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EML4551-2

Team 520: Trane: Improve Air Quality

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Abstract

Due to the pressing times of COVID-19, an HVAC solution is needed to ensure air quality meets the necessary requirements. This project is to identify and validate a sustainable HVAC solution that improves air quality and adheres to government and environmental guidelines to combat COVID-19. It will continue to be sustainable in future markets for residential and commercial applications.

Keywords: HVAC, air quality, coronavirus, bipolar ionization, ionization

Acknowledgement

We would like to thank our sponsor Cameron Griffith with Trane for taking the time to meet with us to provide us with the necessary information about our project. We would also like to thank Dr. McConomy and Dr. Ordonez for giving us mentorship throughout this project. We also wish to thank Jim Stephens for giving us insight into FSU's Utilities and Maintenance operations.

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Notation

ACH – Air exchanges per hour

ASHRAE – American Society of Heating, Refrigeration and Air-Conditioning Engineers

CO2 – Carbon Dioxide

CDC – Centers for Disease Control and Prevention

EPA – Environmental Protection Agency

FAMU – Florida Agricultural and Mechanical University

FSU – Florida State University

HEPA – High-efficiency particulate air

HVAC – Heating, ventilation, and air conditioning

IAQ – Indoor Air Quality

IoT – Internet of Things

MERV – Minimum Efficiency Reporting Value

MRSA – Methicillin-Resistant Staphylococcus Aureus

OEM – Original Equipment Manufacturer

OSHA – Occupational Safety and Health Administration

PHI – Photo Hydro Ionization

PCO – Photocatalytic Oxidation

PPB – Parts Per Billion

PPM – Parts Per Million

UV – Ultra Violet

WHO – World Health Organization

VOC – Volatile Organic Compounds

Chapter One: EML 4551C

1.1 Project Scope

Projection Description

The objective of this project is to develop and verify an HVAC solution that improves air quality while adhering to current guidelines to combat COVID-19 and continue to sustainable in future markets.

Key Goals

The primary goal of this project is to design an energy-efficient HVAC solution that improves air quality and is sustainable for future markets when circumstances change. The solution will adhere to government and environmental guidelines. A variety of technologies will be investigated, and the most promising one will be pursued. The team will verify the usefulness of the chosen solution, and a presentation will be given to Trane and FSU representatives to present findings and offer the proposed solution.

Markets

Due to the increasing threat of the COVID-19 pandemic, air quality management is critical in the effort to the slow of the virus. Any facility that requires adequate air quality, humidity levels, and comfort is a potential market for this product. The primary markets are Trane and FSU's Utilities and Maintenance Department. Secondary markets include other universities and schools, commercial buildings (hospitals, casinos, offices, bars, schools, restaurants, stadiums, etc.), and residential buildings (homes, nursing homes, apartment complexes, etc.).

Assumptions

The team has assumed that the solution will be compatible with existing systems, which will eliminate the need for new infrastructure. The solution must adhere to all associated government/environmental guidelines. School facilities may have limited availability or require special guidelines to be followed due to the pandemic. The system will be tested in Florida climate conditions.

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Stakeholders

The stakeholders associated with this project include our senior design professor, Dr. Shayne McConomy; our advisor, Dr. Juan Ordonez; our sponsor, Trane; our Trane liaison, Cameron Griffith; FSU's Utilities and Maintenance Executive Director, Jim Stephens; and the City of Tallahassee Utilities. The users include indoor facilities that require proper ventilation to ensure adequate air quality, humidity levels, and comfort within the premises. The beneficiaries include those who are susceptible to COVID-19 (elderly, children, individuals with underlying health problems).

1.2 Customer Needs

Questions and Answers:

Question 1: What is currently hindering Trane's HVAC systems in terms of efficiency and air quality?

Answer:

- OEM parts/equipment (York, Carrier, Daikin)
- Costly services

Interpretation: Outsourced equipment and maintenance costs make a large portion of expenses. In house equipment will be used when possible, and maintenance cost will be a consideration.

Question 2: What is expected of our team in terms of building a single component or a complete system?

Answer: The team is expected to satisfy a need, regardless of whether it's through one component or a complete system.

Interpretation: The project will take whatever form is required to achieve its goal.

Question 3: Has Trane made any changes regarding air quality during this COVID-19 pandemic? Can any improvements be made in terms of air quality & if so, how?

Answer: Research and development teams have been working on product testing regarding the different variables associated with the HVAC system (component specifications, component location within the system) to achieve the recommended/optimal humidity levels and IAQ adhering to (ASHRAE, EPA, OSHA) guidelines. New filter technologies including UV germicide filters and bipolar ionization technology are being applied and researched due to these pressing times of the COVID-19 pandemic. An improvement could be made in terms of air quality by increasing the air exchange rate from 4-8 times per hour to something higher (8-10 times per hour?).

Interpretation: The system will improve air quality, and there are many potential methods of doing so.

Question 4: What HVAC components are most prone to failure?

Answer: Depends on the system design and application.

Interpretation: Any component of Trane's HVAC systems is available to be affected by the project.

Question 5: What are the necessary attributes of a Trane HVAC system? (What distinguishes a Trane from a Honeywell?)

Answer: Trane's market consists of ⅓ residential applications and ⅔ commercial applications. The company's driven to provide the lowest life cycle cost, efficient energy usage to reduce carbon emissions, and for sustainability in future markets.

Interpretation: The goals of the project will overlap with the goals of Trane.

Question 6: Will our team's design be focusing more on residential or commercial applications?

Answer: Our team will be focused on air quality and efficiency in facilities like schools and universities.

Interpretation: The project will be designed for use within facilities like schools and universities.

Question 7: Are there any special programs used to design & analyze HVAC systems? Will our team have access to these programs?

Answer: We are free to use any programs for this project, however, we might gain access to Trane's Trace 700 program.

Interpretation: The project is free to use whatever available software that will benefit the design.

Question 8: Who are the stakeholders in this project?

Answer:

- Dr. McConomy - "Technical Buyer"
- Cameron Griffith - Senior Design Mentor (Trane Sponsor) "Executive Buyer"
- Jim Stevens - FSU HVAC Systems Coordinator

Interpretation: The different needs of different types of stakeholders will be met.

Question 9: What government/environmental regulations and guidelines are setting Trane's current product specifications?

Answer: No necessarily enforced regulations (yet), but there are guidelines given by OSHA and the EPA.

Interpretation: Health and safety guidelines will be taken into consideration.

Question 10: What personal customer needs/wants does our team's design need to satisfy?

Answer: The implemented technology must continue to be useful/efficient after the COVID-19 pandemic.

Interpretation: The design will continue to be useful throughout its lifecycle.

Explanation of Results:

The COVID-19 pandemic has made air quality issues more obvious. Our team sat down with project sponsor Cameron Griffith to discuss ways we can help Trane create a practical solution. There are many methods for improving air quality. However, all of them negatively affect system efficiency. Our team is to design a system that maintains excellent air quality without hurting the efficiency of existing HVAC systems. Because air quality and system efficiency are general concerns, not specific to COVID-19, the design will continue to be useful and cost-effective throughout its lifecycle.

1.3 Functional Decomposition

After meeting with our Project sponsor, we were told that the demand for clean building air has never been greater. We learned that many existing HVAC systems are outdated. Many HVAC systems do not exchange the air at a fast-enough rate to keep air from stagnating. Also, we learned that existing advanced particulate filtering solutions are often cost prohibitive to install and service. Based on our interpreted customer needs we divided the project into three systems: Air Quality, Sustainability, and Controls. The first two systems directly satisfy our customers' needs of improving air quality and system efficiency. Our third subsystem is to allow controllability within the HVAC system and to monitor air quality data.

A hierarchical chart (Figure 2, Appendix B) based off of the functional decomposition was created in order to visualize the breakdown of the project's systems. The systems were then expanded upon with desired functions. After creating the hierarchical chart, the systems were then represented within a cross-reference table. This table allows functions to be compared across the different systems for overlap of functionality.

The hierarchical chart illustrates the connection between systems and their functions. The first system we chose was to improve air quality. The customer made it very clear that this is the main priority of the system due to the COVID-19 pandemic. From the interpreted needs, we determined our system needed to be able to clean, dilute, exhaust, and contain indoor air. Being able to clean the air is important to rid the air of contaminants. Diluting the air is necessary to exchange the old air with fresh air. Once the air is exchanged the old air needs to be safely exhausted from the system. Finally, we want the system to contain clean air without leakage. These four functions come directly from Trane; they are essential to good HVAC technology.

The next system identified by the team was to promote sustainability. A big problem with improving air quality is that it typically decreases efficiency. We have been tasked with trying to achieve both to the best of our ability. To promote sustainability within our system, we decided our functions would be to: reduce operating costs, improve system longevity, optimize energy efficiency, and support existing HVAC systems. When dealing with customer applications it is always important to try and reduce installation and running costs. Budgets are often tight and cannot accommodate large renovations. Improving the longevity of the system ensures that the system remains useful in a post-COVID-19 environment. Optimizing energy efficiency vs improved air quality is important. A grossly inefficient system will not result in a useful HVAC system. Furthermore, our design needs to be capable of being retrofit onto existing systems. This is important because it allows many potential use cases in different systems while also being less than the cost of a replacement system. Our sponsor made it clear that practicing sustainable engineering is important to Trane.

Our third system would be the controls aspect of the project. By monitoring certain variables within the system, it allows the system to be more dynamic. It is important that the system can respond to changing conditions. The functions identified were: maintain recommended humidity levels and CO2 levels, a comfortable temperature, and monitor volatile organic compounds (VOCs). It is important to maintain a humidity level that promotes both the comfort of the inhabitants and the reduced growth of bacteria. Elevated CO2 levels can be harmful and uncomfortable. A basic yet important function is that the system should maintain a comfortable temperature. If an HVAC system cannot keep the building comfortable, then it has failed its most basic duty. It is important to monitor and remove VOCs within the system as inhabitants can inhale them and become sick. These four functions enable control of system to the degree necessary to maintain air quality and promote sustainability.

The hierarchy chart was used to determine our basic functions. The cross-reference chart is used to illustrate that some of these functions contribute to multiple sub-systems. Most of the control functions are directly related to air quality. Maintaining humidity level is a function of controls but is integral to air quality. The functional decomposition gives a better understanding of the project by defining the relationships between each function. This understanding is useful for concept generation and selection. The function resolution achieved in our functional decomposition was defined well enough to convey the necessary design without constraining certain aspects.

Table 1) *Cross-Reference Chart*

Table 1. Cross-Reference Chart

Systems	Air Quality	Sustainability	Controls
Functions			
Maintain recommended humidity levels	X		X
Maintain recommended CO2 levels	X		X
Maintain comfortable temperature			X
Monitor VOCs	X		X
Minimize operating costs		X	X
Improve system longevity		X	
Optimize energy efficiency		X	X
Support existing HVAC systems		X	
Clean indoor air	X		
Dilute indoor air	X		
Exhaust indoor air	X		
Contain indoor air	X		X

The functional decomposition illustrates what the project must accomplish fundamentally. No matter what form it takes, the final project will be a controlled system that improves air quality and promotes sustainability.

1.4 Target Summary

After defining the functions of the project in the function decomposition, methods for defining and measuring those functions were examined.

There are four critical targets. If these four targets are met, the project will be a success. Many of the other targets relate to these. A VOC concentration of 0.3 milligrams per cubic meter is defined by the CDC as harmless air. There are conflicting data on this number. Erring on the side of caution, 0.3 is on the lower end of recommended values (a lower concentration is better).

Air changes per hour (ACH) is how often the inside air is entirely exchanged for fresh air. The CDC recommends different values based on the room in question. For example, chemical facilities have higher recommended ACH than grocery stores. 10 ACH is on the high end for applications for facilities like schools and office buildings. Energy usage and operating costs are defined as a percentage of the value of the pre-existing system. When the project is implemented into existing systems, energy usage will unavoidably increase, but a minimal increase is desired. 115% percent energy usage represents a 15% increase in energy use. This is an intermediate value based on other air quality solutions. Operating costs directly related to energy use, but also includes additional maintenance expenses on the additional system component. The desired operating costs of the augmented system is 120% that of the existing system. These metrics are defined so that they scale with the size of the existing system. The following table shows the critical targets and metrics with their functions.

Table 2) *Critical Targets Summary*

Function:	Target:	Metric:
Dilute Indoor Air	10	ACH
Clean Indoor Air	0.3	VOC Concentration (mg/m^3)
Minimize Operating Costs	120%	Current Costs (%)
Optimize Energy-Efficiency	115%	Current Usage (%)

Table 2. Critical Targets Summary Table

Other, noncritical functions are defined by the current guidelines for HVAC systems in the United States. These standards are used because existing systems are already tested based on them. The metrics are CO_2 concentration, humidity control, and temperature control. The functionality of the existing system must be unaffected by the implementation of the project.

There are two other functions that are also measured by ACH. Diluting the indoor air directly means bringing in fresh air but exhausting and containing the air play an important role as well. Each of them contributes uniquely to increasing ACH.

A table detailing each function with its respective metric and target can be found in Appendix C.

Other needs are represented in these targets. It's important that the project promotes the ideals Trane uses to represent itself. Minimizing maintenance cost, and thus operating cost, conveys a robust design with a long lifecycle. Minimizing energy usage connects to an environmentally friendly mindset. Less energy usage means less carbon emissions. Notably, none of the targets and metrics specifically mention COVID. To be a sound economic investment, the system needs to be useful independent of COVID. Decreasing the VOC concentration without a substantial increase in energy usage will always be an attractive feature.

If the critical metrics are measured, the project can be successfully validated. Testing for energy usage is simple. Measuring the energy usage of the implemented design and comparing it to the usage of the subject HVAC system gives all the necessary information. It is common practice to estimate maintenance cost as a fraction of the initial cost a system. With this estimate and energy usage, operating costs is easily calculated. ACH is just a function of the size of the facility and the volumetric flow rate of the system, which can be measured in any number of ways. Measuring the total VOC concentration is more difficult, as there are a variety of chemical compounds that are identified as VOCs. To measure this accurately, a specialized device is required. Due to limited resources, the device would have to be provided either by the college or by Trane.

Many of these targets were determined from the functional decomposition and the customer needs. Each one of these targets has an associated metric as to how to determine if the targets are met. These metrics were determined largely through group research. For targets related to air quality composition, the associated metric was found by consulting industry standards set by ASHRAE and other regulatory agencies (EPA, OSHA, WHO). The installation cost was found as the desired metric for fitting the HVAC system because the system should require little to no modifications to be implemented. Optimizing energy efficiency was expressed as a percentage as this function will scale with the size of the HVAC system. The energy usage will increase for larger HVAC systems as they are used to cool larger areas. This same concept explains why the operating costs were expressed as a percentage as well. This percentage was larger than the energy efficiency as it must account for maintenance of the system as well as energy usage.

1.5 Concept Generation

Methodology

There are many ways to approach improving air quality, which, fundamentally, the goal of the project. There are any number of ways to fill a space with cleaner air. Air can be directly cleaned. Indoor air can be diluted with fresh outdoor air. Many systems underperform to conserve energy. Improvements in energy efficiency can lead to improved air quality without increased energy expenditure. Energy can be found elsewhere and applied in a similar way.

As a result, there is no shortage of usable concepts. Many were provided as recommendations from organizations like the CDC and ASHRAE. Some were offered as interesting possibilities by Trane, and some are very minor changes to existing technology.

Most of the concepts came naturally, but the Crap Shoot method was also used. Everyone is affected by air quality, and any indoor activity is as well. There are plenty of resources to draw on to clean air. Because of this widespread, the Crap Shoot method seemed particularly useful. Almost every possible combination resulted in a usable concept.

Furthermore, most air quality technologies are additive, so any number of them can be used together. Solar panels can offset the energy usage of UV lights. UV lights can be used in conjunction with high quality filters in particularly vulnerable areas. This lends itself to a morphological chart, but because almost any solution can be combined with almost any other solution, it wasn't used.

The following concepts were chosen as the most promising. A summary is given of each. They are further compared in Concept Selection. All generated concepts can be found in Appendix D.

Medium Fidelity Concepts:

Concept 80. Implement antimicrobial coated duct lining to inhibit mold growth within the ductwork and to make duct cleaning more feasible.

Assuming the current system duct lining installed, the inclusion of antimicrobial duct lining would improve the system. The lining acts as an insulator which reduces energy consumption and prevents unwanted water damage which can lead to costly damages. Adding duct lining to an HVAC system also improves airflow by sealing any holes within the duct and increases air quality if the lining is antimicrobial.

Concept 29: Implement Photo Hydro Ionization (PHI) as a purification technique to increase air quality and reduce ozone levels.

An alternative purification technology developed by RGF Environmental Group is photo hydro ionization (PHI). This technology utilizes UV lights and a catalyst to create hydro-peroxide ions to deactivate harmful aerosols. During preliminary testing by Kansas State University, PHI was proven effective against viruses and bacteria such as MRSA and Swine Flu.

Concept 91: Implement Photocatalytic Oxidation (PCO) as a filtration technology.

This filtration technology is analogous to a catalytic converter in automobiles, it is a promising technology that uses high-intensity UV-C lights to radiate a titanium dioxide or quad metal catalyst (as in PHI). As a result, a hydroxyl radical field is developed. These hydroxyl radicals are powerful oxidizers that oxidize carbon-based molecules and microorganisms in the air.

Concept 1: Increase the ACH by increasing the speed of the induction fan motors to dilute the indoor air with more fresh outdoor air.

Increasing the air exchange rate per hour (ACH) is one of the simplest ways to improve air quality, given that the outdoor air is satisfactory. To do this, the speed of the induction fan motors for both intake and exhaust must be increased using a variable frequency drive. By increasing the ACH the indoor air is further diluted by the incoming fresh outdoor air. This dilution reduces the harmful aerosols and particulate matter concentration indoors, effectively improving air quality.

Concept 64: Install Internet of Things (IoT) systems in critical buildings to increase preventative maintenance by sensing data on air quality and equipment status

The future of HVAC is essentially a fully integrated system called Internet of Things (IoT) embedded with sensors, software, and connected devices. This smart system can track data to increase the system's efficiency and ultimately run autonomously. The end-user has very few responsibilities due to the seamless operation of the system. By tracking data with sensors and displaying component states, the end-user can perform maintenance when necessary. The integration of this technology requires advanced machine learning algorithms to identify a particular building's requirements and schedules, which along with the sensors prove to be very costly.

