Center for Applied Energy Research

Small Scale Pilot Plant for the Gasification of Coal and Coal/Biomass Blends and Conversion of Derived Syngas to Liquid Fuels via Fischer-Tropsch Synthesis

DOE Project Number: FE0010482

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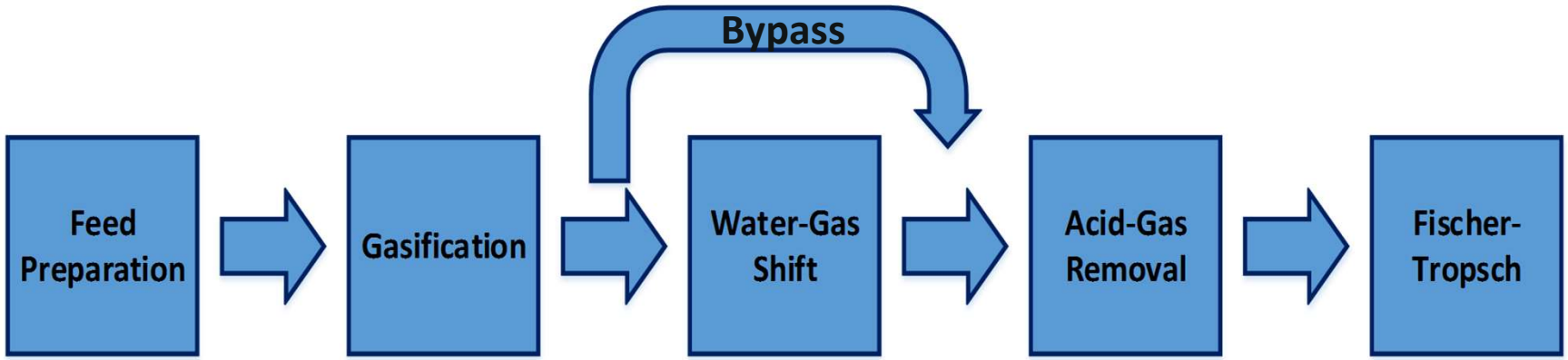
http://www.caer.uky.edu/powergen/home.shtml

Project Objectives and Overview

- Design, construction and operation of integrated coal/biomass-to-liquids (CBTL) facility at a capacity of 1 bbl./day
- Produce liquid fuels from coal only and coal/biomass blend for limiting CO_2 emissions
- Purposely designed for maximum flexibility: modular, skid-mounted, anticipating frequent change-outs; "plug and play;" and future re-purposing



Technology Selection, Design and Fabrication

- Work included process selection, design, fabrication, installation, commissioning and testing

Gasifier – OMB Technology

- Reliability
- Flexibility – multiple burners and wide range of feedstocks
- Arrived December 2013

AGR – Aqueous Amine

- Familiarity - Previous operation experience
- Sulfur removal
- Arrived December 2014

WGS and FT

- Commercial sour shift catalyst (sulfur promoted)
- Microchannel reactor
- Easy to control
- Ease of product separation
- Arrived February 2017

Installation and Operation

On-site Hydromill Feed Preparation

- Ash fusion temperature generally limiting factor of feed

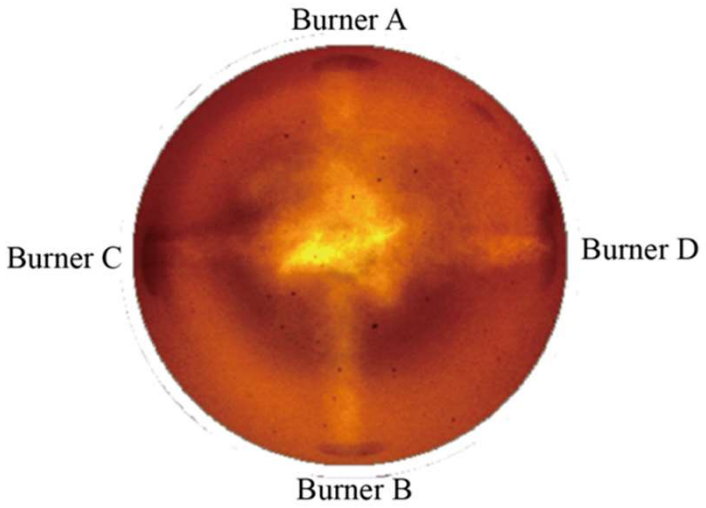
- Important Final Slurry Properties
  - Particle size
  - Viscosity

Typical Properties of CWS

Average particle size (μm)	Mass concentration	Viscosity (mPa·s)
<50	<60%	<250

Multiple Burner Gasification System

- Entrained flow gasifier
  - Coal/water slurry
  - Oxygen blown
  - Molten slag
  - 1 ton/day coal consumption
- Industrial process technology
- Co-feed (coal, biomass and natural gas)



Aqueous-based Acid Gas Removal

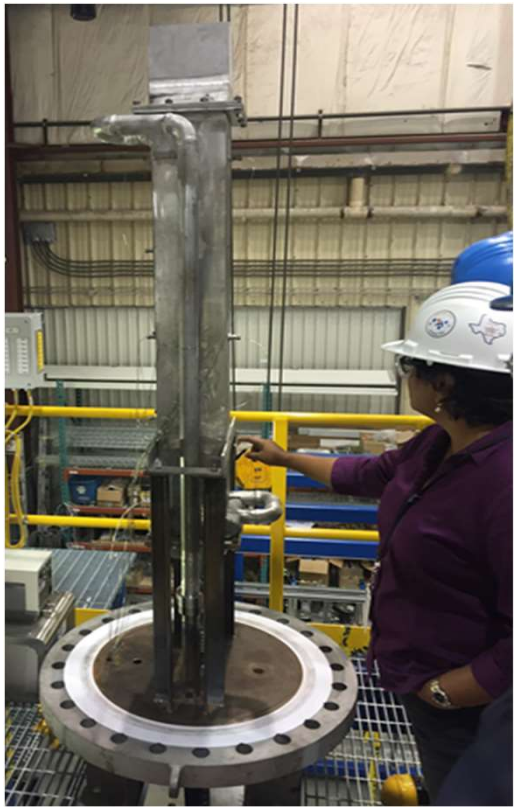
Aqueous Solvent System

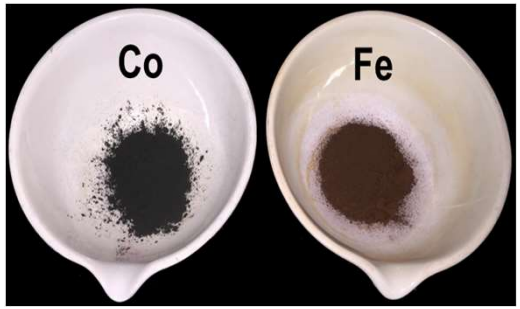
- CAER has 10+ years Experience with Similar Technology
- Thermal and Pressure Swing Absorption
- Howden Burton Corblin metal diaphragm compressor
  - Pressures up to 450 psi
- Wide range of Amine Solvents
- Sulfur Treatment on Both Rejected Acid Gas and Treated Gas
  - Activated carbon

