



Strategy for Passivating Char Efficiently at the Pilot Scale

tcbiomass 2017

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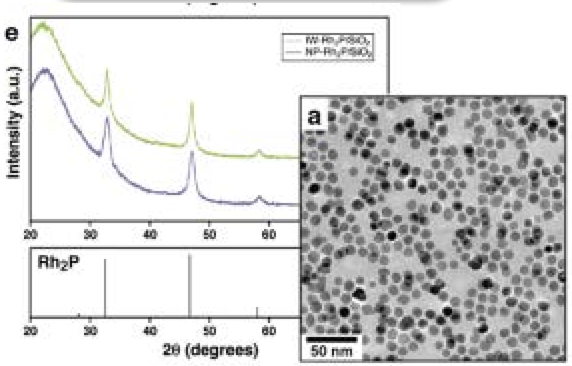
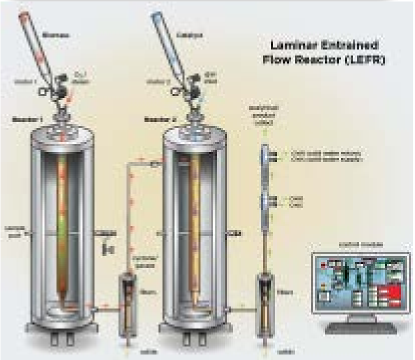
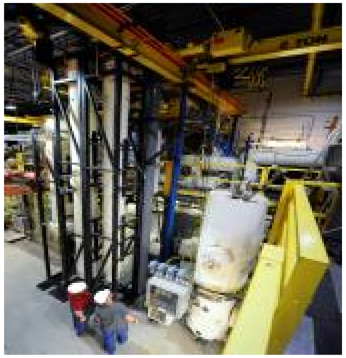
Thermochemical Conversion Research at NREL

Research at multiple scales from fundamental, to bench, to pilot scale

Fundamental Science mg-g → Catalyst Development & Testing g-kg → Scale-up & Demonstration 100’s kg





