CRITICAL CHARACTERISTICS OF WOOD-BASED BIOCHAR CORRELATED WITH THE PYROLYSIS PROCESS IN AN INDIRECT KILN

MICHAEL EIDGE, ALEX EBBEN | FEECO INTERNATIONAL

PRESENTATION OVERVIEW

- Problem statement
- Process overview
- Experimental retention time measurement
- Biochar activation process overview
- Results & Analysis
- Conclusions

PROBLEM STATEMENT

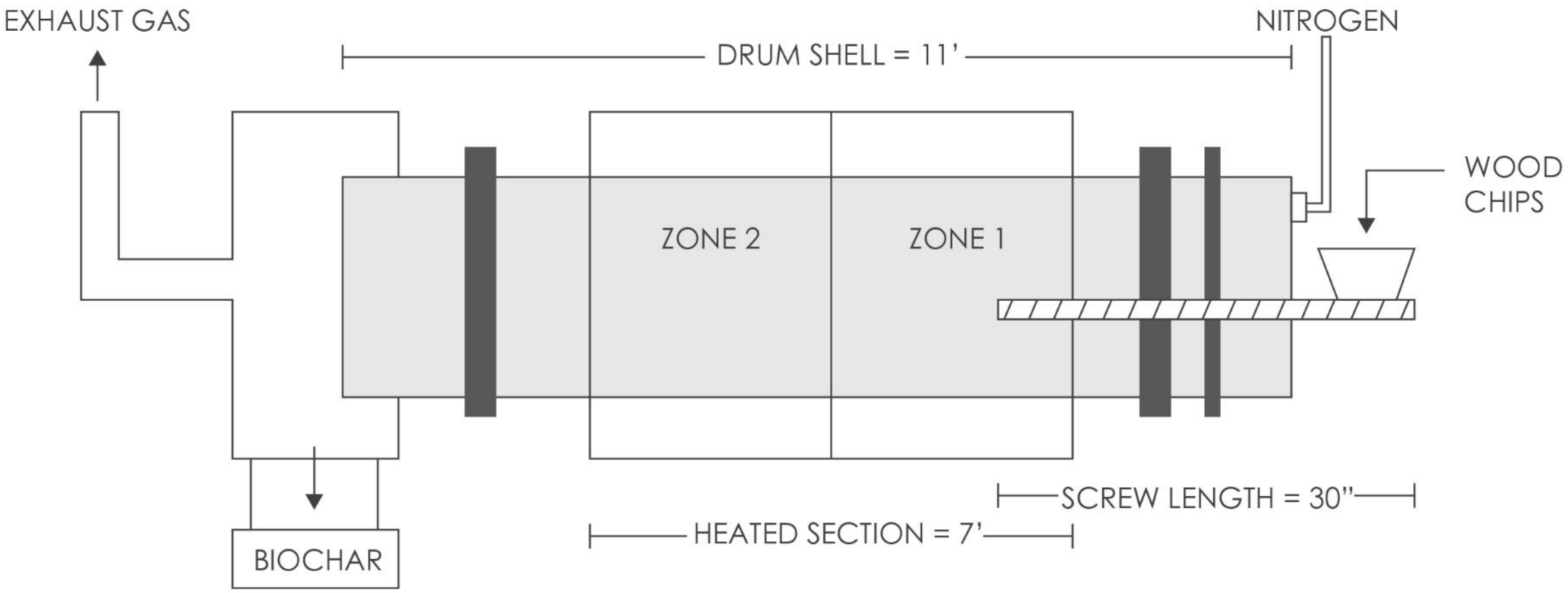
- Inconsistency in source material for biochar
- Inconsistency in production settings in order to achieve desired product quality
  - Carbon content
  - Iodine number
  - Percent yield
  - Heating value
  - Bulk density

PROCESS OVERVIEW

FEECO INDIRECT PILOT KILN:

- 6.5" Dia. x 84" Long (0.17 x 2.1m)
- Capable of operating at 400 – 1,800° F (204 – 982° C)
- Two electrically heated zones
- Thermocouples in each zone
- Adjustable speed and slope for altering bed profile and residence time

