To: Dr. Oman
From: 18F16 Bio-Inspired Design
Date: April 12, 2019
Subject: Testing Proof

Introduction

In the following statements, the Bio-Inspired Design (BID) team will lay out all of the testing completed for the pressure chamber and bio inspired vents. The results of these tests will determine if the system is working properly and which vent design is the best suited to be implemented in to the final design proposed to increase the energy efficiency of SBS west and relieve pressure that is currently present in the plenum of Social Behavioral Sciences West Heating, Ventilation, and Air Conditioning (SBS West's HVAC system).

Engineering Requirements

The engineering requirements are set of requirements generated by the team to allow them to know if their design is on the right track. Due to the nature of this project the team decided to have two sets of engineering requirements. These engineering requirements can be seen in tables 1 and 2. Table 1 is of the engineering requirements for the team's final design and table 2 is of the engineering requirements of the Design of Experiments (DoE).

Table 1: Engineering Requirements and Target Values for Final Design

Engineering Requirements:	**Target Values:**
New Thermal Output = Old Thermal Output	Maintains (=) 72 ℉
Energy Efficiency	Seasonal Energy Efficiency Ratio (SEER): 13 to 21
Size<= Current size	Compatible with 22" x 22" venting area
Durability	Can operate 24/7 with regular maintenance once a month
Temperature management	Desired temperature(72℉) = Operation temperature (72℉)
Display Usage	℉ and psi
Mechanical System/ Bio-Inspired	

Table 2: Engineering Requirements and Target Values for DoE

Engineering Requirements:	**Target Values:**
Increase pressure	Can hold pressure values of 0.5 to 1.5 atmospheric pressure (atm) of gauge pressure
Hold pressure in the chamber	Maintain the pressure in the chamber. No leakage of air
Release pressure of the chamber	Pressure chamber is a closed then an open system once air is released
Standardize venting surface area	Approximately 36 in^2 of air going into the vent and approximately 10 in^2 of air exiting the vent

Throughout the rest of the document it is discussed how these requirements are being met through the test of the systems used in the DoE and the vents themselves. All requirements may not be fulfilled just yet due to some manufacturing and debugging still to be done.

Pressure Chamber Testing

The plexiglass pressure chamber was first tested for its ability to seal to be airtight. The method that the team chose to be the best method was to submerge it under water to check for leaks. When the chamber was submerged it did not experience any leaks. This was determined by inspecting each seam where the plexiglass sheets meet and held together by epoxy. The testing of the chambers sealing can be in the video provided in Appendix A under “Airtight Testing”. Other videos in Appendix A show how the pressure will be added into the system through the valve stem.

Next, the first iteration of the door actuator was mounted to the pressure chamber and sealed. A bicycle pump was attached to the valve stem pressurization port. The team applied air pressure to the chamber but quickly noticed that the trap door was leaking and needed to be redesigned. This leakage of air was seen through the barometer that is connected to Arduino that reads the temperature and pressure of the pressure chamber over time. The team then redesigned the trap door and re-enforced the seal and actuation method to try and create an airtight seal on the trap door.

During the process of manufacturing the trap door and testing the actuation method, the team noticed cracking in the adhesion between the plexiglass walls of the main pressure chamber. This was due to the smooth surface of the plexiglass walls. The team noticed that epoxying the smooth surfaces of the plexiglass does not create a strong hold between the two materials. To solve this problem, the team used a dremel to score the surfaces of the plexiglass to create a rough surface that the plexiglass can settle on.

Due to certain manufacturing circumstances, the pressure chamber currently does not meet the engineering requirement of creating an airtight seal. The team is working on fixing these manufacturing issues and will test the pressure chamber for any leakage of air by submerging it in water. However, the pressure chamber does meet the engineering requirement of pressurizing the system with a bike pump and a valve stem.

Actuation Method Testing

As stated earlier, the team needed to test its actuation method to see if actuation of the pressure releasing trap door can actuate on command, reset, and hold an airtight seal. The first design used magnets to hold the door shut and would release when the magnets were pulled apart. One magnet was placed on the underside of the trap door and one was placed on top of the pressure chamber. The method would hold the door shut and actuate when desired but lacked enough force to hold the trap door tight enough to create an airtight seal.