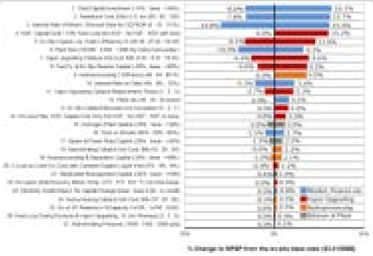


Overarching research necessary to support lab and industrial deployment

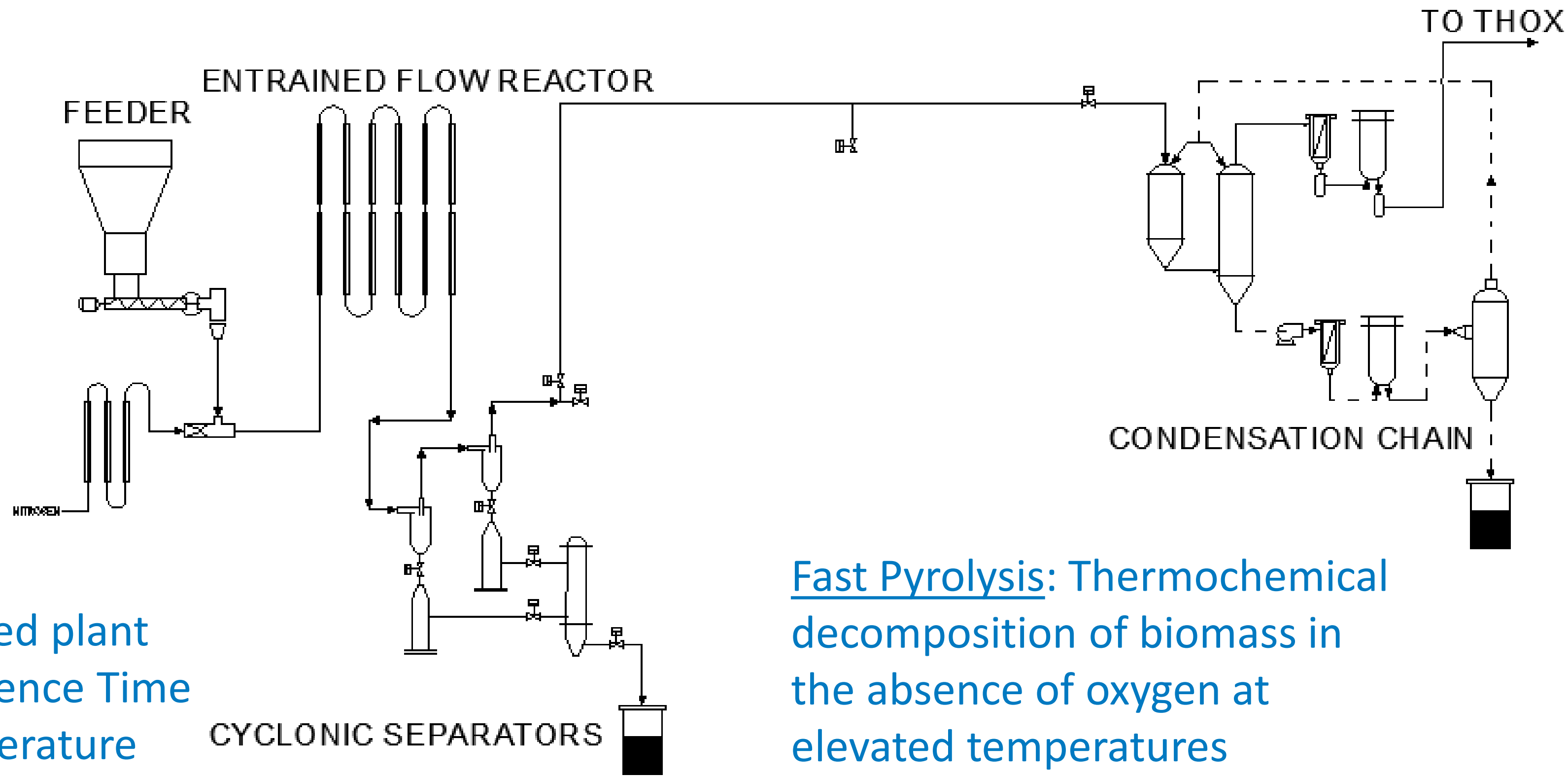
