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EML 4905 Senior Design Project

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BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

Effectiveness of UV Lights Inside Exhaust Chamber of Oven Hoods

Final Report

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This B.S. thesis is written in partial fulfillment of the requirements in EML 4905. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering.

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Luis A. Perez, Christopher Ramos, and Aaron Solomon and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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Abstract

This Senior Design Project incorporates a joining of the senior undergraduate mechanical engineers and professional engineers from Hood Depot. Hood Depot is one of the leading companies in the United States of America that manufactures and distributes commercial kitchen hoods to hotels, residential homes and restaurants. A common problem encountered with kitchen hoods is that the grease particles produced when cooking adheres to the vent walls of the exhaust hood and accumulates over time. This buildup of particles eventually blocks the vents and provides a fuel substance for potential fires which represents a significant danger within the building. To prevent these hazards, the hoods currently use baffles and wash nozzles to reduce grease collection. Though, there are no solutions to remove all grease build up, however there is a new innovative idea in the kitchen ventilation.

Theoretically, the usage of UV-C light breaks down the grease particles into a fine powdery substance. This addition of UV-C light bulbs would be an extra reduction process in the grease collection. The project's difficulties would be the testing of the UV-C light to determine the percentage of grease reduction as well as the optimum installation of the lights to maximize grease reduction. Other limiting factors include time exposure of the UV-C light to the grease, cost of materials and the installation and design of the new hood with all its features (the newest baffle system and the wash nozzles). The goal of this project is to reduce the maintenance of kitchen hoods, creating them to be more efficient and eliminating the hazardous effects.

1. Introduction

1.1 Problem Statement

The purpose of this project is to fully design a kitchen oven hood, while introducing and testing new technology of UV-C lights in the oven hood to improve efficiency of the grease cutting action. The project is broken off into three essential tasks. The first task is to fully test the effectiveness of the UV-C light. The second task is to design the oven hood while maximizing the effectiveness of the UV-C lights as found in the prior results. Finally, the third task is to completely build the design at Hood Depot facilities in Deerfield, Florida.

Figure 1 Veritech Filter

Using new technology with the UV-C lights has to be tested to fully maximize their potential as well as proving the concept of their ability to eliminate grease particles. Creating a testing facility at Hood Depot facilities is essential to properly test the concept of UV-C lights in an oven hood. This first task can be carried out at the facilities of Hood Depot with creating a prototype unit with UV-C lights that will prove the effectiveness of the design. Once receiving the results, they can be properly designed to fully achieve a maximum effectiveness within the final design of the hood.

Upon designing and proving the prototype, the ultimate potential for the UV-C lights the design of the full hood can be achieved. This is done with Inventor Professional; with the sheet metal option to be able to immediately transfer the design to the CNC mill at the facilities of Hood Depot. The design will also involve a Veritech Filter, which cuts the grease by 94%, compared to the standard filters used by Hood Depot. This design will also involve some baffles that will cut grease with its tight corners. All together the Veritech Filter, including the Baffles and the UV-C Lights, will improve the grease fighting ability and allow for the removing of the grease particles to also get rid of the smell. In the design, the UV-C lights must to have washers that can clean the UV-C lights inside of the hood. Additionally, Hood Depot has included a cartridge for the UV-C lights to be easily removed, changed, and washed. Lastly, the third task is to make the design in the CNC machine and completely assemble the design. The access and facilitation of the CNC machine as well as the full disposal of the Hood Depot facilities will ease this task.

1.2 Motivation

Each member of this senior design team has their own specific strengths and interests where engineering is concerned. Upon forming this group, a mutual decision was achieved where each member's opinion and ideas were allowed to be voiced and respected by one another. When the creation of the project was under discussion, the ideas were all pooled together as to what the final project should be and then the limiting factors of the projects ideas were then taken into consideration. Cost of materials and manufacturing was deemed to be the team's greatest concern. With this decision made, a funded project was the most practical decision.

From the options of funded projects available the UV-C light project was decided to be most interesting and engaging.

One of an engineer's main tasks is to analyze everyday problems and determine the most economical yet effective method to solve them. The process of cooking in an enclosed area produces grease particles and fumes at high temperatures into the nearby atmosphere of the cook. The most recent solution to this problem was found to be an exhaust hood. The hood extracts the fumes allowing them to be removed into the atmosphere and thereby allowing the cook to continue working without being inhibited. The problem with exhaust hoods is the maintenance of them. The least maintenance that is required, the more effective the hood and the more desirable the product is to the client. The UV-C light exhaust hood is simply the furthest engineers have gotten in solving the initial problem.

This project is a sub-category of the Heating Ventilation and Air Condition program. The content of this program is instrumental in solving some of the problems of this project. This project also allows for learning and research in a new faculty of engineering (chemical engineering) which this team has not been previously introduced to. The project chosen allows for testing of engineering theories, data collection and possible accreditation in proving an untested process. It also incorporates a design aspect, allowing for varying models of the ventilation system and then a full analysis of the hood's grease reduction capabilities. Another appealing factor of this project was that the hoods designed and constructed by this team are immediately put into production and manufactured on a broad scale allowing for the work to be portrayed.

2. Literature Survey

2.1 Oven Hood

The invention of various forms of extractor hoods in the mid 20th century allowed for the reintroduction of the so-called farmhouse kitchen into popular architecture. The first extractor hood was produced by a company called Vent-a-Hood in 1937. Vent-A-Hood was the first manufacturer of home cooking ventilation and range hoods.

The first range hoods were manufactured in a house with a dirt floor in Dallas, and then sold door to door. The primary ingredient in the success of the kitchen exhaust hoods is Vent-A-Hood's uniquely designed, fire safe, "Magic Lung" blower system. Throughout the years the hoods have been improved but the original concept is central to the design and remains unequalled in the field of ventilation.

The exhaust hood's main purpose is to remove the smoke and steam produced while cooking from the kitchen, thereby reducing a fire hazard and allowing the cook to breathe without inhaling large quantities of the smoke. The hoods are equipped with an exhaust fan that sucks the air through the ventilation system and releases out of the building.

2.2 Grease Filtration

The most significant form of grease filtration in ventilation exhaust hoods are baffles. Baffles are moveable partitions used to create airflow uniform across the hood opening, thus eliminating dead spots and optimizing capture efficiency. Exhaust air passes through the aluminum/stainless steel baffles. As the air turns, the grease particle's momentum throws the particle out of the airstream as it changes direction, causing the particulates to impact upon the baffles. The grease then runs down the baffle into the grease trough, which then drains into a removable grease container. There are currently many different designs to baffles, all varying due to the quantity of grease extraction. The more intricate the design, the more grease is extracted. Baffles also act as fire barrier protection preventing flames from passing through.

This project is utilizing the most effective filter to date. The Veritech FC grease filter is a form of baffle with 94% efficiency in grease capture. This filter is designed with spiral curl coils causing the exhaust air to follow the pattern and interact with a large amount of surface area where the grease particles can adhere to. The filters are environmentally friendly and very easy to clean. The product is manufactured in the UK, and is being specifically custom ordered for this projects specific task and dimensions.

2.3 Grease

Grease is a broad term with many different definitions and references. The grease related to this project is cooking grease. Grease is the byproduct of cooking produced by the fats and oils. Grease can be broken down into three different categories. These categories are submicron particles, steam and spatter. The submicron particles are produced when a drop of grease or water comes in contact with a hot surface and immediately burns off. Particle sizes range from 0.03 to 0.55 microns. This is found in cooking smoke.

Steam is the grease covered moisture and air mixture produced by the long burning of cold or frozen food on a hot surface. Particle size ranges from 0.55 to 6.2 microns. Spatter is the larger more visible effluent that is produced during the cooking process. Particle sizes range from 6.2 to 150 microns. Research and testing has determined that a significant concentration of grease particles can be found in the submicron and steam phases. Most currently applied grease extraction devices remove very large grease particulate that is 10 to 150 microns in size (spatter phase), but are not capable of removing fine particulates that are found in the submicron and steam phases.

2.4 Wash Nozzles

The wash nozzles or pressure nozzles contain a small orifice which is sized to create the desired pressure at a specific flow. When the flow from the pump is forced through this restriction a specific pressure is creating. The size of the orifice should relate to the pump specifications to provide an optimum spraying performance. There are two basic types of pressure washer nozzles. The two basic types are the disconnect type and the NPT threaded MEG type pressure washer nozzles.

Meg Tip washer nozzles are most commonly used as surface and duct cleaners. These pressure washer nozzles are .125 or .25 inches NPT threaded. The impact pressure of the washer nozzle is highly important in this project as it must be high enough to efficiently wash the duct walls but low enough to not damage the UV-C lamps. Impact pressure is highest immediately on the exiting tip and decreases the further the nozzles are from the surface being cleaned. The most effective cleaning distance is from 4 to 12 inches. Increasing the sizzle of a nozzle orifice effectively lowers the pressure produced while maintaining the flow output of the pump. This is the most desired and simplest method to adjust the pressure.

Pressure washer nozzles are wear items. As water flows through the pressure nozzle, the hardened steel of the nozzle will eventually wear away increasing the size of the nozzle’s orifice. This factor has to be taken into consideration when calculating maintenance time. A pressure gauge is a useful and inexpensive addition to help identify if the loss in pressure is nothing more than a worn nozzle or a defective pump. This addition of the washer nozzles to the exhaust hood does not affect the grease, produced but merely helps clean the vent walls to decrease the buildup and allow for longer usage of the exhaust system.

2.5 Safety Components

2.5.1 Current Sensor

The kitchen hood system will be equipped many safety features. One that monitors the fan status to make sure that the filters maintain minimum CFM is a current sensor. A current sensor is a device that detects electrical current (AC or DC) in a wire, and generates a signal proportional to it. The generated signal could be analog voltage or current or even digital output. It can be then utilized to display the measured current in an ammeter or can be stored for further analysis in a data acquisition system or can be utilized for control purpose. This information allows the device to distinguish between a reduced amp draw due to normal changes in the frequency and an abnormal amp drop due to belt loss or other mechanical failures.

2.5.2 Pressure Switch

A pressure switch is a switch that makes electrical contact when a certain set pressure has been reached on its input. The switch may be designed to make contact either on pressure rise or on pressure fall.

2.6 Gasket

A gasket is a sealing that fills up two or more surfaces that are mating. Gaskets essentially prevent leaking of a fluid from one of the mates through to the other. They fill the irregularities of the two materials creating a tight, firm seal. In this case, it’s to prevent the grease and air mixture from passing into the control panel and filling the electrical components with grease. Gaskets are made of many materials and while using those materials specific characteristics to maximize the sealing for the specific application.

2.7 Exhaust Fan

The exhaust fan utilized in the kitchen hood is dependent on the size of kitchen the hood is being installed into and if there is a requirement for the CFM's of air flow. The fan inlet connection also needs to be considered. In order to assure proper fan performance, caution must be exercised in fan placement and connection to the ventilation system. Variables such as obstructions, poorly designed elbows, transitions and improperly selected dampers can cause reduced performance, excessive noise, and increased mechanical stress. For optimum performance the ventilation system must provide uniform and stable airflow into the fan, a uniform airflow through the damper if a damper is installed in the fan, the dampers must open fully, and sharp turns from the entrance of the hood should be avoided as this can cause uneven flow. A use of turning vanes in such elbows would reduce adverse effects in the flow. To control the CFM air flow, certain fans are also installed with a variable fan speed control. Another consideration for exhaust hood fans is the curb and roof opening it is being installed into. All of these considerations determine the choice of fan installed because they reduce cost and installation time by ensuring compatibility between the fan, the curb and roof opening, and the kitchen hood requirements.

3. Project Objective

The growing concern of building safety has been brought to high demand with many deathly incidents over the last decade. A common problem with kitchen extraction systems is that grease inevitably gets carried over into the extraction ductwork. If this grease builds up, it provides fuel for a fire and represents a significant fire risk within the building. Also, the odors from kitchen ventilation systems can be a major nuisance depending on the location, cuisine, and point of extract. These problems can be addressed by Ultra Violet (UVC) light to provide secondary grease removal and odor destruction.

High efficiency baffle filters will provide the first stage of grease removal and also act as a physical barrier to restrict the spread of flames. The extracted air then passes through the UV reaction chamber located deep inside the canopy, well away from prying eyes and protected with safety interlocks. This process will decrease the grease build up by 35-45%.

When the grease is exposed to UV light, it breaks down and turns to a fine ash which adheres to the UV lamps. The use of UV removes the remaining smaller grease particles that are not able to be extracted by the baffle filters, resulting in clean exhaust hood interiors, duct systems and exhaust fans. The automatic daily water wash system cleans the ash deposits and the remaining is removed by means of a cloth. The filters are removed and washed approximately every two months.

4. Design Alternatives

4.1 Overview of Conceptual Design Developed

Design of the prototype of the UV-C lights will allow for the proper placement and properties of the UV-C light throughout the final oven hood design. The UV-C testing will properly demonstrate the effectiveness of UV-C in the oven hood. Thus, proving the concept, and allowing the final design of the complete oven hood.

Design of the oven hood with the UV-C light was fully designed on a computer aided designing program and visual understanding of the required 1000 cubic feet per minute flow through the Veritech filter, to properly operate and maximize its performance. This can be visually represented through a computer aided design as well as computer aided simulation and analysis.

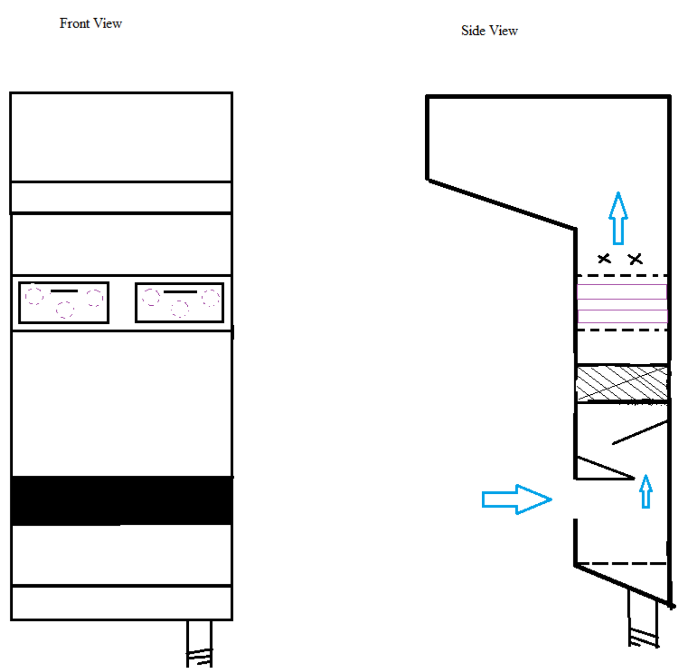

Figure 2 Preliminary Designs

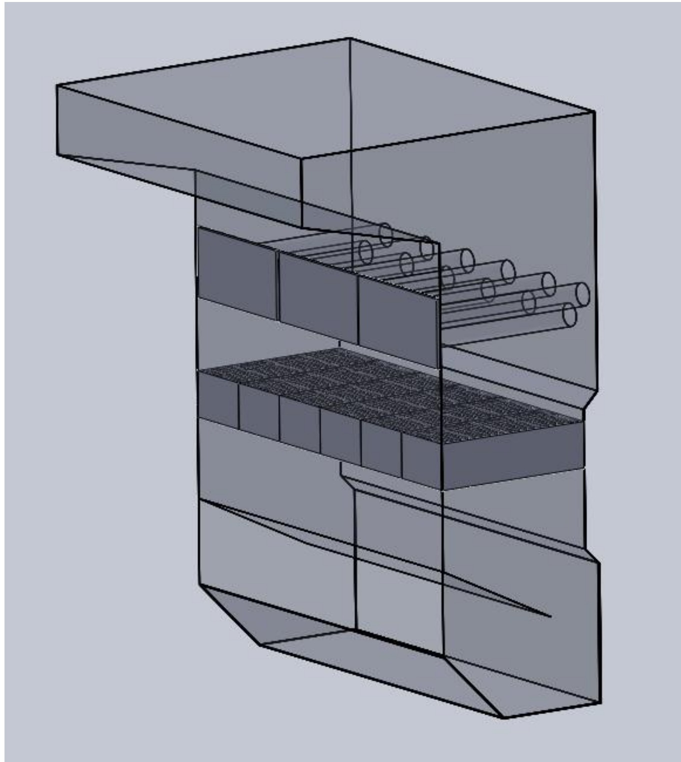

Figure 3 Solidworks Model

4.2 Prototype Testing Overview

The prototype, in essence, is a proof of concept. Since the introduction of UV-C lights is new, proper testing has not been completed by ASHRAE, an International technical society organized to advance the arts and sciences of heating, ventilation, air-conditioning and refrigeration. Proper testing will be completed with the proper design for the prototype piece. Minor design requirements must be met, including the distances and the intensity of the UV-C field. These requirements are specified on the light bulbs as well as having a 2 inch distance of effectiveness.

The UV-C lights are known to break apart the grease particles, but there are two chemical processes that occur during the chemical decomposition. The direct UV-C light is believed to break the particles apart as well as the ozone that the UV-C light creates. There will indeed be two prototypes that will test to prove which one of the two processes creates the most amounts of grease particle break-up, or whether it's both routes that are working in conjuncture to maximize the grease particle conversion to a fine powder.

