Low-Cost and Recyclable Oxygen Carrier and Novel Process for Chemical Looping Combustion

DE-FE0031534

UND

Envergex
Sparking Innovations

By

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U.S. DEPARTMENT OF ENERGY

NETL

MICROBEAM TECHNOLOGIES, INC.

CARBON TEC ENERGY CORPORATION

Presentation Overview

- Project Overview
- Background on existing CLC projects at UND/Envergex LLC
- Project Objectives
- Technical Approach
- Scope of Work
- Questions/Discussion

Project Overview

Overall Goal: Demonstrate transformational technology that overcomes two key CLC technology gaps:

- high cost of OC replacement/loss
- incomplete fuel conversion, resulting in reduced CO_2 capture efficiency and an oxygen demand downstream of the CLC reducer reactor.

Funding: Department of Energy $1,500,000; Cost-share - $375,000

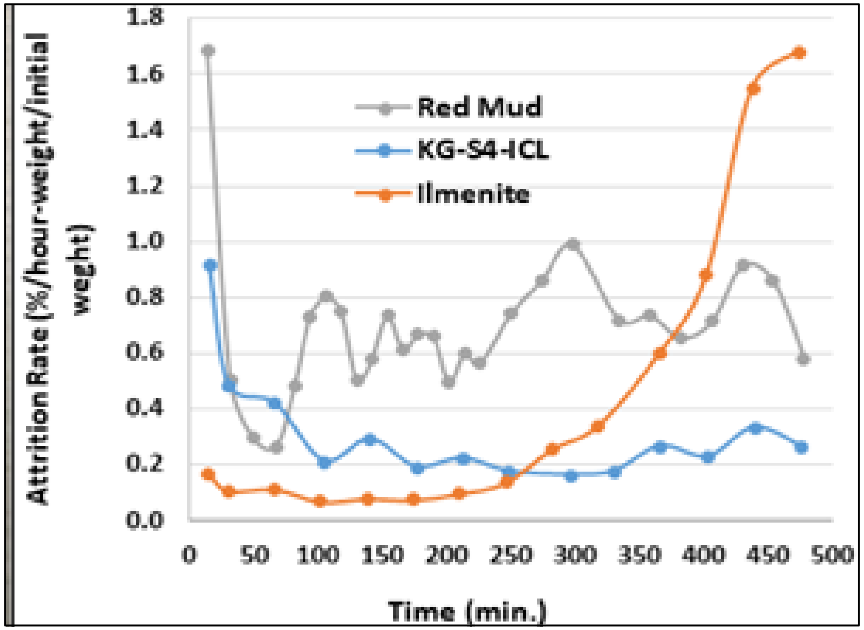
Project Participants:

1. University of North Dakota – Institute for Energy Studies (Lead)
2. Envergex LLC
3. Barr Engineering
4. Microbeam Technologies, Inc. (pending)
5. Carbontec Energy Corporation

Existing Projects

1. **Attrition Evaluation**
2. **Char Stripping**
3. **Spout – Fluid Bed Development**
   - Developing a novel reactor geometry to be used for chemical looping combustion
   - Developing a modeling tool co-currently with the reactor geometry to facilitate scale up