Process Guarantees:

- 95+% removal of CO_2
- 99.99% removal of sulfur (less than 1ppm)

WGS and Microchannel FT Reactor

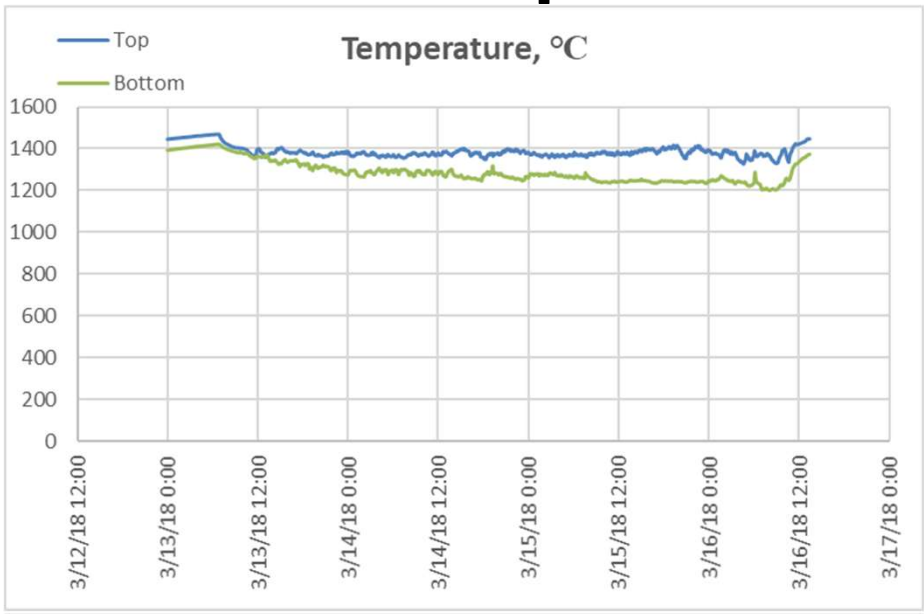


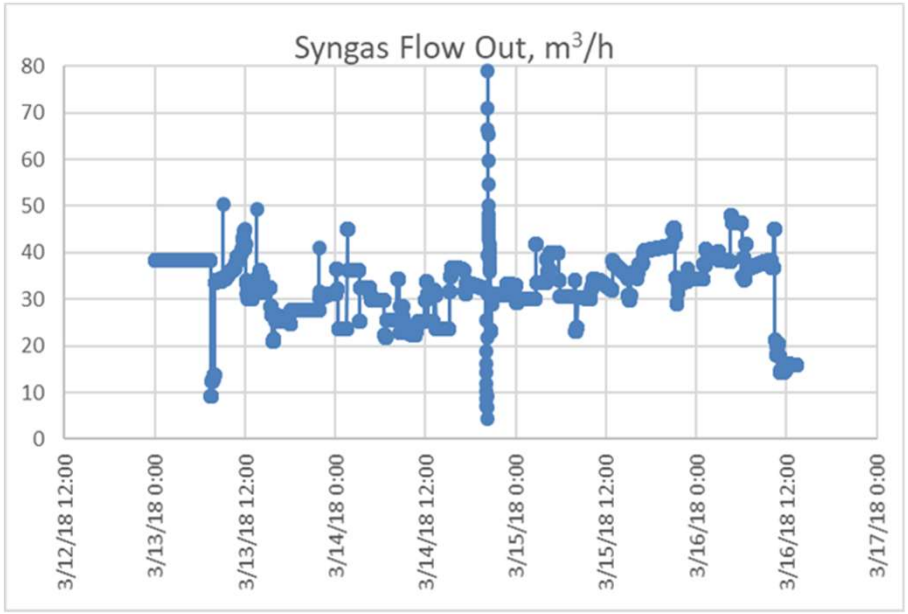


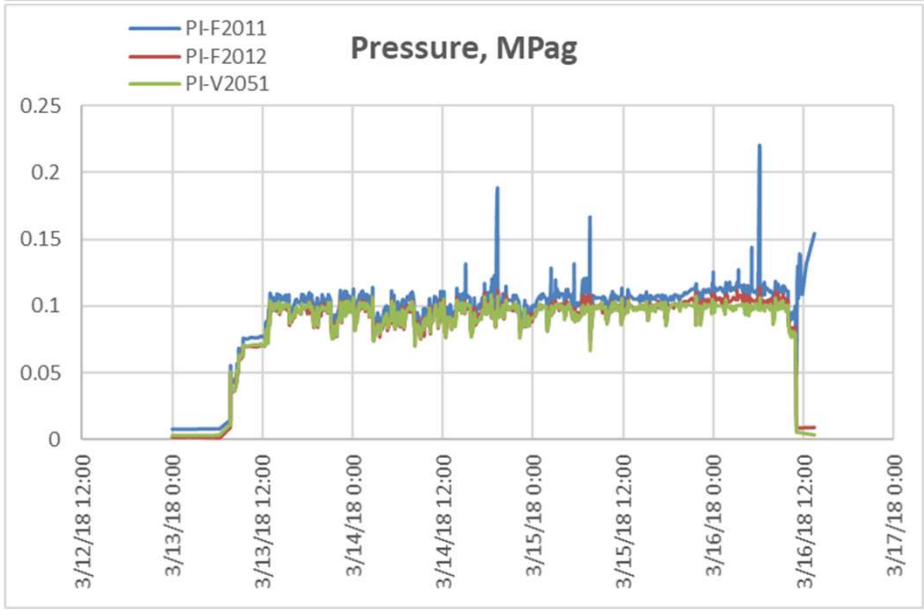
- WGS is packed bed reactor with commercial sour shift catalyst (sulfur promoted/tolerant, Cobalt and Molybdenum based)
- FT Reactor is aluminum heat exchanger inside a steel kettle
- Utilizes a specialty high pressure oil coolant system to maintain reactor T
- Capable of utilizing either Fe or Co based catalysts
  - Difference in feed H_2/CO molar ratio
- 20.6 lbs of 0.1%Pt-20%Co/Al_2O_3 catalyst loaded
- Product separation:
  - Hot trap at 140C
  - Cold trap at 5C
- Water Gas Shift and FT modules were designed and built by Zeton Inc. with assistance from Stovlbaek Consulting

