



Envergex LLC

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Institute for Energy Studies, University of North Dakota



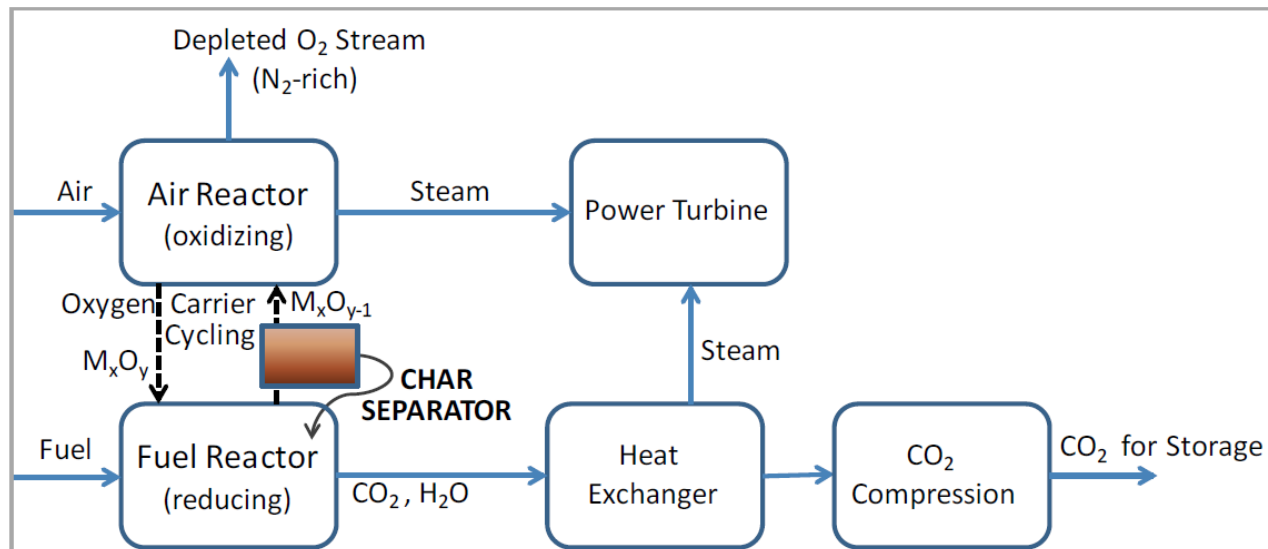
Small Business Innovation Research (SBIR/STTR) Phase II Department of Energy

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



➤ 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

- **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

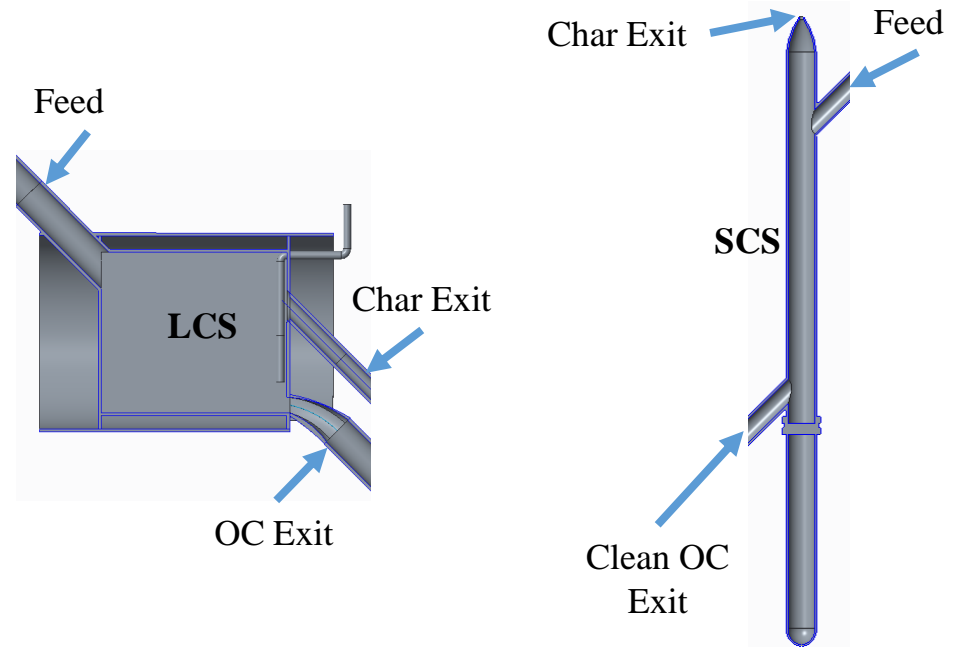
The Particle Char Separator (PCS) comprises two units:

- 1. Large Char Separator (LCS):**
Removal of coarse $> 100 \mu\text{m}$.