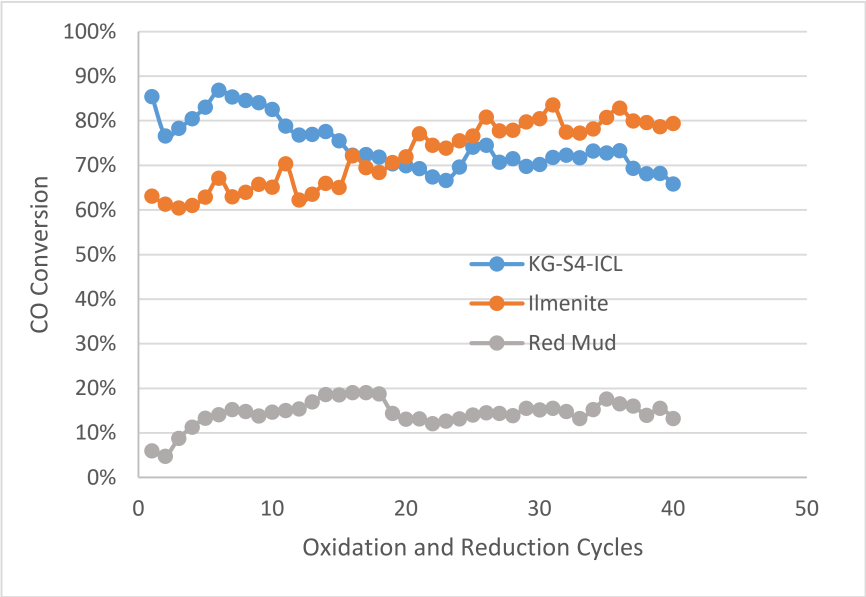
Technical Approach – Overall Process

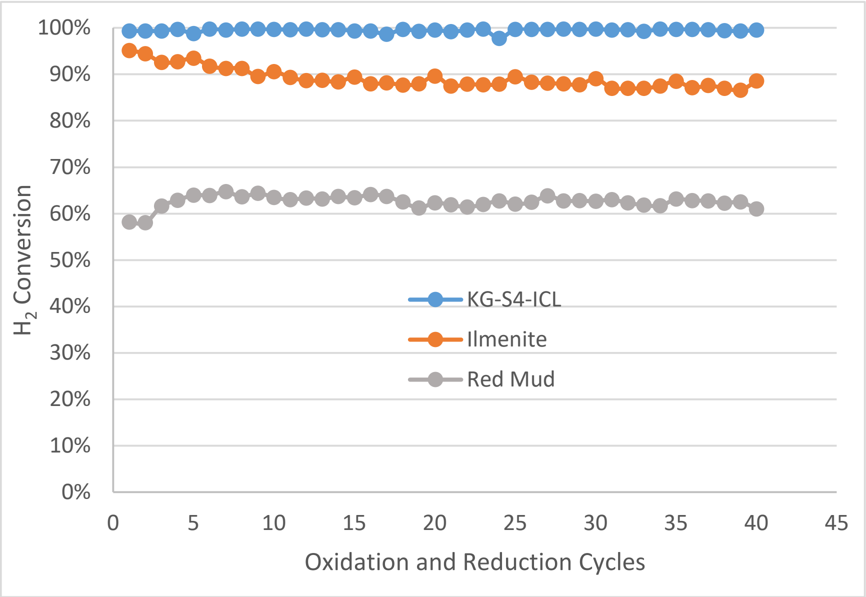


Unique oxygen carrier composition and manufacturing platform:

- Main component enriched iron oxide powder: abundant and low-cost domestic production
- Blending in a small proportion of low-cost additives to avoid agglomeration tendency of pure iron oxide
- Preliminary attrition results promising

Technical Approach – Overall Process





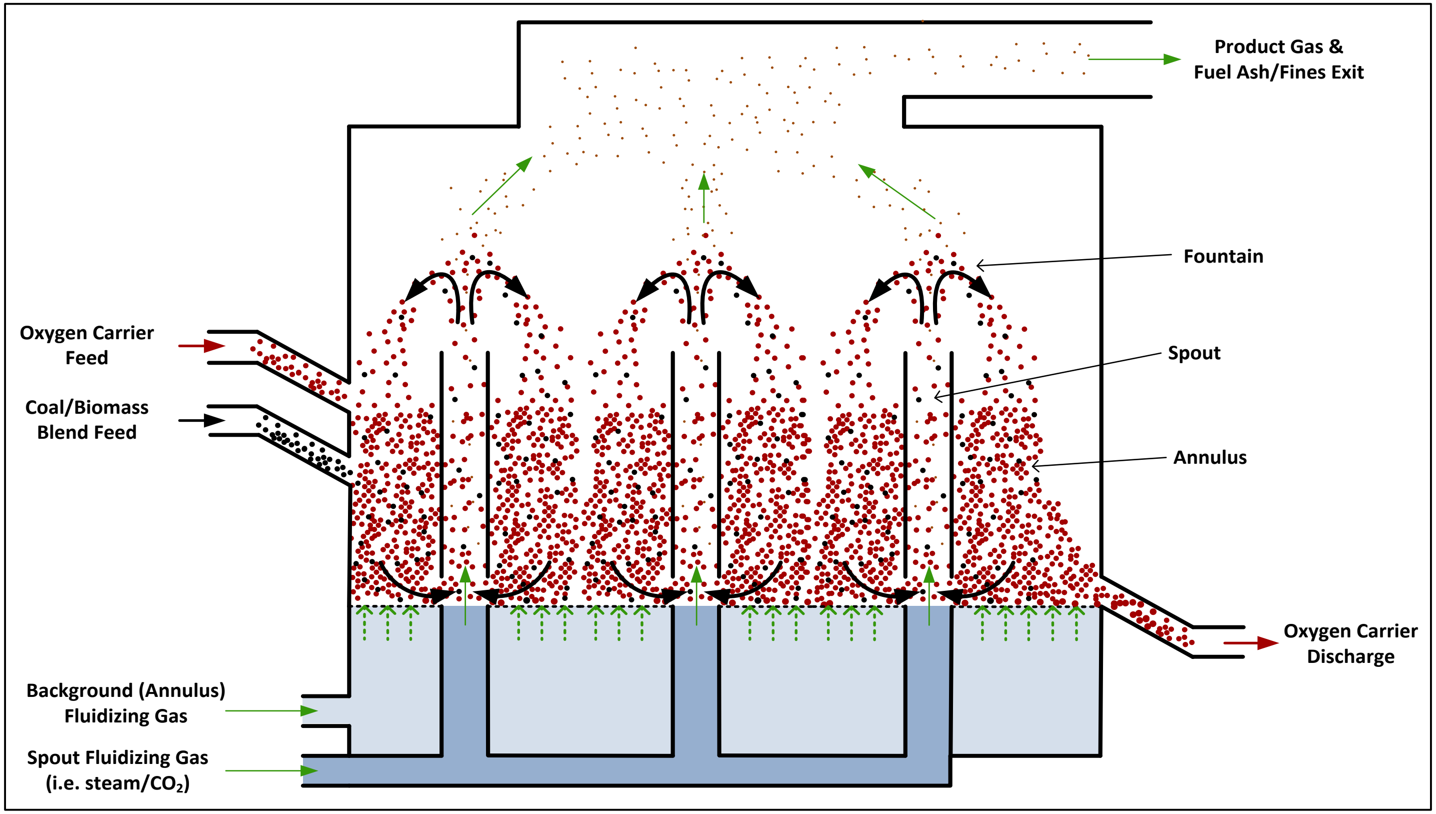
Tested in laboratory scale reactor (High Temperature Redox Attrition Test Unit):

