AN INVESTIGATION OF THE PERFORMANCE OF NATATORIUM SYSTEMS

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Introduction

Background

Recently Grands Forks's competitive swimming programs have been fighting an up-hill battle. There are multiple factors that have been the cause of this but the most common has been that the city's indoor pools have been shutting down. This is due to the age and design of the buildings. The two most common pools being used at the time in Grand Forks are UND's Hyslop and Central High School's pool. Both buildings have had recent problems with moisture getting into their exterior walls causing them to be weakened and start to deteriorate from the inside. As of writing this, the Hyslop is planned for demolition in the summer of 2024 and Central High School recently was given money to repair the pool's exterior walls.

In November of 2023 Grand Forks has given the go ahead to start planning for a new multisport facility. The facility will house basketball, tennis, and badminton courts as well as a new aquatic center. This will most likely be the new facility that houses the club and maybe high school team.

Aim

The air quality in an aquatic facility should be the number one priority when it comes to designing these buildings. The aim of this research is to investigate how we can design a natatorium that efficiently circulates the air to keep the air quality at a comfortable level for those sitting in the stands and focusing on the swimmers that are competing and the coaches standing on the pool deck.

Significance

Focusing on the air movement in any building is vital so it doesn't become stagnant, helping prevent the development of respiratory issues for those who use the space. This is a major component when it comes to designing any kind of typology that needs a heavy-duty HVAC system. The significance of this research will be to help design a system that keeps air moving and fresh while pushing chlorine particles out. This will provide the comfort needed to stay in an aquatic center for long periods of time.

Figure 1: Central High Pool

Figure 2: UND Hyslop

Introduction

Proposed Outcomes

What I set out to accomplish with this research is a better understanding of how the more complicated building systems such as HVAC are designed specifically for a building and how those systems function. This will be achieved by the research needed to properly size equipment, learning how aquatic facilities manage and layout their systems. I will also need to know the proper amount of air changes needed for this project and the amount of air circulation speed needed to circulate air throughout the building.

A secondary goal I will be to looking at is how to adapt these buildings for various seasons throughout the year. Looking into this I will need to focus on how the relative humidity indoor and outdoor air affects the humidity of the facility and adjust the interior air temperature to accommodate.

Base Information

Below is a list of the bare minimum information needed for a pool to function properly. This is what I will be using to reference to help make any of the decisions I make during my experimentation.

Temperature:
- Water: 80-84
- Air: 84

Humidity:
- Relative: 55%
- Summer: 60%
- Winter: 50%

Air Change Rate:
- Minimum of 6-8 per hour

Air Flow Rate:
- Regular Air Flow: 100-50 ft/s
- Air Flow Across the Water: 10-30 ft/s

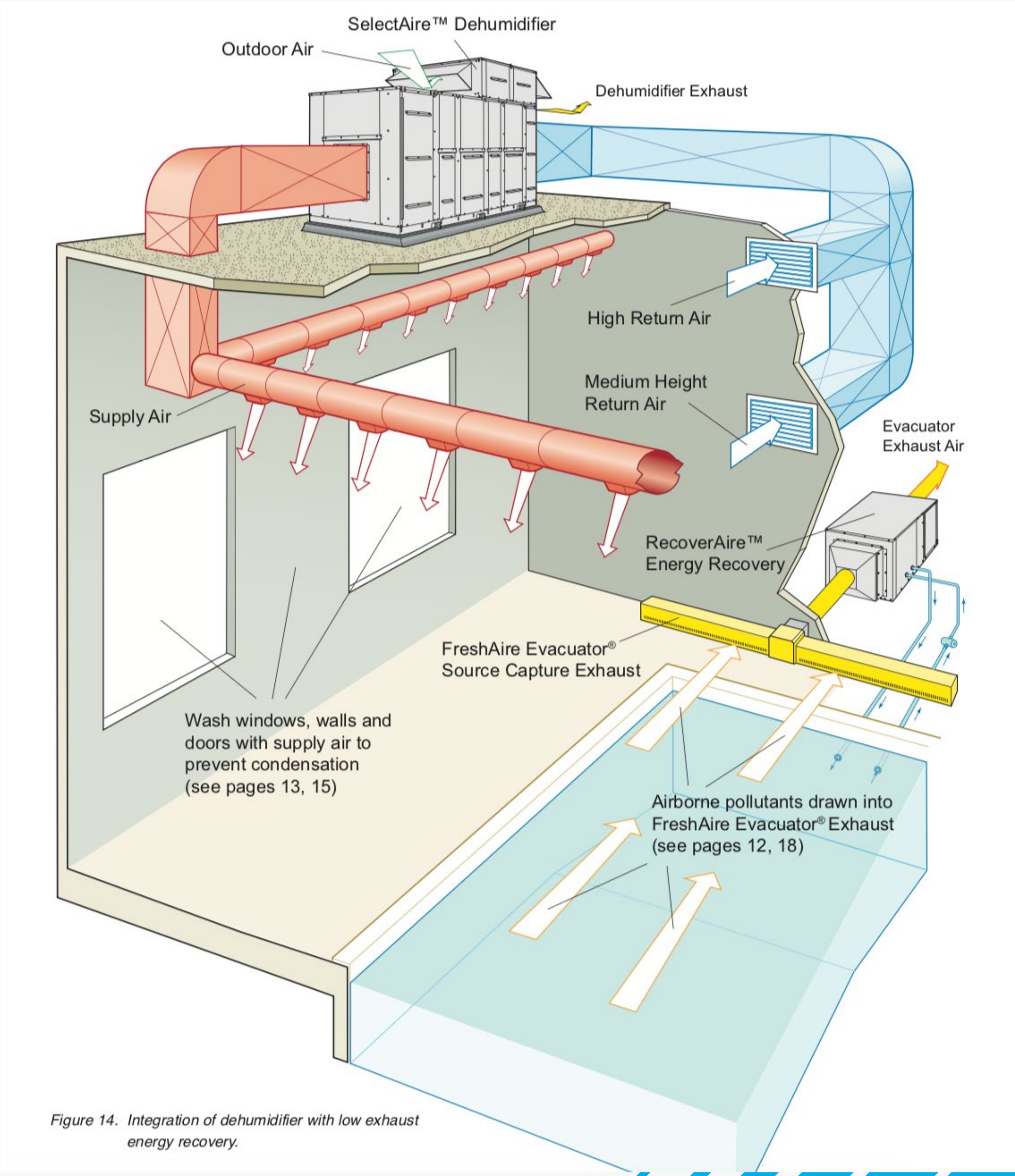

Figure 3: https://www.desert-aire.com/sites/default/files/Brochure-21st-Century-Pool-Design-Guide-DA030.pdf

Methodology

Initial Trials

During the first month of my research, most of my time was spent figuring out how to use Autodesk CFD (computation fluid dynamics). The initial plan was to build three different models in Revit and put those models into the CFD program. This process at the start did not work in my favor for multiple reasons. The biggest issue I believe is that Autodesk CFD (the student version at least) could not handle the scale of the building that I am trying to work with. Other issues stemmed from the HVAC system Revit provides semmed to be causing problems with making the shell not fully sealed. I also had to take out furnishings like bleachers and diving blocks/ boards to make the model load faster.

Eventually, with the help of my professor we found a solution to the problem. I would use SketchUp to create multiple section cuts of the pool. This method will be much faster to produce testing results and would allow me to easily understand how the building would function and discover where issues may occur in the system.

Approach

My new approach for my project is to create section cuts in SketchUp of one pool as a dependent variable. I will then design an HVAC system layout for the pool which will be used to test how the air circulation performs within the building. After each test I will modify the HVAC system to see how each of the changes would affect the air flow or to see what changed elements caused issues. This will be done three times with the hope of each iteration improving upon the last.

There will also be three tests done on each iteration to see varying levels of efficiency of the air circulation. I will be adjusting the air flow rate of the main system. Each test will start at 100 ft/s and go down by a factor of 25 ft/s for the next two. This should allow me to see which flow rate would be the most optimal to use.

Lastly there will be a fan that will be set a no more than 30 ft/s. This fan will be used to simulate the exhaust that pushes the chlorine particles that would be produced. This is an important element to include because the fan is what pushes the particles and keeps them from piling up along the water's surface and pool deck. If this was not included particle build up would cause damage to the athlete's respiratory functions.

