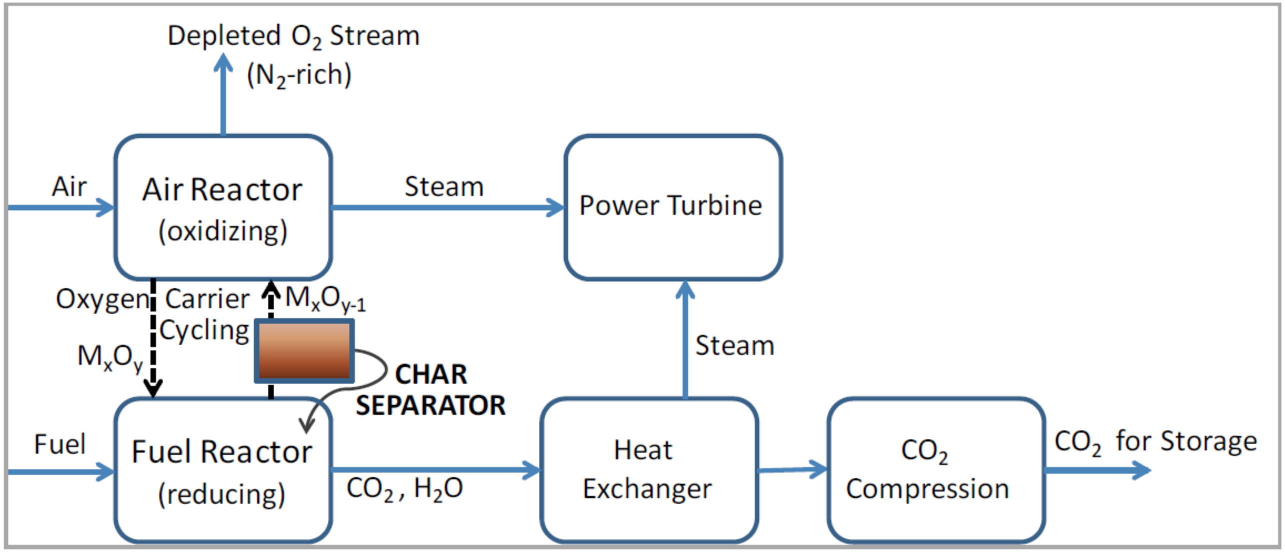
Small Business Innovation Research (SBIR/STTR) Phase II
Department of Energy

Method for Separation of Coal Conversion Products from Sorbents/Oxygen Carriers (DE-SC0013832)

BACKGROUND

- **Chemical-Looping Combustion**
  - Oxygen carriers (OC) undergo oxidation/reduction
  - Oxygen supplied for solid or gaseous fuel combustion
  - Flue gas not diluted by N_2 (only CO_2/H_2O)
  - OC regenerated in air



PRESENTATION OVERVIEW

- Project objective
- Equipment
- Design specifications
- Material
- Results/Discussion
- Future work

PROJECT OBJECTIVE

- **This project addresses development of a separation technology – Particle Char Separator (PCS) - for segregating fuel-based contaminants (char and ash) from oxygen carrier (OC) material in the context of chemical looping combustion (CLC)**

- Challenges to efficient separation of char include:
  1. Large throughput of material with low carbon fraction (OC/fuel ratio ~100-200; char is ~ 0.2-0.5%)
  2. High separation target (removal of 80% of char)
  3. Agglomeration on larger OC
  4. Attrition of OC in fluidized-type systems

EQUIPMENT

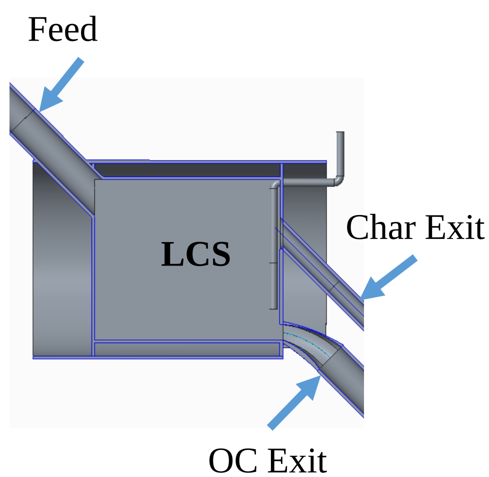
The Particle Char Separator (PCS) compromises two units:

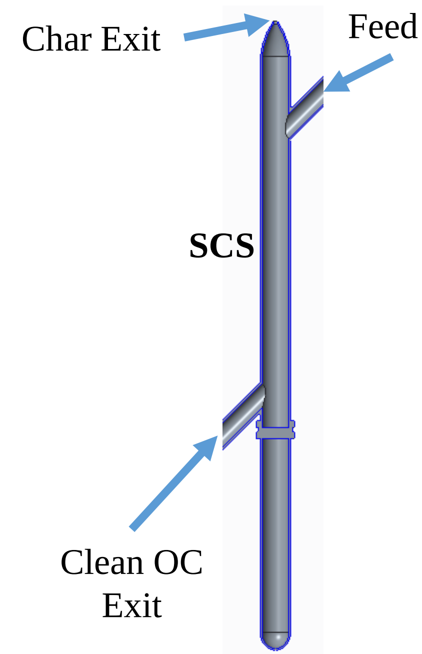
1. **Large Char Separator (LCS):** Removal of coarse > 100 µm.

   Principle: At low bed velocities, dissimilar solids segregate in fluid beds[1]

2. **Small Char Separator (SCS):** Polishing unit after the LCS

   Principle: Difference in terminal velocity between OC and char





Target: Achieve 80% char removal with 20% recycle of OC (split)

1. Rowe, P.N. and Nienow, A.W. (1976) 'Particle mixing and segregation in gas fluidised beds. A review', vol. 15, pp. 141-147

