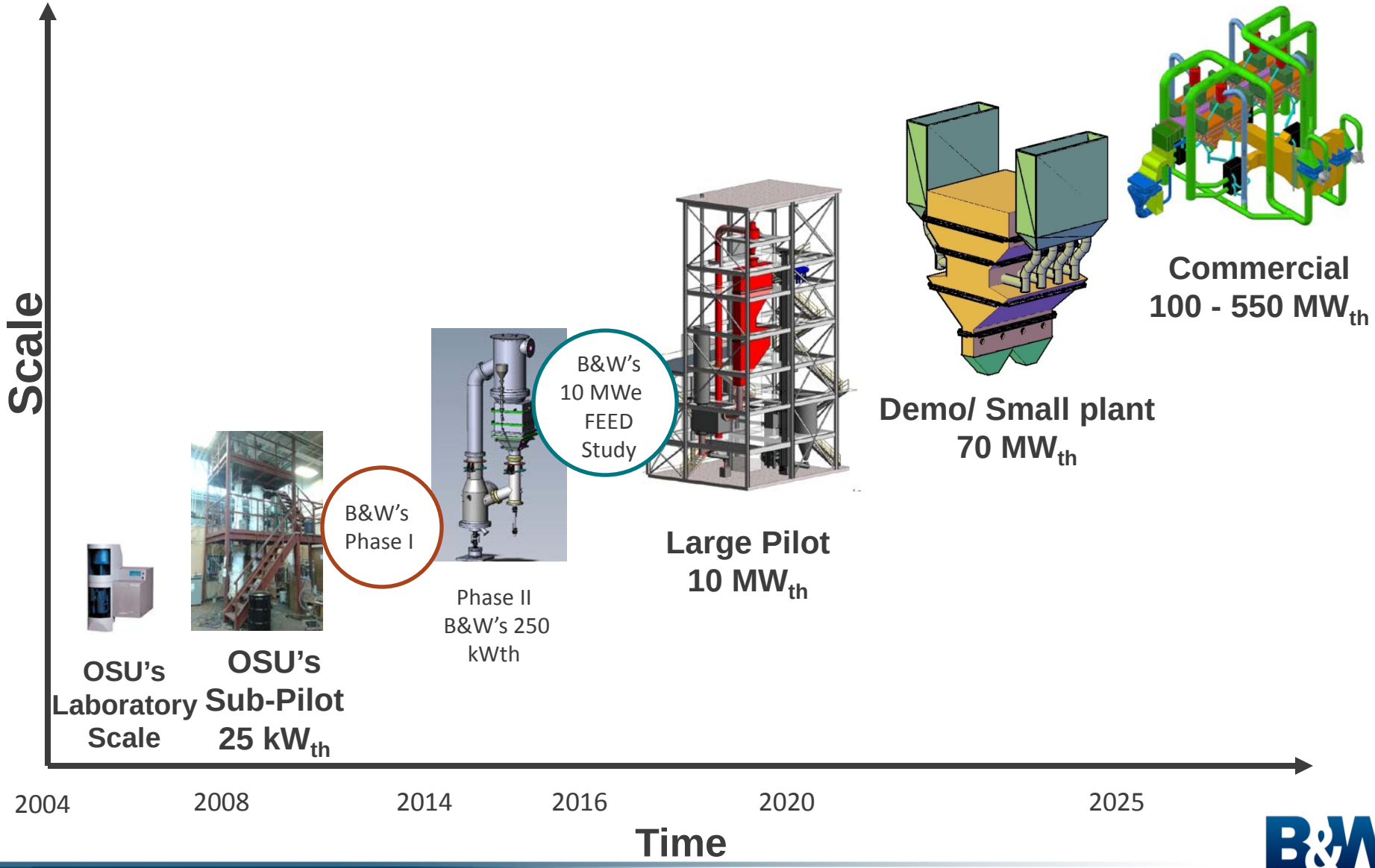
- Laboratory testing – cold flow model
- Design of pilot plant facility (250 kW_{th})
- Cost estimate and schedule for fabrication construction and testing of pilot facility