Gasifier - Operation Data from Coal Operation

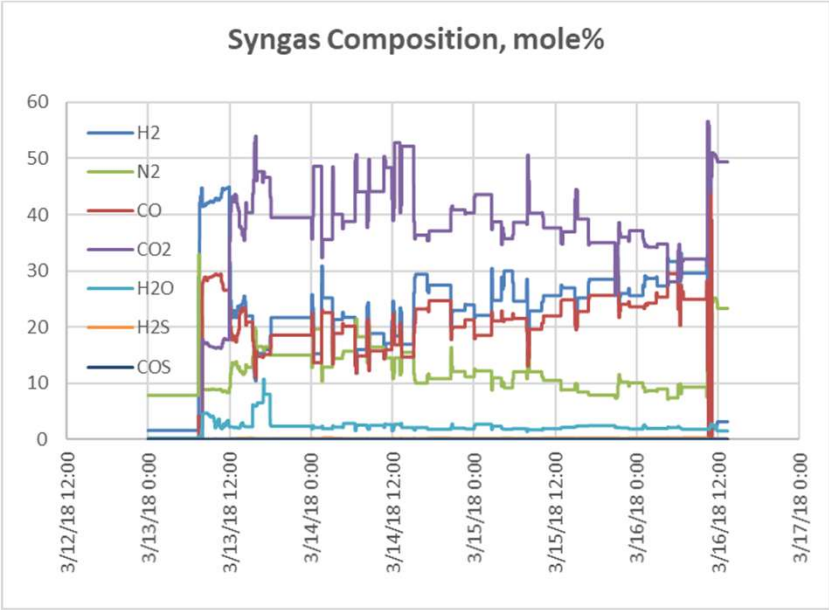
- Full facility operation
- 1 week operational period
- Operationally stable for entire testing run
- Feed details
  - 60% solids/40% water