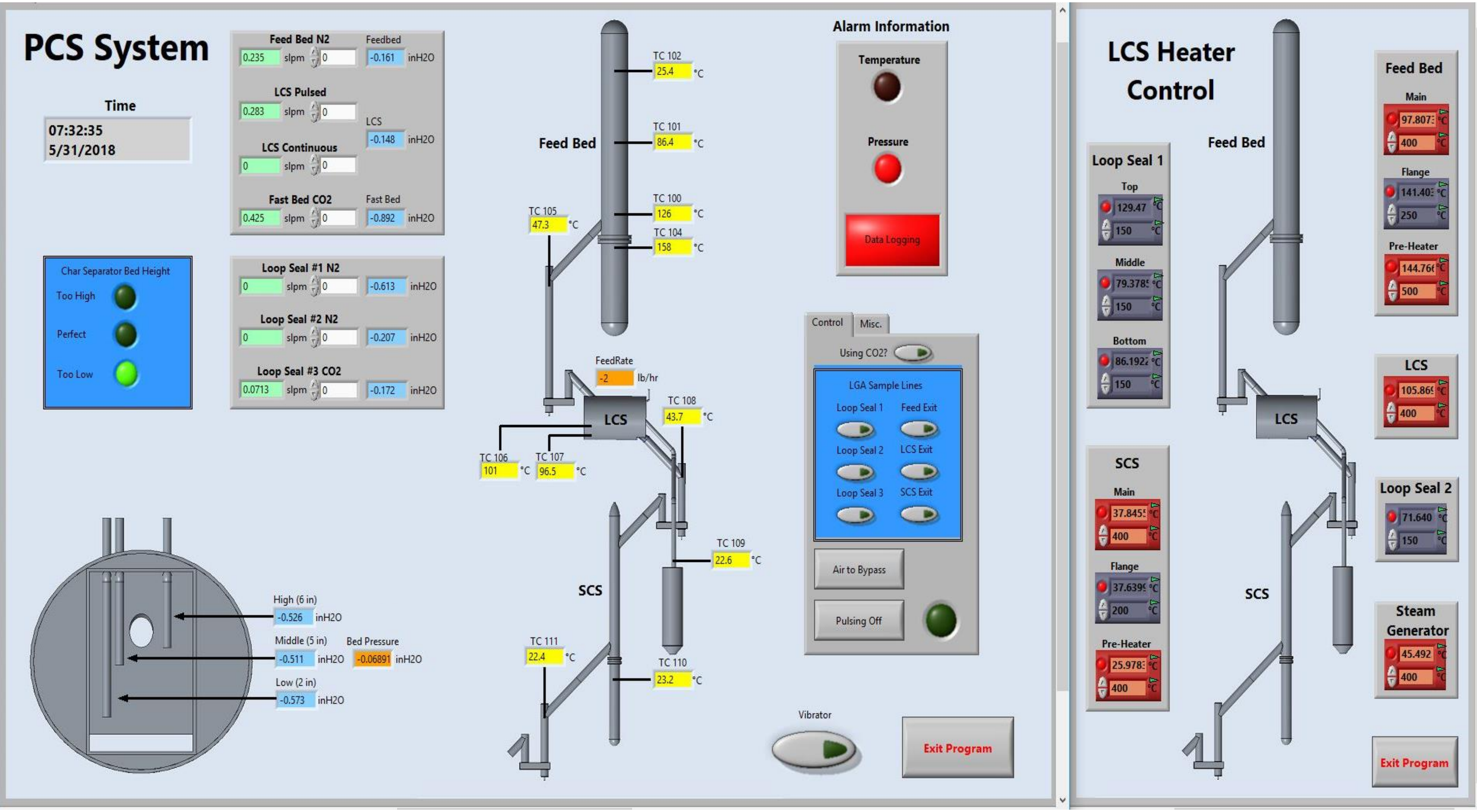
DESIGN SPECIFICATIONS

- Hot system:
  - Feed rate: ~ 50 kg./hr.
  - Designed as batch unit – 100 kg of solids pre-heated to desired temperature
  - Fluidizing gas: LCS – Steam/N_2; SCS – CO_2
- Cold system:
  - Feed rate: ~ 500 kg./hr.
  - Designed as batch unit – 500 kg. of solids kept at ambient temperature
  - Fluidizing gas: house air for all units

Hot system

Cold system

PROCESS CONTROL – HOT SYSTEM



MATERIALS & METHODOLOGY

- OC = ilmenite; Activated carbon (AC) as char substitute
- Starting Char/AC distribution from GE Power's former CLC pilot unit
- To date, testing at 25°C and 300°C to identify operational issues
- Testing at 800°C after addressing operational robustness (at temperature)

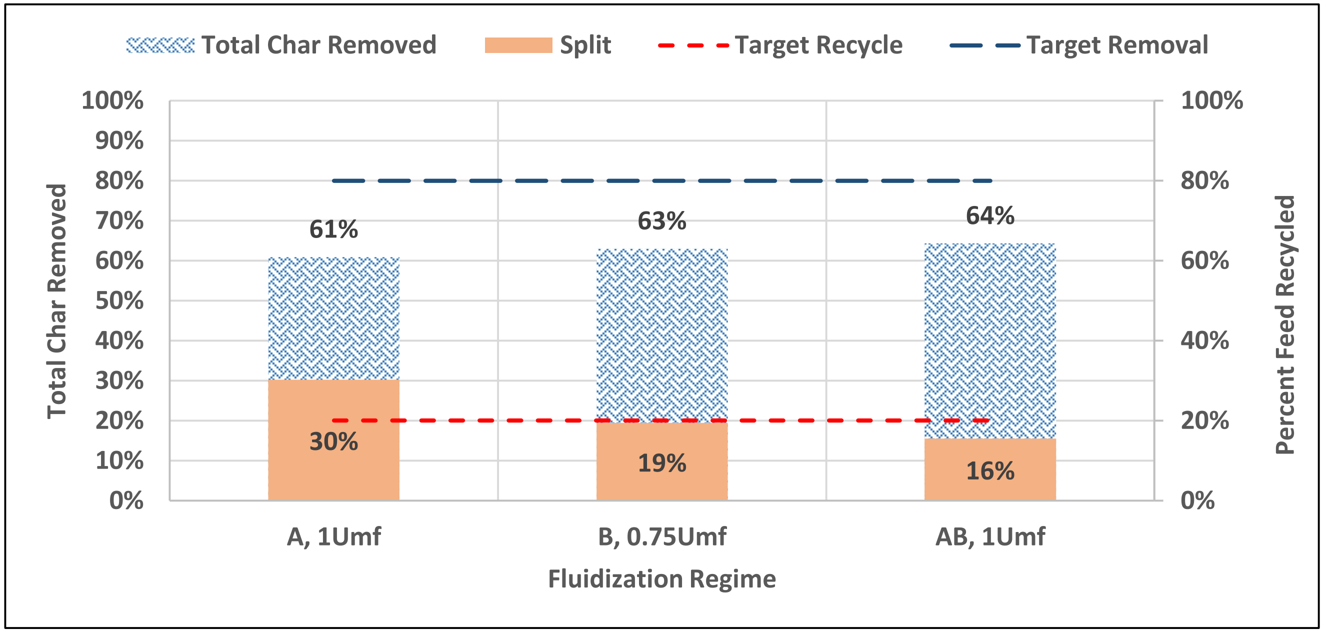
Size (µm)	OC Distribution %	AC Distribution* %
> 297	3%	9%
297 - 149	95%	25%
149 - 105	2%	21%
105 - 74		17%
< 74		28%

