Efficacy of FTIR Analysis in Determining CO_2 Loading on Diglycolamine

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Outline

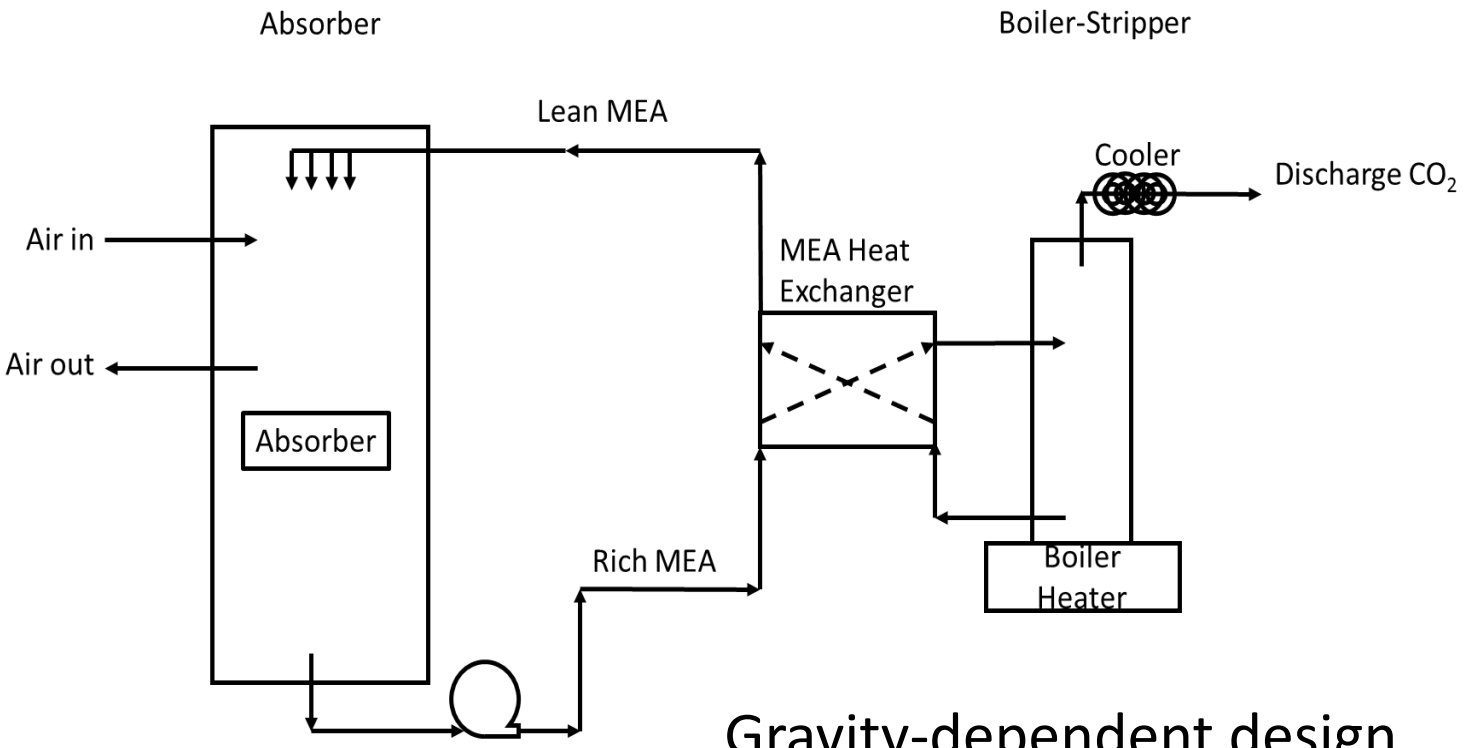
- Liquid amine background
- Microgravity adaptation
- FTIR motivation
- Experimental Method
    - pH Desorption
    - FTIR Analysis/ Calibration
- Results
- Discussion

Liquid Amine Background

- Industrial plant gas sweetening (H_2S, CO_2 removal)
- Liquid amine systems used in submarines since the 1950s
  - Monoethanolamine (MEA) scrubbers
  - Maintained CO_2 concentration at 1% of the atmosphere
- Advantages over solid sorbent bed systems
  - Power and volume savings
- Potential usage in human spaceflight
  - JSC evaluation of various liquid amines in FY16

Liquid Amine Background

Typical CO_2 removal plant process diagram



Gravity-dependent design

Microgravity Adaptation

Goal: design a liquid amine-based CO_2 capture system that can operate in microgravity

- Contactor designs for adsorbing and desorbing
- Captured liquid flow
- CO_2 mass flux
- Separation of gas and liquid

Microgravity Adaptation

Adsorb vs Degas (regeneration) mechanics for Diglycolamine (DGA)

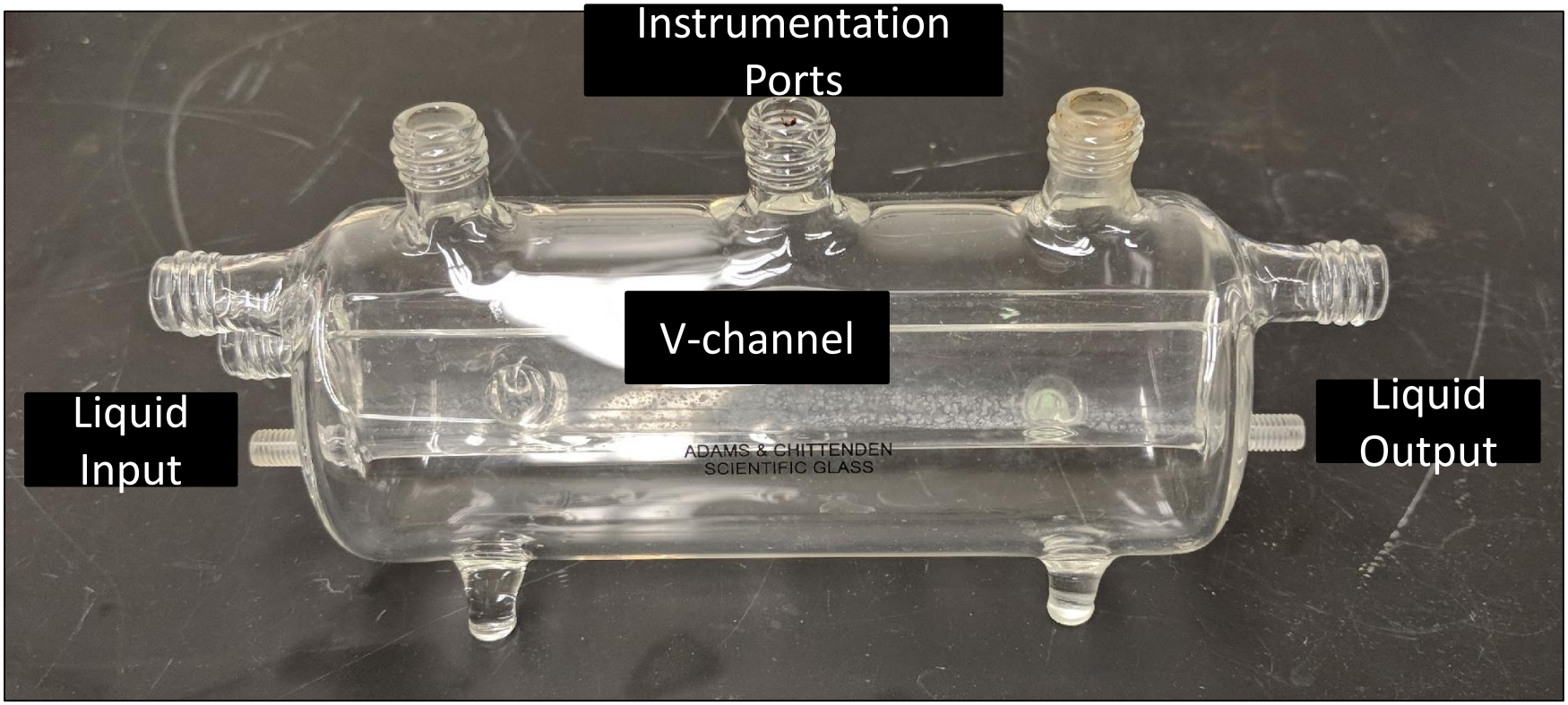
- Tasks split between JSC and ARC

Focal points for ARC:

