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Oxygen adsorption and self-heating of fast pyrolysis biochar at the pilot scale

Biochar 2018

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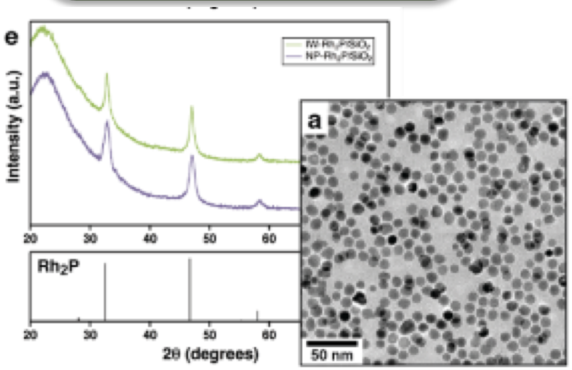
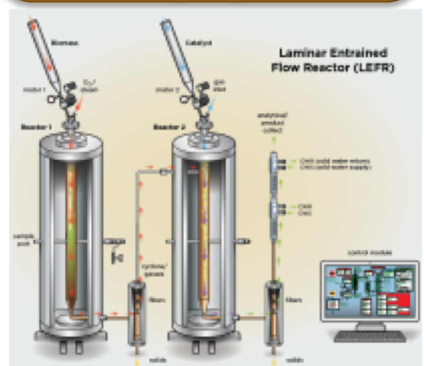
Thermochemical Conversion Research at NREL