Aside from the UV lights, there will be a cartridge system designed for easy replacement. The cartridge system will maximize the results acquired from the testing done with the UV lights.

4.2.1 Prototype Testing

In speaking with Dr. Yaru Song at Florida Internationals University (FIU), who is in chemistry lab departments with the Gas Chromatography Mass Spectrometer (GCMS), design will involve a simple baffle system with no other means of filtration, other than the baffle itself on a dry hood system. After the first turn, it will be introduced to a series of direct UV-C lights spaced 4 inches apart in a non-sequential series with two rows. This will test the effectiveness of lights on the grease. The design will involve a simple extraction fan to prevent ozone stagnation, as well as stagnant air which in fact increases the amount of grease throughout the duct system. This will be recovered and tested at the FIU GCMS labs.

Another design will test the effectiveness of the ozone layer specifically in the prototype oven hood. This method, if proven effective, will decrease the amount of heat generated in the oven hood, as well as minimize the amount of washers, in turn lower the price. The UV-C lights will be pulled through an extractor and pushed through a fan that will mix the UV-C light ozone created by the UV-C lights with the grease particles that are trailing up the hood oven. The lights shall have no specific organization inside of the oven, as for the ozone created will be breaking apart all of the particles.

4.3 Proposed Design 1

Once the prototypes of the hoods have been fully tested and proven, the design of the hood will come accordingly. The oven hoods will be a wet oven hood, meaning there will be a washing system for the UV-C lights as well as washing the Veritech Filter. The water will be lead to a pan that leads to a drain. The grease will be immediately introduced Hood Depots most effective filter, Veritech Filter, which will then lead to multiple baffles to continue "cutting" the grease to minimize the amount of grease until finally being introduced to the UV-C lights. The extractor has to be pulling out the air at 1000 CFM to work through the Veritech filter and to prevent any form of stagnant flow which will increase the grease and cause ineffectiveness in the oven hood design.

The UV-C lights will be placed in the more effective of the two design to maximize their effectiveness and always stay within their 2 inch range of effectiveness. They will be placed in a series of two rows and having the columns varying in intermittent series allowing for the proper air flow to be reached. They will be installed in a cartridge that can easily be removed through the front panel to avoid having to use a ladder over the oven itself, thus preventing injury. The cartridges will allow for easy removal to change and clean each light tube individually.

Washers will be installed next to the light tubes to prevent grease build up, rendering the UV-C light useless. Since this is a wet oven hood system, the filter will also l have its own washer system for easier maintenance. The water will run through the system of baffles, which will in turn prevent it from falling back out, and exit to a pan that will run out to a grease drain.

The air flow at all times inside of the oven system must be maintained at 1000 CFM, ensuring turbulence, to properly pass through the Veritech filter. Inside of the oven hood there should at no point be a stagnation of air, which can be achieved with proper reduction of diameter and proper horse power (HP) in the extractor.

Lastly, the oven hood has to meet UL listing certification. There must be multiple check valves to detect, among other things, if the extractor is malfunctioning, if there is a grease fire, the fan status, and the filter status. This information will then be transferred to a User-Interface console (UI), which will receive the information and act accordingly to solve such issue, or in any other case alert the operator of such malfunctions.

4.4 Chamber

In the hood oven chamber comes the design of the cartridge as well as the design of the washer nozzles. The washer nozzles will be following a standard practice from the field. The calculations used to derive the different pressures and pumps used for the nozzles are calculated and are in the major components section of this report.

As for the cartridge of the system, it had multiple designs within itself and many prototype versions. The cartridge will hold all of the UV lights as well as allow for easy removal of the lights while maintaining no fluid leaking into the control box or the rest of the oven hood for that matter. This was achieved by choosing the right gasket, as properly described in the major components section of this report.

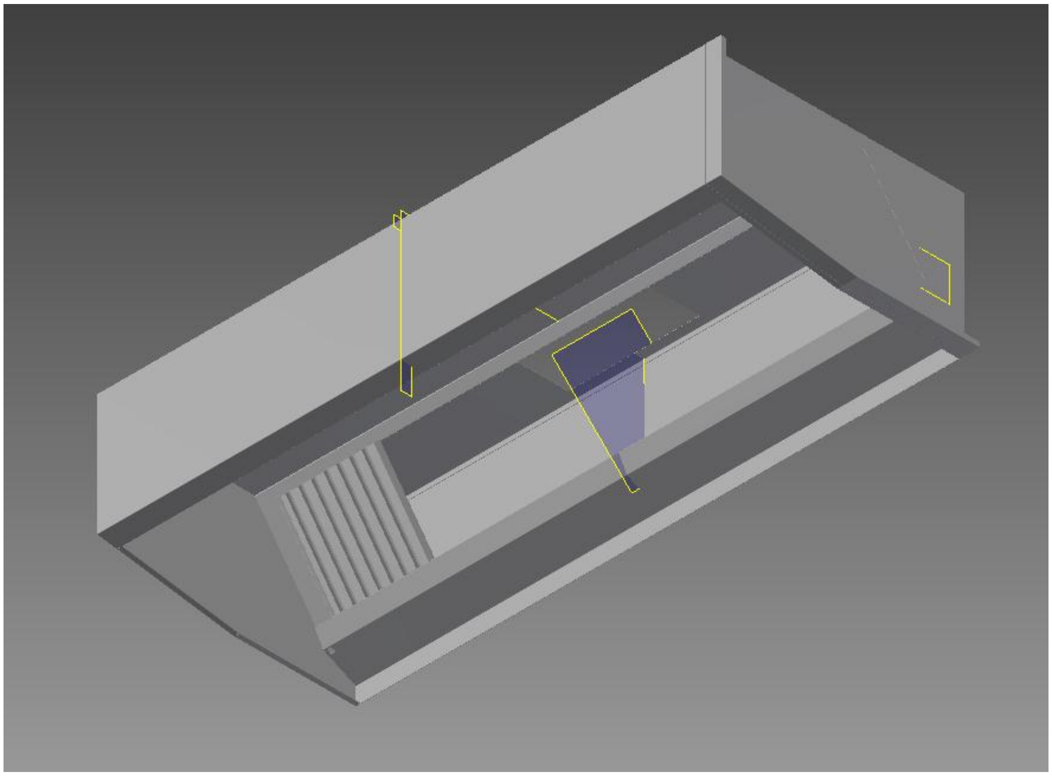

Figure 4 The Chamber with the hood

4.4.1 Prototype Cartridge

The cartridge was designed in mind to maximize the UV lights in the chamber. The initial design was used without the proper knowledge of the maximum bends that the machines at our disposal could make.

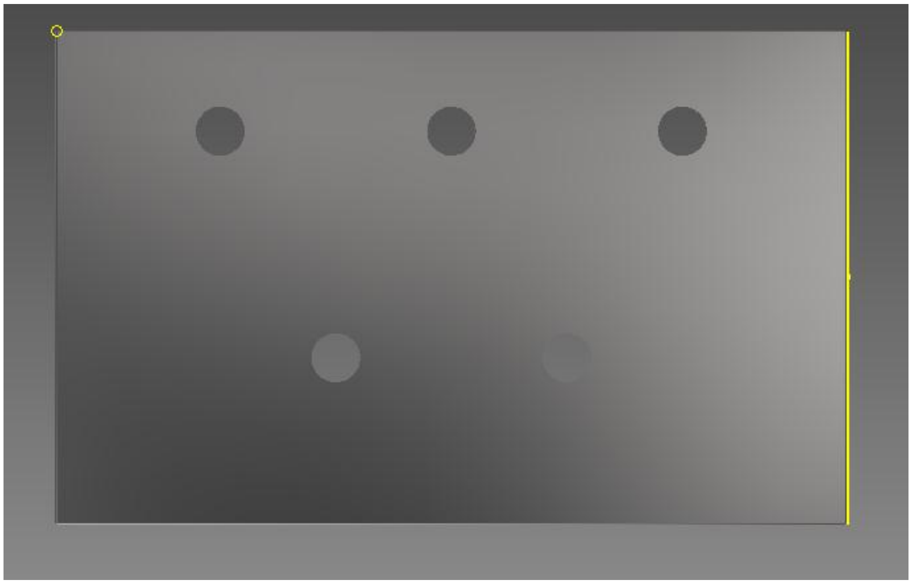

Figure 5 Staggered UV light configuration used to maximize effectiveness

The cartridge was also designed to have a control box. The control box was going to be used to house the electrical components of the UV lights. The control box was also going to be made of the same sheet metal with punches in on the sides for easy removal as required.

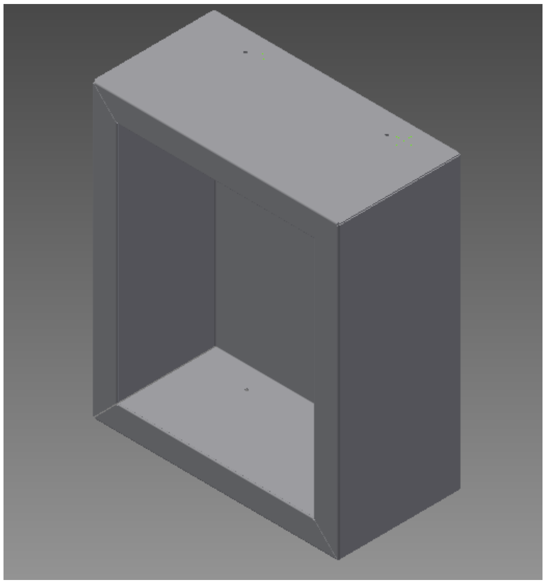

Figure 6 Control Box

Lastly, the initial designed sported door handles for easy removal from the chamber. The door handles were found on McMaster-Carr to have excellent anti-grease properties.

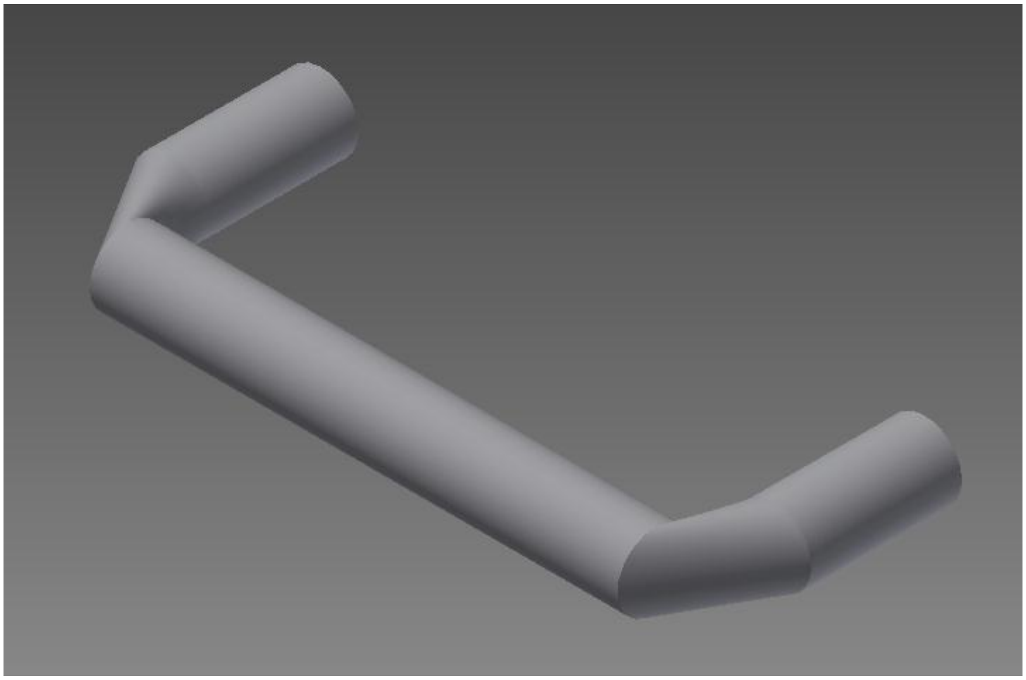

Figure 7 Door Handle

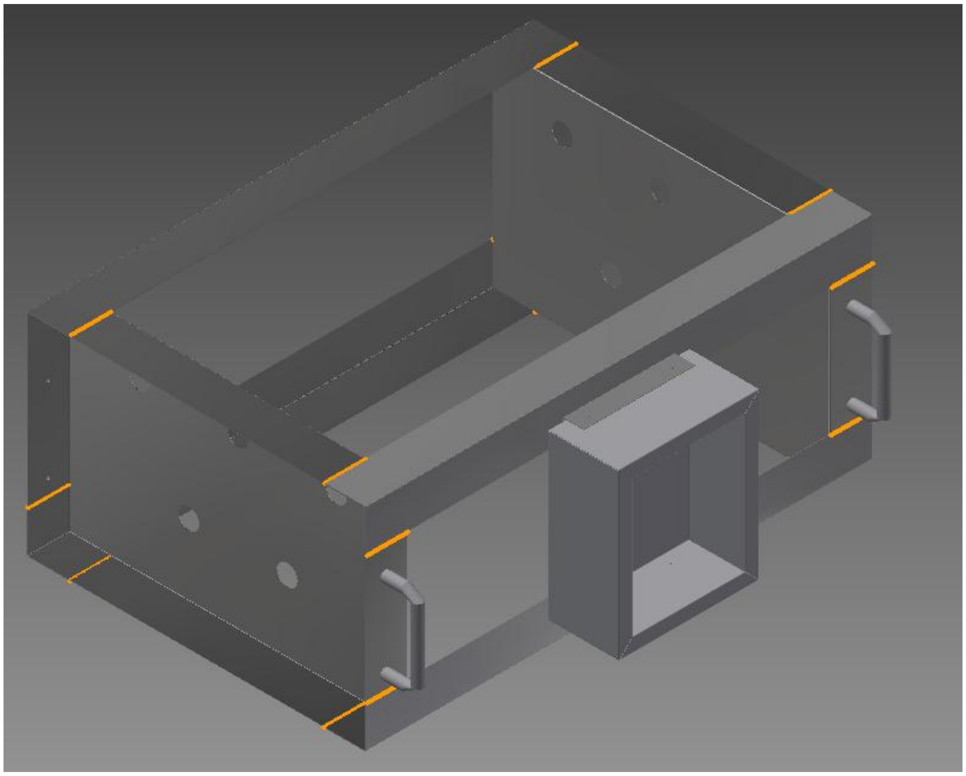

Figure 8 Initial prototype with door handles and control box

As shown above, the bends on the sheet metal were made for a 3” bend. This had to be changed for the final design.

4.4.2 Final Design

After consulting with Hood Depot and the UV light suppliers, the dimensions had to be changed. Some accessories would have to be even knocked off. First to go was the door handles. The door handles were excellent to provide ease of access to the consumer, but they in essence proposed a hazard. The door handles could not handle the temperatures required for a UL listing, therefore they had to be scrapped. Next, by using the new dimensions, the control box was suppressed from the final design. The control box, though needed, had to be changed and would be remade according to the bulb ballast size and necessity. Shown below is an isometric view of the final design clearly showing the lack of the door handles and control box, while showing the proper bend sizes.

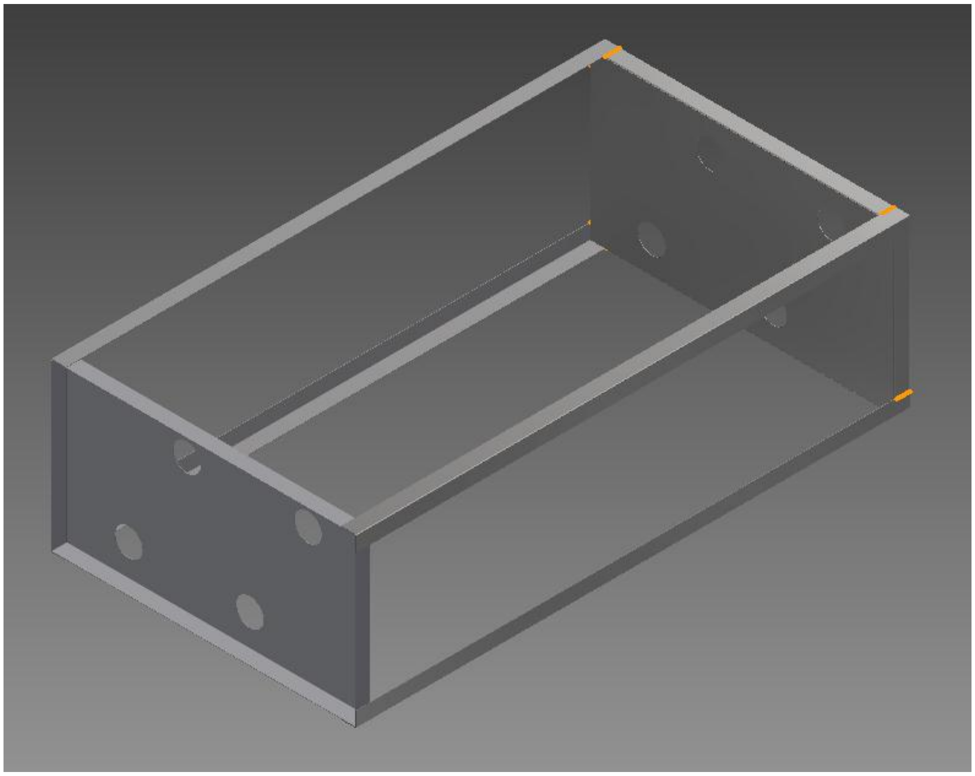

Figure 9 Final Box Design

The orange beads show the tack welds that would be used throughout the prototype design. As shown in the figure above, one can see the new UV lights configuration. After having spoken with the UV light provider, Heraeus lighting, the light configuration was maximized to 4 bulbs in this staggered manner.