NETL–ODSA Pilot PHASE II-B

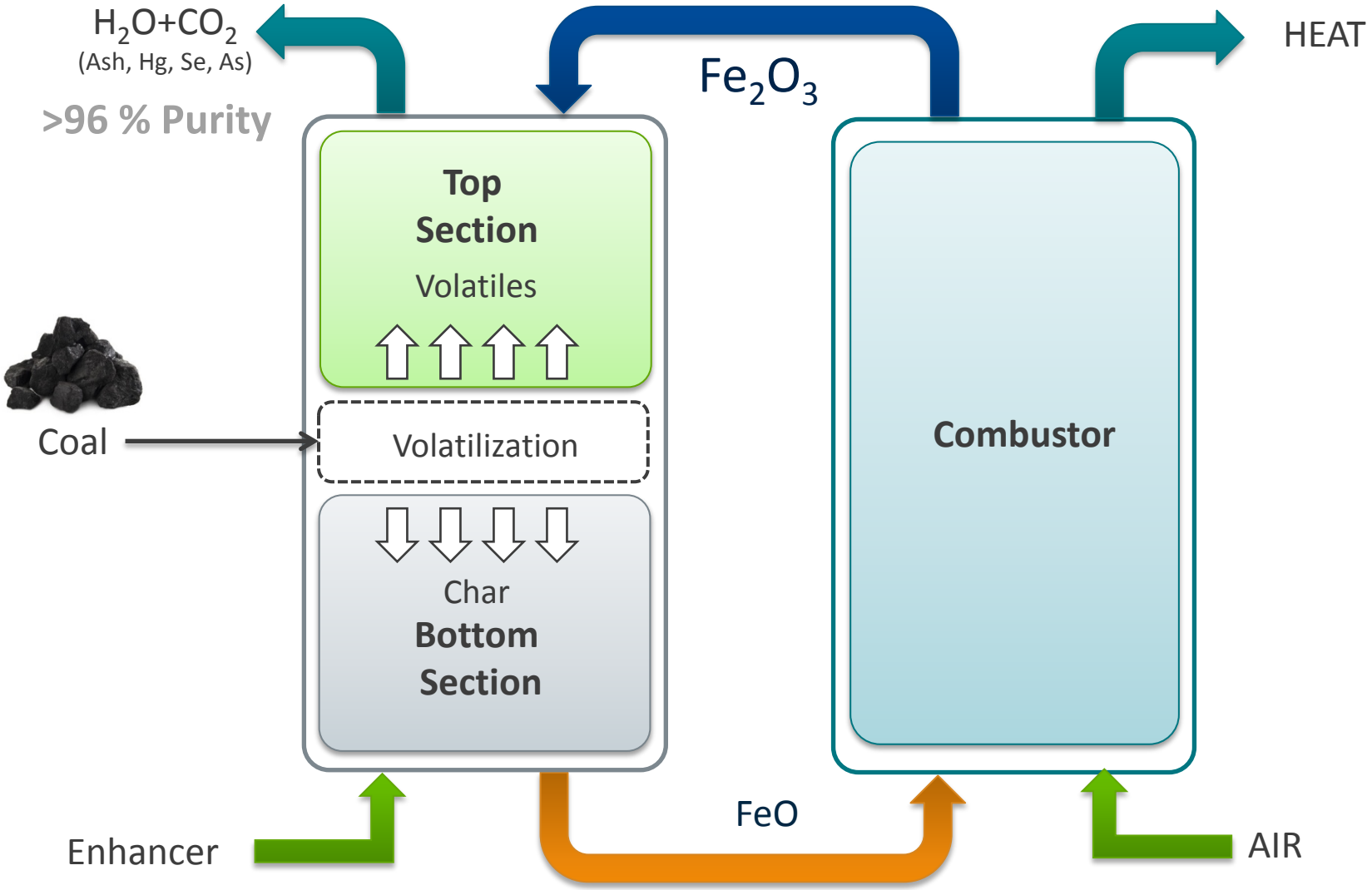
Year: 2015-2017

- Construction of CDCL pilot facility
- Testing of CDCL Pilot Unit
- Performance analysis and reporting
- Commercialization path – large-scale testing