	LCS	SCS
Hot Flow Unit		
Solids Feed, kg/s	30 - 86	
Solids Flux, kg/m^2.s	0.2 – 0.5	1.8 – 4.9
Bed Velocity, cm/s	1.2 – 2.4	43
Temperature, °C	300 - 370	220 - 290
Min. Fluidization, cm/s	1.2	NA
Initial Char Content, %	0.5 – 0.8	
Cold Flow Unit		
Solids Feed, kg/s	340 - 480	
Solids Flux, kg/m^2.s	1.1 – 1.6	11.4 – 16.4
Bed Velocity, cm/s;	2.3 – 3.1	NA
Min. Fluidization, cm/s	3.1	NA
Initial Char Content, %	0.6 – 0.7	

Results
1000 lb./hr. (25 °C)

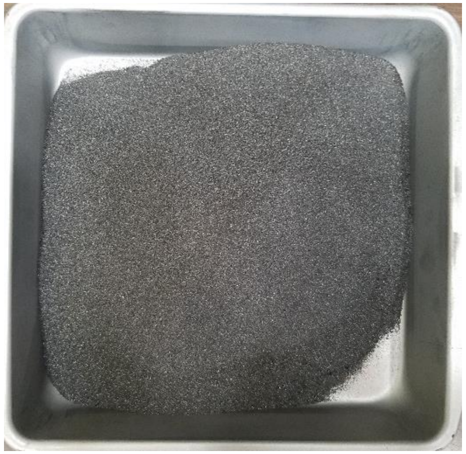
- Three fluidization modes tested.
- Best results for AB fluidization: 64% AC removal and 16% split

Fluidization Mode	Description
A	Bubbling Mode
B	Modified Fluidization
AB	Combination of both



Results
1000 lb./hr. (25 °C)

Tops – Char rich



Bottoms – Char depleted

Poor flow regime

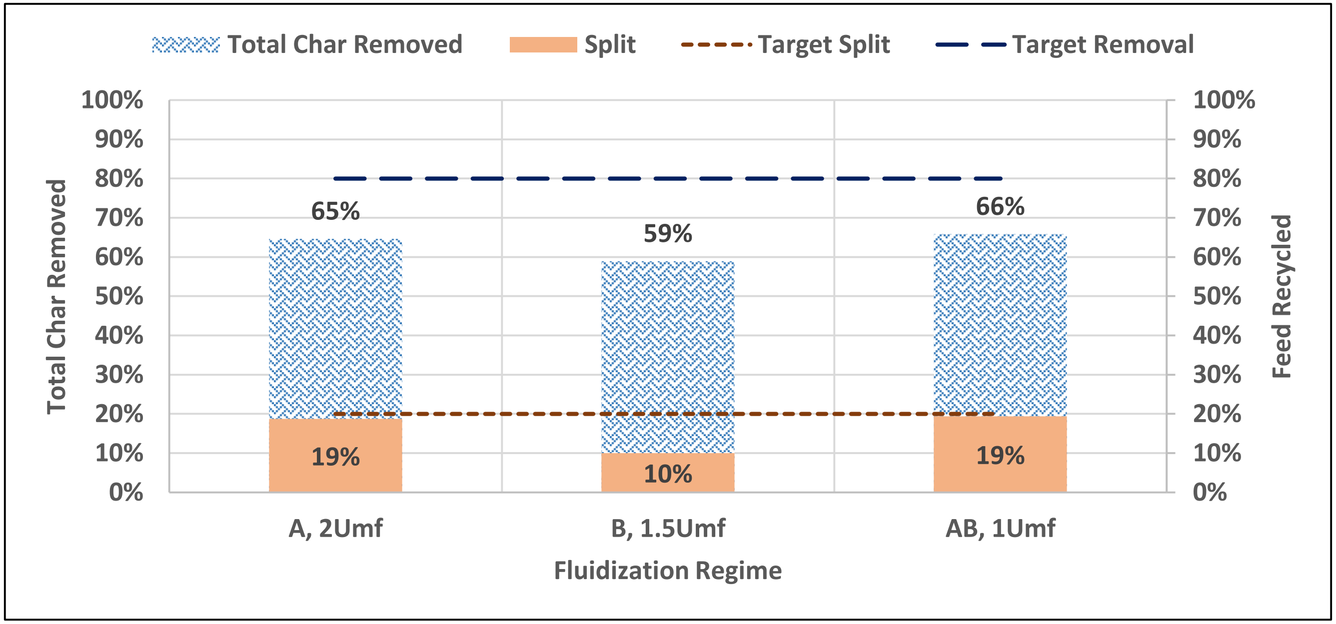
Optimal flow regime

Results
100 lb./hr. (300 °C)