- Hydrogen conversion very good
- CO conversion also promising

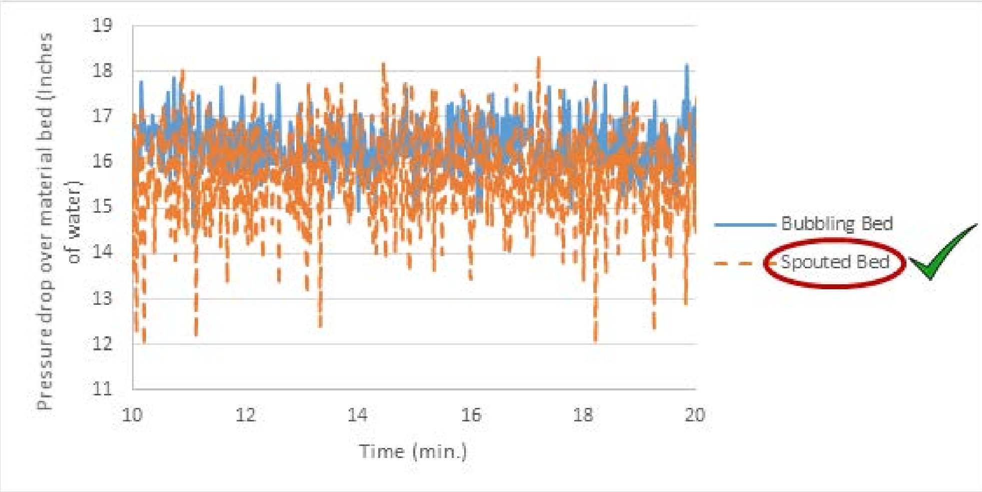
Technical Approach – Overall Process

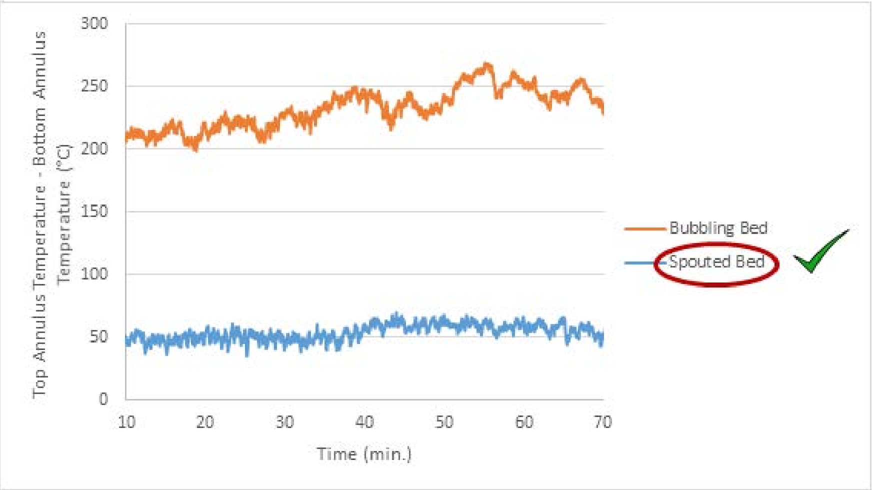
SPOUT FLUID-BED REDUCER DESIGN:

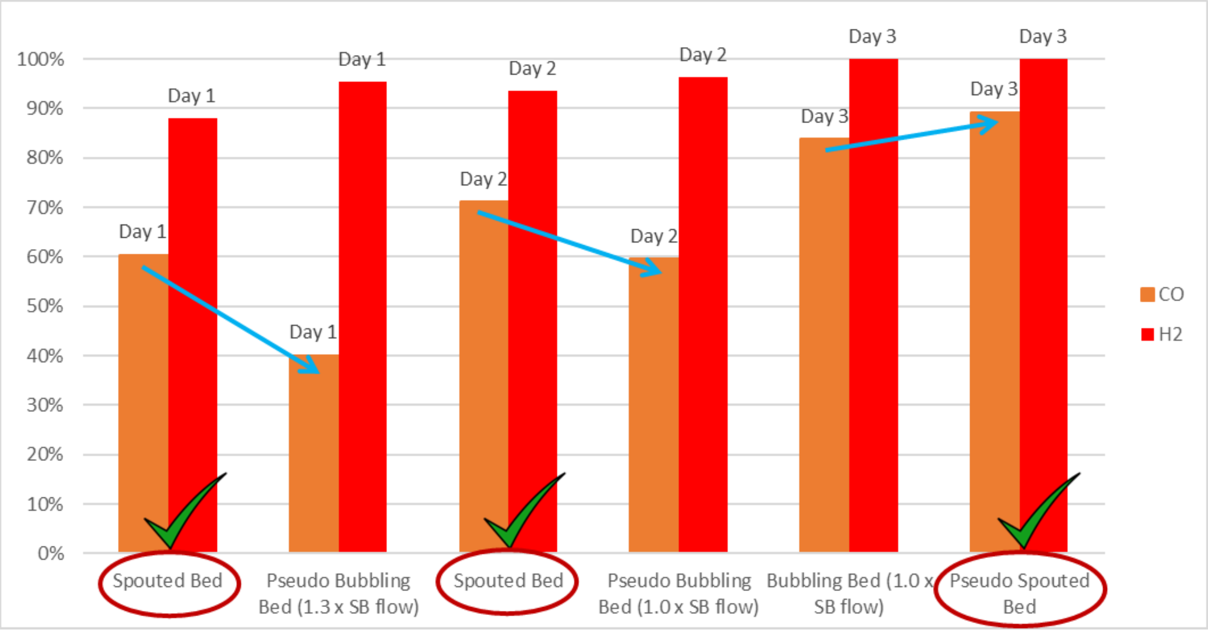
- High velocity in draft tube (turbulent to transport regime)
- Low velocity in annulus (low to minimum fluidization velocity)
  - Annulus operates like a “moving bed”
  - Better solid-gas interactions