High Fidelity Concepts:

Using geothermal energy to augment or power an HVAC system isn't new technology, but it isn't widely used. The temperature of the earth is fairly consistent after a certain depth. By burying a heat exchanger at a depth where the temperature is uniformly moderate, a house can be cooled in the summer and heated in the winter. For a large, horizontal heat exchanger, it only needs to be buried about two meters deep.

Geothermal heat exchangers have become popular options for ecological minded residential applications. Rather than using natural gas or electricity to condition air, a single pump is needed to flow water through the buried heat exchanger.

In the case of large commercial buildings, it's possible the demands would overcome the supply a geothermal system creates. Even in this case, there are savings to be made by augmenting a traditional HVAC system with a geothermal one. This is especially notable if the system needs to be run all the time, with peaks in troughs in demand. During such troughs, the geothermal system could provide all the required energy, and during peaks the traditional system can fill in the rest.

Note, this type of system is different from a geothermal powerplant. These plants dig thousands of feet to where the earth is extremely hot and use that energy to generate steam to create electricity. The scaled down version of that technology considered for HVAC purposes does not generate electricity. (Concept 13)

The use of better filters is an unexciting but very likely solution to most air quality issues. There are many advantages to this solution. Notably, most systems don't need to be modified for higher quality filters. This factor cannot be over emphasized. It represents huge savings in both money and time. No required modification to the existing system obviously saves money, but modifications also take time. Many institutions are trying to get people back indoors as quickly as possible. This solution can be implemented over a weekend.

They are also scalable to whatever air quality issues are prevalent. MERV 13 filters and above are at least somewhat effective against most airborne VOCs. Above that, they become increasing effective. Areas that are particularly vulnerable can be fitted with higher quality filters without any more investment than a higher rated filter. This greatly simplifies the solution for facilities with varying buildings or systems. An example is Florida States' campus, where every building was built differently with a different HVAC system at a different time. Research labs can be fit with MERV 18 while general lecture halls can be fitted with a lower rated filter, but the work and time put in are the same.

Furthermore, these filters don't require any extra dilution of the indoor air. This means no additional heating or dehumidification needed. The system should function almost exactly as it did with the old filters.

However, higher quality filters to result in a higher pressure drop, and this can strain some systems. Old systems fit with high rated filters can struggle or stall under the increased load. Newer system won't frequently struggle with this. Regardless, the system has to work harder to overcome the increased pressure drop. This does result in an increase in power draw, but it's difficult to say whether it is significant or not. The major cost incurred with this solution is the upfront cost of the filters. (Concept 26)

Bipolar ionization is a newer technology. As such, there are conflicting data and claims as to its uses and effectiveness. There is little scientific, peer-reviewed literature on the subject. If this is the chosen solution, testing will be a much more significant part of the project. However, it is potentially extremely effective solution.

It works by applying a charge to molecules in the air, both negative and positive. These ions allow for groups of molecules and particles to gather and collect. These conglomerations of small particles can become large enough to be caught in filters or heavy enough to fall to the ground. Either way, the particles are removed from the air. The ionized molecules also react with viruses, bacteria, and mold in the air, killing them. So, the technology works to filter the air as well as neutralize harmful organic particulate.

Bipolar ionization systems aren't very expensive to install, but a very high voltage is required to create the ionized molecules. It's unclear to what degree this would affect energy consumption of a system.

Compared to other air quality solutions, bipolar ionization most directly affects the concentration of viruses in the air, making it a prominent contender for combatting COVID. (Concept 10)

1.6 Concept Selection

House of Quality

The identified customer needs were tied to specific engineering characteristics in the house of quality shown in Table 3. These characteristics include mass, energy consumption, flow rate, contaminant concentration, & installation cost. A rating was given for each characteristic depending on the influence it has on each customer requirement. These ratings were summed and then multiplied by the importance weight factor found in the binary pairwise comparison, located in appendix E. The relative weight for each customer need was found and ranked. The results of the house of quality show that flow rate is the priority engineering characteristic followed by, contaminant concentration, energy consumption, installation cost, & mass.

Table 3) *House of Quality*

House of Quality						
Engineering Characteristics						
Improvement Direction		↓	↓	↑	↓	↓
Units		kg	kW	m^3/s	ppm	USD
Customer Requirements	Importance Weight Factor	Mass	Energy Consumption	Flow Rate	Contaminant Concentration	Installation cost
1. Air Quality	**4**		3	9	9	
2. Longevity	**1**			9	9	
3. Energy Efficiency	**2**		9	3		
4. Total Cost	**1**					9
5. Retrofit	**2**	3				9
Raw Score	**159**	6	30	51	45	27
Relative Weight %		0.038	0.189	0.321	0.283	0.170
Rank Order		5	3	1	2	4

Table 3: House of Quality

AHP

From the AHP, it became apparent that combatting COVID was an important factor in the analysis of each concept. Air quality was clearly the most heavily favored factor, followed by energy consumption and being a retrofit design. Total cost and system longevity were weighted the lowest. The comparison was normalized for ease of use.

Table 4) *Pairwise Comparison*

Pairwise Comparison - Normalized						
	1	2	3	4	5	Criteria Weight
1. Air Quality	0.639	0.446	0.369	0.443	0.620	0.503
2. Longevity	0.071	0.050	0.025	0.246	0.013	0.081
3. Energy Efficiency	0.128	0.149	0.074	0.246	0.013	0.122
4. Total Cost	0.071	0.010	0.015	0.049	0.266	0.082
5. Retrofit	0.091	0.347	0.517	0.016	0.089	0.212
Total	1	1	1	1	1	1

Table 4. Normalize Pairwise Comparison

Air quality directly reflects the effectiveness of the design. If high air quality is achieved, the design is successful. Other factors change the degree of that success, but this is clearly the primary goal of the project.

A retrofit design reflects in the total cost, but also the time for installation. This is important for commercial buildings trying to get people back to work, or schools trying to get people back to class. Some design, like high quality filters, can be installed over the weekend. Other designs require significantly more time and resources to put in place. This could be a limiting factor if schools are resuming class.

Energy consumption represents operation costs to the consumer. Some concepts would result in increases in energy consumption by at least an order of magnitude. These designs frequently worked well in cleaning the air but aren't sustainable environmentally or economically.

Total cost and system longevity are both important factors to the design, but less important to its overall success. They both reflect the economic investment in the design, which is obviously important to the consumer, but only if the system functions properly in the first place.

Pugh Matrices

The first Pugh chart compares the five medium and three high fidelity concepts selected with a baseline datum solution. The datum represents the current HVAC solution used by FSU. From the chart it can be seen that many concepts were very close in their rankings of pluses and minuses. The four best performing concepts were compared with a new Pugh chart.

Table 5) *Pugh Matrix - 1*

Pugh Matrix - 1									
		Concepts							
Engineering Characteristics		1	2	3	4	5	6	7	8
Mass	Datum	+	+	+	+	+	-	S	+
Energy Consumption		+	+	+	-	+	+	+	+
Flow Rate		-	-	-	+	-	+	-	-
Contaminant Concentration		+	+	+	+	+	+	+	+
Installation cost		+	-	-	+	+	-	+	+
# of pluses		4	3	3	4	4	3	3	4
# of minuses		1	2	2	1	1	2	1	1

Table 5. Pugh Matrix - 1

To better compare them, a new datum was chosen. Concept 2, photo-hydro ionization, was chosen because it was one of the concepts that represented a good baseline of positives and negatives. Concepts 3, 6, and 7 were eliminated due to their mediocre performance. This new datum was tabulated into Table 4 below. Concept 8 compared slightly better than the other remaining concepts.

Table 6) *Pugh Matrix - 2*

Pugh Matrix - 2					
		Concepts			
Engineering Characteristics		1	4	5	8
Mass	Datum Concept 2	+	+	+	+
Energy Consumption		+	-	+	+
Flow Rate		-	+	+	+
Contaminant Concentration		+	+	+	+
Installation cost		+	+	-	+
# of pluses		4	4	4	5
# of minuses		1	1	1	0

Table 6. Pugh Matrix – 2

Final Selection

After the selection process, bipolar ionization is left as the final concept. It was concept 10 in Concept Generation, and Concept 8 in Selection. The process works to both filter the air and kill harmful suspended organics. It uses a high voltage to create charged molecules in the air. These ions react with and neutralize bacteria, mold, and viruses directly. They also attract clumps of particulate that are large enough to be easily removed from the air.

From the house of quality, it was determined that flow rate is the most important characteristic, with contaminant concentration closely second. While bipolar ionization doesn't increase flow rate, it only slightly hinders it. It's also notably good at reducing the contaminant concentration.

There were not many concepts that so directly neutralize viruses in the air. Combined with comparatively easy installation, that makes bipolar ionization a reasonable candidate for combatting COVID. These were two heavily weighted factors that this concept excelled in. This can be seen in table 6, the second Pugh matrix.

All tables can be found in Appendix E.

Chapter Two: EML 4552C

2.1 Restated Project Definition & Scope

Restated Project Definition

With the onset of the COVID-19 pandemic, schools and businesses sought solutions to the air accompanying air quality crisis. In addition to mask-wearing and social distancing, many organizations looked to HVAC solutions. The goal of this project is to identify and verify one such solution. The chosen concept should be environmentally friendly, useful independent of COVID, and, ultimately, reduce the risk of the virus spreading.

Redefined Scope

The scope of the project became more narrow. Rather than designing a new device or system, the plan is to validate an existing technology. Specifically, ionization was selected. Many schools and organizations began using ionizers for anti-viral purposes in mid-2020, but there was and is very limited evidence to support that practice. This is a safety issue and an ethical one. The benefits of further testing this technology were clear.

Manufacturers of these ionizers made many claims about their usefulness. This project focused on their effect on airborne VOC concentration and on biological samples.

Testing Procedure

VOC Test

The VOC test is to measure the effects an ionizer has on VOC concentration. These tests will be conducted in room B136 at the FAMU-FSU College of Engineering.

Initial Data Collection – Initial data will be collected over several hours under normal operating conditions. A VOC monitor will be used to measure the concentration of VOCs in the air. This data set will be the control.

Final Data Collection – The ionizer will be installed in the system, as per manufacturer specifications, and data collection will be conducted over the same time of day under the same operating conditions.

Test Results – The data from each set will be analyzed and summarized.

Reporting – A final report will be written up including the results from each test, the details of the testing location, and the specific operating conditions.

Ion Test

The Ion test is to verify that the ionizer is producing both positive and negative ions. These tests will be conducted in room B136 at the FAMU-FSU College of Engineering.

Initial Data Collection – The ion concentration is measured in the classroom without the ionizer in operation.

Final Data Collection – The ion concentration is measured in the classroom over several hours with the ionizer in operation. Measurements will begin immediately after the ionizer is turned on.

Test Results – The gathered data will be compared to determine the change in ion concentration.

Reporting – A final report will be written up including the results from each test, the details of the testing apparatus, and the specific operating conditions.

Mold Test

The mold test is to measure the effects an ionizer has on the viability of mold spores. Light and temperature conditions will be kept constant throughout all tests. These tests will be conducted in room B136 at the FAMU-FSU College of Engineering.

Initial Data Collection – Mold spores will be suspended in an agar solution in petri dishes. Two control sample sets will be taken. The first set will simply be sealed and incubated. The second control sample set will be placed in a room for a set time. During this time, the ionizer will not be running. The dishes will then be sealed and incubated.

Final Data Collection – The set of test samples will be placed in the same room, but the ionizer will be in operation. There will be several test sample sets taken with varying exposure times. After each allotment of time, the samples will be sealed and incubated.

Test Results – The samples will be compared to determine any change in growth rate.

Reporting - A final report will be written up including the results from each test, the details of the testing apparatus, and the specific operating conditions.

2.2 Results

Ion Concentration Test:

The results of the ion test indicated that our ionization module was effectively generating positive and negative ions into the airstream. The negative concentration increased threefold during one hour of operation and decreased rapidly as the module was powered off back down to around 1000 ions/cm^3. The positive concentration fluctuated sporadically during operation and at a lower magnitude.

Figure 1) Negative Ion Concentration.

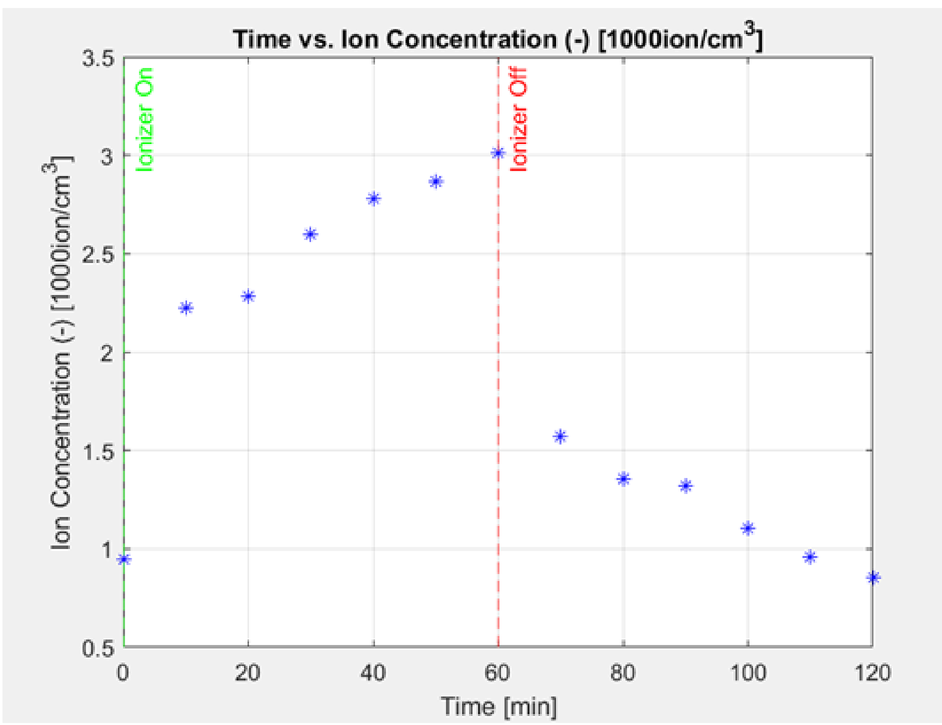
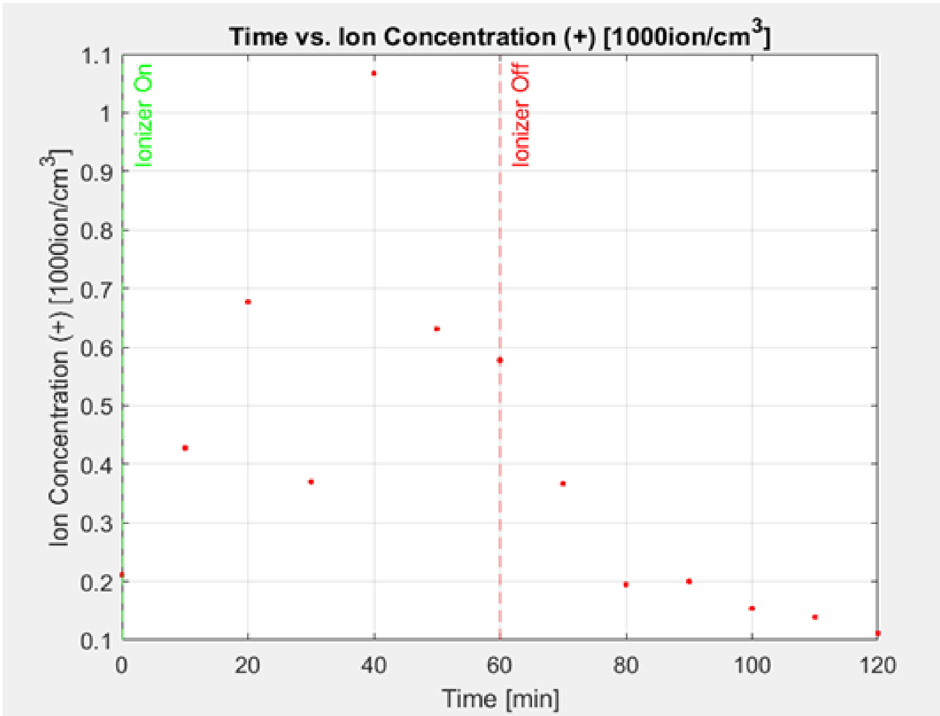


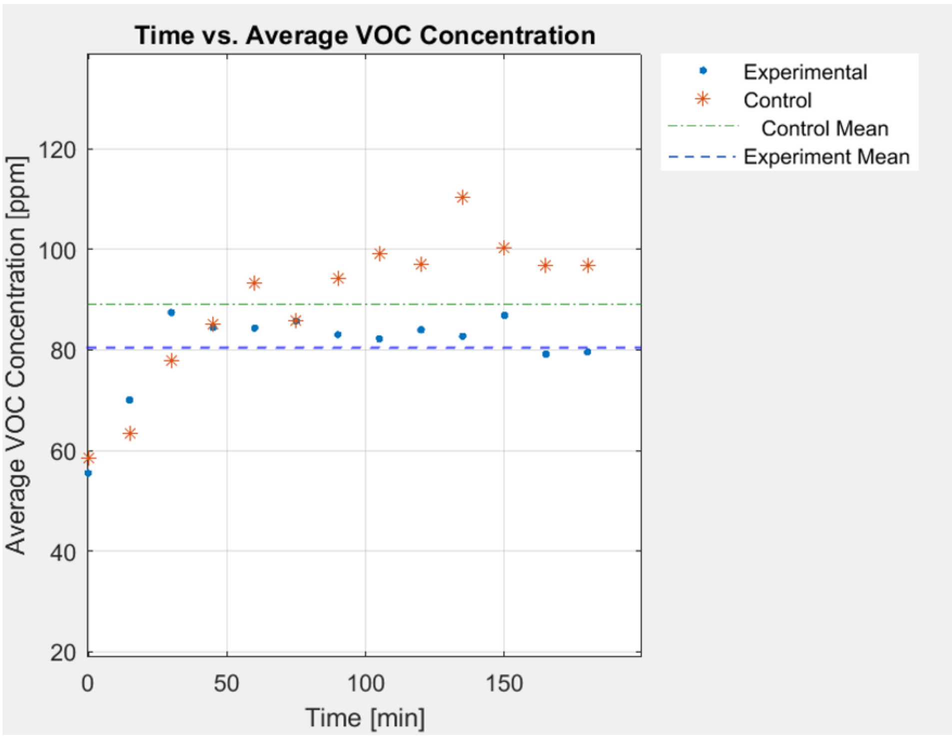
Figure 2) Positive Ion Concentration.