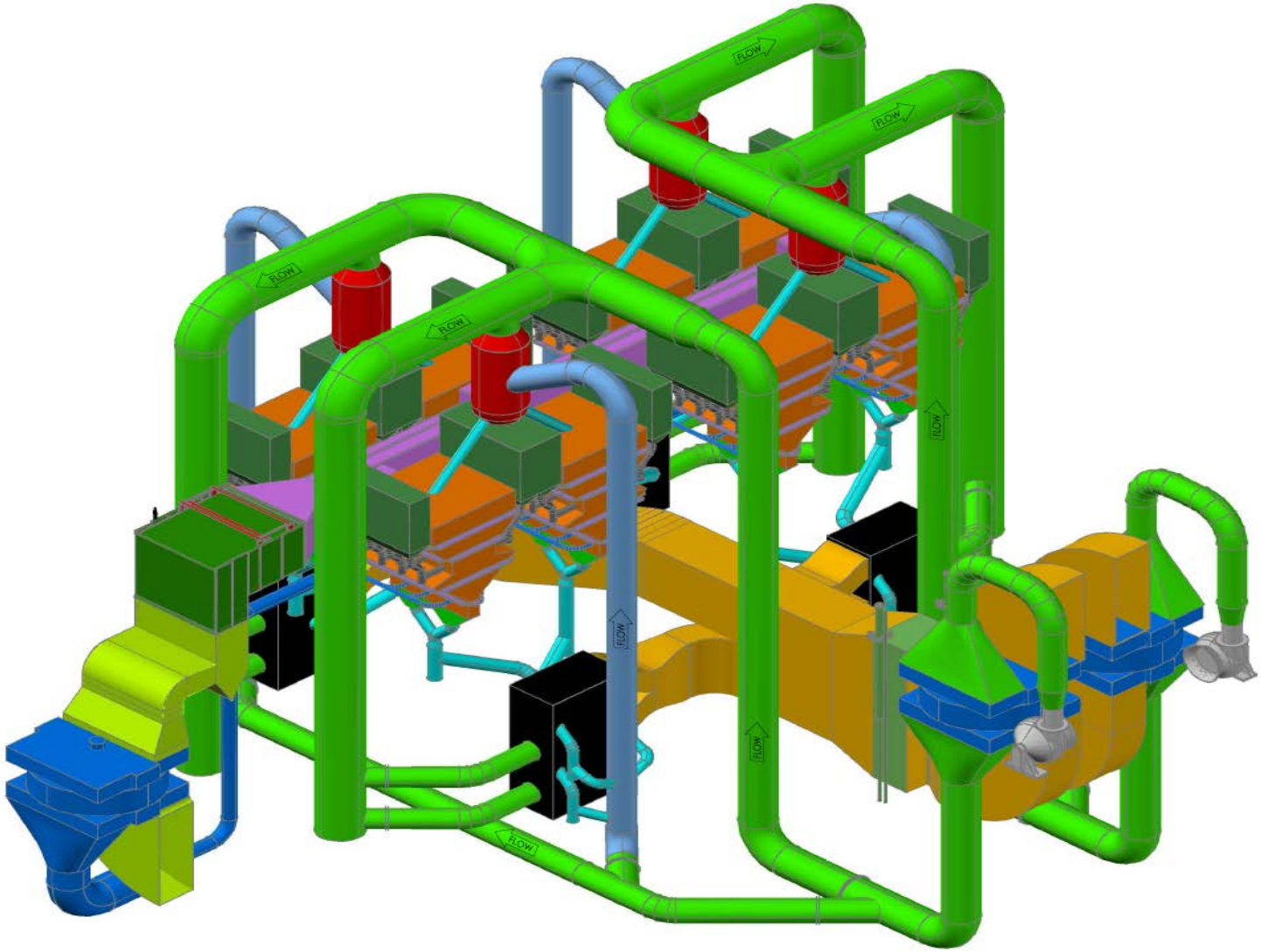
Coal Direct Commercialization Path



CDCL Process Overview



CDCL Commercial Plant Design and Engineering



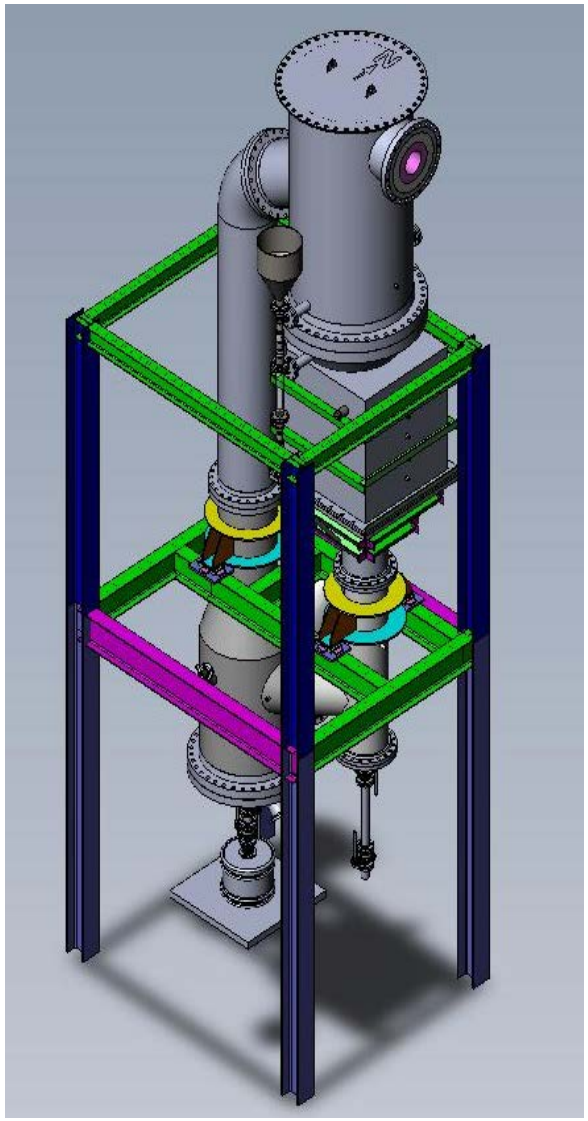
Phase I: Technology Gap Analysis

Design/Technology Issues	Ongoing/Past Mitigation	Planned Mitigation	Future Mitigation
Particles			
Manufacturing Cost	Under OSU's Scope	Particle Manufacturer (JM)	Multiple Manufacturers
Attrition	250 kWth / NCCC	Attrition Tests / 250 kWth	10 MWe Large Pilot
High Temperature Resistance	TGA	TGA / 250 kWth	10 MWe Large Pilot
Reducer			
Coal Injection & Distribution	25 kWth Sub-Pilot	Coal RXN Model / 250 kWth	10 MWe Large Pilot
Char Residence Time	25 kWth Sub-Pilot	Coal RXN Model / 250 kWth	10 MWe Large Pilot
Ash Separation / Enhancer Gas	CFM / 25 kWth Sub-Pilot	CFM / 250 kWth	10 MWe Large Pilot
Char Carryover	CFM / 25 kWth Sub-Pilot	CFM / 250 kWth	10 MWe Large Pilot
Pressure Drop	Phase I /25 kWth Sub-Pilot	250 kWth	10 MWe Large Pilot
CO_2 Purity	25 kWth Sub-Pilot	250 kWth	10 MWe Large Pilot
Sulfur, NOx, Hg Emissions	25 kWth Sub-Pilot	Small-pilot Unit	10 MWe Large Pilot
Alkaline Management	2" BFB Studies	2" BFB Studies	10 MWe Large Pilot
Combustor			
Heat Exchanger surface	B&W's CFB Technology	B&W's CFB Technology	10 MWe Large Pilot
Auto-thermal Operation	Phase I (Calculation)	250 kWth	10 MWe Large Pilot
Process			
Operation	25 kWth Sub-Pilot / NCCC	250 kWth	10 MWe (modular)
Start up/Shut down	25 kWth Sub-Pilot / NCCC	250 kWth	10 MWe (modular)
Safety	25 kWth Sub-Pilot / NCCC	250 kWth	10 MWe (modular)

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

Phase II: 250 KW_{th} Pilot Unit Design



Pilot Design:

- Reducer Design
- Material and Energy Balances
- Support Structure Design
- Detail Construction Drawings

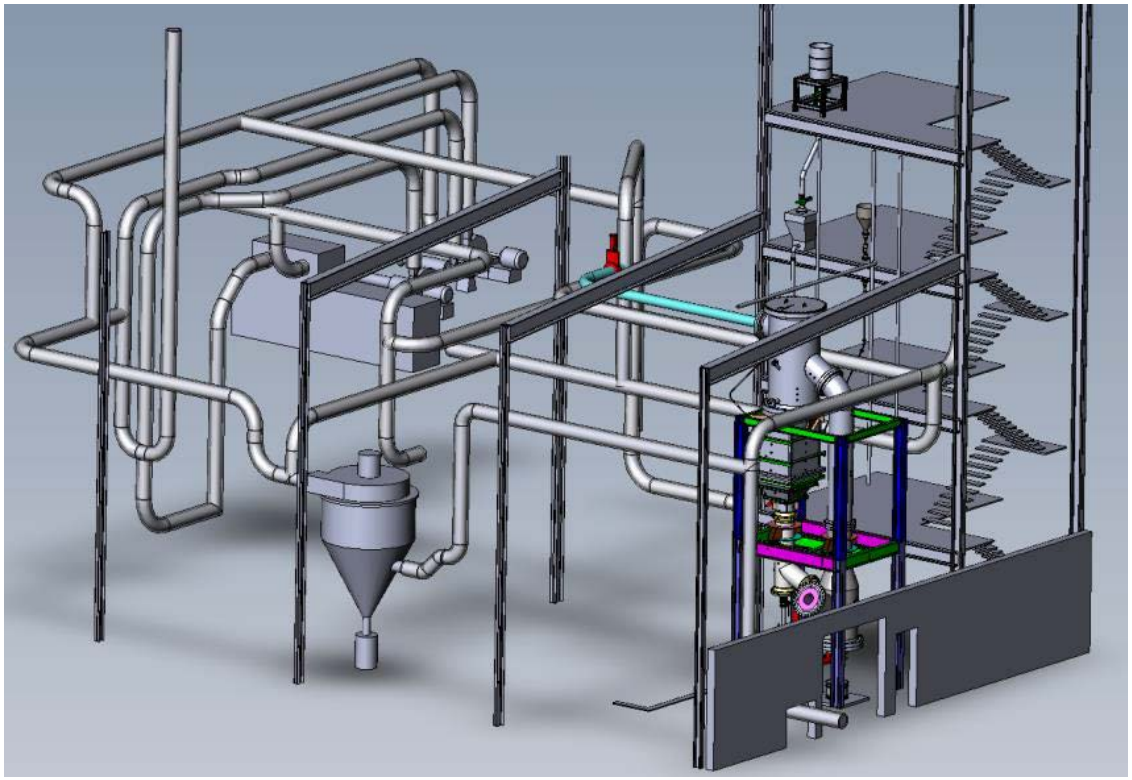
Specifications

- Materials: Refractory lined Carbon Steel
- Overall Height: 32 ft
- Footprint = 10’ x 10’
- 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 transport: Pneumatic
- Active metal: Iron based
- Size: 1.5 mm