- Degas rate
  - Temperature
  - Surface Area
  - Liquid Flowrate (contact time)
  - CO_2 loading
  - H_2O concentration

Degasser Design

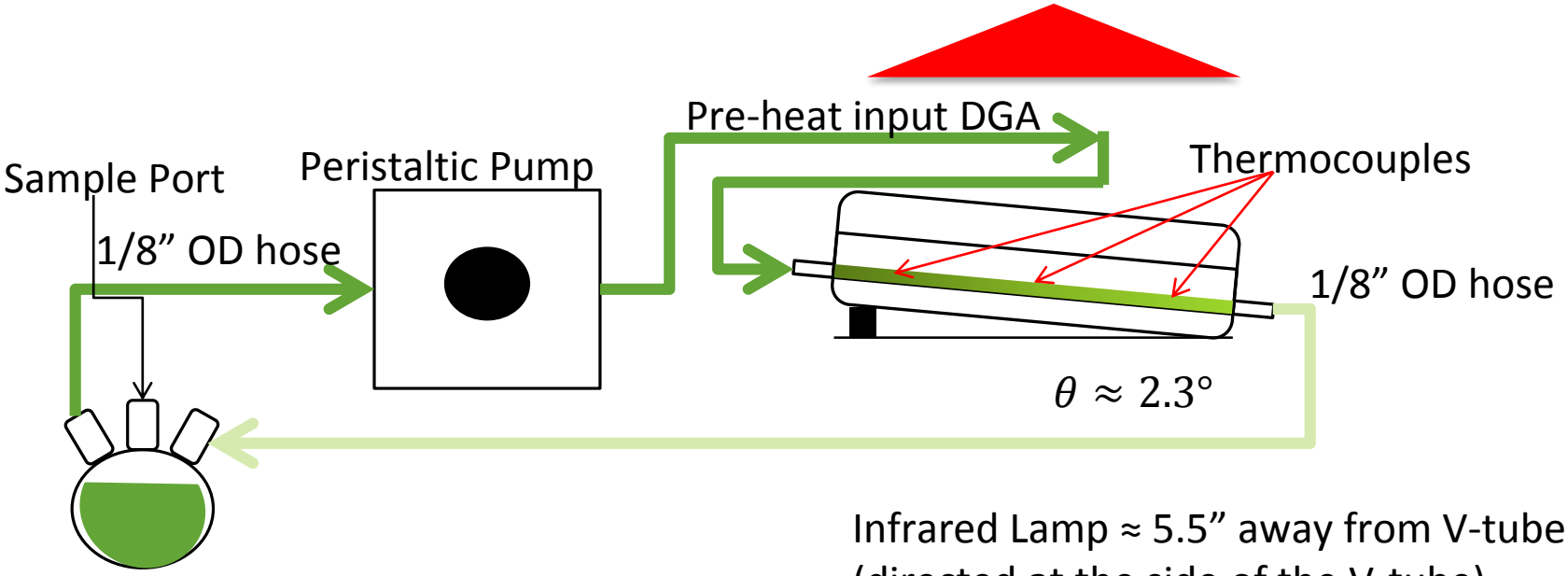
Goal: Design a scaled-down v-channel contactor that facilitates characterization of DGA degas mechanics



Glass V-tube

Degasser Design

Continuous flow sampling



FTIR Motivation

How do we measure CO_2 loading in the DGA?

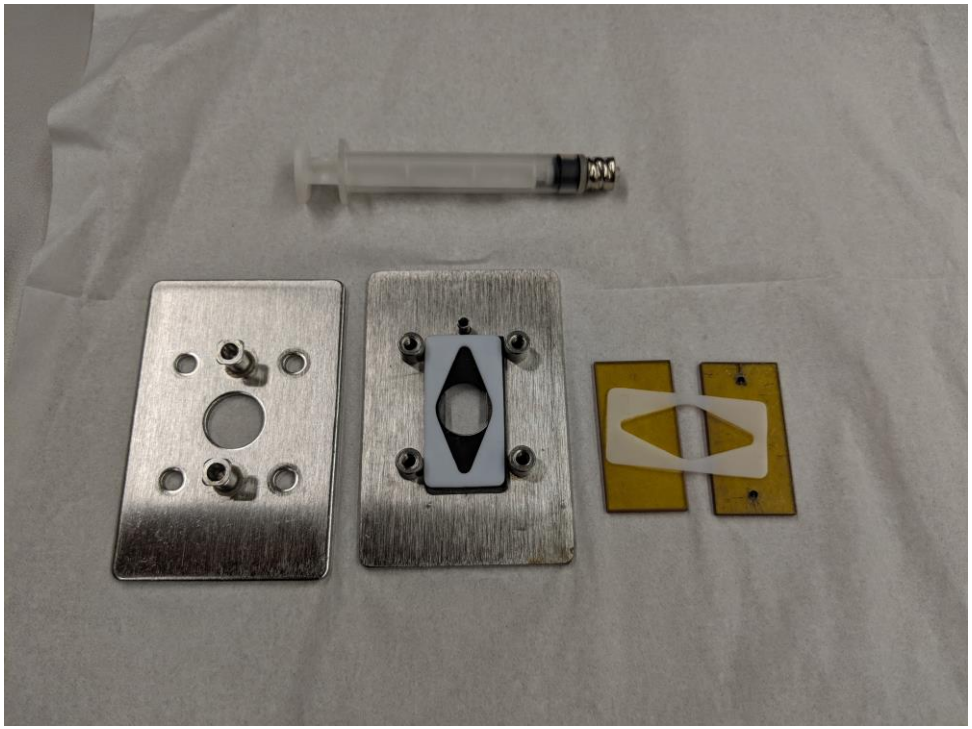
- ~~Solution pH level~~
- ~~Viscosity~~
- ~~Raman Spectroscopy~~
- Fourier Transform Infrared Spectroscopy (FTIR)
  - MEA CO_2 loading (Einbu, Aslak, et al., 2012)
- pH desorption method (Rogers, Tanya, et al., 2017)
  - "Acid desorption" "Acid Test"
  - 96%-98% CO_2 recovery (Zhou, Shan, et al., 2010)

pH desorption requires ~1mL of solution
FTIR can potentially only require ~100µL

FTIR Procedure

Buck Scientific demountable IR window liquid cell

- 4mm ZnSe crystal windows
- 0.015mm sample spacer
- Samples loaded with luer lock gastight syringe
- Entire window disassembled and cleaned with DI water and isopropanol between sample analysis runs