VOC Concentration Test:

The VOC test determined that the ionization treatment was partially effective in decreasing the concentration of off-gassed acetone by about 10%. As seen below, the average VOC concentration when the ionizer was off was around 89.1 ppm. Whereas the average VOC concentration during treatment was around 80.4 ppm.

Figure 3) VOC Concentration



Surface Mold Test:

The following images show the growth of the exposed mold samples after 7 days. The results of the mold test were not analytical like the other two tests, it instead was empirical. From the samples it was noted that the controls had significant growth over a period of 7 days. The exposure time had varied results on the mold samples.

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

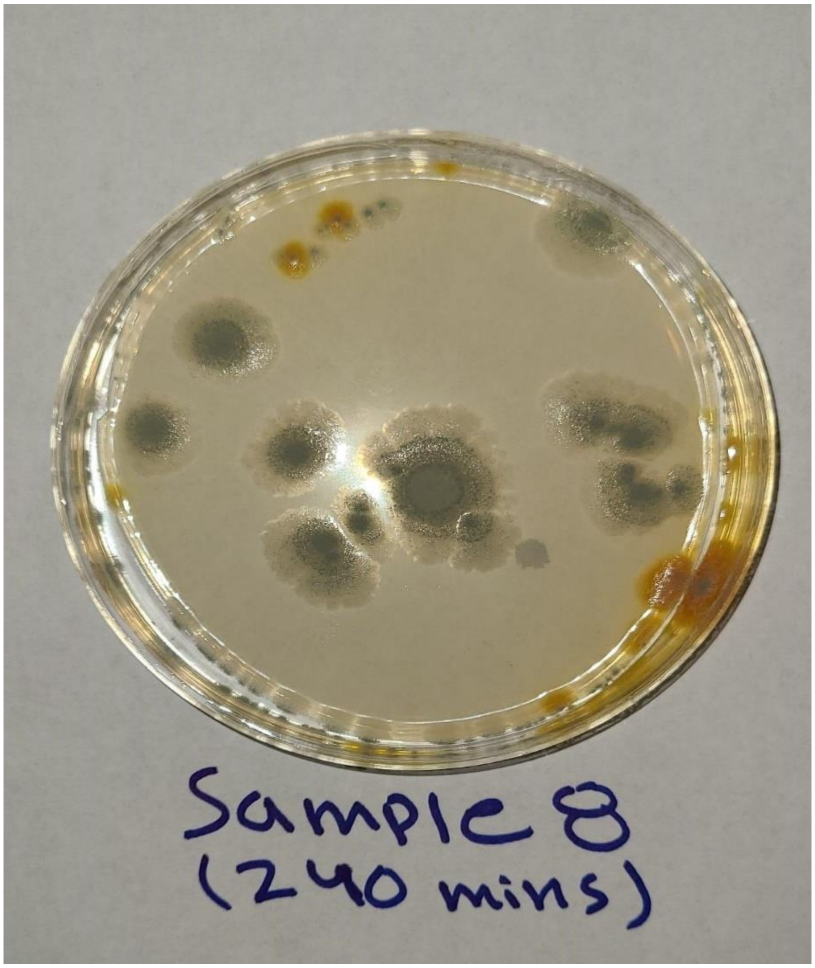


Figure 13

2.3 Discussion

The ion test was conducted to show that the ionizer we had was operating as expected. A noticeable increase in ion concentration was expected in the treated space. If the ionizer had been operating incorrectly, it would have invalidated the rest of the results. Fluctuations were noticed, especially in the positive ion concentration. The door of the room was opened at least once during testing, and this could have affected results. The results of this experiment weren't critical. It was concluded that the ionizer was operating properly.

The VOC test showed a decrease in VOC concentration. The decrease was around 10% after several hours. This is not a particularly impressive result. Compared to the claims of the manufacturers, and compared to other HVAC solutions, this decrease was low. The data set was limited, and there were fluctuations throughout testing. The degree of fluctuation could be due to many variables that influence the concentration of VOCs such as temperature, humidity, and flow behavior within the room. More data over a longer period of time would benefit this testing.

The mold testing was largely inconclusive. Accurate methods of calculating mold growth were unavailable, so the comparison is limited to visual examination, and the difference was significant enough to draw conclusions this way. Most of the experimental samples showed less mold growth, but not remarkably so. Samples 1 and 2 were the controls. Samples 1, 2, 3, 6, 8 experienced less growth than that of samples 4, 5, and 7. Sample exposure time increased with each sample. No clear correlation between ion exposure time and mold growth can be concluded. This testing would benefit from more samples and accurate methods of measuring mold growth. This would likely involve sending samples to third party labs for testing.

2.4 Conclusions

There was minimal effect on both VOC concentration and surface mold growth. We noted a slight decrease in VOC concentration and no significant change in growth. It is possible there is an effect on mold growth, but without more precise measuring methods, the gathered data is inconclusive.

There are different HVAC technologies that are better suited to the tasks we tested and others. Ionizers should only be used for controlling particulate matter and antibacterial purposes. These uses have been thoroughly tested and positive conclusions have been reached. Even then, higher rated filters perform better in filtering particulate, so ionizer should only be used if pressure drop is an issue.

It is possible that ionizers have a more significant effect on VOCs and bioaerosols, but without further testing, it is irresponsible and unethical to use them for those purposes.

2.5 Future Work

Future Testing

Much more testing needs to be conducted on ionizers before they can responsibly be used for anti-viral purposes. Viral samples should be used for these tests. Mold samples were used in place of viral samples for biosafety reasons. To accurately determine the effect that ionizers have on viruses, viruses must be used in testing. Tests should be conducted on aerosolized and surface samples. The MS2 bacteriophage is recommended for testing. It is harmless to people and a representative viral sample. If possible, flu and coronavirus samples should be tested as well, for the most accurate results.

Surface mold was tested because aerosolized spores posed several health and safety risks. Testing with aerosolized mold spores should be done. The mold spores should be disbursed into an airstream through a ductwork with an ionizer. In the room the ductwork is servicing, the air should be impacted into Petri dishes. Those dishes should be incubated and compared to a control after some time has passed. One of the major criticisms of the manufacturer testing was the overly long exposure times. In an airstream, the mold may only be exposed to ions for a short period of time. Different exposure times should be tested, with the understanding that shorter times are more realistic.

It is possible the anti-viral effect reported by manufacturers is due to the ozone production of the ionizers they tested. Some ionizers produce ozone, and some ionizers do not. It is important to distinguish whether the ozone or the ions are responsible for any results.

Finally, further testing should gather significantly more data than the testing conducted for this project. VOC levels were measured in unrealistic conditions because testing could not be conducting during operation hours. It would be better to take measurements in several classrooms, some with ionizers and some without, for a long period of time. Times of up to a month or more would be desirable. Average and peak measurements (VOC, mold, particulate matter) could be compared between the classrooms with and without the ionizers. This would give real-world conclusions about the effectiveness of ionizers regarding those metrics.

Appendices

Appendices

Appendix A: Functional Decomposition

Mission Statement

Provide a strategy for combating COVID-19 by improving air quality to promote public health and safety.

Team Roles

- Jake Hamilton - *Design Engineer*
    - The Design Engineer will be responsible for most mechanical design aspects as well as design review. Responsibilities include creating design drafts, performing design calculations, and overseeing the design process.
- Nicholas Holm - *Environmental Engineer*
    - The Environmental Engineer will be responsible for ensuring design and implementation meets environmental standards. Tasked with researching best practices and guidelines relating to health and safety of HVAC design.
- Andi Santeiro - *Quality Control Engineer*
    - The Quality Control Engineer will be in charge of testing, and managing the materials. Responsibilities include running tests using a select group of programs, as well as analyzing all materials used throughout the project.
- Joseph Thyer - *Project Manager*

- The Project Manager will manage communication between group members and project stakeholders, keep track of project budget and timelines, and finalize and submit all assignments.

- Gavin Young - *Fluids Engineer*
  - The Fluids Engineer will be responsible for most thermal fluids calculations relating to heat transfer, fluid mechanics, and thermodynamics of the system. Also responsible for the design of thermal fluid components within the system.

Team roles were assigned based on experience and abilities. Role changes and role responsibilities will be discussed during Zoom meetings or through our Discord server. Roles will be set; however, adjustments can be made if all group members are notified and come to an agreement. Group members must be notified within 48 hours of possible role change.

Communication

The group will discuss time availability and share general work schedules. Changes in availability can be discussed during the weekly scheduled meetings. We will meet primarily through Zoom and Discord. Correspondence will be done via email. Physical meetings will be limited as much as possible. If physical meetings become necessary, we will strive to conduct them safely and responsibly. Group members will be expected to respond to messages within 12 hours.

Dress Code

Client Zoom or video meetings will be business casual, requiring pants and a polo or button-down shirt. If the client indicates a different preferred dress code, changes will be made accordingly. Group presentations will be business casual, requiring pants and a polo or button-down shirt. Members will coordinate at least 24 hours before the scheduled meeting to decide on a cohesive appearance.

Attendance Policy

We will meet weekly every Tuesday after class from 7:45 PM - 8:45 PM (or starting when class ends and ending when needed) for weekly progress reports and to discuss future mission-critical project tasks. Additionally, there will be an optional meeting every Thursday from 7:45 PM - 8:45 PM to discuss project objectives. Meetings with sponsors and advisors will be scheduled as needed and will be held via Zoom or Discord.

Attendance will be mandatory for mission-critical group meetings and weekly progress report meetings. If a group member is unable to attend a meeting, he/she is expected to notify the group at least 24 hours in advance.

The project manager will record attendance. If a group member continually misses meetings, it will be discussed with the group. If it continues to be a problem, the Senior Design Advisor will be contacted.

Statement of Understanding

I hereby acknowledge that I have read the above Code of Conduct and agree to abide by the rules and regulations established for this group.

Signatures:

Jake Hamilton

Nicholas Holm

Andi Santeiro

Joseph Thyer

Gavin Young

____

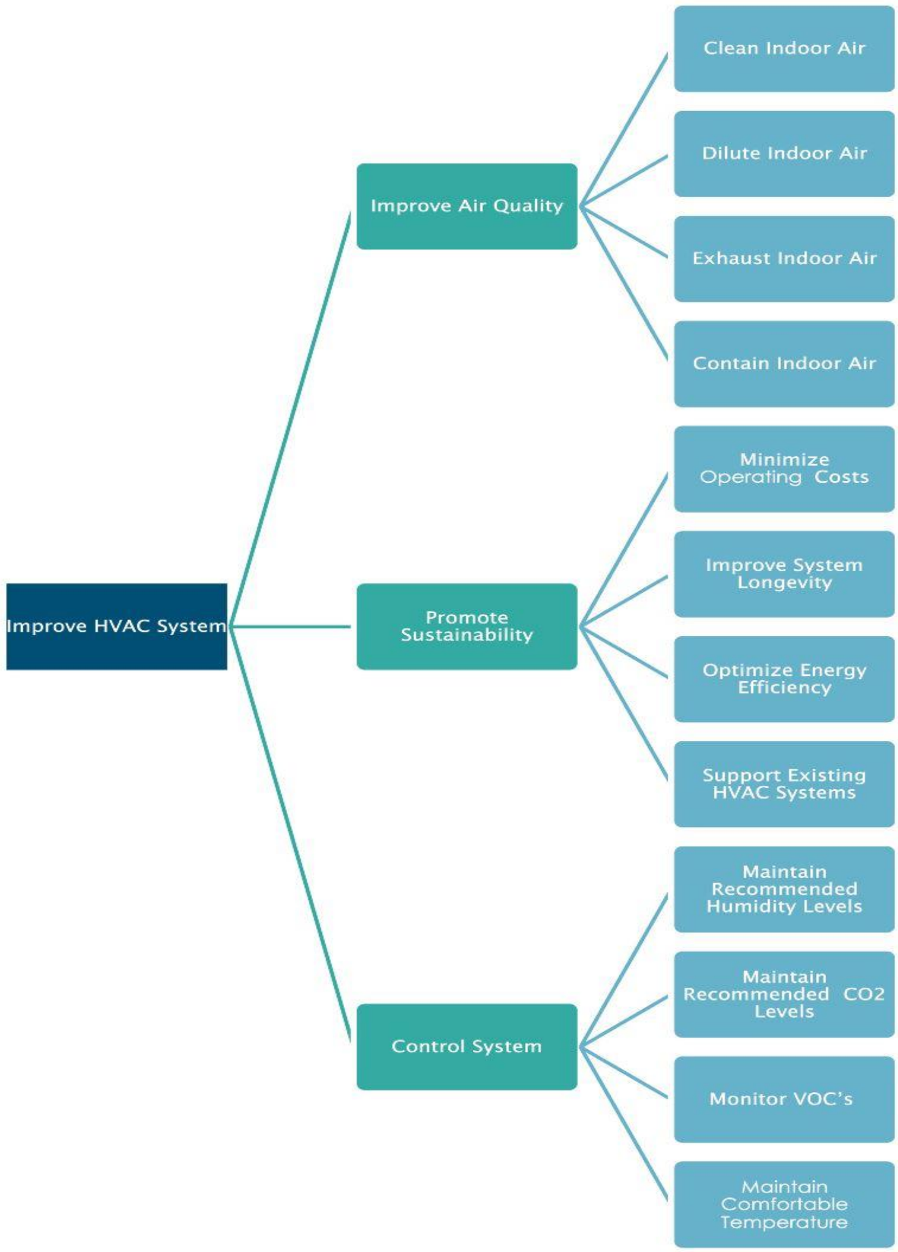
Appendix B: Functional Decomposition

Figure 1. Work Breakdown Structure

Milestone #:	Tasks:	Sub-Tasks:	Assigned to:
1	Project Scope		
		1.1 Project Description	Andi
		1.2 Key Goals	Nicholas
		1.3 Primary Market	Jake
		1.4 Secondary Market	Gavin
		1.5 Stakeholders	Joseph
		1.6 Assumptions	Jake
		1.7 Write Document	Nicholas
		1.8 Review Document	Joseph
		1.9 Submit Document	Joseph
2	Work Breakdown Structure		
		2.1 Tabulate Tasks in Descending Order	Jake
		2.2 Assign Each Task to a Resource	Gavin
		2.3 Write Document	Nicholas
		2.4 Review Document	Joseph
		2.5 Submit Document	Joseph
3	Customer Needs		
		3.1 Research HVAC system components	Jake
		3.2 Gather Customer Data	Nicholas
		3.3 Synthesize Customer Data	Andi
		3.4 Organize Customer Needs	Joseph
		3.5 Establish Relative Importance of Needs	Gavin
		3.6 Reflect on Results	Andi
		3.7 Write Document	Nicholas
		3.8 Review Document	Joseph
		3.9 Submit Document	Joseph
4	Functional Decomposition		
		4.1 Research Patents & Regulations on HVAC	Nicholas
		4.2 Describe Physical Action	Jake
		4.3 Describe Outcome	Gavin
		4.4 Break Down Project into Units	Andi
		4.5 Write Document	Andi
		4.6 Review Document	Joseph
		4.7 Submit Document	Joseph
5	Targets and Metrics		
		5.1 Perform Benchmarking on Existing Products	Jake
		5.2 Identify Product Requirements & Restraints	Andi
		5.3 Assign Metrics to be used in Validation	Gavin
		5.4 Assign Specific Targets to each Goal	Jake
		5.5 Write Document	Nicholas
		5.6 Review Document	Joseph
		5.7 Submit Document	Joseph
6	Virtual Design Review #1		
		6.1 Make Presentation	Jake
		6.2 Review Presentation	Andi

		6.3 Practice Presentation	Joseph
		6.4 Submit Presentation	Joseph
		6.5 Give Presentation	Joseph
7	**Concept Generation & Selection**		
		7.1 Set Meeting	Jake
		7.2 Generate Concepts	Andi
		7.3 Risk Assessment	Nicholas
		7.4 Narrow Down Concepts	Joseph
		7.5 Select Final Concept	Gavin
		7.6 Review Document	Joseph
		7.7 Submit Document	Joseph
8	**Virtual Design Review #2**		
		8.1 Make Presentation	Nicholas
		8.2 Review Presentation	Gavin
		8.3 Practice Presentation	Joseph
		8.4 Submit Presentation	Joseph
		8.5 Give Presentation	Joseph
9	**Virtual Design Review #3**		
		9.1 Make Presentation	Andi
		9.2 Review Presentation	Gavin
		9.3 Practice Presentation	Nicholas
		9.4 Submit Presentation	Joseph
		9.5 Give Presentation	Joseph
10	**Create Spring Project Plan**		
		10.1 Outline Objectives	Jake
		10.2 Create Timeline	Nicholas
		10.3 Assign Objectives to Team Members	Andi
		10.4 Review Document	Joseph
		10.5 Submit Document	Joseph
11	**Evidence Manual**		
		11.1 Abstract	Nicholas
		11.2 Disclaimer	Jake
		11.3 Appendices	Gavin
		11.4 Assemble Document	Andi
		11.5 Review Document	Joseph
		11.6 Submit Document	Joseph

Figure 2. Hierarchical Chart



Appendix C: Target Catalog

Table 1: Target Catalog Table

Function:	Target:	Metric:
Dilute Indoor Air	10	ACH
Contain Indoor Air	10	ACH
Exhaust Indoor Air	10	ACH
Clean Indoor Air	0.3	VOC Concentration (mg/m^3)
Maintain VOC Concentration	0.3	VOC Concentration (mg/m^3)
Control CO2 Concentration	1000	ppm CO2
Control Humidity Level	45-55	%Humidity
Control Temperature	24-26	°C
Minimize Operating Costs	120%	Current Costs (%)
Optimize Energy-Efficiency	115%	Current Usage (%)

Appendix D: Concept Generation

Concepts Generated:

Concept 1. Increase the ACH by increasing the speed of the induction fan motors to dilute the indoor air with more fresh outdoor air.

Concept 2. Install independent purification filters in the ductwork before the systems air reaches the occupied space, these can potentially be powered by energy recovery. (solar, geothermal, gym equipment, ect.)

Concept 3. Improve the current COVID alterations by utilizing existing vacancy sensors to also control fan speed for different degrees of air ventilation rate

Concept 4. Decrease energy usage by consistently cleaning heating/cooling coils.