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



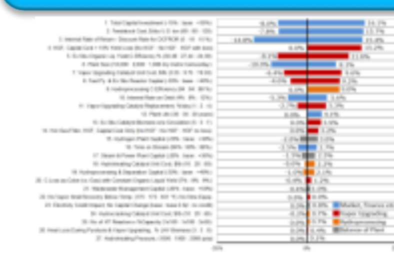


Overarching research necessary to support lab and industrial deployment

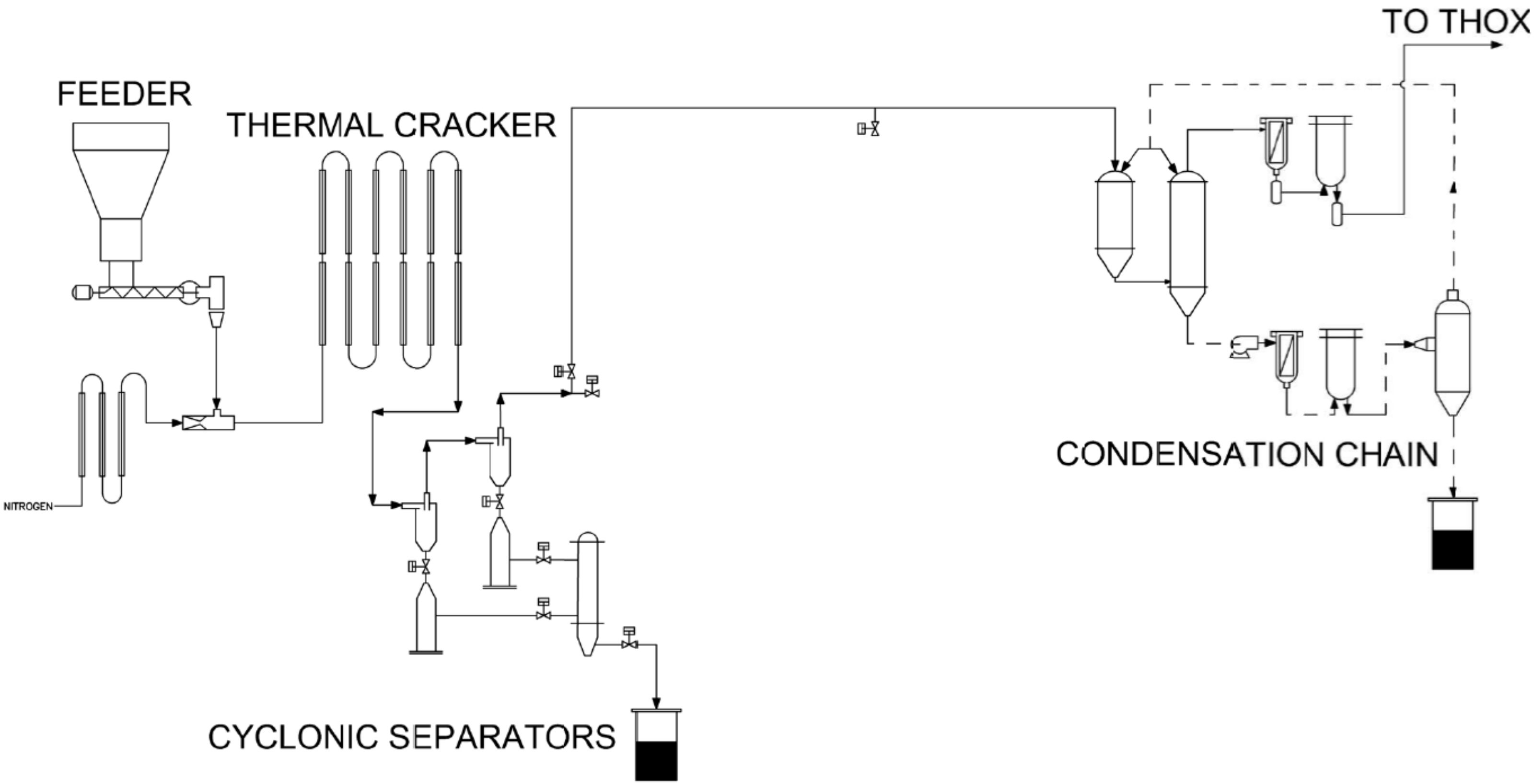
Feedstocks

Bio-Oil Characterization

Technoeconomic Analysis



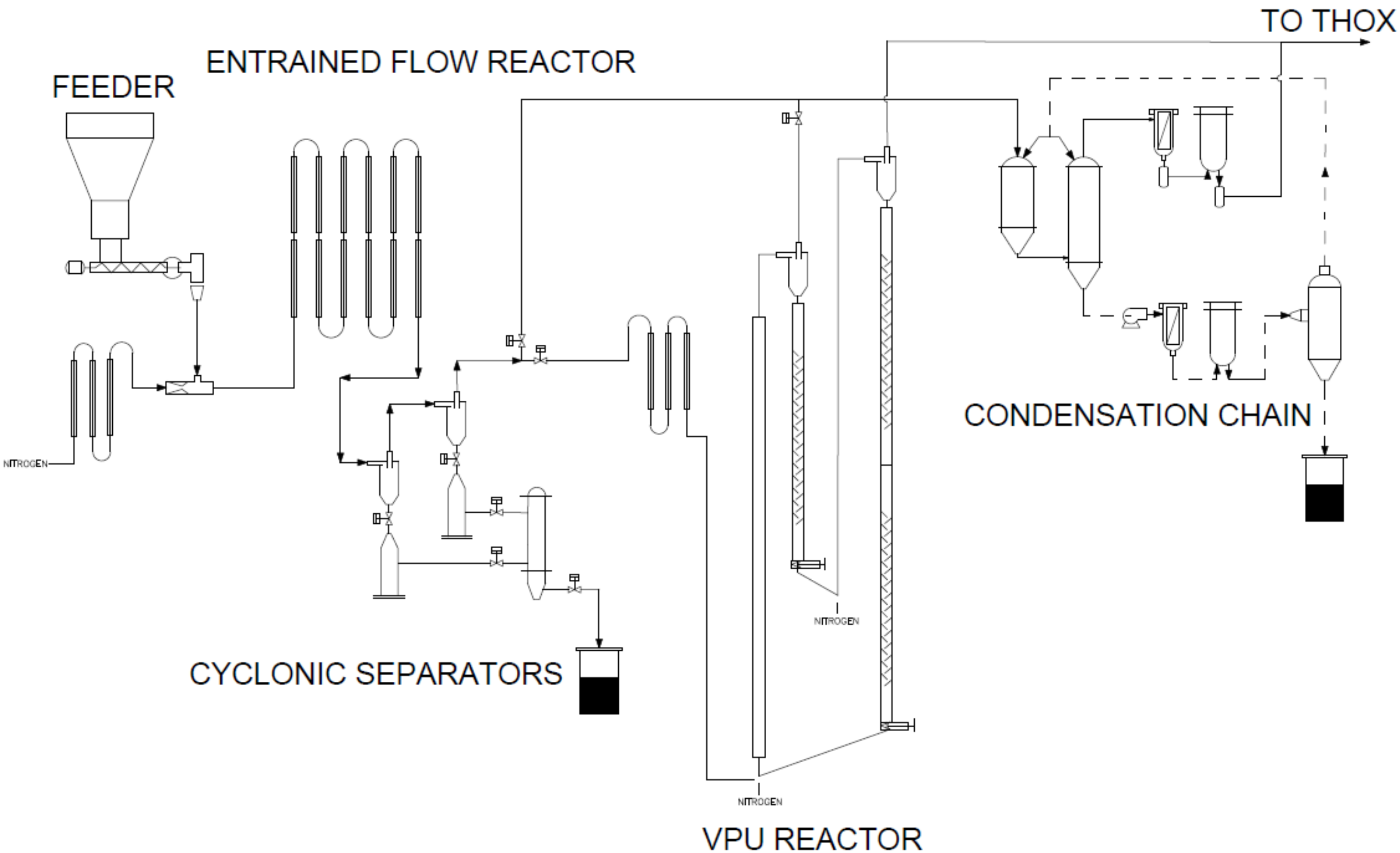
TCPDU Flow Diagram – Configured for Fast Pyrolysis



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

<u>Fast Pyrolysis</u>: Thermochemical decomposition of biomass in the absence of oxygen at elevated temperatures in a short period of time