PROCESS OVERVIEW



EXPERIMENTAL RETENTION TIME MEASUREMENT

- Used equations to predict retention time
  - Perry's Chemical Engineers' Handbook [1]
  - Passage of Solid Particles Through Rotary Cylindrical Kilns (United States of America, Department of Commerce) [2]
  - Flow of granular material through an inclined, rotating cylinder fitted with a dam [3]
- Equations were verified experimentally using a tracer
- Variables effecting retention time
  - Particle shape
  - Bulk density
  - Dynamic angle of repose
  - Slope of drum
  - Drum rotational speed

1. Perry, R. H., Green, D. W., & Maloney, J. O. (1984). *Perry's Chemical Engineers' Handbook* (Sixth ed.). McGraw-Hill.
2. Sullivan, J. D., Maier, C. G., & Ralston, O. C. (1927). *Passage of Solid Particles Through Rotary Cylindrical Kilns* (United States of America, Department of Commerce). Washington D.C., WA: Government Printing Office.
3. Scott, D. M., Davidson, J. F., Lim, S. -., & Spurling, R. J. (2008). Https://www.sciencedirect.com/science/article/pii/S0032591007003609. *Powder Technology, 182*(3), 466-473. Retrieved August, 2018, from https://www.sciencedirect.com/journal/powder-technology.

