Fast Pyrolysis of Biomass using Concentrated Solar Radiation

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Presentation Agenda

- Introduction
- Motivation
- Research Objectives
- Experiment
  - Components
  - Set-Up
- Upgrade Methods
  - Four Stage Collection System
  - Addition of Alcohol
- Results
- Conclusions
- Future Work

Introduction

- Current Problems
  - Concerns about depleting oil and gas reserves
  - Increased difficulty and cost in oil and gas extraction
  - Increased gasoline prices
- Need for alternative energy sources
- Pyrolysis of biomass produces bio-fuel that has potential to replace petroleum based liquid fuels [1]
- Solar heating eliminates electrical or combustion based heating

Introduction - Pyrolysis

- High temperature reaction (400°C - 700°C)
- Absence of oxygen
- Produces char, bio-oil, gases and water
- Fast pyrolysis refers to high heating rates
- Fast pyrolysis produces highest amount of bio-oil [2]

Motivation

- Bio-oil unsuitable for direct replacement of petroleum fuels [3]
  - High viscosity
  - Poor stability
  - Acidic pH level
  - High water content
- Need better methods to upgrade fuel

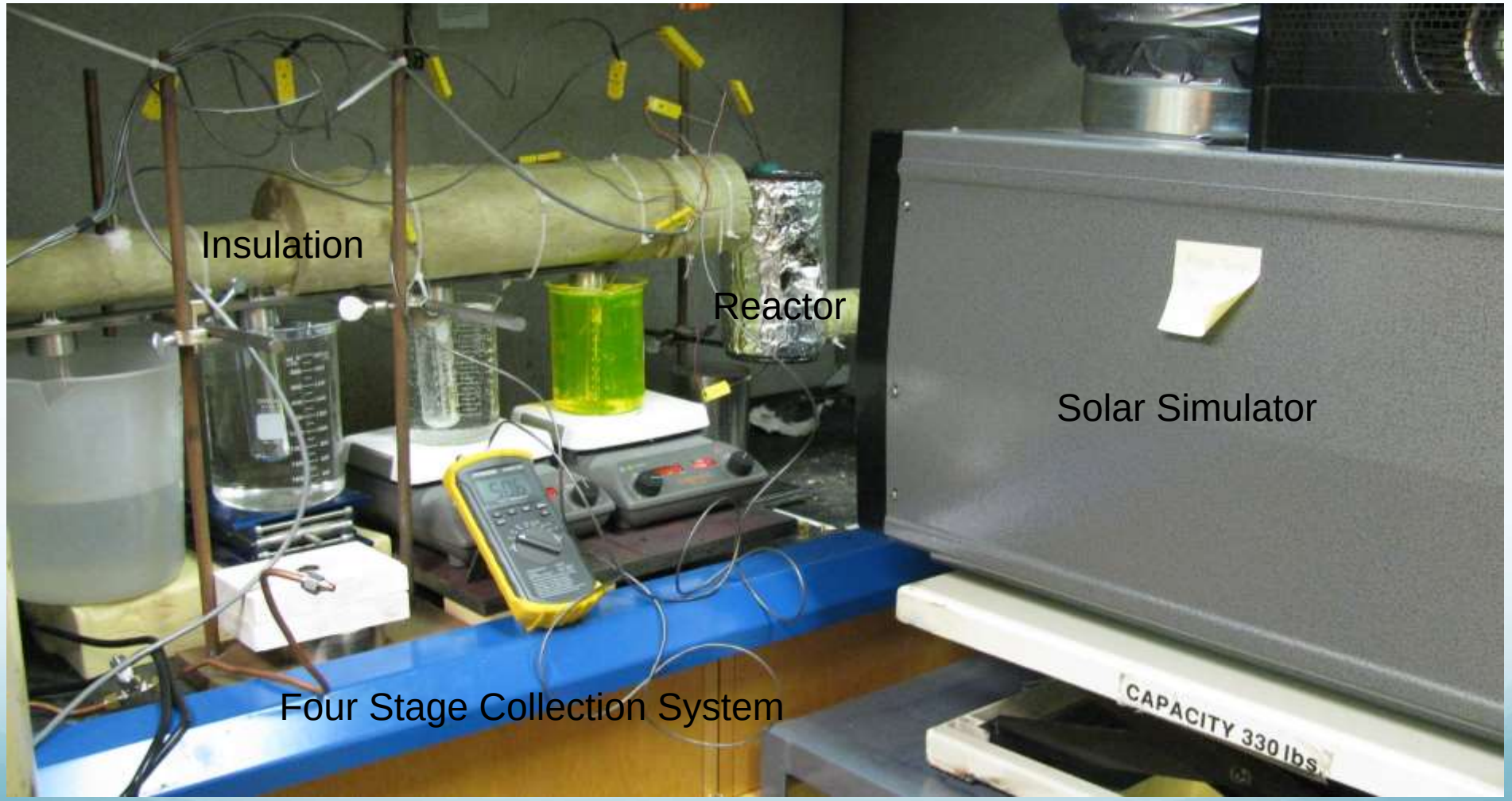
Research Objectives

- Long Term
  - Develop a method of using biomass and concentrated solar radiation to produce transportation grade fuels
- Short Term
  - Thorough literature review of biomass fast pyrolysis
  - Learn operation of solar simulator, micro gas chromatograph (GC), liquid GC and other test equipment
  - Develop improved method of producing bio-oil from pyrolysis in lab
  - Hypothesize and test methods of upgrading bio-oil

