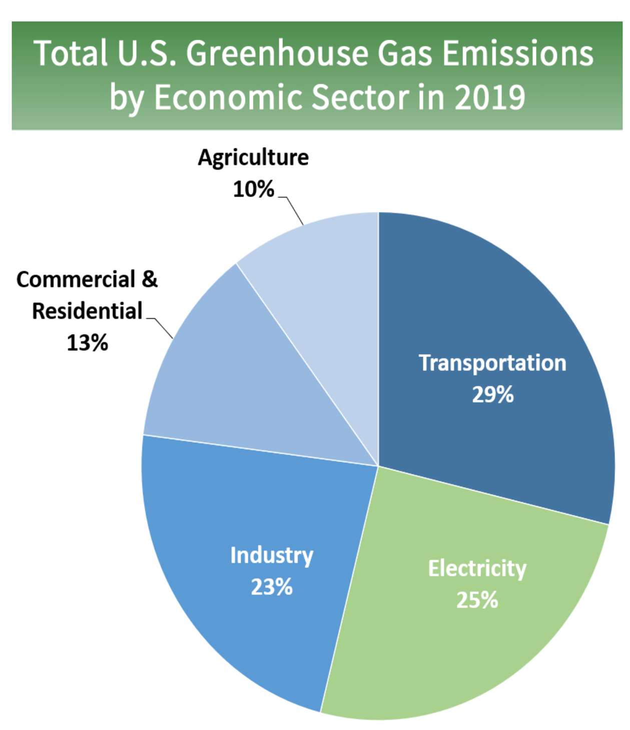
Enhancing Thermal Stratification in a Solar Thermal Storage Tank

Joseph Noreika, Advisors: Julia Nicodemus, Ph.D. and Joshua H. Smith, Ph.D.

Department of Mechanical Engineering, Lafayette College, Easton PA

Motivation

- Climate change is become an increasingly prevalent issue throughout the world. This is leading to many negative effects including more prevalent flooding and runoff, loss of biodiversity and ecosystems, and rising sea levels.
- The decade of 2011-2020 was the hottest decade on record, which can be attributed to worsening climate change. For reference, there were 6,558 million metric tons of CO_2 equivalent emitted in 2019.
- When referencing the figure to the right, it can be seen that commercial and residential emissions accounts for 13% of total emissions in the U.S. Of this sector, nearly two-thirds is a result of space and water heating.
- As a result, improving the efficiency of residential heating devices is beneficial.



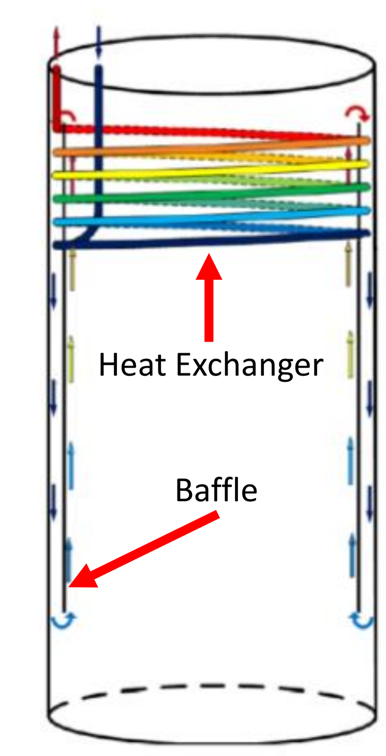
[1]