TCPDU Flow Diagram – Configured for Ex-situ CFP



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

Feedstocks used for fast pyrolysis

}~2mm→
}~200µm→

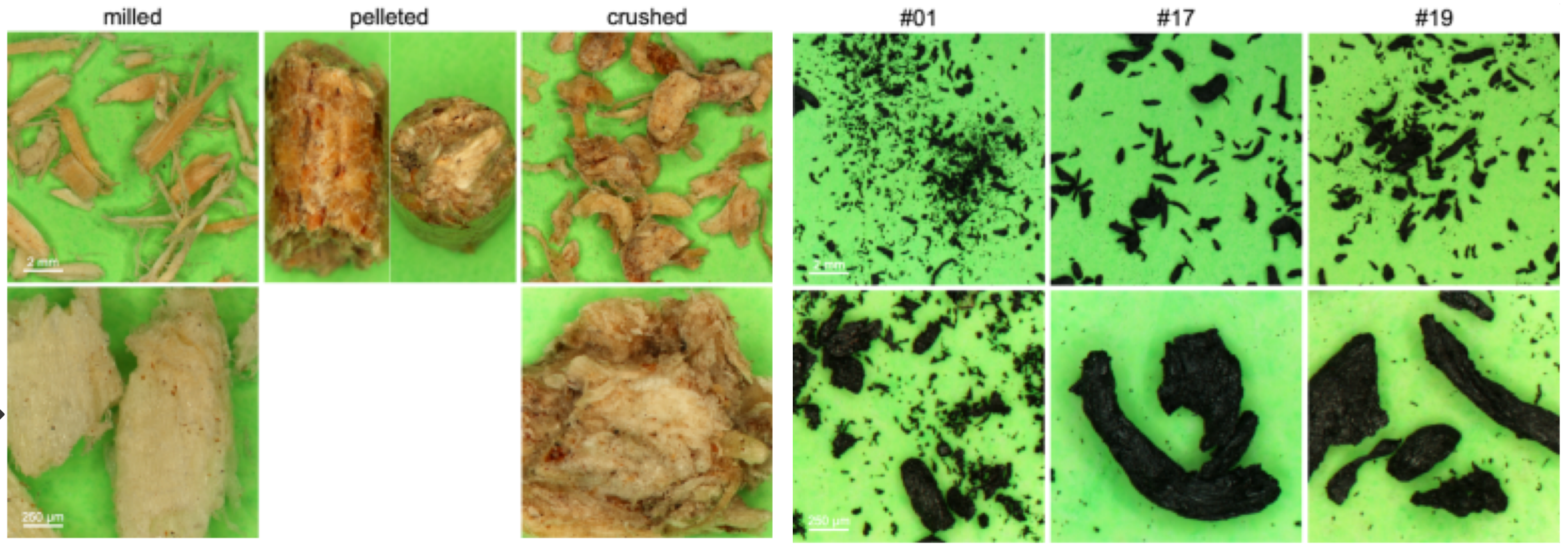


Photo Credit: Bryon Donohoe

Small feed particles, usually <2mm
Pine or forestry residues
3-12% ash content

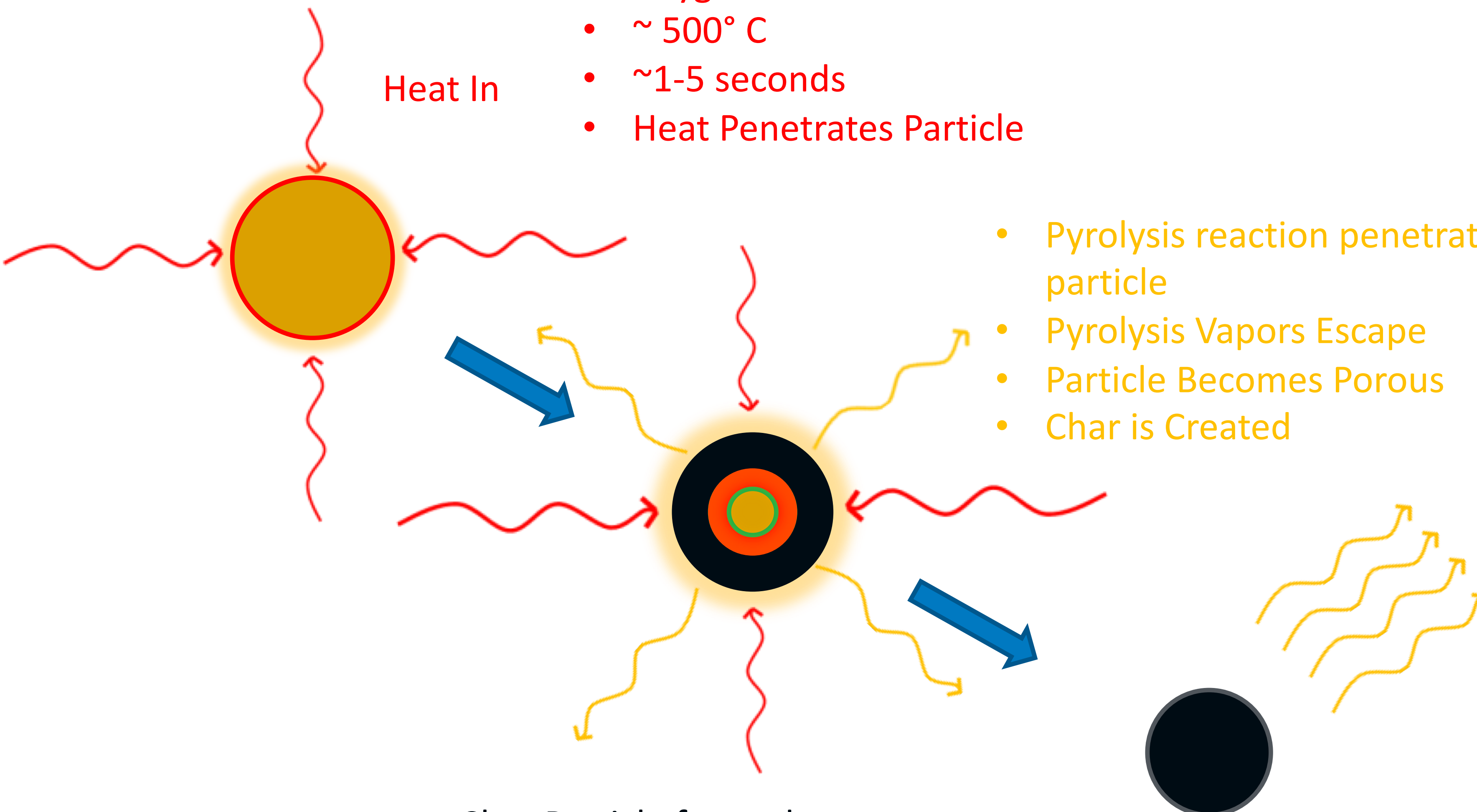
Char particles reduced in size, but similar in shape to feed particles