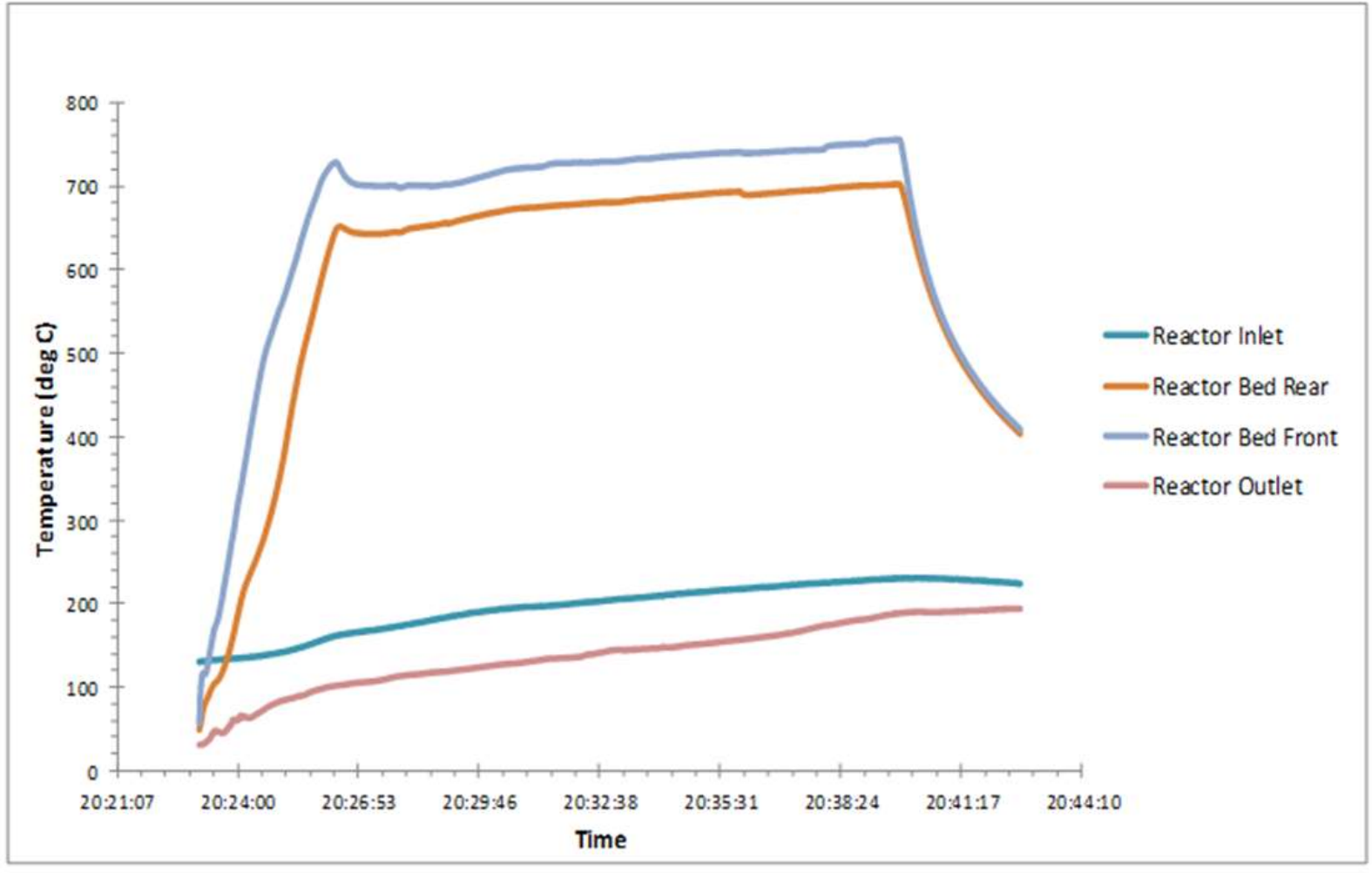
Experiment Components

- Biomass
  - Used wood pellets 1-2 cm in length
  - 15 – 20 g samples reacted
- Reactor
  - Quartz tube reactor
  - Inlet – preheated N2
  - Outlet – pyrolysis products
- Concentrated Solar Simulator
  - 5 kWe
  - Xenon Arc Bulb
- Insulation
  - Ceramic wool
  - Mineral wool
  - Aluminum foil tape