Hot Flow:

- AB slightly better
- For A and B, bed velocities doubled
- Doubling bed velocity improved performance of A to match performance of AB

Fluidization Mode	Description
A	Bubbling Mode
B	Modified Fluidization
AB	Combination of both

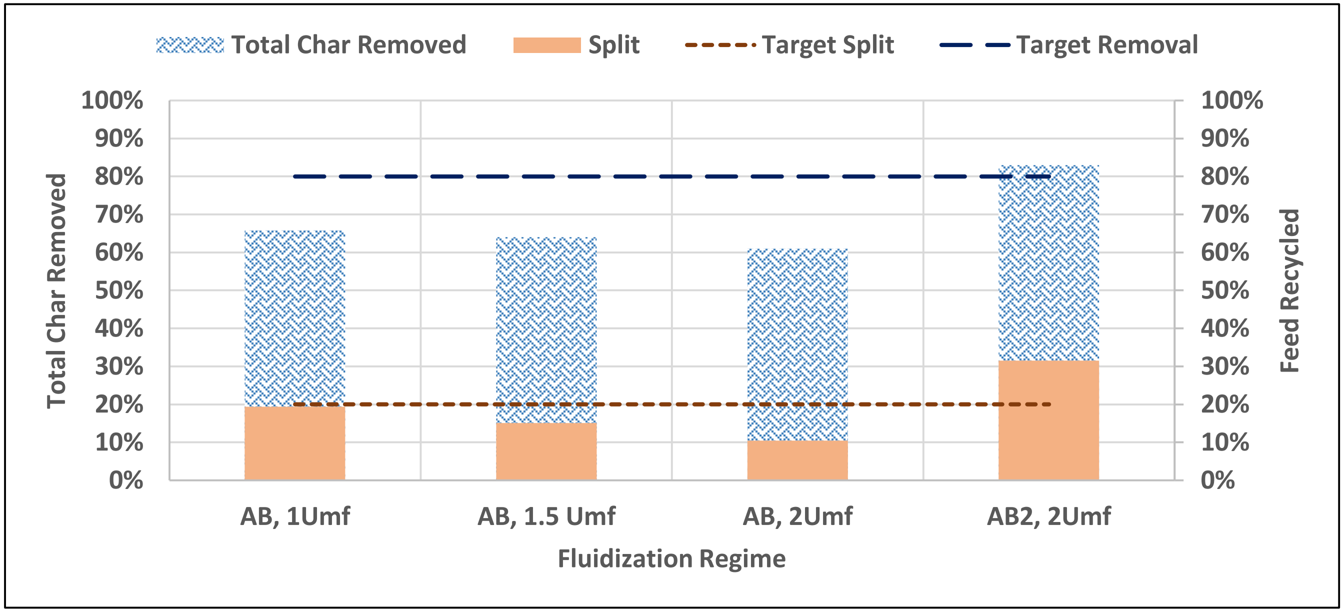


Results
100 lb./hr. (300 °C)

Hot Flow:

- Additional testing of AB mode
- Split is most important factor
- Effect of bed velocity over shadowed by split

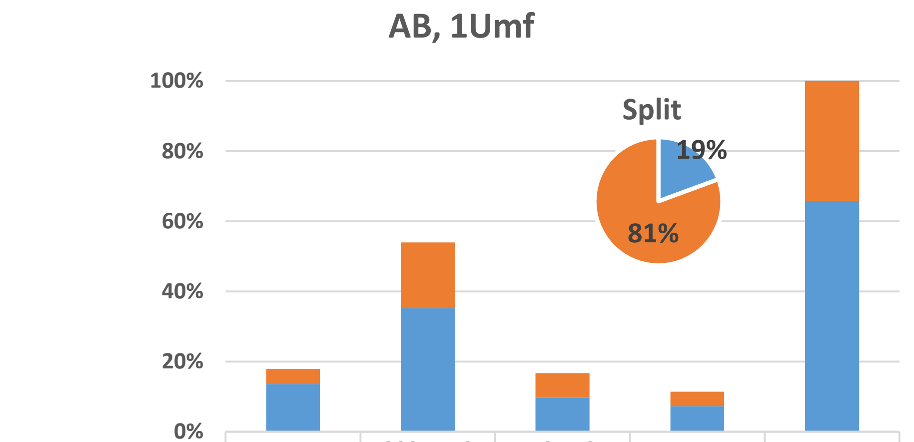
Fluidization Mode	Description
A	Bubbling Mode
B	Modified Fluidization
AB	Combination of both