Concept 5. Explore alternative refrigerant choice to minimize the use of ozone-depleting substances which will reduce carbon emissions and increase efficiency

Concept 6. Implementing indoor gardens to increase air quality

Concept 7. Place window exhaust units in buildings to remove contaminated air

Concept 8. Increase the use of open windows for natural ventilation

Concept 9. Have containers that capture and retain fresh air

Concept 10. Utilize bipolar ionization through HVAC mounted ionizers

Concept 11. Become robots that don't breathe air

Concept 12. Place portable air purifiers in classrooms

Concept 13. Direct plumbing underground to a depth with cooler temperatures to use less energy to cool fluids. (Geothermal Heating and Cooling)

Concept 14. Increase cleaning standards to remove dust and other pollutants from the buildings

Concept 15. Use excess energy from fitness centers to power UVC germicide filters within the ductwork

Concept 16. Run pipes under the Leach gym pool to be used as a heat exchanger

Concept 17. Start an indoor air quality health club at FSU

Concept 18. Open windows in classrooms to let in fresh air

Concept 19. Continue classes online to reduce student exposure

Concept 20. Enforce the Tobacco-Free Campus to include electronic vaporizers inside classrooms that emit harmful chemicals

Concept 21. Increase humidity and heat in classrooms as Covid-19 does not survive as well in these conditions.

Concept 22. Conduct classes outdoors

Concept 23. Wear hazmat suits in classrooms

Concept 24. Contact trace ill students and quarantine possible infected students

Concept 25. Temperature check every individual before coming into class

Concept 26. Upgrade filters from MERV 13 to either MERV (14-16) or HEPA and calculate the associated theoretical pressure drop and energy consumption.

Concept 27. Clean all existing HVAC equipment to remove mold and pollutants

Concept 28. Remove sources of pollutants at air intake locations

Concept 29. Implement Photo Hydro Ionization (PHI) as a purification technique to increase air quality and reduce ozone levels

Concept 30. Seal up leaks and deficiencies in existing buildings

Concept 31. Integrate a streamlined ductwork system to achieve a maximum indoor air ventilation rate

Concept 32. Examine food storage standards at FSU mess halls to avoid pollutant producing pests

Concept 33. Put fans in classrooms to lower temperatures while using less energy

Concept 34. Limit room capacity to reduce heat in rooms

Concept 35. Increase the radius of no-smoking zones around the campus buildings

Concept 36. Provide student and staff training on managing indoor air quality

Concept 37. Provide a PSA to surroundings residents on ways to improve IAQ within their homes and businesses

Concept 38. Increase MERV filter rating to 13+ while increasing the AHU's fan motor speed to accommodate 10 ACH depending on the state of the vacancy sensor

Concept 39. Substitute the fan blade material for a lighter one, decreasing the power necessary to turn the fan

Concept 40. Implement a strict filter cleaning regiment to ensure maximum system airflow

Concept 41. Replace surfaces on classroom objects with more sterile materials

Concept 42. Substitute paint and carpets that emit harmful VOC's into the occupied space with sterile materials

Concept 43. Introduce MERV filters at the room vent level for increased filtration

Concept 44. Hire a routine cleaning service to disinfect areas

Concept 45. Use activated charcoal in combination with HEPA grade filters to diminish system contaminants

Concept 46. Use integrated solar panels to power auxiliary devices for the system to reduce the load on primary components (coils, fans)

Concept 47. Use the desiccant wheel to improve system efficiency

Concept 48. Use light fan blades to increase energy efficiency (concept 39)

Concept 49. Replace outdated fan drives with variable frequency drives to ensure accurate fan speed for different ventilation rate requirements

Concept 50. Exhaust hotspots like restrooms continuously

Concept 51. Implement the Trane Catalytic Air Cleaning System (TCACS) to utilize a combination of air cleaning technologies

Concept 52. Add thermal diffusers to rooms to utilize the benefits of VAV systems without the cost

Concept 53. Consider running the HVAC system at maximum outside airflow for 2 hours before and after spaces are occupied, in accordance with manufactory recommendations.

Concept 54. Disable Demand-Control Ventilation (DCV) to keep outdoor airflow at design occupancy levels and ultimately improve dilution

Concept 55. Coat key surfaces with antimicrobial soil-resistant (AMSR) coating to reduce bacteria, mold, and rust from forming

Concept 56. Introduce CO_2 air scrubbers into places with high traffic and low air exchange rate.

Concept 57. Substitute V belts with direct couplers from the electric motor to the fans to reduce particulate debris accumulation within the system

Concept 58. Integrate WiFi/Bluetooth occupancy sensors to control the systems ventilation rate

Concept 59. Implement a filter replacement/check maintenance program to periodically ensure that there is a clean filter that properly fits each air handler

Concept 60. Upgrade the CO_2 sensors in the Dirac library to accurately record higher CO_2 concentrations (2000+ ppm) and couple it with the system

Concept 61. Add a carbon capture chamber into the HVAC system using solid amine sorbents

Concept 62. Add more windows in the Dirac library and utilize natural ventilation when permittable

Concept 63. Perform thorough duct inspection to mitigate mold growth and check for system leaks

Concept 64. Install the Internet of Things (IoT) systems in critical buildings to increase preventative maintenance by sensing data on air quality and equipment status

Concept 65. Add or improve upon insulation to existing HVAC ducts to better trap energy within the airflow to maintain temperature and humidity levels.

Concept 66. Research alternative refrigerants and expansion devices to remain sustainable after the inevitable R22 ban

Concept 67. Implement an artificial intelligence controller to vary HVAC demand based on building parameters and pedestrian traffic

Concept 68. Synchronize class schedules to minimize output times for the HVAC system.

Concept 69. Implement higher quality air filters

Concept 70. Implement a central dehumidification system in older buildings that are prone to mold growth.

Concept 71. Ensure all vents are not obstructed by furniture or equipment to maintain the maximum flow rate.

Concept 72. Periodically hire an indoor air quality specialist to evaluate the air.

Concept 73. Develop a thorough maintenance schedule to perform preventative maintenance before issues arise.

Concept 74. Limit building occupancy to a minimum.

Concept 75. Use only Trane products, because they are superior in quality

Concept 76. Place shoe cleaning mats at entrances to prevent dirt and pollutants from being deposited deeper inside the building.

Concept 77. Place activated charcoal bags at locations with poor air quality.

Concept 78. Reduce the use of harmful pesticides around campus. The chemicals release VOCs that can travel into the HVAC system

Concept 79. Use a stand-alone ductless system in highly contaminated areas in conjunction with the existing fixed duct system

Concept 80. Implement antimicrobial coated duct lining to inhibit mold growth within the ductwork and to make duct cleaning more feasible

Concept 81. Utilize AirNow's Air Quality Flag Program to inform the public the EPA's AQI and coordinate personnel activities accordingly

Concept 82. Implement a secondary natural ventilation system driven by either buoyancy or wind

Concept 83. Replace existing heat pumps with electrocaloric cooling alternatives. Reduces greenhouse gas emissions from the system.

Concept 84. Renovate buildings with building-integrated heat and moisture exchangers built into walls. This system will work in conjunction with the HVAC system to condition the indoor air

Concept 85. Perform routine checks on the chiller system piping to ensure no working fluid is leaking IAQ concerns associated with water chillers involve the potential release of the working fluids from the chiller system

Concept 86. Use Vaporized Hydrogen Peroxide (H2O2) to fill a space to disinfect the air and surfaces while the building is unoccupied

Concept 87. Implement needle-point bipolar ionization to improve air quality

Concept 88. Use Duct Sealing to Avoid Duct Leakage to save energy

Concept 89. Utilize thermal energy from the Sun to power auxiliary portable air purifiers throughout FSU's campus

Concept 90. Continue the mask requirements

Concept 91. Implement Photocatalytic Oxidation (PCO) as a filtration technology

Concept 92. Ice powered air conditioning

Concept 93. Add cryogenic heat exchangers to improve efficiency

Concept 94. Focus on teaching horticulture within the college of engineering to grow plants to clean the air.

Concept 95. Supply each student with an oxygen tank

Concept 96. Harness heat from the computer lab

Concept 97. Open a floriculture college

Concept 98. Store all VOC outgassing materials and substances outside

Concept 99. Irradiate the air in the air handler to kill viruses.

Concept 100. Remove all carpeting from all buildings.

Appendix E: Concept Selection

Legend	
1	Antimicrobial Coating
2	PHI
3	PCO
4	ACH
5	IoT
6	Geothermal
7	Filters
8	Ionization

Table 1E. Concept Legend

House of Quality						
Engineering Characteristics						
Improvement Direction		↓	↓	↑	↓	↓
Units		kg	kW	m^3/s	ppm	USD
Customer Requirements	Importance Weight Factor	Mass	Energy Consumption	Flow Rate	Contaminant Concentration	Installation cost
1. Air Quality	**4**		3	9	9	
2. Longevity	**1**			9	9	
3. Energy Efficiency	**2**		9	3		
4. Total Cost	**1**					9
5. Retrofit	**2**	3				9
Raw Score	**159**	6	30	51	45	27
Relative Weight %		0.038	0.189	0.321	0.283	0.170
Rank Order		5	3	1	2	4

Table 2E. House of Quality

Binary Pairwise Comparison						
	1	**2**	**3**	**4**	**5**	**Total**
1. Air Quality	-	1	1	1	1	4
2. Longevity	0	-	0	1	0	1
3. Energy Efficiency	0	1	-	1	0	2
4. Total Cost	0	0	0	-	1	1
5. Retrofit	0	1	1	0	-	2
Total	0	3	2	4	1	10

Table 3E. Binary Pairwise Comparison

Pairwise Comparison						
	1	**2**	**3**	**4**	**5**	**Total**
1. Air Quality	1	9	5	9	7	31.0
2. Longevity	0.111	1	0.333	5	0.143	6.59
3. Energy Efficiency	0.200	3	1	5	0.143	9.34
4. Total Cost	0.111	0.20	0.200	1	3.000	4.51
5. Retrofit	0.143	7.00	7	0.333	1	15.5
Total	1.57	20.2	13.5	20.3	11.3	

Table 4E. Pairwise Comparison

Pairwise Comparison - Normalized						
	1	2	3	4	5	Criteria Weight
1. Air Quality	0.639	0.446	0.369	0.443	0.620	0.503
2. Longevity	0.071	0.050	0.025	0.246	0.013	0.081
3. Energy Efficiency	0.128	0.149	0.074	0.246	0.013	0.122
4. Total Cost	0.071	0.010	0.015	0.049	0.266	0.082
5. Retrofit	0.091	0.347	0.517	0.016	0.089	0.212
Total	1	1	1	1	1	1

Table 5E. Normalize Pairwise Comparison

Pugh Matrix - 1									
		Concepts							
Engineering Characteristics		1	2	3	4	5	6	7	8
Mass	Datum	+	+	+	+	+	-	S	+
Energy Consumption		+	+	+	-	+	+	+	+
Flow Rate		-	-	-	+	-	+	-	-
Contaminant Concentration		+	+	+	+	+	+	+	+
Installation cost		+	-	-	+	+	-	+	+
# of pluses		4	3	3	4	4	3	3	4
# of minuses		1	2	2	1	1	2	1	1

Table 6E. Pugh Matrix 1

Pugh Matrix - 2					
		Concepts			
Engineering Characteristics		1	4	5	8
Mass	Datum Concept 2	+	+	+	+
Energy Consumption		+	-	+	+
Flow Rate		-	+	+	+
Contaminant Concentration		+	+	+	+
Installation cost		+	+	-	+
# of pluses		4	4	4	5
# of minuses		1	1	1	0

Table 7E. Pugh Matrix 2

Appendix F: MATLAB Code

Table of Contents

Test 1 – VOC Concentration

```
Date: B136 3/20/21
Time: 12PM-6PM
Location: B136
```

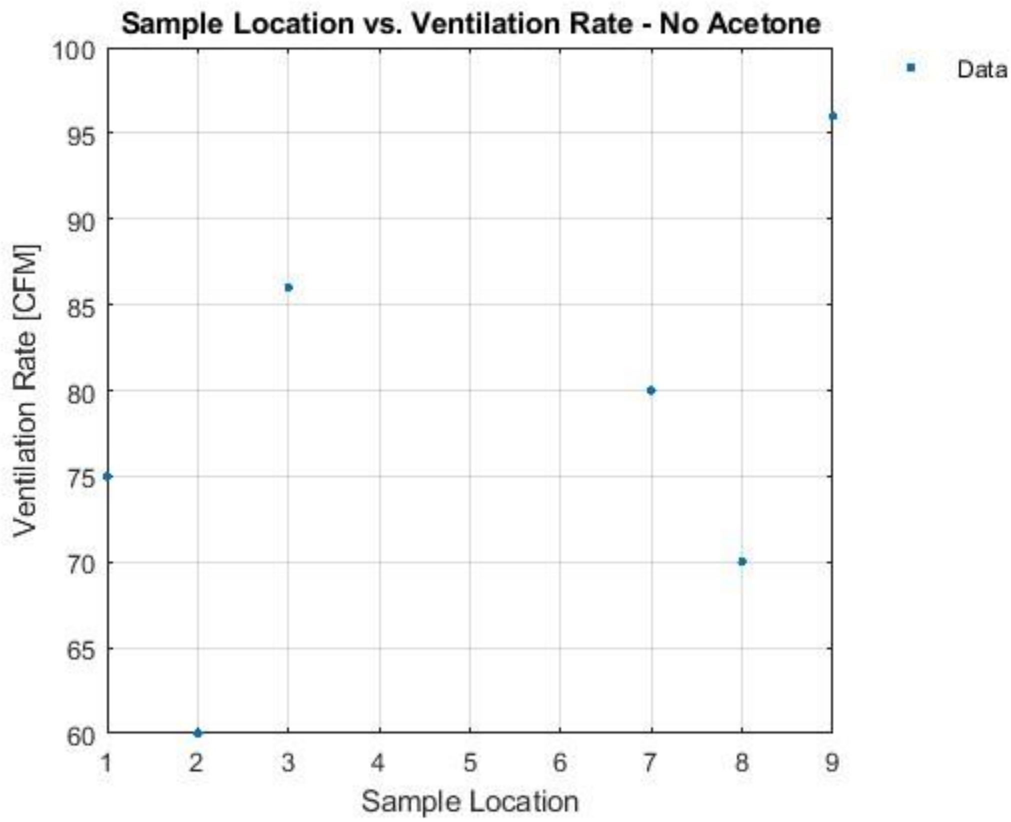
```
%clc %clear
all format
compact
```

Control Group (No Acetone)

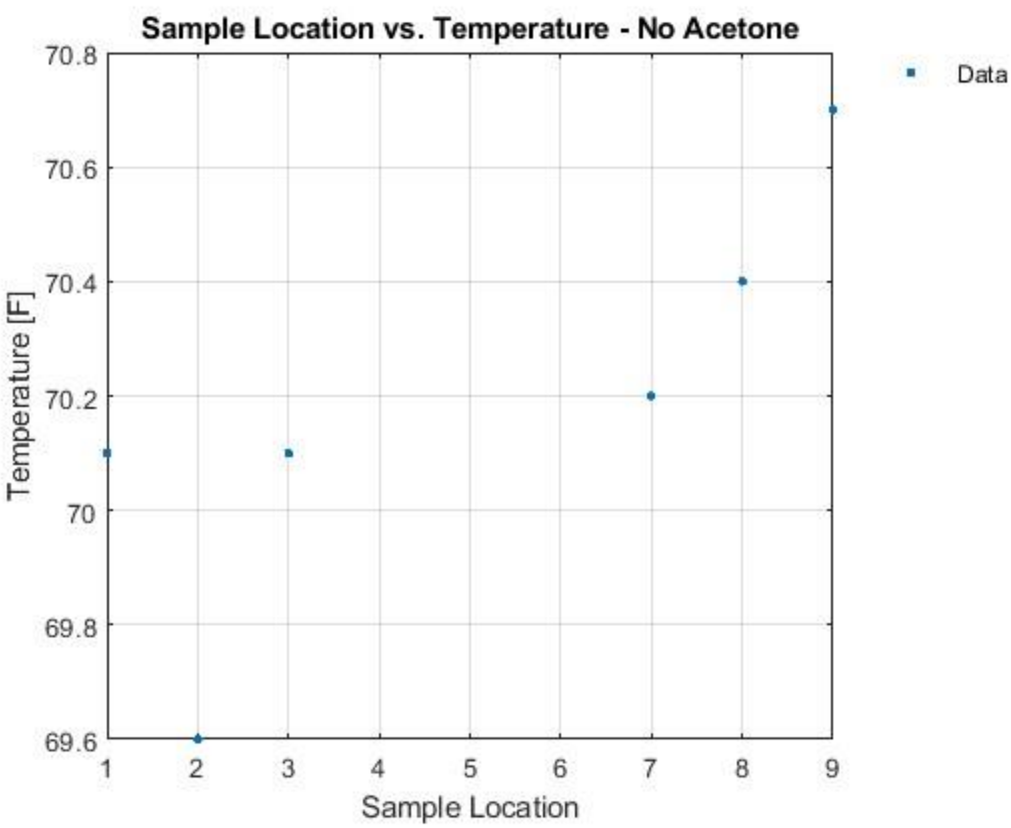
Ventilation Rate [CFM]

```
location1 = [1 2 3 7 8 9]; location2 = [1:9]; vent_data =
table2array(control([1:3,7:9],3))% Importing data from  excel
spreadsheet avg_vent = mean(vent_data)

% Temperature [F] temp_data = table2array(control([1:3,7:9],5))%
Importing data from  excel spreadsheet temp_data1 = [70.1 69.6
70.1 70.2 70.4 70.7]; avg_temp = mean(temp_data1)

% VOC [ppb] VOC_data = table2array(control(17:25,3)) % Importing
data from excel  spreadsheet

avg_VOC = mean(VOC_data) TWA_VOC = 0; peak_VOC =
table2array(control(17,6)) % Importing data from excel
spreadsheet
```