5. Analytical Analysis and Structural Design

The oven hood will be resting on the floor as well as bolted onto the wall in the rear. Thus, the overall integrity of the hood should not be affected. Even with the addition of the Veritech Filters and the UV-C lights that are not ordinary for oven hoods the structure should not be altered.

The Veritech Filter has been chosen and the custom order will be done by the Veritech Filtration Company. This filter is 2nd element through the three tiered element of the oven hood system. The main system of the hood as well as the frame will experience negligible deformation when the entire oven hood is operated at its maximum ranges.

The majority of the oven hood system will be made with stainless for its lack of oxidation and strict use in food contact systems. The extreme resistance to rusting makes stainless steel the optimal choice for the oven hood applications, regardless of the cost. Designing a wet hood, washers and nozzles, almost immediately forces a stainless steel material. The material has to be resistant to the sporadic, yet constant, fluid from the nozzles. Add the fact that there is food and there cannot be any rust in the material of choice.

The UV-C lights will be wrapped in a sleeve-like design. The sleeves will have to be UV-C light resistant to prevent any form of deterioration of the material as well prevent any form of short circuit caused by a breach in the sleeve. The plastic will also have to withstand to the temperature ranges within the oven hood. With this in mind the material of choice is a clear CPVC. The clear CPVC can withstand temperatures up to 210 ^{o}F as well as being fully UV-C resistant for such applications.

5.1 Hood Design

The oven hood was analyzed to properly choose a proper fan and ensure that the design requirements were met. From the information given, a volumetric flow rate of 1000 cubic feet per minute through the Veritech filter was required for optimum performance of grease extraction. The hood was also designed for a range of volumes of the kitchen volumes. However, extreme conditions may require "Minutes per Change" outside of the specified range. The geographical location and average duty level of the area affects the flow rate required. For hot climates and heavier than normal area usage, a lower value for the minutes may be used to change the air more quickly. For moderate climates with lighter usage, select a higher number in the range. To calculate the flow rate required to adequately ventilate the area, the room volume was divided by the appropriate "minutes per change" value. The volume of kitchen the hood is installed into also determines the volumetric flow rate required by the fan to produce a negative pressure. An average size of a commercial kitchen was used for initial calculations. For proper choice of an exhaust fan the amount of static pressure the fan needs to overcome is also required.

Noting that the Veritech filter could not be modeled, a value of pressure drop was assumed for initial calculations. For the cartridge, the pressure difference was calculated utilizing the CFD programming from the SolidWorks program. These values were also compared to a hand calculation of the pressure drop across the bulb area only with the assumption that the bulbs could be treated as a tube bank. The values calculated compared with the SolidWorks calculations with minimal error, ensuring the validity of the program. This pressure drop from the cartridge designed plus the pressure drop from the Veritech filter was used to calculate the static pressure.

5.2 Effectiveness of Ultraviolet Light

In the design of the cartridge, from proper research and consulting with professors from the university as well as chemical engineers in the HVAC program, we learned a bit about the UV light and its effectiveness and requirements. The first assumption is that the lights would be affecting gaseous by-products of combustion and cooking, such as carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x) and possibly sulfur dioxide (SO_2). The UVC, per se, does not necessarily affect the molecules. What is important is the 185 nanometer (nm) emissions, which is in “vacuum ultraviolet” (VUV) range, so named because it interacts strongly with oxygen and thus only transmits appreciably through a vacuum. VUV starts at 220nm, the point at which the photons are energetic enough to split oxygen molecules and create ozone. These deep UV wavelengths such as the 185 nanometers are just getting into the realm of ionizing radiation. This means that the electromagnetic radiation whose photons are energetic enough to detach electrons from atoms and/or dissociate chemical bonds. This is the reason that ozone (O_3 radicals) is produced by these UV lamps. The 185nm ultraviolet light is energetic enough to dissociate the oxides of nitrogen and sulfur, and can fully oxidize carbon monoxide to a less harmful carbon dioxide. However, dissociation of these bonds leaves behind free species like sulfur and possibly radicals (short-lived, highly reactive molecules/atoms with an unstable electron configuration), which can immediately recombine or react further upstream.

Accordingly, the 185nm photons can split the bonds that make up grease and other organic particles in the exhaust stream if the air velocity is low enough to give sufficient residence time and the particle size and concentration is low enough. The ozone that is produced also contributes to oxidizing the fat molecules. This is why the UV-C lights were installed as the last form of filtration due to its effectiveness only on the smallest particles. The conclusion from this research is that this change in the chemical composition of the by-products of cooking that result in grease would reduce the amount of grease built up and also affect the physical properties of the ‘build up’ of the grease allowing it to be easier to clean off the duct walls.

5.3 Cartridge Design

Considering the short path of 185nm radiation through the air, the lamp spacing in the cartridge was critical in affecting the effectiveness of the UV lamps emission. Upon consulting with the company that sold these lamps, the recommendation was at least 10 centimeters from any surface and a minimum of 20 centimeters between the lamps themselves. With this information we redesigned our initial cartridge prototype and utilized only 4 bulbs with the proper spacing to maximize the effectiveness.

5.4 Wash Nozzles:

The wash nozzles chosen depended on the required pressure for the UV lamps and duct walls to be cleaned. This pressure was estimated to be ranging between 10 to 20 pounds per square inch. This value could only have been achieved with proper modeling of the piping system to ensure the pressure was reduced to this value or with the use of a compressor on the line. However the piping schematic was not provided by the company and therefore calculations were made based on a reduced pipe layout and assumed values. Based on the calculations, the nozzle was then chosen from the catalog that fit the criteria. The basic piping layout is shown in figure below:

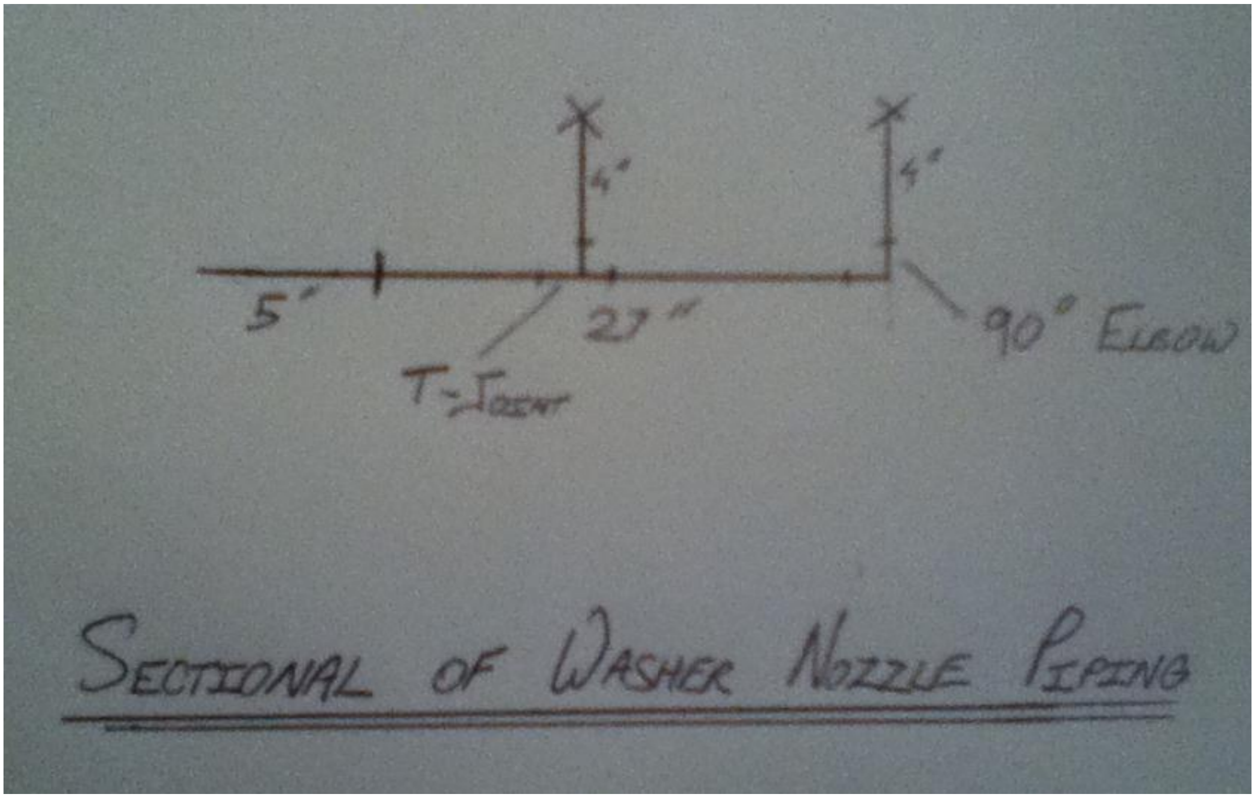

Figure 10 Diagram of Washer Nozzle Piping

5.5 Technical Data on UV Lamps

Figure 11 Illustrating UV Lamp

Based on the information from the UV lamp company provider (Heraeus) the NIQ and NAQ lamps vary only in length and corresponding power output. However NIQ series is for higher ambient temperatures (40-80°C) whereas the NAQ is for 20-40°C. A typical exhaust temperature found from an ASHRAE article was rated at 65 degrees Celsius. This value suggested that the NIQ model be chosen. The operating life of the bulb was provided as 10000 hours. This corresponds to an approximation of a year and 2 months of operation allowing the user to know suitably decide when the bulbs would be required to be replaced.

Vacuum UV lamp Model NIQ for 40°C - 80°C *

Power supply

*air temperature in the hood

Technical Data UV Oxidation Lamp	
Suitable for an airflow rate	1500 - 2200 m3/h
Useful operating time	10.000 h Vacuum UV
Lamp wall temperature	< 100oC
Lamp base dimensions	50 mm long x 24 mmΦ

Lamp type	Operating Temperature Allowed	Electric. Power		Total length
NIQ 170 / 90 XL	(40° - 80° C)	160 W		900 mm

Table 1 Technical Data UV Oxidation Lamp

5.6 Initial Hand Calculations

5.6.1 Fan Selection:

With our commercial kitchen size = 14ft * 20ft * 8ft = 2240ft^3

Suggested Air Changes for Proper Ventilation

$$CFM = \frac{\text{Room Volume}}{\text{Min./Chg.}}$$

Room Volume = L x W x H

Area	Min./Chg.	Area	Min./Chg.	Area	Min./Chg.
Assembly Hall	3-10	Dance Hall	3-7	Mill	3-8
Attic	2-4	Dining Room	4-8	Office	2-8
Auditorium	3-10	Dormitories	5-8	Packing House	2-5
Bakery	2-3	Dry Cleaner	2-5	Plating Room	1-5
Bar	2-4	Engine Room	1-3	Printing Plant	3-8
Barn	12-18	Factory	2-7	Projection Room	1-2
Beauty Parlor	2-5	Foundry	1-5	Recreation Room	2-8
Boiler Room	1-3	Garage	2-10	Residence	2-6
Bowling Alley	3-7	Generator Room	2-5	Restaurant	5-10
Cafeteria	3-5	Gymnasium	3-8	Restroom	5-7
Church	4-10	Kitchen	1-5	Store	3-7
Classroom	4-6	Laboratory	2-5	Transfer Room	1-5
Club Room	3-7	Laundry	2-4	Warehouse	3-10
Corridors/Halls	6-20	Machine Shop	3-6		
Dairies	2-5	Meeting Room	3-10		

Table 2 Proper Ventilation Chart

Based on the chart acquired from the fan company's website the maximum minutes per change was chosen, a value of 5 minutes per change.

CFM = Room Volume / Minutes per Change =

Equation 1 CFM Calculation

$$2240/5 = 448 \text{ ft}^3/\text{min}$$

$$\text{Total CFM required} = 1000 \text{ (filter value required)} + 448 = 1448 \approx 1500 \text{ ft}^3/\text{min}$$

Equation 2 Calculating Total CFM

Typical ranges of static pressures for exhaust hoods lies between .625 and 1.5 inches of water. An average value of 1 inch of water was chosen. An assumed value of 0.1 inch of static pressure was assigned to the Veritech filter. A maximum air speed within the hood of 437ft/min = 2.2 m/s was provided by the Hood Depot company. Utilizing this information the pressure from this speed equals,

$$P = (\rho * V^2) / 2 = (1.035 * 2.2^2) / 2 = 2.505 \text{ Pa}$$

Equation 3 Pressure from density and velocity

$$h = p / (g * \rho) = 2.505 / (9.81 * 1000) = 0.000255 \text{ m} = .01 \text{ inches of water}$$

Equation 4 Height of Water

$$\text{Total pressure} = 1 + 0.1 + 0.01 = 1.11 \text{ inches of water}$$

Equation 5 Total Pressure

This pressure plus the pressure loss across the cartridge allowed for the selection of the fan from the catalog.

5.6.2 Wash Nozzles:

The calculations were performed on a sectional drawing of the piping system. Utilizing a nominal diameter of 1 inch schedule 40 with a flow area of 5.574 cm^2, inner diameter of 2.664 cm, the length of the pipe used in the section is 1.016m. The desired output pressure is known to be 15 – 20 psi. Choosing the upper bound value of 20 psi (137900Pa) and assuming based on piping design or by use of a compressor from sectional entrance to exit the pressure difference is 200 pa. The pipe contains a T-joint and a 90 degree elbow. The area remains constant implying $V_1 = V_2$. $Z_2 = 4$ inches and $Z_1 = 0$. The Bernoulli equation with friction and losses equals

$$P_1/\rho g + V_1^2/2g + Z_1 = P_2/\rho g + V_2^2/2g + Z_2 + fl/D_h\ (V/\ 2g) + K\ (V^2/2g)$$

Equation 6 Bernoulli Equation

Rearranging:

$$V^2 = 2\ (199.9)\ /\ 1000\ ((f(1.016)/.02664) + (1.9 + 1.4))$$

Equation 7 Solving for Velocity

$$Re = \rho VD\ /\ \mu = 1000 * V * .02664\ /\ .89 * 10^{-3} = 3*10^4 V$$

Equation 8 Reynolds Number

From Moody Diagram, friction factor f = .032

Therefore V = .297 m /s

$$Q = AV = 5.574 * 10^{-4}\ (.297) = 1.65 *10^{-4} m^3/s$$

Equation 9 Volumetric Flow Rate

Nozzle no. 328865K264 was chosen from the McMaster-Carr catalog of nozzles.

5.6.3 Cartridge Calculations:

Length = 900mm = 0.9m

Diameter = 24mm = 0.024m

Operating temperature allowed = 40° - 80° C

Assumptions:

- Cartridge assembly assumed to be Tube bank
- Air is active fluid
- Flow area only includes tube banked area
- Air temperature assumed to be 65°C = 338 K
- Properties interpolated from Table A.4
- Surface temp of bulb assumed to be 70°C = 343K
-

Thermophysical Properties of Air	
Temp. of Exhaust Gas (K)	338
Temp. of Bulbs (K)	343
Density, ρ (kg/m^3)	1.034936
Cp(KJ/kg*K)	1.00852
Kinematic Viscosity, ν (m^2/s)	1.97128E-05
Conductivity, k (W/m*K)	0.029112
Pr	0.70168
Pr Bulb	0.70098

Table 3 Thermophysical Properties of Air

From geometry,

$S_T = 6.66$ inches = .169 m

$S_L = 3.78$ inches = .096 m

$$V_{max} = (S_T / (S_T - D)) * V = (0.169 / (0.169 - .024)) * 2.2 = 2.56 \text{ m/s}$$

Equation 10 Max Velocity

$$Re_{max} = (\rho * V_{max} * D) / \mu = (V_{max} * D) / \nu = (2.56 * 0.024) / (19.71 * 10^{-6}) = 3117.2$$

Equation 11 Reynolds Number

(Turbulent)

$$\text{Pressure Drop, } \Delta p = N_L \chi ((\rho * V_{max} * V_{max}) / 2) f$$

Equation 12 Pressure Drop

From Fig. 7.14 of 5th Edition Introduction to Heat Transfer

There is no graphical line for $P_T = S_T / D = 0.169 / 0.024 = 7.04$

$P_L = S_L/D = .096/.024 = 4$

$P_T/P_L = 1.76$

From value assumed from graph, friction factor, f = .07

$\chi = 1.1$

Pressure Drop, Δp = ((2)(1.1)(1.034*2.56 *2.56)) / 2) (.03)   = .224 N/m^2

These results of these calculations reflect and represent appropriately the finite element analysis performed in SolidWorks with a level 6 meshing. As properly described and shown in Section 6 of this report.