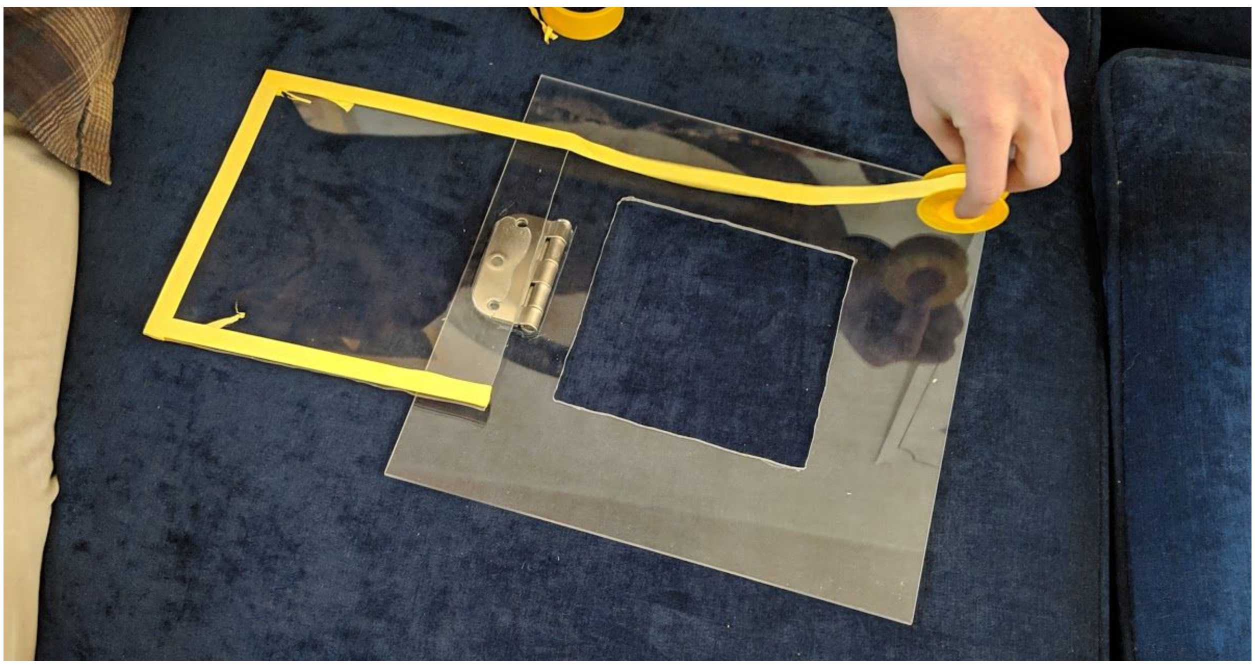

Figure 1: Gasket Tape Layed Around Door Actuation Method

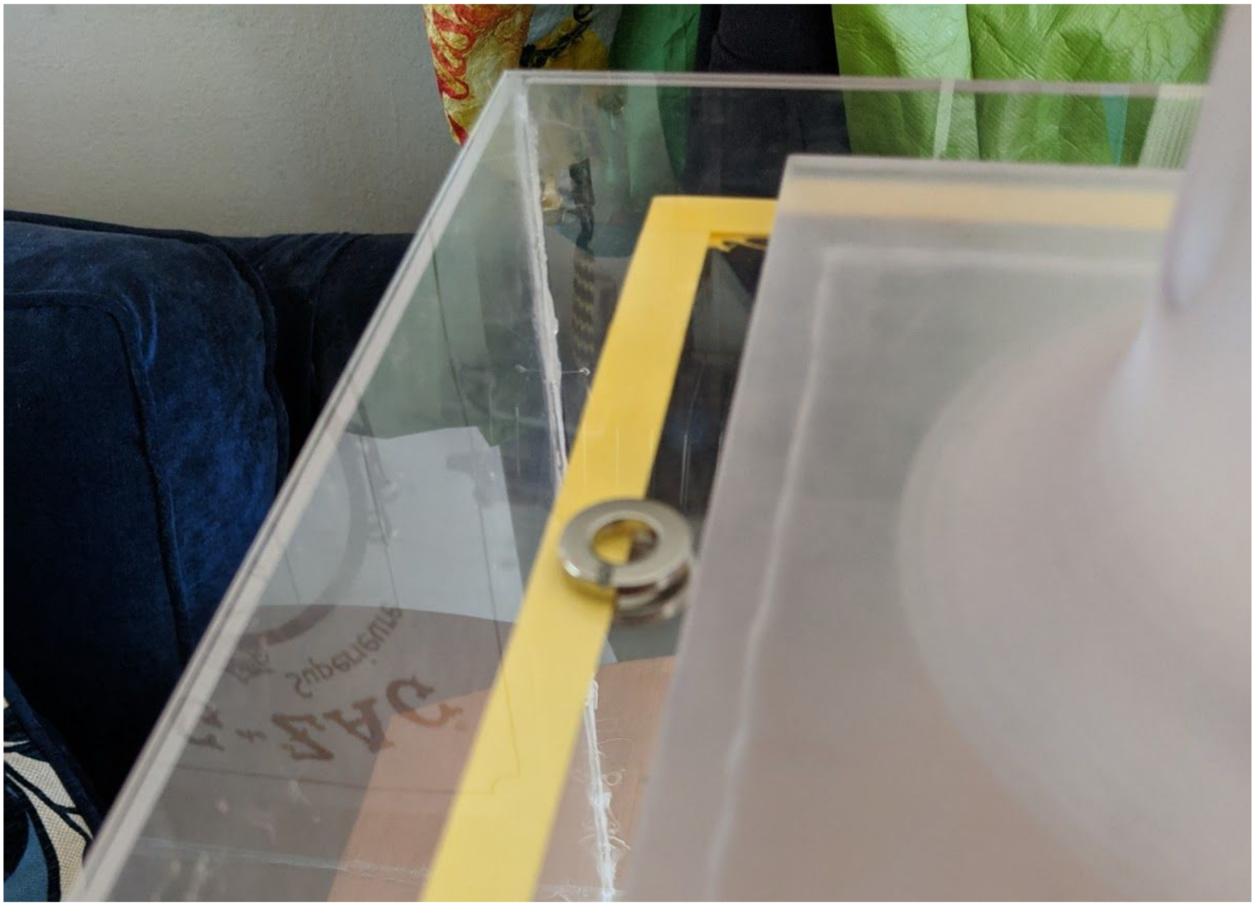

Figure 2: Door Actuation Method Held by Magnets

The next method that was designed incorporated a push button latch system. This system utilizes weather stripping outlining the door actuator to create an airtight seal between the door and the top part of the pressure chamber when the door is closed. The latching system allows the door actuator to swing down using a button and can relatch to the button repeatedly. However, when the team finished fabricating the actuation system, the team realized that relatching the door would be an issue since the door is bigger than the hole used to release the pressure. The team then designed a handle that is attached to the door that can be swung to relatch the door to the top piece of the pressure chamber. By adding the latching system to the door actuator, this subsystem meets the engineering requirements of releasing the pressure since the door can open and close.