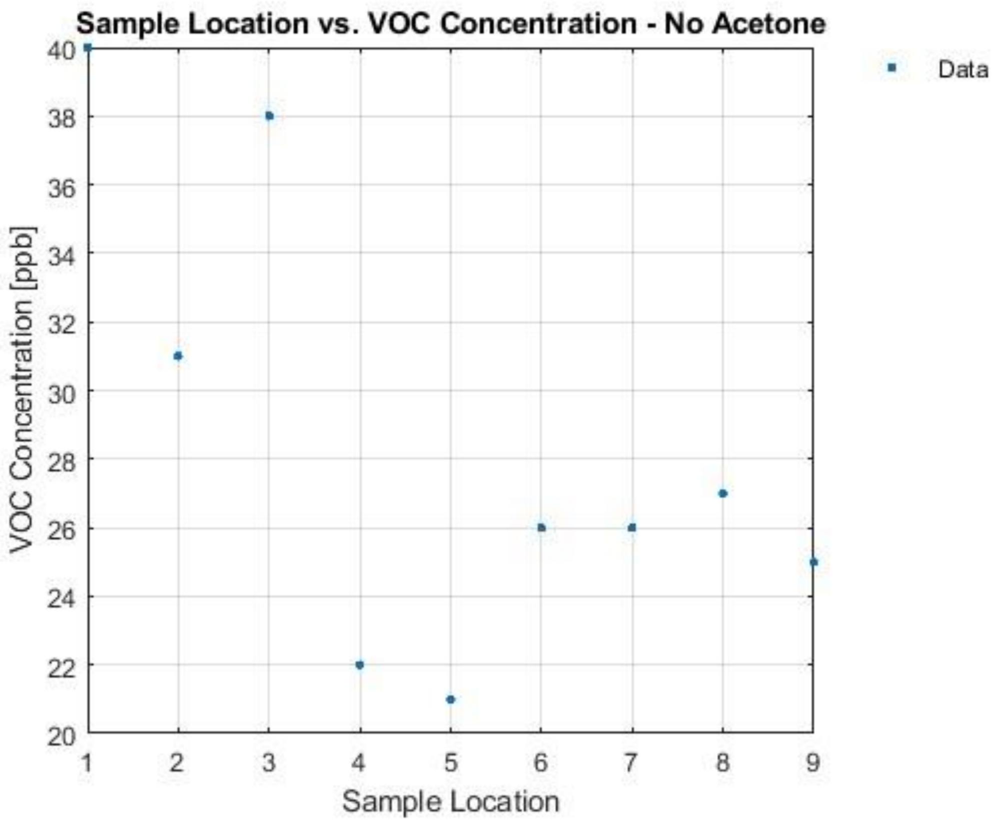
```
figure() plot(location1,vent_data,'.','MarkerSize',8)
grid on xlabel('Sample Location') ylabel('Ventilation
Rate [CFM]') title('Sample Location vs. Ventilation Rate
- No Acetone')
legend('Data','Mean','Location','bestoutside')

figure()
plot(location1,temp_data1,'.','MarkerSize',8) grid
on xlabel('Sample Location') ylabel('Temperature
[F]') title('Sample Location vs. Temperature - No
Acetone')
legend('Data','Mean','Location','bestoutside')

figure() plot(location2,VOC_data,'.','MarkerSize',8) grid
on xlabel('Sample Location') ylabel('VOC Concentration
[ppb]') title('Sample Location vs. VOC Concentration - No
Acetone') legend('Data','Mean','Location','bestoutside')

vent_data =
75
    60
    86
    80
70      96 avg_vent =
77.8333 temp_data =
6×1 categorical array
     70.1
     69.6
     70.1
     70.2
     70.4
     70.7
avg_temp =
70.1833
VOC_data =
    40
    31
    38
    22
    21
    26
    26
    27      25 avg_VOC =    28.4444
peak_VOC =      55 Warning: Ignoring
extra legend entries.
Warning: Ignoring extra legend entries.
Warning: Ignoring extra legend entries.
```



Sample Location vs. Ventilation Rate - No Acetone
Data
Ventilation Rate [CFM]
100
95
90
85
80
75
70
65
60
1 2 3 4 5 6 7 8 9
Sample Location



Sample Location vs. Temperature - No Acetone
Data
Temperature [F]
70.8
70.6
70.4
70.2
70
69.8
69.6
1 2 3 4 5 6 7 8 9
Sample Location



Control Group (with Acetone)

```
time = [0:15:180];

% Sample point 1 %
Ventilation Rate [CFM]


vent_data1 = table2array(Test1day1([1:3,7:9],3))% Importing data
from  excel spreadsheet avg_vent1 = mean(vent_data1)


% Temperature [F] temp_data1 = table2array(Test1day1([1:3,7:9],5))%
Importing data from  excel spreadsheet avg_temp1 = mean(temp_data1)

% VOC [ppm] VOC_data1 = table2array(Test1day1(122:130,3)) %
Importing data from  excel spreadsheet

avg_VOC1 = mean(VOC_data1)
TWA_VOC1 = table2array(Test1day1(122,4))
```

```
peak_VOC1 = table2array(Test1day1(122,6)) % Importing data from
excel  spreadsheet

% Sample point 2 %
Ventilation Rate [CFM]


vent_data2 = table2array(Test1day1([10:12,16:18],3))% Importing
data  from excel spreadsheet avg_vent2 = mean(vent_data2)


% Temperature [F] temp_data2 =
table2array(Test1day1([10:12,16:18],5))% Importing data  from excel
spreadsheet avg_temp2 = mean(temp_data2)

% VOC [ppm] VOC_data2 = table2array(Test1day1(131:139,3)) %
Importing data from  excel spreadsheet

avg_VOC2 = mean(VOC_data2) TWA_VOC2 = table2array(Test1day1(131,4))
peak_VOC2 = table2array(Test1day1(131,6)) % Importing data from
excel  spreadsheet


% Sample point 3 %
Ventilation Rate [CFM]


vent_data3 = table2array(Test1day1([19:21,25:27],3))% Importing
data  from excel spreadsheet avg_vent3 = mean(vent_data3)


% Temperature [F] temp_data3 =
table2array(Test1day1([19:21,25:27],5))% Importing data  from excel
spreadsheet avg_temp3 = mean(temp_data3)

% VOC [ppm] VOC_data3 = table2array(Test1day1(140:148,3)) %
Importing data from  excel spreadsheet

avg_VOC3 = mean(VOC_data3) TWA_VOC3 = table2array(Test1day1(140,4))
peak_VOC3 = table2array(Test1day1(140,6)) % Importing data from
excel  spreadsheet


% Sample point 4
% Ventilation Rate
[CFM]

vent_data4 = table2array(Test1day1([28:30,34:36],3))% Importing
data  from excel spreadsheet avg_vent4 = mean(vent_data4)
```

```
% Temperature [F] temp_data4 =
table2array(Test1day1([28:30,34:36],5))% Importing data  from excel
spreadsheet avg_temp4 = mean(temp_data4)

% VOC [ppm] VOC_data4 = table2array(Test1day1(149:157,3)) %
Importing data from  excel spreadsheet

avg_VOC4 = mean(VOC_data4) TWA_VOC4 = table2array(Test1day1(149,4))
peak_VOC4 = table2array(Test1day1(149,6)) % Importing data from
excel  spreadsheet

% Sample point 5 %
Ventilation Rate [CFM]


vent_data5 = table2array(Test1day1([37:39,43:45],3))% Importing
data  from excel spreadsheet avg_vent5 = mean(vent_data5)


% Temperature [F] temp_data5 =
table2array(Test1day1([37:39,43:45],5))% Importing data  from excel
spreadsheet avg_temp5 = mean(temp_data5)

% VOC [ppm] VOC_data5 = table2array(Test1day1(158:166,3)) %
Importing data from  excel spreadsheet

avg_VOC5 = mean(VOC_data5) TWA_VOC5 = table2array(Test1day1(158,4))
peak_VOC5 = table2array(Test1day1(158,6)) % Importing data from
excel  spreadsheet

% Sample point 6 %
Ventilation Rate [CFM]


vent_data6 = table2array(Test1day1([46:48,52:54],3))% Importing
data  from excel spreadsheet avg_vent6 = mean(vent_data6)


% Temperature [F]

temp_data6 = table2array(Test1day1([46:48,52:54],5))% Importing
data  from excel spreadsheet avg_temp6 = mean(temp_data6)

% VOC [ppm] VOC_data6 = table2array(Test1day1(167:175,3)) %
Importing data from  excel spreadsheet

avg_VOC6 = mean(VOC_data6) TWA_VOC6 = table2array(Test1day1(167,4))
peak_VOC6 = table2array(Test1day1(167,6)) % Importing data from
excel  spreadsheet
```

```
% Sample point 7 %
Ventilation Rate [CFM]


vent_data7 = table2array(Test1day1([55:57,61:63],3))% Importing
data  from excel spreadsheet avg_vent7 = mean(vent_data7)


% Temperature [F] temp_data7 =
table2array(Test1day1([55:57,61:63],5))% Importing data  from excel
spreadsheet avg_temp7 = mean(temp_data7)

% VOC [ppm] VOC_data7 = table2array(Test1day1(176:184,3)) %
Importing data from  excel spreadsheet

avg_VOC7 = mean(VOC_data7) TWA_VOC7 = table2array(Test1day1(176,4))
peak_VOC7 = table2array(Test1day1(176,6)) % Importing data from
excel  spreadsheet


% Sample point 8 %
Ventilation Rate [CFM]


vent_data8 = table2array(Test1day1([64:66,70:72],3))% Importing
data  from excel spreadsheet avg_vent8 = mean(vent_data8)


% Temperature [F] temp_data8 =
table2array(Test1day1([64:66,70:72],5))% Importing data  from excel
spreadsheet avg_temp8 = mean(temp_data8)

% VOC [ppm]

VOC_data8 = table2array(Test1day1(185:193,3)) % Importing data from
excel spreadsheet

avg_VOC8 = mean(VOC_data8) TWA_VOC8 = table2array(Test1day1(185,4))
peak_VOC8 = table2array(Test1day1(185,6)) % Importing data from
excel  spreadsheet



% Sample point 9 %
Ventilation Rate [CFM]


vent_data9 = table2array(Test1day1([73:75,79:81],3))% Importing
data  from excel spreadsheet avg_vent9 = mean(vent_data9)
```

```
% Temperature [F] temp_data9 =
table2array(Test1day1([73:75,79:81],5))% Importing data  from excel
spreadsheet avg_temp9 = mean(temp_data9)

% VOC [ppm] VOC_data9 = table2array(Test1day1(194:202,3)) %
Importing data from  excel spreadsheet

avg_VOC9 = mean(VOC_data9) TWA_VOC9 = table2array(Test1day1(194,4))
peak_VOC9 = table2array(Test1day1(194,6)) % Importing data from
excel  spreadsheet


% Sample point 10 %
Ventilation Rate [CFM]


vent_data10 = table2array(Test1day1([82:84,88:90],3))% Importing
data  from excel spreadsheet avg_vent10 = mean(vent_data10)


% Temperature [F] temp_data10 =
table2array(Test1day1([82:84,88:90],5))% Importing data  from excel
spreadsheet avg_temp10 = mean(temp_data10)

% VOC [ppm] VOC_data10 = table2array(Test1day1(203:211,3)) %
Importing data from  excel spreadsheet

avg_VOC10 = mean(VOC_data10)
TWA_VOC10 = table2array(Test1day1(203,4))

peak_VOC10 = table2array(Test1day1(203,6)) % Importing data from excel
spreadsheet


% Sample point 11 %
Ventilation Rate [CFM]


vent_data11 = table2array(Test1day1([91:93,97:99],3))% Importing
data  from excel spreadsheet avg_vent11 = mean(vent_data11)


% Temperature [F] temp_data11 =
table2array(Test1day1([91:93,97:99],5))% Importing data  from excel
spreadsheet avg_temp11 = mean(temp_data11)

% VOC [ppm] VOC_data11 = table2array(Test1day1(212:220,3)) %
Importing data from  excel spreadsheet
```

```
avg_VOC11 = mean(VOC_data11) TWA_VOC11 =
table2array(Test1day1(212,4)) peak_VOC11 =
table2array(Test1day1(212,6)) % Importing data from excel
spreadsheet


% Sample point 12 %
Ventilation Rate [CFM]


vent_data12 = table2array(Test1day1([100:102,106:108],3))%
Importing  data from excel spreadsheet avg_vent12 =
mean(vent_data12)


% Temperature [F]
temp_data12 = table2array(Test1day1([100:102,106:108],5))%
Importing  data from excel spreadsheet avg_temp12 =
mean(temp_data12)

% VOC [ppm] VOC_data12 = table2array(Test1day1(221:229,3)) %
Importing data from  excel spreadsheet

avg_VOC12 = mean(VOC_data12) TWA_VOC12 =
table2array(Test1day1(221,4)) peak_VOC12 =
table2array(Test1day1(221,6)) % Importing data from excel
spreadsheet


% Sample point 13
% Ventilation Rate
[CFM]

vent_data13 = table2array(Test1day1([109:111,115:117],3))%
Importing  data from excel spreadsheet avg_vent13 =
mean(vent_data13)


% Temperature [F] temp_data13 =
table2array(Test1day1([109:111,115:117],5))% Importing  data from
excel spreadsheet avg_temp13 = mean(temp_data13)

% VOC [ppm] VOC_data13 = table2array(Test1day1(230:238,3)) %
Importing data from  excel spreadsheet

avg_VOC13 = mean(VOC_data13) TWA_VOC13 =
table2array(Test1day1(230,4)) peak_VOC13 =
table2array(Test1day1(230,6)) % Importing data from excel
spreadsheet
```

```
% Final Data - Control

avg_ventfinal = [avg_vent1 avg_vent2 avg_vent3 avg_vent4 avg_vent5
avg_vent6 avg_vent7 avg_vent8 avg_vent9 avg_vent10 avg_vent11
avg_vent12 avg_vent13]

avg_tempfinal = [avg_temp1 avg_temp2 avg_temp3 avg_temp4 avg_temp5
avg_temp6 avg_temp7 avg_temp8 avg_temp9 avg_temp10 avg_temp11
avg_temp12 avg_temp13]

avg_VOCfinal = [avg_VOC1 avg_VOC2 avg_VOC3 avg_VOC4 avg_VOC5
avg_VOC6  avg_VOC7 avg_VOC8 avg_VOC9 avg_VOC10 avg_VOC11 avg_VOC12
avg_VOC13] TWA_VOCfinal = [TWA_VOC1 TWA_VOC2 TWA_VOC3 TWA_VOC4
TWA_VOC5 TWA_VOC6  TWA_VOC7 TWA_VOC8 TWA_VOC9 TWA_VOC10 TWA_VOC11
TWA_VOC12 TWA_VOC13] peak_VOCfinal = [peak_VOC1 peak_VOC2 peak_VOC3
peak_VOC4 peak_VOC5  peak_VOC6 peak_VOC7 peak_VOC8 peak_VOC9
peak_VOC10 peak_VOC11  peak_VOC12 peak_VOC13]

figure() plot(time,avg_ventfinal) grid on
xlabel('Time [min]') ylabel('Average Ventilation
Rate [CFM]') title('Average Ventilation Rate vs.
Time - Control')

figure() plot(time,avg_tempfinal) grid on
xlabel('Time [min]') ylabel('Average
Temperature [F]') title('Average Temperature
vs. Time - Control') figure()
plot(time,avg_VOCfinal) grid on xlabel('Time
[min]') ylabel('Average VOC Concentration
[ppm]') title('Average VOC Concentration vs.
Time - Control')

      figure()
plot(time,TWA_VOCfinal)   grid   on
xlabel('Time   [min]')   ylabel('TWA
[ppb]')  title('TWA  VOC  vs.  Time  -
Control')

figure() plot(time,peak_VOCfinal) grid on
xlabel('Time [min]') ylabel('Peak VOC
Concentration  [ppm]') title('Peak VOC
Concentration vs. Time - Control')

vent_data1 =
79
    55
    55
    72
69      95
avg_vent1 =
```

```
70.8333
temp_data1
=
70.1000
   69.8000
   69.7000
   69.8000
   70.0000
   70.2000
avg_temp1 =
69.9333
VOC_data1 =
   41.6000
   69.2400
   51.4100
   63.3900
   65.9800
   59.5000
   51.4400
   67.5500
   57.2800
avg_VOC1 =
58.5989
TWA_VOC1 =
342
peak_VOC1 =
106.4000
vent_data2 =
79
    59
    88
    75
70      96
avg_vent2 =
77.8333
temp_data2
=
70.7000
   70.9000
   71.1000
   71.2000
   71.4000
   71.6000
avg_temp2 =
71.1500
VOC_data2 =
   69.9200
   61.4200
   57.7000
```

```
   75.6700
   67.5900
   73.9200
   53.8100
   59.1500
   50.6900
avg_VOC2 =
   63.3189
TWA_VOC2 =
227
peak_VOC2 =
83.7800
vent_data3 =
80
    59
    88
    80
    67
96
avg_vent3 =
78.3333
temp_data3
=
70.4000
   70.2000
   70.0000
   69.8000
   69.7000
   69.3000
avg_temp3 =
69.9000
VOC_data3 =
   72.7000
   75.0900
   73.1100
   93.5300
   91.7300
   75.3500
   77.2400
   73.0100
   69.2300
avg_VOC3 =
   77.8878
TWA_VOC3 =
274
peak_VOC3 =
117.7000
vent_data4 =
84
```

```
    60
    88
    80
      67
97
avg_vent4 =
79.3333
temp_data4
=
68.8000
   68.8000
   68.8000
   68.4000
   68.4000
   67.8000
avg_temp4 =
68.5000
VOC_data4 =
   71.5000
   86.1100
   75.8700
   82.5000
   92.8500
  101.0000
   79.4100
   92.6100
   83.8800
avg_VOC4 =
   85.0811
TWA_VOC4 =
109
peak_VOC4 =
108.1000
vent_data5 =
78
    55
    85
    79
    64
92
avg_vent5 =
75.5000
temp_data5
=
69.2000
   69.1000
   69.2000
   69.4000
   69.9000
```

```
   70.2000
avg_temp5 =
69.5000
VOC_data5 =
   85.0000
   92.3000
   95.9600
   97.5000
   97.9300
   97.9900
   94.9200
   88.9700
   88.6200
avg_VOC5 =
   93.2433
TWA_VOC5 =
314
peak_VOC5 =
123.5000
vent_data6 =
77
    56
    86
    81
      71
99
avg_vent6 =
78.3333
temp_data6
=
71.3000
   71.5000
   71.5000
   71.4000
   71.3000
   71.1000
avg_temp6 =
71.3500
VOC_data6 =
  109.3000
   97.9600
   74.0100
   78.6700
   83.5900
   82.0200
   77.0000
   80.4900
```

```
   88.7700
avg_VOC6 =
   85.7567
TWA_VOC6 =
272
peak_VOC6 =
109.3000
vent_data7 =
76
    60
    88
    84
      71
97
avg_vent7 =
79.3333
temp_data7
=
70.7000
   70.5000
   70.1000
   70.0000
   69.7000
   69.3000
avg_temp7 =
70.0500
VOC_data7 =
   72.3800
   90.1300
   86.5300
  110.7000
  114.3000
  115.3000
   88.4700
   90.3000
   79.9900
avg_VOC7 =
   94.2333
TWA_VOC7 =
114
peak_VOC7 =
125.6000
vent_data8 =
79
    61
    87
    80
      72
90
```