Feedstocks

Bio-Oil Characterization

Technoeconomic Analysis



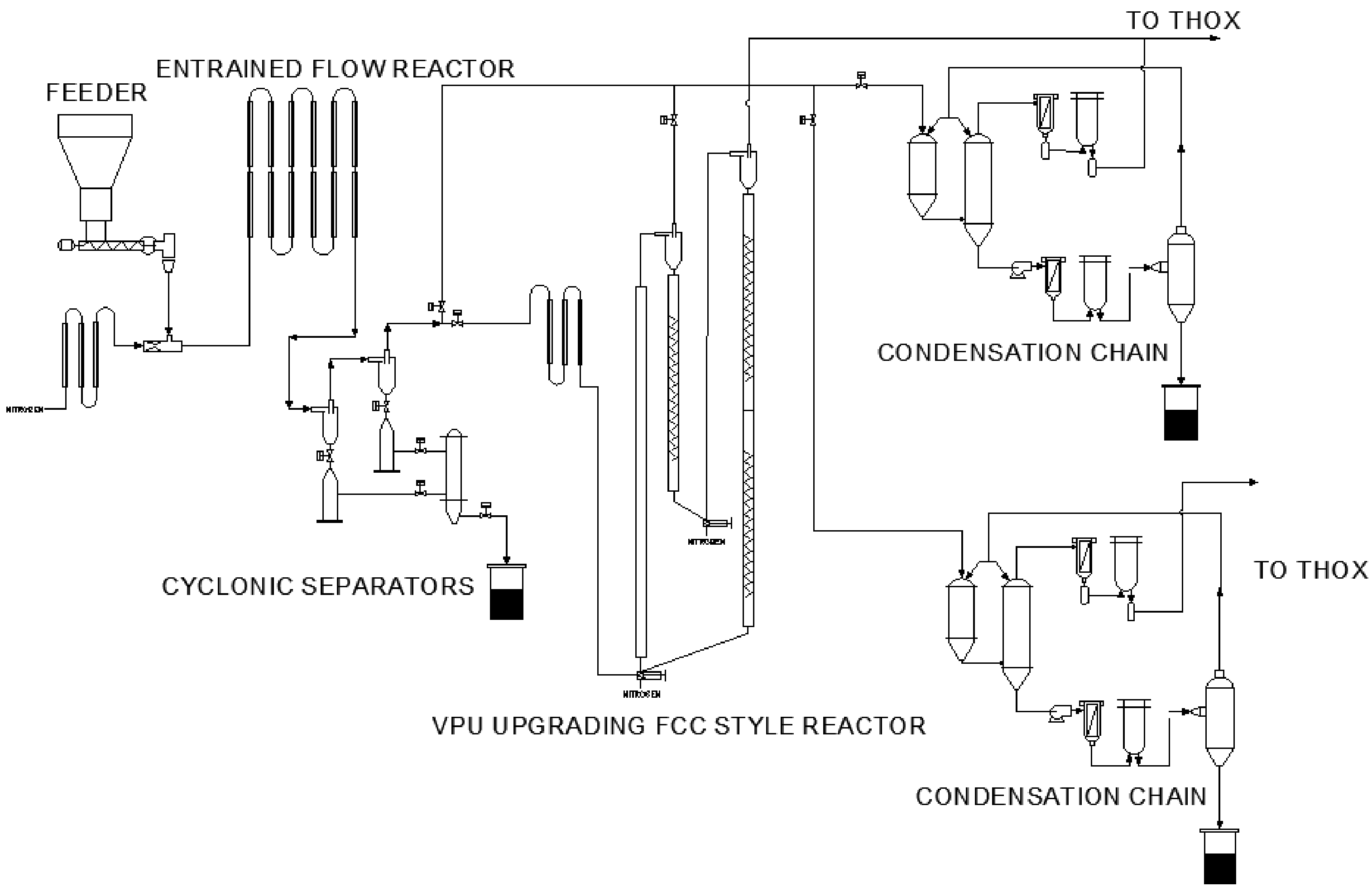
TCPDU Flow Diagram – Configured for Fast Pyrolysis