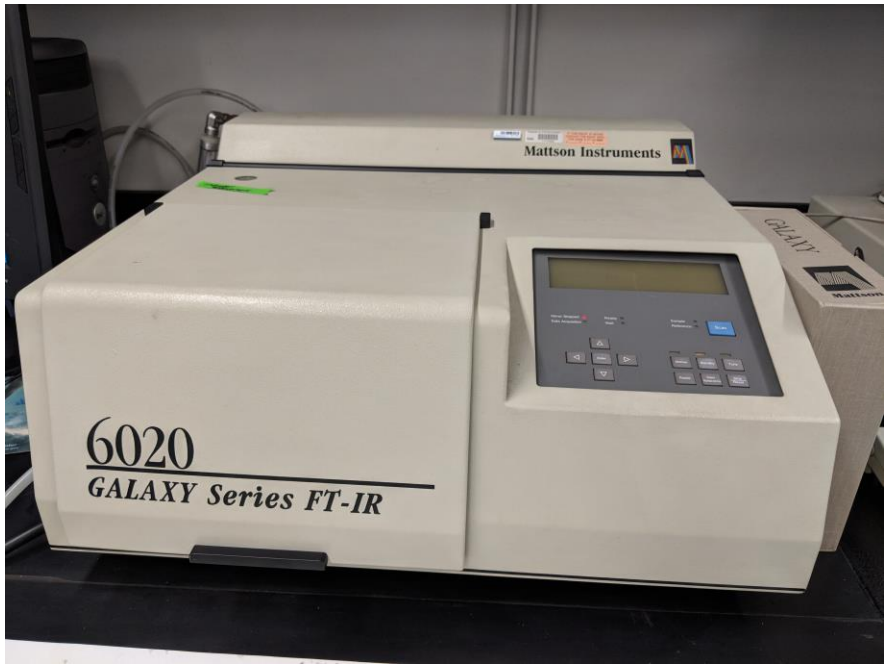
FTIR Procedure

Mattson Galaxy 6020 FTIR using WinFIRST v2.10

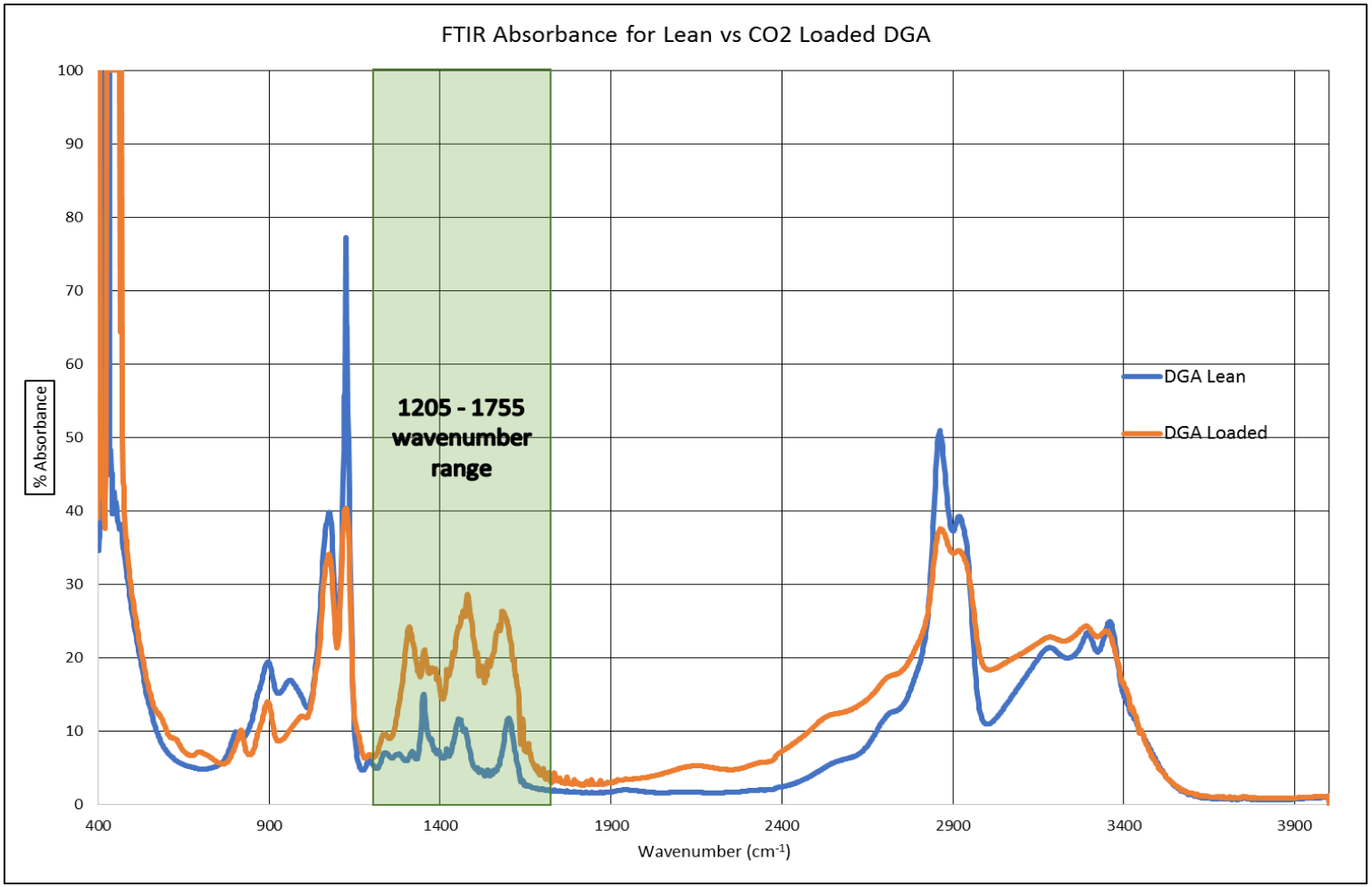
- Transmittance collected at 10kHz
- Wavenumbers 400 – 4000 cm^{-1}
- Resolution = 4

Spectragryph V1.1.0

- Baselines and pre-loaded calibration standards
- Experimental samples normalized on peak at 894 cm^{-1}
  - Peak that remained consistent in all samples of DGA