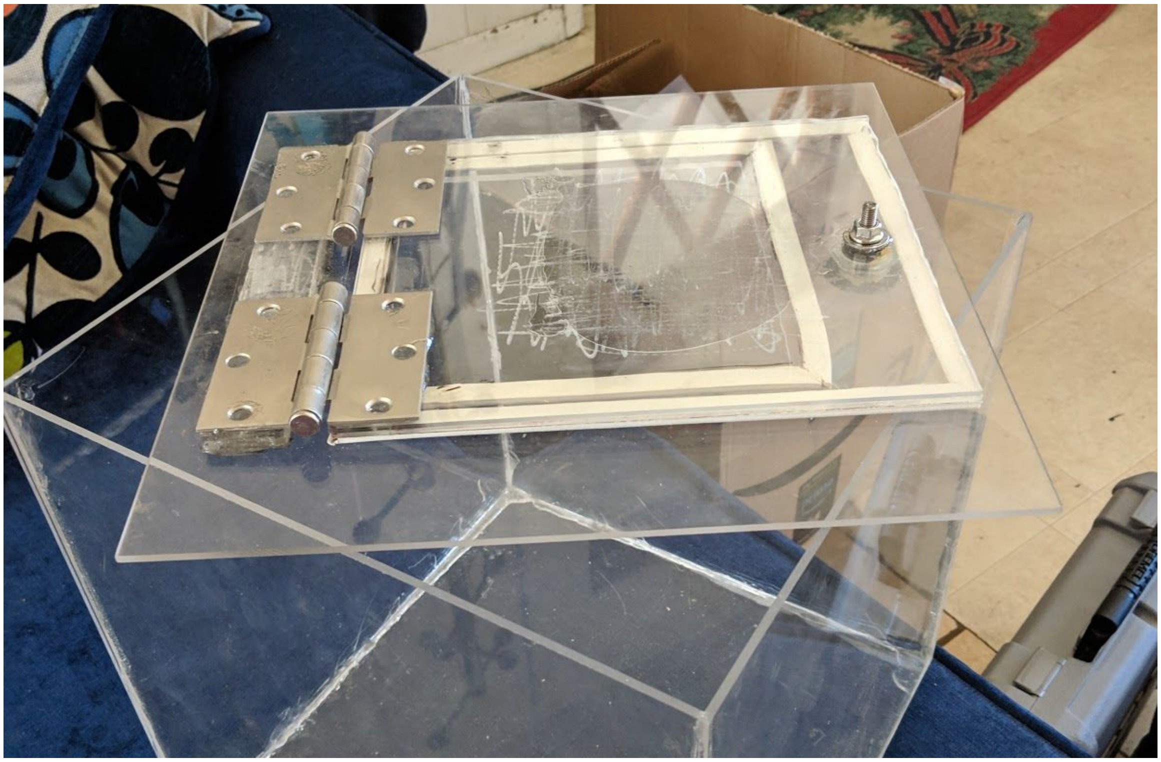

Figure 3: Underside of Door Actuation Method with Weather Stripping

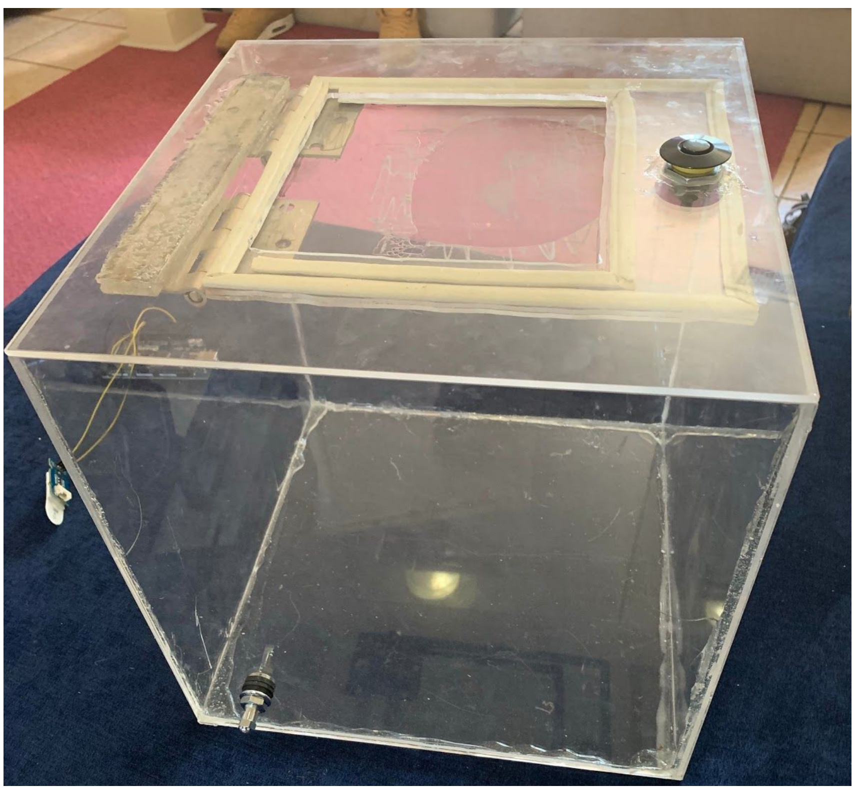

Figure 4: Pressure Chamber with Latching System

The actuation method of the trap door has almost been finalized. The team has been able to create a way to release and reseal the trap door. The testing of the trap door can be seen in the video placed in Appendix A under “Actuation Method Testing 1”. The only aspect to still be tested regarding the trap door, is whether it will properly seal the air within the chamber. This is the next thing scheduled to be tested.