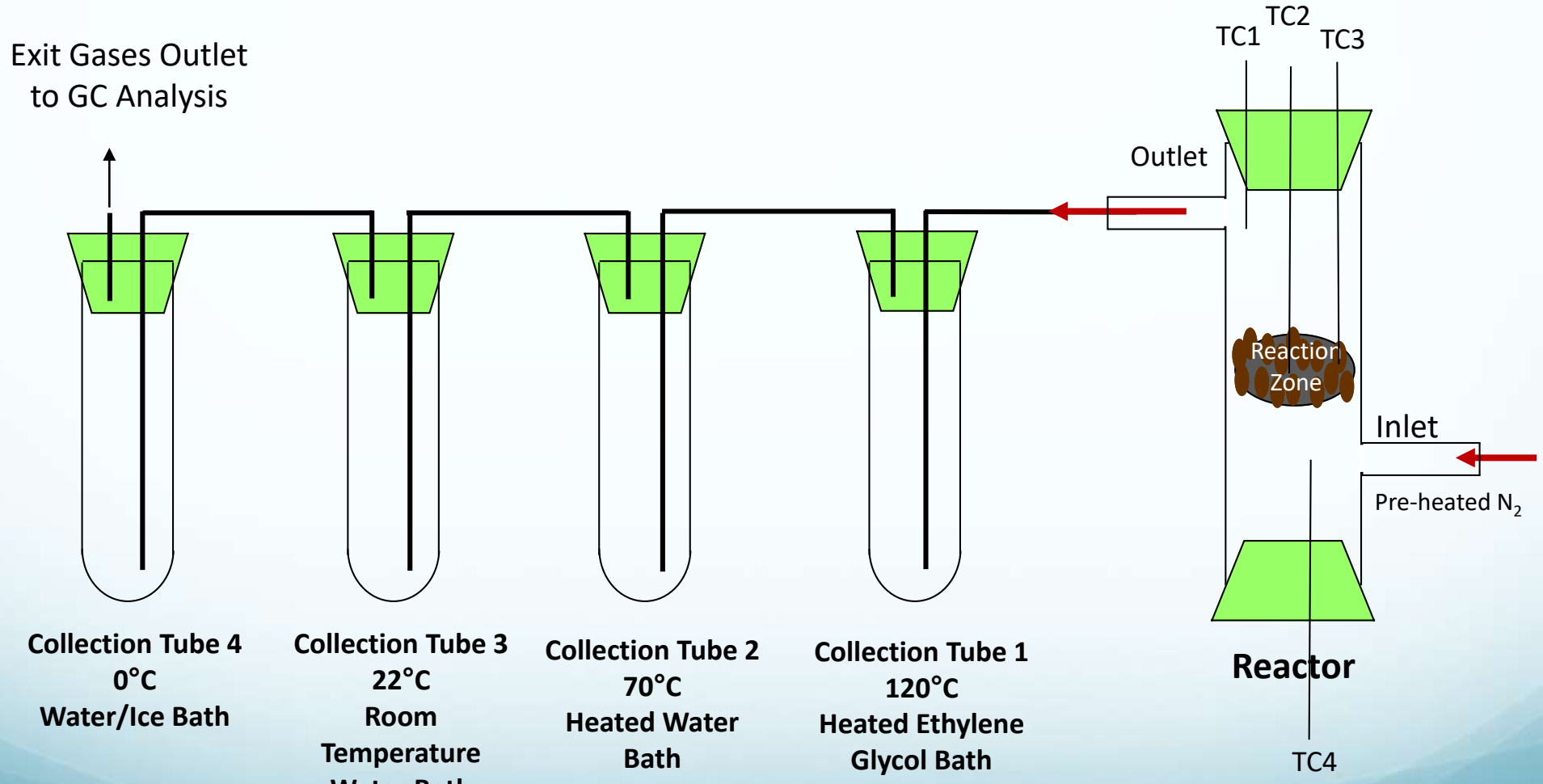
Experimental Setup



Experimental Temperatures



Four Stage Collection System



Bio-Oil mixed with Butanol

- Other groups successful in improving fuel quality with the addition of alcohol [4]
- Hand mixed light bio-oil with butanol
  - 1:1 ratio by volume
  - 5 minute mixing time
- Aging comparison
  - 5 minutes
  - 2 days