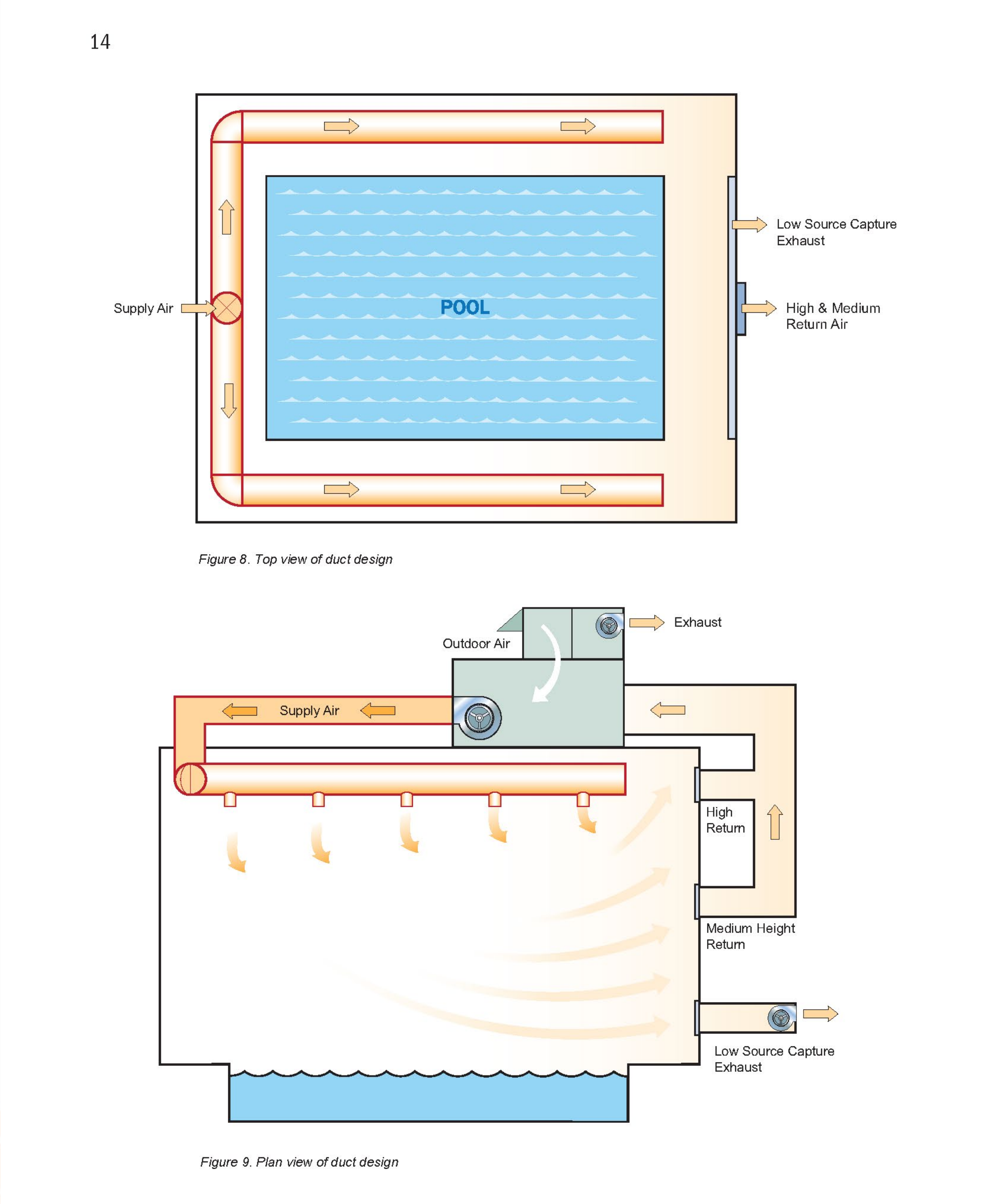

Figure 4: https://www.desert-aire.com/sites/default/files/Brochure-21st-Century-Pool-Design-Guide-DA030.pdf

Results

Data Collection

Each variant will be using the same three section cuts for testing. The first test being the length of the pool followed by the width of the pool in the shallow and deep end.

The length section of the pool shows where the supply and returns are placed. The supply will be towards the ceiling. This is so fresh air can be taken easily from the roof of the building and sent down to ventilate the space. Spaced out through the main supply duct will be fans. These fans are important for the system because as the air is sent from the supply the air pressure weakens as it travels to the ends of the duct, they will help push the fresh air through the duct and down to the pool.

On the bottom left-hand side of the length section is another supply duct. This is called the exhaust which will be set at 30 ft/s for all tests. The exhaust is not designed to ventilate the pool but to help push the chlorine particles towards a return as they settle along the surface of the water and pool deck.

On the right-hand side of the section will be the placement of the return ducts. This is where the air sent from the supply will be filtered from the chlorine particles. As each test is conducted these will change positions and sizing to help better understand where it would be most efficient to have the returns placed. The width tests are laid out almost the same. The two major differences between the length and the width tests is now we can see both supply ducts and the layouts and sizing of the returns.

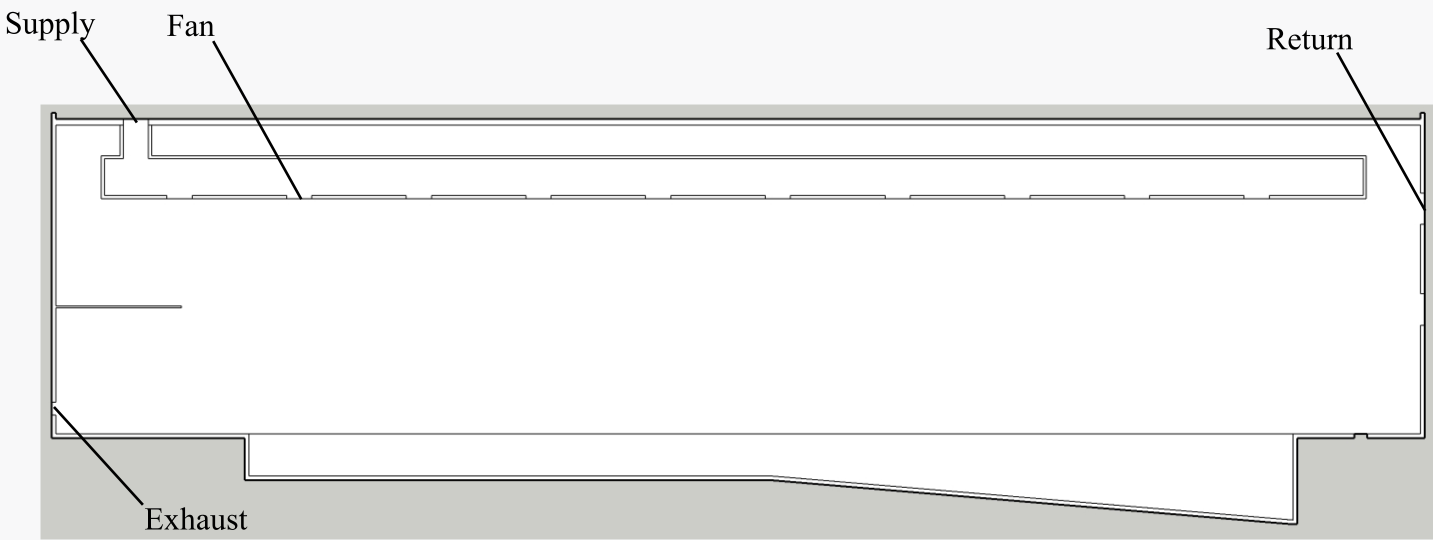

Figure 5: Length of Pool

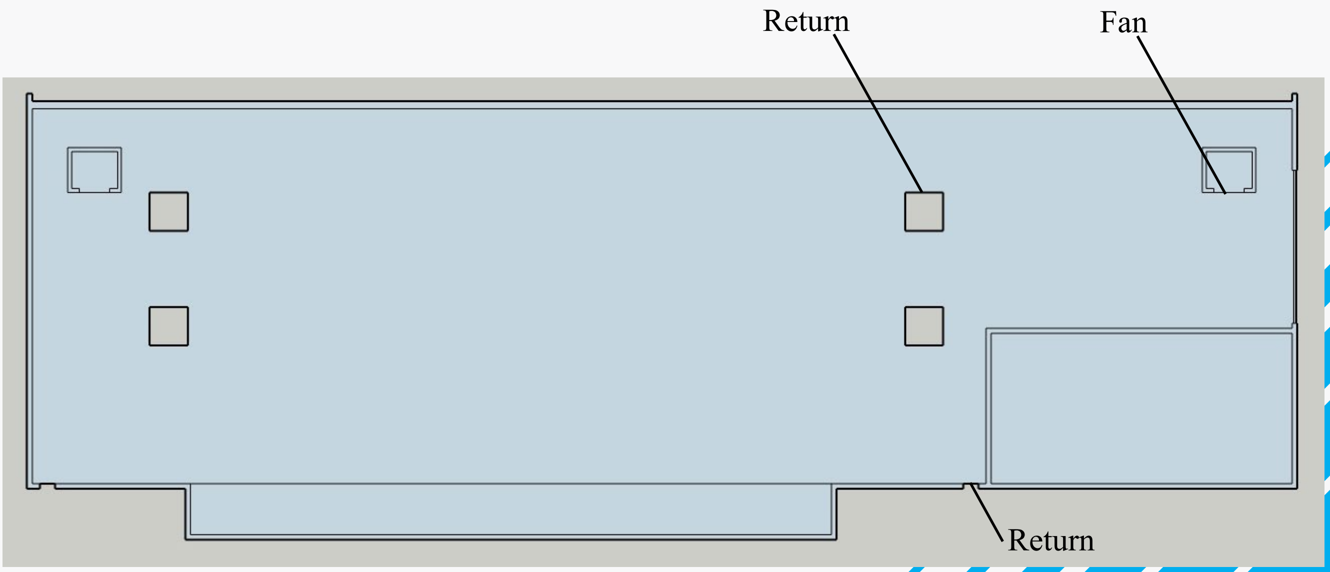

Figure 6: Width of Pool

Results

Variant 1

For variant one I wanted to keep it simple to start with. The idea was to get familiar with the CFD program and figure out the proper settings to use for the rest of the tests. Variant one's supply ducts were kept to a square shape along with the return ducts.