½ Ton/Day
Continuous feed plant
Variable Residence Time
Variable Temperature
Variable Flowrate
Ex-Situ CFP coming soon!

Fast Pyrolysis: Thermochemical decomposition of biomass in the absence of oxygen at elevated temperatures

TCPDU Flow Diagram – Configured for Ex-situ CFP



Catalytic Fast Pyrolysis: Fast Pyrolysis performed with catalytic upgrading of products while in the vapor phase. Catalysts target deoxygenation, hydrogenation, and improved C-C coupling.

Char- What is it?

- Char is a carbon-rich derivative of biomass that may be produced by the incomplete thermal decomposition of biomass in the absence of oxygen

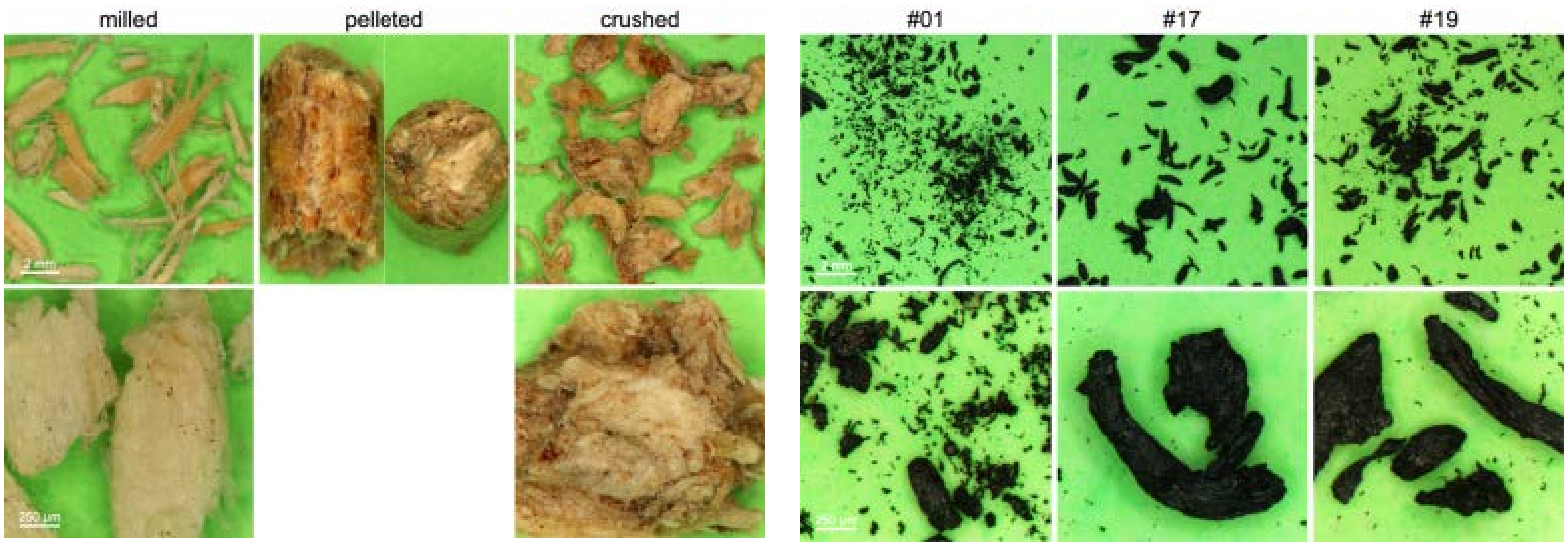


Photo Credit: Bryon Donohoe

Basic Char Properties

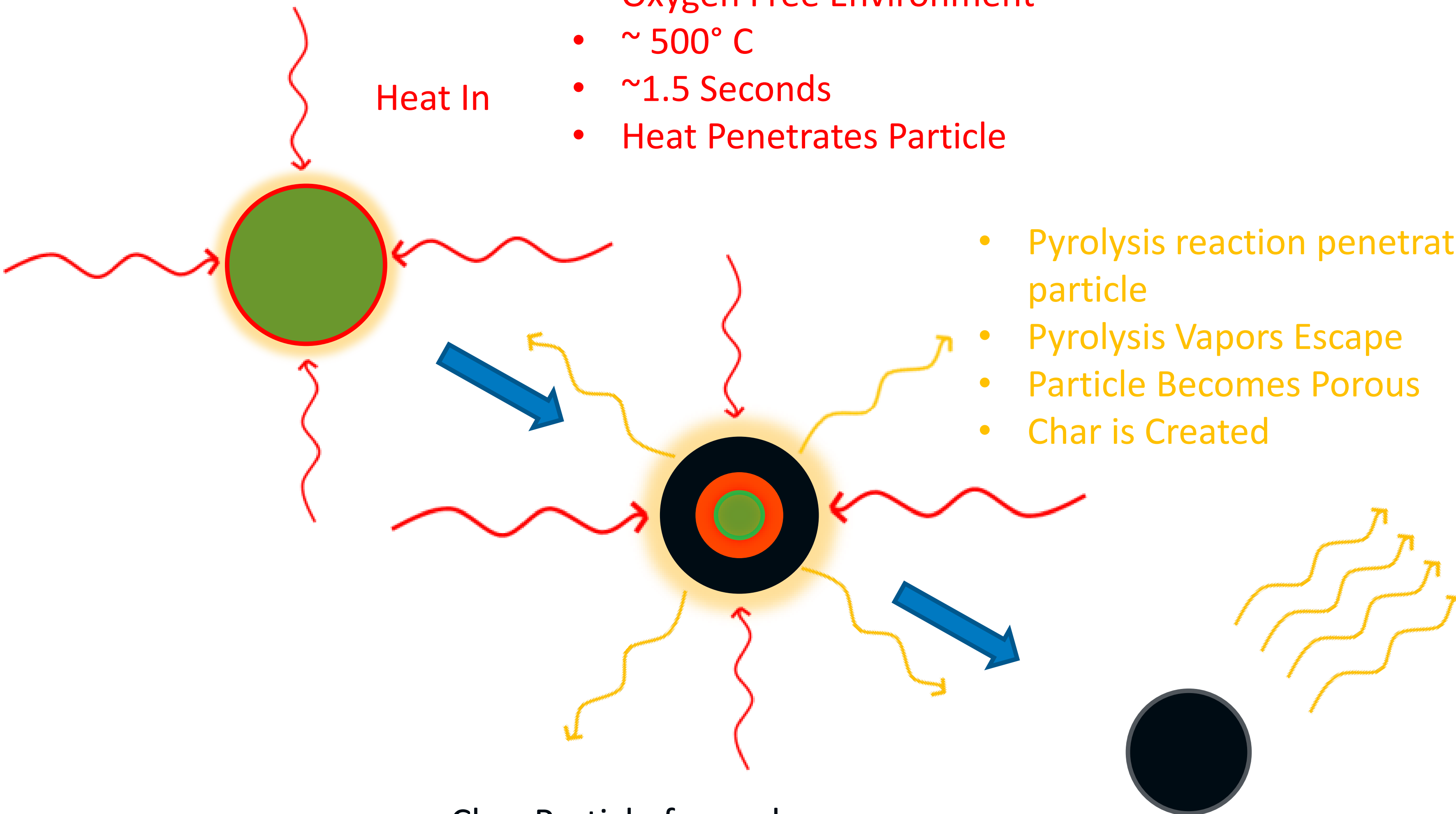
- Irregular shape
- High porosity
- Self insulating

Char properties are highly dependent on the conditions in which the char was created.