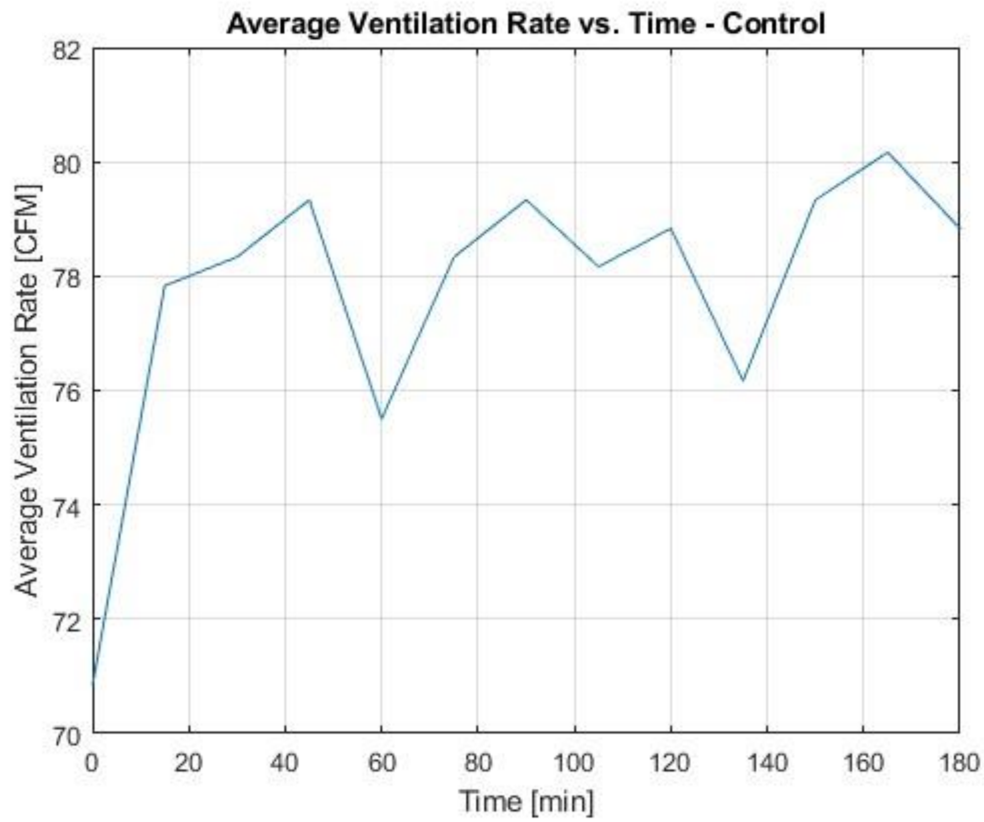
```
avg_vent8 =
78.1667
temp_data8
=
69.7000
   69.5000
   68.4000
   68.7000
   68.6000
   68.2000
avg_temp8 =
68.8500
VOC_data8 =
   98.3000
   95.4000
   85.3000
   99.7900
  101.4000
   88.3200
  109.5000
  105.5000
  109.0000
avg_VOC8 =
   99.1678
TWA_VOC8 =
324
peak_VOC8 =
196.9000
vent_data9 =
83
    60
    85
    80
    69
96
avg_vent9 =
78.8333
temp_data9
=
68.8000
   69.0000
   68.7000
   69.0000
   69.0000
   68.9000
avg_temp9 =
68.9000
VOC_data9 =
   76.3300
```

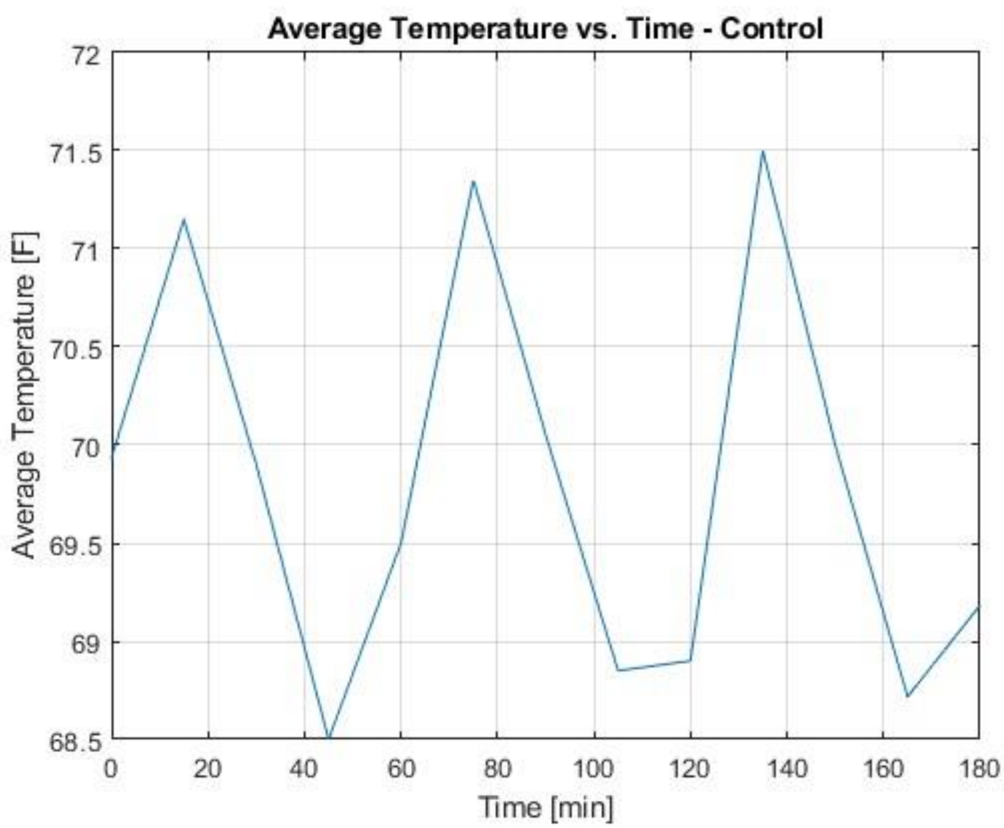
```
   88.6700
   83.4700
   98.6600
  114.7000
   97.2600
   96.6200
  117.3000
  100.0000
avg_VOC9 =
   97.0011
TWA_VOC9 =
553
peak_VOC9 =
141.4000
vent_data10
=     80
    57
    80
    78
    68
94
avg_vent10 =
76.1667
temp_data10
=    70.8000
   70.9000
   71.5000
   71.9000
   71.8000
   72.1000
avg_temp10 =
71.5000
VOC_data10 =
   67.9800
  109.2000
  127.0000
  108.2000
  134.6000
   99.2500
  101.3000
  136.6000
109.2000
avg_VOC10 =
110.3700
TWA_VOC10 =
751
peak_VOC10 =
200.3000
```

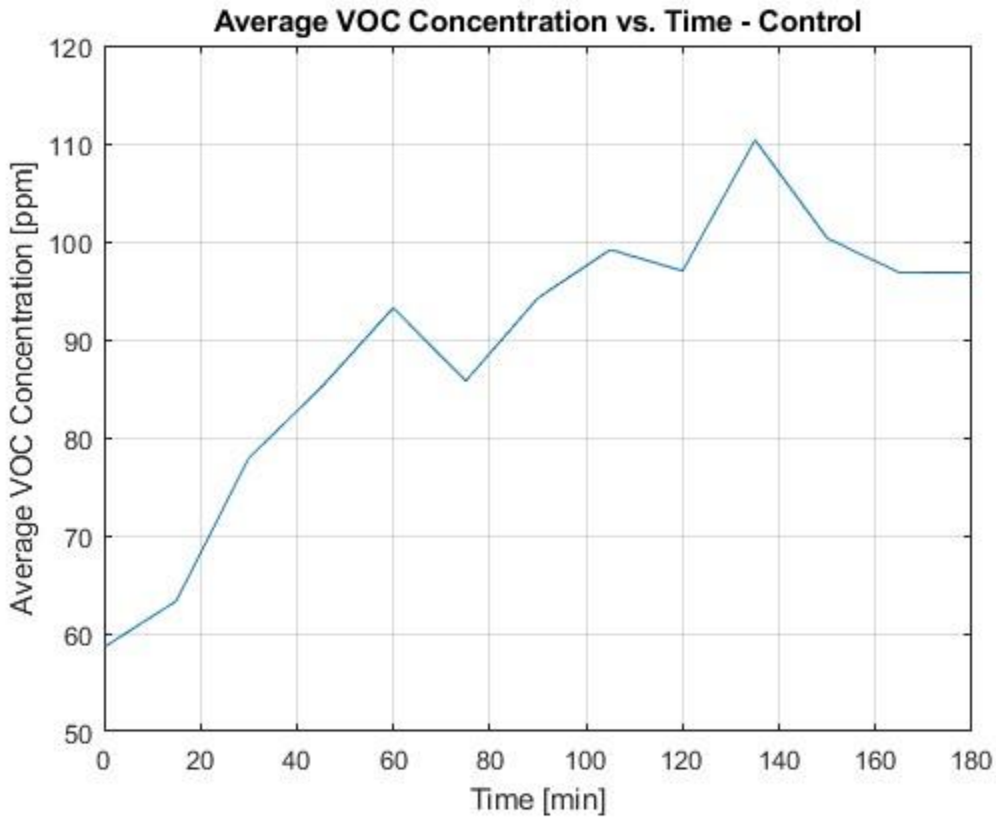
```
vent_data11
=      79
    58
    88
    83
    71
97
avg_vent11 =
79.3333
temp_data11
=     70.5000
   70.6000
   70.2000
   69.9000
   69.6000
   69.2000
avg_temp11 =
   70.0000
VOC_data11 =
  109.8000
  113.6000
   92.7000
  111.4000
  106.0000
   87.8000
   80.7900
   99.6600
  101.2000
avg_VOC11 =
100.3278
TWA_VOC11 =
312
peak_VOC11 =
121.7000
vent_data12
=      77
    63
    90
    81
    71
99
avg_vent12 =
80.1667
temp_data12
=     69.5000
   69.2000
   68.6000
   68.7000
   68.3000
```

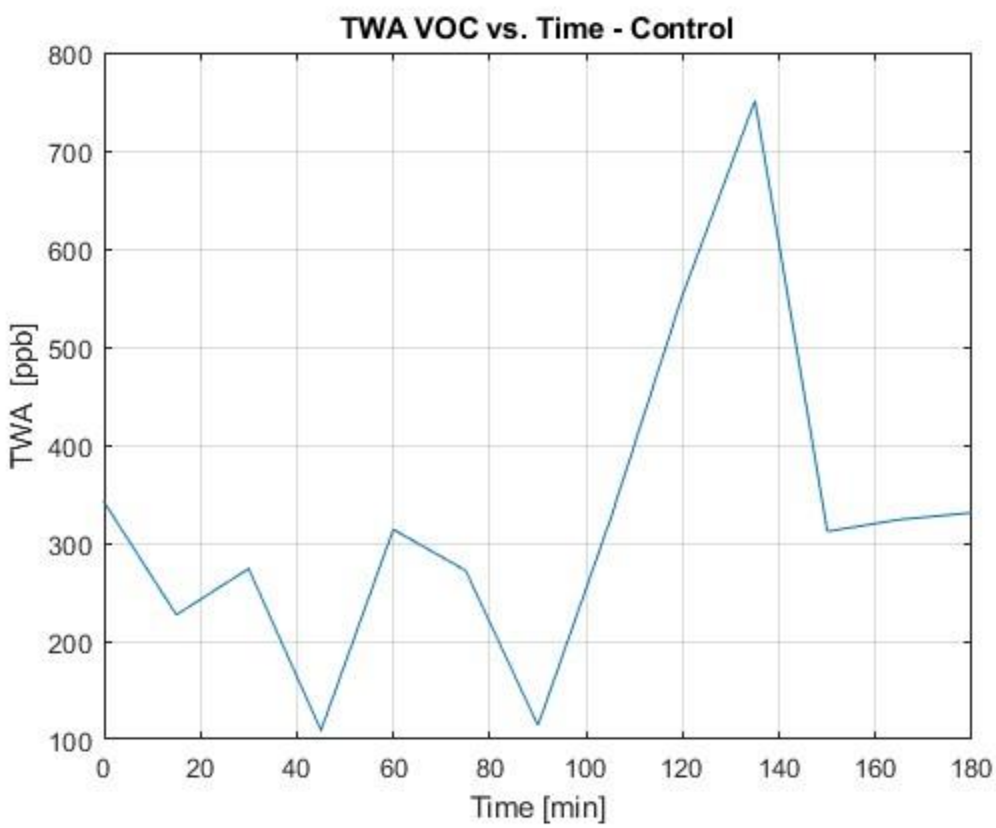
```
   68.0000
avg_temp12 =
68.7167
VOC_data12 =
   80.5400
   84.9000
  108.9000
   93.9000
  119.5000
   96.2500
   91.8800
  101.7000
93.7100
avg_VOC12 =
96.8089
TWA_VOC12 =
324
peak_VOC12 =
141.5000
vent_data13
=     77
    60
    88
    82
    71
95
avg_vent13 =
78.8333
temp_data13
=    69.4000
   69.6000
   69.1000
   69.1000
   69.0000
   68.9000
avg_temp13 =
69.1833
VOC_data13 =
   72.3000
   84.3000
  118.2000
   94.4000
  103.8000
  103.7000
   90.6000
  102.7000
101.7000
avg_VOC13 =
96.8556
```

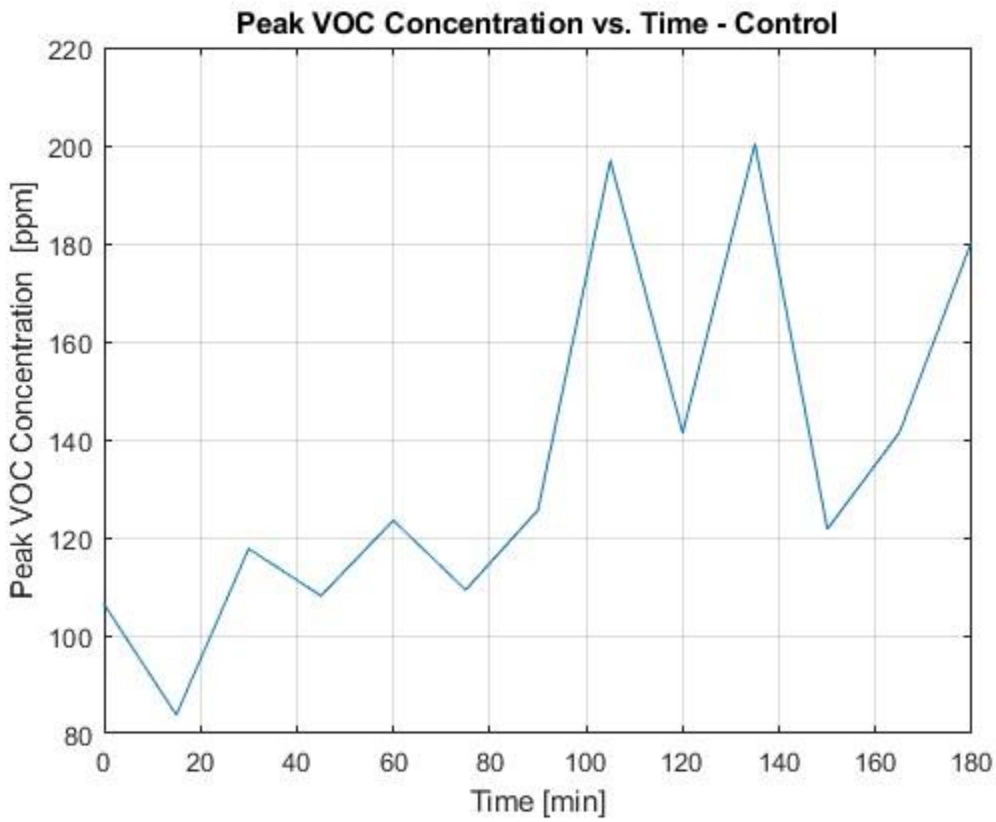
```
TWA_VOC13 =    331
peak_VOC13 =
180.6000
avg_ventfinal =
Columns 1 through 7
   70.8333   77.8333   78.3333   79.3333   75.5000   78.3333   79.3333
  Columns 8 through 13    78.1667   78.8333   76.1667
79.3333   80.1667   78.8333 avg_tempfinal =   Columns 1
through 7
   69.9333   71.1500   69.9000   68.5000   69.5000   71.3500   70.0500
  Columns 8 through 13    68.8500   68.9000   71.5000
70.0000   68.7167   69.1833 avg_VOCfinal =   Columns 1
through 7
   58.5989   63.3189   77.8878   85.0811   93.2433   85.7567   94.2333
  Columns 8 through 13
   99.1678   97.0011  110.3700  100.3278   96.8089   96.8556
TWA_VOCfinal =
   342   227   274   109   314   272   114   324   553   751
312   324   331 peak_VOCfinal =   Columns 1 through 7
  106.4000   83.7800  117.7000  108.1000  123.5000  109.3000  125.6000
  Columns 8 through 13
  196.9000  141.4000  200.3000  121.7000  141.5000  180.6000
```


Average Ventilation Rate vs. Time - Control
Average Ventilation Rate [CFM]
82
80
78
76
74
72
70
0
20
40
60
80
100
120
140
160
180
Time [min]


Average Temperature vs. Time - Control
Average Temperature [F]
72
71.5
71
70.5
70
69.5
69
68.5
0
20
40
60
80
100
120
140
160
180
Time [min]


Average VOC Concentration vs. Time - Control
Average VOC Concentration [ppm]
Time [min]


TWA VOC vs. Time - Control
TWA [ppb]
Time [min]