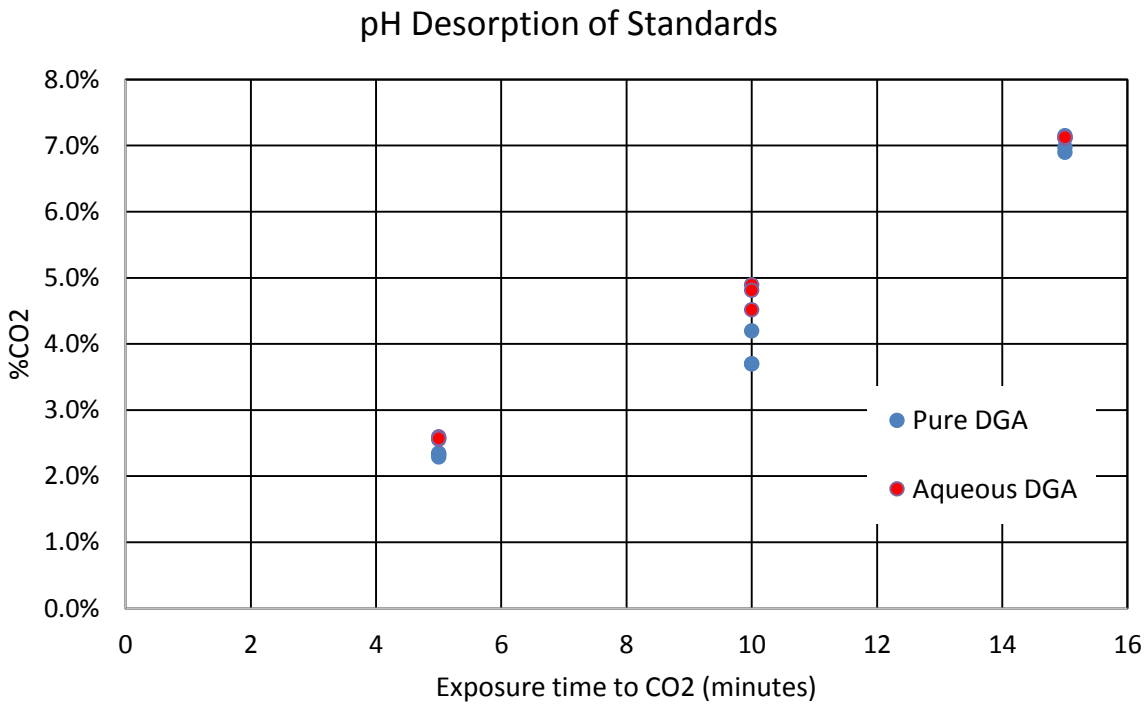


FTIR Calibration

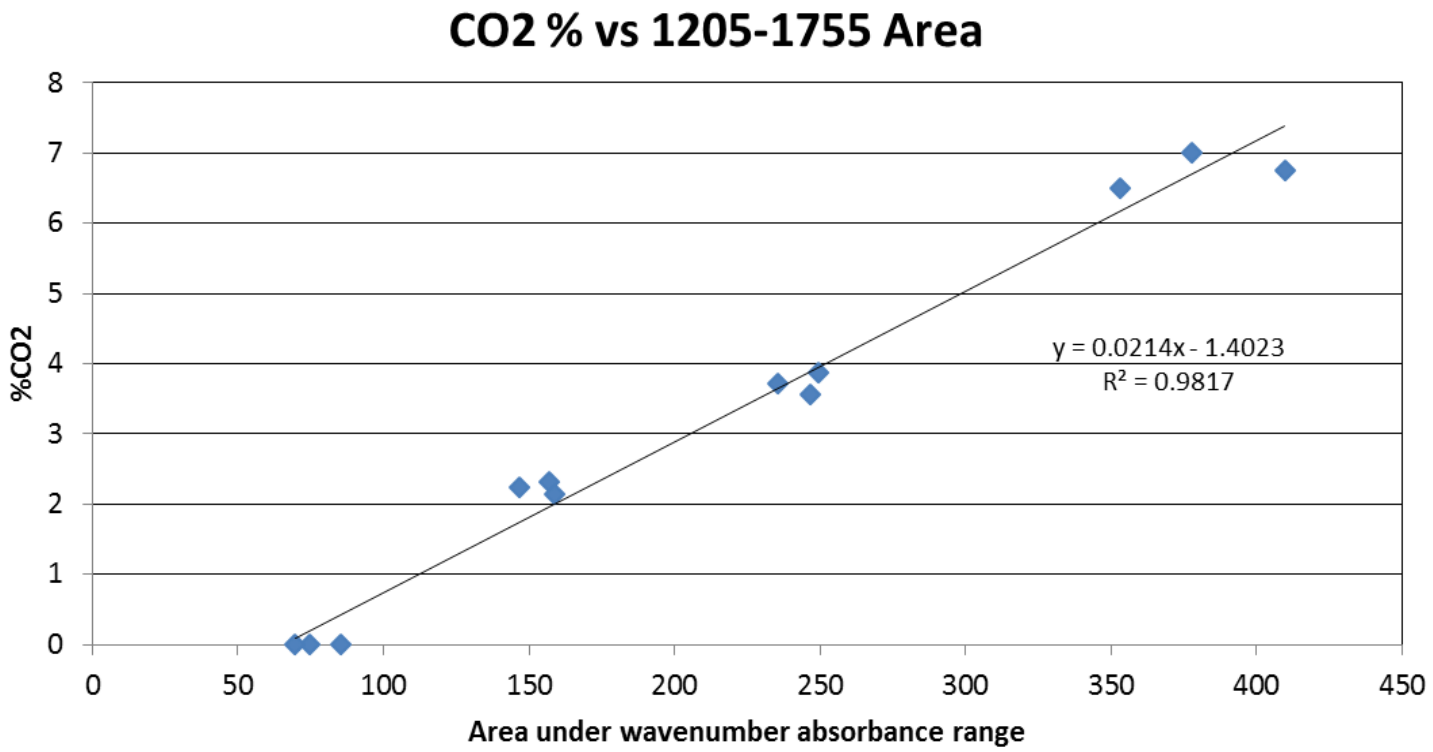


FTIR Calibration

Calibrate against pH desorption for range of CO_2 % loading on DGA

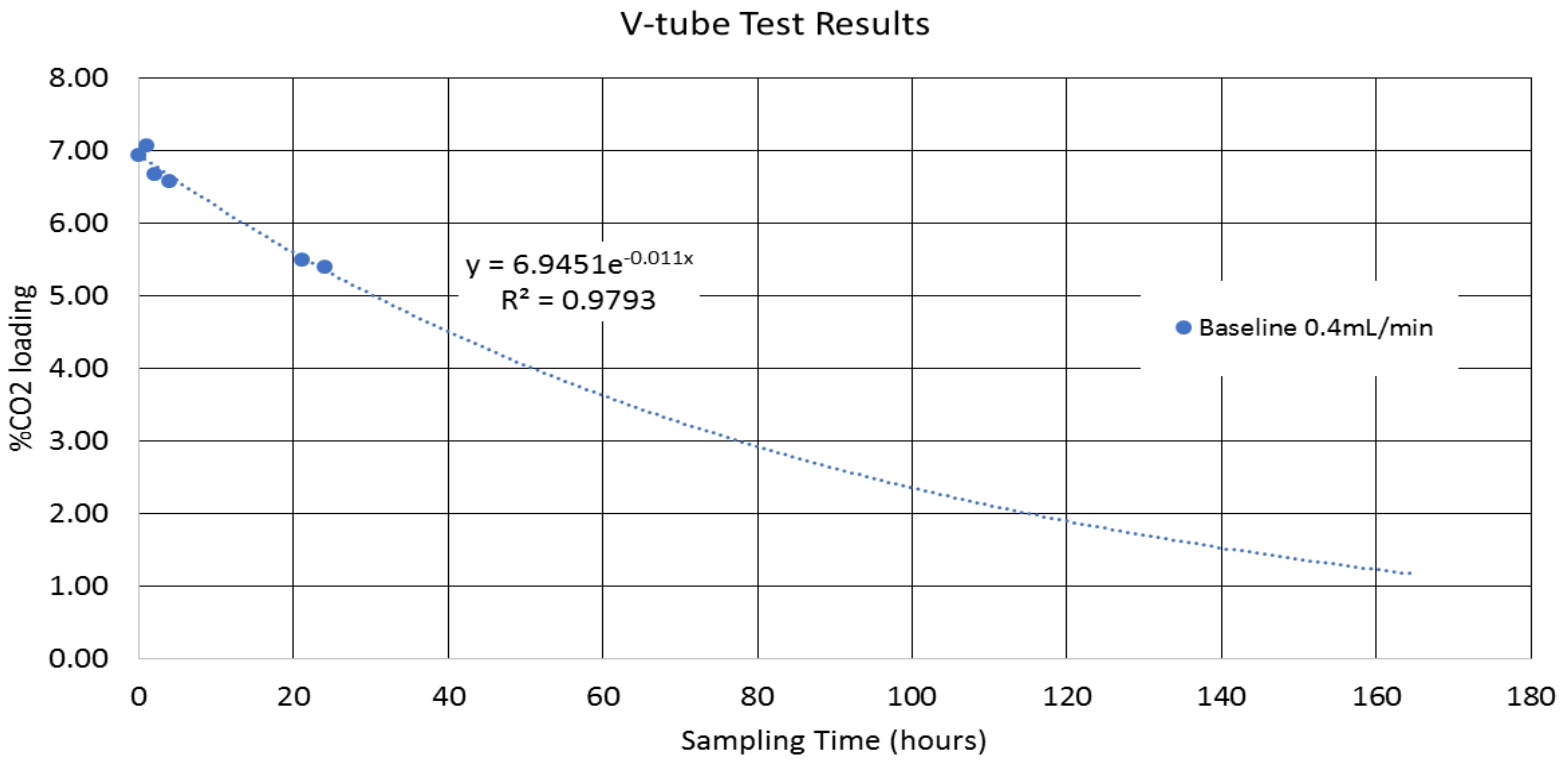


FTIR Calibration



