# CFD Simulation on Air Gap Membrane Test Cell Geometries

**Aaron Chan, Mechanical Engineering**
Mentor: Dr. Reza Lakeh
Kellogg Honors College Capstone Project

## Introduction

Membrane Distillation (MD) utilizes a thermally driven process for distillation. A vapor permeable membrane sits in between a hot flow and a cold flow. Vapor of the hot flow slowly diffuses through the membrane and condenses in or near the cold flow. Air Gap Membrane Distillation (AGMD) adds an air gap to minimize heat losses, increasing thermal efficiency. ANSYS Fluent is used to simulate different geometries to better understand several variables affect performance of a test cell.

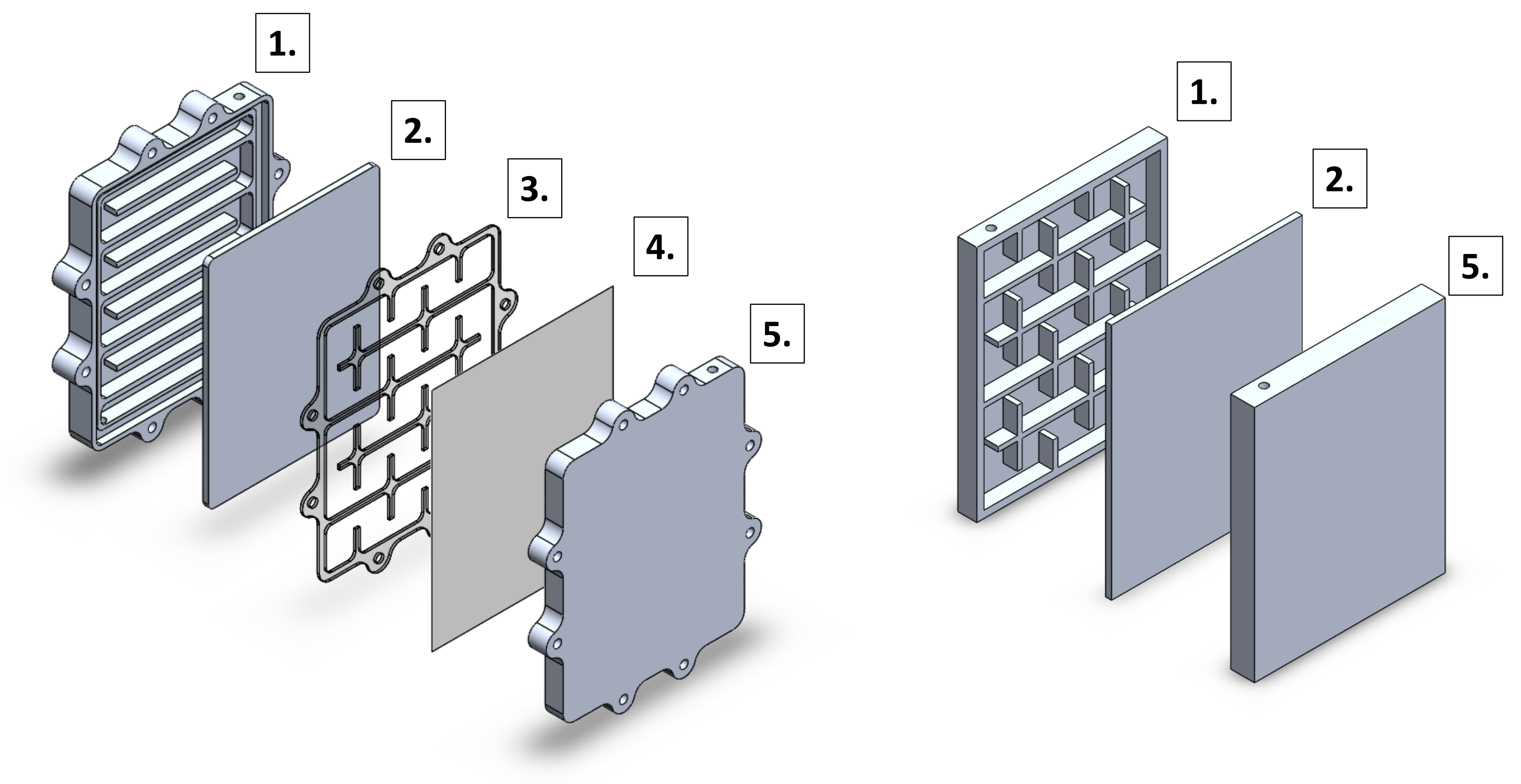

**Figure 1.** The actual model of the test cell (top) and the simplified model used for simulations (bottom). Items: 1. Cold Feed Channel, 2. Condensing Plate, 3. Spacer Plate, 4. Membrane, 5. Hot Feed Channel

Figure 1 shows the difference between the real test cell and the simulated test cell. The simplification is made to reduce computational time as well as to create a more structured mesh. The effect of air gap width and baffle size was examined. These parameters are chosen because literature has shown that they are important in determining the thermal efficiency as well as the output permeate flux.