Principle: At low bed velocities, dissimilar solids segregate in fluid beds¹

- 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)

- Hot system:
 - Feed rate: ~ 50 kg./hr.
 - Designed as batch unit – 100 kg of solids pre-heated to desired temperature
 - Fluidizing gas: LCS – Steam/N₂; SCS – CO₂
- 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



PCS System

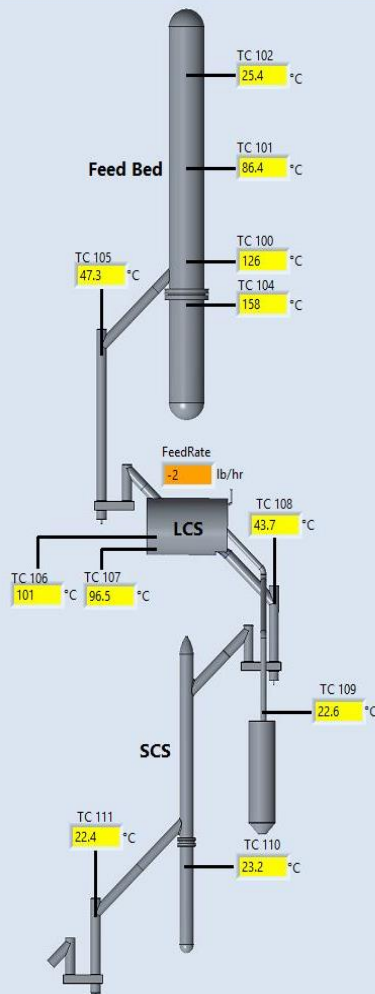
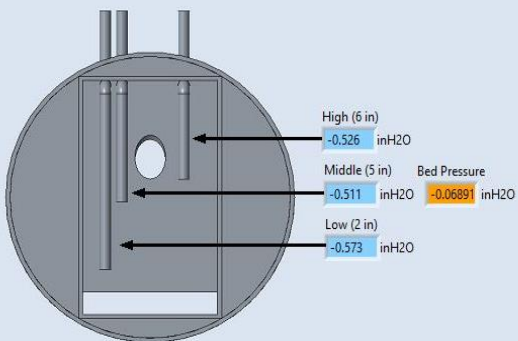
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Char Separator Bed Height



Feed Bed N2	Feedbed
0.235 slpm	0 -0.161 inH2O
LCS Pulsed	LCS
0.283 slpm	0 -0.148 inH2O
LCS Continuous	LCS
0 slpm	0 -0.892 inH2O
Fast Bed CO2	Fast Bed
0.425 slpm	0 -0.892 inH2O
Loop Seal #1 N2	Loop Seal #1
0 slpm	0 -0.613 inH2O
Loop Seal #2 N2	Loop Seal #2
0 slpm	0 -0.207 inH2O
Loop Seal #3 CO2	Loop Seal #3
0.0713 slpm	0 -0.172 inH2O



Alarm Information

Temperature



Pressure



Data Logging

Control Misc.

Using CO2?