Char has many uses ranging from a boiler fuel to soil amendments. Char also has similar characteristics to activated carbon

Char Formation in Fast Pyrolysis

- Oxygen Free Environment
- ~ 500° C
- ~1.5 Seconds
- Heat Penetrates Particle



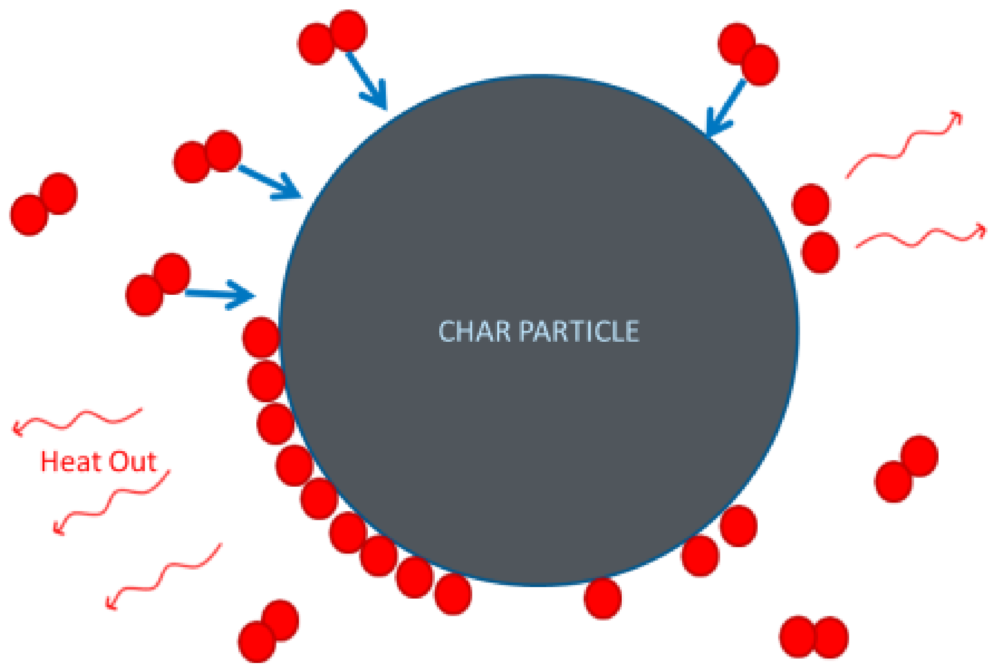
- Pyrolysis reaction penetrates into particle
- Pyrolysis Vapors Escape
- Particle Becomes Porous
- Char is Created

- Char Particle formed
- Smaller relative volume than Biomass Particle
- High surface-area-to-volume ratio

Fast pyrolysis char reacts with air

- Fast Pyrolysis creates char in Oxygen-deficient environment
- When exposed to air, char will initially react with air giving off heat
- Char is self insulating, exacerbating exotherm

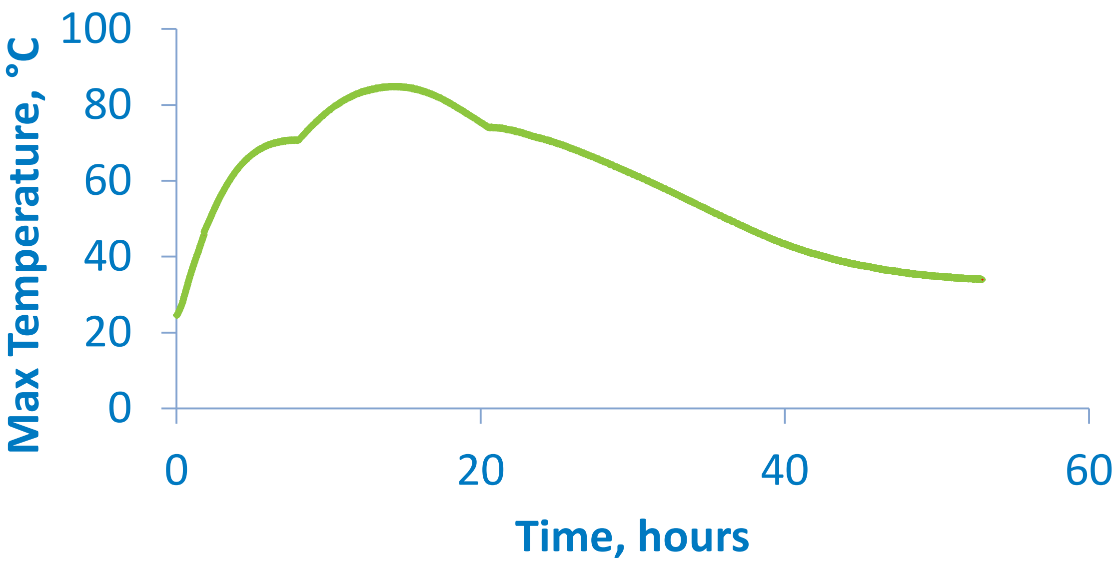
Adsorption of Oxygen and Water (Hydration) creates exotherm



Exotherm may release enough energy for temperature to increase until smoldering commences