Research Objectives

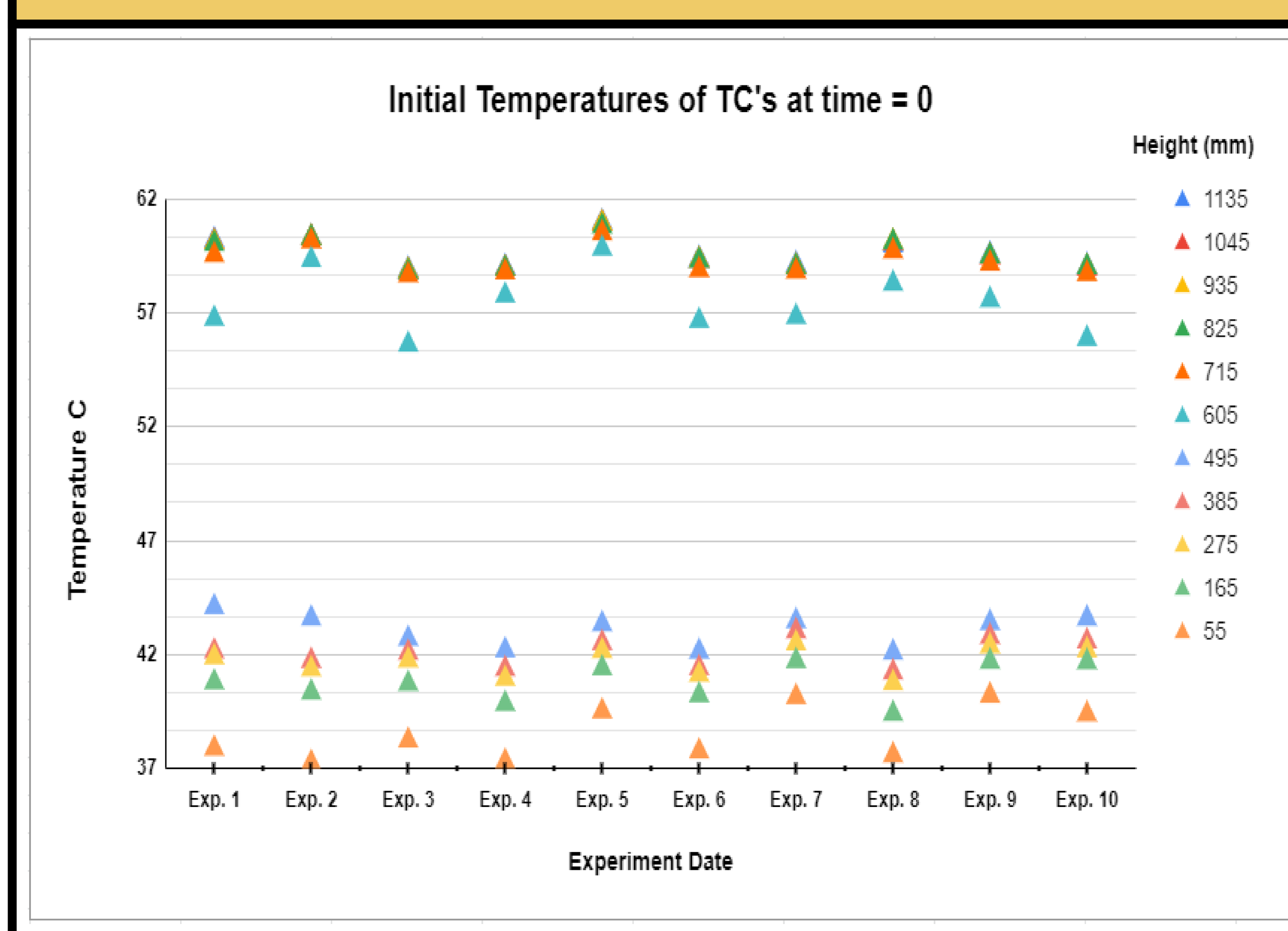
1. Conduct experiments in an initially thermally stratified tank to determine if thermal stratification can improve rate of energy discharge in the tank while avoiding fluid velocity degradation.
2. If velocity degradation occurs, investigate whether or not there is an initial condition (smaller cold band height or smaller temperature difference between bands), that would create balance between stratification and fluid velocity.

Experimental Apparatus

- The image to the right shows a diagram of the storage tank with an immersed heat exchanger and a baffle, which is optimized from previous studies from the Lafayette Solar Lab.
- In order to achieve initial thermal stratification in the tank, water was fed in from a diverting valve located at the bottom of the tank in various increments. The tank was filled in the following order:
  - The 1st fill was 61°C, the 2nd fill was 20°C, and the 3rd fill was 61°C . The height and proportion of fills were varied depending upon the experiment type.
  - The 2nd and 3rd fills mix with each other, resulting in a hot upper band and a colder lower band of water in the tank.