6. SolidWorks Flow works Analysis

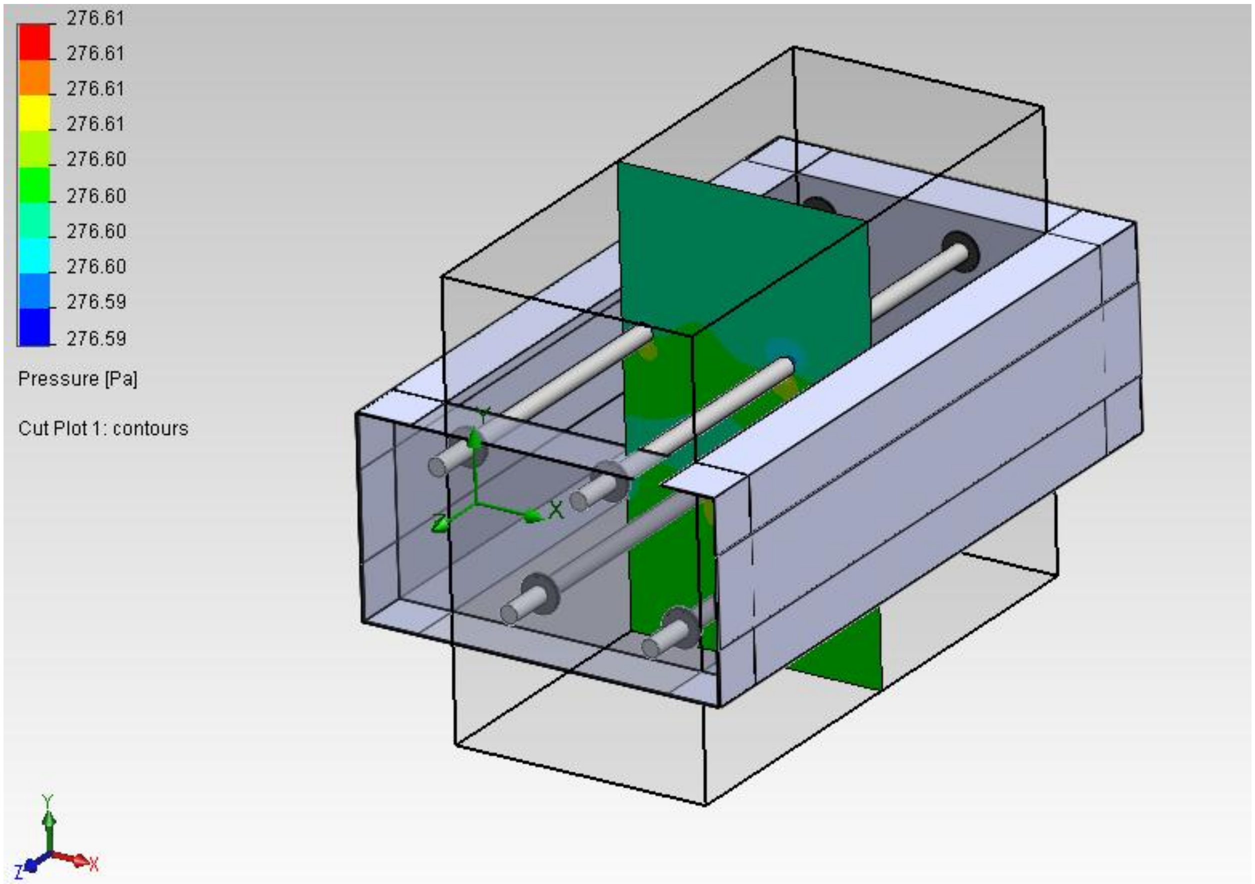

Figure 12 Pressure Variation Through the cartridge, Isometric view

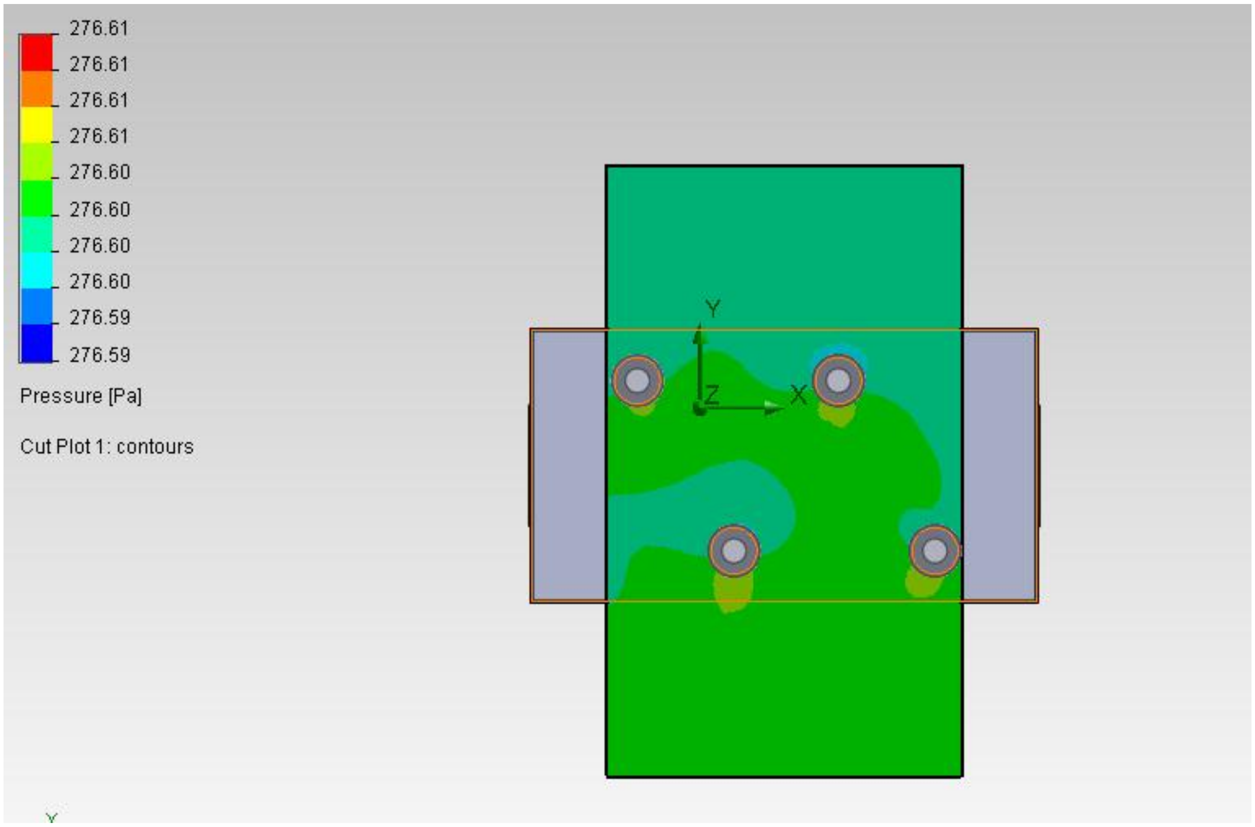

Figure 13 Pressure Variation Through the Cartridge, Front view

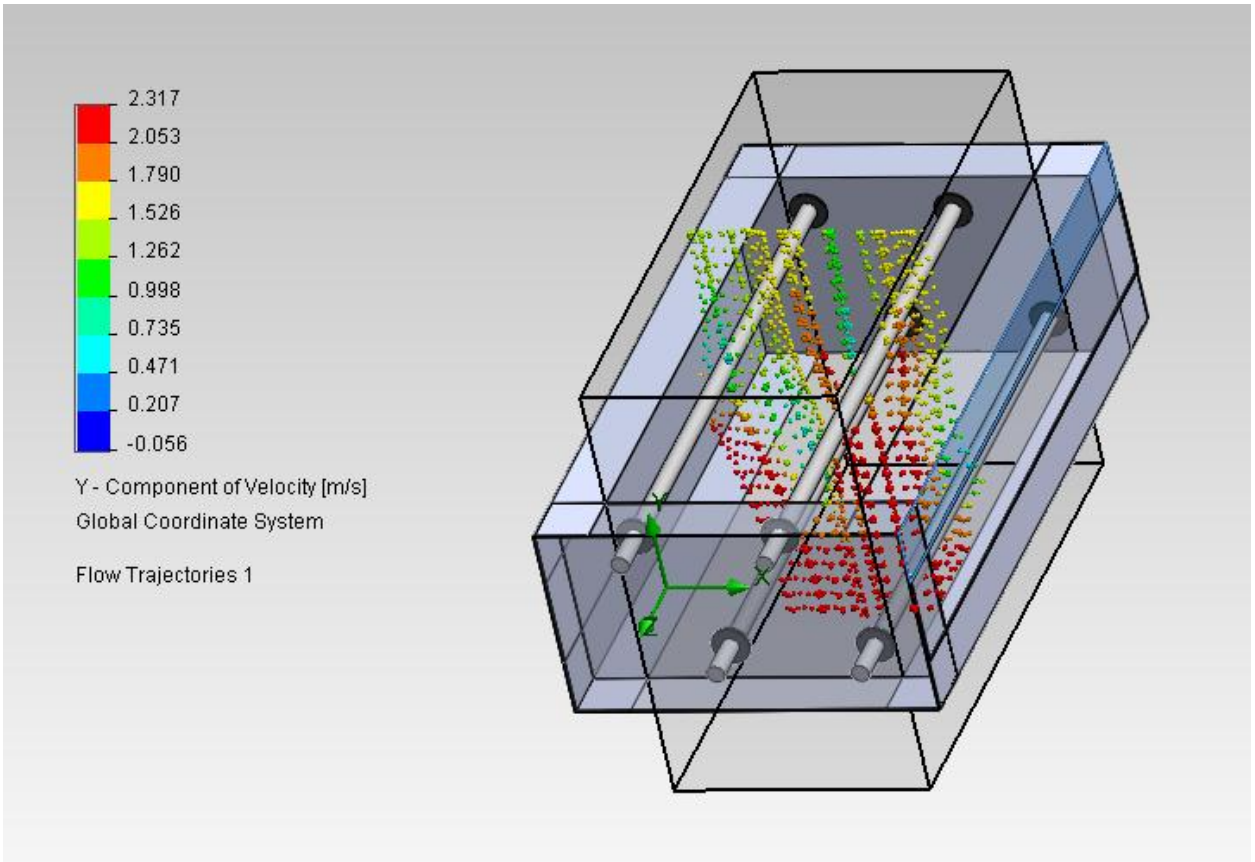

Figure 14 Velocity distribution of the fluid through the cartridge, Isometric view

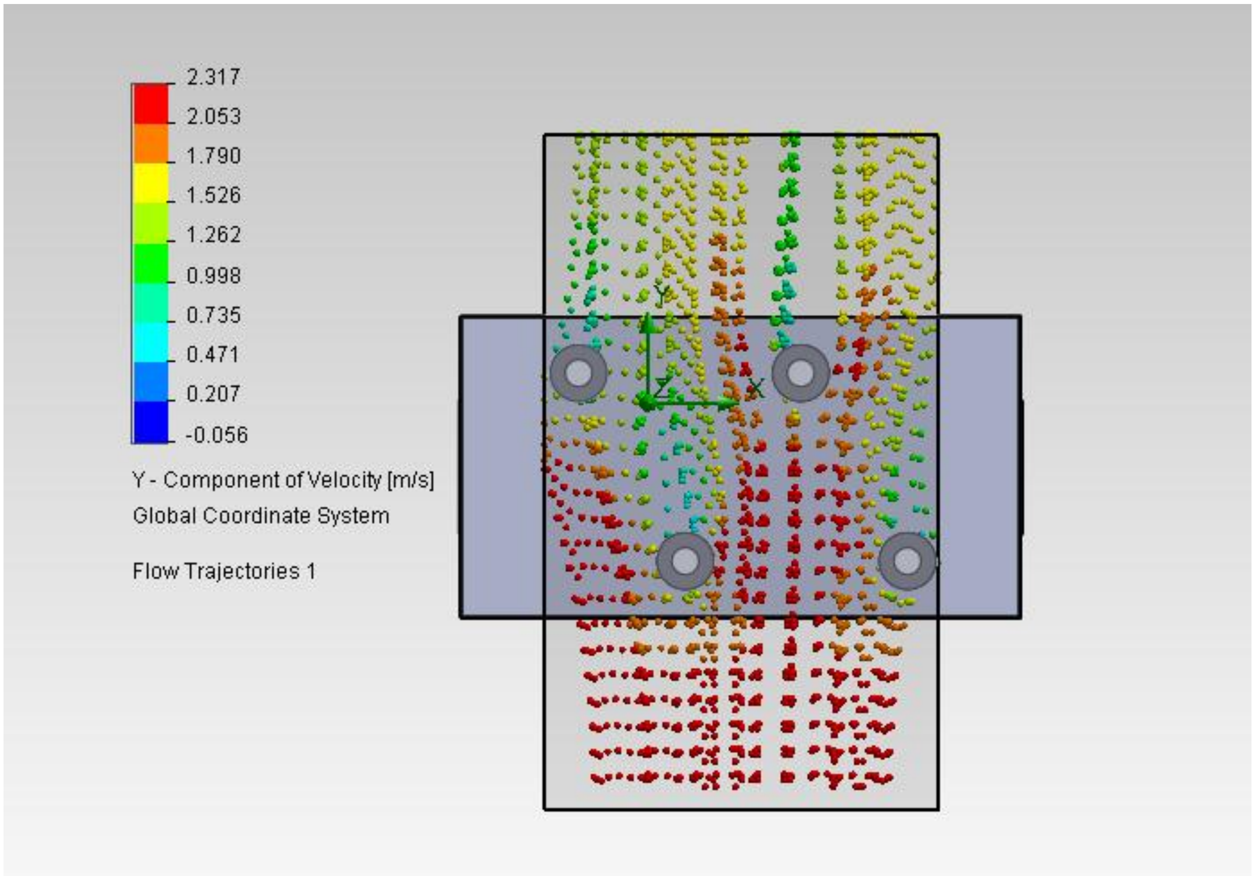

Figure 15 Velocity distribution of the fluid, Front View

From the graph, the pressure difference after multiple iterations is approximately 3.2 Pascal. This matches the calculated data from section 5

N.B. this pressure drop is only attributed to flow around UV lamps and not entire Cartridge.