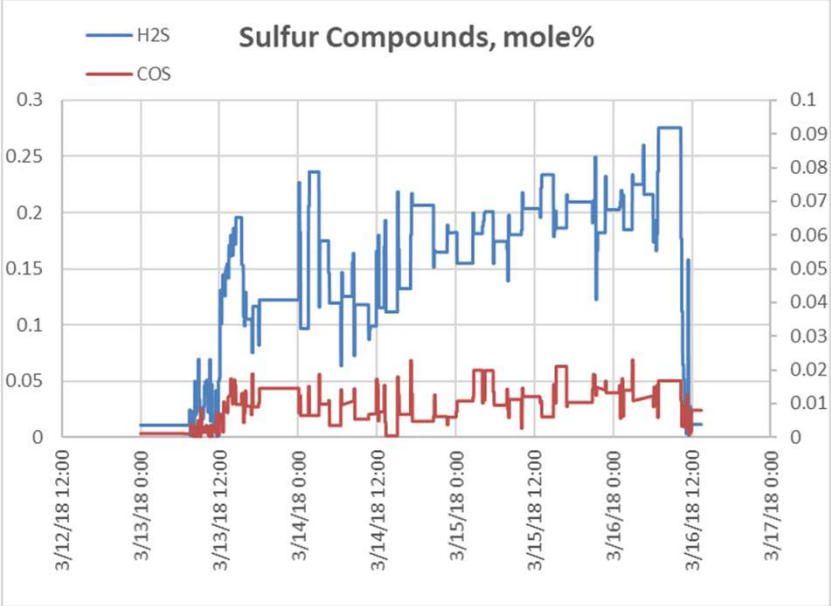




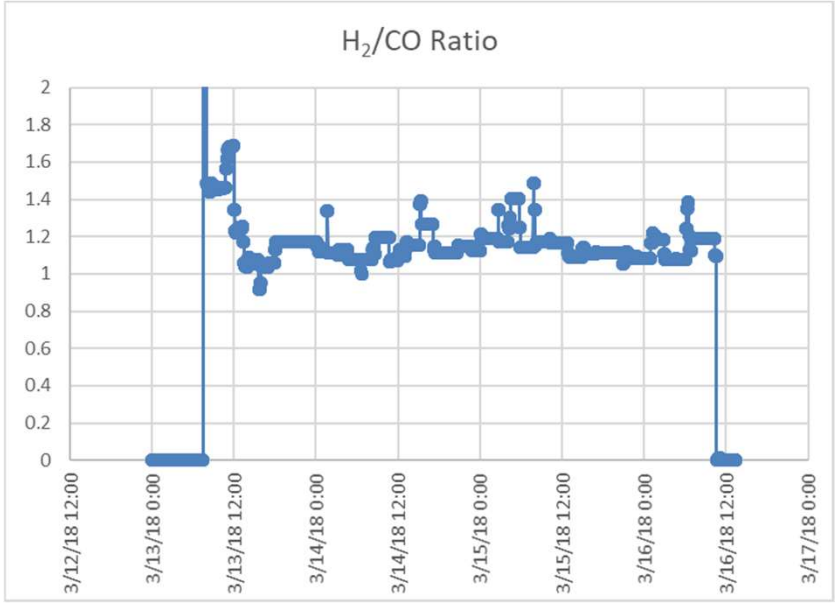


Gasifier – Operation Data



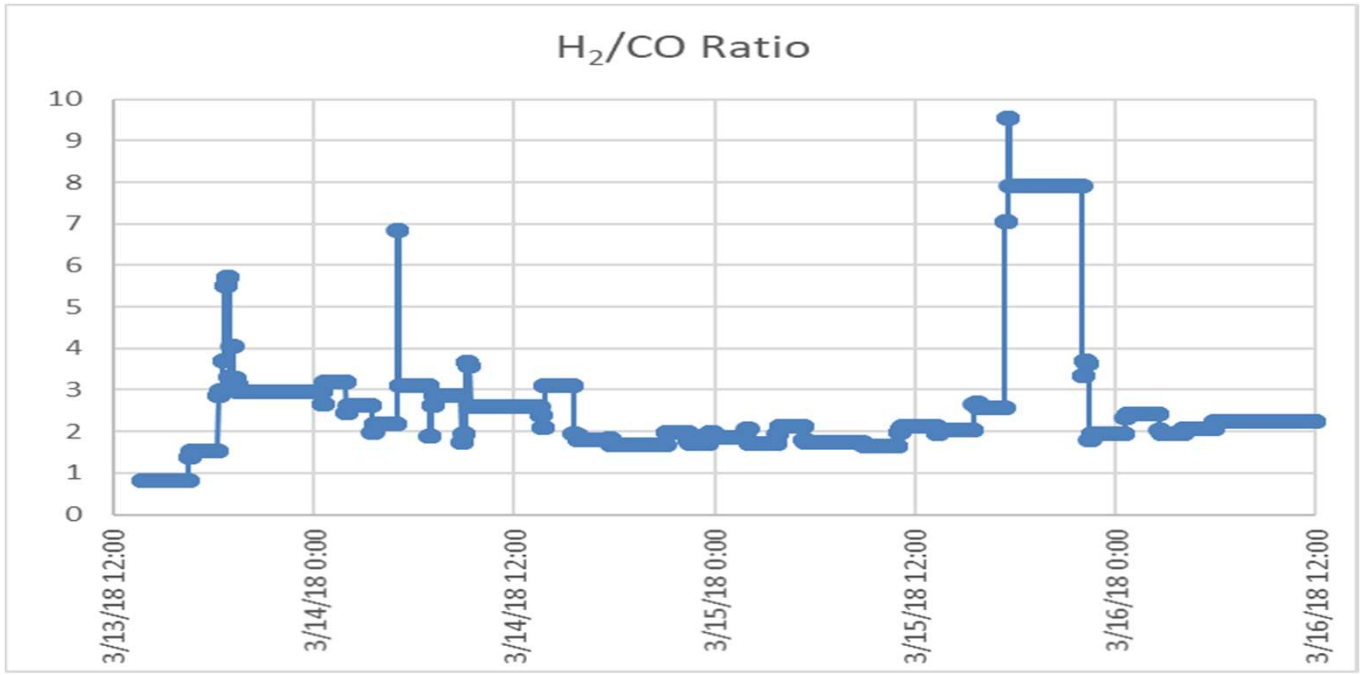


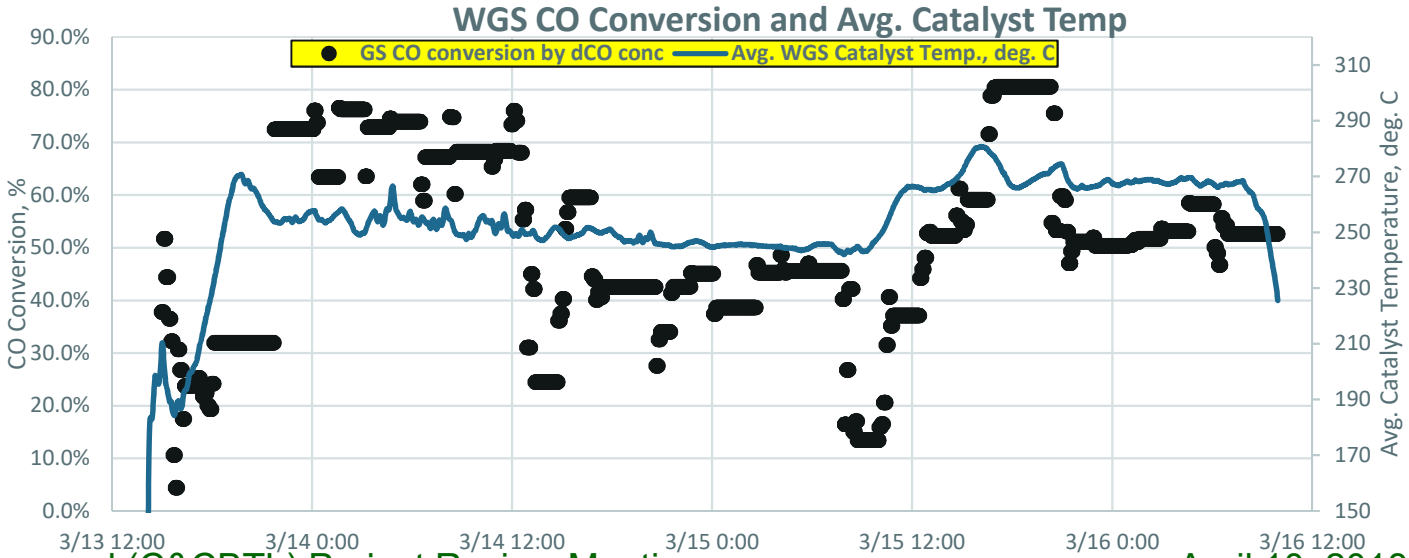
- Syngas quality stable during full run
- H_2/CO important syngas quality measure for downstream utilization
  - Ratio stable around 1.1 to WGS unit



WGS – Operation Data

Stationary Parameters:
- SG to WGS ~ 21 - 23 kg/h`
- Steam to WGS ~ 12-14 kg/h
- S/DG inlet WGS ~ 1 vol/vol
- P ~ 0.7 - 1.0 barg`

