Methane Capture & Biomass Production Test Chamber

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Department of Mechanical Engineering

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Abstract

Atmospheric methane retention remains one of the globes leading causes for global warming. To combat these environment concerns, our engineering team developed an instrument, hereafter referred to as a bioreactor, which captures and repurposes methane emissions from ambient air. The bioreactor houses a strain of methanotroph bacteria which in low-concentration environments metabolize methane into a biomass byproduct. This biomass has shown promise as a sustainable animal feed.

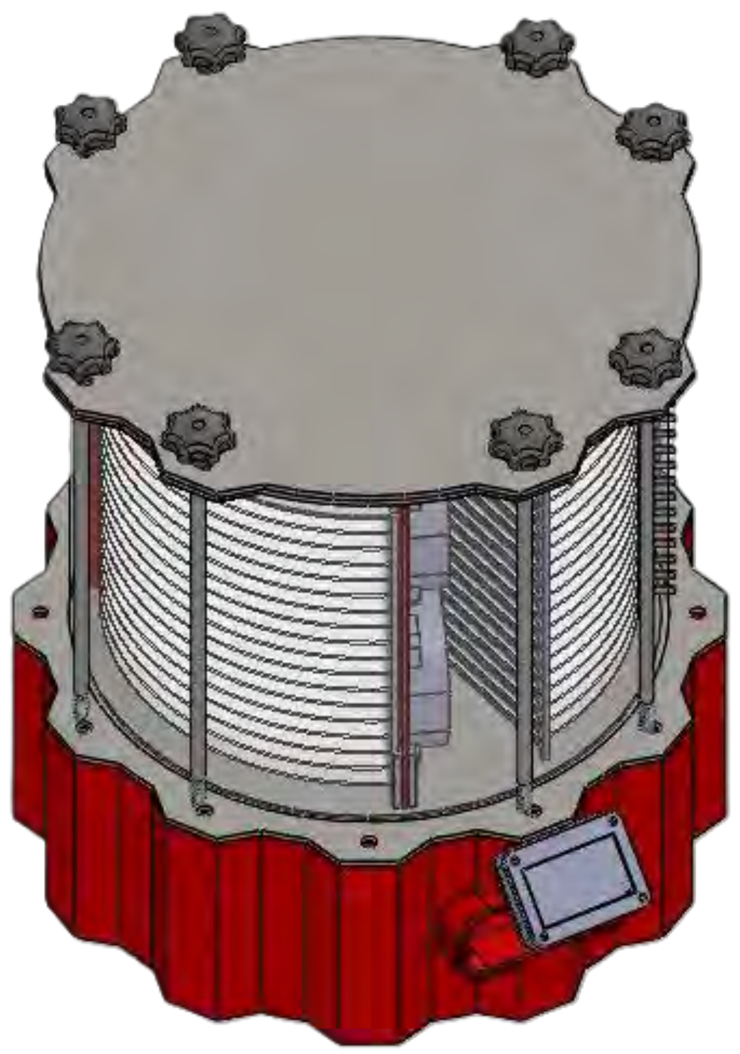

Figure 1: Isometric view of the final bioreactor CAD model

Problem

Recent decades have indicated an alarming increase in the concentration of greenhouse gases, with methane accounting for roughly 33% of all greenhouse emission. To help combat the global climate and ecological crisis, this project aims to optimize the removal of methane in low concentration environments, of around 10 ppm to 10,000 ppm. This would include key areas such as farms, landfills, and wastewater treatment plants. This project integrates a novelly studied thin-film technique with a newly researched strain of methanotroph (methane-eating prokaryote), developed by Dr. Mary Lidstrom at the University of Washington.

Internal Airflow	300 – 750 CFM
Max. internal pressure	9.2 psi
Sensors	Temperature, flowrate, humidity, pressure
Touchscreen controls	Residency time, flowrate, salt distribution, biomass harvest, open/close valves