Phase II: 250 KW_{th} Pilot Plant Facility Design

Pilot Plant Facility Design

- Auxiliary Equipment Specifications
  - Coal Handling
  - Gas Heating, Cooling & Cleanup
  - Ash and Oxygen Carrier Handling Equipement
- P&ID Diagrams
- HazOp Analysis
- Equipment Specifications
- Control Specifications
- Cost Estimate
- Fabrication, Construction and Installation Schedules



Phase II: 250 KW_{th} Pilot Fabrication

Phase II: 250 kW_{th} Pilot Construction & Installation

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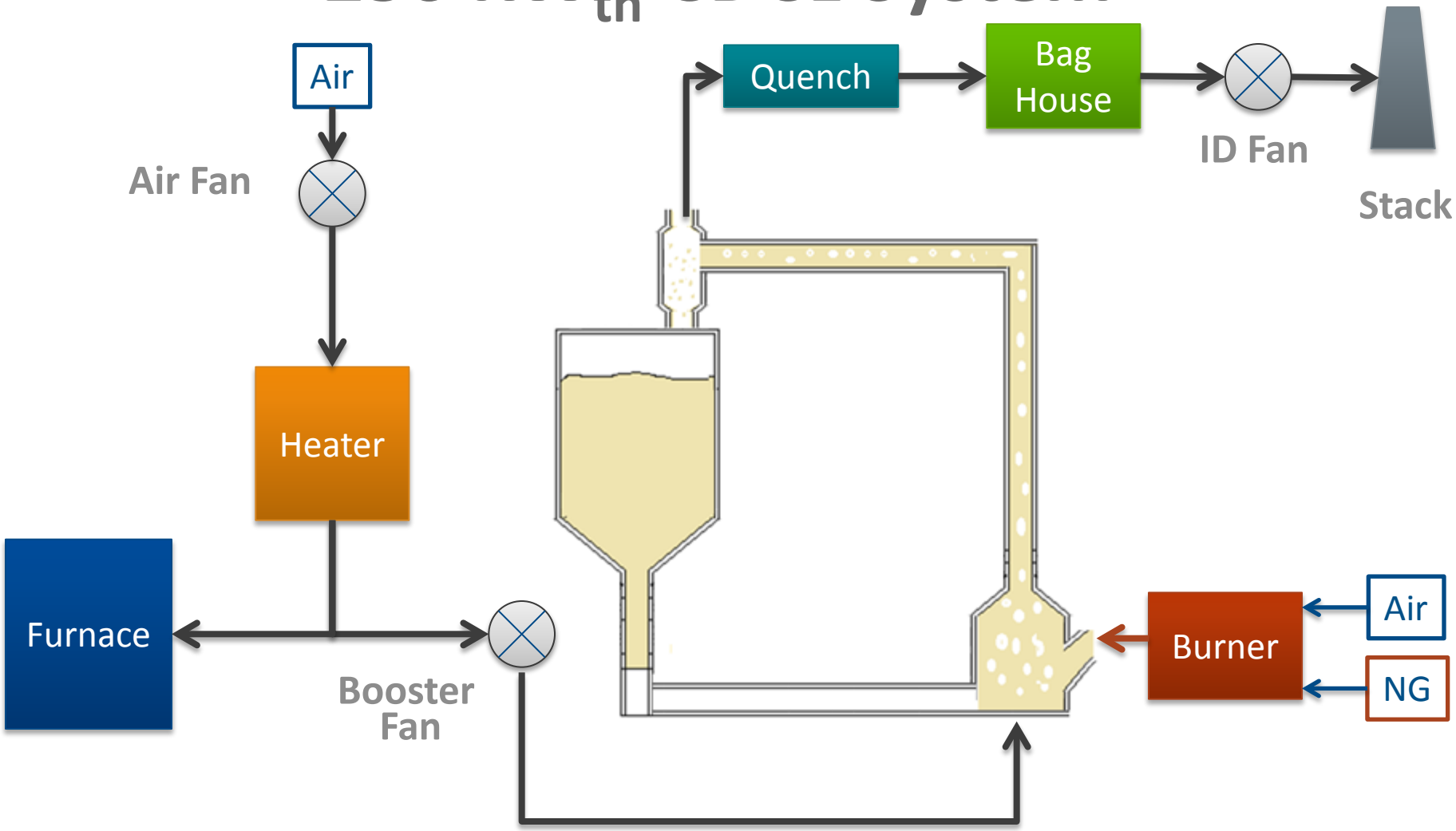
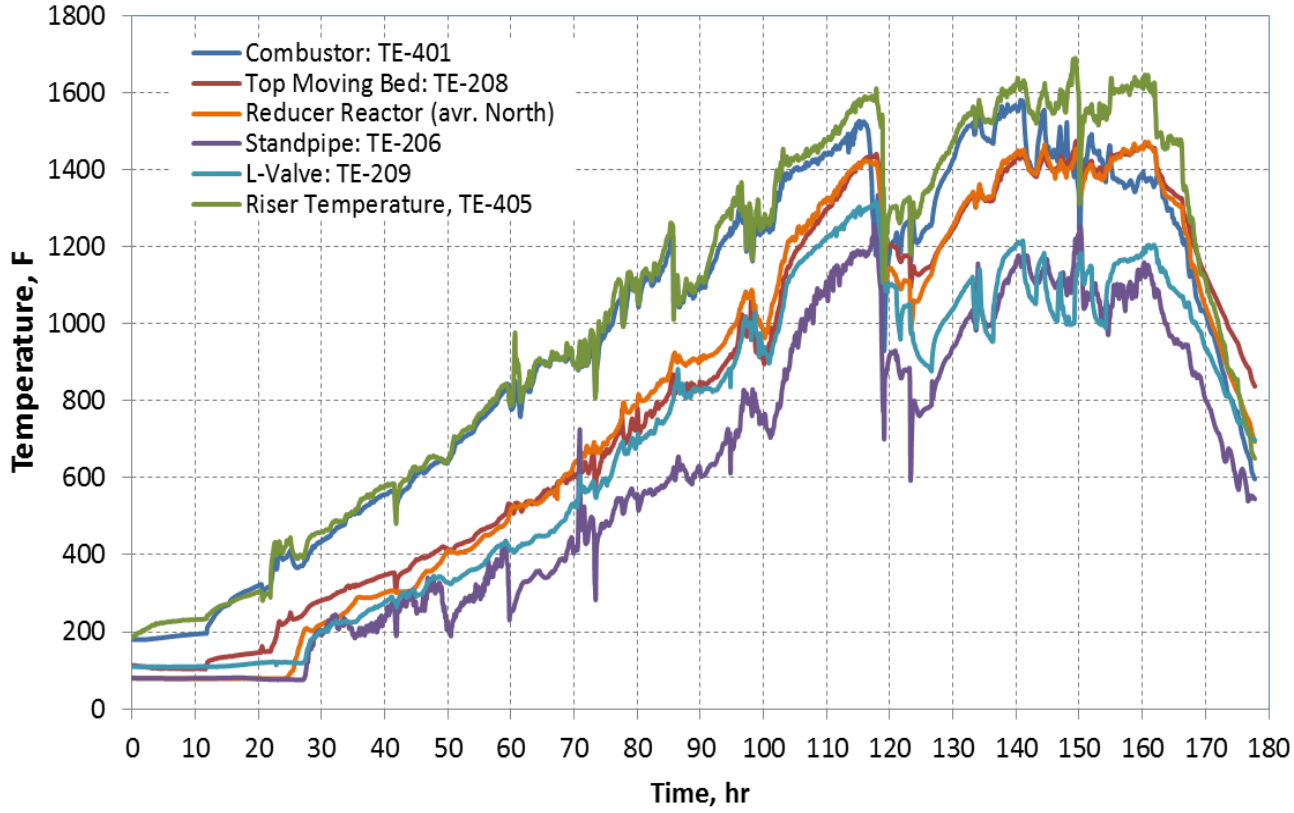
250 KW_{th} CDCL System