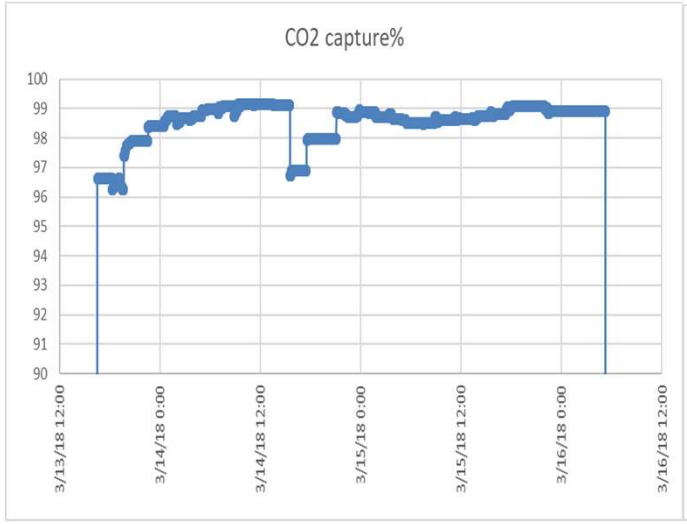


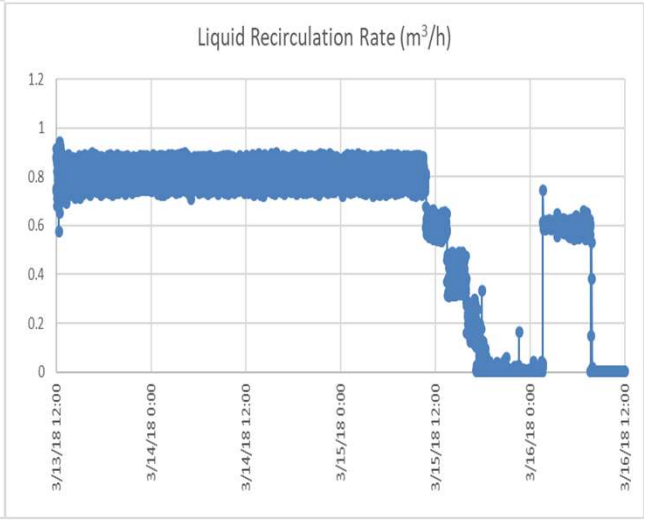


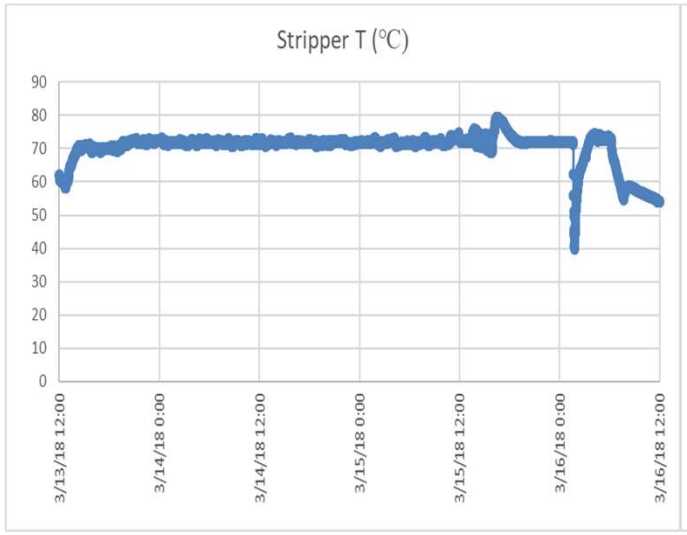
Acid Gas Removal – Operation Data

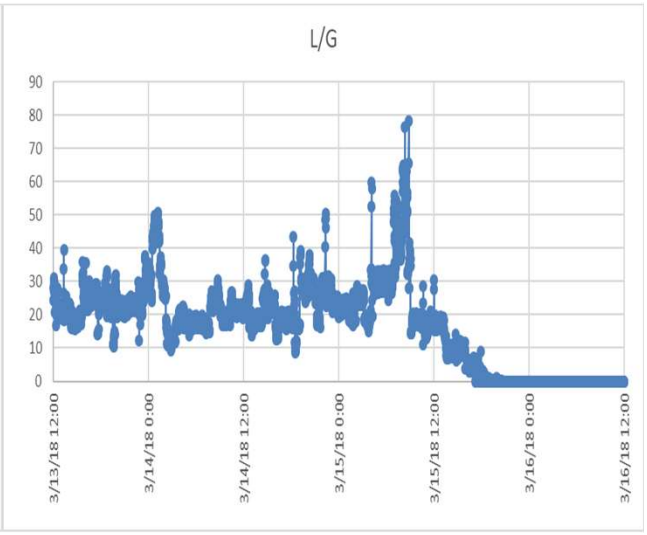
Aqueous Solvent System

- GC for syngas composition
- Draeger Tubes for sulfur measurement at low concentrations
- CO_2 removal at 98%+
- Sulfur removal to below 0.2ppm

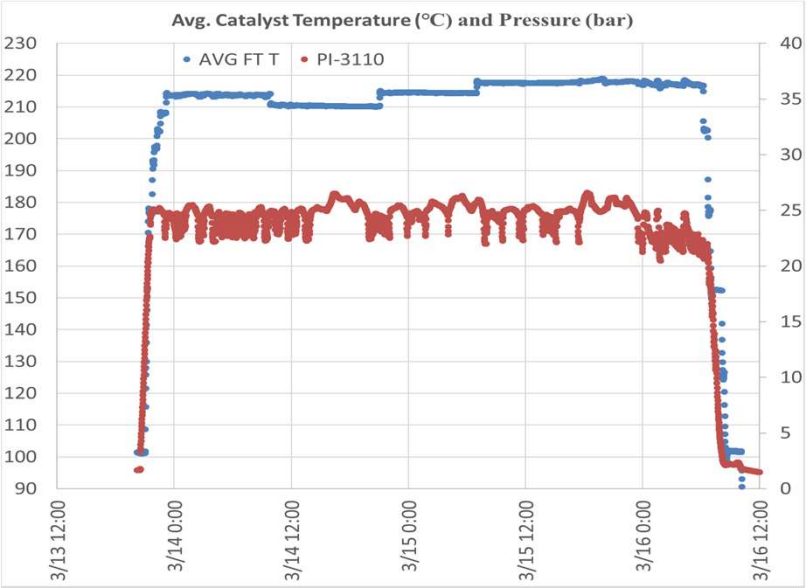


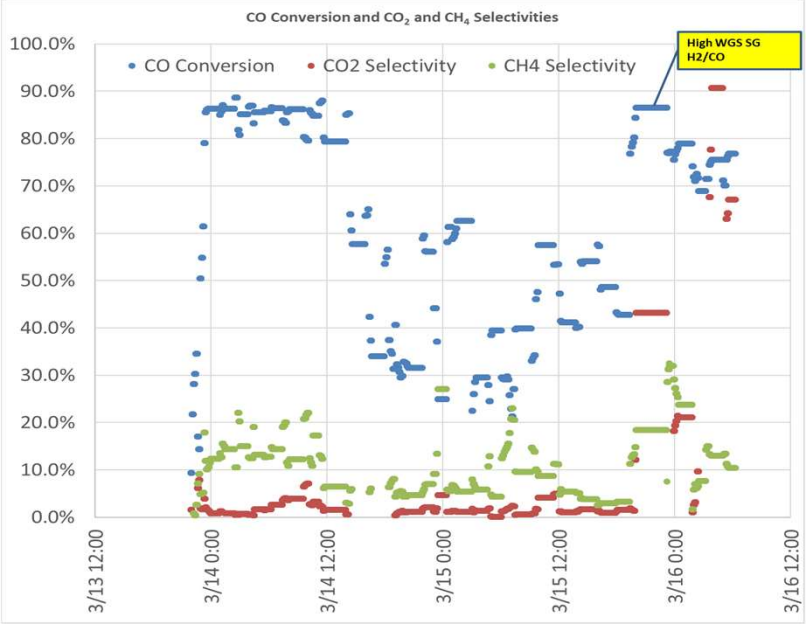






FT – Operation Data





- Practically limited by flow through FT reactor Bed
  - Higher pressure drop than anticipated
  - Different than lab reactor
  - Flow less than design(22 kg/hr)
- Stable
  - Operating T: 210-220C
  - Operating P: 24 bar (~350psi)
- Reactor Temperature and H_2/CO ratio used to control product and conversion
  - Higher T = higher conversion
  - Higher H_2/CO ratio at inlet = higher conversion
- Conversion varied between 30-85% based on testing conditions