LGA Sample Lines

- Loop Seal 1 Feed Exit
- Loop Seal 2 LCS Exit
- Loop Seal 3 SCS Exit

Air to Bypass

Pulsing Off

Vibrator



Exit Program

LCS Heater Control

Loop Seal 1

Top

129.47 °C

150 °C

Middle

79.378 °C

150 °C

Bottom

86.192 °C

150 °C

SCS

Main

37.845 °C

400 °C

Flange

37.639 °C

200 °C

Pre-Heater

25.978 °C

400 °C

Feed Bed

Main

97.807 °C

400 °C

Flange

141.40 °C

250 °C

Pre-Heater

144.76 °C

500 °C

LCS

Main

105.86 °C

400 °C

Loop Seal 2

Main

71.640 °C

150 °C

Steam Generator

Main

45.492 °C

400 °C

Exit Program

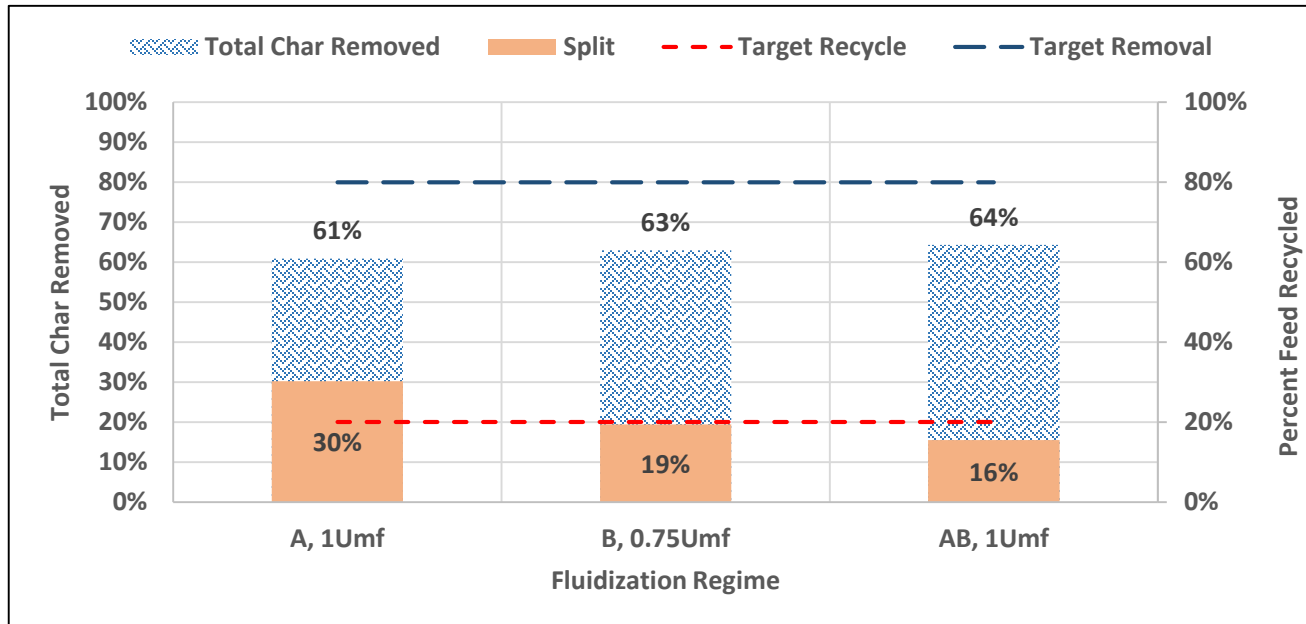
- OC = ilmenite; Activated carbon (AC) as char substitute
- Starting Char/AC distribution from GE Power's former CLC pilot unit
- To date, testing at 25°C and 300°C to identify operational issues
- Testing at 800°C after addressing operational robustness (at temperature)