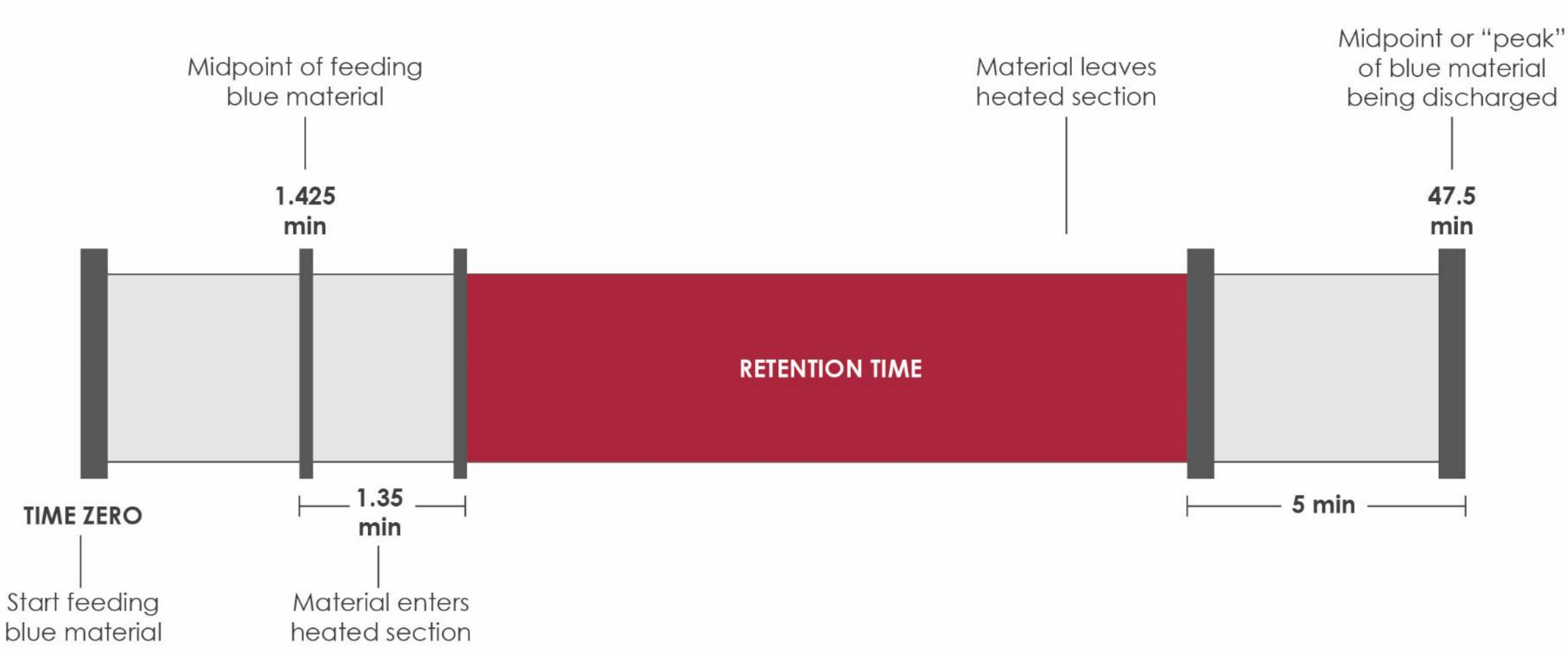
EXPERIMENTAL RETENTION TIME MEASUREMENT

40 minute retention time measurement

- Blue dye used as a tracer to measure retention time and bed distribution
- Wood chips were dyed and dried to the same moisture as un-dyed wood chips
- 0.25 lbs. of blue material was fed into the process when the process was at steady state and the heat was turned off