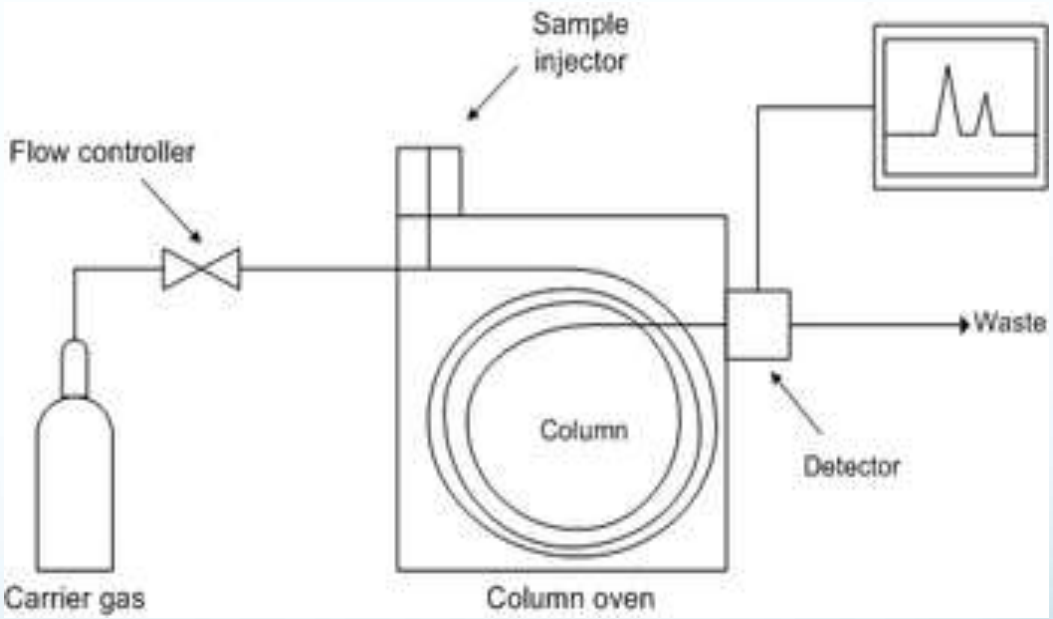
Results – Four Stage Collection System

- Successful separation of reaction products
- 1st experiment
  - 120°C – heavy tar-like bio-oil
  - 70°C – light bio-oil and water
  - 22°C – no collection
  - 0°C – water
- 2nd experiment
  - 120°C – heavy tar-like bio-oil
  - 70°C – no collection
  - 22°C – light bio-oil
  - 0°C – water