Table 1: Bioreactor design specifications

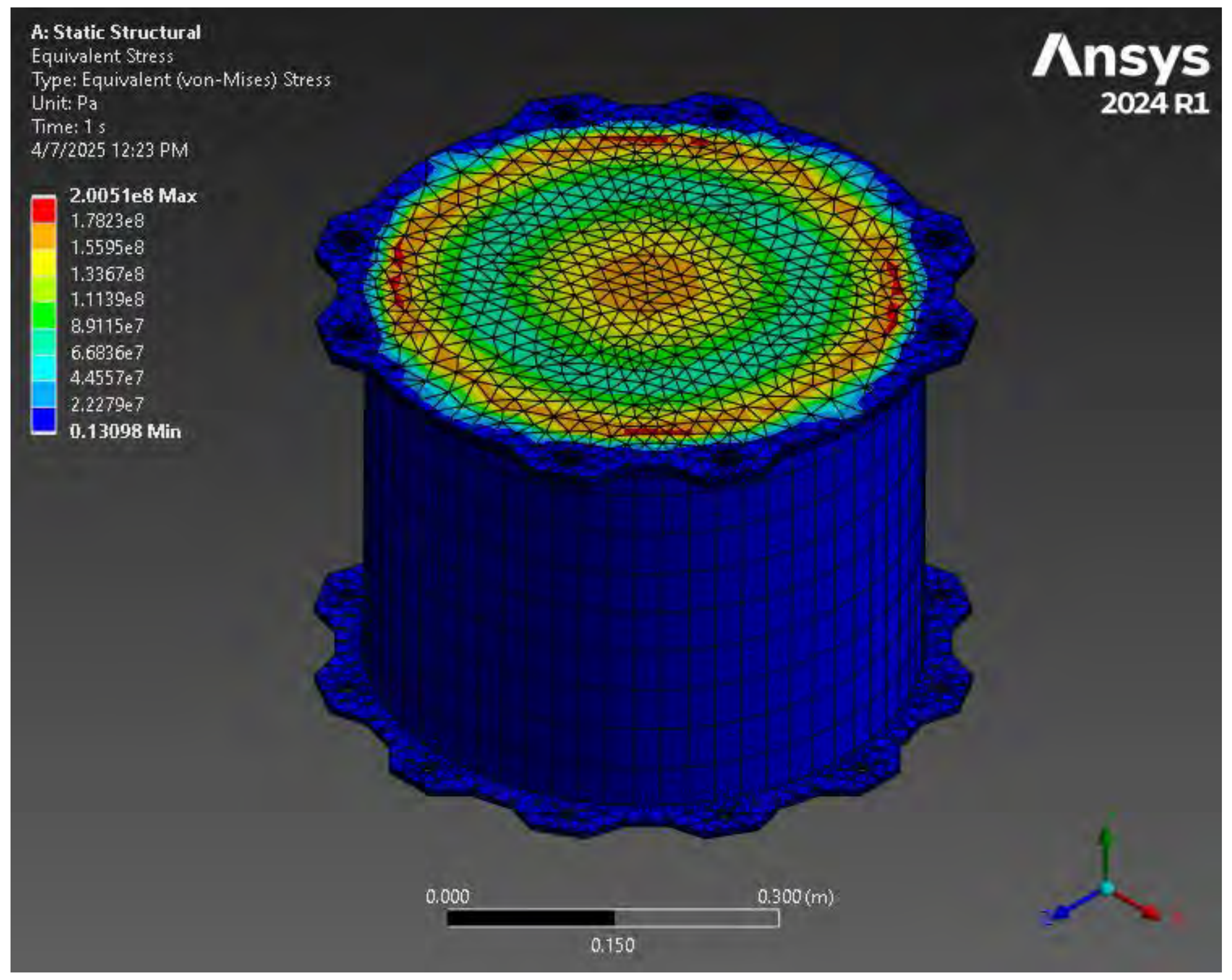

Figure 2: FEA model showing stress calculations caused by an internal pressure of 2.5 atm.

Design Methods

Previous methanotroph reactors have utilized passive open-ended systems which allow air to flow freely through a fixed inlet-to-outlet path. Even at scaled up sizes, these previous systems typically fail to provide the necessary reaction time necessary for the bacteria to complete metabolization of the ambient methane. Engineering research concluded that a recycling process with ambient air moved over the methanotrophs would yield higher methane mass transfer to the procaryotes. The novel approach is facilitated by compressing air into the main chamber and circulating it for an adjustable cycle time. The Gnielinski correlation for mass transfer further supported this conclusion through peer reviewed calculations and simulations.

$$Nu_D = \frac{\left(f/_8\right)(Re_D - 1000)Pr}{1 + 12.7\left(f/_8\right)^{1/2}\left(Pr^{2/3} - 1\right)}$$

Results

Our team conducted several physical tests to ensure the functionality and safety of bioreactor subsystems, as well as multiple computational tests to predict and analyze the behavior of air inside the chamber. Using a physics model built in MATLAB, we were able to find that a flowrate of 750 CFM and 18 trays was optimal for our design. Atmospheric pressure, and 5 minutes of residency time yields approximately 82.5 percent methane removal from a given batch. Basic FEA analysis conducted in Ansys Mechanical also concluded that, due to the flatness of our lid, abnormally large magnitudes of bending stress occur, causing our maximum achievable pressure to be around 9.2 psi, based on a safety factor of 4 below the yield strength of steel. However, while this number is lower than we initially anticipated, achieving this internal pressure still increases the rate of methane transfer to the bacteria by 50% to 62.5%.