Arduino Testing

In order to record the temperature and pressure each vent will experience, an Arduino code was created to record the data over a set of time. The Arduino code used records the temperature and pressure over the course of two seconds. However, for our DoE, the team needs to measure the temperature and pressure over the course of one millisecond which the Arduino code is able to do. The video in Appendix A under “Actuation Method Testing 2” shows the Arduino code recording the temperature and pressure of the system every two seconds.

This meets the engineering requirements of displaying the usage of the system. The Arduino code displays the temperature and pressure of the system on a computer that can then be transferred to MATLAB to display graphs of the results.

Vent Testing

The testing of the vents was done by just making sure the vents printed function as they are intended to. Additionally, the vents is tested to see if they have a standardized outlet area of 10 in^2 . Measuring the outlet area of each vent, the vents have an outlet area of around 10 in^2 , therefore it meets the engineering requirement of standardizing the outlet area. The vents designed also meets the engineering requirement of being bio-inspired. The four vents that were designed was based on a pine cone, the Fibonacci sequence, a termite mound, and a flower. The four bio-inspired vents are shown in figures 5-8.

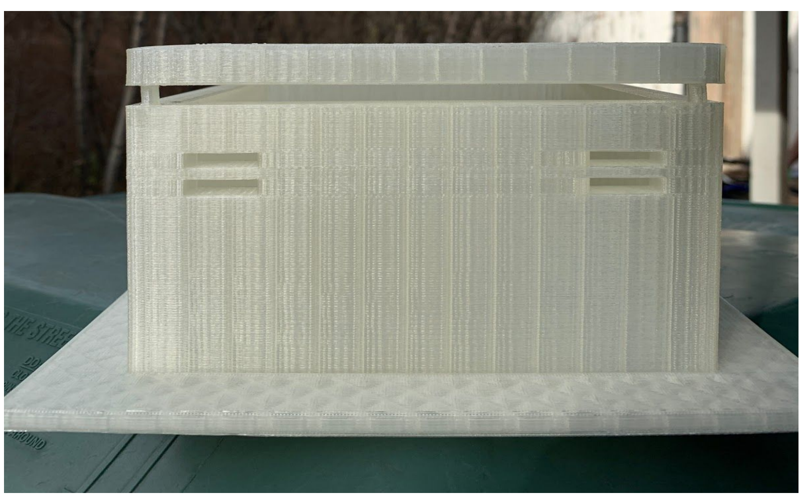

Figure 5: Pinecone vent

Figure 5 shows the design of pinecone vent. The pinecone design is meant to release the air naturally through eight holes in the walls and eight holes in the roof. Moreover, there is a small gap between the roof and the four walls to make sure that the ventilation process is done in a short time.