- Samples were taken at the discharge
- The “peak” or midpoint of the blue material being discharged was determined

EXPERIMENTAL RETENTION TIME MEASUREMENT

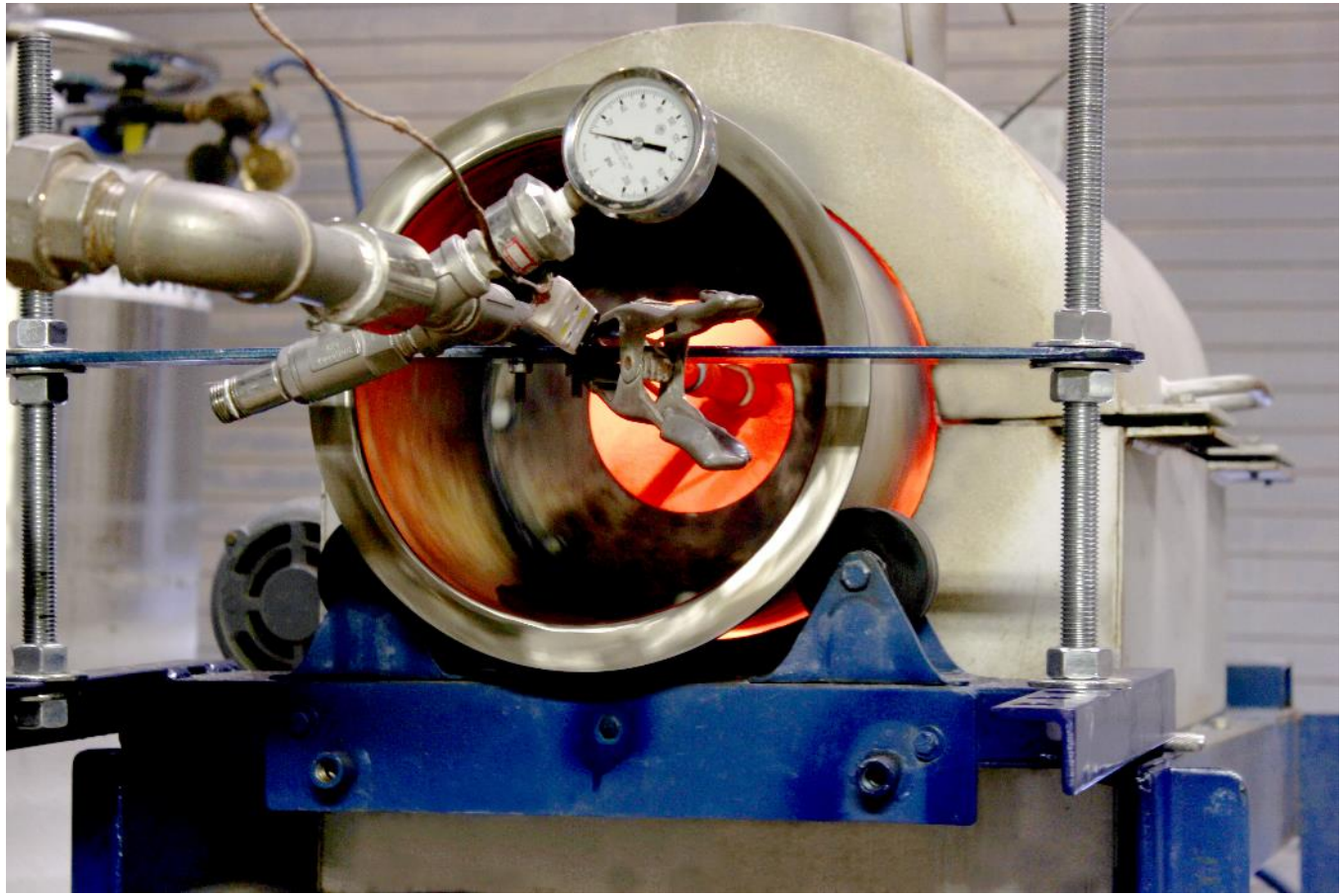
$$\boldsymbol{Retention\ Time} = 47.5 - (1.425 + 1.35 + 5) \approx 40\ \boldsymbol{minutes}$$