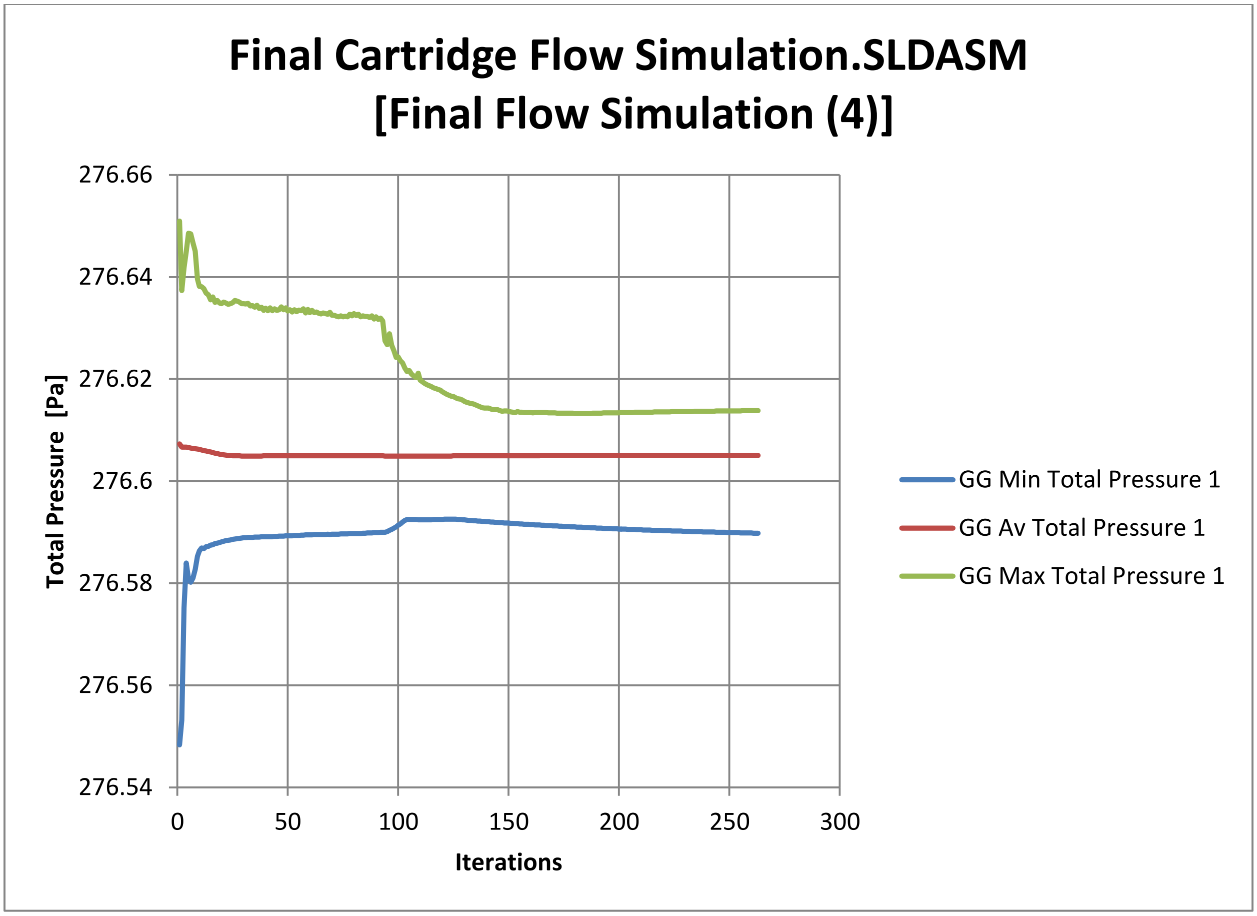

Figure 16 Final Cartridge Flow Simulation

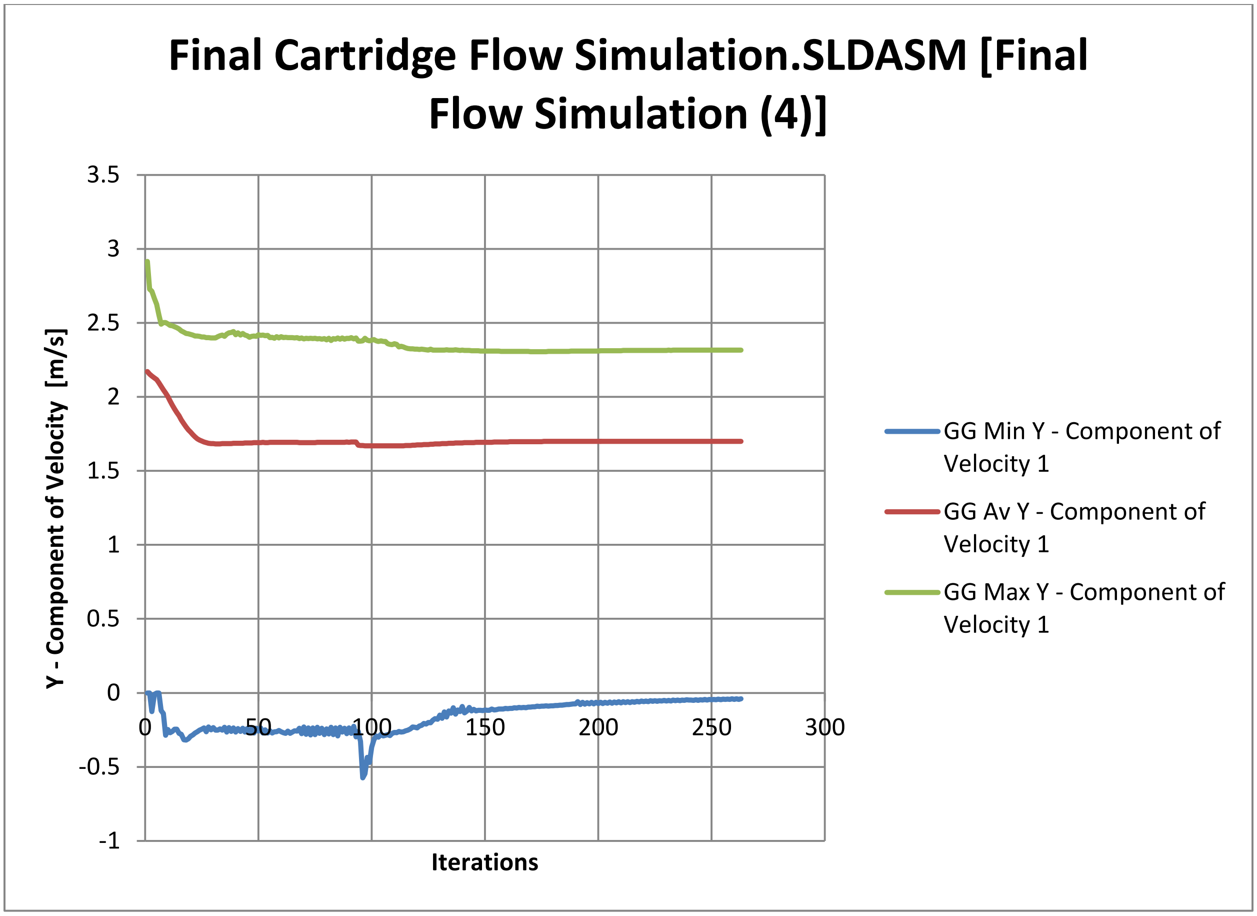

Figure 17 Final Cartridge Flow Simulation

6.1 Flow of Entire Cartridge

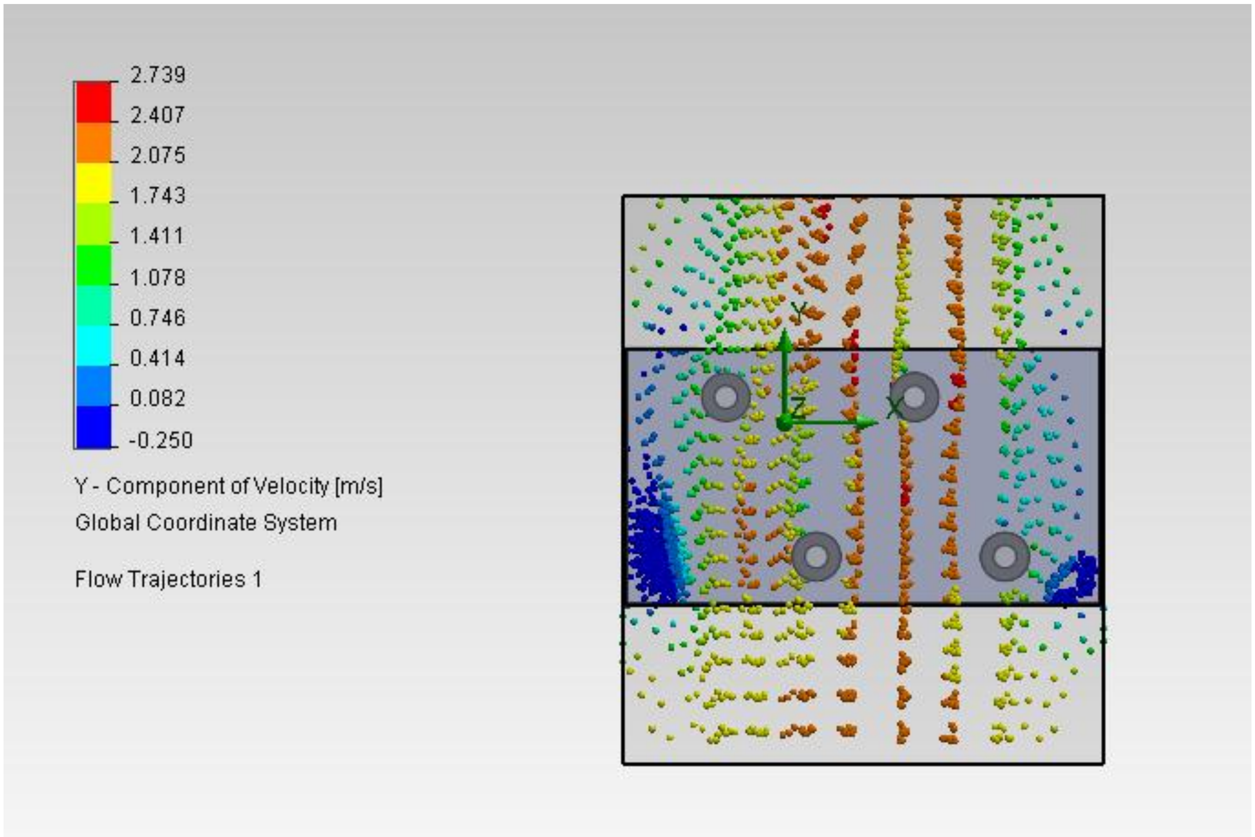

Figure 18 Velocity profile through the duct, Front View

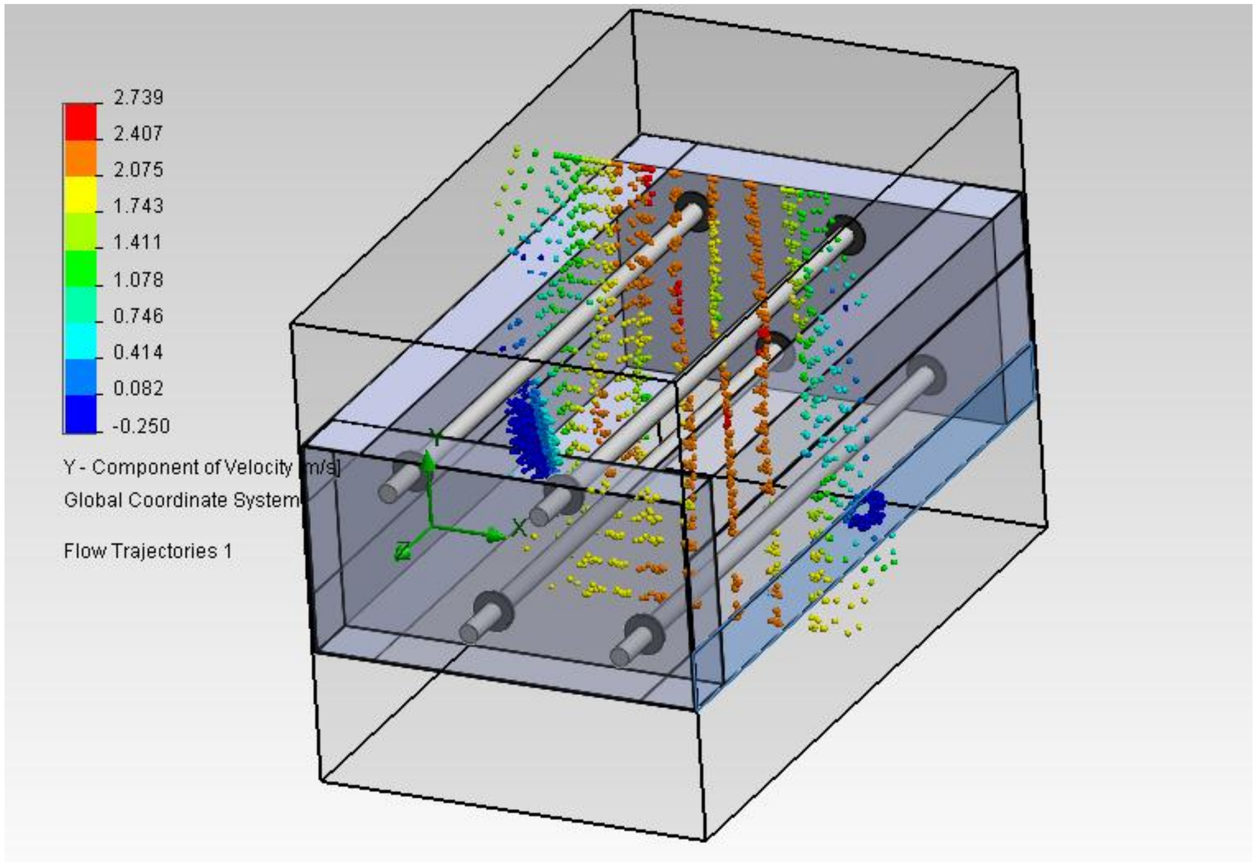

Figure 19 Velocity Profile of cartridge through the duct, Isometric View

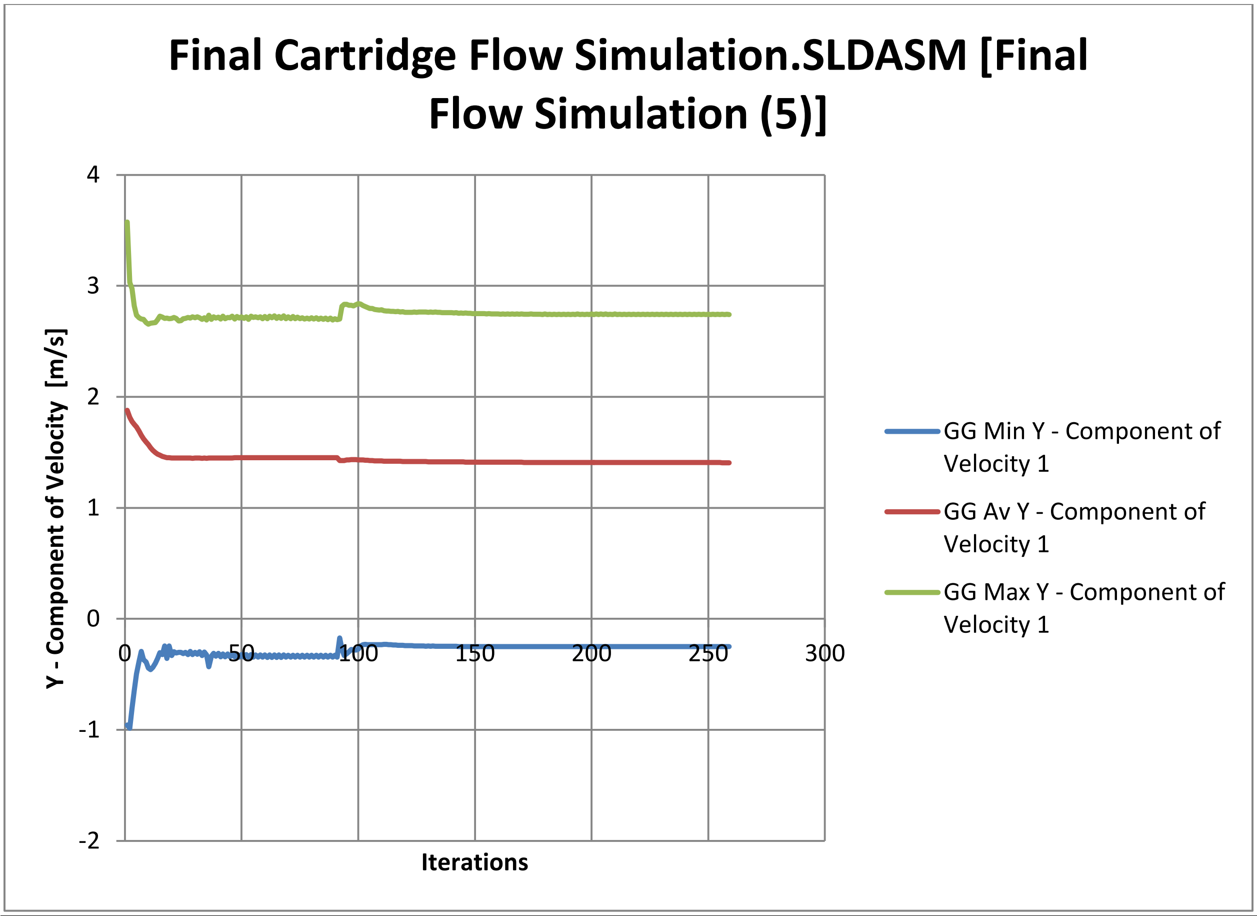

Figure 20 Velocity graph across cartridge

7. Major Components

7.1 Filters

7.1.1 Baffle Filter

Baffle filtration works by forcing the grease to enter through the layers and immediately changing the direction of the air, with the grease, working as a grease cutter. This initial baffle, aside from an initial filter, helps displace the cleaning solution fluid over to the reservoir to be evacuated. The oven hood will only use one baffle as it will immediately come in contact with the second tier of filtration.

Figure 21 Baffle Filter Insert

7.1.2 Veritech Filter

In order to maximize the UV-C lights, the group is proposing to use high efficiency filters, so that the filters do the bulk of the work. The most efficient filter in the market currently available is the Veritech Filter, by Veritech Filtration Company located in England. The Veritech Filter will take the majority of the grease out of the system and allow the UV-C lights to work with minimum amount of grease and increase its effectiveness. The Veritech Filter requires a minimum of 1000 CFM flowing through the filter for it to work properly. The Veritech Filter has multiple coils that are closely knit together to in fact behave extremely similar to a baffle system and cut the grease similarly.

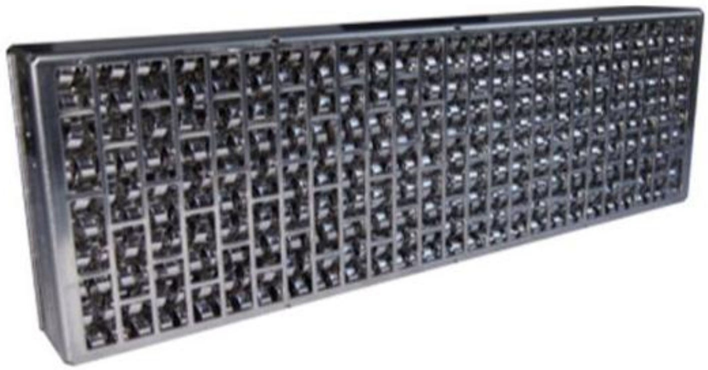

Figure 22 Veritech Filter - Courtesy of Veritech Filtration Company

7.2 UV-C Lights

The UV-C lights will serve as the third and final barrier to eliminate and destroy the grease particles. The UV-C lights can as well remove odor causing bacteria in the grease particles, thus essentially removing odor as well. The UV-C lights are the primary component that will require testing to maximize efficiency. The UV-C lights have to be tested in terms of exposure time required, as well positioning to increase the effectiveness of the UV-C lights inside of the oven hood. Installed in the cartridge system, the UVC System kills a high percentage of grease. Individual results depend on careful installation and maintenance and on the actual amount of time your system fan operates. The UV system turns on when air is flowing and leaves the lamp on for 40 minutes after the airflow stops. If airflow resumes during the 40 minutes, the timer resets to 40 minutes. When no airflow is detected for 40 minutes, the lamp turns off until the next occurrence of airflow. The UV System is designed to prevent accidental contact with electrical voltage and with ultraviolet rays in the sealed unit–the ultraviolet lamp does not illuminate. It is recommended that every month you verify that your ultraviolet lamp is operating. Operating conditions listed below.