FT – Final Products from Coal

55 operating hours

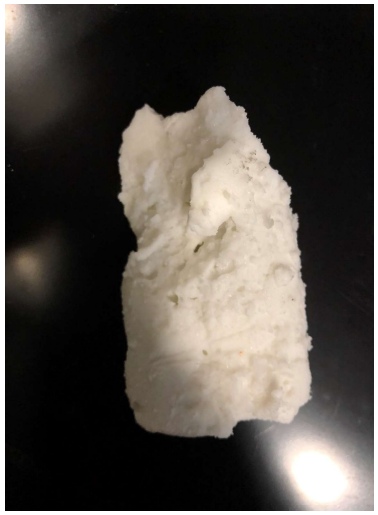
Yields:

Wax: 27.25kg

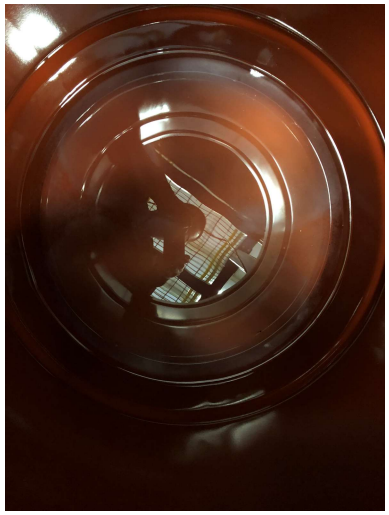
Oil: 31.25 kg

water: 57.50kg

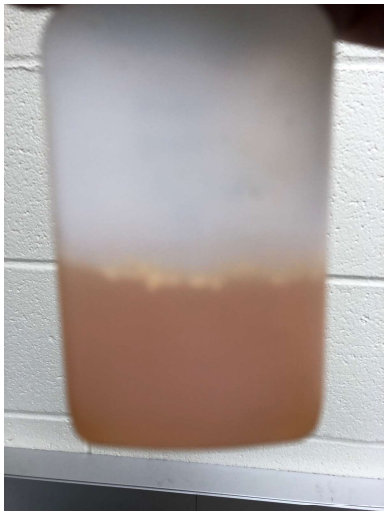
Wax



Oil



Water



FT – Product Composition

Oil

Component	Area %
C8 alkane	9.86
C9 alkane	13.55
C10 alkane	13.88
C11 alkane	12.55
C12 alkane	11.45
C13 alkane	9.86
C14 alkane	8.02
C15 alkane	6.12
C16 alkane	4.50
C17 alkane	3.15
C18 alkane	2.15
C19 alkane	1.45
C20 alkane	0.97
C21 alkane	0.68
C22 alkane	0.49
C23 alkane	0.39
C24 alkane	0.27
C25 alkane	0.21
C26 alkane	0.16
C27 alkane	0.28

Wax

Component	Area %
C14 alkane	1.00
C15 alkane	2.19
C16 alkane	1.75
C17 alkane	2.79
C18 alkane	3.21
C19 alkane	3.46
C20 alkane	3.39
C21 alkane	3.36
C22 alkane	3.34
C23 alkane	3.37
C24 alkane	3.56
C25 alkane	3.77
C26 alkane	4.28
C27 branched alkanes	1.13
C27 branched alkanes	1.47
C27 branched alkanes	1.63
C27 branched alkanes	2.20
C27 alkane	5.32
C28 branched alkanes	1.89
C28 branched alkanes	0.93
C28 branched alkanes	6.00
C28 alkane	4.04
C29 alkane	3.66
C30 alkane	3.24
C31 alkane	3.08
C32 alkane	2.82
C33 alkane	2.61
C34 alkane	2.34
C35 alkane	2.31
C36 alkane	2.00
C37 alkane	1.78
C38 alkane	1.57
C39 alkane	1.38
C40 alkane	1.21
C41 alkane	1.04
C42 alkane	0.94
C43 alkane	0.82
C44 alkane	0.72
C45 alkane	0.63
C46 alkane	0.68
C47 alkane	0.52
C48 alkane	0.50
C49 alkane	0.40
C50 alkane	0.32
C51 alkane	0.30
C52 alkane	0.21
C53 alkane	0.20
C54 alkane	0.15
C55 alkane	0.14
C56 alkane	0.08
C57 alkane	0.13
C58 alkane	0.07
C59 alkane	0.10

Summary

- Project successfully completed
- Full facility is now operational for any demands
  - Scheduled to host multiple vendors for CTL and gas separation development
- Leveraging CTL facility for small modular gasification