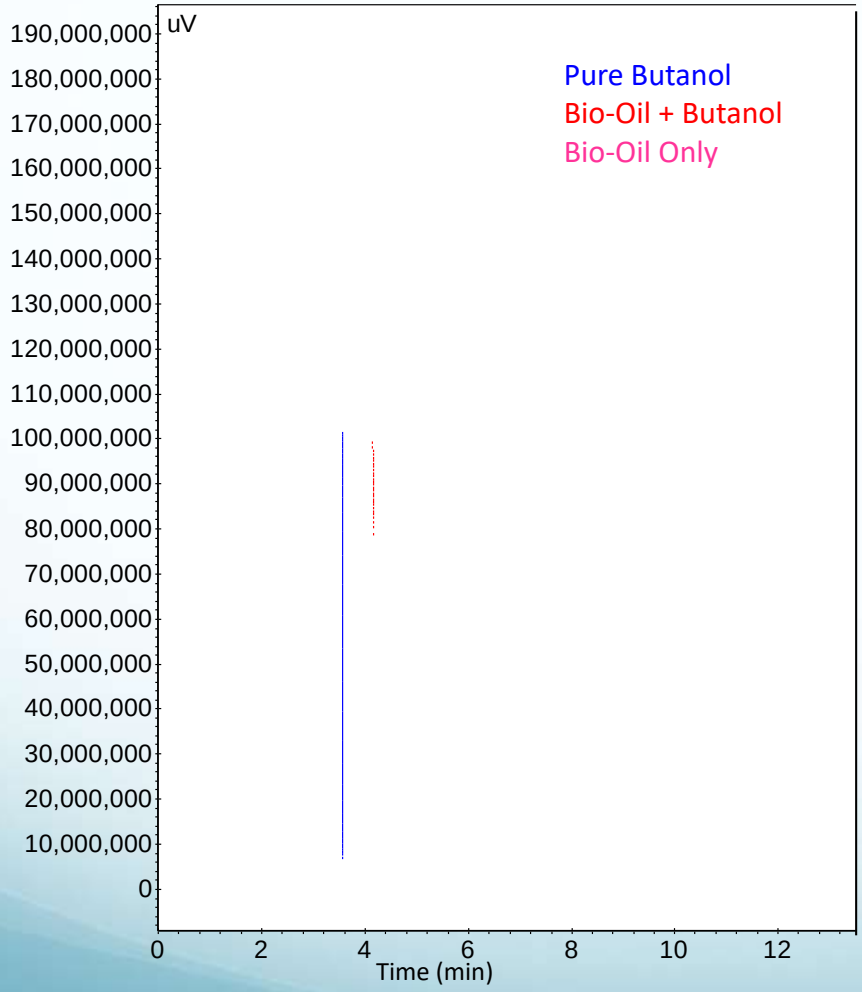
Bio-Oil Sample

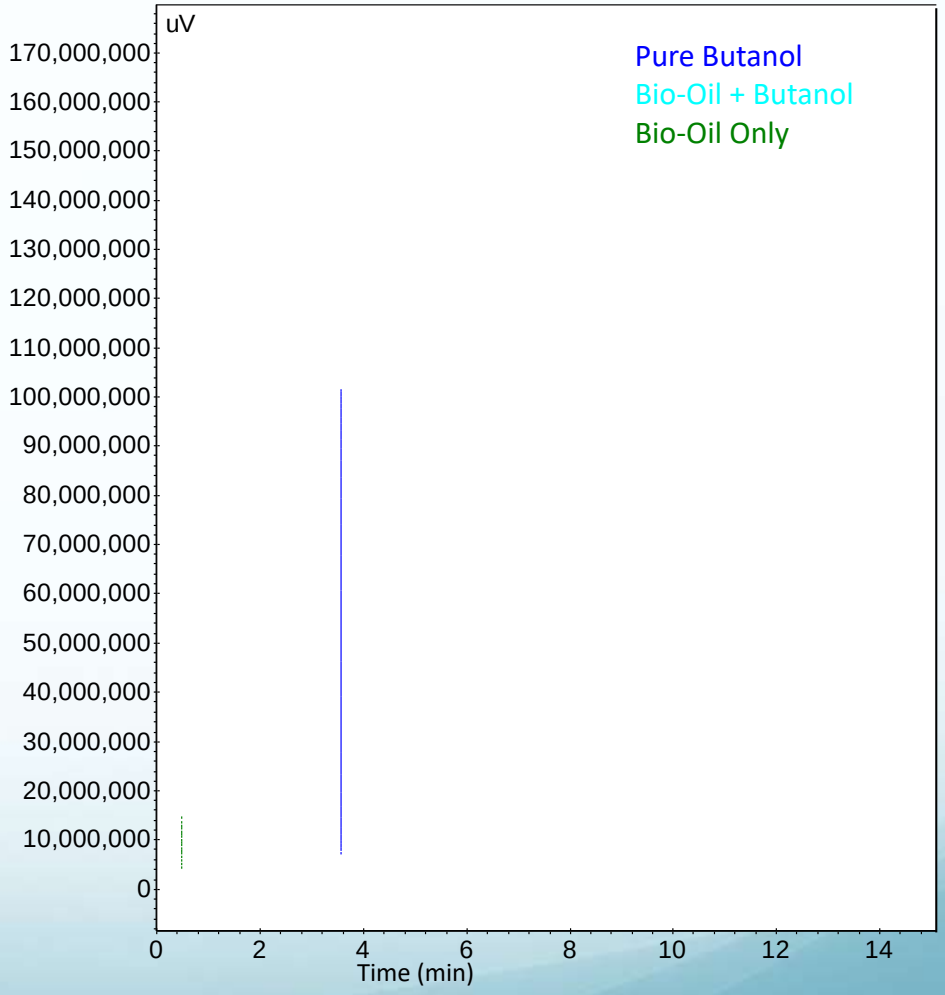
Gas Chromatography Analysis

- Sample passed through small flow tube – column
- Different detection times based on sample characteristics
- Comparison of detection times shows similarities and differences between substances