Char properties are highly dependent on the feedstock and conditions of creation

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

Char Formation in Fast Pyrolysis

- Oxygen Free Environment
- ~ 500° C
- ~1-5 seconds
- Heat Penetrates Particle

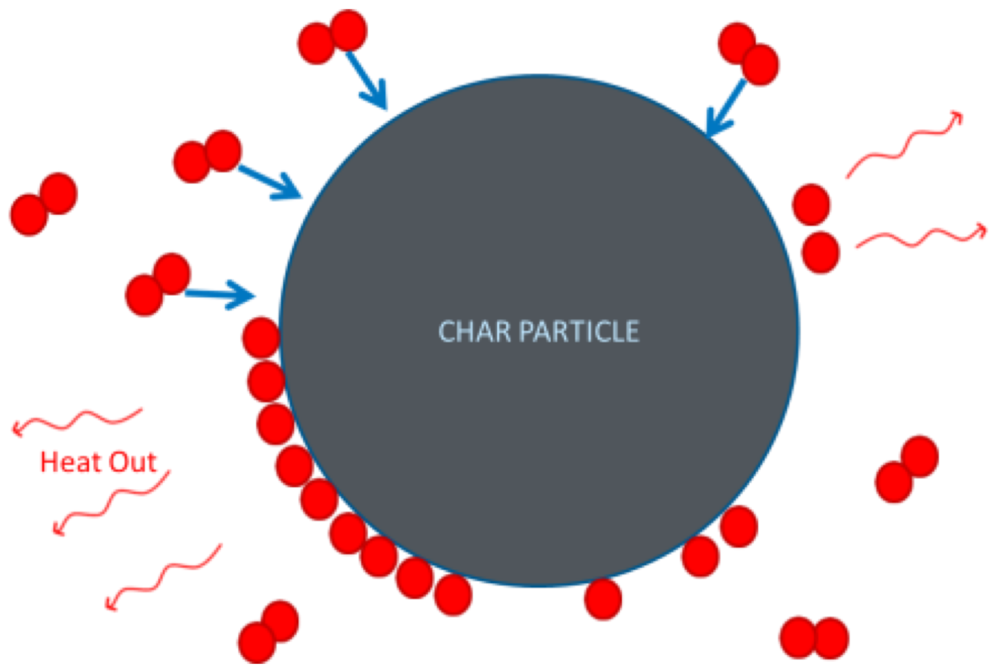


- Pyrolysis reaction penetrates into particle
- Pyrolysis Vapors Escape
- Particle Becomes Porous
- Char is Created

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

Fast pyrolysis char reacts with air

Adsorption of Oxygen and Water (Hydration) creates exotherm



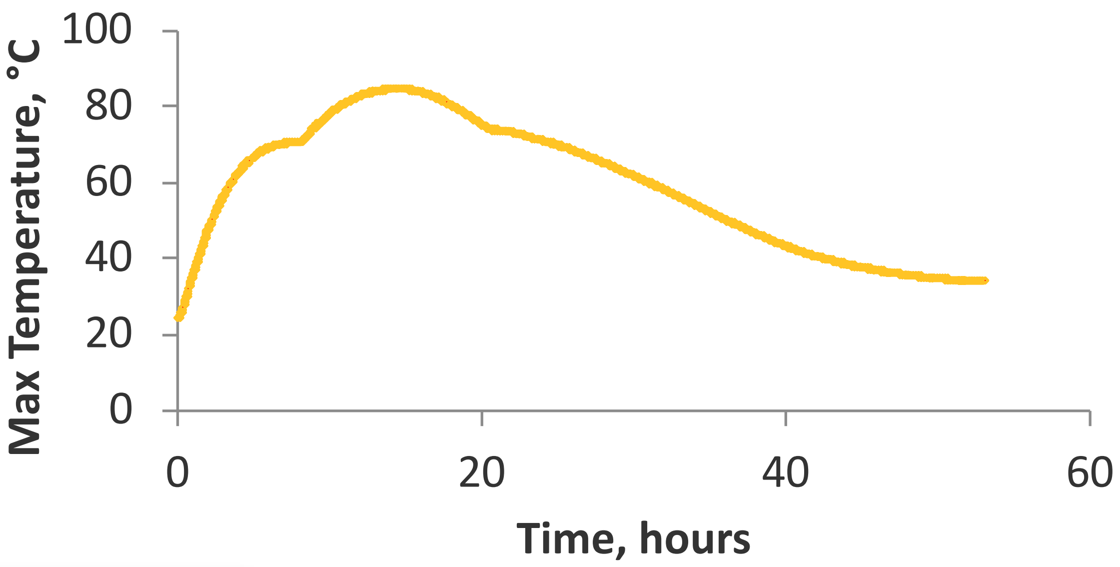
- Fast Pyrolysis creates char in Oxygen-deficient environment
- When exposed to air, char will initially react with air giving off heat
- Char is self insulating, exacerbating exotherm