Acknowledgements

- DOE-NETL: Arun Bose, Jenny Tennant, David Lyons, and Jason Hissam
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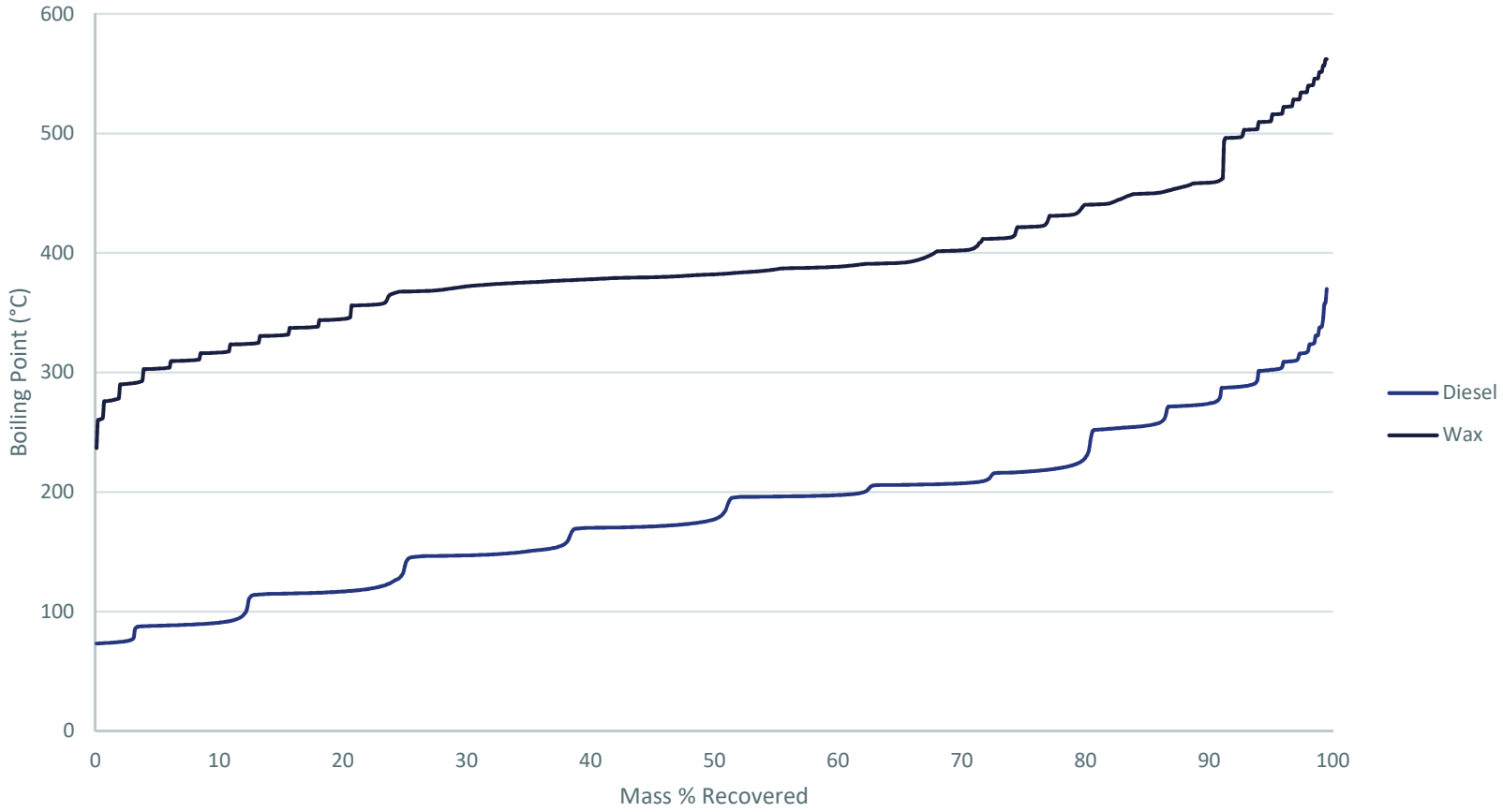
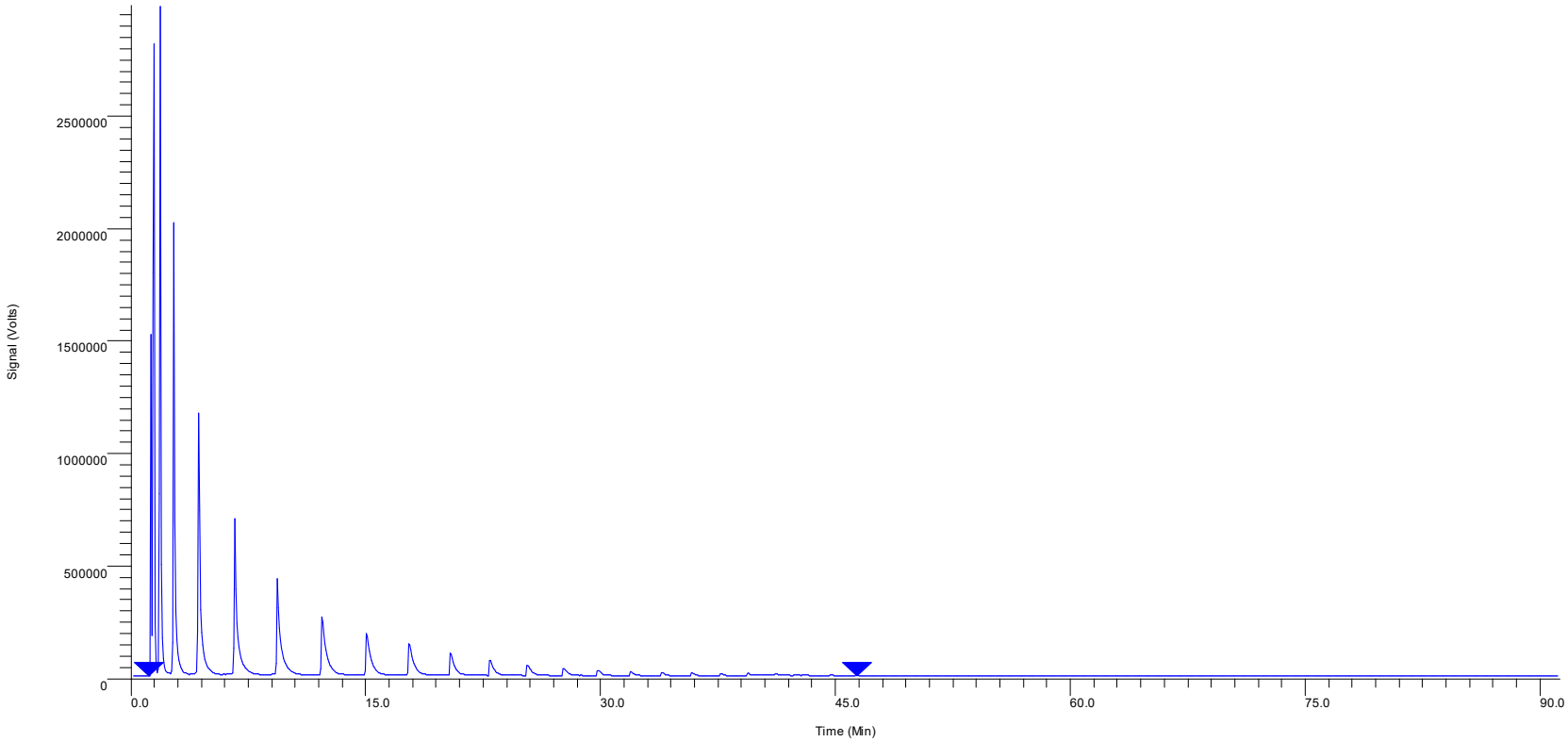
- Stovlbaek Consulting: Peter Pedersen
- Zeton: Ravin Dave and Danielle De Sousa
- CEEDI: Wang Qiuming and Tao Li