Initial Informal Testing-No active passivation used

Drum allowed to self-passivate with lid removed

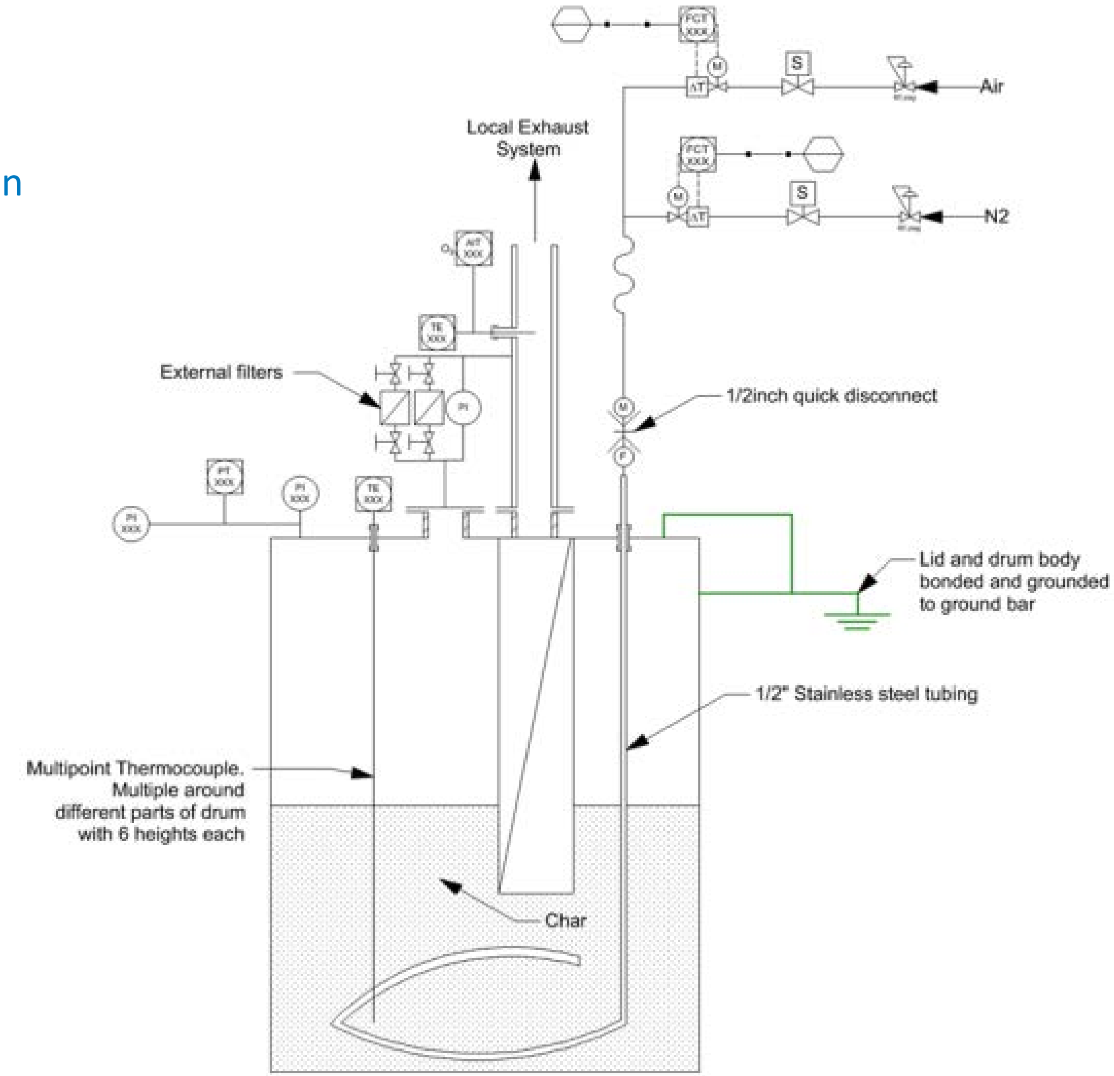


Char bed has reached smoldering temperatures and is reducing itself to ash

TCPDU Passivation Strategy

- Introduction of Oxygen in controlled manner
- Monitors Temperature at 18 points within char bed
- Uses forced convection to speed passivation process
- Monitors Oxygen content entering and exiting drum
- Monitors drum pressure
- Uses an adjustable algorithm to handle varying feedstocks
- Does not allow char bed temp to exceed preset high temperature