Experimental Group (with Acetone)

```
time = [0:15:180];

% Sample point 1 %
Ventilation Rate [CFM]


vent_data1e = table2array(Test1day1([1:3,7:9],4))% Importing data
from  excel spreadsheet avg_vent1e = mean(vent_data1e)


% Temperature [F] temp_data1e = table2array(Test1day1([1:3,7:9],6))%
Importing data from  excel spreadsheet avg_temp1e = mean(temp_data1e)

% VOC [ppm] VOC_data1e = table2array(Test1day1(122:130,9)) %
Importing data from  excel spreadsheet

avg_VOC1e = mean(VOC_data1e)
TWA_VOC1e = table2array(Test1day1(122,10))
```

```
peak_VOC1e = table2array(Test1day1(122,12)) % Importing data from
excel spreadsheet

% Sample point 2 %
Ventilation Rate [CFM]


vent_data2e = table2array(Test1day1([10:12,16:18],4))% Importing
data  from excel spreadsheet avg_vent2e = mean(vent_data2e)


% Temperature [F] temp_data2e =
table2array(Test1day1([10:12,16:18],6))% Importing data  from excel
spreadsheet avg_temp2e = mean(temp_data2e)

% VOC [ppm] VOC_data2e = table2array(Test1day1(131:139,9)) %
Importing data from  excel spreadsheet

avg_VOC2e = mean(VOC_data2e) TWA_VOC2e =
table2array(Test1day1(131,10)) peak_VOC2e =
table2array(Test1day1(131,12)) % Importing data from  excel
spreadsheet


% Sample point 3 %
Ventilation Rate [CFM]


vent_data3e = table2array(Test1day1([19:21,25:27],4))% Importing
data  from excel spreadsheet avg_vent3e = mean(vent_data3e)


% Temperature [F] temp_data3e =
table2array(Test1day1([19:21,25:27],6))% Importing data  from excel
spreadsheet avg_temp3e = mean(temp_data3e)

% VOC [ppm] VOC_data3e = table2array(Test1day1(140:148,9)) %
Importing data from  excel spreadsheet

avg_VOC3e = mean(VOC_data3e) TWA_VOC3e =
table2array(Test1day1(140,10)) peak_VOC3e =
table2array(Test1day1(140,12)) % Importing data from  excel
spreadsheet


% Sample point 4
% Ventilation Rate
[CFM]
```

```
vent_data4e = table2array(Test1day1([28:30,34:36],4))% Importing
data  from excel spreadsheet avg_vent4e = mean(vent_data4e)


% Temperature [F] temp_data4e =
table2array(Test1day1([28:30,34:36],6))% Importing data  from excel
spreadsheet avg_temp4e = mean(temp_data4e)

% VOC [ppm] VOC_data4e = table2array(Test1day1(149:157,9)) %
Importing data from  excel spreadsheet

avg_VOC4e = mean(VOC_data4e) TWA_VOC4e =
table2array(Test1day1(149,10)) peak_VOC4e =
table2array(Test1day1(149,12)) % Importing data from  excel
spreadsheet

% Sample point 5 %
Ventilation Rate [CFM]


vent_data5e = table2array(Test1day1([37:39,43:45],4))% Importing
data  from excel spreadsheet avg_vent5e = mean(vent_data5e)


% Temperature [F] temp_data5e =
table2array(Test1day1([37:39,43:45],6))% Importing data  from excel
spreadsheet avg_temp5e = mean(temp_data5e)

% VOC [ppm] VOC_data5e = table2array(Test1day1(158:166,9)) %
Importing data from  excel spreadsheet

avg_VOC5e = mean(VOC_data5e) TWA_VOC5e =
table2array(Test1day1(158,10)) peak_VOC5e =
table2array(Test1day1(158,12)) % Importing data from  excel
spreadsheet

% Sample point 6 %
Ventilation Rate [CFM]


vent_data6e = table2array(Test1day1([46:48,52:54],3))% Importing
data  from excel spreadsheet avg_vent6e = mean(vent_data6e)


% Temperature [F]

temp_data6e = table2array(Test1day1([46:48,52:54],5))% Importing
data  from excel spreadsheet avg_temp6e = mean(temp_data6e)
```

```
% VOC [ppm] VOC_data6e = table2array(Test1day1(167:175,3)) %
Importing data from  excel spreadsheet

avg_VOC6e = mean(VOC_data6e) TWA_VOC6e =
table2array(Test1day1(167,4)) peak_VOC6e =
table2array(Test1day1(167,6)) % Importing data from excel
spreadsheet


% Sample point 7 %
Ventilation Rate [CFM]


vent_data7e = table2array(Test1day1([55:57,61:63],4))% Importing
data  from excel spreadsheet avg_vent7e = mean(vent_data7e)


% Temperature [F] temp_data7e =
table2array(Test1day1([55:57,61:63],6))% Importing data  from excel
spreadsheet avg_temp7e = mean(temp_data7e)

% VOC [ppm] VOC_data7e = table2array(Test1day1(176:184,9)) %
Importing data from  excel spreadsheet

avg_VOC7e = mean(VOC_data7e) TWA_VOC7e =
table2array(Test1day1(176,10)) peak_VOC7e =
table2array(Test1day1(176,12)) % Importing data from  excel
spreadsheet


% Sample point 8 %
Ventilation Rate [CFM]


vent_data8e = table2array(Test1day1([64:66,70:72],4))% Importing
data  from excel spreadsheet avg_vent8e = mean(vent_data8e)


% Temperature [F] temp_data8e =
table2array(Test1day1([64:66,70:72],6))% Importing data  from excel
spreadsheet avg_temp8e = mean(temp_data8e)

% VOC [ppm]

VOC_data8e = table2array(Test1day1(185:193,9)) % Importing data from
excel spreadsheet

avg_VOC8e = mean(VOC_data8e) TWA_VOC8e =
table2array(Test1day1(185,10)) peak_VOC8e =
```

```
table2array(Test1day1(185,12)) % Importing data from  excel
spreadsheet


% Sample point 9 %
Ventilation Rate [CFM]


vent_data9e = table2array(Test1day1([73:75,79:81],4))% Importing
data  from excel spreadsheet avg_vent9e = mean(vent_data9e)


% Temperature [F] temp_data9e =
table2array(Test1day1([73:75,79:81],6))% Importing data  from excel
spreadsheet avg_temp9e = mean(temp_data9e)

% VOC [ppm] VOC_data9e = table2array(Test1day1(194:202,9)) %
Importing data from  excel spreadsheet

avg_VOC9e = mean(VOC_data9e) TWA_VOC9e =
table2array(Test1day1(194,10)) peak_VOC9e =
table2array(Test1day1(194,12)) % Importing data from  excel
spreadsheet


% Sample point 10 %
Ventilation Rate [CFM]


vent_data10e = table2array(Test1day1([82:84,88:90],4))% Importing
data  from excel spreadsheet avg_vent10e = mean(vent_data10e)


% Temperature [F] temp_data10e =
table2array(Test1day1([82:84,88:90],6))% Importing data  from excel
spreadsheet avg_temp10e = mean(temp_data10e)

% VOC [ppm] VOC_data10e = table2array(Test1day1(203:211,9)) %
Importing data from  excel spreadsheet

avg_VOC10e = mean(VOC_data10e)
TWA_VOC10e = table2array(Test1day1(203,10))

peak_VOC10e = table2array(Test1day1(203,12)) % Importing data from
excel spreadsheet


% Sample point 11 %
Ventilation Rate [CFM]
```

```
vent_data11e = table2array(Test1day1([91:93,97:99],4))% Importing
data  from excel spreadsheet avg_vent11e = mean(vent_data11e)


% Temperature [F] temp_data11e =
table2array(Test1day1([91:93,97:99],6))% Importing data  from excel
spreadsheet avg_temp11e = mean(temp_data11e)

% VOC [ppm] VOC_data11e = table2array(Test1day1(212:220,9)) %
Importing data from  excel spreadsheet

avg_VOC11e = mean(VOC_data11e) TWA_VOC11e =
table2array(Test1day1(212,10)) peak_VOC11e =
table2array(Test1day1(212,12)) % Importing data from  excel
spreadsheet


% Sample point 12 %
Ventilation Rate [CFM]


vent_data12e = table2array(Test1day1([100:102,106:108],4))%
Importing  data from excel spreadsheet avg_vent12e =
mean(vent_data12e)


% Temperature [F]
temp_data12e = table2array(Test1day1([100:102,106:108],6))%
Importing  data from excel spreadsheet avg_temp12e =
mean(temp_data12e)

% VOC [ppm] VOC_data12e = table2array(Test1day1(221:229,9)) %
Importing data from  excel spreadsheet

avg_VOC12e = mean(VOC_data12e) TWA_VOC12e =
table2array(Test1day1(221,10)) peak_VOC12e =
table2array(Test1day1(221,12)) % Importing data from  excel
spreadsheet


% Sample point 13
% Ventilation Rate
[CFM]

vent_data13e = table2array(Test1day1([109:111,115:117],4))%
Importing  data from excel spreadsheet avg_vent13e =
mean(vent_data13e)
```

```
% Temperature [F] temp_data13e =
table2array(Test1day1([109:111,115:117],6))% Importing  data from
excel spreadsheet avg_temp13e = mean(temp_data13e)

% VOC [ppm] VOC_data13e = table2array(Test1day1(230:238,9)) %
Importing data from  excel spreadsheet

avg_VOC13e = mean(VOC_data13e) TWA_VOC13e =
table2array(Test1day1(230,10)) peak_VOC13e =
table2array(Test1day1(230,12)) % Importing data from  excel
spreadsheet


% Final Data - Control

avg_ventfinale = [avg_vent1e avg_vent2e avg_vent3e avg_vent4e
avg_vent5e avg_vent6e avg_vent7e avg_vent8e avg_vent9e avg_vent10e
avg_vent11e avg_vent12e avg_vent13e]

avg_tempfinale = [avg_temp1e avg_temp2e avg_temp3e avg_temp4e
avg_temp5e avg_temp6e avg_temp7e avg_temp8e avg_temp9e avg_temp10e
avg_temp11e avg_temp12e avg_temp13e]

avg_VOCfinale = [avg_VOC1e avg_VOC2e avg_VOC3e avg_VOC4e
avg_VOC5e  avg_VOC6e avg_VOC7e avg_VOC8e avg_VOC9e avg_VOC10e
avg_VOC11e  avg_VOC12e avg_VOC13e] TWA_VOCfinale = [TWA_VOC1e
TWA_VOC2e TWA_VOC3e TWA_VOC4e TWA_VOC5e
 TWA_VOC6e TWA_VOC7e TWA_VOC8e TWA_VOC9e TWA_VOC10e TWA_VOC11e
TWA_VOC12e TWA_VOC13e]
peak_VOCfinale = [peak_VOC1e peak_VOC2e peak_VOC3e peak_VOC4e
peak_VOC5e peak_VOC6e peak_VOC7e peak_VOC8e peak_VOC9e peak_VOC10e
peak_VOC11e peak_VOC12e peak_VOC13e]

figure() % subplot(1,2,1)
plot(time,avg_ventfinale,'.','MarkerSize',8
) grid on xlabel('Time [min]')
ylabel('Average Ventilation Rate [CFM]')
title('Time vs. Average Ventilation Rate')

hold on plot(time,avg_ventfinal,'*')
legend('Experimental','Control','Location','bestoutside'
) figure()

% subplot(1,2,2)
plot(time,avg_tempfinale,'.','MarkerSize',8
) grid on xlabel('Time [min]')
ylabel('Average Temperature [F]')
title('Time vs. Average Temperature')
```

```
hold on
plot(time,avg_tempfinal,'*')
legend('Experimental','Control')
% sgtitle('Balometer Data')

figure()
plot(time,avg_VOCfinale,'.','MarkerSize',8
) grid on xlabel('Time [min]')
ylabel('Average VOC Concentration [ppm]')
title('Time vs. Average VOC
Concentration')

hold on plot(time,avg_VOCfinal,'*')
legend('Experimental','Control','Location','bestoutside'
)

hold on

      plot(0:12)  h  =  yline(80.37,  'b--',
'LineWidth',                              1);
legend('Experimental','Control','Experimen
t  Mean','Location','bestoutside') figure()
%                             subplot(1,2,1)
plot(time,TWA_VOCfinale,'.','MarkerSize',8
) grid on xlabel('Time [min]') ylabel('TWA
[ppb]') title('Time vs. TWA VOC')

hold on
plot(time,TWA_VOCfinal,'*')
legend('Experimental','Control','Location','bestoutside'
)

figure() % subplot(1,2,2)
plot(time,peak_VOCfinale,'.','MarkerSize',8
) grid on xlabel('Time [min]') ylabel('Peak
VOC Concentration  [ppm]') title('Time vs.
Peak VOC Concentration') % sgtitle('VOC
Data')

hold on plot(time,peak_VOCfinal,'*')
legend('Experimental','Control','Location','bestoutside'
)
% sgtitle('VOC Data')

vent_data1e
=     75
    57
    85
    78
```

```
    69
97
avg_vent1e =
76.8333
temp_data1e
=    71.2000
   70.8000
   72.4000
   72.5000
   72.8000
   73.2000
avg_temp1e =
72.1500
VOC_data1e =
   45.2000
   58.5000
   53.5000
   58.7000
   59.2000
   46.9000
   57.6500
   58.3000
   61.2000
avg_VOC1e =
55.4611
TWA_VOC1e =
176
peak_VOC1e =
66.1200
vent_data2e
=     79
    58
    86
    83
    72
96
avg_vent2e =
79
temp_data2e
=    71.4000
   71.2000
   71.0000
   70.7000
   70.4000
   70.0000
avg_temp2e =
70.7833
VOC_data2e =
   50.7000
```

```
   55.7000
   75.2000
   81.3000
   91.7000
   69.5000
   72.3100
   66.9000
   66.8000
avg_VOC2e =
70.0122
TWA_VOC2e =
247
peak_VOC2e =
117.2000
vent_data3e
=      77
    57
    90
    79
      70
95
avg_vent3e =
78
temp_data3e
=     70.0000
   69.8000
   70.1000
   69.9000
   69.7000
   70.3000
avg_temp3e =
69.9667
VOC_data3e =
   63.8000
   71.4000
   73.6000
   94.7000
  112.6000
  102.6000
   76.8000
  114.6000
76.7000
avg_VOC3e =
87.4222
TWA_VOC3e =
291
peak_VOC3e =
159.8000
```

```
vent_data4e
=     75
    62
    84
    79
    70
    92
avg_vent4e =
77
temp_data4e
=    70.1000
   70.4000
   69.8000
   69.7000
   69.8000
   70.2000
avg_temp4e =
70
VOC_data4e =
   65.8000
   71.9000
   73.9000
   81.5000
   94.8000
   91.7000
   85.6000
   94.8000
   99.7000
avg_VOC4e =
84.4111
TWA_VOC4e =
275
peak_VOC4e =
126.1000
vent_data5e
=     80
    60
    88
    78
    69
94
avg_vent5e =
78.1667
temp_data5e
=    70.1000
   70.1000
   69.7000
   69.9000
   70.2000
```

```
   70.1000
avg_temp5e =
70.0167
VOC_data5e =
   70.0400
   73.5000
   75.6000
   96.4000
  100.5000
   84.7000
   79.9000
   95.9000
   82.4000
avg_VOC5e =
84.3267
TWA_VOC5e =
298
peak_VOC5e =
164.3000
vent_data6e
=     77
    56
    86
    81
      71
99
avg_vent6e =
78.3333
temp_data6e
=    71.3000
   71.5000
   71.5000
   71.4000
   71.3000
   71.1000
avg_temp6e =
71.3500
VOC_data6e =
  109.3000
   97.9600
   74.0100
   78.6700
   83.5900
   82.0200
   77.0000
   80.4900
   88.7700
avg_VOC6e =
85.7567
```

```
TWA_VOC6e =
272
peak_VOC6e =
109.3000
vent_data7e
=      76
    57
    84
    80
    71
98
avg_vent7e =
77.6667
temp_data7e
=    69.9000
   70.1000
   69.7000
   70.1000
   69.5000
   69.4000
avg_temp7e =
69.7833
VOC_data7e =
   59.8000
   72.4000
   68.7000
   80.6000
   94.9000
   93.6000
  103.1000
   88.6000
   85.5000
avg_VOC7e =
83.0222
TWA_VOC7e =
260
peak_VOC7e =
117
vent_data8e
=      77
    57
    86
    80
    71
97
avg_vent8e =
78
temp_data8e
=    68.7000
```

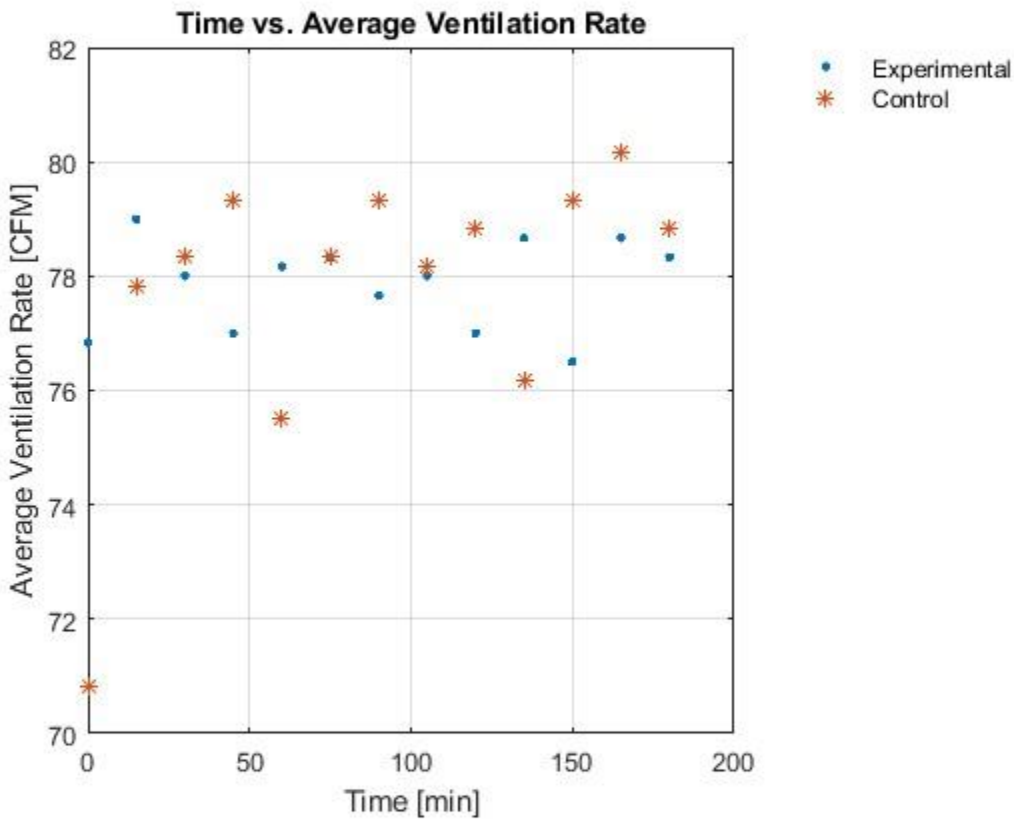
```
    69.9000
    69.8000
    69.6000
    69.1000
    68.7000
avg_temp8e =
69.3000
VOC_data8e =
    60.1000
    71.2000
    67.3000
    97.5000
   100.2000
    93.1000
    89.3000
    80.7000
    80.5000
avg_VOC8e =
82.2111
TWA_VOC8e =
   293
peak_VOC8e =
119.4000
vent_data9e
=     81
     60
     80
     77
     70
94
avg_vent9e =
77
temp_data9e
=     69.3000
    70.2000
    70.1000
    69.9000
    69.5000
    69.1000
avg_temp9e =
69.6833
VOC_data9e =
    77.7000
    82.2000
    84.1000
    88.1000
    88.3000
    76.3000
    85.2000
```