Technical Data UV Oxidation Lamp	
Model	NIQ 170 / 90 XL
Electr. Power	160 W
Total Length	900 mm
Suitable for an airflow rate	882 CFM
Useful operating time	10.000 h Vacuum UV
Lamp wall temperature	< 100oC
Lamp base dimensions	50 mm long x 24 mmΦ

Table 4 UV Specs

Figure 23 UV-C Light

7.3 Washer Nozzle

The washer nozzles will be implemented in strategic positions to fully cover all of the UV-C lights as well as the Veritech Filter. The cleaning fluid will be disposed into a reservoir at the bottom of the oven hood that will be evacuated. The washer nozzles cannot be blocked up by the grease in the system, as well as reach each UV-C light to constantly keep the UV-C light plastic sleeves clean and working at full capacity. To quickly change spray angles, remove the nozzle and snap on a new one. All have a 1/4" connection and are for use primarily with pressure washers. The 0° spray angle produces a solid stream spray pattern; all other angles produce a flat spray pattern. The Nozzle is made of Type 416 stainless steel with color-coded nylon guards for easy identification. Maximum pressure is 4,000 psi.

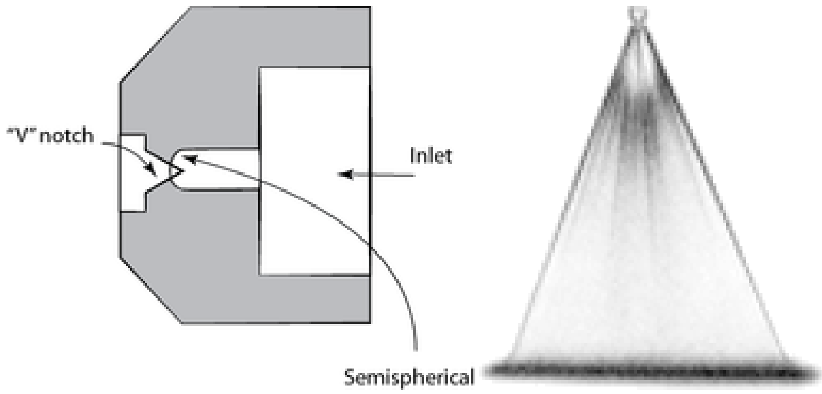

Figure 24 Flat Spray

Figure 25 Washer Nozzles

7.4 Current Sensor

The Hawkeye 904 microprocessor-based current status switches provide a unique solution for accurately monitoring status of motors controlled by variable frequency drives. The H904 stores the sensed amperage values for normal operation at various frequency ranges in non-volatile memory. Some key features of the H904 are:

- Self-adjusting trip point…factory programmed to detect belt loss under current conditions
- Provides accurate status for VFD loads
- Automatically compensates for the effects of frequency and amperage changes associated with VFDs
- LED indicates normal and alarm conditions
- Huge labor savings—no need to calibrate in live starter enclosures...install and go
- Available with a relay...status and control in one package, saving time and space
- Bracket can be installed in three different configurations...added flexibility
- Monitors both frequency and amperage...distinguishes normal drops in amperage due to frequency changes from abnormal drops due to mechanical failure
- Split-core design is ideal for retrofits...no need to remove conductor
- 5-year limited warranty

Figure 26 Current Sensor

7.5 Exhaust Fan

The fan being used is the GB-121 Roof Downblast Exhaust Belt & Direct Drive from Greenheck. For the conditional requirements of our hood (1000 cubic feet per minute through our Veritech filter and maintaining 1 inch of water of static pressure) this fan has a max operating speed of 1725 rpm's and 1600 cfm's. This fan was chosen to compensate for the pressure losses throughout the hood due to the additions of the components and various bends within the hood design.

The GB model is the belt drive model and was chosen due its optimum operation for average length and/or average resistance ductwork and high volume/average pressure. The fan also has a variable speed controller which would receive its information to operate at a specific speed to maintain the 1000 cfm through the veritech filter. This variation will be controlled by a variable frequency drive. The fan also has a damper attached to it which is designed to prevent outside air from entering back into the building when the fan is off. Found in the figures below are the images of the exhaust hood and its components.

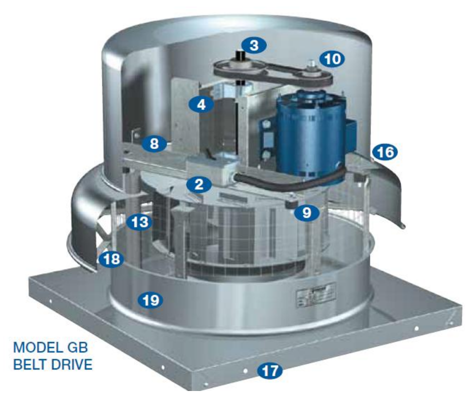

Figure 27 Exhaust Fan

1) **Disconnect Switch -** NEMA-1 switch is factory mounted and wiring is provided from the motor as standard (other switches are available). All wiring and electrical components comply with the National Electrical CodeR (NEC) and are either UL Listed or Recognized.

2) **Fan Shaft** - Precisely sized, ground and polished so the first critical speed is at least 25% over the maximum operating speed. Where the shaft makes contact with bearings, tight tolerances result in longer bearing life.

3) **Bearings** - 100% factory tested and designed specifically for air handling applications with a minimum L10 life in excess of 100,000 hours (L 50 life of 500,000 hours).

8) **Lifting Points -** Various lifting points are located on the drive frame and bearing plate (on select sizes).

9) **True Vibration Isolation** - Vibration isolators, with no metal-to-metal contact, support the drive assembly and wheel for long life and quiet operation.

10) **Drive Assembly** - Belts, pulleys, and keys are oversized 150% of driven horsepower. Machined cast pulleys are adjustable for final system balancing. Belts are static-free and oil-resistant.

13) **Internal Conduit Chase** - A large diameter conduit for installing electrical wiring through the curb cap into the motor compartment.

16) **Fan Shroud** - One-piece, heavy-gauge aluminum with a rolled bead for extra strength directs exhaust air downward.

17) **Mounting Holes** - Curb cap has pre - punched mounting holes to ensure correct attachment to the roof.

18) **Internal Supports** - Heavy-gauge supports and bracing are added for additional strength to withstand a wind of 150 mph (75 psf).

19) **Reinforced Wind Band** - High wind fans include additional reinforcement for maximum strength.

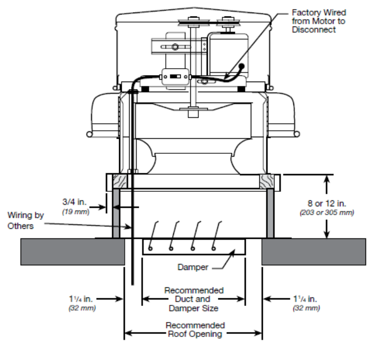

Figure 28 Sectional 2-D Model of Exhaust Fan

7.6 Cartridge

Since the bulbs will need service and maintenance at the end of every cooking day, an easy system had to be designed for simple removal of the unit. The cartridge will be made out of 20 gauge sheet metal. The sheet metal makes it complaint in all food use due to its properties. It also offers a high temperature tolerance which is essential for the overall oven hood to receive UL Listing.

The cartridge system will be docking the UV bulbs in a staggered pattern shown on figure 11. The staggered flow maximizes the flow through the bulbs ultimately ensuring that the air and grease mixture gets distributed through the bulbs. Having gone through the Veritech filter, which requires a high Reynolds number, hence, a turbulent air flow, the air flow reaching the bulbs will be turbulent and further maximizing the time and the effectiveness of the UV lights on the grease compounds.

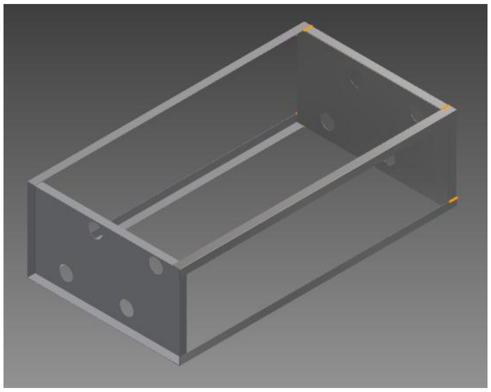

Figure 29 Staggered Pattern Front Plane

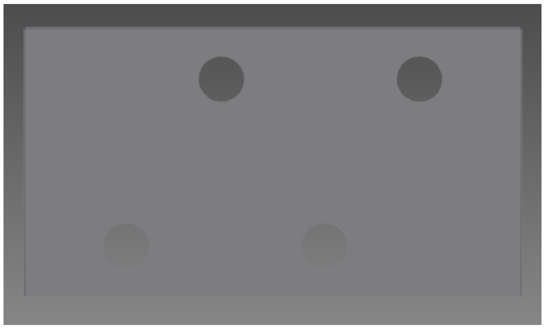

Figure 30 Staggered Pattern

7.6.1 GASKETS

As earlier described on grease compounds, grease is very messy and is the main parameter in terms of designing. As to say, all the design constraint and requirements are to meet the specific grease parameters. Therefore, when choosing the proper gaskets sealing the UV lights is the main purpose and priority. Gaskets were used to properly seal the UV lights in the cartridge and in the chamber. In choosing the proper gaskets multiple materials had to be taken into account. The materials were narrowed down to polytetrafluoroethylene (PTFE), and silicone based gaskets. Silicone offers a much better variety and ability for food and pharmaceutical systems. But the limiting factor of silicone is its temperature range.

Silicone only has a temperature range up to 450^{o} F. Looking at PTFE material it has by the greatest temperature range amongst the different materials used for gaskets. PTFE can hold up to 500^{o}F which, in turn will allow this unit to be UL listed. Not to be outdone, the PTFE is excellent for non-stick applications. All the materials meet and exceed sanitary standards as well as being USDA compliant. Therefore choosing PTFE became the proper solution for the situation. Choosing gaskets with a 1¼” outer diameter with a .94” inner diameter bulb diameter ensures a tight squeeze to guarantee there will be no leaking into the bulb control box.

8. Proposed Testing

A prototype is an early sample or model built to test a concept or process. It serves to act as something to be replicated or learned from. This project is a contracted job by a company known as Hood Depot. The final construction of our hood will be the prototype of the UV light exhaust hood that Hood Depot intends on inspecting and putting into production. A full miniature model replica of the hood with all the installed components was not found to be feasible for this project's time frame and was also deemed to be disadvantageous. Within the project description however the team was set the task of testing the effectiveness and efficiency of the UV light. This testing method is where our pseudo-prototype was developed.

After much detailed research from both primary and secondary sources and combining our engineering knowledge, a potential testing method for the exhaust hood was developed where an assembly of parts with different measuring instruments was put together. This assembly serves as our prototype. The prototype is currently still in production. However it consists of a capsulation vessel, tubing, a Rayonet Photochemical Reactor, filter, vacuum pump, dosimeter, filter, test tubes and a Gas Chromatography Mass Spectrometer, hot plate and various foods.

The prototype assembly begins with the food being cooked on the hot plate. The capsulation vessel will then be placed over the cooked food allowing for the smoke/grease vapor to flow through the tubing connected to it. This tubing is connected to a vacuum pump. This pump regulates the flow rate out to the output tube. This tube is then passed through the photochemical reactor. Within the photochemical reactor, a dosimeter would be attached to measure the light intensity being emitted from the UV Lights within the reactor. As the reaction between the grease particles and the UV-C light occurs, the end products are pumped further along the tube into a filter. Figure 1.1 depicts an initial design of the prototype illustrating the capsulation vessel, vapor pump and the Rayonet reactor.

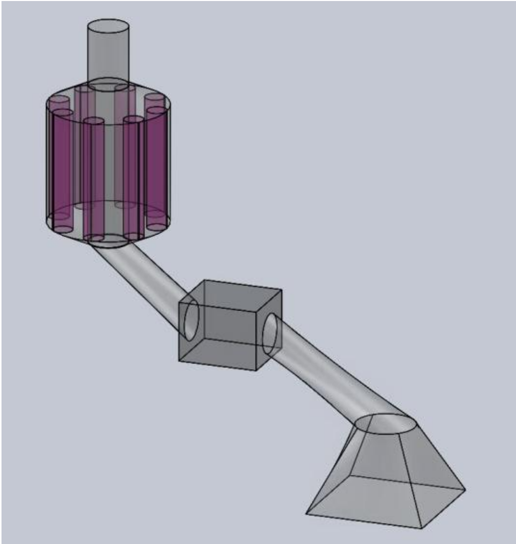

Figure 31 Prototype Model

The grease collected from the filter is then placed within the gas chromatography mass spectrometer and further analyzed.

9. Prototype System Description

The testing procedure has several stages as well as limiting factors to the experiment which need to be taken into the account. The variables that directly affect the effectiveness of this UV light segment of the filtration system of the hood are the length of time the UV-C light needs to be exposed to the grease vapor to allow for the chemical reaction to fully take place, the light intensity of the UV-C light that is required to cause the photolysis, the light configuration that maximizes exposure to the grease vapor and the amount of cubic feet per minute (cfm's) that need to be maintained throughout the kitchen hood. By collecting the data from the prototype, the results should allows for all of these factors to be analyzed, giving the optimum results for the final prototype of the exhaust hood that Hood Depot will be using. The major limiting factor that is being taken into consideration is that the theory states that the UV-C light breaks down the smaller particles of the grease vapor. In our prototype design, this will not be accounted for as there is no initial filtration of the grease vapor.

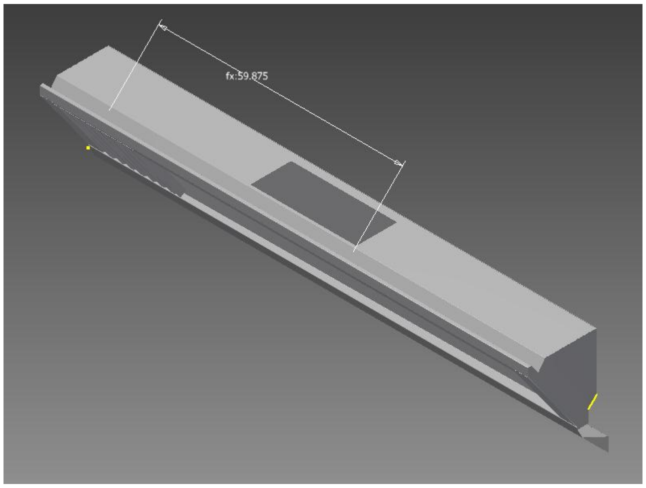

Figure 32 Prototype Oven Hood

Figure 33 Oven Hood

The testing procedure first consists of measuring the amount of grease vapor that is produced by a specific food group with a known fat content. The food will be cooked within the capsulation vessel allowing for the grease to travel through the tubes and through a filter. A sample from this filter will be then taken and measured using the gas chromatography mass spectrometer. This will produce a quantified value of how much grease is being produced. The apparatus will then be cleaned thoroughly. The same food group with exactly the same known fat content will be cooked again and placed into the full prototype. The pump's power will be noted to calculate the volumetric flow rate of the grease vapor `being outputted.

The tubing will then pass through the photochemical reactor while being observed for any visual change. The light intensity from the dosimeter will be recorded as well as the light configuration within the reactor. A sample from the filter will then be taken again and measured using the gas chromatography mass spectrometer to determine whether any physical or chemical changes occurred in the new samples. Sample will be taken at timed intervals to determine how long is required for any chances to take place. This entire test will be repeated several times while varying the light intensity, light configuration and volumetric flow rate to account for the factors that affect the efficiency and effectiveness of the UV light filtration system. The results will be tabulated, graphed and analyzed. These results will be compared to the initial values collected to determine whether any changes have occurred. Once the data has been analyzed, the optimum operating values can be determined and applied.

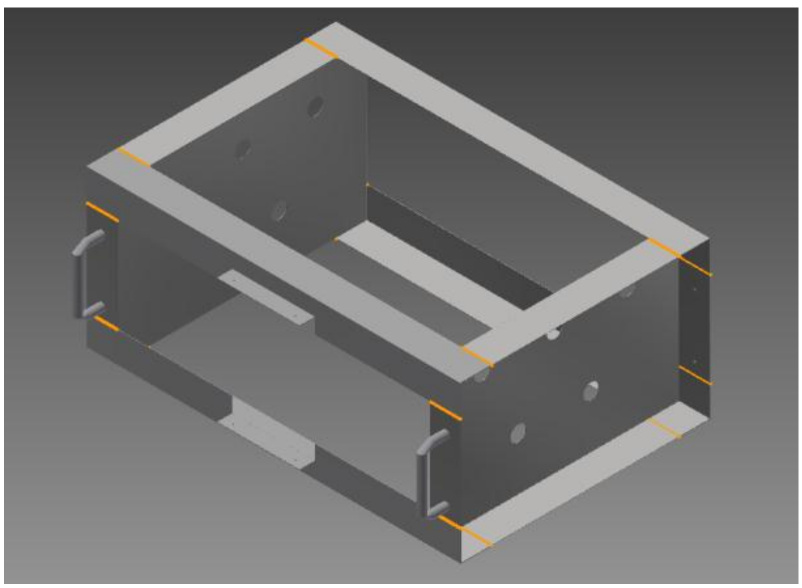

Figure 34 Prototype Cartridge for Testing

10. Production

Using the sheet metal application of Inventor Pro, the production was made easy. Using realistic bends, welds, and punches it made the production task feasible and reasonable (Referring to Figure 9 that was the final design that got punched at Hood Depots facilities).

10.1 Schematic Drawing

The schematic provides the manufacturers and machinists the ability to view exact dimensions to prove their feasibility in the construction phase.