Technical Approach – Overall Process



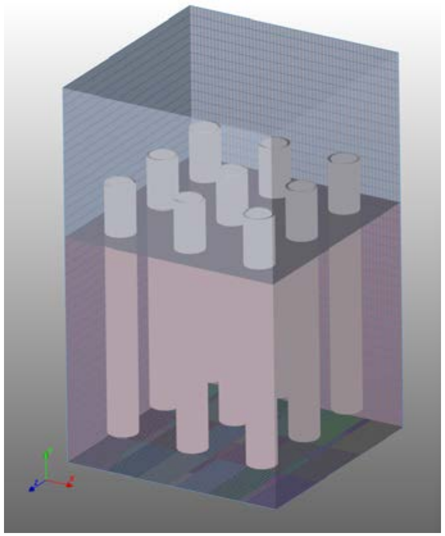


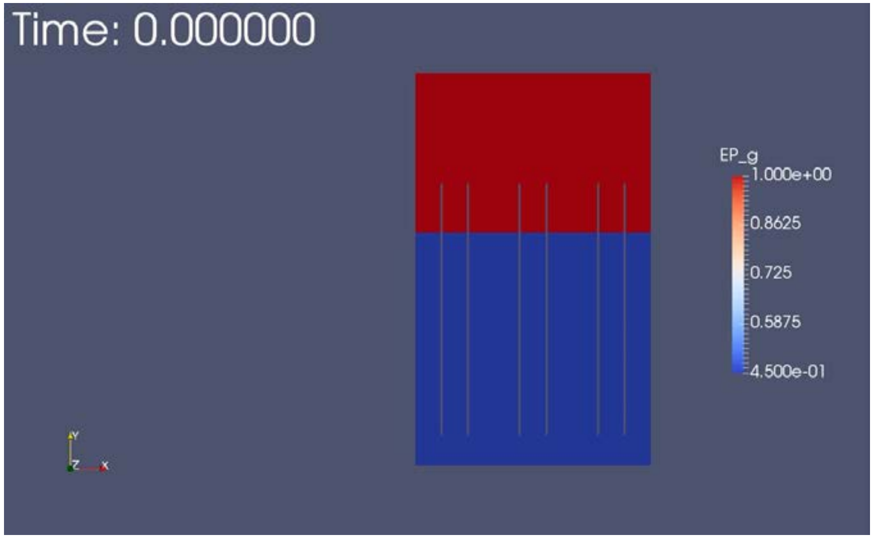


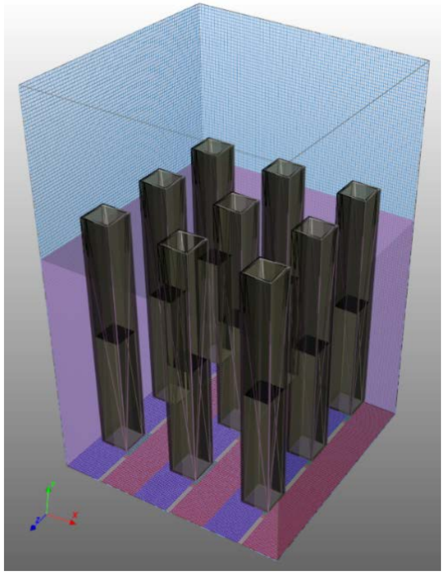
Technical Approach – Overall Process

➢ 3-D MFiX Models – Hydrodynamics

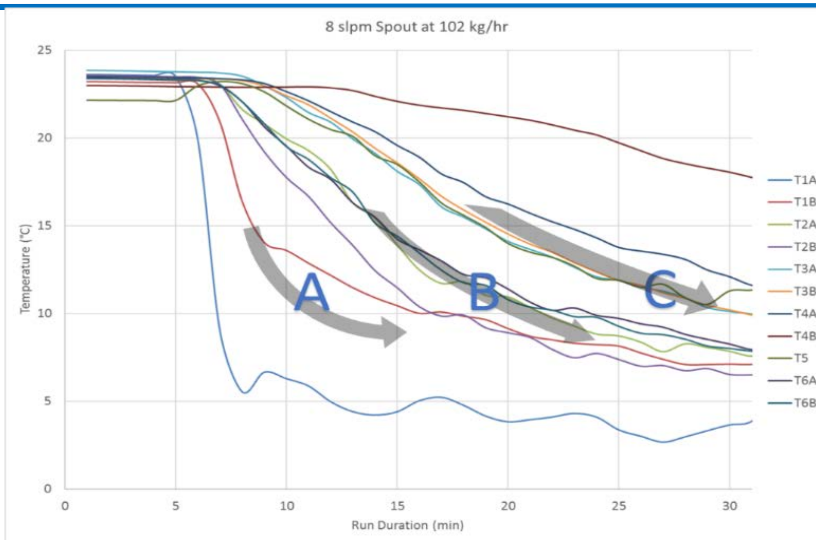
- Cylindrical draft tubes replaced with rectangular → Simplifies modeling
- Use to investigate flow patterns of OC
- 3-D isothermal case with variable material inlet and outlet mass flows
- Implementing custom solver to run simulations more robustly