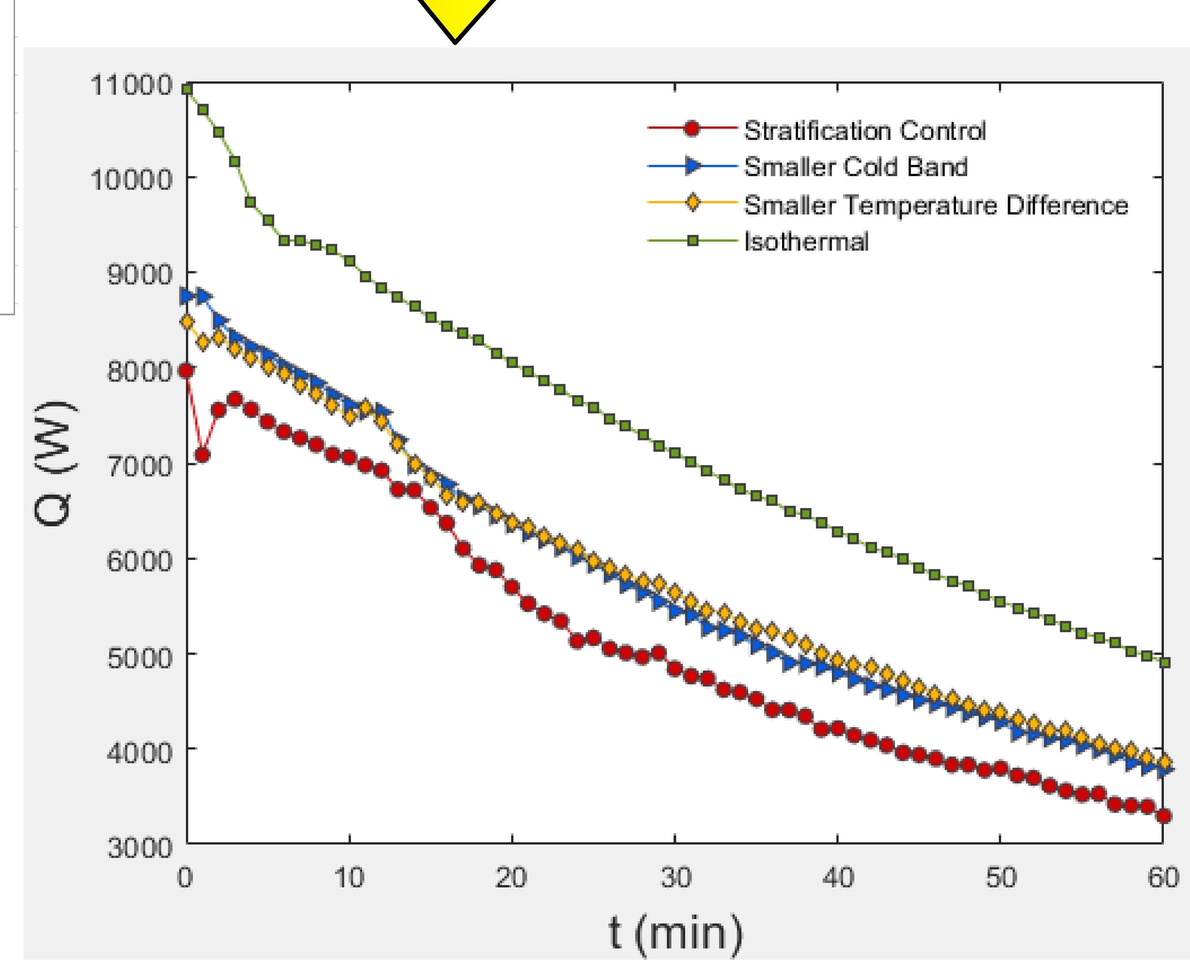


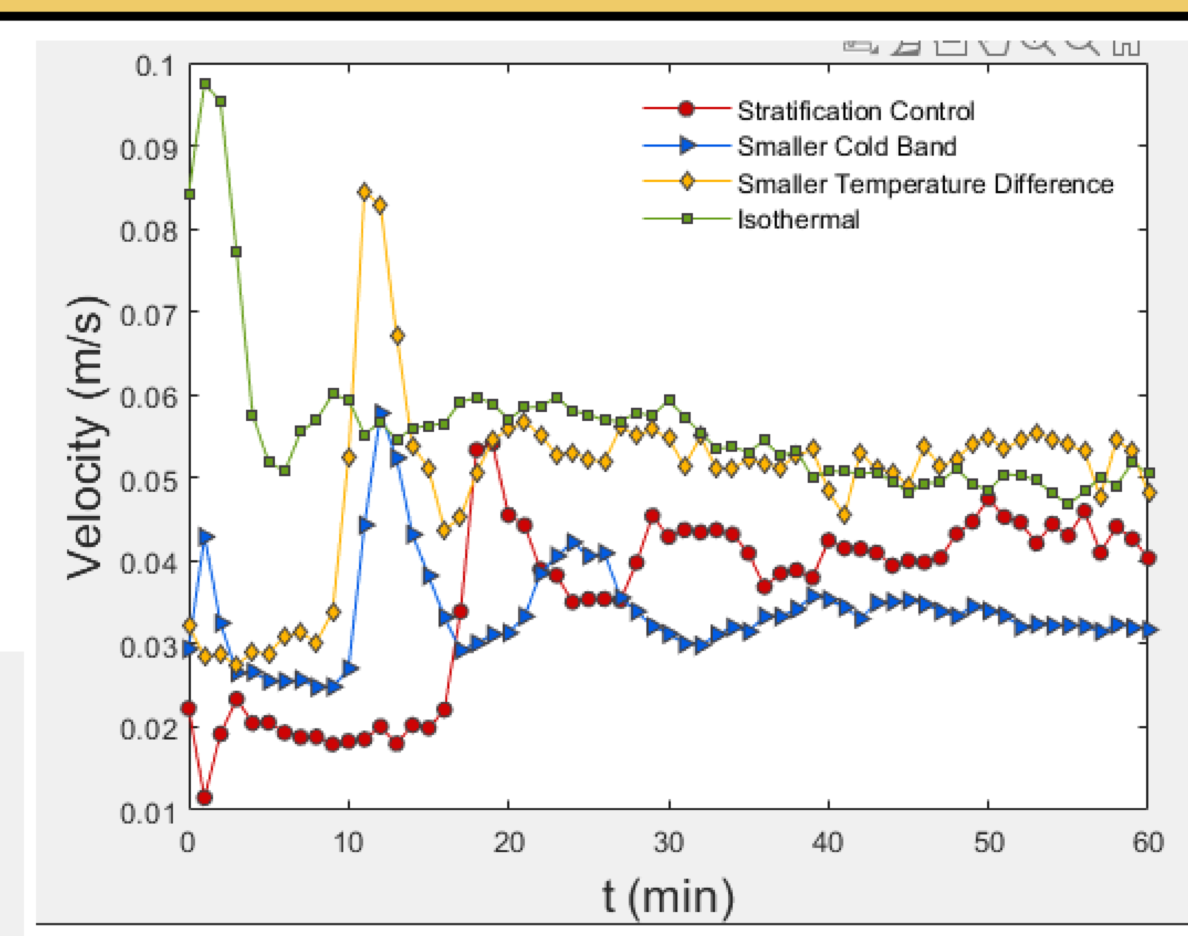
Results



The initial temperatures plot above shows the temperatures for each of the storage tank thermocouples in 10 different experimental trials for the "stratification control" experiment type.

Heat transfer rate (Q) is a measure for the rate at which heat is transferred from the storage tank to the heat exchanger.





The velocity plot above shows the estimated velocities of the plumes flowing across the heat exchanger for the varying experiment types.

Conclusions and Future Work

- The initially stratified tank in "stratification control" experiments had lower fluid velocity and heat transfer rate than an isothermal tank experiment. We know that the two contributing factors to improving heat transfer are improved thermal stratification and increased velocity of the fluid flowing across the heat exchanger.
- Both the smaller cold band and smaller temperature difference trials improved heat transfer but were still lower than the isothermal trial. The smaller temperature difference trials had increase fluid velocity, and the smaller cold band experiments had higher temperature fluid flowing over the heat exchanger.
- Future work could entail the design and implementation of an inlet device with a simultaneous charging and discharging loop to maintain thermal stratification in the experimental tank.

Acknowledgements

Thank you to my advisors, Professor Julia Nicodemus and Professor Joshua Smith, and to the David and Lorraine Freed Undergraduate Research Symposium for further supporting my undergraduate research experience.

References

[1] EPA. Sources of greenhouse gas emissions, 2019. URL https://www.epa.gov/ghgemissions/ sources-greenhouse-gas-emissions.