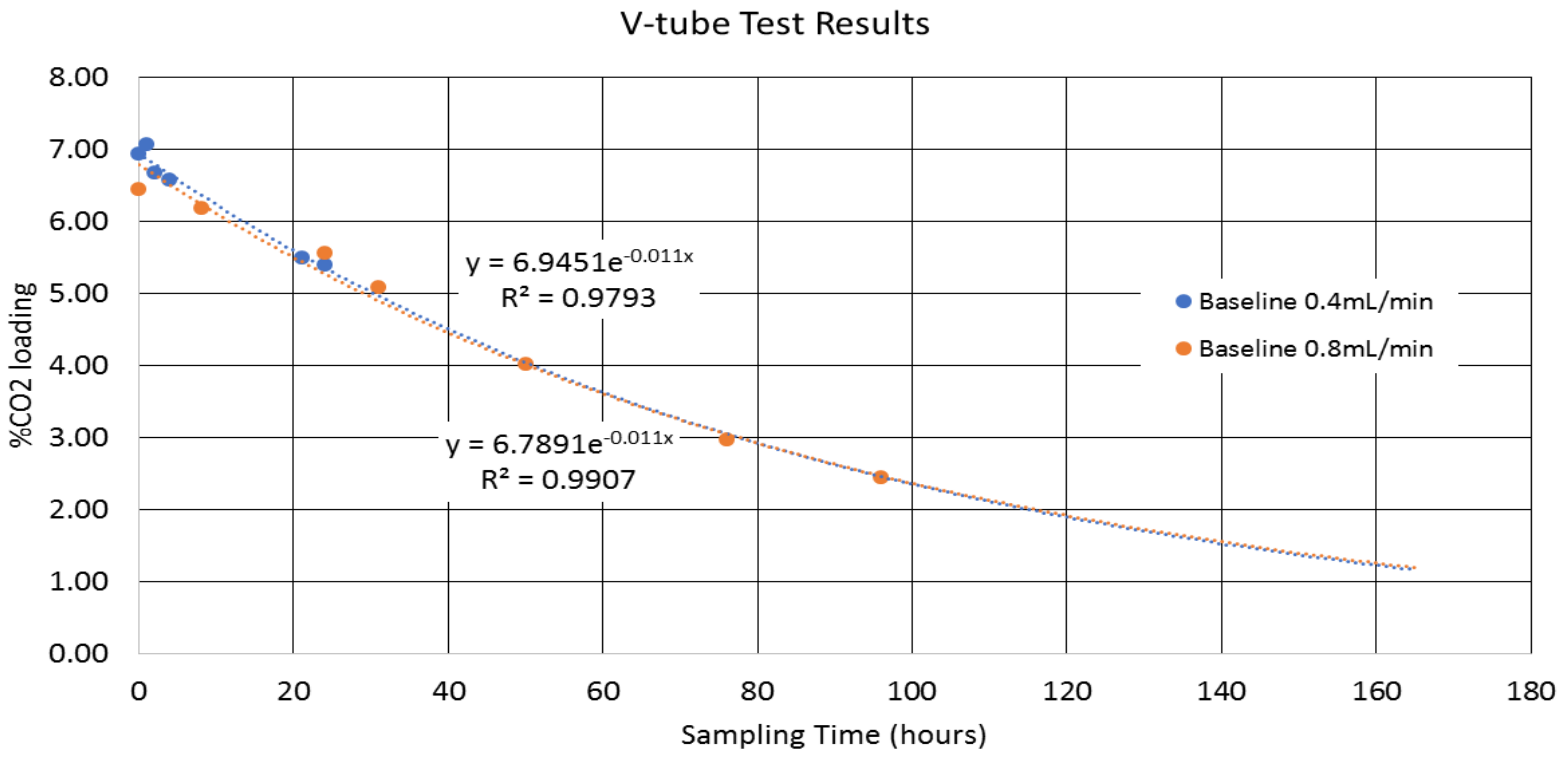
Calibration points for DGA run at various concentrations of water solution (0%, 4%, and 8%)

Results



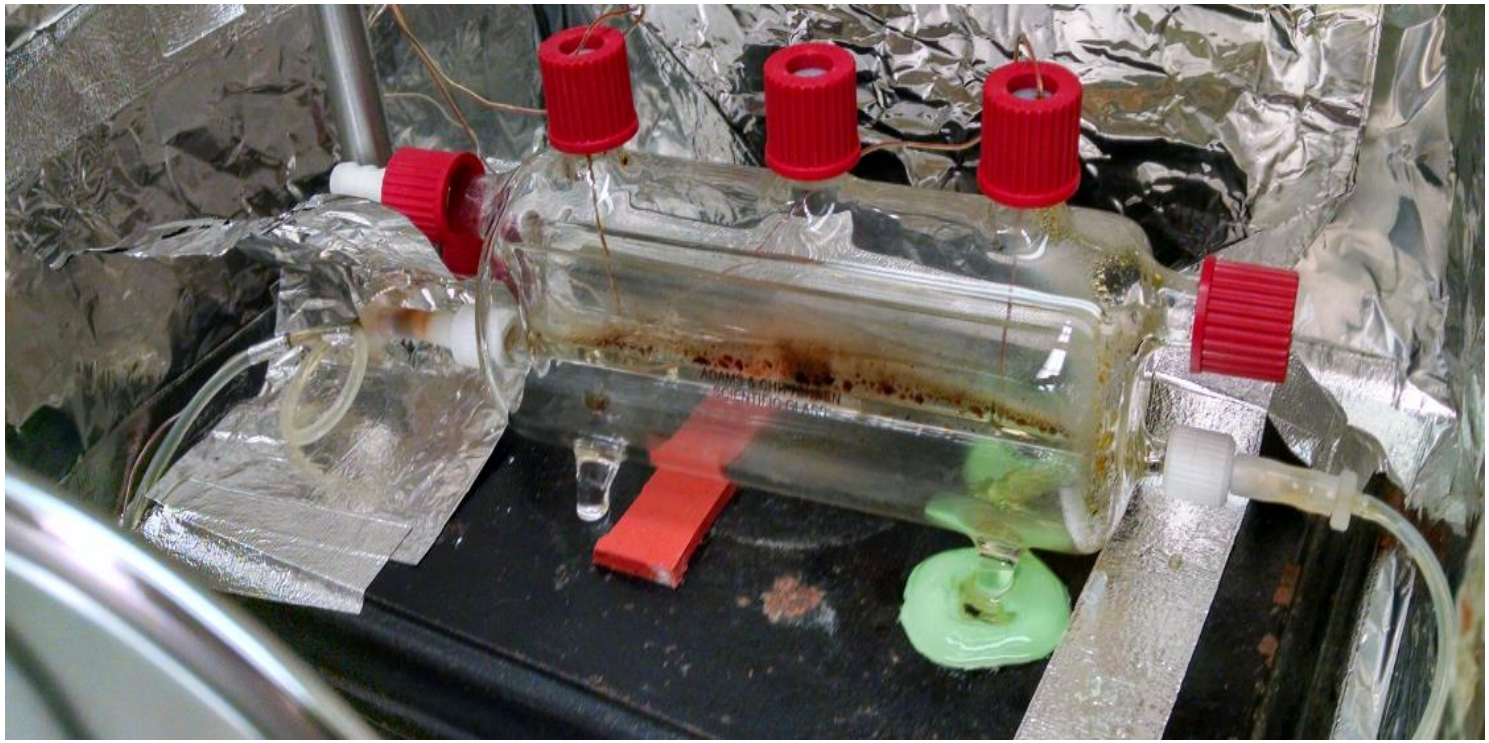
Initial baseline – pure DGA, 85°C, ~0.4mL/min flowrate, continuous flow sampling, no sweep gas