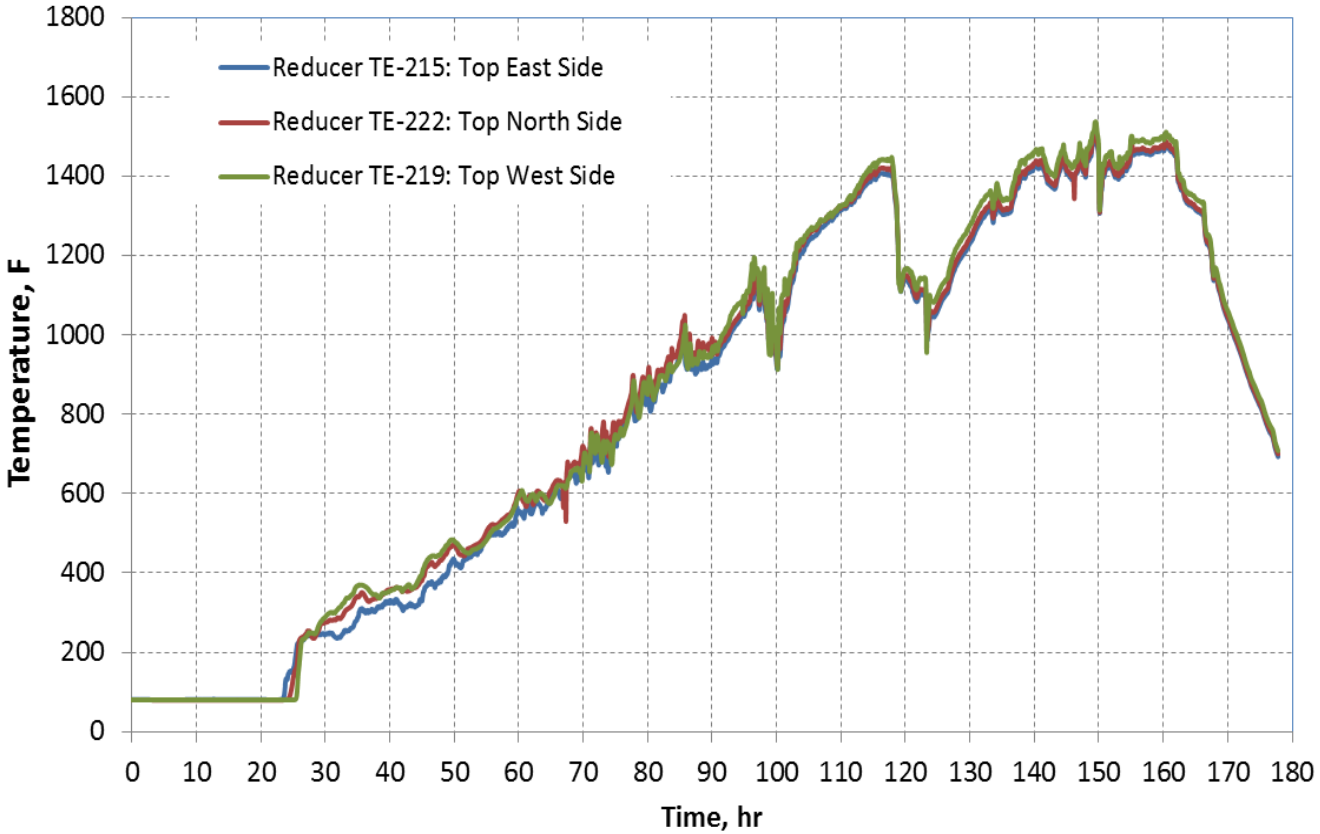


250 kW_{th} CDCL Pilot Plant Test Results



Refractory Bake-Out (March-2017)