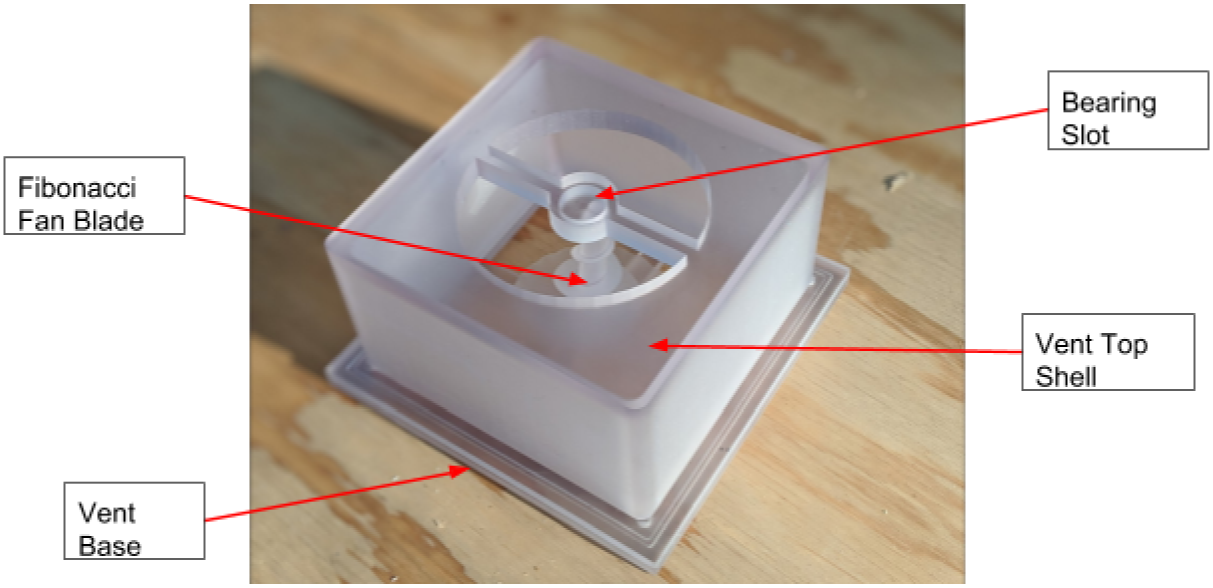

Figure 6: Fibonacci Vent

Figure 6 shows the Fibonacci vent. This design incorporated a blade based on the Fibonacci sequence which is placed in between bearings for the blade to rotate. Figure 7 shows the termite mound vent. This vent is based on how termite mounds vent through holes within the mound. This vent is able to allow air to flow through the holes, releasing the pressure.

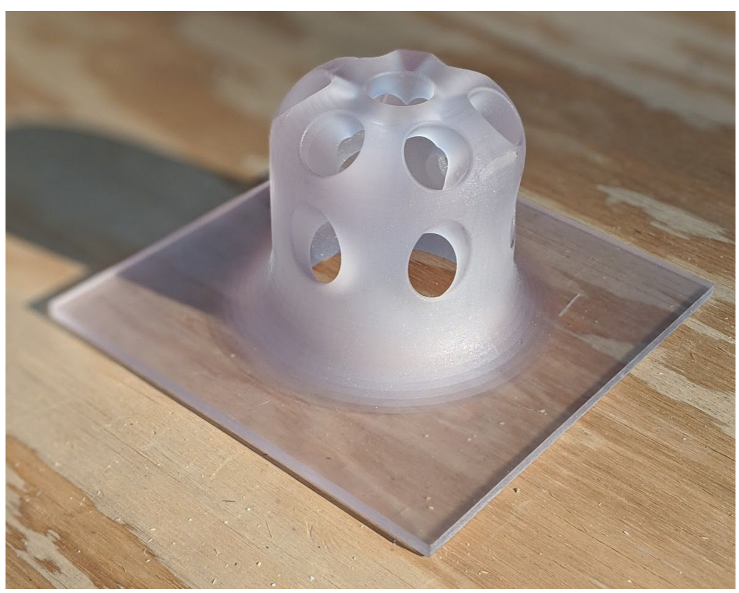

Figure 7: Termite Mound Vent

Figure 8 shows the flower vent. This vent is based on how a flower blossoms. It incorporates pedals that move up and down, or open and close, based on the amount of air flowing in the vent.