Conclusion and Future Steps

Our prototype optimizes efficiency, modularity, and ease of use for researchers furthering the exploration of novel methanotroph technology. Extensive modeling and simulation of the system has ensured functionality, however physical testing remains inconclusive due to methanotroph samples not being available. The design and manufacturing process highlighted several parameters that should be considered for further optimization. Future iterations to this work should focus on sourcing stronger shell materials, optimizing reactor geometry towards withstanding higher ranges of pressure, and integrating more ergonomic harvesting designs. This project serves as a key technological advancement towards combating the global climate crisis, through the reduction of ambient methane.

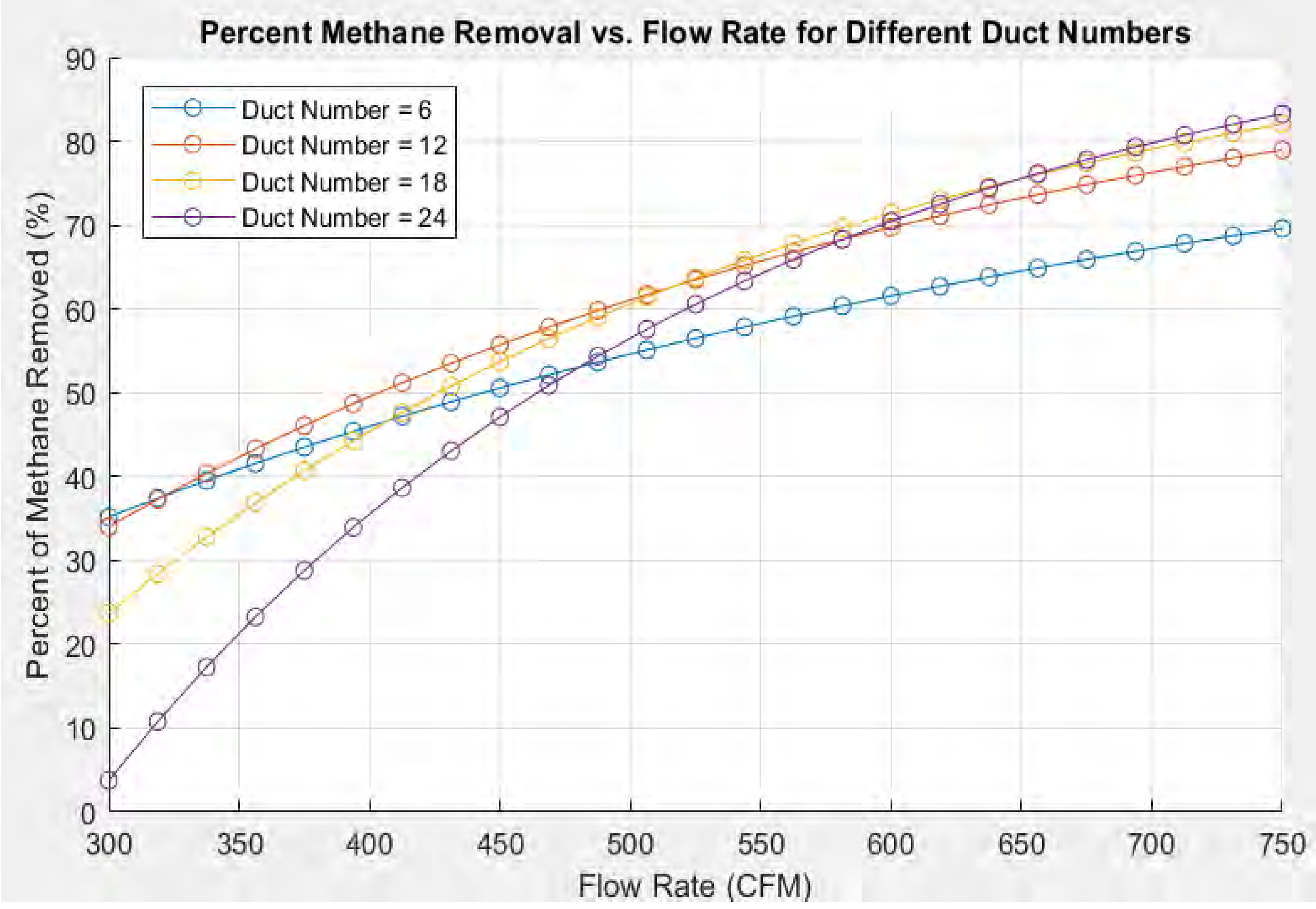

Figure 3: Methane removal percentage plotted against flowrate in CFM, justifying the selection of 18 trays in our shelving unit design.

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