250 kW_{th} CDCL Pilot Plant Test Results



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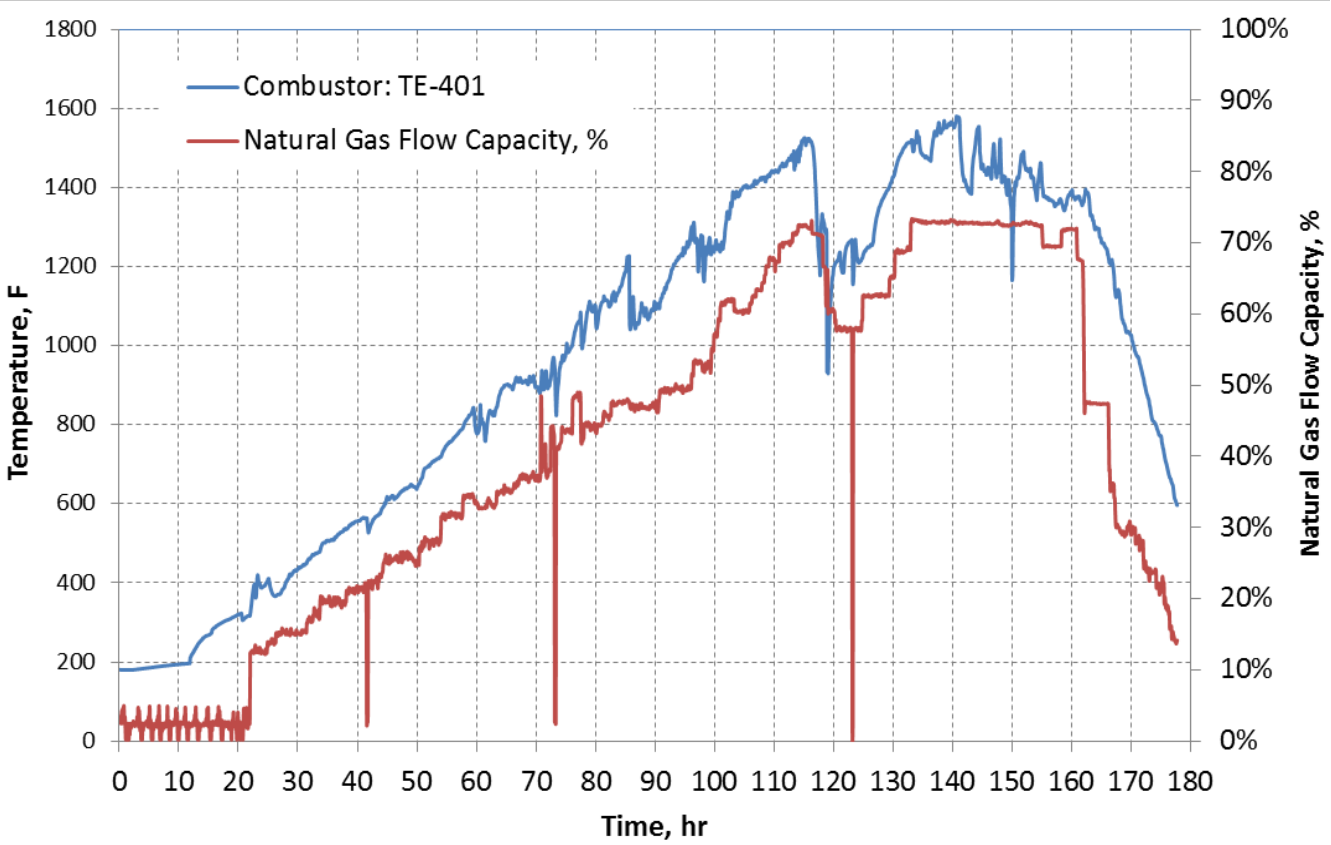
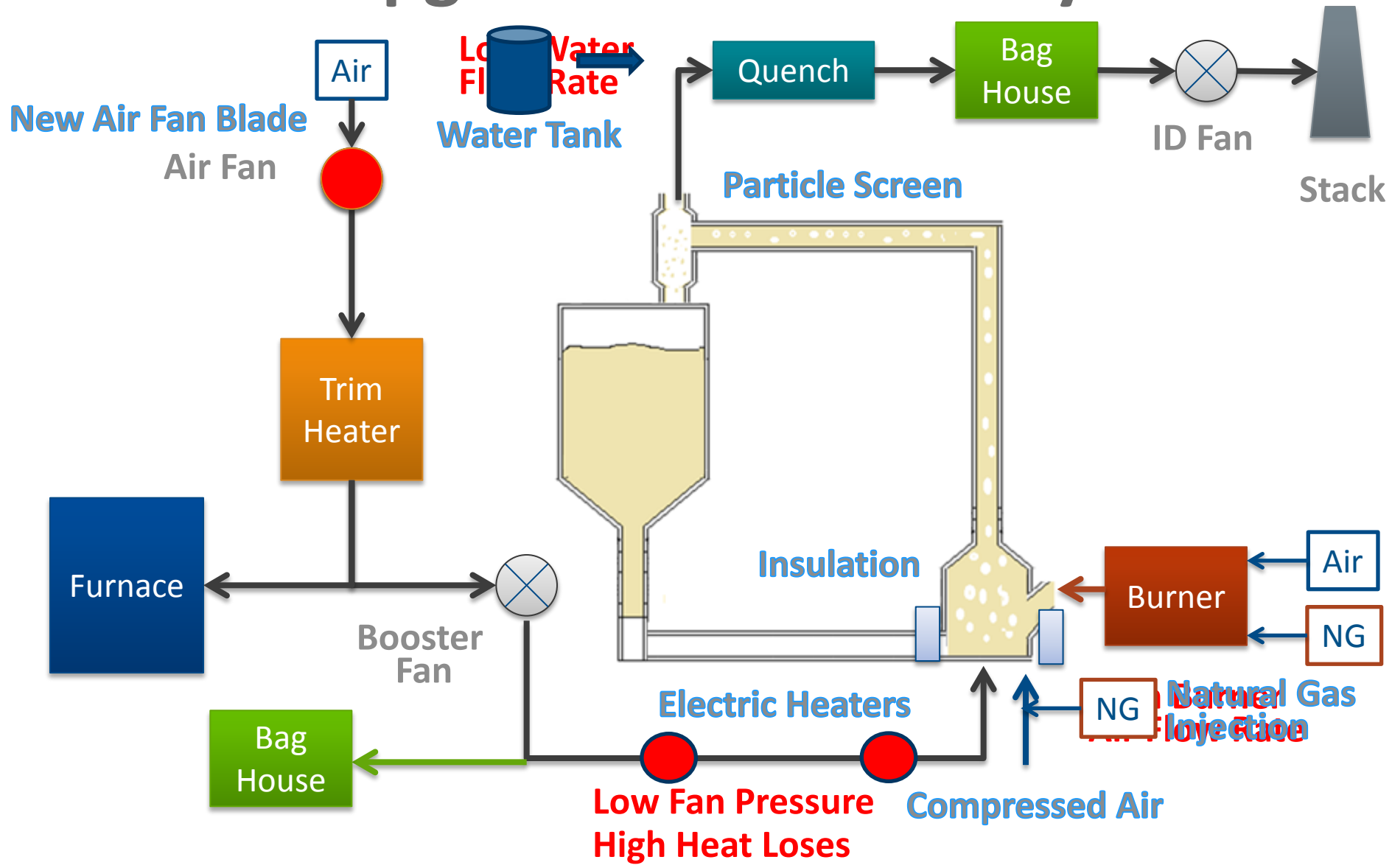