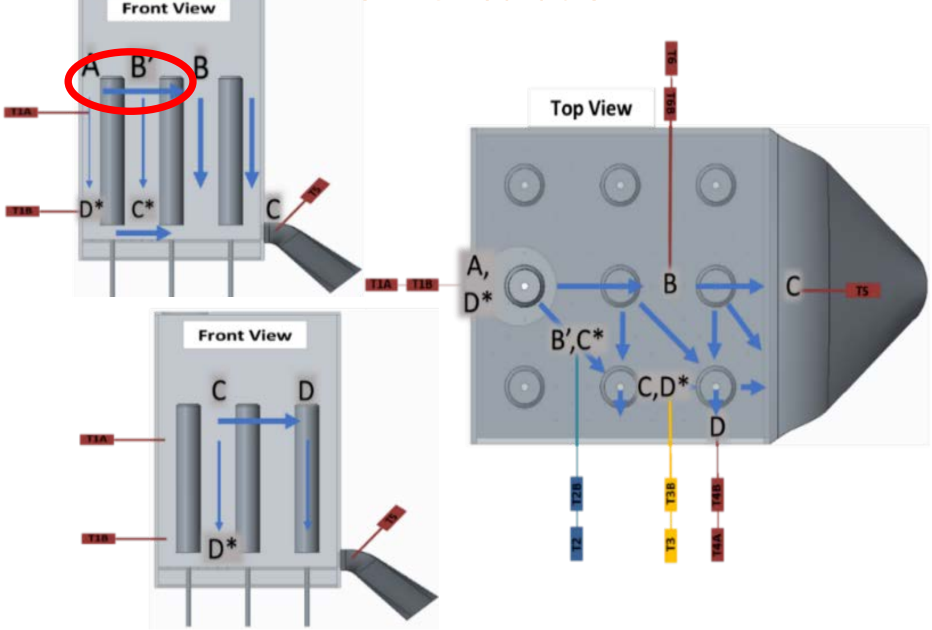
Technical Approach – Overall Process



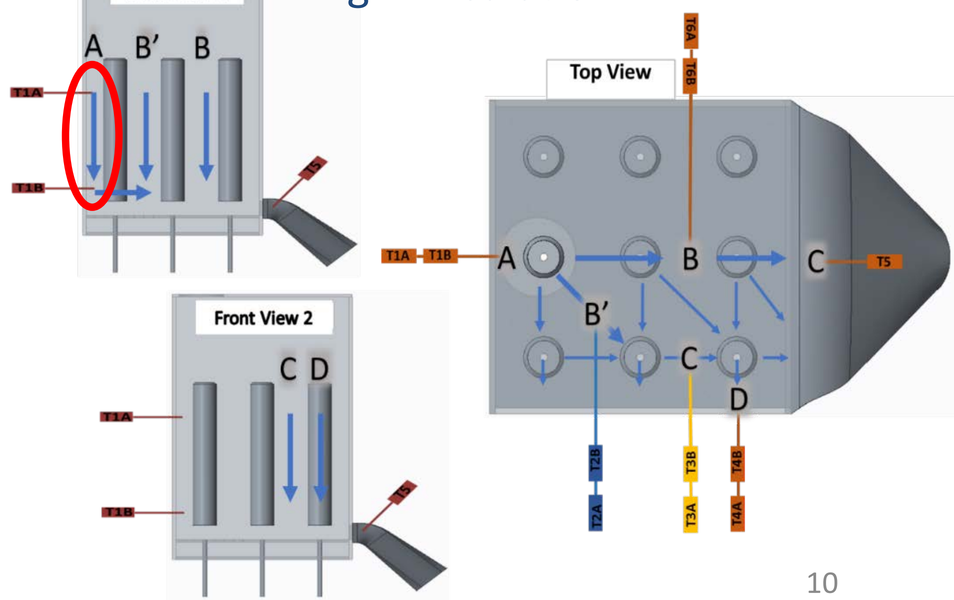
➢ Residence Time and Circulation

- OC cooled to < 5°C
- Thermocouples used to monitor effect of circulation and feed rate
- High Circulation vs Low Circulation
- Compare experimental and simulation data

Low Circulation

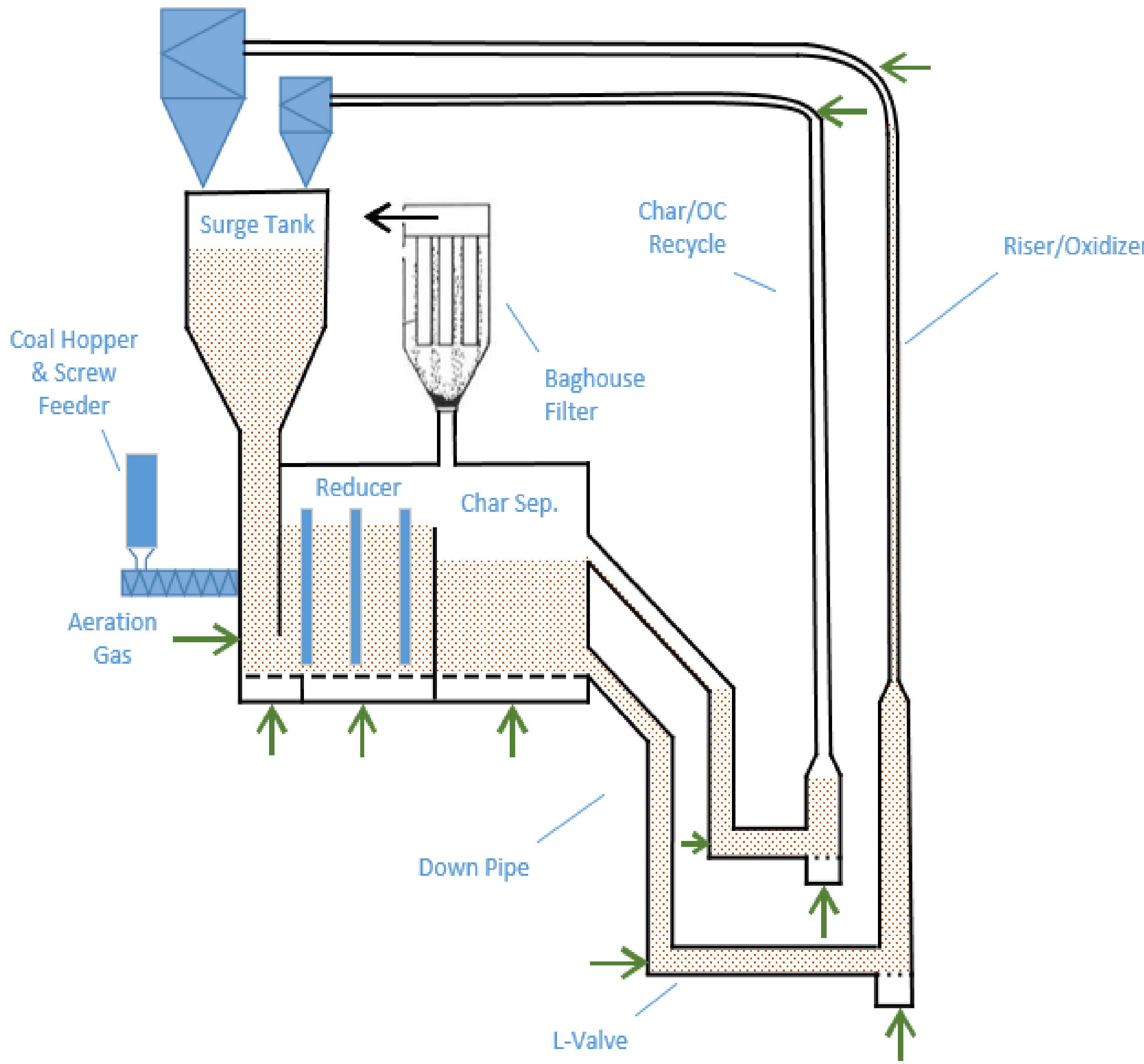


High Circulation



Technical Approach – Overall Process

- Use unique hydrodynamics available with the SFB reducer design
  - Thermodynamics limits combination of fuel gas conversion and deep OC reduction
  - Counter-current operation of the annulus in the SFB can help to improve on this limit
- Incorporate the PCS carbon stripper technology
- Goal: 90% CCR with no/minimal reducer exhaust oxygen demand