## Parameters

The gap width is simulated for 0.093 inches and 0.4 inches. The baffle sizes were varied from 0.7 inches,1.1 inches, and 1.5 inches as shown in Figure 2.

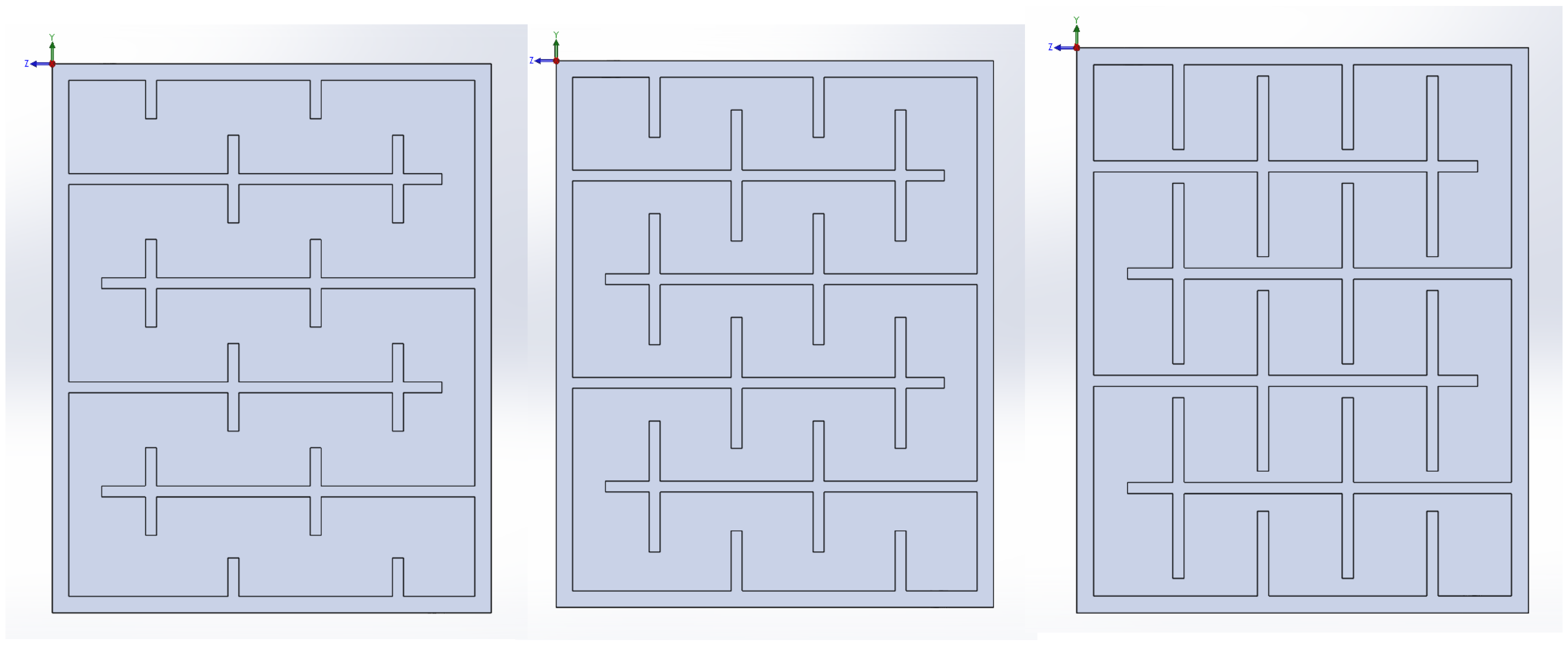

**Figure 2.** Different sized baffles. Smallest (left), Medium (center), Largest (right)

## Results of Varying Air Gap Width

Increasing the air gap width increases the resistance of heat transfer form the hot to cold side. The heat transfer coefficient decreased two-fold from a 0.093 inch gap to a 0.4 inch gap. The heat transferred is obviously less, increasing thermal efficiency of the test cell due to heat loss. However, Alklaibi et al. [1] also noted that after 2 mm (0.079 inches) mass transfer resistance starts to dominate and no longer improves the efficiency of the process. Every test cell is unique though, so more analysis is needed to find the optimal air gap width.