Results



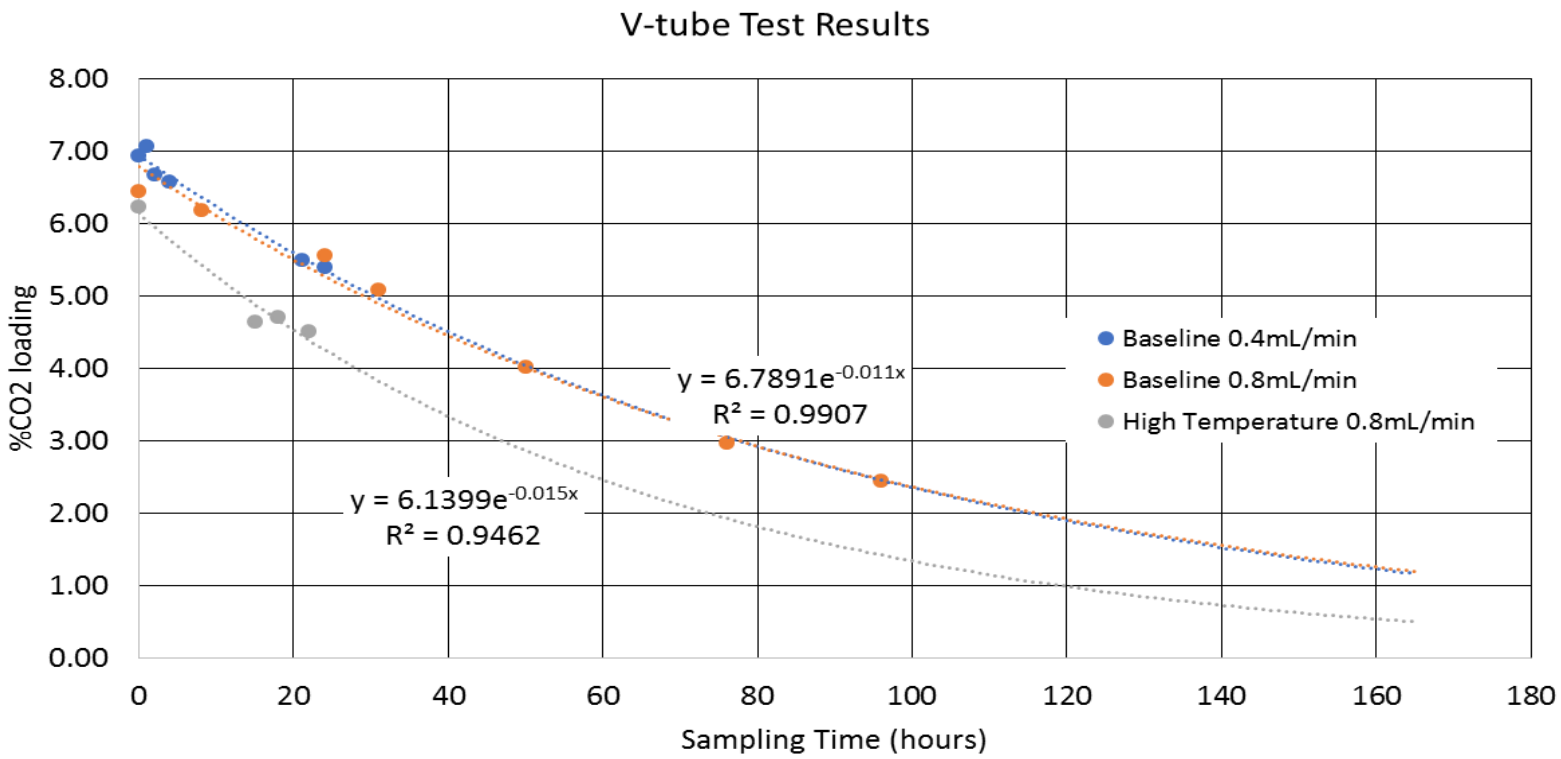
Modified baseline – pure DGA, 85°C, ~0.8mL/min flowrate, continuous flow sampling, no sweep gas

Results



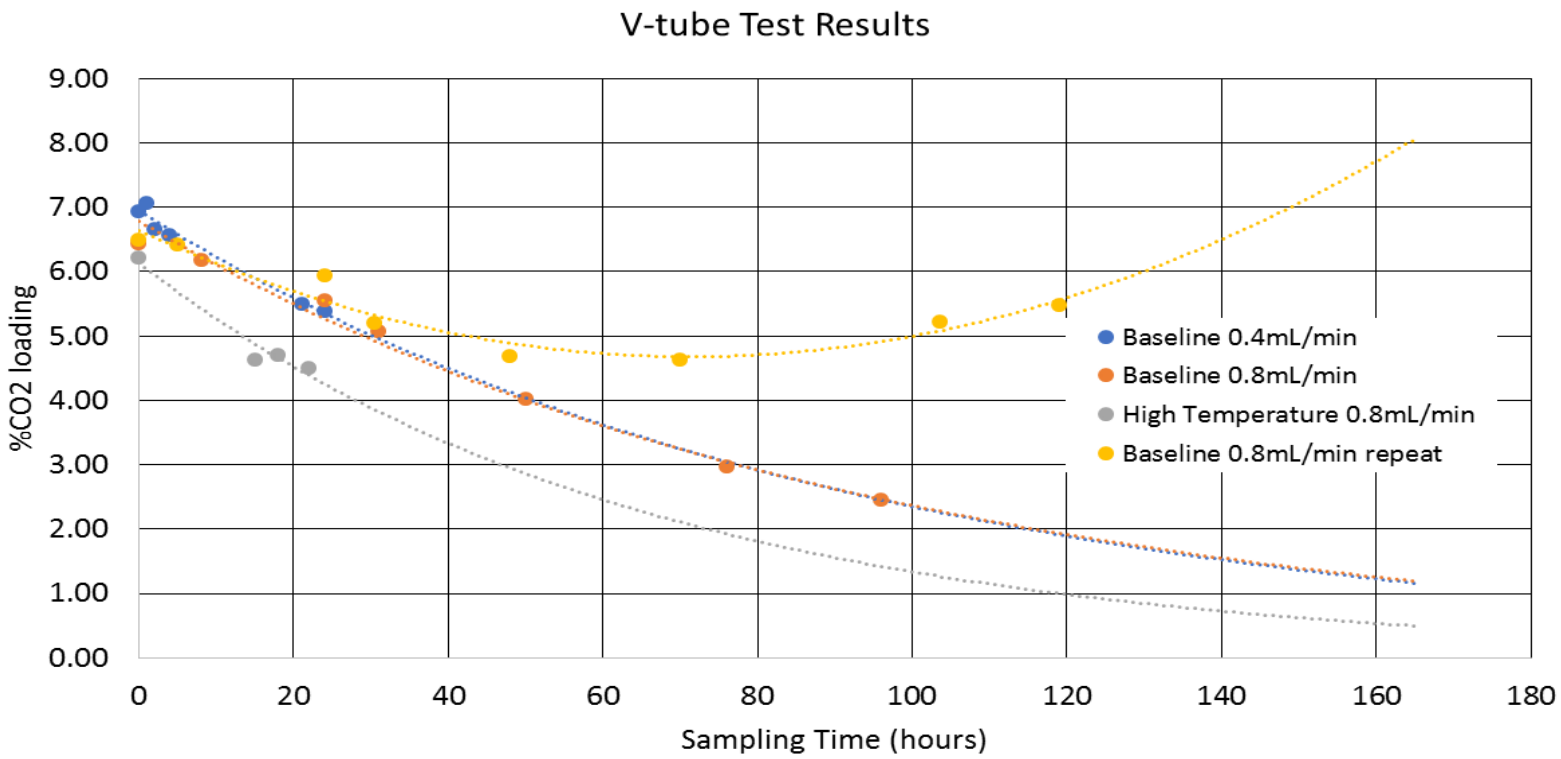
Discoloration of evaporated (and re-condensed) DGA