BIOCHAR ACTIVATION PROCESS OVERVIEW

- **FEECO INDIRECT BATCH KILN:**

- 10.5" Dia. x 24" Long (0.27 x 0.61m)
- Capable of operating at 400 – 1,800° F (204 – 982° C)
- Adjustable propane flame and drum rotation speed
- Thermocouples measuring shell and product bed temperature
- Saturated and superheated steam injection possible



BIOCHAR ACTIVATION PROCESS OVERVIEW

1. Biochar made in the FEECO indirect pilot kiln was then placed in the batch indirect kiln
2. Heated up to 1650 °F with nitrogen
3. Saturated steam injected at ~5 lb/hr for 1 hour at >1500 °F
4. Cooled with nitrogen to <160 °F
5. Resulted in Iodine numbers of 1300+

Wood Chips

Biochar

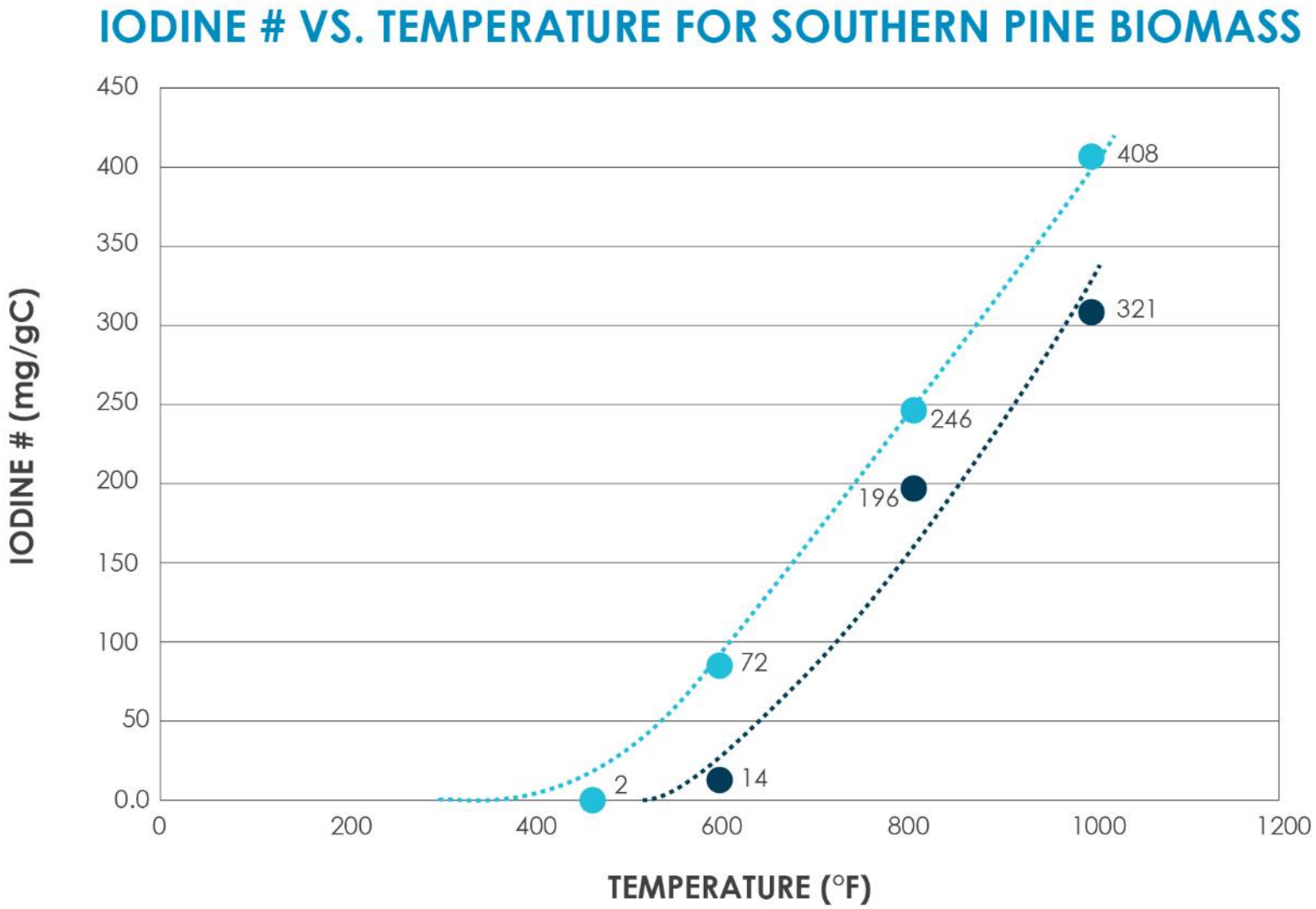
Activated Biochar

RESULTS & ANALYSIS

- The Iodine number is defined as the milligrams of iodine adsorbed by 1.0 g of carbon
- Estimation of surface area and pore volume
- Effected by retention time and temperature