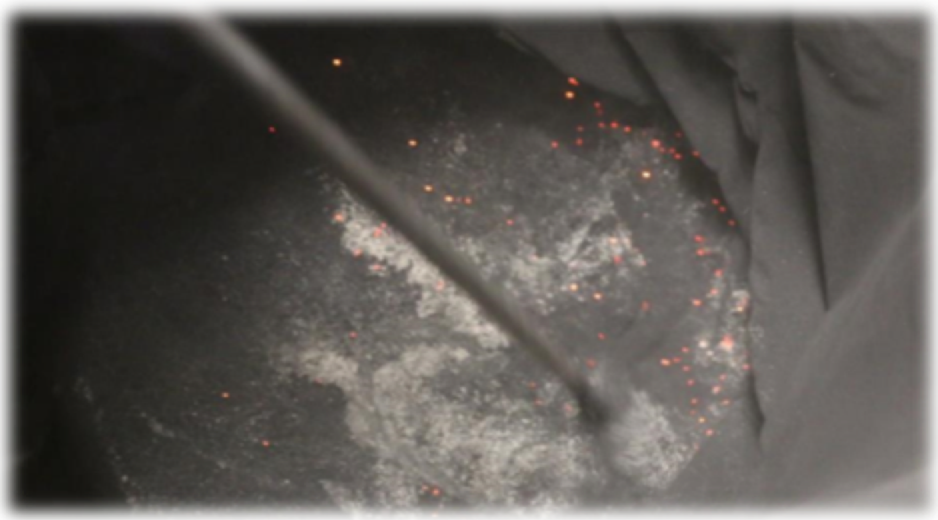
Exotherm may release enough energy for temperature to increase until smoldering commences