Results



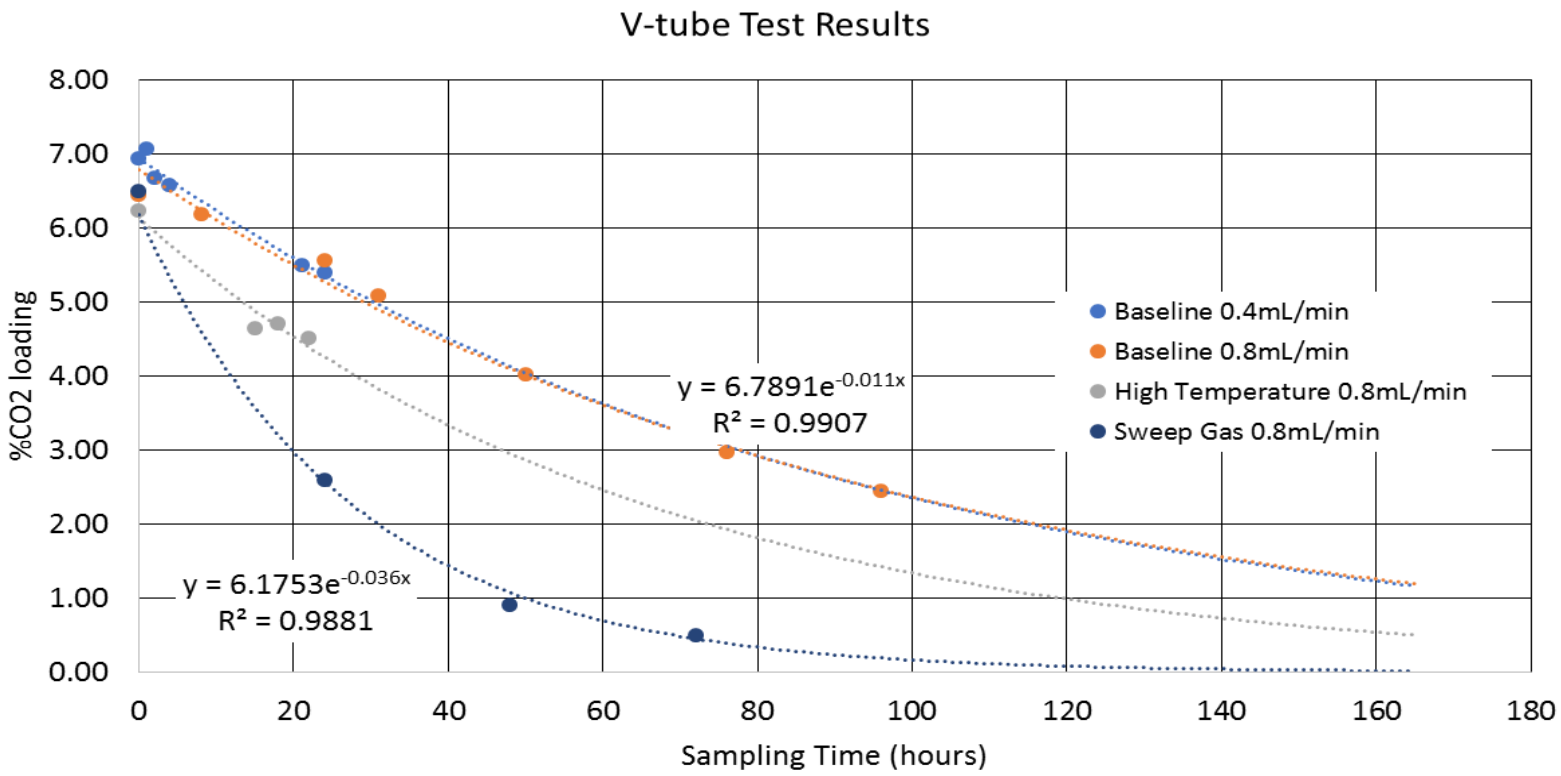
Experimental – pure DGA, 105°C, ~0.8mL/min, continuous flow sampling, no sweep gas

Results



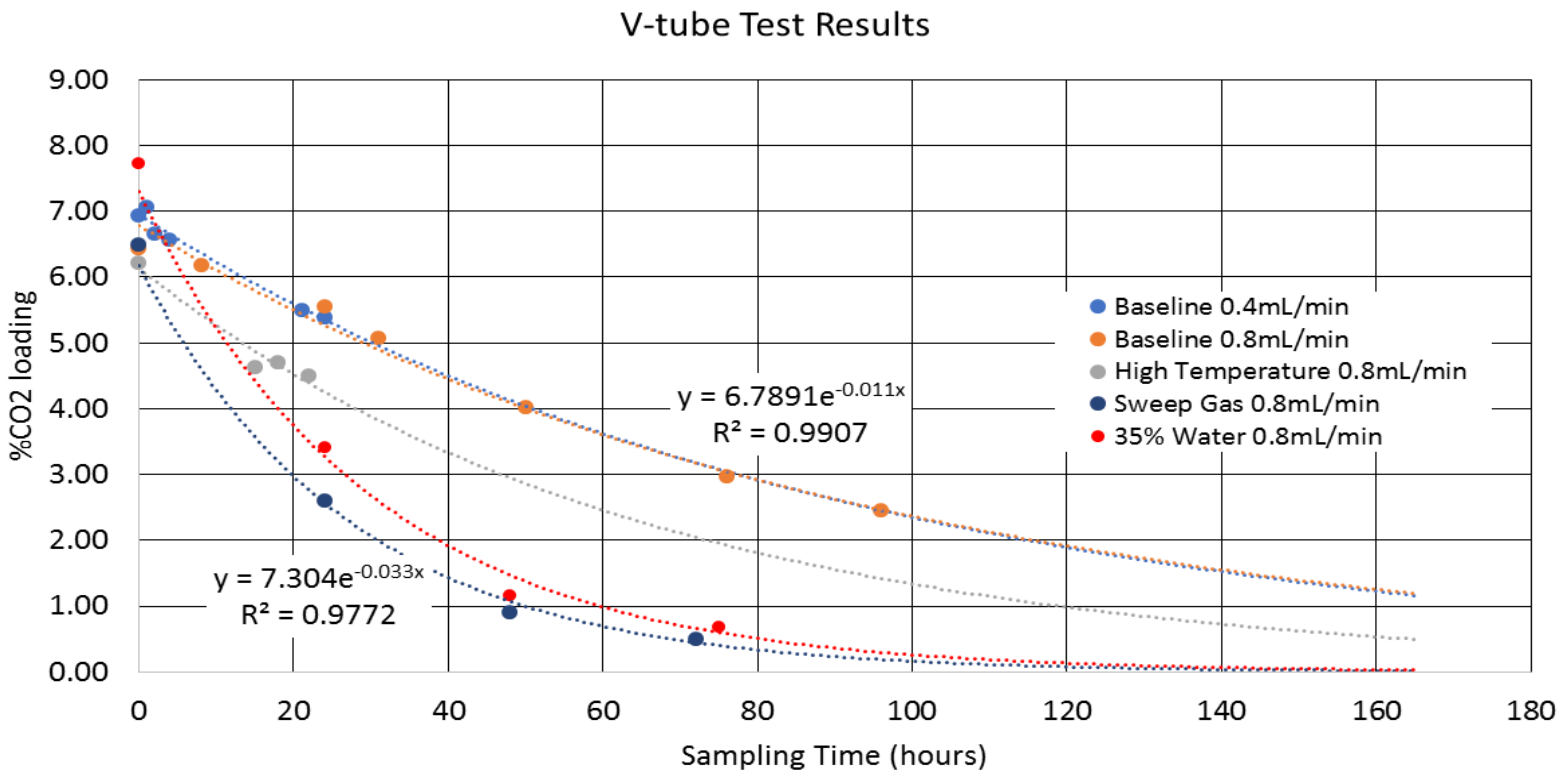
Baseline – pure DGA, 85°C, ~0.8mL/min, continuous flow sampling, no sweep gas