Refractory Bake-Out (March-2017)

Upgrades to the facility



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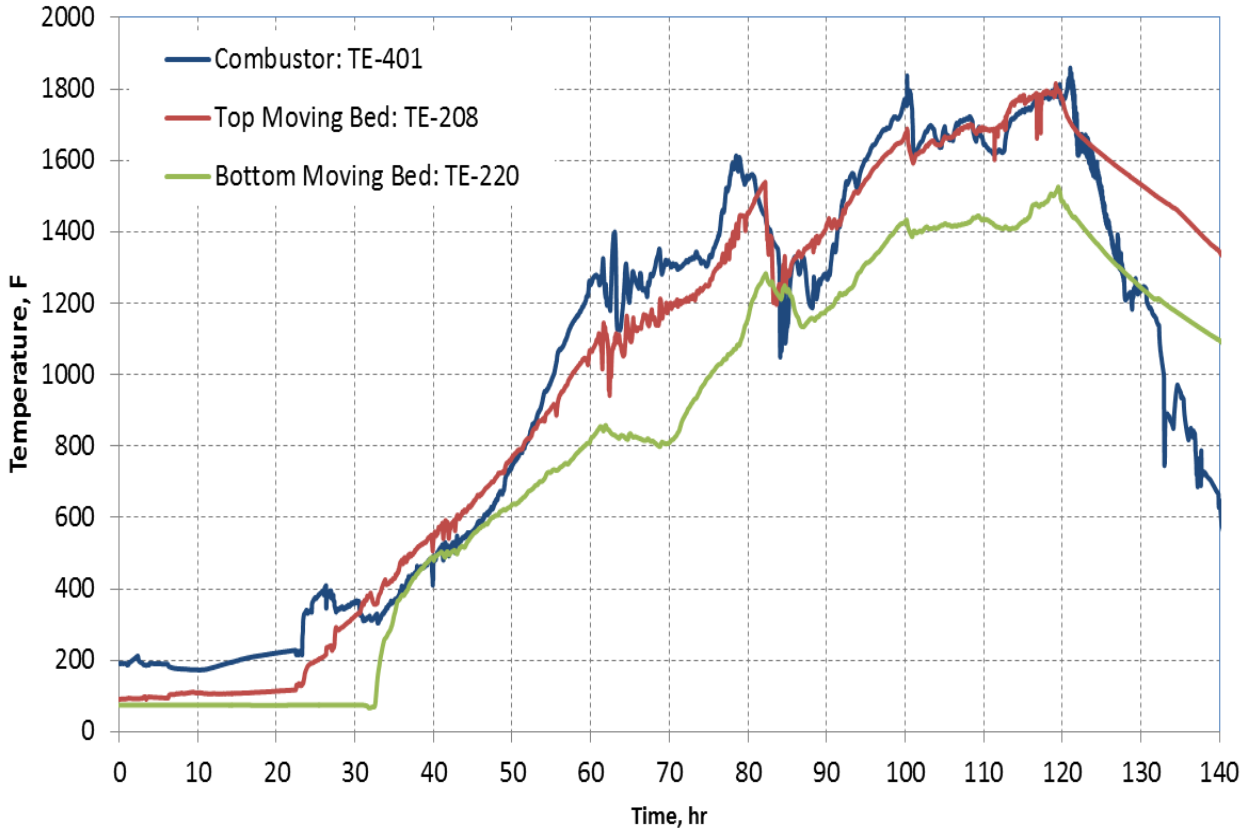
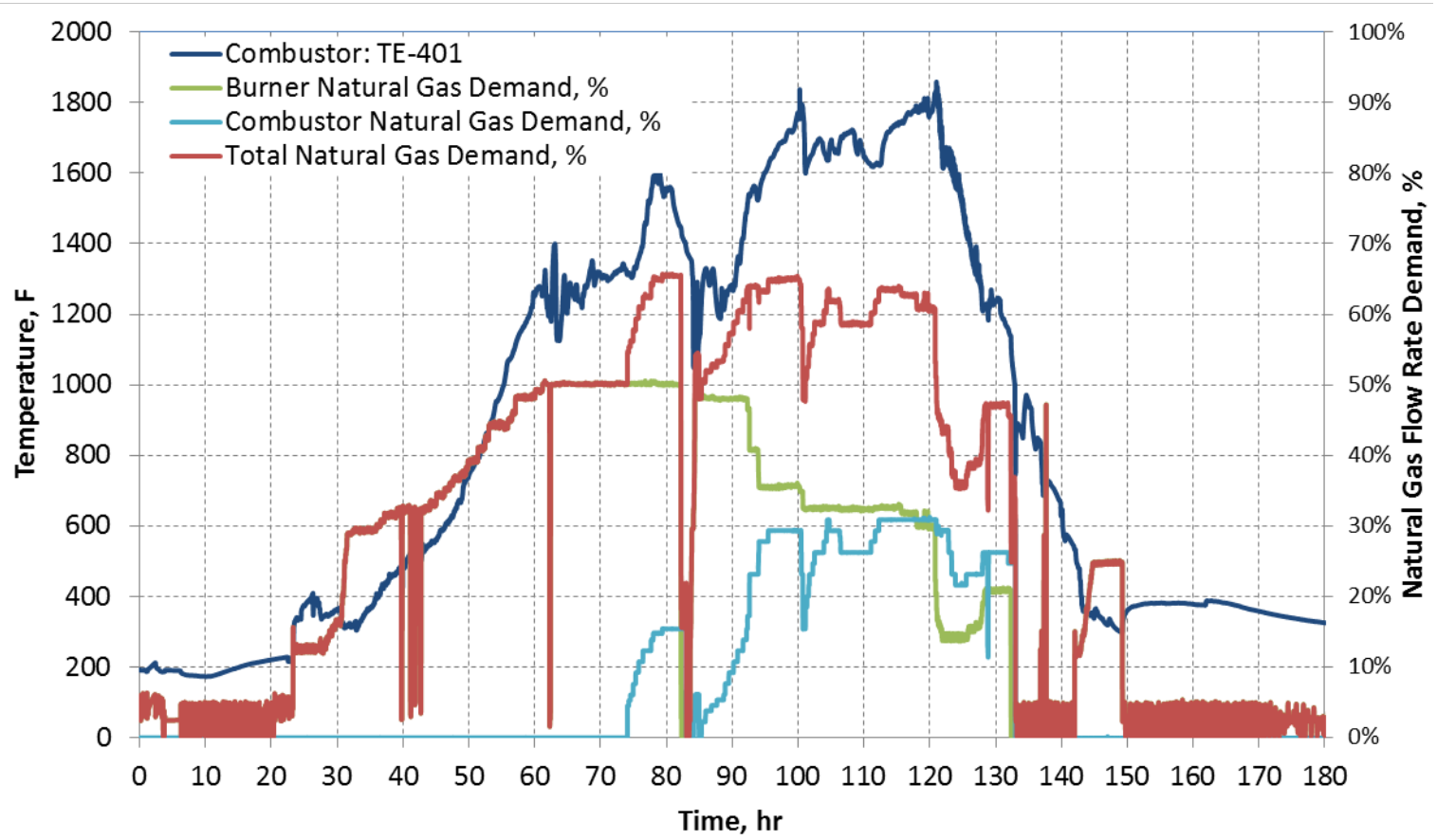