Initial Informal Testing-Char exposed to atmospheric air

Char reached high temperatures and took days to passivate

Drum allowed to self-passivate with lid removed



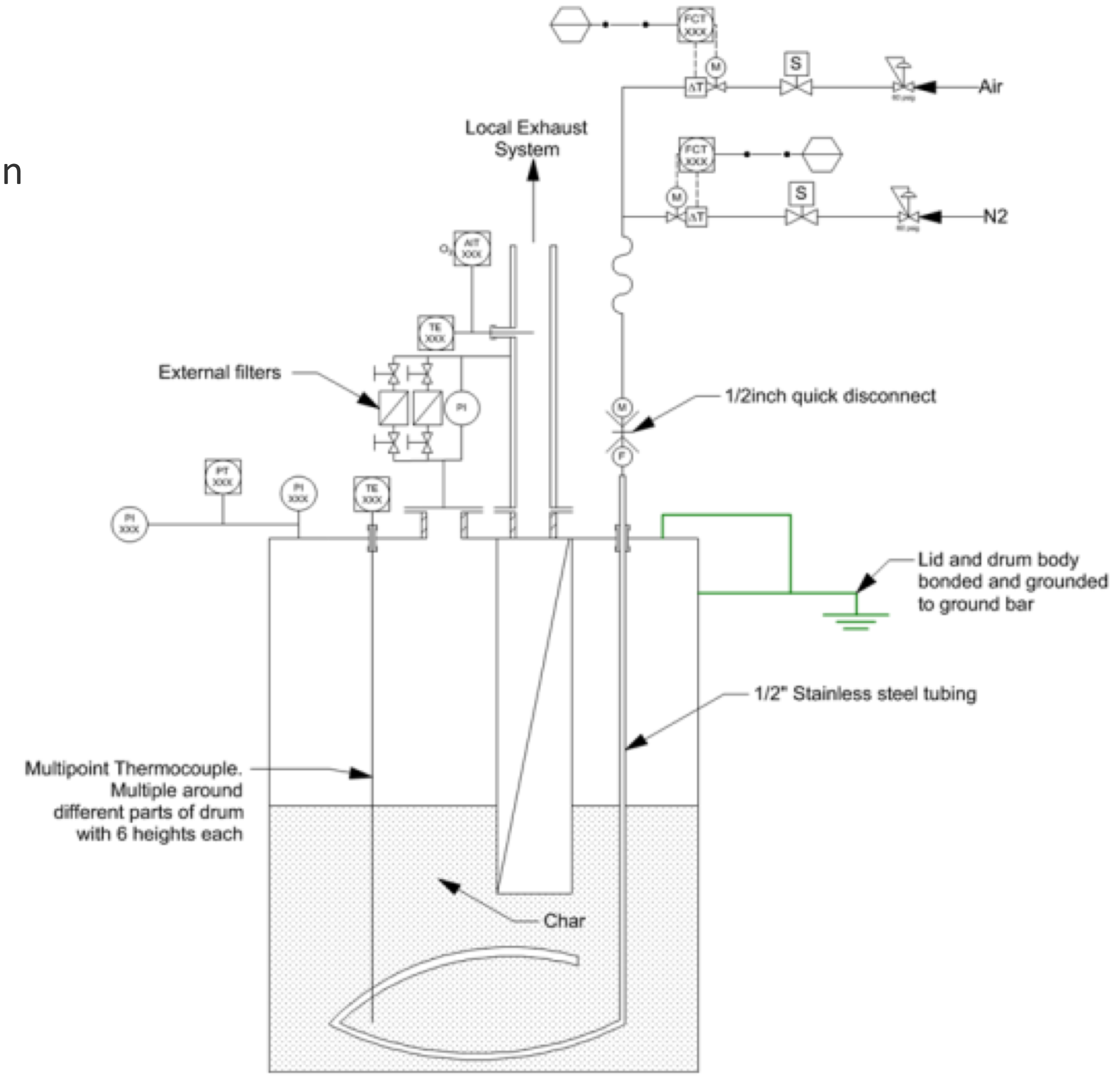


Char bed has reached smoldering temperatures and is reducing itself to ash

TCPDU Passivation Strategy

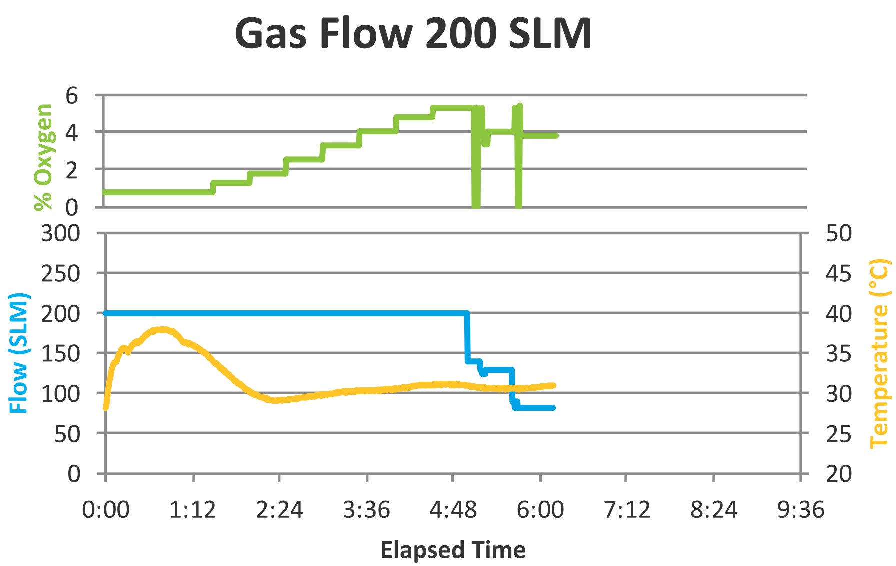
- Introduction of Oxygen in controlled manner
- Monitors Temperature at 18 points within char bed
- Uses forced convection to speed passivation process
- Monitors Oxygen content entering and exiting drum
- Monitors drum pressure
- Uses an adjustable algorithm to handle varying feedstocks
- Does not allow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

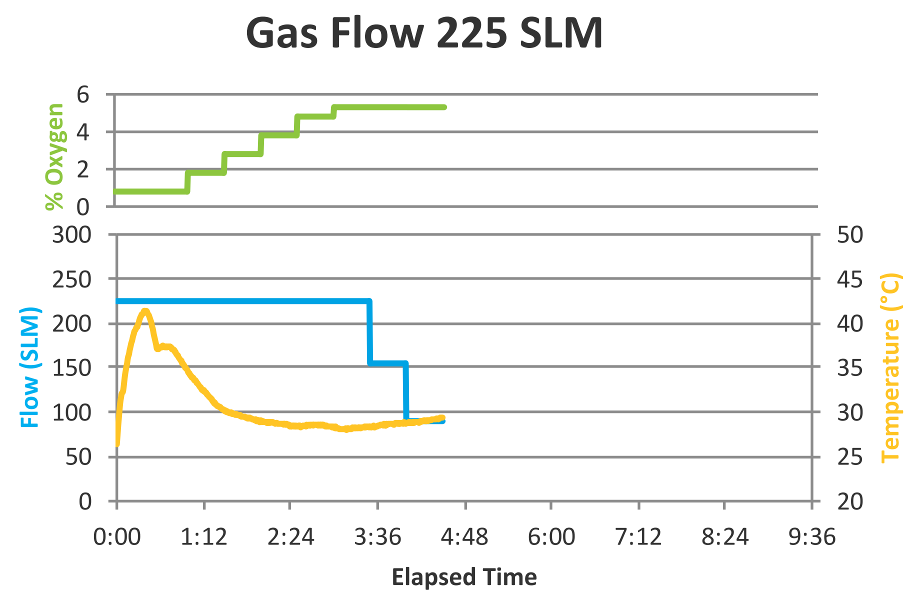
GOAL: Passivate char safely, efficiently, and maintain char properties



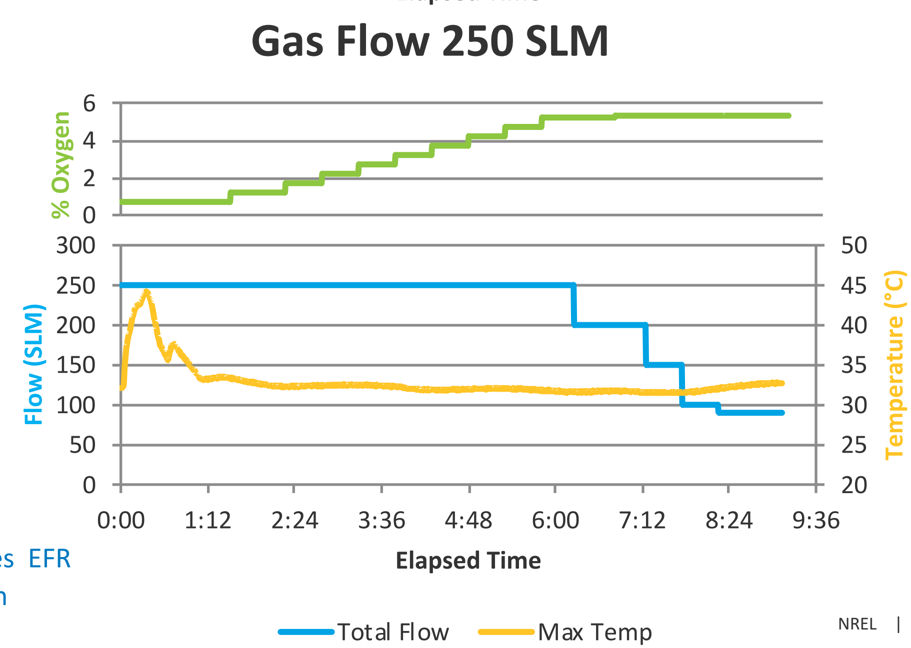
Estimated Limiting Oxygen Concentration (LOC) for pyrolysis char ~10% (Hauptmanns 2015) Testing performed has been limited to ~5.5% Oxygen by volume