The returns were placed accordingly to allow for plenty of space between them for air to flow and rise freely. The returns in the floor along the side walls are to catch the initial chlorine particles that form and are pushed from the exhaust fan while the pool is currently active. The other two rows of returns are to help catch any particles that were missed.

The end results of each test at the various are speeds showed plenty of air movement. Variant Ones biggest issue was the placement of the Left-hand side return ducts the width sections. Since the supply was aimed directly down to the floor a lot of that supply air went straight to the closest return. While this isn't totally accurate to how this would actually function it should be noted that even on the right-hand side the air that is supplied almost immediately flows toward a return before hitting the ground.

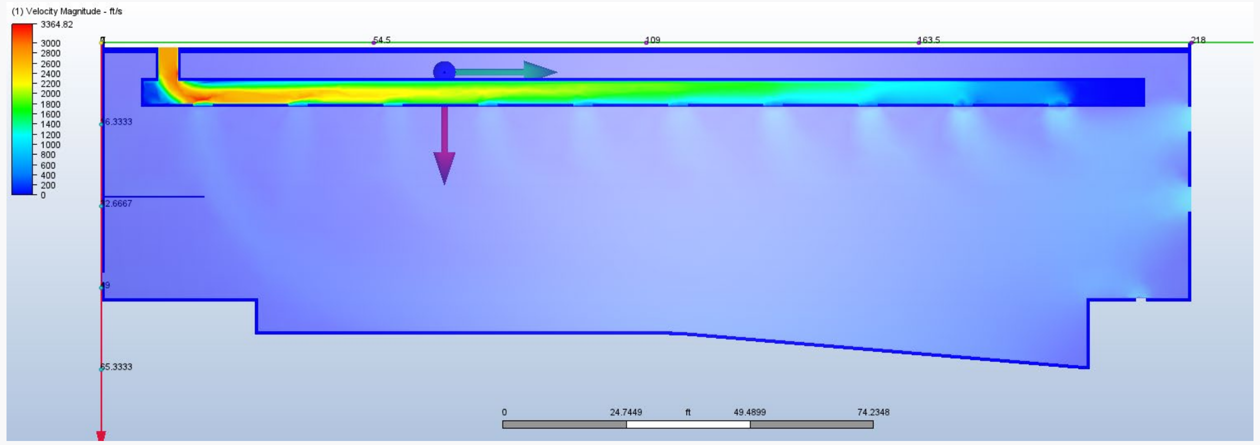

Figure 7: Variant 1 Length at 75 ft/s

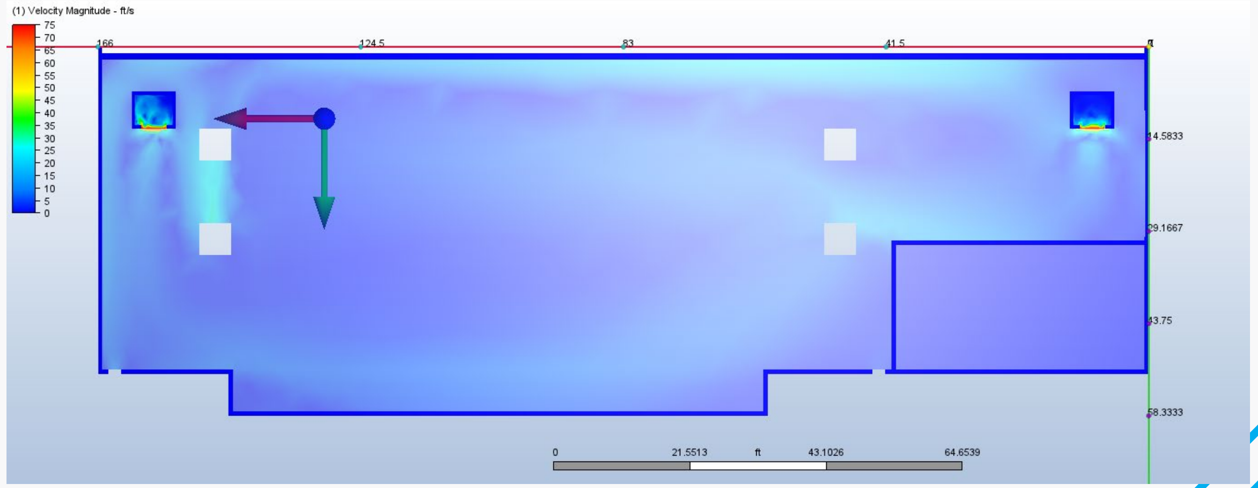

Figure 8: Variant 1 Width 1 at 75 ft/s

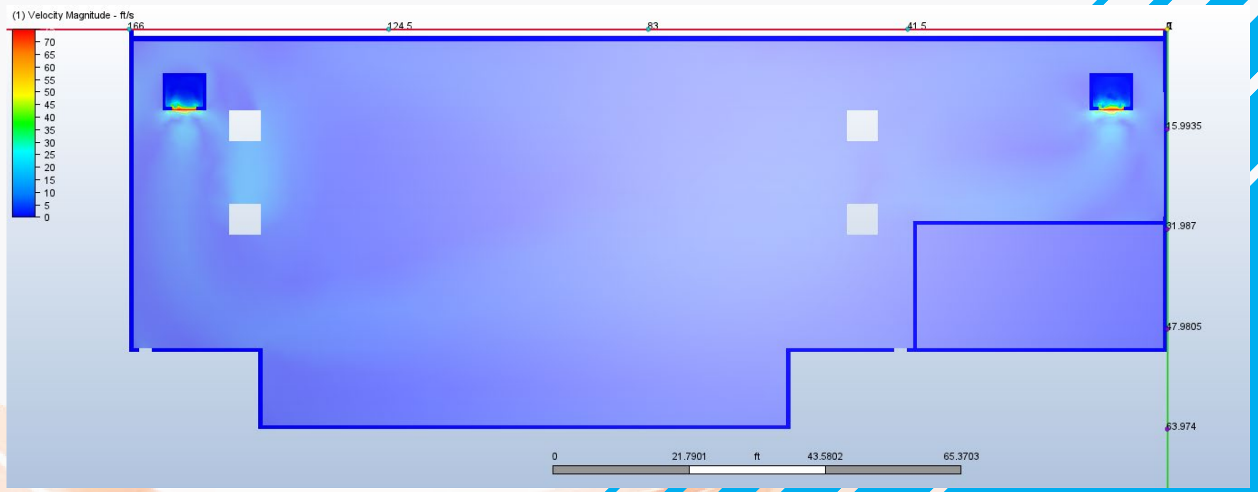

Figure 9: Variant 1 Width 2 at 75 ft/s

Simulations

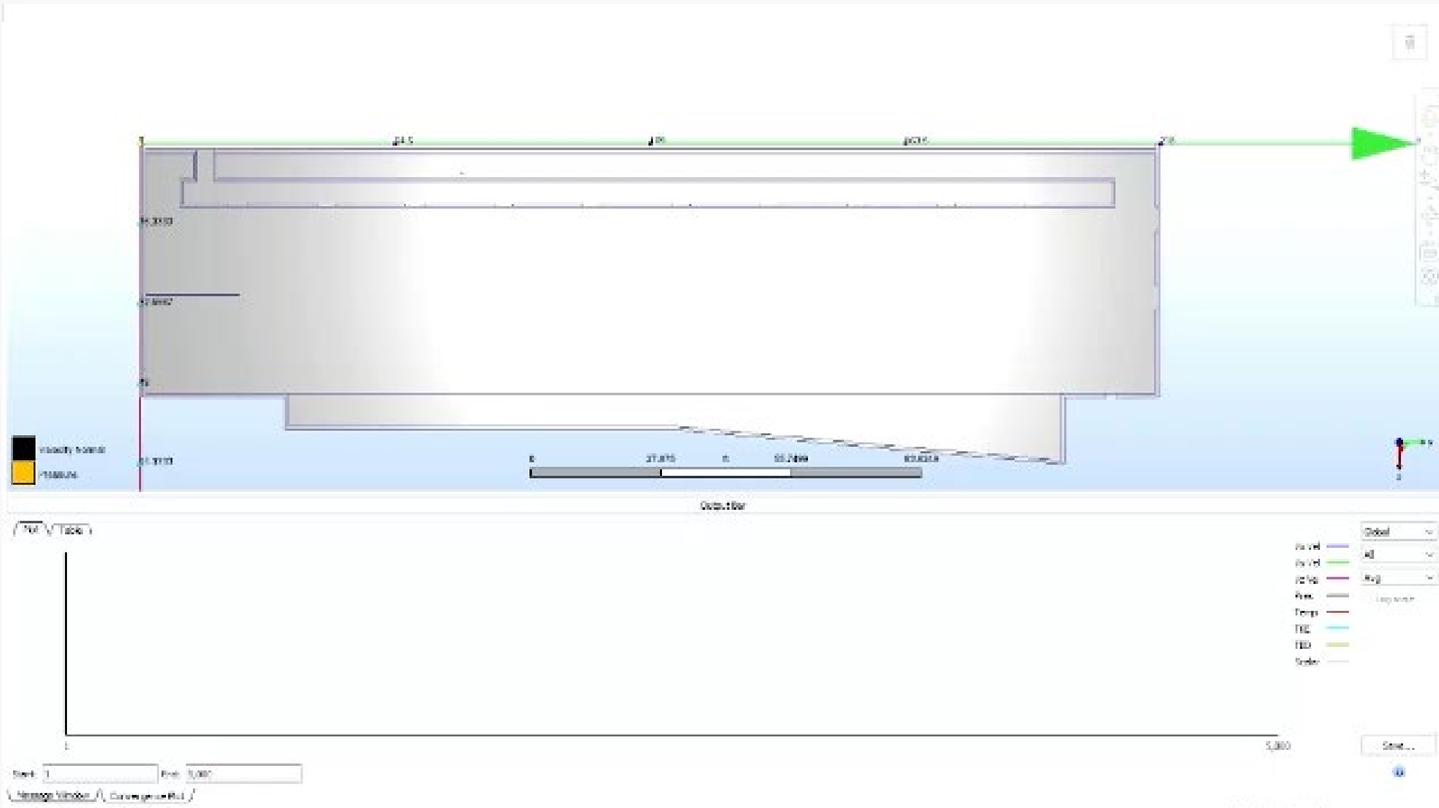

Figure 10: Variant 1 Length Simulation

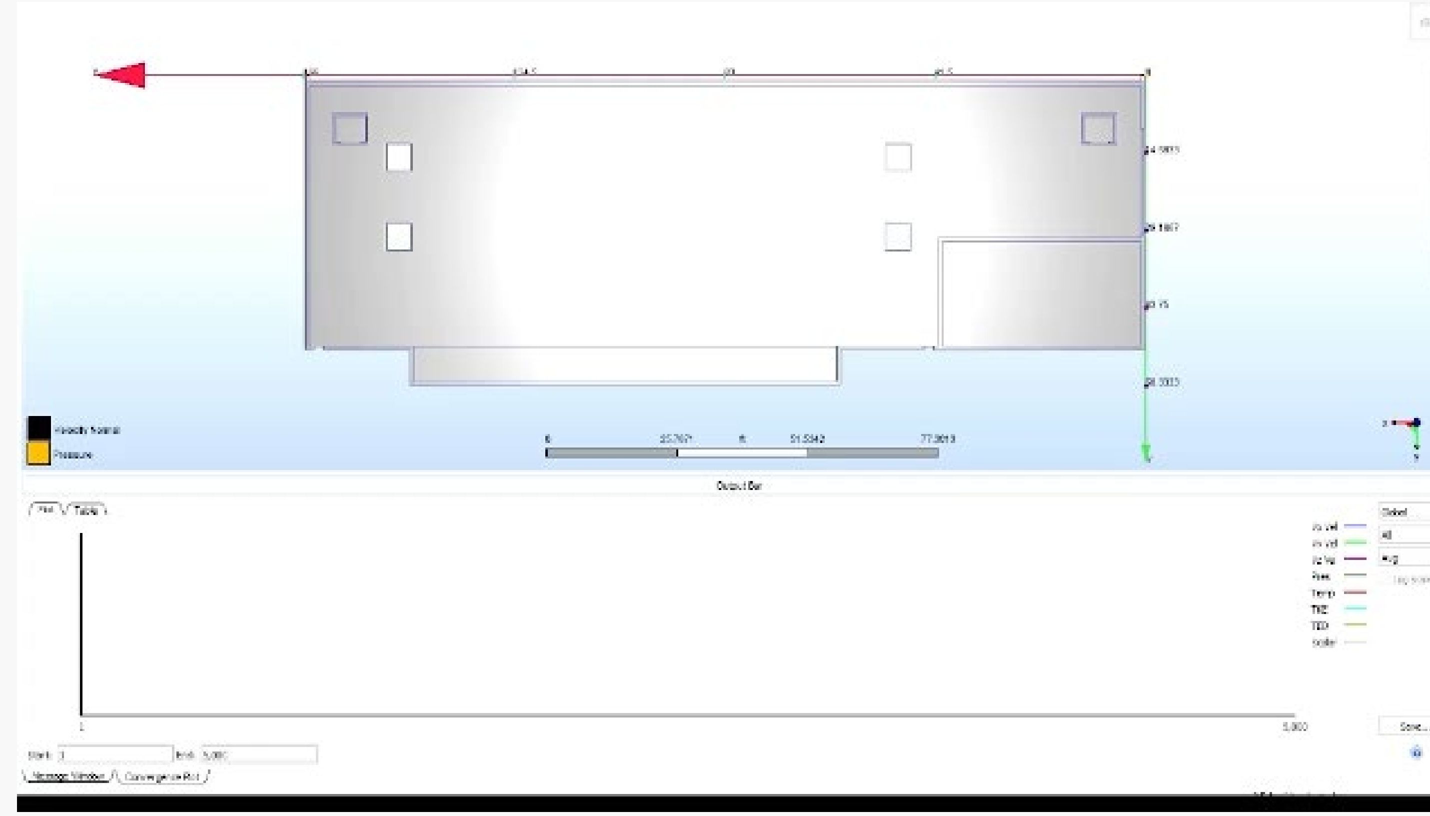

Figure 11: Variant 1 Width 1 Simulation

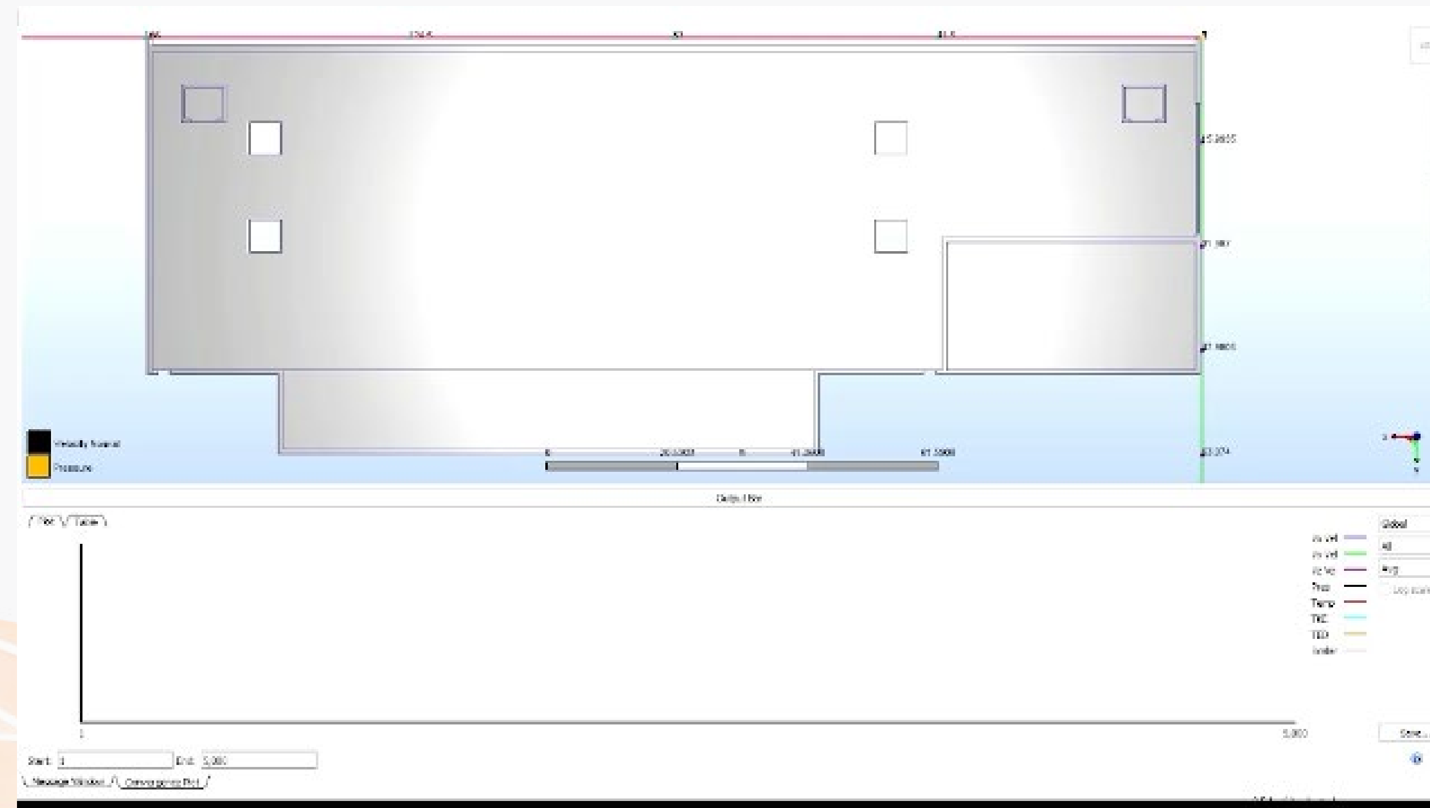

Figure 12: Variant 1 Width 1 Simulation

Results

Variant 2

Once Variant One was completed I finally had a good understanding of how the program worked and easily figured out what to improve upon after reading a few documents about natatorium and system design. The most important change I made for Variant Two was making the supply ducts a circular shape. The reason for this change was to keep the build up of condensation low along the windows and exterior walls, the supply duct fans would have to be aimed towards said elements. Making this change allows the air to be pushed down the wall making it so the air has the proper amount of time circulate before being sent to the returns.

For the returns I added two more returns and made them taller. I also moved the left-hand side returns away from the supply ducts. These changes were done to allow for more air movement to happen while having more access for the old air to return to without having the risk of particle build-up within the pool.

I also had a conversation with a pool consultant to help me decide how I should layout these systems. He told me that the returns that are within the pool deck should be closer to the pool rather than the walls. With them being close to the wall risks them of being covered by towels or swim bags that would be present during a competition causing chlorine particles to not be properly ventilated. Knowing that I moved the floor returns toward the middle of the floor.

The results of this test were much improved over the previous one. The change in return placement and changing the angle of the supply dramatically helped with the air flow seen in the figures. On both sides the air properly slides down the wall and onto the floor which its indented path should have been on the previous test.