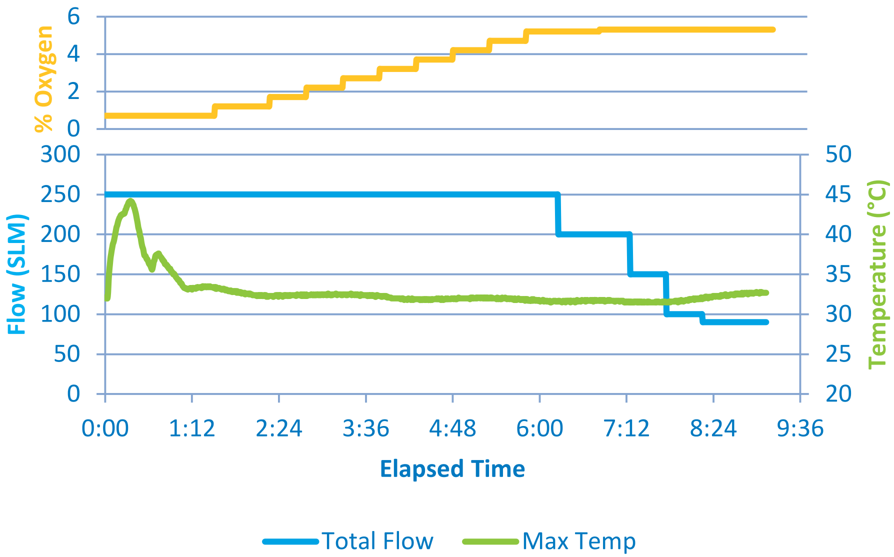
GOAL: Passivate char more quickly than we generate it in a safe manner



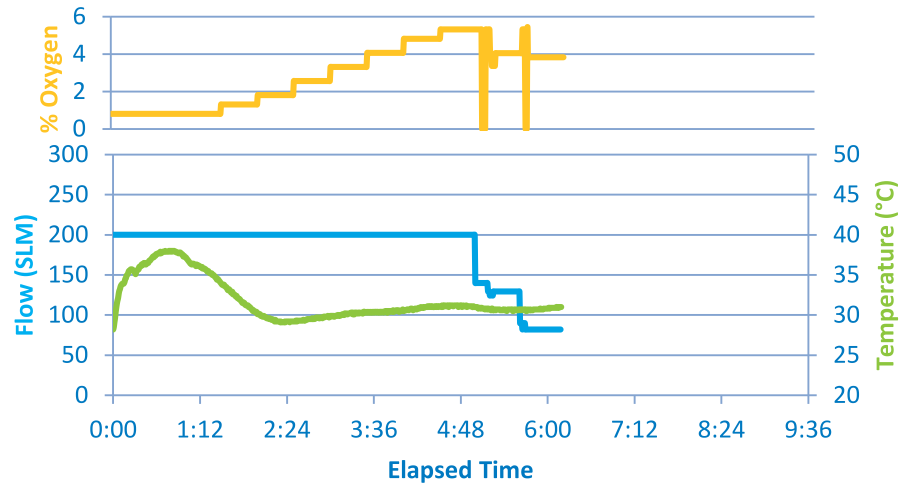
Estimated Limiting Oxygen Concentration (LOC) for pyrolysis char ~10% (Hauptmanns 2015) Testing performed has been limited to ~5.5% Oxygen by volume