Tuning Passivation Parameters-Pine





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



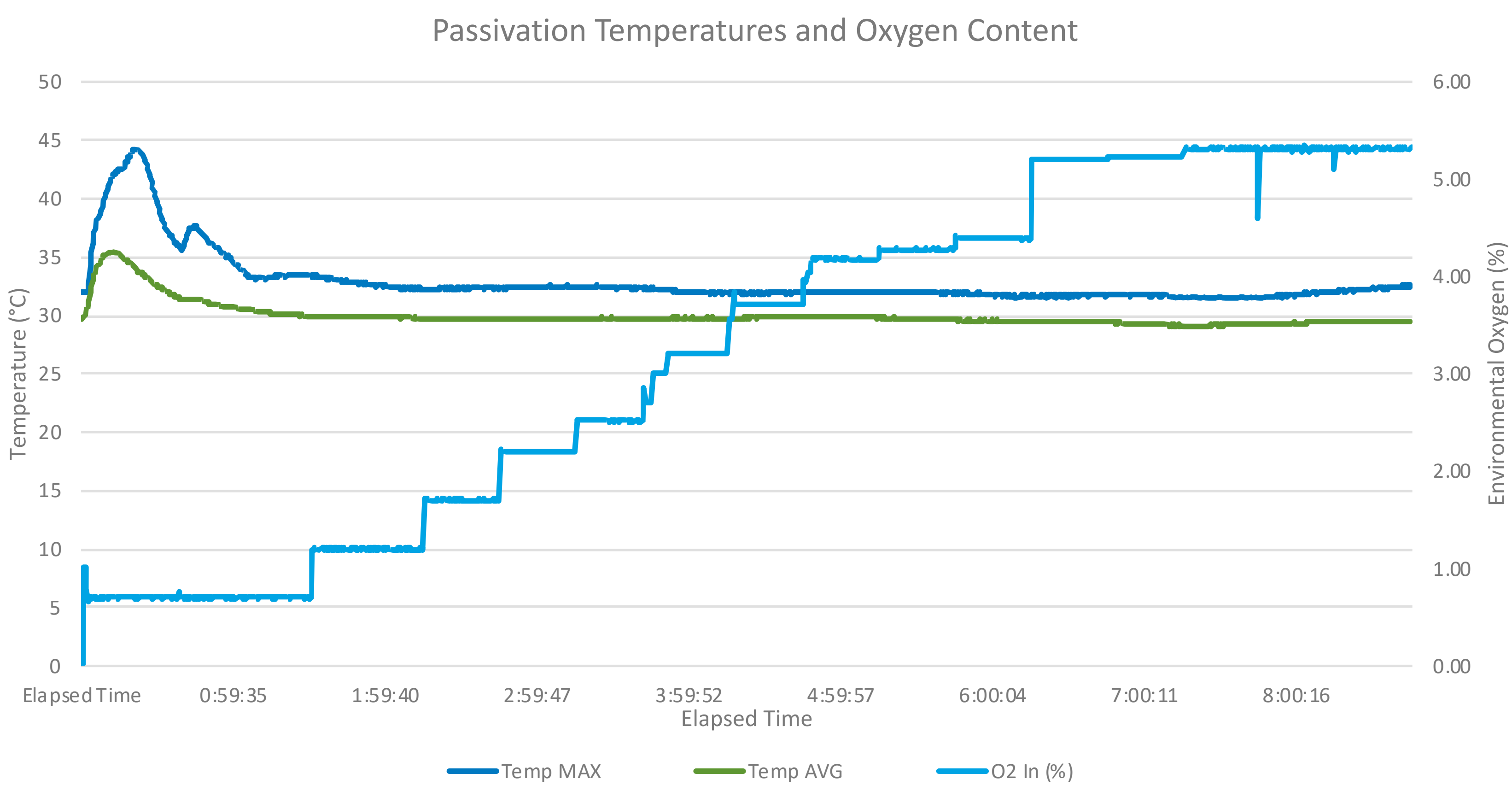
Char generated at 15kg/h Biomass:15kg/h Nitrogen feed rate at 500°C, 9 zones EFR

*These conditions were optimized for oil quality targets of concurrent research

Evaluating Passivation Criteria

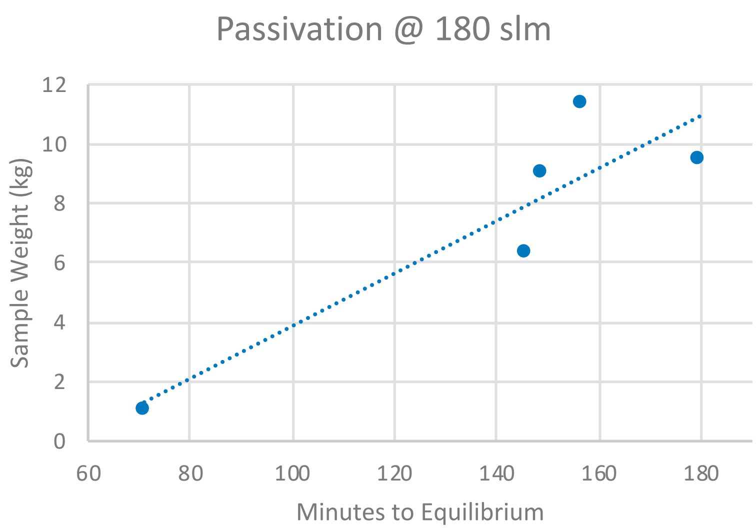
Passivation strategy lasts much longer than exotherm