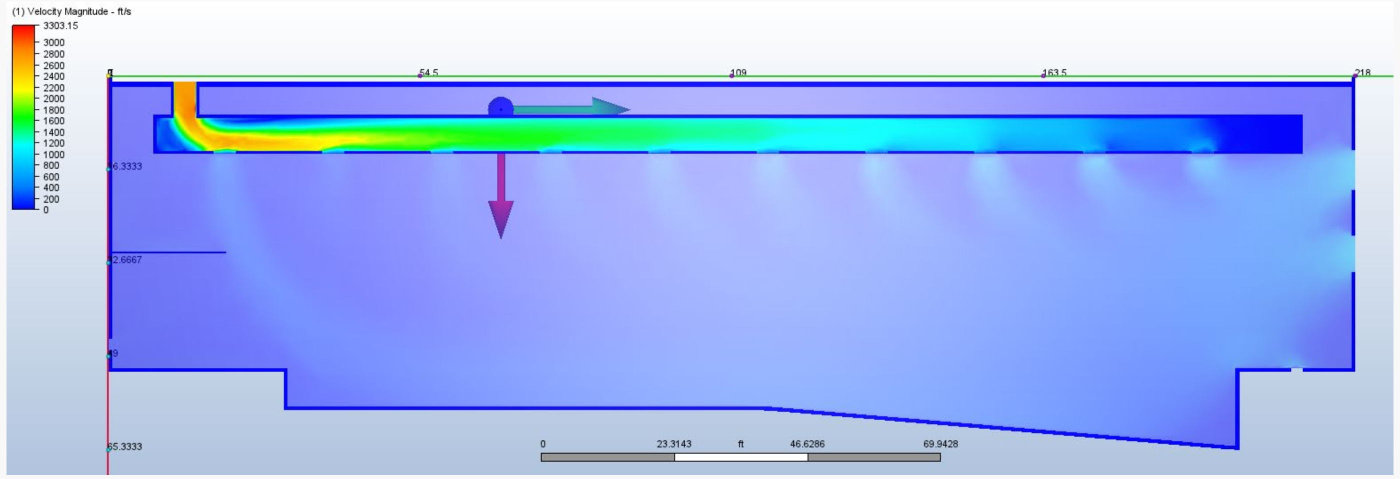

Figure 13: Variant 2 Length at 75 ft/s

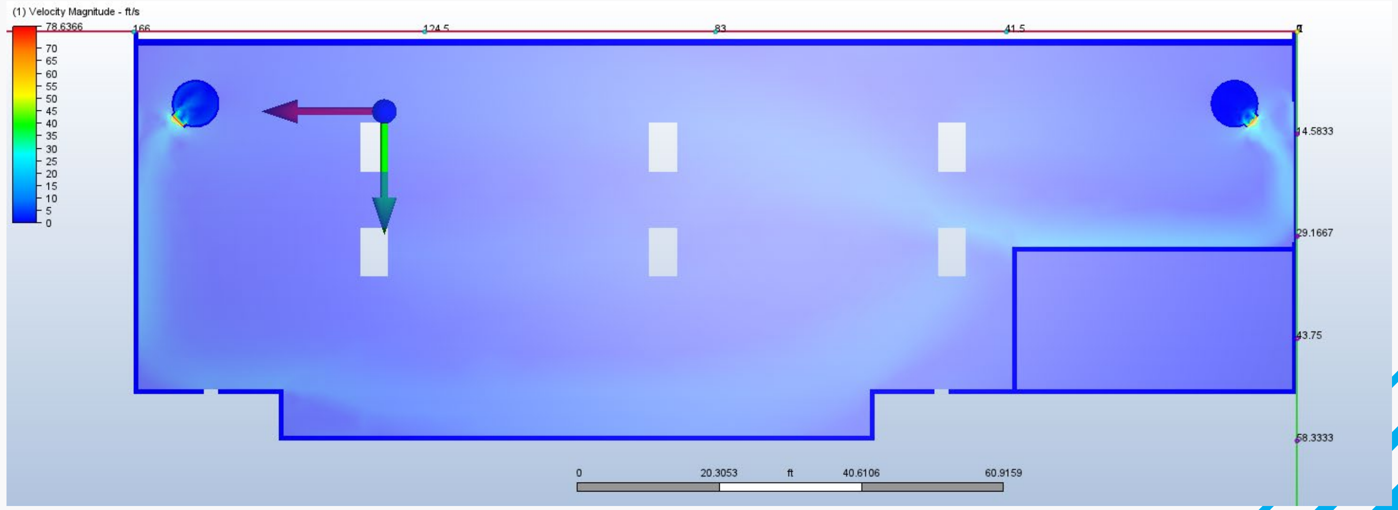

Figure 14: Variant 2 Width 1 at 75 ft/s

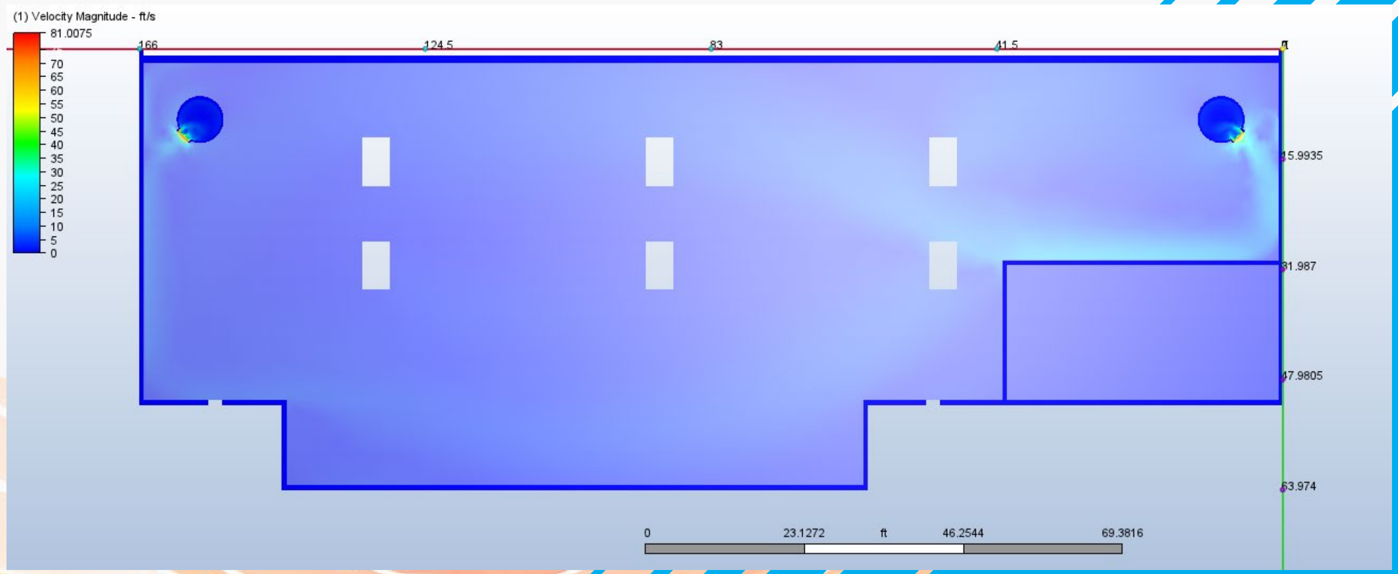

Figure 15: Variant 2 Width 2 at 75 ft/s

Simulations

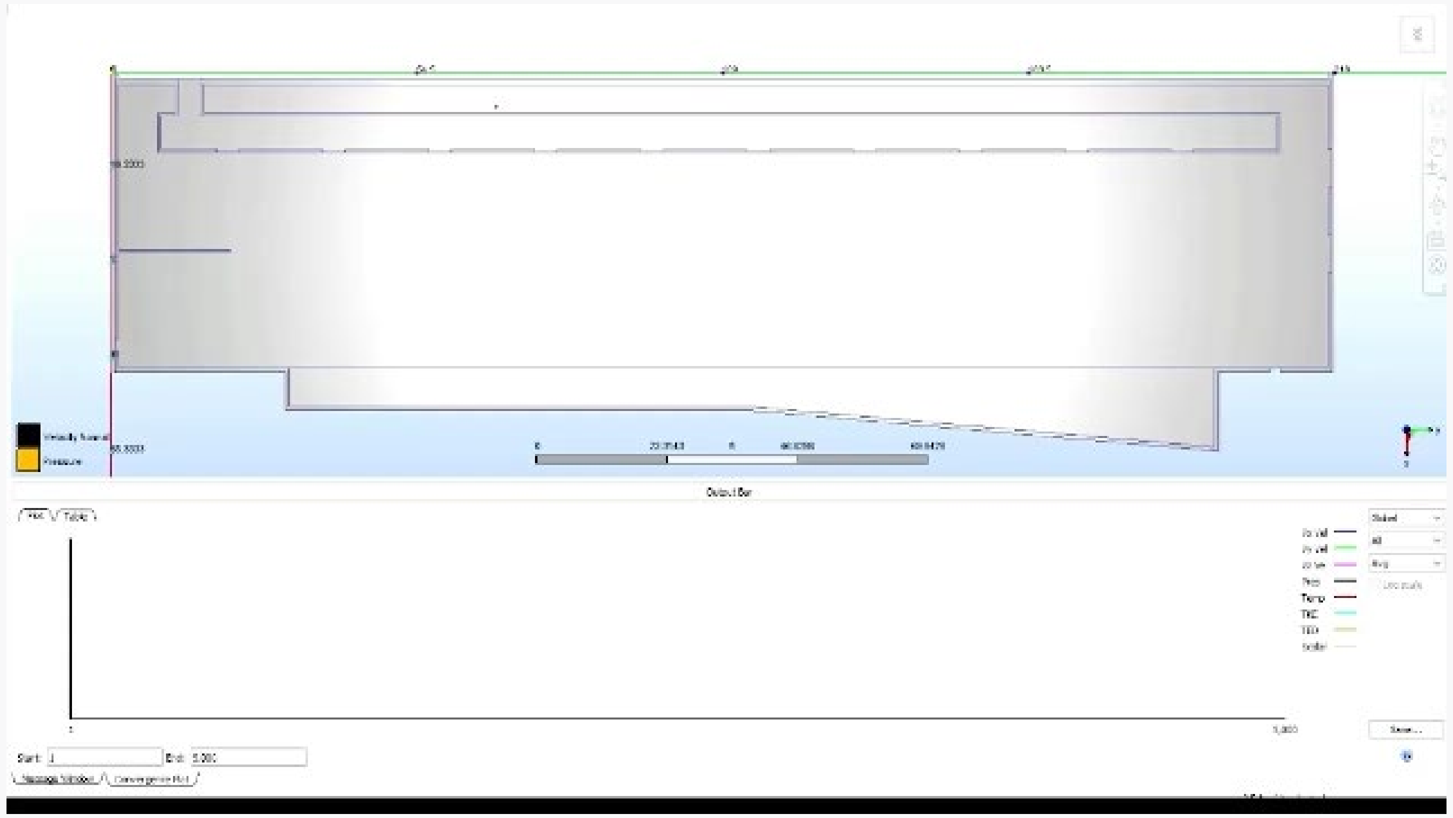

Figure 16: Variant 2 Length Simulation

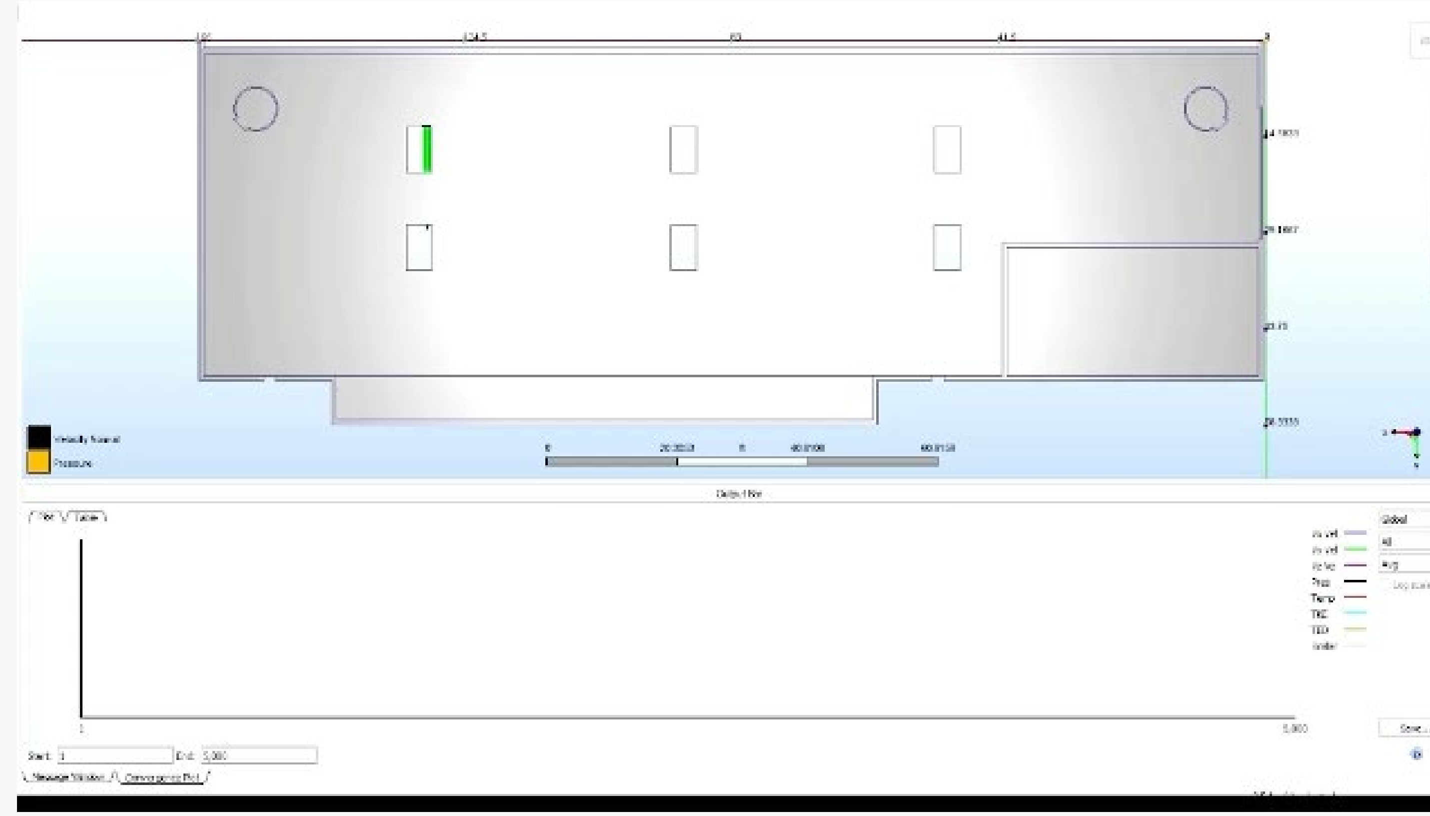

Figure 17: Variant 2 Width 1 Simulation

Figure 18: Variant 2 Width 2 Simulation

Results

Variant 3

For Variant 3 I kept the new supply ducts and added one smaller duct. This new duct's main function is to cool the spectators that would fill the stands. I got this idea from coaching a meet at The Hulbert Aquatic Center in Fargo. As this was its only function, I could allow it to be smaller and have half the air flow the main supply ducts provided.