Results



Experimental – pure DGA, 85°C, ~0.8mL/min, continuous flow sampling, 400mL/min N_2 sweep gas

Results



Experimental – 35% H_2O + 65% DGA, 85°C, ~0.8mL/min, continuous flow sampling, no sweep gas

Discussion and Current/Future Work

Moderate success using FTIR spectroscopy to analyze CO_2 % loading on DGA

- Repeatability
- Reducing sampling volume

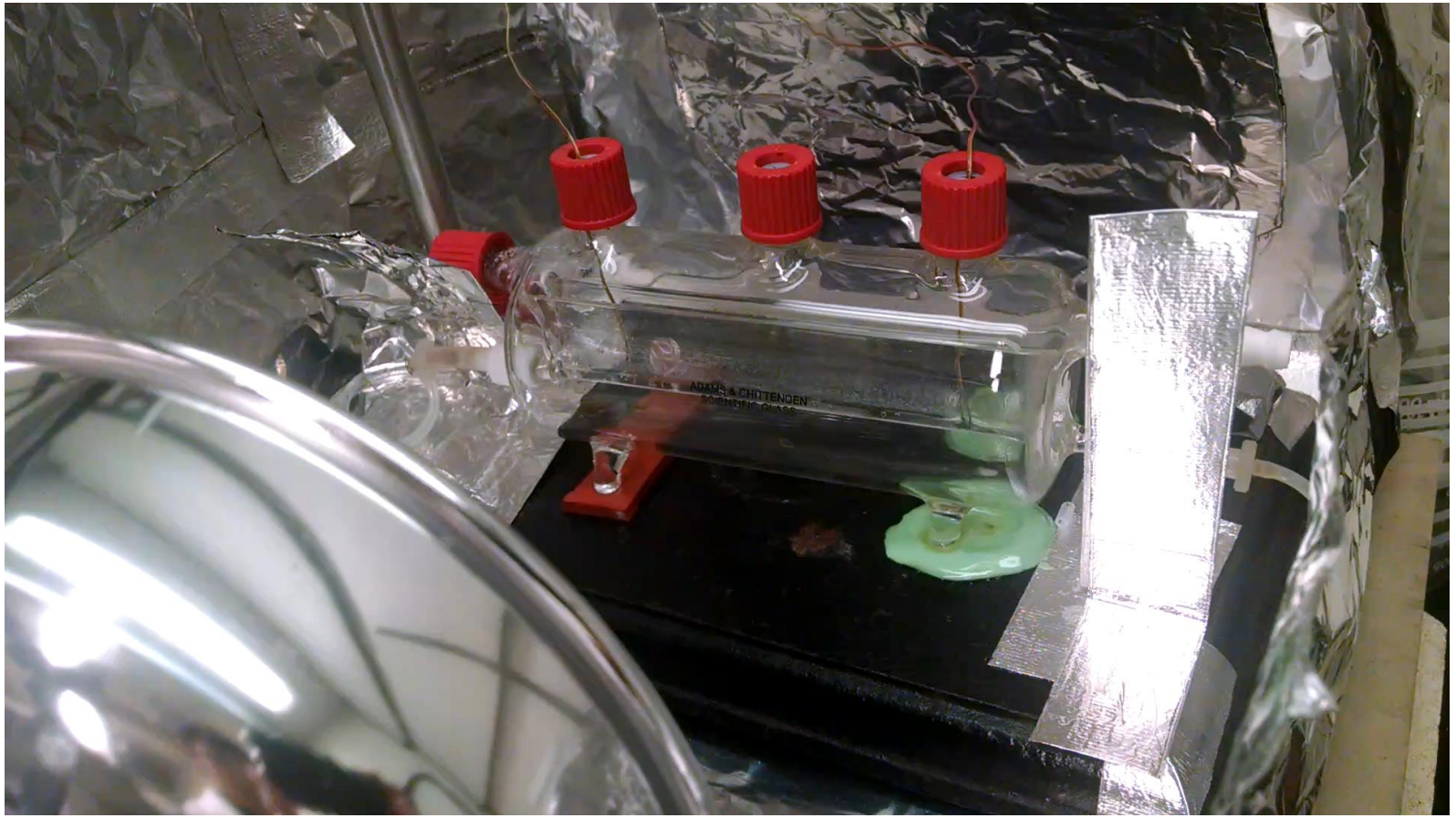
35% H_2O + 65% DGA solution

- Single pass flow
- Scaling up
- Bubbling
- Re-capturing evaporated H_2O and DGA

Acknowledgements

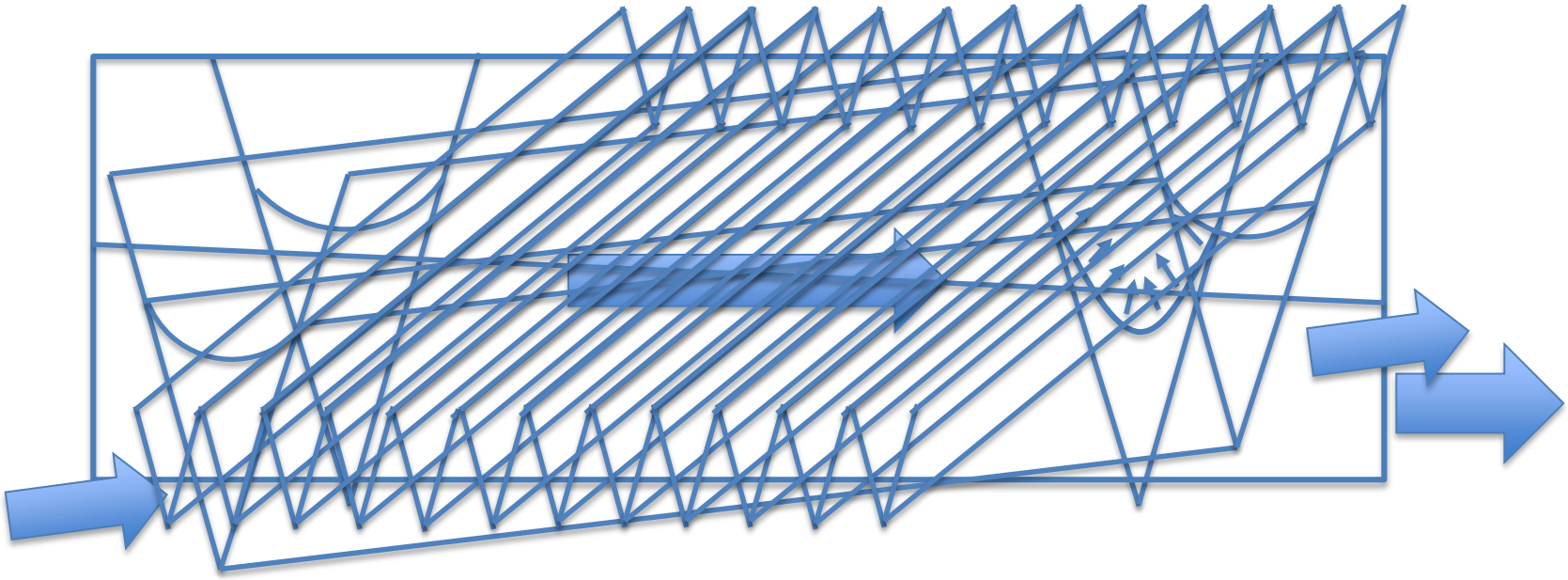
Many thanks to the team at JSC, especially Tanya Rogers and Giraldo Alvarez, who provided valuable insights and inputs throughout the experimental testing process.

Backup Slides



Microgravity Adaptation

Potential design solution: “V-channel” direct air contactor



Degasser Design

Single-pass flow sampling