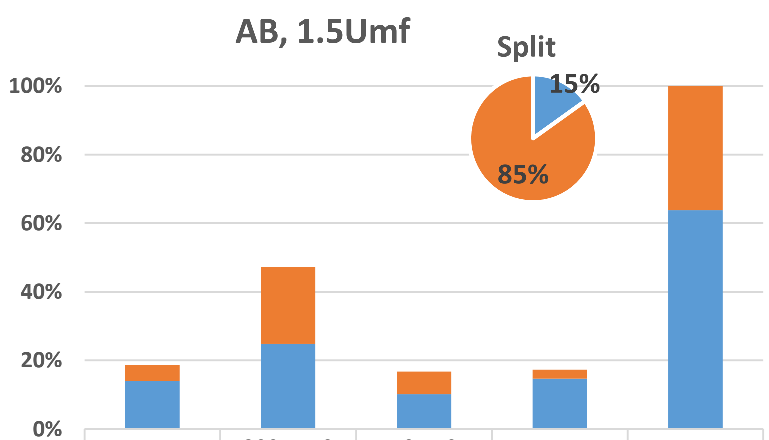
Results
100 lb./hr. (300 °C)

Looking at distribution of AC in streams:

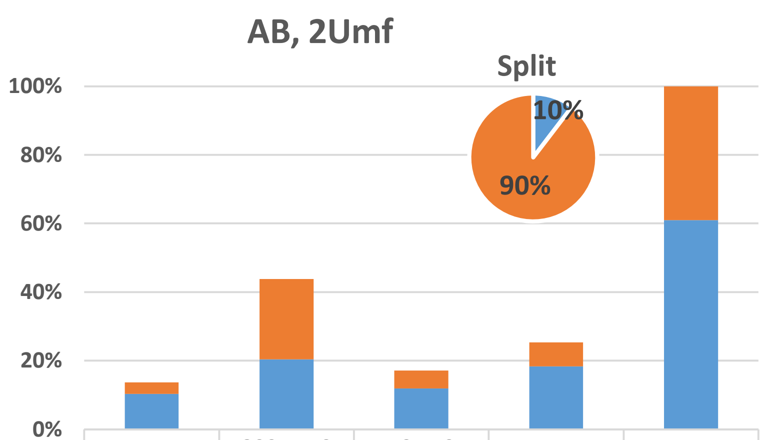
- 150-300 µm is biggest contributor to "unremoved" AC
- Split minimizes amount of 150-300 µm that is not separated



	> 300 µm	300 - 149 µm	149 - 105 µm	< 105 µm	Total
Clean OC	4.3%	18.7%	7.1%	4.1%	34.2%
Recycle Stream	13.6%	35.3%	9.6%	7.3%	65.8%



	> 300 µm	300 - 149 µm	149 - 105 µm	< 105 µm	Total
Clean OC	4.6%	22.3%	6.6%	2.7%	36.2%
Recycle Stream	14.0%	24.9%	10.1%	14.7%	63.8%



	> 300 µm	300 - 149 µm	149 - 105 µm	< 105 µm	Total
Clean OC	3.4%	23.4%	5.2%	7.0%	39.0%
Recycle Stream	10.3%	20.4%	11.9%	18.3%	61.0%

Challenges & Next Steps

Main Challenges:

1. Feed and discharge rate controlled by loop seals. Loop seal feed rate sensitive to fluidizing gas flow. Temperature fluctuations from moving solids affect fluidizing gas. Bigger challenge during operation at 800°C
2. Accurately controlling the split between tops and bottoms.

Proposed Solutions:

1. Integration with CLC system will improve temperature profile through the unit and ensure better steady-state operation
2. Addition of low flow mass flow controllers to better control loop seal control gas flow rates.

Acknowledgement and Disclaimer

Acknowledgement: "This material is based upon work supported by the Department of Energy under Award Number DE-SC0013832."

Questions?