After reading more about how the return air should be managed, I learned that the return should be set as close to the ceiling as possible. The reason for this is because as the supply air is sent these are much cooler than the air that's already within the building. As these particles move throughout the space, they will start to warm up causing them to be less dense which then makes them rise towards the ceiling. With that in mind, I removed the second column of returns and raised the top two to be about 4 feet from the ceiling. The reason for removing the two columns was because with these four returns being spaced out along with the ones on the floor there should now be plenty of space between each return to pull in old air as it starts to rise. There was also a new floor return on the right-hand side added to help with more ventilation.

The results for this test I would say are fairly close to the previous one. The newly added supply looks to have helped the right side be fully ventilated. The left side seems to have very little circulation compared to the previous test. I believe I could push the wall returns out to the side a few feet to help with a bit more air movement.

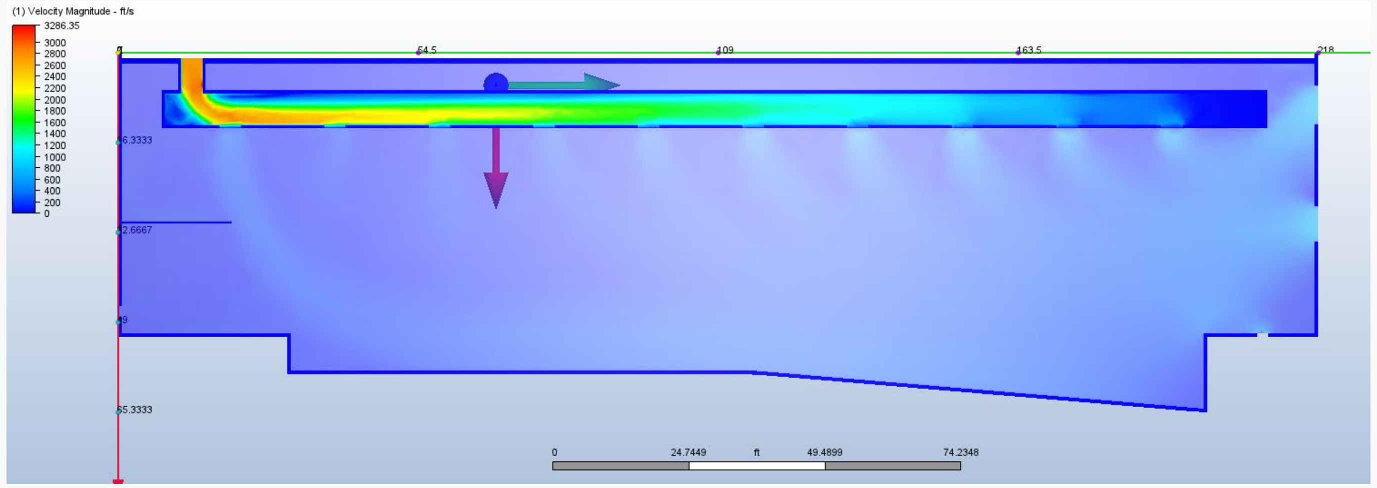

Figure 19: Variant 3 Length at 75 ft/s

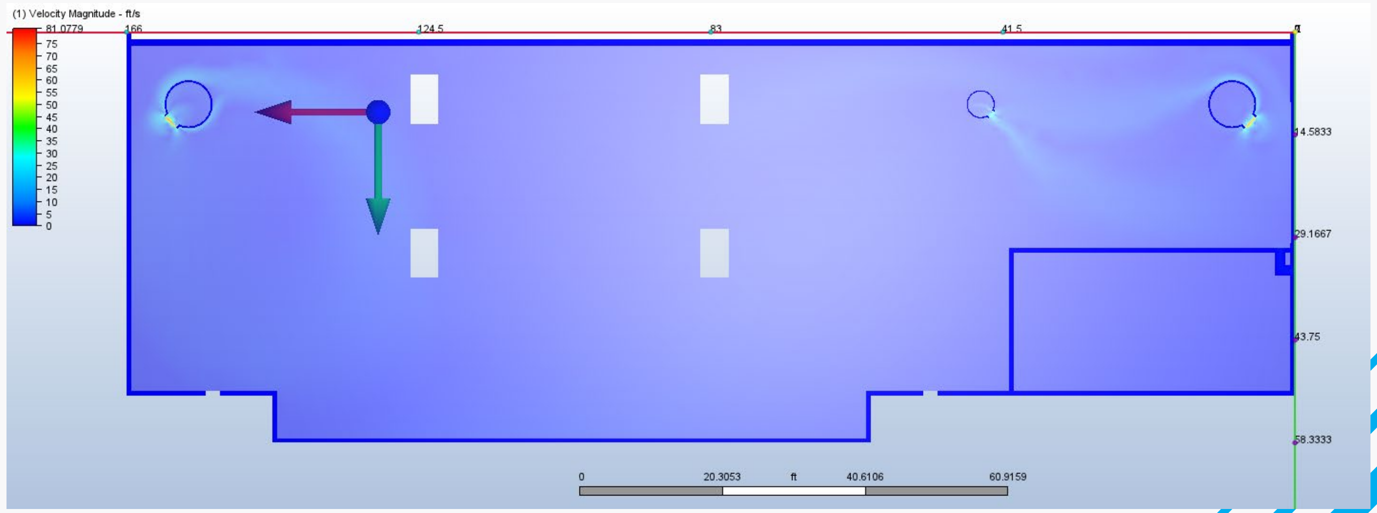

Figure 20: Variant 3 Width 1 at 75 ft/s

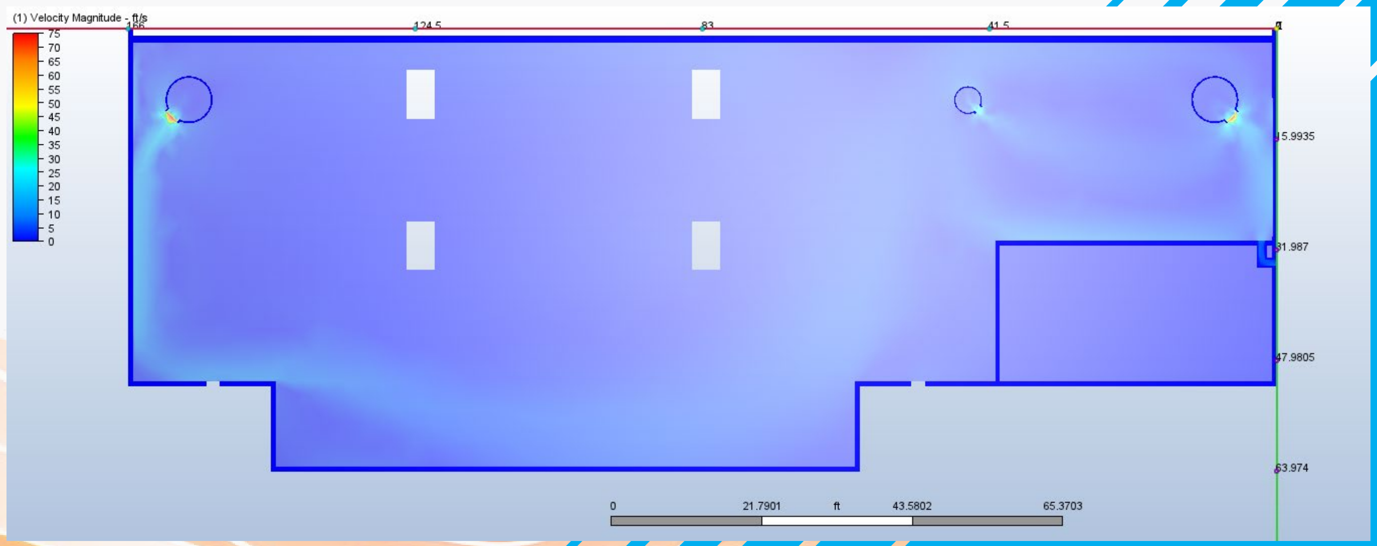

Figure 21: Variant 3 Width 2 at 75 ft/s

Simulations

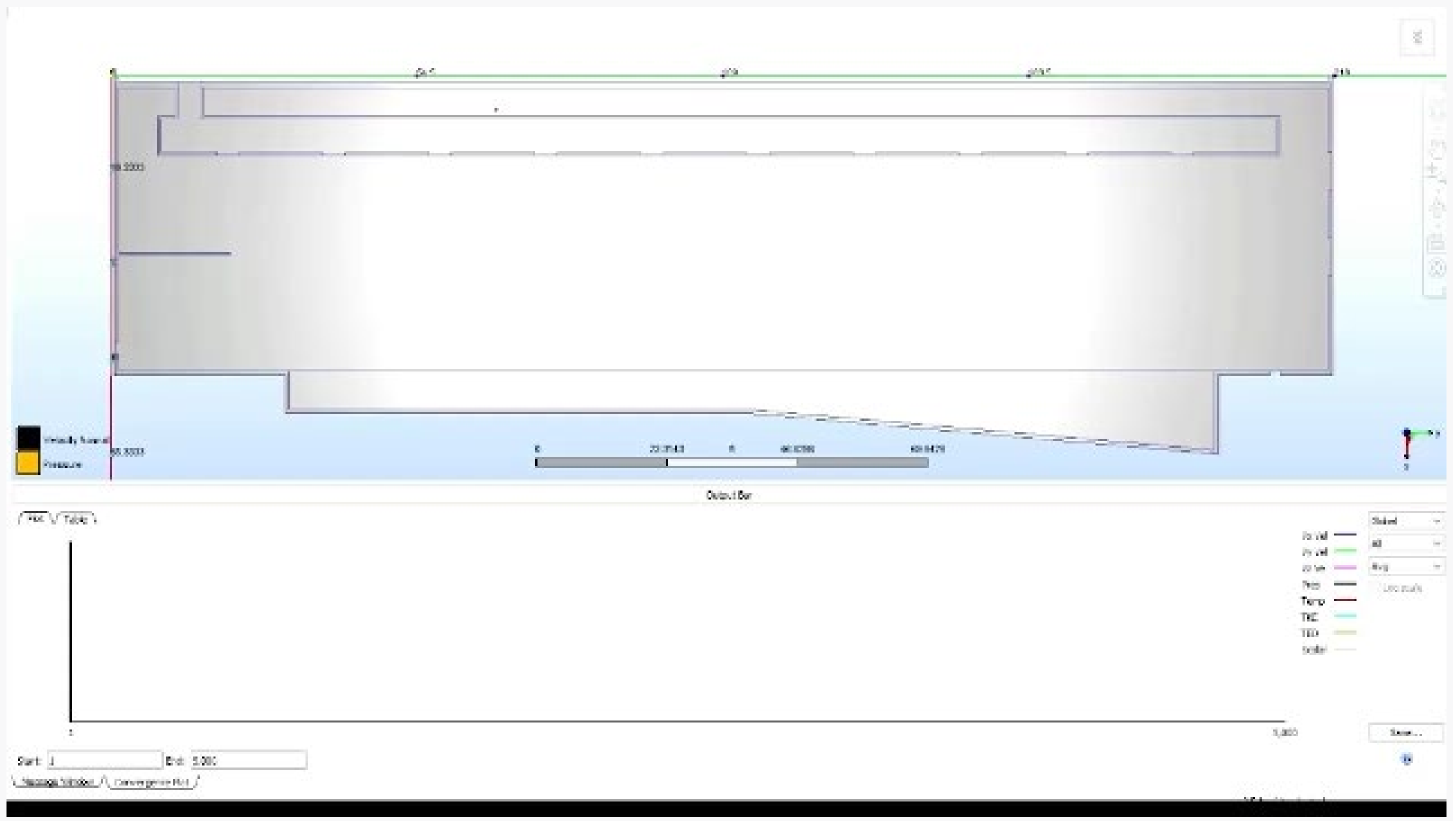

Figure 22: Variant 3 Length Simulation

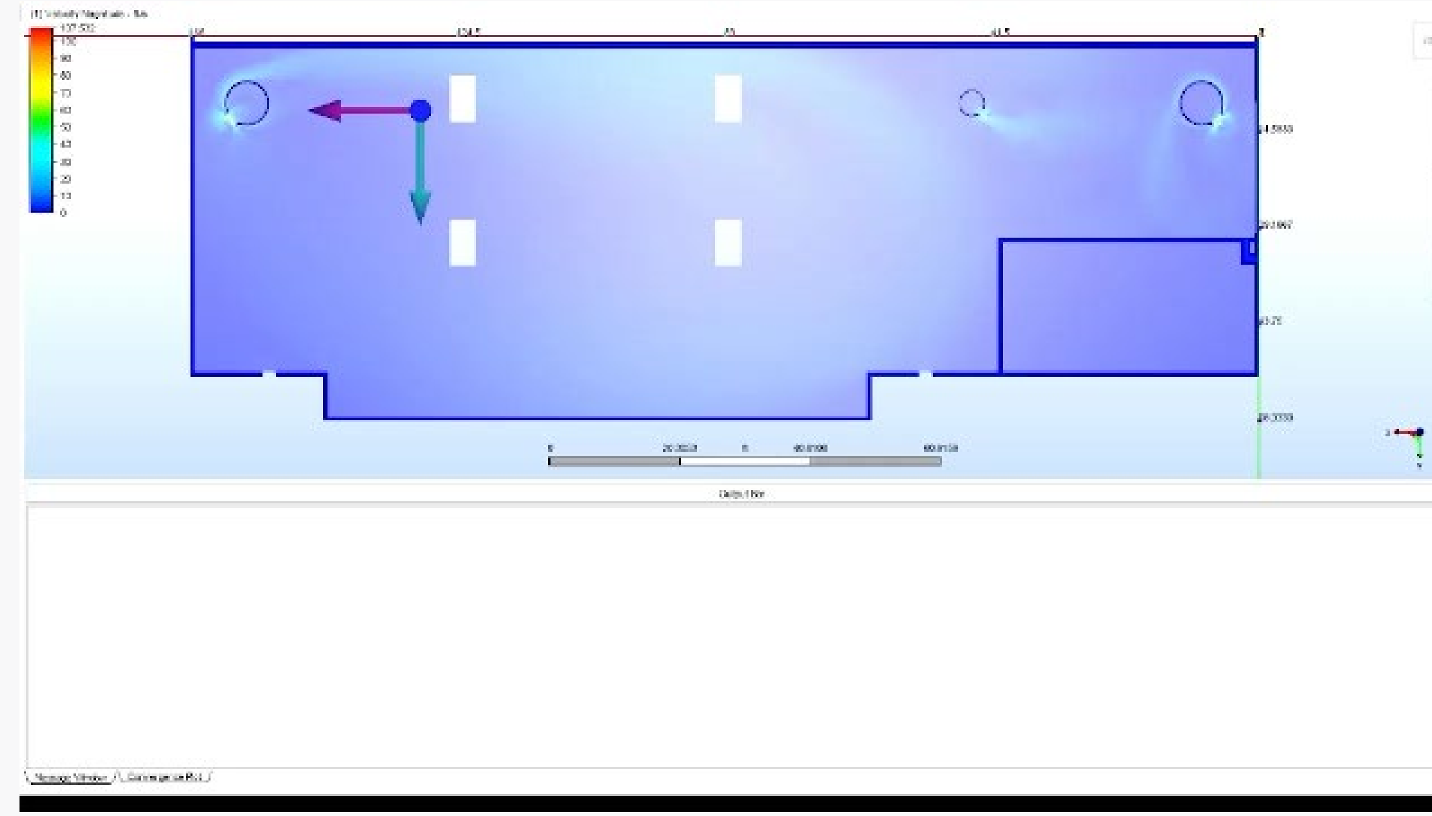

Figure 23: Variant 3 Width 1 Simulation

Figure 24: Variant 3 Width 2 Simulation

Conclusions

Initial Thoughts

Overall, I believe I have been successful in what I set out to accomplish with this research. I've learned so much through this process on the workflow for a CFD program and experimenting how different air speeds affect such a big space. Finding a balance between using an air speed between 75-50 ft/s will be the most effective to use for this project. This range allows for plenty of air circulation to happen within the space and not causing the pool deck to be too cold for the swimmers to handle. This will be an important factor to consider keeping all users of the space to be in a comfortable state.