● Southern Pine
40 min. Retention Time

● Southern Pine
20 min. Retention Time

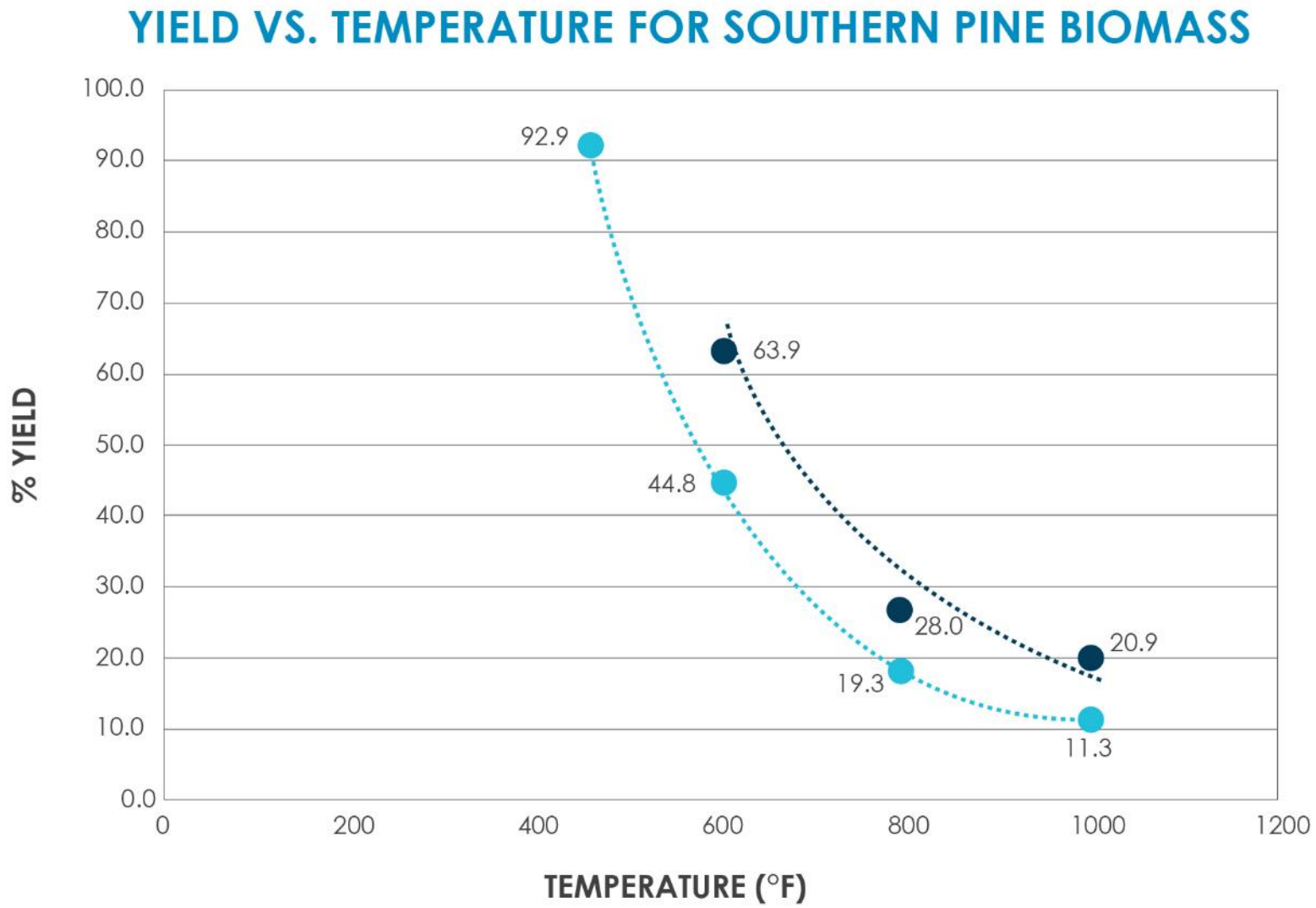


RESULTS & ANALYSIS

- Percent yield is assuming feed material is at zero percent moisture
- Indication of the rate of production
- Effected by retention time and temperature

- Southern Pine
  40 min. Retention Time

- Southern Pine
  20 min. Retention Time



DIFFERENT WOOD SPECIES 20 MIN. RETENTION TIME AT 600° F

- Lower percent yield for hard woods except for bark and balsam fir
- No significant change in iodine number
- Greater percent carbon for hard woods except for bark and balsam fir

WOOD	WOOD TYPE	PERCENT YIELD	PERCENT CARBON	IODINE #	ACTIVATED IODINE #
White Birch	Hard	56.4	65.51	16	1345
Quaking Aspen Poplar	Hard	51.3	67.14	43	-
Balsam Fir	Soft	55.9	66.56	47	604*
Southern Yellow Pine	Soft	63.9	54.72	14	-
Red Spruce	Soft	62.9	59.23	0	1306
Red Spruce Bark	Soft Bark	61.6	68.79	14	-

**Partial activation with limited steam for <10 minutes*

PROCESS DATA – SOUTHERN PINE BIOMASS

TEMP. (°F)	RETENTION TIME (min.)	PERCENT YIELD	IODINE #	PERCENT CARBON	BULK DENSITY (lbs./ft.3)	HEATING VALUE (Btu/lbs.)
600	20	63.9	14	54.7	12.2	9517
800	20	28.0	196	70.0	10.4	11525
1000	20	20.9	321	80.0	9.1	13411
450	40	92.9	2	48.7	13.5	8588
600	40	44.8	72	63.9	11.5	10172
800	40	19.3	246	66.9	10.5	10656
1000	40	11.3	408	80.2	9.9	13495

Increase in Temperature

- Decrease in percent yield
- Increase in iodine number
- Increase in percent carbon
- Decrease in bulk density
- Increase in heating value