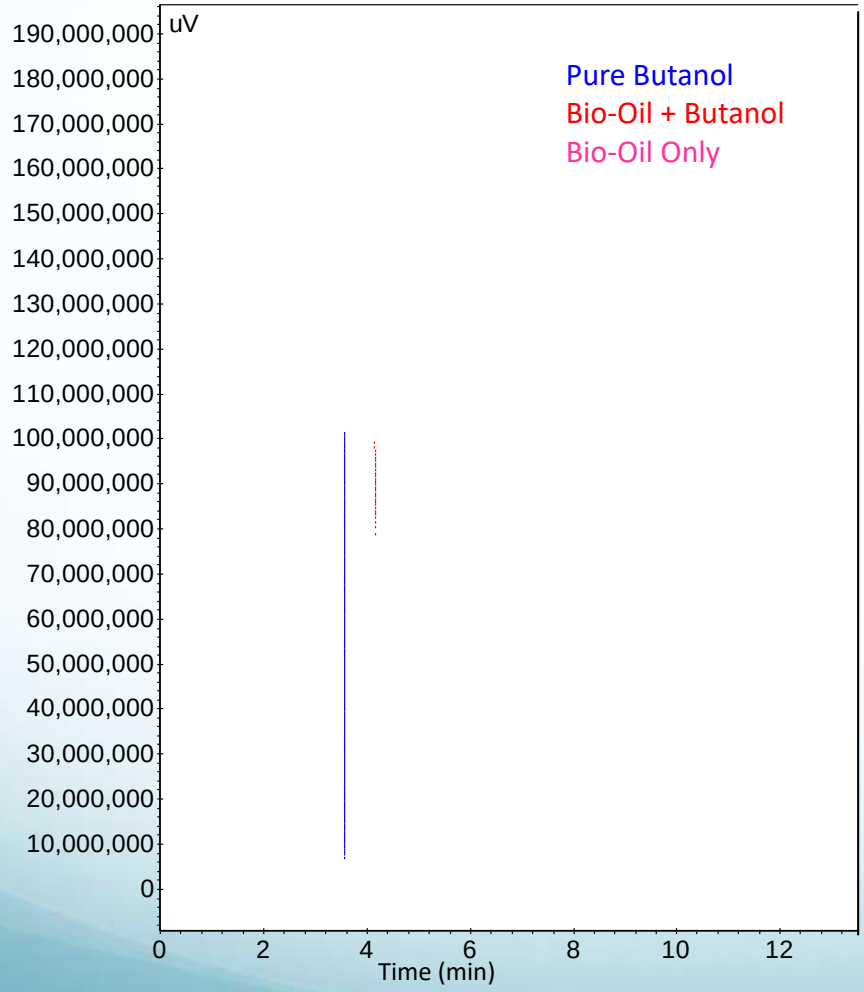
Results – Bio-Oil + Butanol Mixture





Comparison of Pure Butanol, Bio-Oil + Butanol Mixture and Bio-Oil Only (left - 70°C tube collection, right - 22°C tube collection