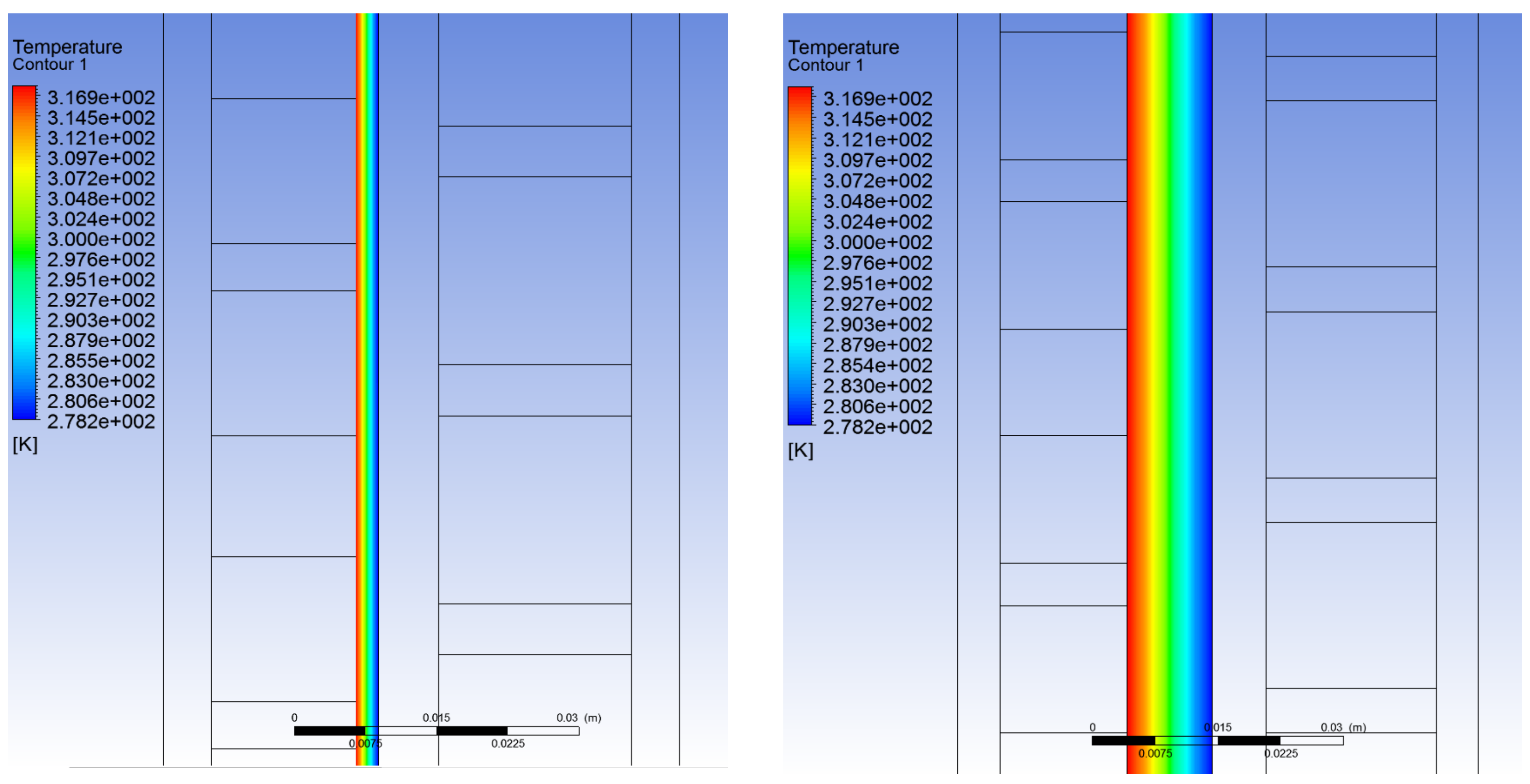

**Figure 3.** Temperature gradients of air gaps

## Results of Varying Baffle Size

Varying baffle size has a negligible effect on heat transfer throughout the cell. This may be due to the almost negligible change in temperature in the feed flow. The size of the test cell does not allow for a large gradient in temperature barring other parameters such as flow rate. In increase in turbulence and residence time, however, is observed. As seen in Figure 4 The larger baffles create larger recirculation regions. Alsaadi et al. [2] suggests greater residence time decreases energy consumption and permeate flux. Increased residence time should increase permeate flux, though, due to the longer time for the diffusion process to happen. The greater turbulence also decreases temperature polarization increasing efficiency as Camacho et al [3] states. Increasing baffle size seems to create a more efficient test cell as long as critical pressures are not exceeded.