Project Objectives

Specific Objectives:

1. Demonstrate novel OC manufacturing platform: high performance of "engineered" OCs, but with cost structure of natural ores
2. Identify OC phase transformations and interactions with coal impurities that could impact OC/process performance and OC recyclability; identify mitigation strategies
3. Test a novel combination of CLC components at the 10 kW_{th}-scale using existing projects at UND and Envergex LLC.
4. Perform economic assessment to demonstrate progress towards DOE cost of CO_2 capture and cost of electricity targets

Scope of Work

- Task 1 – Project Management and Planning
- Task 2 – Laboratory-scale OC Manufacturing & Assessment
- Task 3 – Modeling and Laboratory-scale Evaluation of OC Performance with Coal
- Task 4 – 10 kW_{th} Integrated System Installation
- Task 5 – Scaled-up OC Manufacturing
- Task 6 – 10 kW_{th} Testing
- Task 7 – Process Design and Techno-Economic Analysis

Task 2 Overview

Subtask 2.1 – OC Manufacturing

- ~40 unique OC formulations
- Composition, binder loading, particle size, granulation method, curing

Subtask 2.2 – OC Characterization and Performance Testing

- Determine physical/chemical characteristics before/after exposure to CLC tests
- Perform CLC testing: reducing gas conversions, impact of sulfur, attrition, agglomeration
- Parameters to include: temperature, gas/solid contact time, reducing gas composition, jet velocity
- **Down-select to 2 OCs based on testing**

Subtask 2.3 – Longer-term Operation and Recyclability Evaluation

- **~500 redox cycles**; Evaluate long term performance
- Collect fines generated and evaluate CLC performance/characteristics of reformulated fines compared to fresh OC

Task 3 Overview

Subtask 3.1 – Fluidized Bed Testing with Coal

- Use coal as reductant instead of reducing gases
- Parametric and longer-term testing
- Down-select to 1 OC formulation

Subtask 3.2 – Experimental Evaluation of OC/Coal Ash Interactions

- TGA-DSC: Identify zones of phase transformations/reactions of OC/coal ash; characterization to determine OC transformations
- Temperature, contact time, gas phase composition, ash type/composition

Subtask 3.3 – Thermochemical Equilibrium Modeling

- HSC Chemistry 9.0: model reactions of OC with coal ash
- Investigate agglomeration potential using viscosity models
- Develop mitigation strategies to minimize detrimental impacts

Subtask 3.4 – OC Fines Separation and Recyclability

- Tests to identify impact of coal impurities on OC recyclability

Tasks 4-6 Overview

Task 4 – 10 kW_{th} System Installation

- Leverage existing and to-be-constructed equipment from existing projects
- SFB reducer, PCS carbon stripper, Novel process configuration
- Circulating CLC system

Task 5 – Scaled-up OC Manufacturing

- ~1000 kg of down-selected OC formulation
- Evaluate physical/chemical characteristics to compare to lab quantities

Task 6 – 10 kW_{th} Testing

- Reducer/oxidizer temperature, OC residence time
- Reducer coal/char residence time
- OC/Coal ratio
- ~100 hours of testing at optimized conditions for two coal types