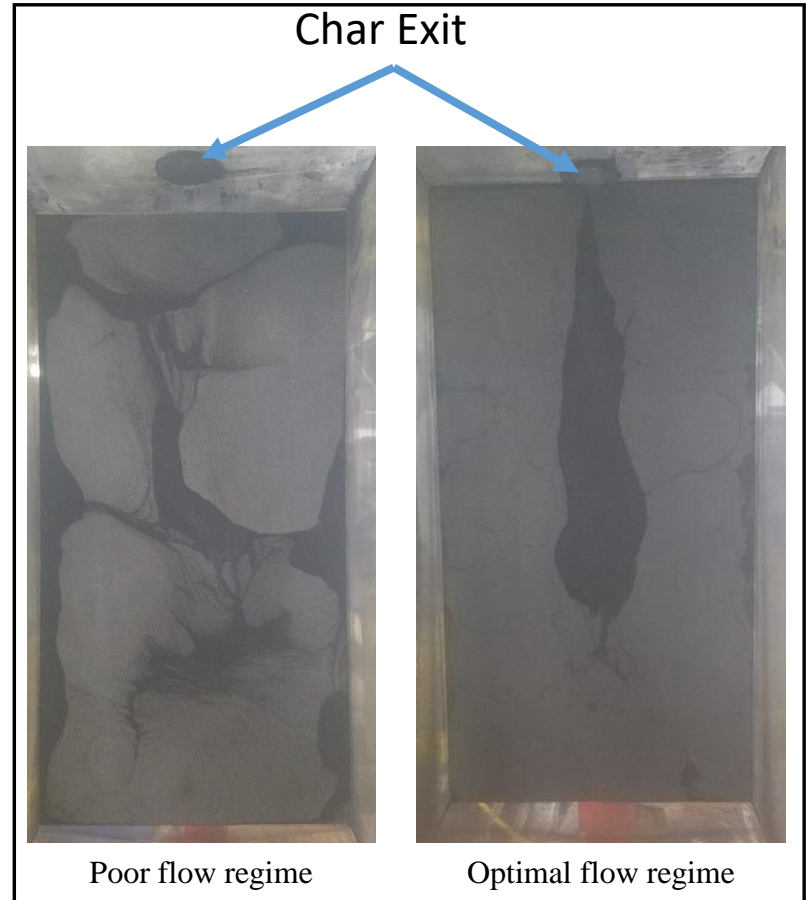
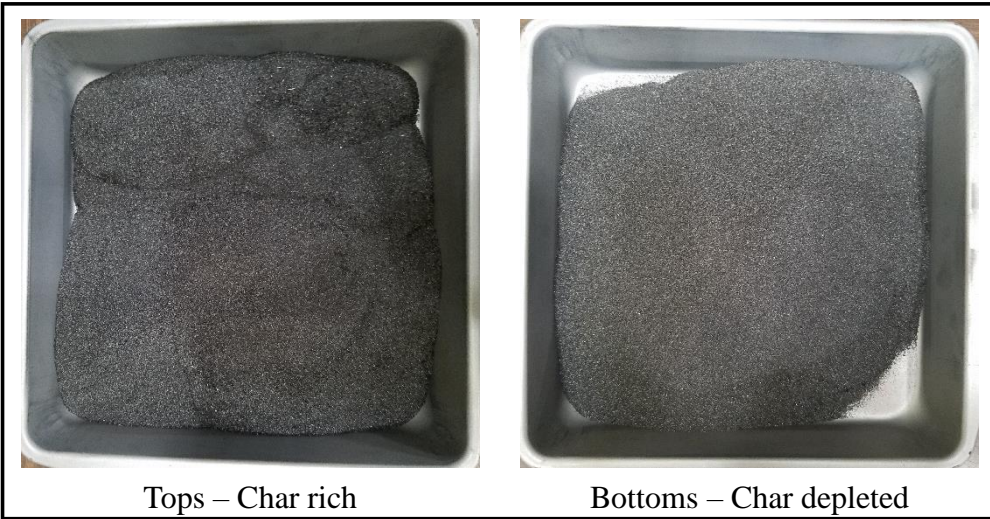
Size (µm)	OC Distribution %	AC_Distribution* %
> 297	3%	9%
297 - 149	95%	25%
149 - 105	2%	21%
105 - 74		17%
< 74		28%