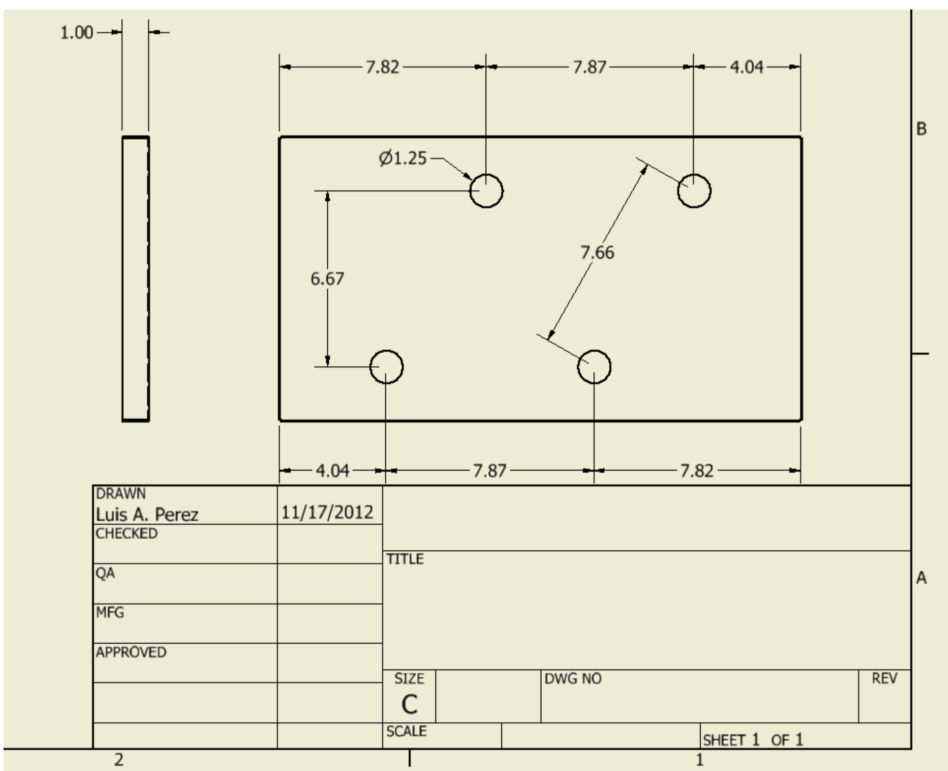

Figure 35 Cartridge Holder Schematics

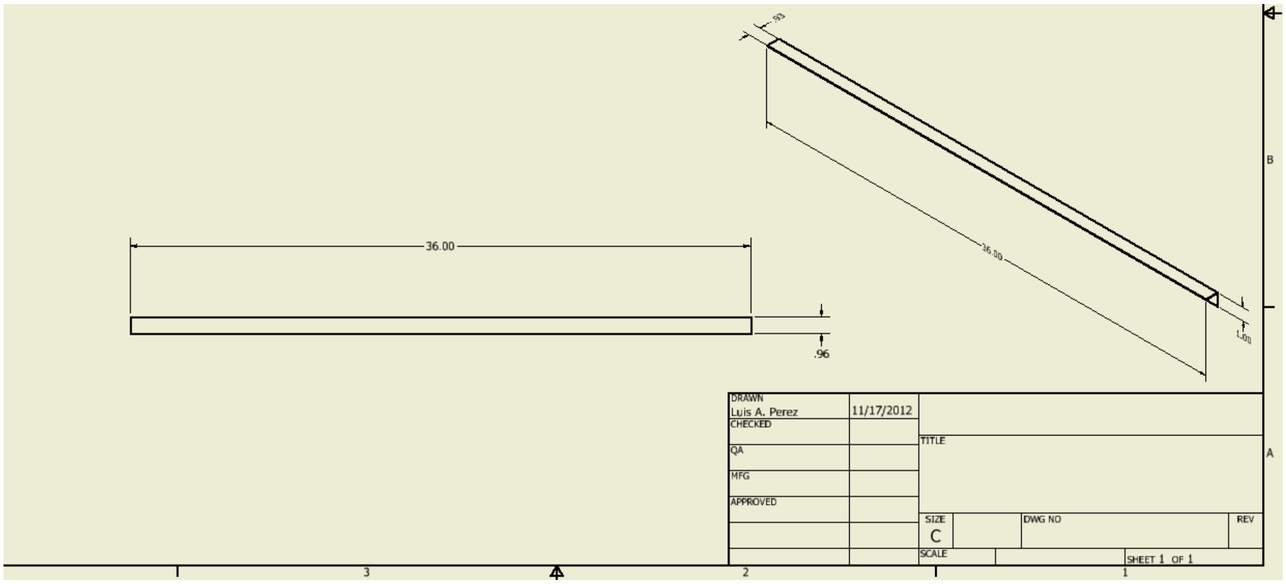

Figure 36 Angle Arm Schematics

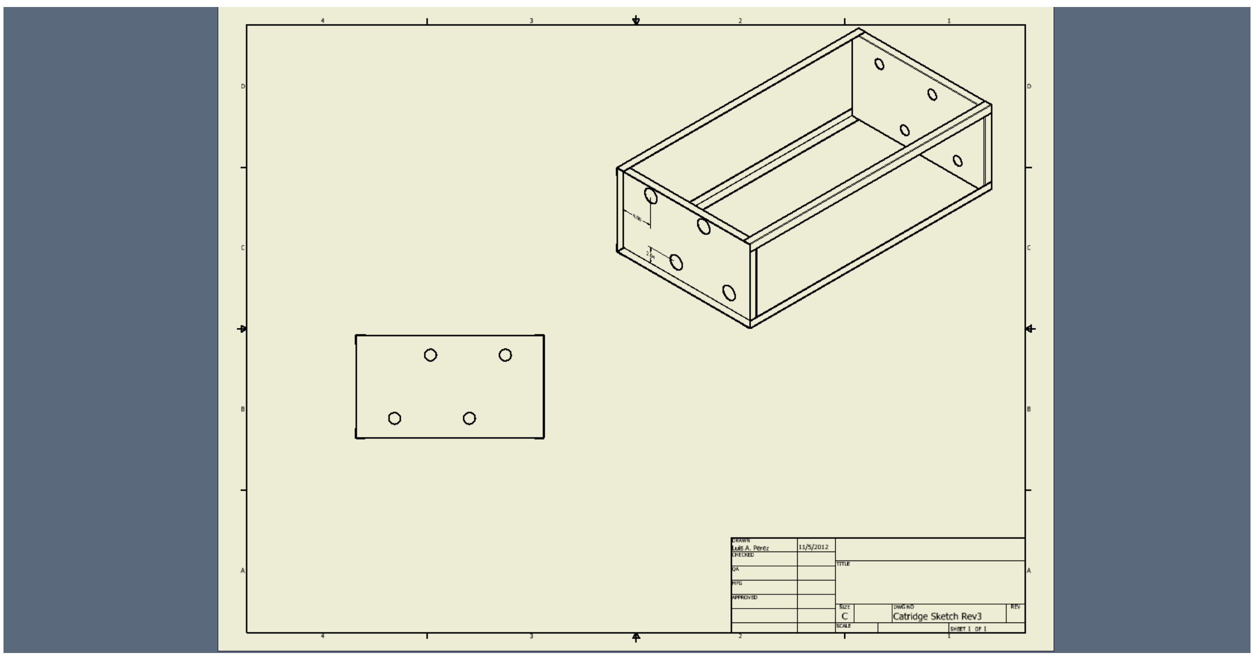

Figure 37 Cartridge Schematic

10.2 Flat Pattern

The flat patterns show the manufacturer what needs to be punched, pressed, and or bent. It's an easier tool that allows for easier viewing as well as providing feasibility to the manufacturer.

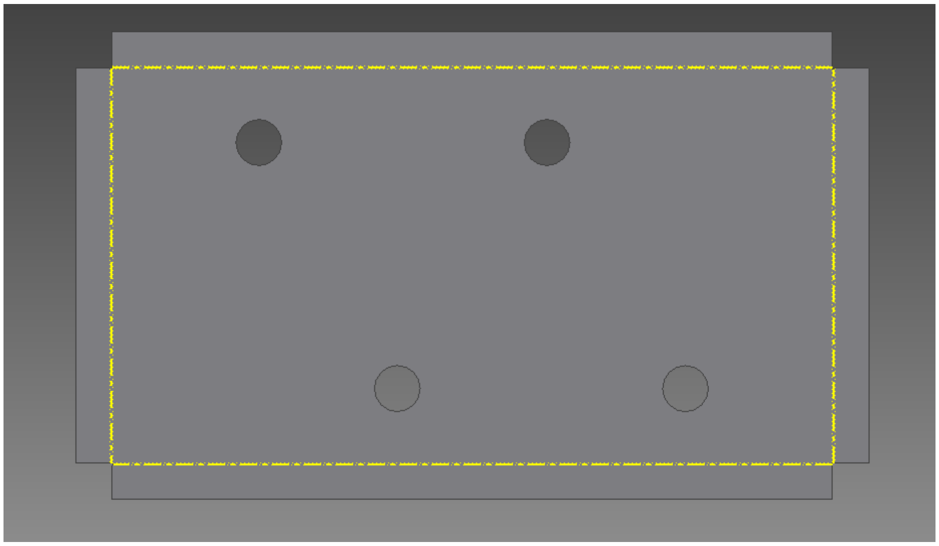

Figure 38 Cartridge Holder Flat Pattern

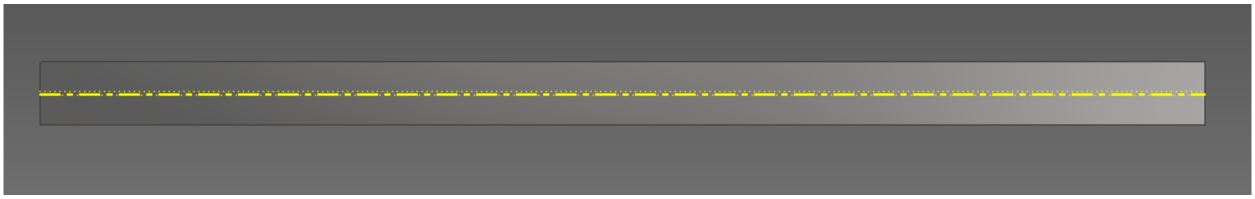

Figure 39 Angle Arm Flat Pattern

As shown in both figures 26 and 27 the bends and punches will prove to be fairly simple.

Figure 40 Cartridge Production

11. Cost Analysis

A prototype represents the shell of an actual production application. Prototypes are built early in the development lifecycle and they are used to provide valuable insight into look-and-feel, and the general workflow of an application. The initial phase of our team is to examine the product to ensure any potential obstacles are discovered and resolved prior to production in order to minimize the need for additional design changes. Then the team works closely with current and potential customers and suppliers to meet aggressive prototype launch timelines. Capital equipment in place at Hood Depot helps to reduce up front tooling costs for small production builds and keeps prototype costs low.

KITCHEN HOOD PROTOTYPE				
DESCRIPTION	**PART NUMBER**	**QTY**	**UNIT PRICE**	**EXT PRICE**
STATIC PRESSURE TRANSMITTER		1	$20.00	$20.00
STATIC PRESSURE TRANSMITTER PROBE		1	$40.00	$40.00
EXHAUST FAN START/STOP COMMAND		0	$15.00	$0.00
EXHAUST FAN STATUS		0	$50.00	$0.00
FILTER		1	$10.00	$10.00
FILTER STATUS SWITCH		1	$65.00	$65.00
FILTER STATUS SWITCH PROBE		2	$13.00	$26.00
UV LIGHT STATUS		0	$150.00	$0.00
WASHER NOZZLES		0	$40.00	$0.00
DIGITAL CONTROLLER		0	$350.00	$0.00
SUBPANEL		0	$500.00	$0.00
CONFIGURATION, ADDRESSING, DOWNLOADING,LABELING	ENGINEERING	24	$65.00	$1,560.00
COMMISSIONING	ENGINEERING	24	$65.00	$1,560.00
SUBMITTALS AND WIRING DIAGRAMS	ENGINEERING	0	$65.00	$0.00

INTEGRATION	ENGINEERING	0	$65.00	$0.00
INSTALLATION	INSTALLATION	1	$500.00	$500.00
			SUB-TOTAL	$3,781.00
			FREIGHT	$50.00
			SUB-TOTAL	$3,831.00
		7.0%	SALES TAX	$268.17
			TOTAL	$4,099.17

Table 5 Cost Analysis

11.1 Project Bid

Project Director		**Perez, Luis**		
A. Personnel				
Name		**Telephone**	**Person Hrs**	**Salary**
1	Perez, Luis	305-2989956	1100	$1,000.00
2	Ramos, Christopher	786-553-2733	1100	$1,000.00
3	Solomon, Aaron	786-406-4859	1100	$1,000.00
4	Hood Depot Tech	1-800-322-8730	200	$500.00
6	**Subtotal**			$3,500.00
B. Fringe Benefits (10% of A.6)				$350.00
C. Total Salaries, Wages, and Fringe Benefits (A.6 + B)				$3,000.00
D. Miscellaneous Costs				
1	**Materials and Supplies**			$3,000.00
2	**Computer Time ($0.25 per minute of on-line time)**			$100.00
3	**Other**			$0.00
4	**Subtotal**			$3,100.00
E. Travel				$150.00
F. Consultant Services (Name and Amount)				
1	Hood Depot			$500.00
2	Chemistry Professor			$75.00
3	**Subtotal**			$575.00
G. Total Direct Costs (C+D.4+E+F.3)				$6,825.00
H. Indirect Costs (50% of G)				$3,412.50
I. Amount in This Bid (G + H)				$10,237.50

Table 6 Project Bid Form

11.2 Quote

KITCHEN HOOD				
DESCRIPTION	PART NUMBER	QTY	UNIT PRICE	EXT PRICE
STATIC PRESSURE TRANSMITTER		1	$20.00	$20.00
STATIC PRESSURE TRANSMITTER PROBE		1	$40.00	$40.00
EXHAUST FAN START/STOP COMMAND		1	$15.00	$15.00
EXHAUST FAN STATUS		1	$50.00	$50.00
FILTER		1	$10.00	$10.00
FILTER STATUS SWITCH		1	$65.00	$65.00
FILTER STATUS SWITCH PROBE		2	$13.00	$26.00
UV LIGHT STATUS		1	$150.00	$150.00
WASHER NOZZLES		3	$40.00	$120.00
DIGITAL CONTROLLER		1	$350.00	$350.00
SUBPANEL		1	$500.00	$500.00
CONFIGURATION, ADDRESSING, DOWNLOADING,LABELING	ENGINEERING	48	$65.00	$3,120.00
COMMISSIONING	ENGINEERING	48	$65.00	$3,120.00
SUBMITTALS AND WIRING DIAGRAMS	ENGINEERING	4	$65.00	$260.00
INTEGRATION	ENGINEERING	2	$65.00	$130.00
INSTALLATION	INSTALLATION	1	$1,500.00	$1,500.00
			SUB-TOTAL	$9,476.00
			FREIGHT	$50.00
			SUB-TOTAL	$9,526.00
		7.0%	SALES TAX	$666.82
			TOTAL	$10,192.82

SYSTEM TOTAL			
		SUB-TOTAL	$9,476.00
		FREIGHT	$50.00
		SUB-TOTAL	$9,526.00
	7.0%	SALES TAX	$666.82
		TOTAL	$10,192.82

Table 7 Project Quote

11.3 Energy Savings

With an upward trend in utility costs in the U.S. of 6% annually restaurant owner, must spend a larger portion of revenue to pay for utility costs associated with the hot water system. The annual cost for conventional water heating systems operated in Florida in a typical quick- and full-service restaurant is displayed in Table 5. The projected operating cost of $3,500 and $19,650 translates to a substantial portion of the restaurant’s total utility bill. With the reduce cost in the wash down system, detergent pumps and drain system use. Hot water wash is a large operating expense when compared to UVC systems. There is little to no steam cleaning required throughout the duct system. Clean ducts and fans extend the life of the system. The result is a substantial reduction in cleaning costs for air pollution control systems with sums reaching a high of $2,000.00 to $20,000.00 dollars in maintenance cost a year.