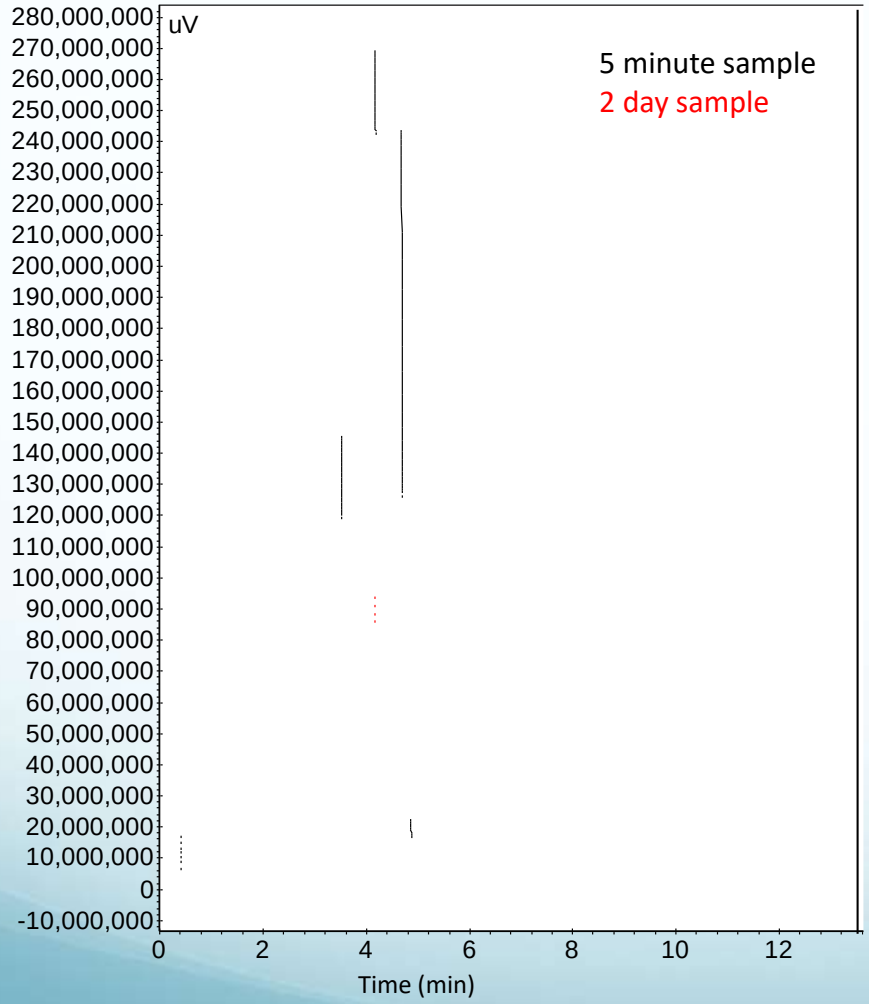
Results – Bio-Oil + Butanol Mixture

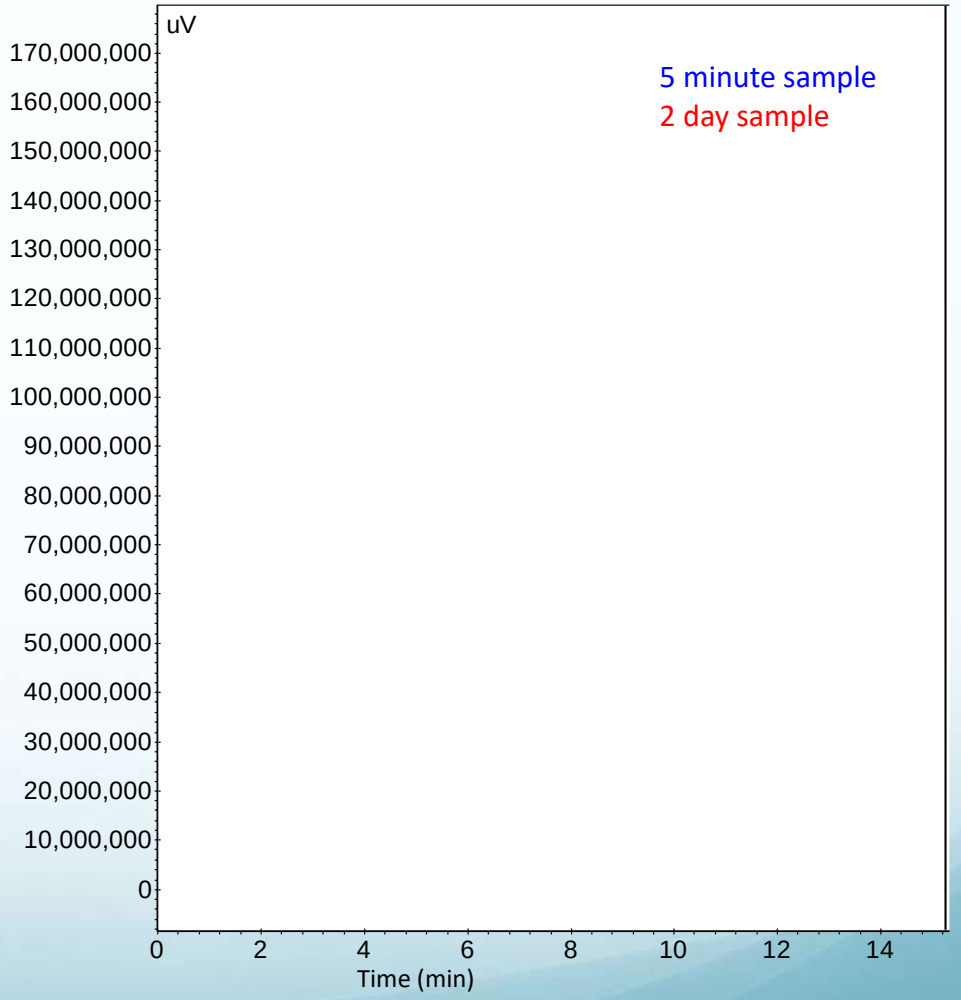


Comparison of Pure Butanol, Bio-Oil + Butanol Mixture and bio-oil only for bio-oil from 70°C collection tube

- If only physical mixing expect two peaks in bio-oil + butanol mixture
  - One to match bio-oil
  - One to match butanol
- This is not the case
- Indicates chemical reactions occurred

Results – Aging Comparison





Aging Comparison of Bio-Oil + Butanol Mixture (left - 70°C collection tube, right - 22°C collection tube

Conclusions

- Successful bench scale pyrolysis reactor
- Four stage collection system successfully separated reaction products
- Evidence of chemical reactions between bio-oil and butanol
- Future work needed to determine actual components

Future Work

- Conduct mass and energy balance on system
- Determine efficiency of the process (percent solar energy to chemical energy)
- Perform in-depth analysis on output gases of reaction
- Perform in-depth analysis on product bio-oils to determine components
- Continued testing for stability of bio-oil and butanol mixture over time
- Increase the scale of the reactor and collection system

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References

[1] *Pyrolysis of Wood and Bark in an Auger Reactor: Physical Properties and Chemical Analysis of the Produced Bio-oils.* **Ingram, Lonard, et al., et al.** 2008, Energy and Fuels, pp. 614-625.

[2] *Effect of Acid, Alkali, and Steam Explosion Pretreatments on Characteristics of Bio-Oil Produced from Pinewood.* **Wang, Srinivasan, et al.,** 2011, Energy and Fuels, pp. 3758-3764.

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[4] **Steele, Phillip, et al., et al.** *Method to Upgrade Bio-Oils to Fuel and Bio-Crude. 0192072* United States, Aug 11, 2011.