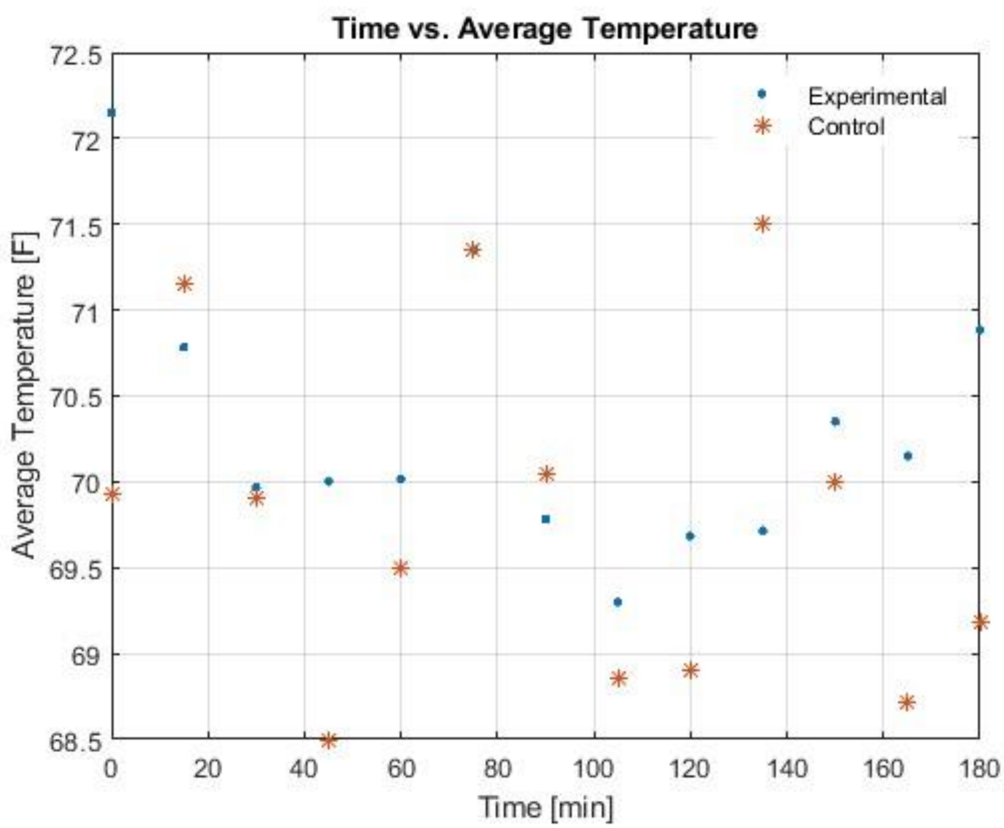
```
   89.7000
   84.1000
avg_VOC9e =
83.9667
TWA_VOC9e =
553
peak_VOC9e =
141.4000
vent_data10e
=      78
    59
    85
    82
    72      96
avg_vent10e =
78.6667
temp_data10e
=     69.5000
   70.1000
   70.2000
   69.9000
   69.5000
   69.1000
avg_temp10e
=     69.7167
VOC_data10e
=
   75.4000
   83.4000
   78.5000
   88.0000
   87.9000
   76.1000
   83.2000
   89.0000
   82.8000
avg_VOC10e =
82.7000
TWA_VOC10e =
510
peak_VOC10e =
136.8000
vent_data11e =
76
    57
    84
    81
      69
92
```

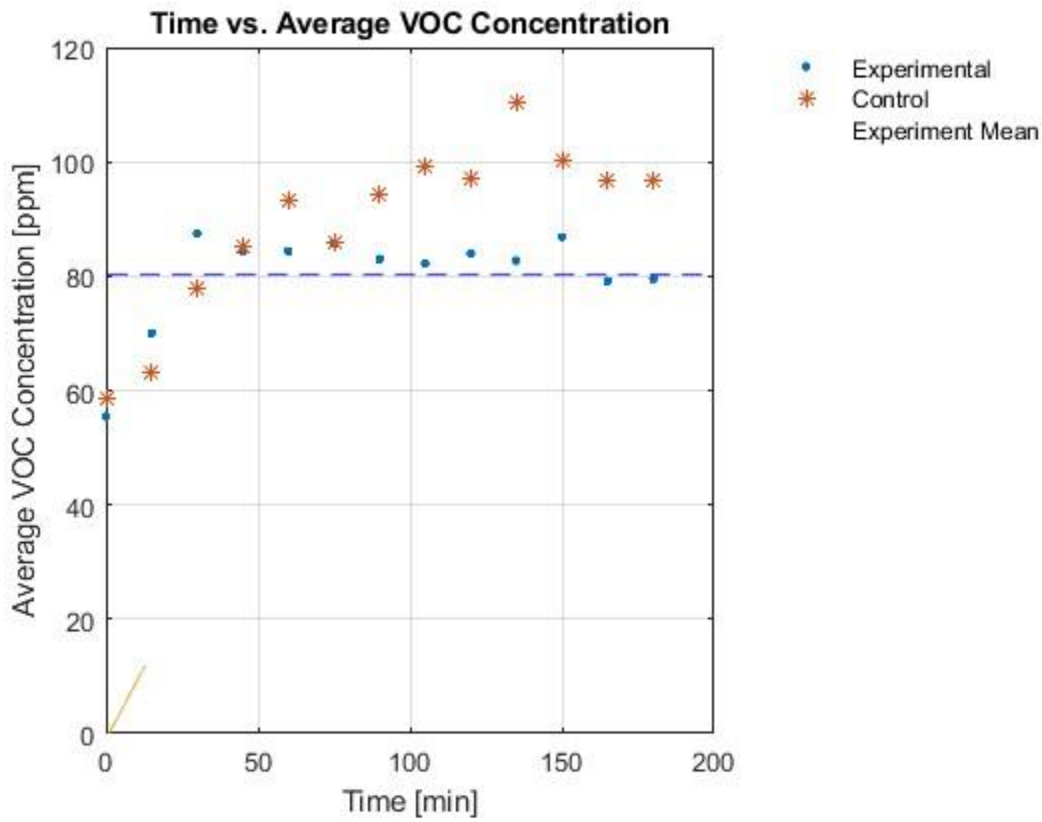
```
avg_vent11e =
76.5000
temp_data11e
=    69.9000
   70.4000
   70.3000
   70.2000
   70.6000
   70.7000
avg_temp11e
=    70.3500
VOC_data11e
=
   67.0000
   76.0000
   69.5000
   91.6000
  101.0000
   94.3000
   91.9000
  102.1000
88.3000
avg_VOC11e =
86.8556
TWA_VOC11e =
456
peak_VOC11e =
115.9000
vent_data12e =
80
    61
    88
    79
      70
94
avg_vent12e =
78.6667
temp_data12e
=    69.7000
   69.6000
   70.1000
   70.2000
   70.6000
   70.7000
avg_temp12e
=    70.1500
VOC_data12e
=
   60.9000
```

```
    71.2000
    71.7000
    85.9000
    82.4000
    77.8000
    93.4000
    87.5000
    81.7000
avg_VOC12e =
79.1667
TWA_VOC12e =
449
peak_VOC12e =
101.8000
vent_data13e =
78
    63
    87
    82
    69     91
avg_vent13e =
78.3333
temp_data13e
=     70.3000
    70.5000
    70.8000
    71.0000
    71.2000
    71.5000
avg_temp13e
=     70.8833
VOC_data13e
=
    61.9000
    69.2000
    70.3000
    79.6000
    89.7000
    82.7000
    85.1000
    92.2000
    85.1000
avg_VOC13e =
79.5333
TWA_VOC13e =     498
peak_VOC13e =
108.2000
avg_ventfinale =
Columns 1 through 7
```

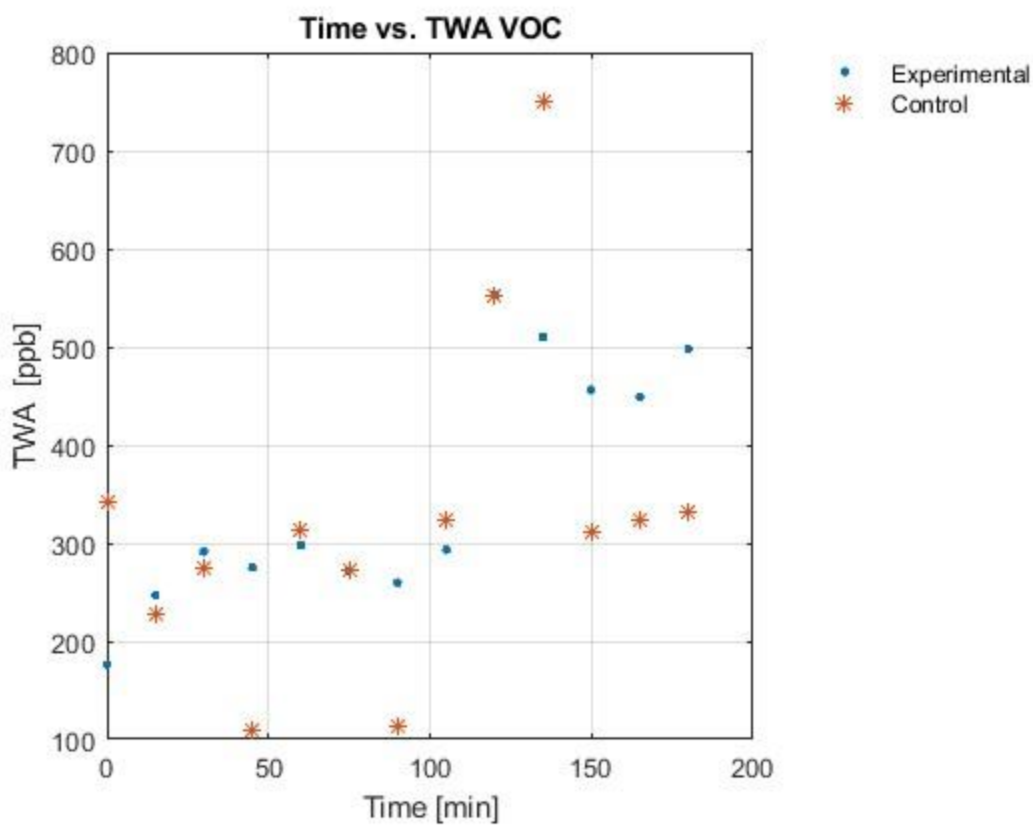
```
   76.8333   79.0000   78.0000   77.0000   78.1667   78.3333   77.6667
  Columns 8 through 13    78.0000   77.0000   78.6667
76.5000   78.6667   78.3333 avg_tempfinale =   Columns 1
through 7
   72.1500   70.7833   69.9667   70.0000   70.0167   71.3500   69.7833
  Columns 8 through 13    69.3000   69.6833   69.7167
70.3500   70.1500   70.8833 avg_VOCfinale =   Columns 1
through 7
   55.4611   70.0122   87.4222   84.4111   84.3267   85.7567   83.0222
  Columns 8 through 13
   82.2111   83.9667   82.7000   86.8556   79.1667   79.5333
TWA_VOCfinale =
   176   247   291   275   298   272   260   293   553   510
456   449   498 peak_VOCfinale =   Columns 1 through 7
   66.1200  117.2000  159.8000  126.1000  164.3000  109.3000  117.0000
  Columns 8 through 13
  119.4000  141.4000  136.8000  115.9000  101.8000  108.2000
```


Time vs. Average Ventilation Rate
Experimental
Control
Average Ventilation Rate [CFM]
Time [min]
82
80
78
76
74
72
70
0
50
100
150
200

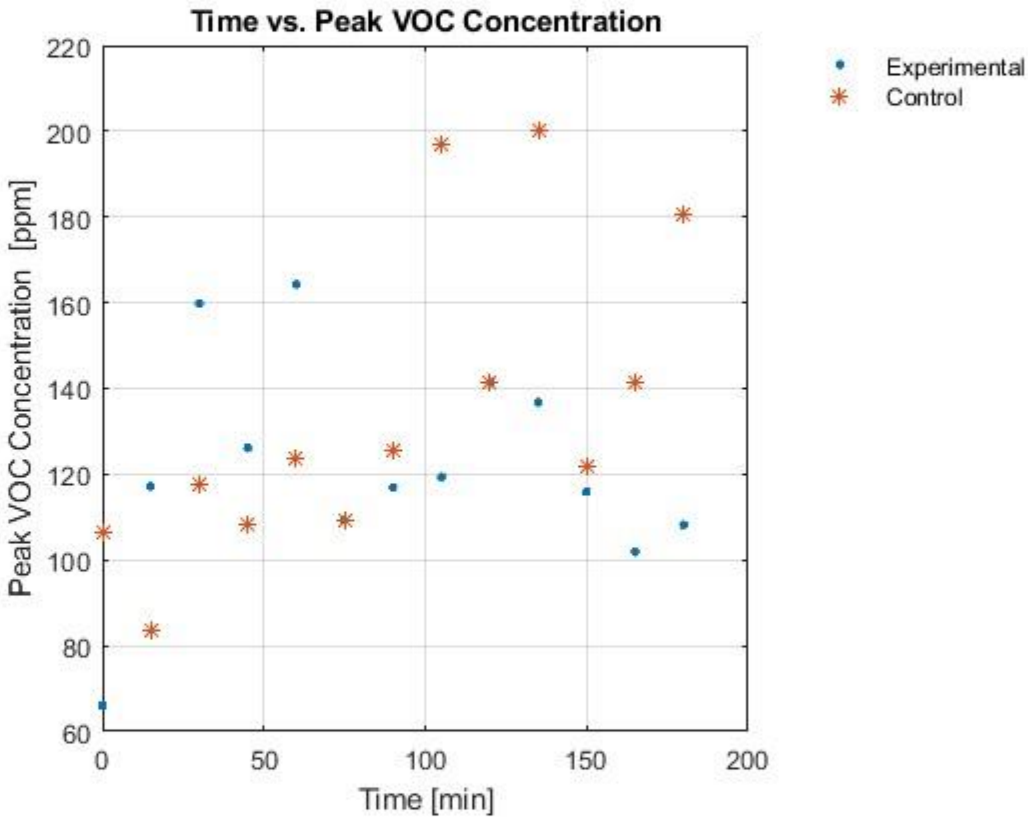

Time vs. Average Temperature
Experimental
Control
Average Temperature [F]
Time [min]
72.5
72
71.5
71
70.5
70
69.5
69
68.5
0
20
40
60
80
100
120
140
160
180



Time vs. Average VOC Concentration
Average VOC Concentration [ppm]
Time [min]
Experimental
Control
Experiment Mean
0
20
40
60
80
100
120
0
50
100
150
200



Time vs. TWA VOC
TWA [ppb]
Time [min]
Experimental
Control
100
200
300
400
500
600
700
800
0
50
100
150
200



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Appendix G: Risk Assessment

Name of Project: Trane: Improve Air Quality & Efficiency		**Date of submission: 12/4/20**
Team member	**Phone number**	**Email**
Jake Hamilton	(321) 427-2803	jsh14e@my.fsu.edu
Nicholas Holm	(954) 732-2503	nah19f@my.fsu.edu
Andreu Santeiro	(305) 484-5947	afs16@my.fsu.edu
Joseph Thyer	(850) 510-6575	jmt16d@my.fsu.edu
Gavin Young	(727) 453-8563	gry18@my.fsu.edu
Faculty mentor	**Phone number**	**Email**
Dr. Shayne McConomy	(850) 410-6624	smcconomy@eng.famu.fsu.edu
Dr. Juan Ordonez	(850)-644-8405	ordonez@eng.famu.fsu.edu

Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

The ionization unit utilized high voltage. Testers will wear insulating gloves and rubber soled shoes. The device will always be checked for residual charge before being handled.

The tested air flow will contain small particulate. Testers will wear respiratory masks and safety goggles. The testing apparatus will be carefully designed to contain the particulate and air flow.

Organic growth will be tested. Testers will wear respiratory masks, safety goggles, and gloves. The testing apparatus will be carefully designed to contain mold and bacterial growth.

A testing apparatus will be constructed or assembled. Sharp edges may present themselves during construction. Testers will wear long sleeves and long pants, close toed shoes, and gloves.

OSHA regulations were checked in regard to personnel safety when working with high voltage and small particulate.

Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

Assess the victim and the scene. If necessary, call the local emergency number to activate the EMS system. If the victim is conscious, ask for permission to provide care. Provide required care or wait for proper care providers.

List emergency response contact information:

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

Name	**Phone number**	**Faculty emergency contact**	**Phone number**
Fire Department	(850) 891-6600	Dr. Shayne McConomy	(850) 410-6624
Bruce Thyer	(850) 508-8880	Dr. Juan Ordonez	(850)-644-8405
		Donald Hollett	(850) 410-6600

Safety review signatures			
Team member	**Date**	**Faculty mentor**	**Date**
Jake Hamilton	12/1/20	Dr. Shayne McConomy	12/1/20
Nicholas Holm	12/1/20	Dr. Juan Ordonez	12/1/20
Andreu Santeiro	12/1/20		
Joseph Thyer	12/1/20		
Gavin Young	12/1/20		

Report all accidents and near misses to the faculty mentor.

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