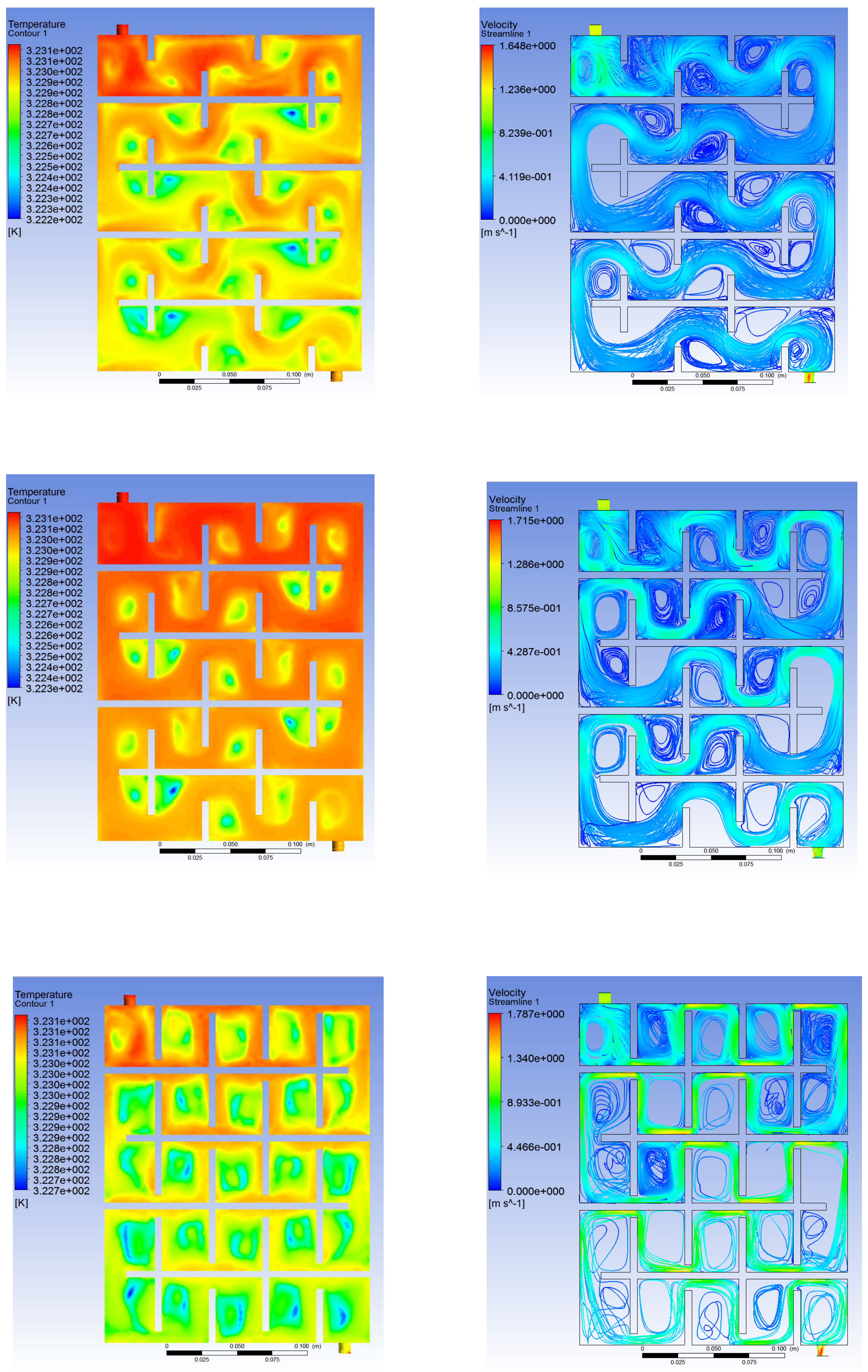

**Figure 4.** Temperatures (left) and Velocity Streamlines (right) of different baffle sizes. Smallest (top), Medium (middle), Largest (bottom)

## Conclusion

Changing the geometry of an AGMD test cell has large consequences on its efficiency and output. Air gap width must be optimized to reduce parasitic heat loss while maintaining permeate flux for every test cell design. Increasing air gap width increases thermal efficiency, but decreases permeate flux. Increasing baffle size increases residence time and turbulence which increase efficiency. Maximum turbulence should be sought after until critical pressures are reached.

## Future works

This test cell was validated through a mesh analysis and experimental data. However, mass transport was not simulated and is a must for further analysis of the test cell. Actual optimization of this test cell using ANSYS Fluent can be done in the future.

## References

[1] Alklaibi, A., & Lior, N. (2006, June 02). Heat and mass transfer resistance analysis of membrane distillation. Retrieved from https://www.sciencedirect.com/science/article/pii/S0376738806003760

[2] Alsaadi, A., Ghaffour, N., Li, J. -., Francis, L., Maab, H., & Amy, G. (2013, June 06). Modeling of air-gap membrane distillation process: A theoretical and experimental study. Retrieved from https://www.sciencedirect.com/science/article/pii/S0376738813004705

[3] Camacho, L. M., Dumée, L., Li, J. Z., Duke, M., Gomez, J., & Gray, S. (2013, January 25). Advances in Membrane Distillation for Water Desalination and Purification Applications. Retrieved from http://www.mdpi.com/2073-4441/5/1/94