Being limited to only a two-dimensional workflow for my research was a challenge. Since it is only a flat space, I had to think of some work arounds when laying out my systems. While this was still effective and led to more creative thinking, as a result it would be more ideal to be working with a more three-dimensional model instead.

This workflow has allowed me to have a much better understanding of how a natatorium is designed and how precise each of the systems needs to be to function properly than I previously had. I will continue to use Autodesk CFD to develop a final design for next semester that will be a more detailed and refined model compared to these previous tests.

Going Forward

While working on my research I was not able to do any testing on the humidity and temperature of the pool. These two elements are very important factors to consider also for designing a natatorium. If these are not calibrated properly it can lead to making the pool feel muggy and hot for everyone or being too cold for the swimmers to be comfortable. As I continue to work, I believe trying to implement these elements would help further my understanding of how each of these individual parts come together as a whole.

Researching the various building codes for a natatorium will be another major factor now that I have a baseline to work with. Doing this will make sure there is enough seating for swimmers and spectators, the duct work is of the proper size, and each space is big enough to account for occupancy loads. I am very excited to see where this research will take me while I continue to push forward and improve upon the skills I have learned already.

Successes

- Learned how to use a CFD program to analyze air movement
- Increased knowledge gained on natatorium design
- Figuring out the base conditions needed for a pool to function
- Found creative ways to work around the limitations of using the new work flow

Limitations

- Longer than expected delay for learning hoe to use Autodesk CFD
- The use of a two dimensional model over of a three dimensional one
- Couldn't have water and air in the same model
- Didn't have enough time to work with temperature and humidity levels

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