	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	

- 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

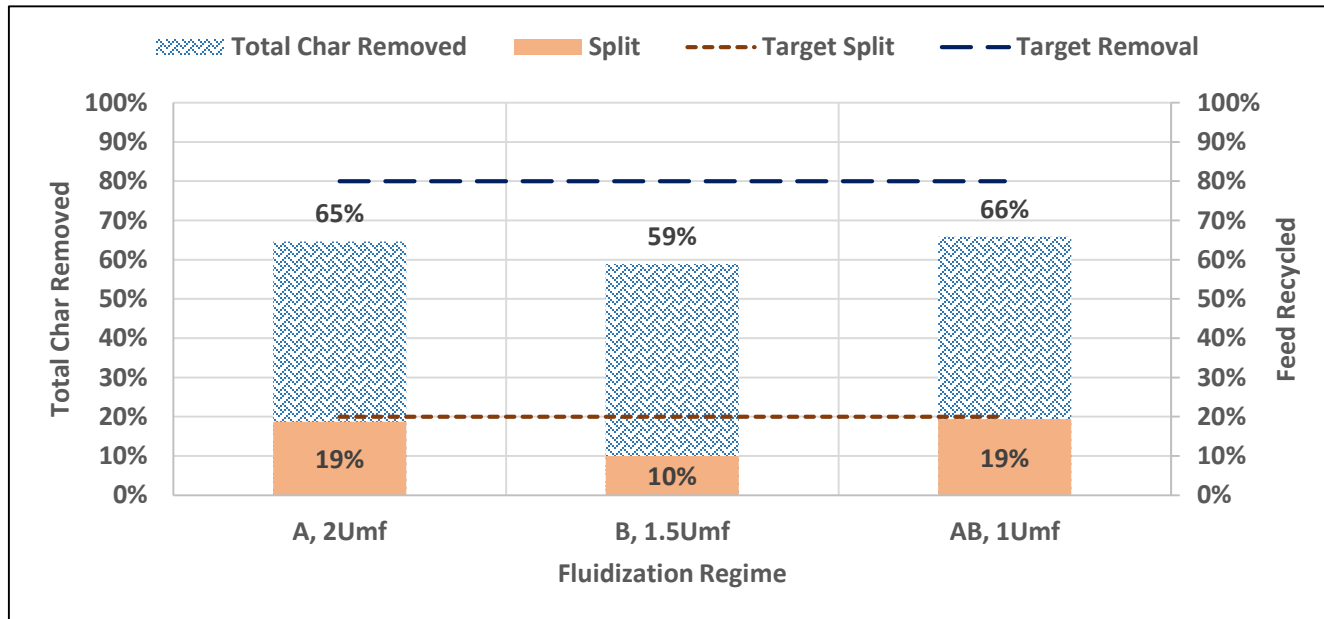




Hot Flow:

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

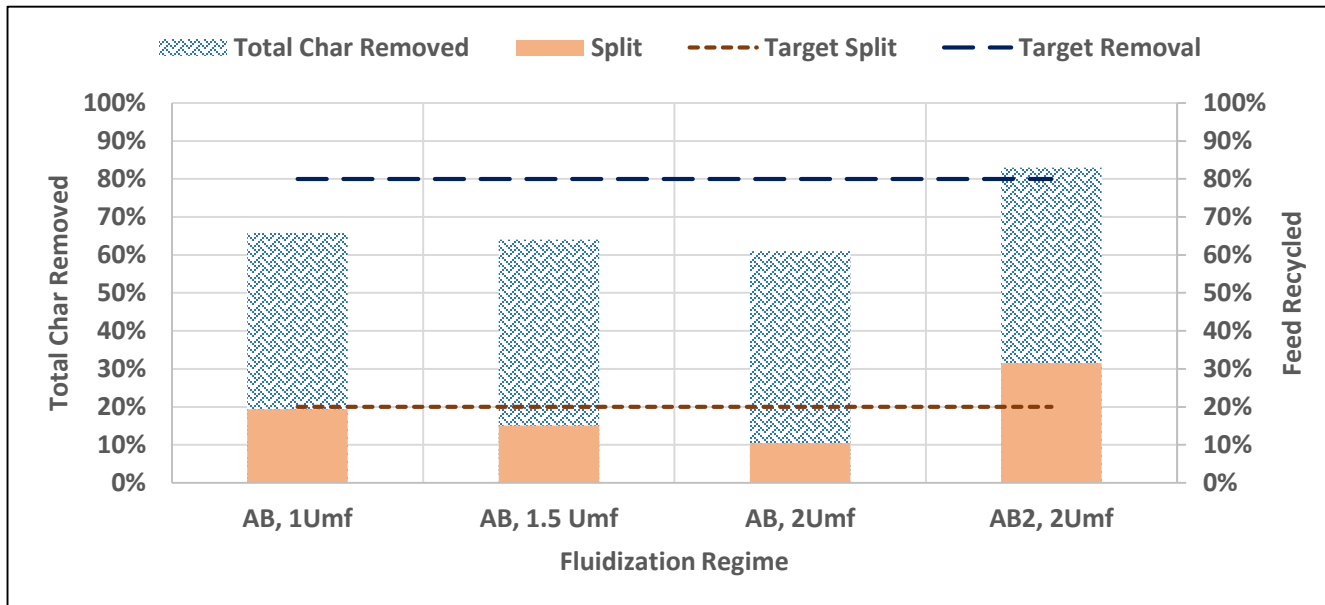
Fluidization Mode	Description
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Hot Flow:

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

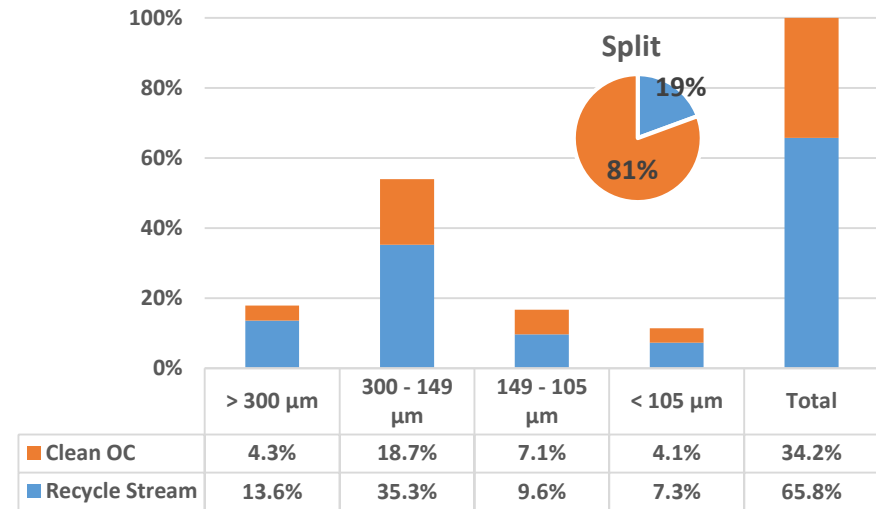
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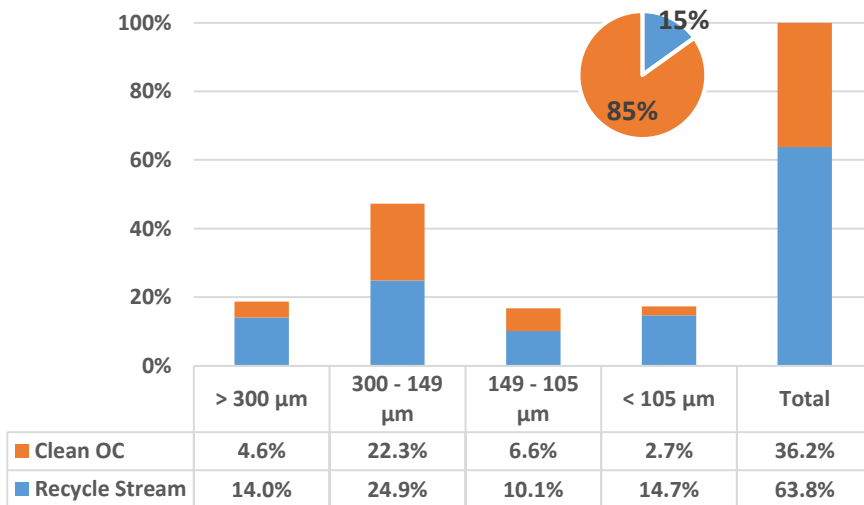
Looking at distribution of AC in streams:

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

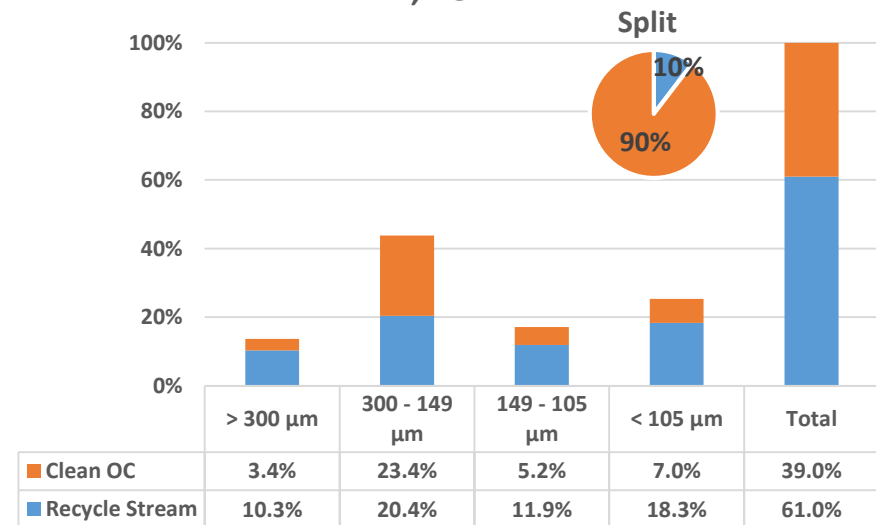
AB, 1Umf



AB, 1.5Umf



AB, 2Umf



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

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Questions?