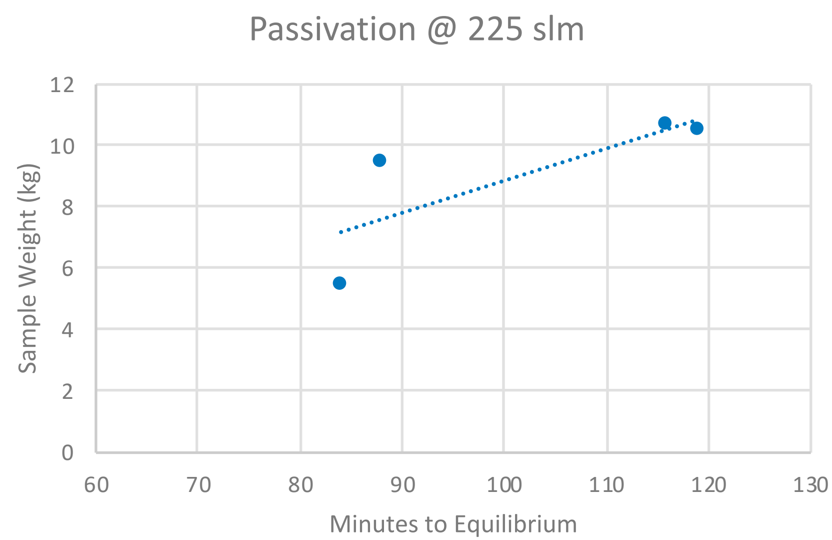
- Environmental Oxygen 5.5% Maximum
- Oxygen uptake at equilibrium
- No appreciable temperature rise



Conclusions

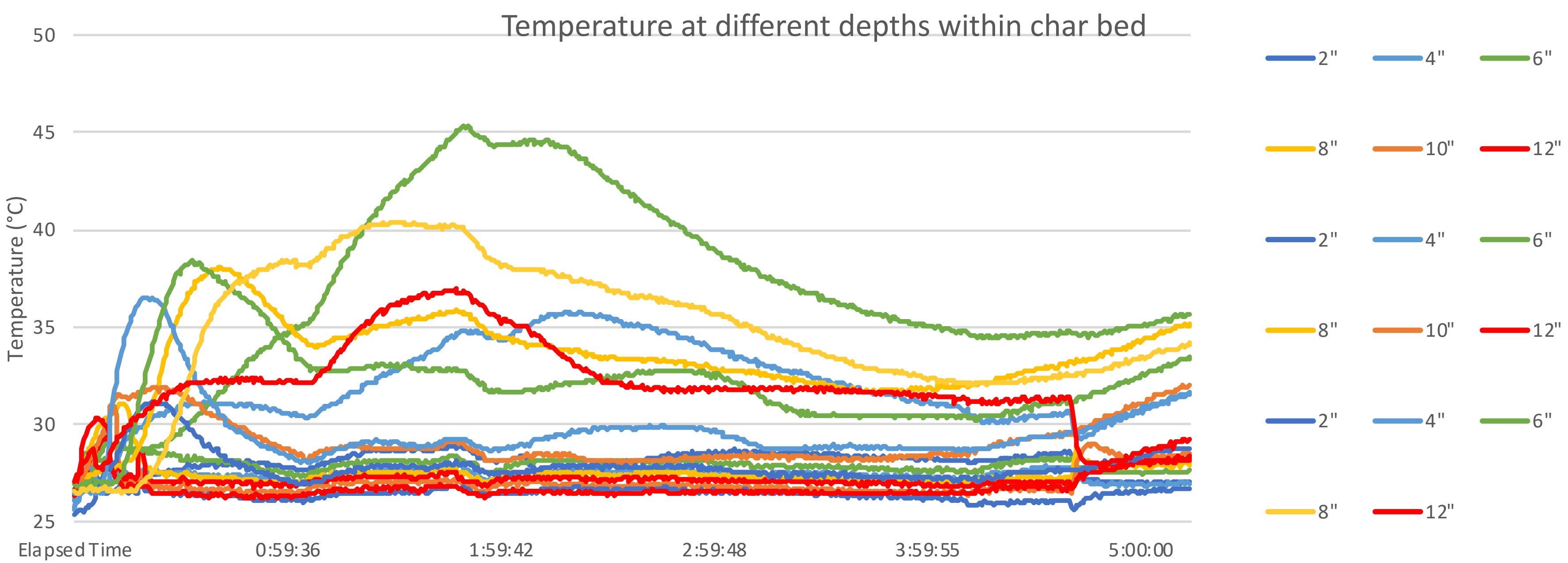
- Very little oxygen needed to create significant exotherm when air is introduced to char
- Char passivation duration can be greatly reduced by using an active passivation strategy-we can passivate faster than we generate
- Passivation parameters may be tailored to specific feedstocks and/or run conditions





Challenges/Future Work

- Exotherm moves through sample inconsistently
- Sparger clogging reduces expected flows
- Filter clogging reduces expected flows and changes reaction pressure
- Maximum temperature parameter difficult to maintain effectively
- Scalability – Current system difficult to scale effectively
- Add humidity to assess hydration effects



Acknowledgements

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Questions?

Thank you

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