Task 7 Overview

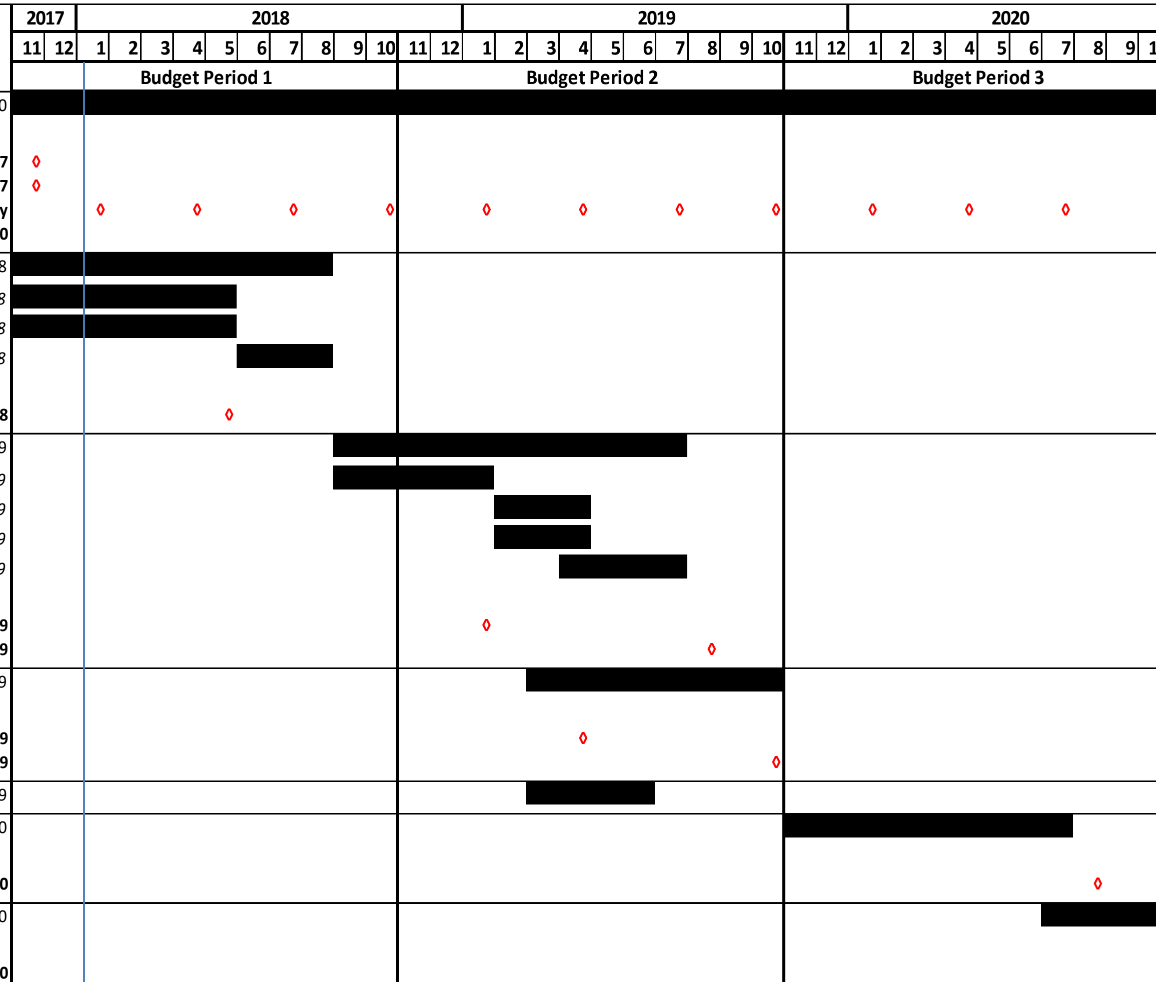
Task 7 – Process Design and Techno-Economic Assessment

- Benchmark: NETL's Reference Plant Designs and Sensitivity Studies (Stevens et al 2014)
- Process modeling using Aspen Plus®
- Determine economic metrics
- Led by qualified 3rd party A&E Firm – Barr Engineering Company

Stevens, R. et al., 2014: "Guidance for NETL's Oxy-combustion R&D Program: Chemical Looping Combustion Reference Plant Designs and Sensitivity Studies," DOE-NETL Report 2014/1643

Project Schedule

Task/Subtask/Milestone Description	Start Date	End Date
Task 1 - Project Management & Planning	11/01/17	10/31/20
Milestones		
Update Project Management Plan		**11/30/17**
Kickoff Meeting		**11/30/17**
Quarterly Report		**Quarterly**
Final Technical Report		**10/31/20**
Task 2 - Lab-scale OC Manufacturing & Assessment	11/01/17	08/31/18
Subtask 2.1 - OC Manufacturing	*11/01/17*	*05/31/18*
Subtask 2.2 - OC Characterization and Testing	*11/01/17*	*05/31/18*
Subtask 2.3 - Long-term Cyclic Testing and Recyclability Evaluation	*06/01/18*	*08/31/18*
Milestones		
Down-selection to two OC types		**05/31/18**
Task 3 - Modeling and Laboratory-scale Evaluation of OC Performance with Coal	09/01/18	07/31/19
Subtask 3.1 - Fluidized Bed Testing	*09/01/18*	*01/31/19*
Subtask 3.2 - TGA Testing	*01/01/19*	*03/31/19*
Subtask 3.3 - Thermodynamic Modeling	*03/01/19*	*04/30/19*
Subtask 3.4 - OC Fines Separation and Recylability	*04/01/19*	*07/31/19*
Milestones		
Down-selection to one OC type		**01/31/19**
OC Characterization and Testing Summary Report		**08/31/19**
Task 4 - 10 kWth Integrated System Installation	03/01/19	10/31/19
Milestones		
System Design Package Report		**04/30/19**
System Commissioning		**10/31/19**
Task 5 - Scaled-up OC Manufacturing	03/01/19	09/30/19
Task 6 - 10 kWth Testing	11/01/19	07/31/20
Milestones		
10 kWth Testing Summary Report		**08/31/20**
Task 7 - Process Design and Technical and Economic Analysis	07/01/20	10/31/20
Milestones		
Technical and Economic Analysis Report		**10/31/20**



Note: Actual Start date January 18, 2018

Acknowledgement and Disclaimer

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Questions/Discussions

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