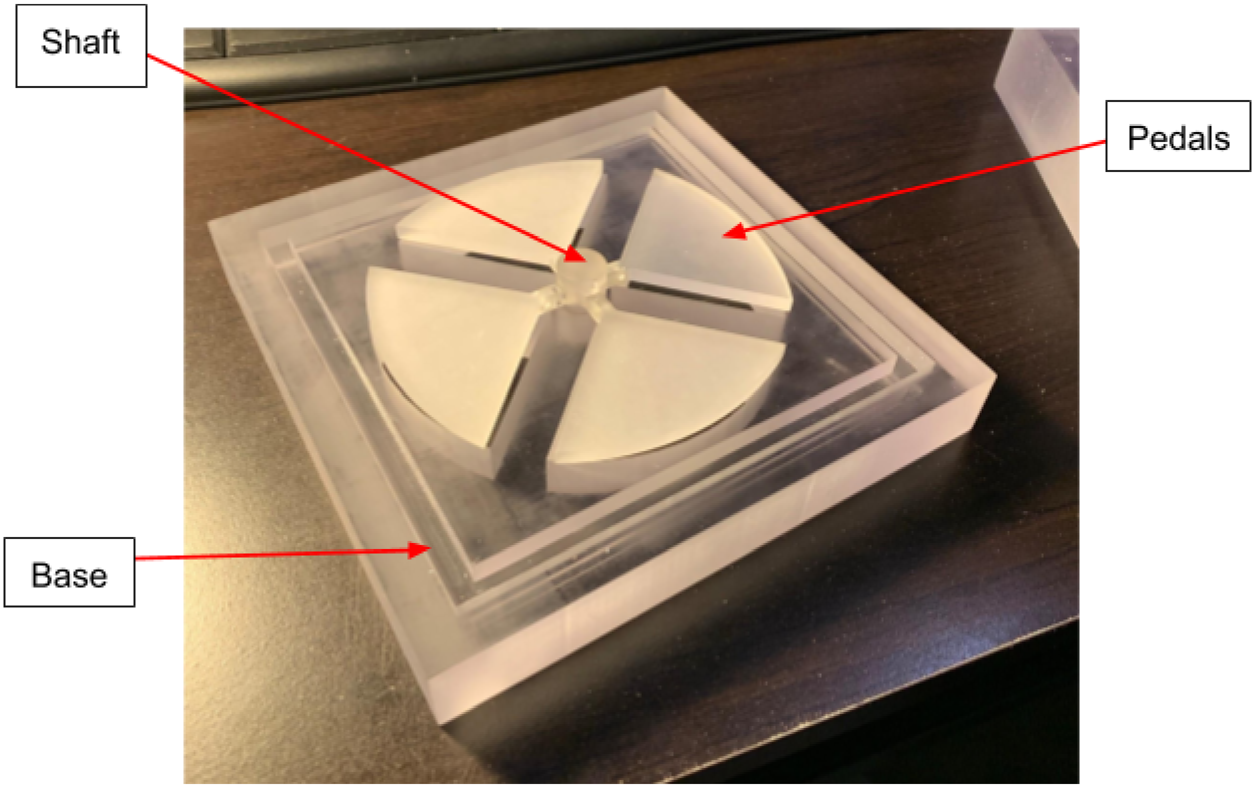

Figure 8: Flower Vent

Testing of each vent included seeing if each vent does what it was intended to do. For example, the Fibonacci vent's blade spins through the use of bearings while the flower vent's pedals is able to move up and down when there is a flow of air passing through the vent. This meets the engineering requirements of increasing the energy efficiency by relieving the pressure of the system, being durable by running constantly throughout the year, and it is less than or equal to the current size of the system since it will be integrated to the current ventilation system of SBS West.

Conclusion

When testing different aspects and subsystems of our DoE setup, problems begin to arise with the various systems such as the door actuation system not being able to relatch itself. After multiple redesigns were performed, the team was able to finalize the subsystems of the DoE and were able to complete the testing of these systems. After the testing of these systems, it was proved that the subsystems work properly. Although much of the DoE design has been tested, the team has still yet to complete the DoE testing. This is due to manufacturing issues that arose during the redesign which requires the sealing of the chamber still needing to be completed. Furthermore, the team needs to test the complete setup of the DoE (all subsystems assembled) to ensure no air will escape during pressurization of the chamber. Once this is completed, the team will be able to complete the experimentation of the vents.

Appendix A

Actuation Method Testing 1
https://www.youtube.com/watch?v=qCsuuHE3fFQ&feature=youtu.be

Actuation Method Testing 2
https://www.youtube.com/watch?v=FoGZrfaCuSU

Pressure Chamber Testing
https://www.youtube.com/watch?v=Ucfw-_FItzw&feature=youtu.be

Airtight Testing
https://www.youtube.com/watch?v=N5M4VsZ26Qo&feature=youtu.be