Second Test Run (June-2017)

250 kW_{th} CDCL Pilot Plant Test Results



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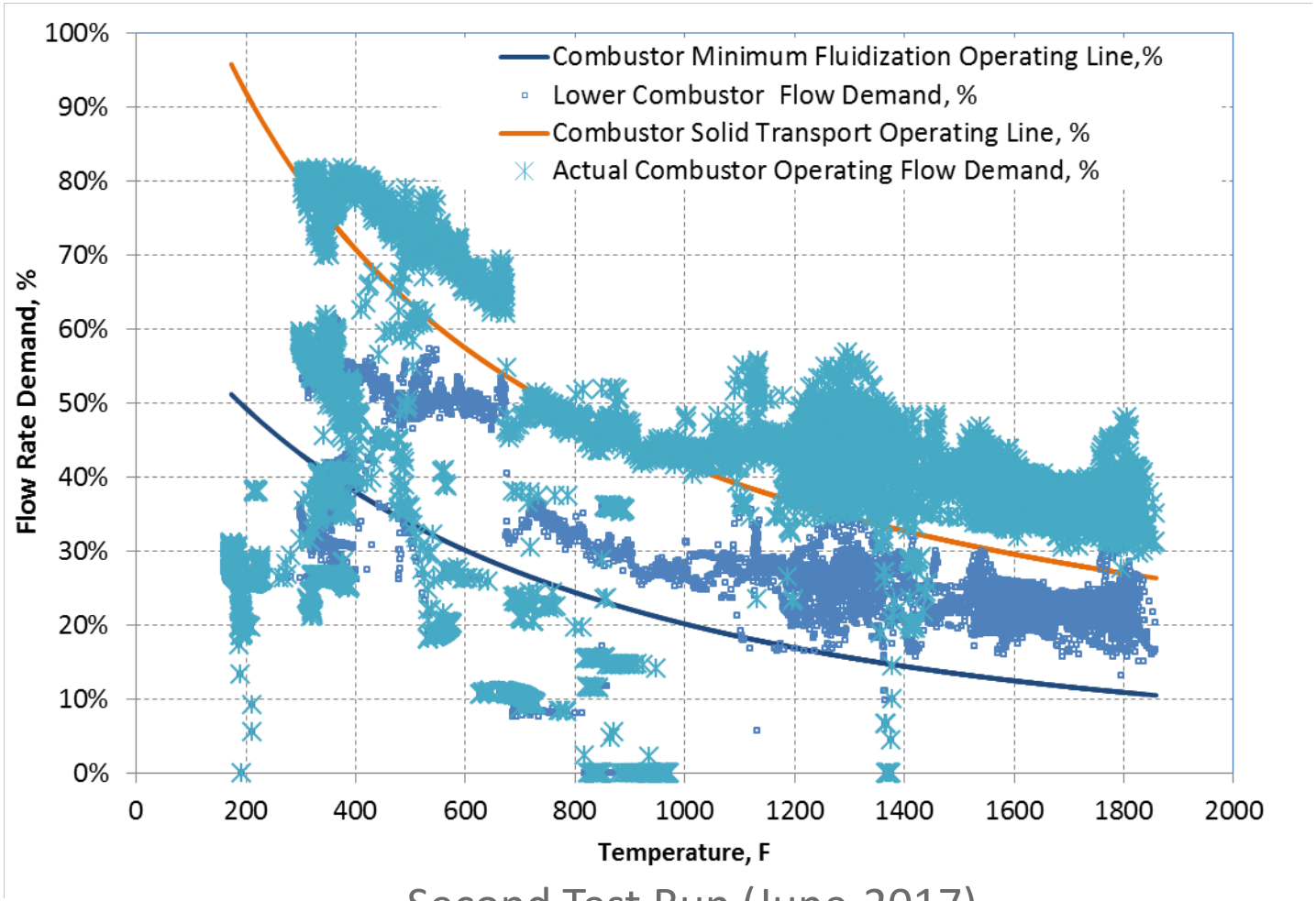

Second Test Run (June-2017)

Conclusions

- CDCL Process represents a 2nd generation oxyfuel combustion technology capable of substantially reducing the cost of electricity increase associated with CO_2 capture

- Phase II 250 kW_{th} pilot plant design, construction and commissioning activities are complete
  - Operating temperature for coal injection (~1,800°F) achieved
  - Initial coal testing shows nearly 100% CO_2 purity in flue gas
  - Over 200 hours of operation in two separate runs (>100 hours each)
  - Flue gas cooler / quench unit design verified & improved
  - Particle make-up & coal feed systems demonstrated & calibrated

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