Tuning Passivation Parameters-Pine

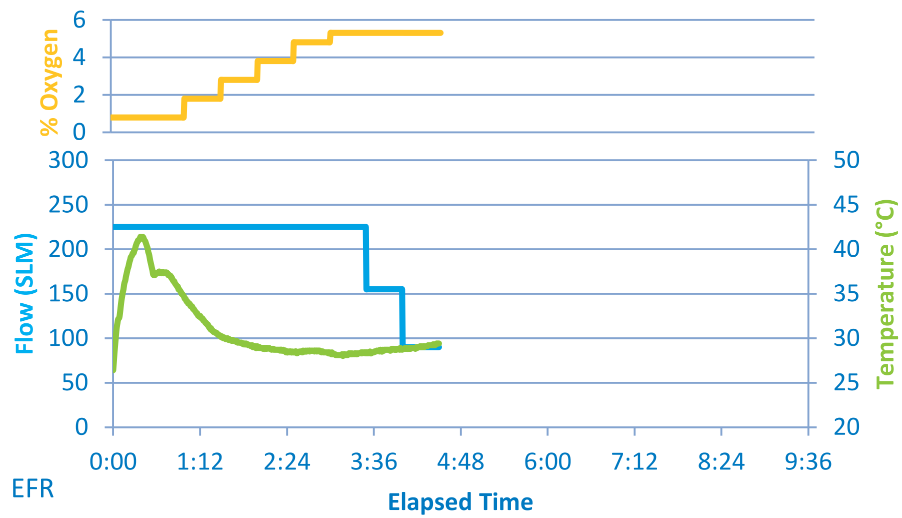
Pine Char Sample 1



Pine Char Sample 4



Pine Char Sample 14

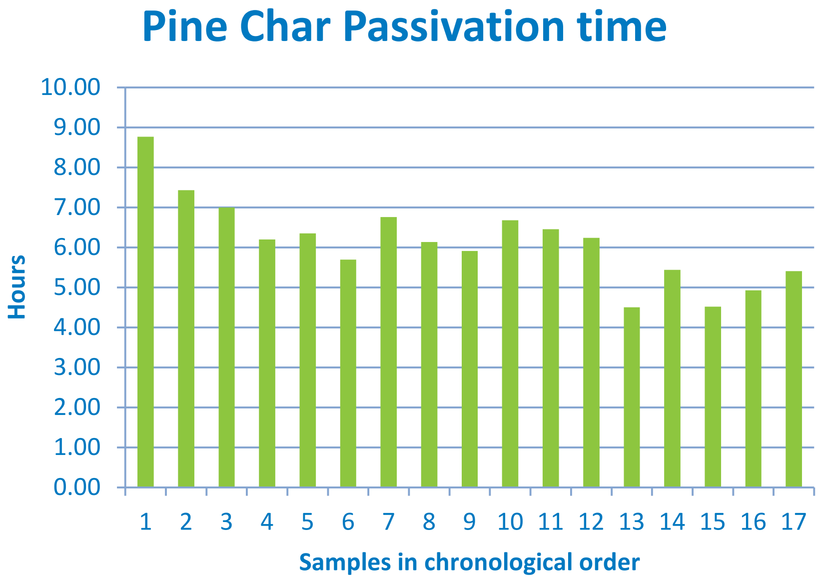


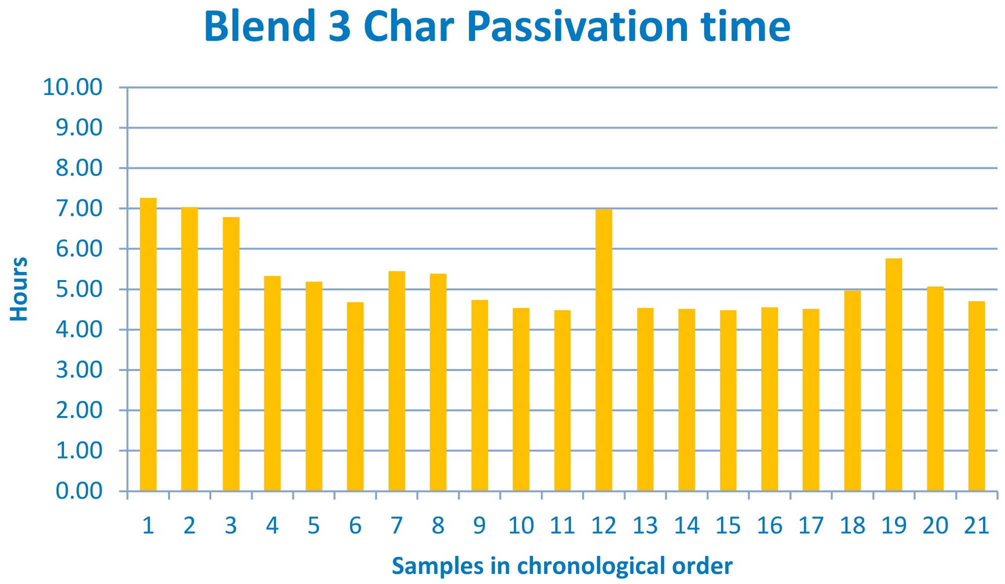
By adjusting the passivation parameters we were able to cut passivation time dramatically

Char generated at 15kg/h Biomass:15kg/h Nitrogen feed rate at 600°C, 9 zones EFR
*These conditions were optimized for oil quality targets of concurrent research

Conclusions

- Very little oxygen needed to create significant exotherm when air is introduced to char
- Char passivation duration can be greatly reduced by using an active passivation strategy-we can passivate faster than we generate
- Flowrate through Char bed appears to be a significant factor in cooling char
- Passivation parameters may be tailored to specific feedstocks and/or run conditions





Future Work

- Continue to hone passivation parameters
- Evaluate criteria for successful passivation
- Modify system to increase gas flow to drum
- Explore higher temp containment options for more expedient passivation
- Evaluate filters for higher flow regimes
- Lock parameters and correlate to sample weight to evaluate scaling potential
- Measure/Add humidity to passivation to evaluate hydration reaction effects

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Questions?

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