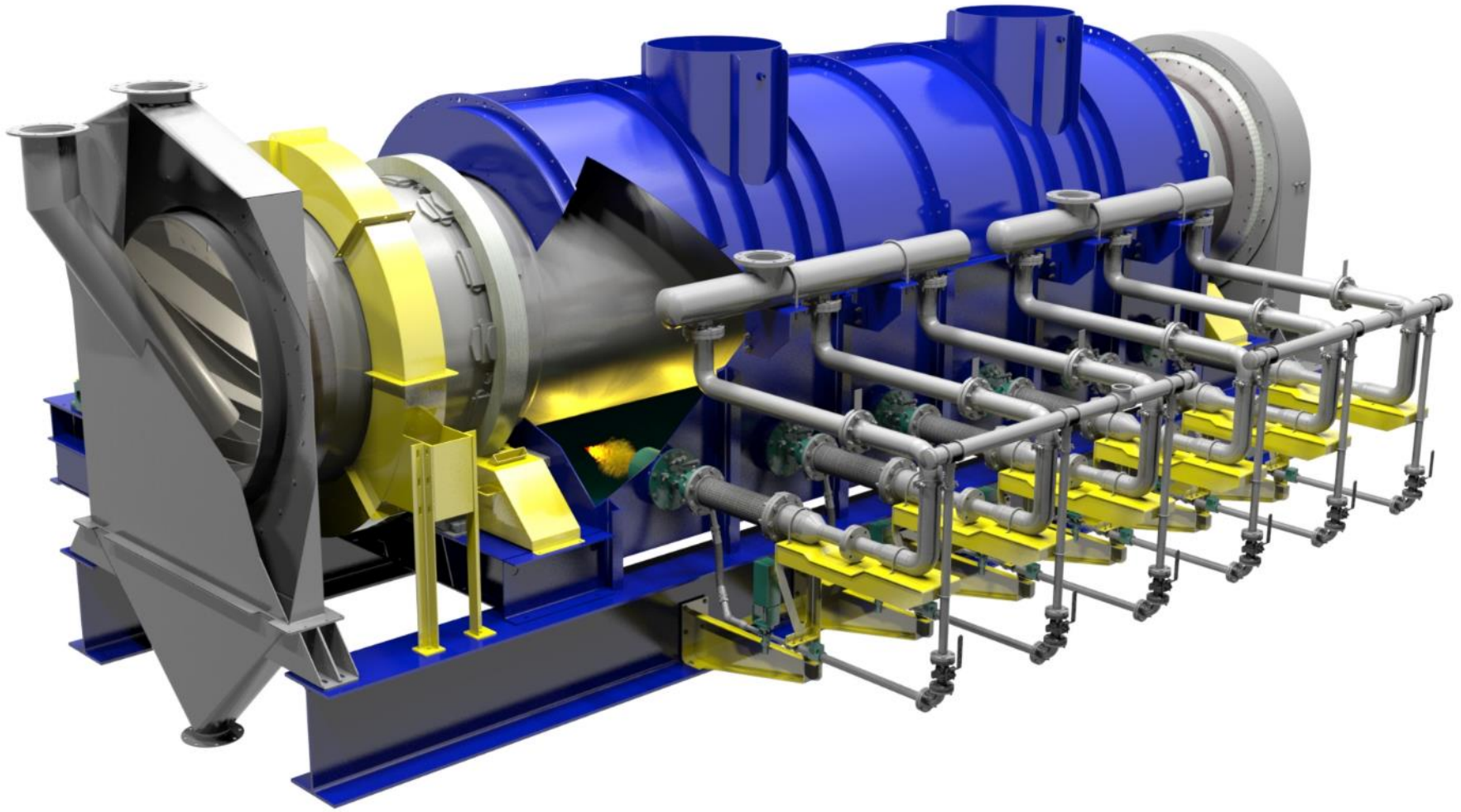
Increase in Retention Time

- Decrease in percent yield
- Increase in iodine number
- No significant change in percent carbon
- No significant change in bulk density
- No significant change in heating value

CONCLUSIONS

- Critical product specifications vary significantly with changes in retention time, temperature, and feedstock
- Product specifications should be optimized to meet target market specifications and maximize production
- Similar studies should be done in order size commercial size equipment and optimize process to the feedstock

QUESTIONS?



FEECO INTERNATIONAL

US Headquarters
(920)468-1000
Toll Free: (800) 373-9347
3913 Algoma Road
Green Bay, WI USA
FEECO.com/contact

Representatives Worldwide