Extra Slides

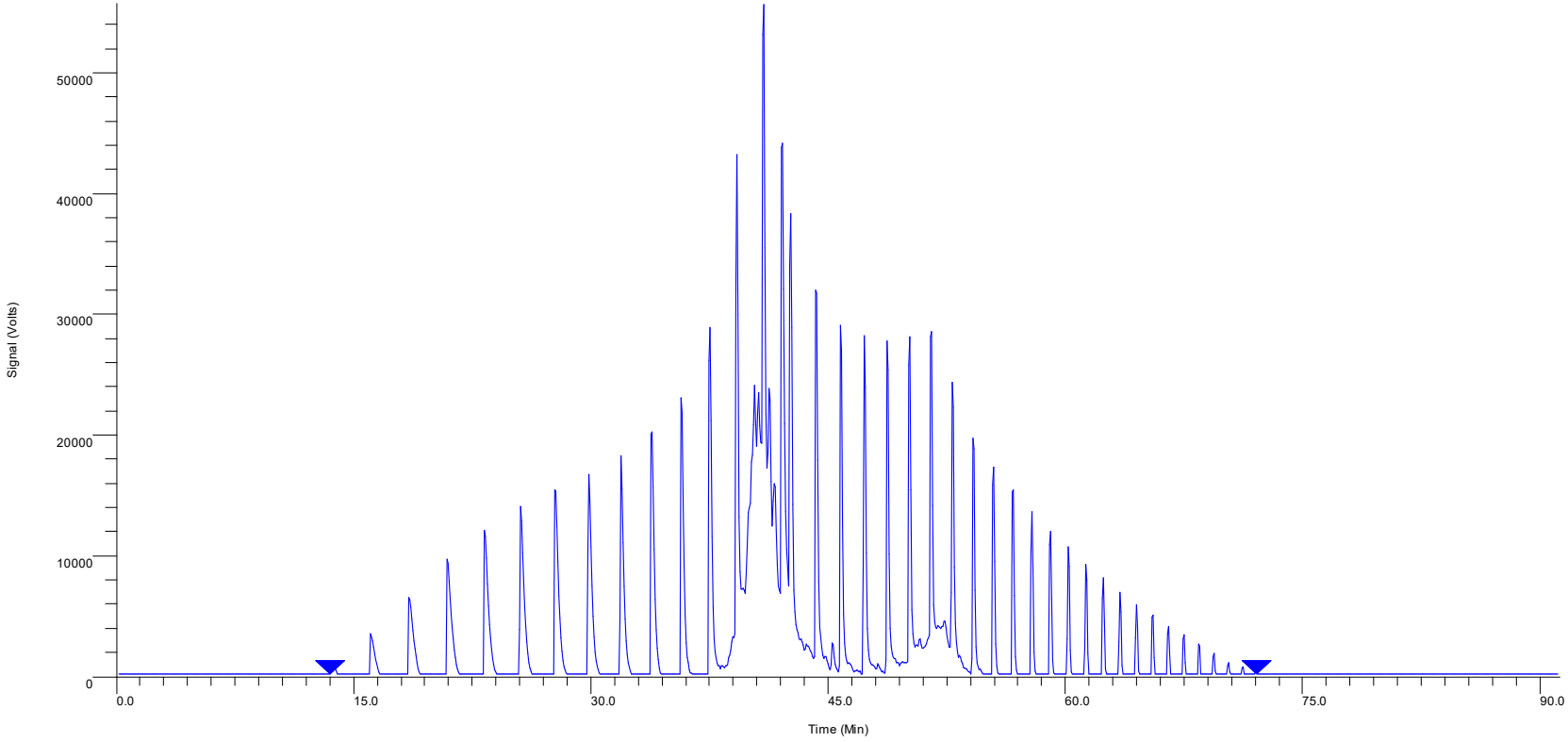
Boiling Point Distribution Plot



319 Diesel

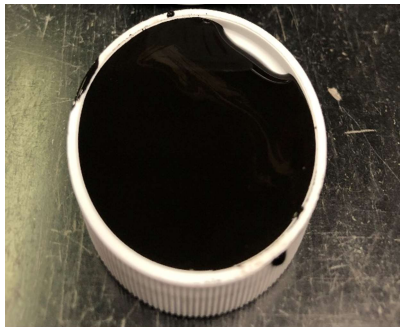

Signal (Volts)
2500000
2000000
1500000
1000000
500000
0
0.0
15.0
30.0
45.0
60.0
75.0
90.0
Time (Min)

319 Wax

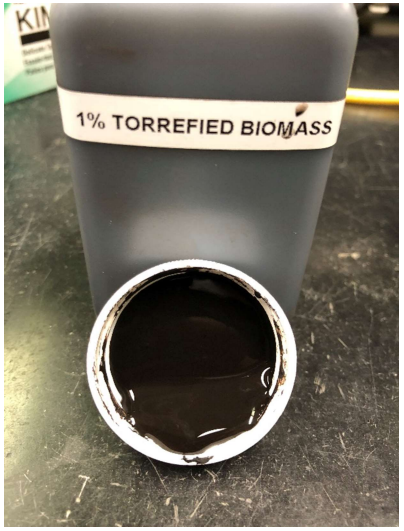

Signal (Volts)
50000
40000
30000
20000
10000
0
0.0
15.0
30.0
45.0
60.0
75.0
90.0
Time (Min)

Coal/Biomass Slurry Preparation

Coal/Water Slurry



Coal/Water Slurry with 1% torrefied biomass



Coal/Water Slurry with 5% torrefied biomass

Coal/Water Slurry with 10% torrefied biomass

Viscosity:	Control	10% higher than control	50% higher than control	Too high for measurement (paste)

The control sample is the normal slurry used when performing coal only gasification. The other samples are mixtures with torrefied biomass in the labeled proportion.

- 10% torrefied biomass sample is a solid paste after mixing. It is unable to be used for gasification on CAER system
- 5% torrefied biomass sample is very thick and viscosity is 50% higher than control. Unable to be used on CAER system.
- 1% torrefied biomass sample is only about 10% higher than control. Potentially can be used in current form