Effect of Thermal Gradient on Diffusion through PTFE Membrane

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Research Investigations

- Effect of thermal gradient on overall diffusivity of gaseous microbial respiration byproducts through Polytetrafluorethylene (PTFE) membrane
- Inducing a thermal gradient within Diffusion Testing Apparatus
- Investigating effectiveness of heating membrane in soil sensor

Background

Image 1: AI Rendered Soil Sensor Prototype

- Few Industry 4.0 solutions exist for optimizing agricultural methods based on environment specific soil profile
- Soil profiling analysis of microbial content in soil via gaseous respiration byproduct concentrations for optimizing agricultural production affecting crop selection and rotation
- Sensor detecting respiration products requires membrane semi-permeable to gases and impervious to water
- Engineered diffusion testing operation to examine effect of thermal gradient, including building in-line thermocouple and heat exchanger; as well as system for overall diffusive analysis
- Past work involves ensuring waterproofing via CO2/water mix instead of pure CO2 gas, apparatus design, process design
- Fick's First Law: $J = -D\frac{dC}{dx}$
- D, Diffusivity Constant: $D = D_0 e^{-\frac{E_a}{k_B T}}$
- Thermal energy balance for heat exchanger length, dz:

$$mCp\frac{dT}{dz} = -hd\pi\left(T(dz) - T(z_{in})\right)$$

Methodology & Design

Figure 1: Diffusion Testing Apparatus

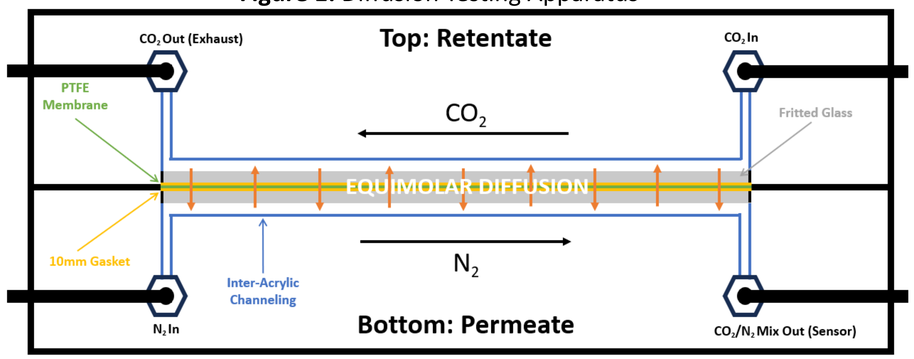
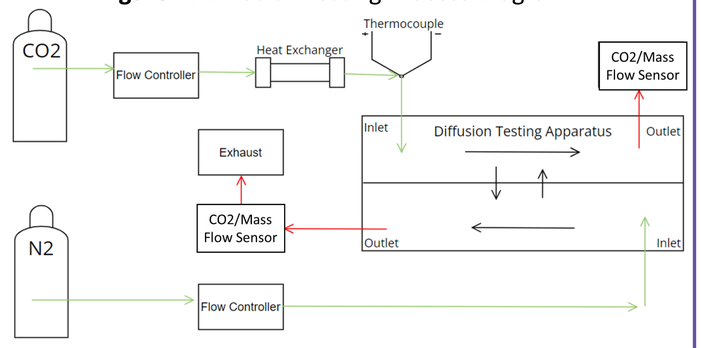
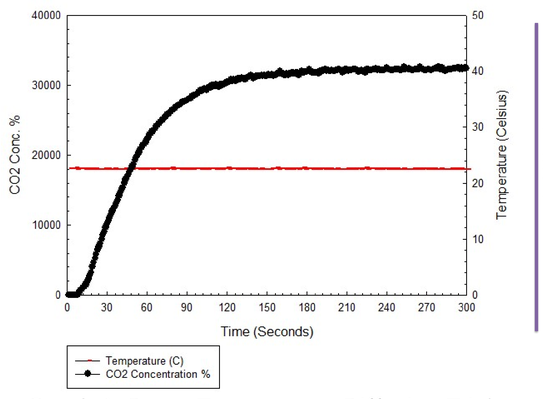


Figure 2: Diffusion Testing Process Diagram

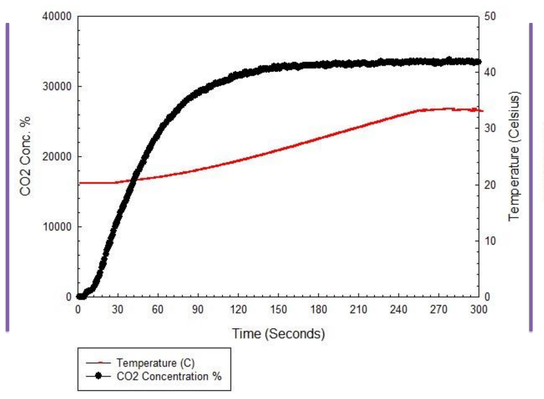


- 2 SLPM N_2 carrier gas flow is initiated to permeate side; 1 SLPM CO_2 flow is initiated to retentate side of DTA
- Counter current flow and high carrier gas flowrate ensures diffusion gradient is maintained
- Matheson digital mass flow sensors regulate and read mass flow rates with a computationally determined mass balance

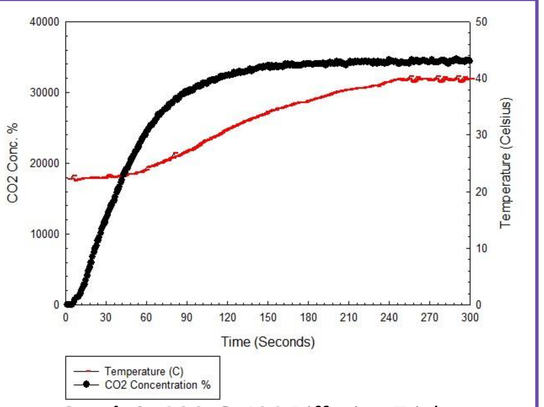
Results



Graph 1: Room Temperature Diffusion Trial



Graph 2: CO2 @ 33C Diffusion Trial



Graph 3: CO2 @ 40C Diffusion Trial

Temperature	SS CO2 Concentration (Permeate)	% Conc.	% Conc. Increase (From RT)
RT: 21.5C	32300 +/- 100 ppm	32.3 +/- 0.1	0.00%
33C	33600 +/- 100ppm	33.6 +/- 0.1	4.03%
40C	34500 +/- 100ppm	34.5 +/- 0.1	6.81%

Table 1: Diffusion Trial Results

- Found CO2 concentration on permeate side to be 6.81% on average across 5 trials in 40C trial
- Diffusivity is improved at temperatures requiring theoretically low power output
- Calculated mass balance across retentate and permeate sides

Future Work

- Investigating impact of packed soil on diffusion capabilities of PTFE membrane
- Analyzing diffusion and waterproofing capabilities of membrane in cool and freezing conditions
- Inducing heat via highly resistant material such as graphite within structure as opposed to heated inlet gas

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