Typical hot water system cost for restaurants						
	Water Use (gal/d)	Gas Use (therms/yr)	Water/Sewer Cost	Gas Cost	Electricity Cost	Annual Utility Cost
Quick Service	500	1400	$2,000.00	$1,500.00	-	$3,500.00
Full Service	2500	8800	$9,800.00	$9,700.00	$150.00	$19,650.00

Table 8 Typical hot water system cost for restaurants

12. Project Management

12.1 Timeline

Task	Start Dates	Duration (Days)	Duration (Hours)	Hour per Individual
Project Selection	November 17, 2011	70	1680	560
Topic Presentation	January 15, 2012	25	600	200
Synopsis Report	February 1, 2012	15	360	120
10% Report	February 7, 2012	25	600	200
Proposed Design	February 28, 2012	15	360	120
Poster Design	February 26, 2012	25	600	200
25% Report	March 21, 2012	20	480	160
Proposal	March 22, 2012	25	600	200
Cost Analysis	March 28, 2012	25	600	200
Structural Design	April 15, 2012	35	840	280
Structural Analysis	May 12, 2012	21	504	168
75% Report	May 29, 2012	60	1440	480
Manufacturing	July 15, 2012	27	648	216
Testing	August 10, 2012	20	480	160
100% Report	August 22, 2012	65	1560	520
Presentation Rehearsal	October 19, 2012	47	1128	376
Senior Presentation	December 5, 2012	1	24	8

Table 9 Numerical Representation of Timeline

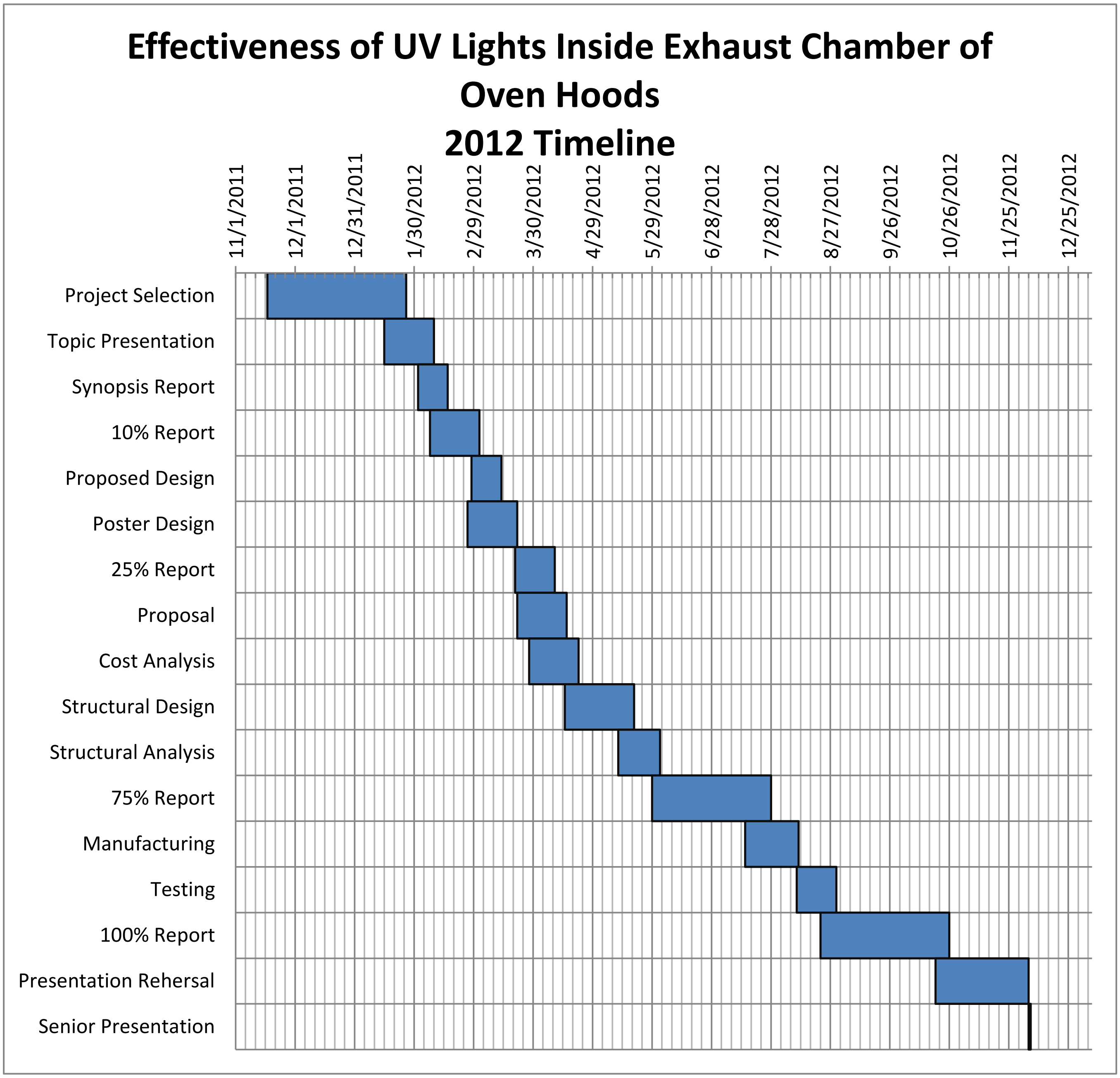

Table 10 2012 Timeline Gantt Chart

13. Conclusion

The UV-C lights inside of the oven hood can essentially cut the costs of present day high rise grease filters. The restaurants in urban locations cannot exhaust the grease through the roof of the high rise building. Nor can they not exhaust such grease gasses on nearby streets or alleys for health concerns, as well as strict laws forbidding such actions. Air quality is a major concern for both the environment in commercial kitchens. By Hood Depot keeping its position as the technology leader in commercial kitchen ventilation, and collaborating with FIU our research has incorporated Ultra Violet light technology in their High Efficiency Kitchen Hood. There are two primary chemical reactions that take place in the UV oxidation process.

The UV lights emit radiation in the UV-C band and also create ozone in the vicinity immediately surrounding the lamps. The chemical process taking place when UV-C directly hits molecular chains and breaks them into smaller compounds is called Photolysis. The second chemical process that takes place is when the ozone, created from the interaction of the UV light with the oxygen molecules in the air, continues to react with the grease molecules as they move through the exhaust ducts to the outside. This process is called Ozonolysis. System efficiency is the starting point for a fully operable UV system. Hood Depot's line of high efficiency hoods will now be equipped with Capture Ray UV-technology.

Critical to the effectiveness of the UV system, the first stage grease extraction will be with the Veritech filters. It removes the larger grease particles allowing the UV system to effectively act on the smaller particles. There was great importance to maximize exposure of the exhaust airflow to UV light chamber for the computational fluid dynamics simulation that was used to optimize the airflow calculations in the UV chamber. As an ASHRAE research project, the emissions calculations were documented from different cooking processes.

13.1 Key Benefits of a UVC Hood System

- Cleans grease out of hood chamber, ductwork and exhaust fan, leaving a cleaner and safer exhaust system.
- No special installation requirements or costs.
- Self-monitoring for lamps and fan operation.
- System requires no wash down and uses less than 300 watts of light for every seven feet of hood.
- The system has the same maintenance requirements as a standard baffle filter hood, with the filters cleaned periodically in a dishwasher.

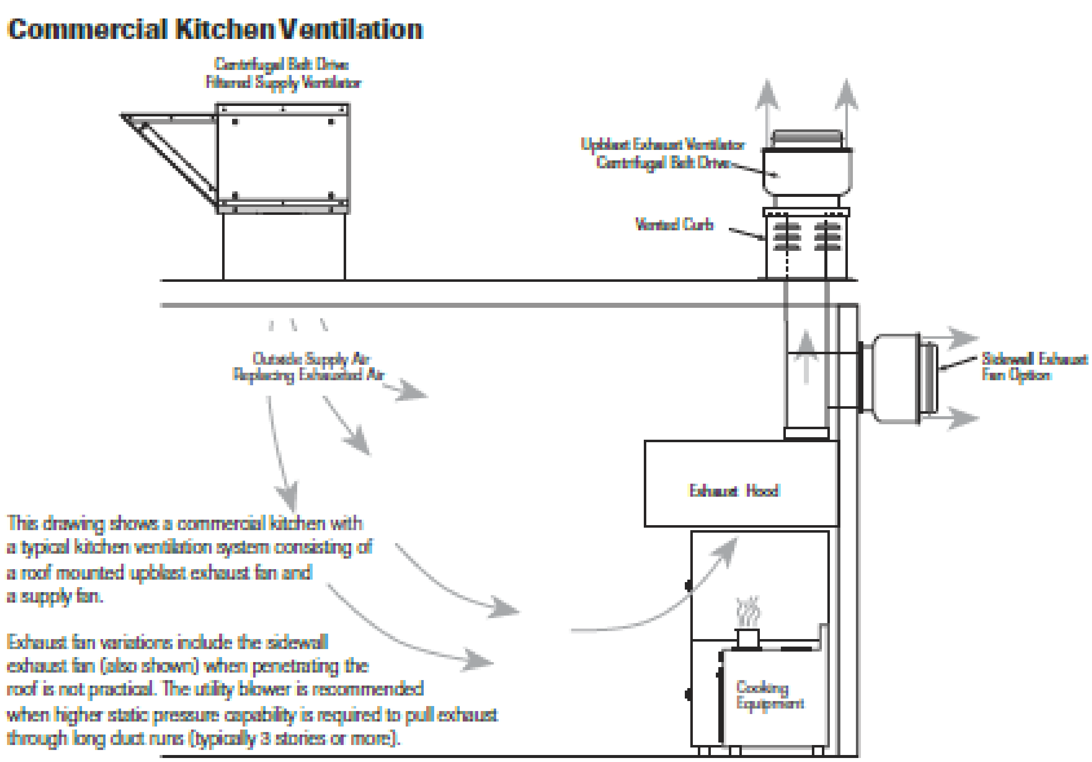

Figure 41 Full System Diagram

14. References

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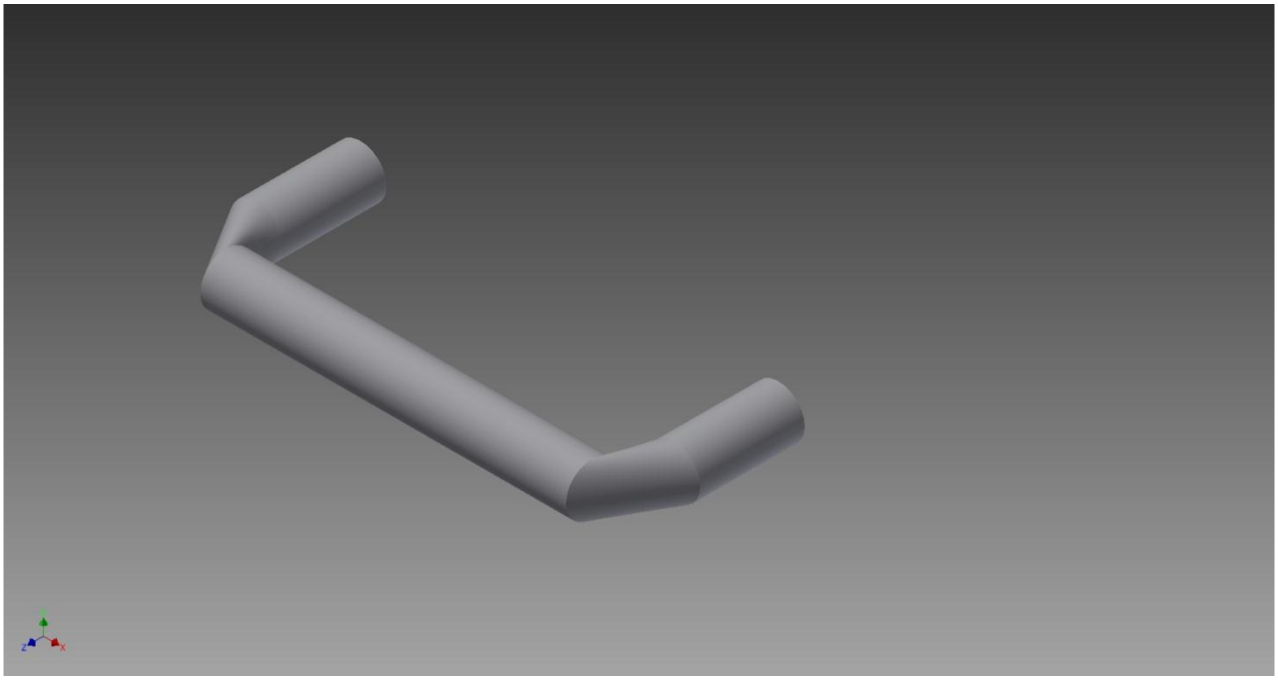
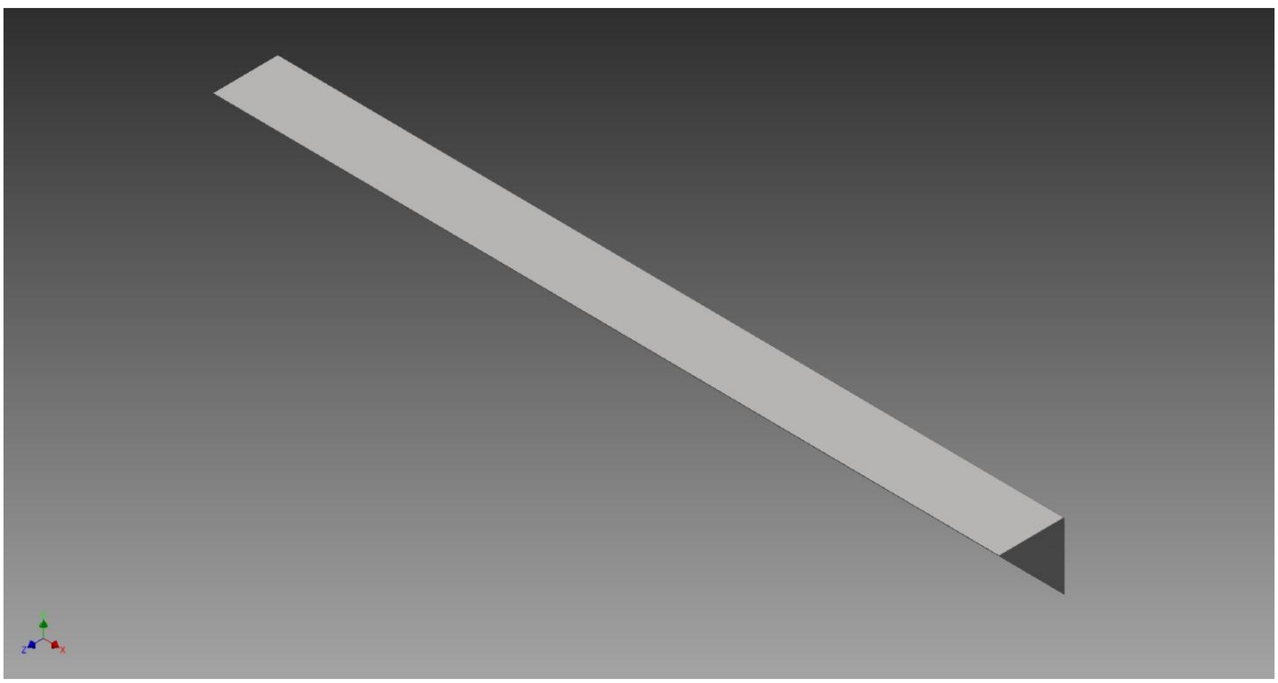
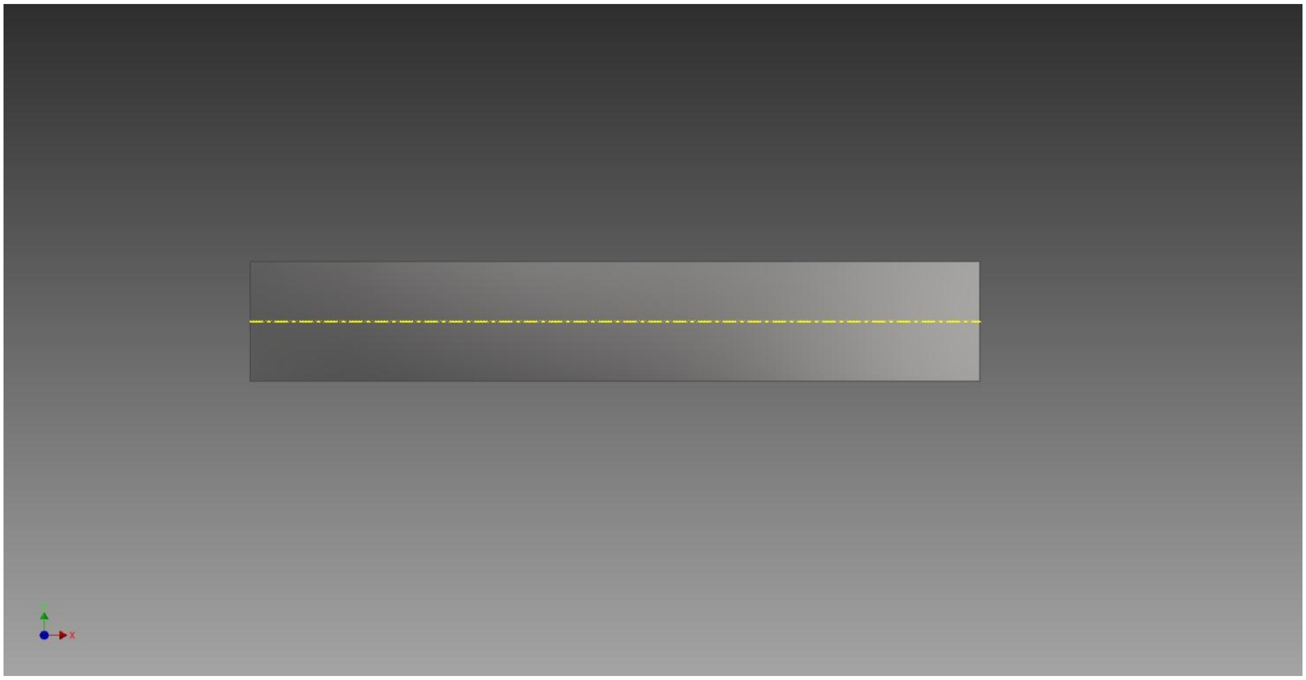
15. Appendix

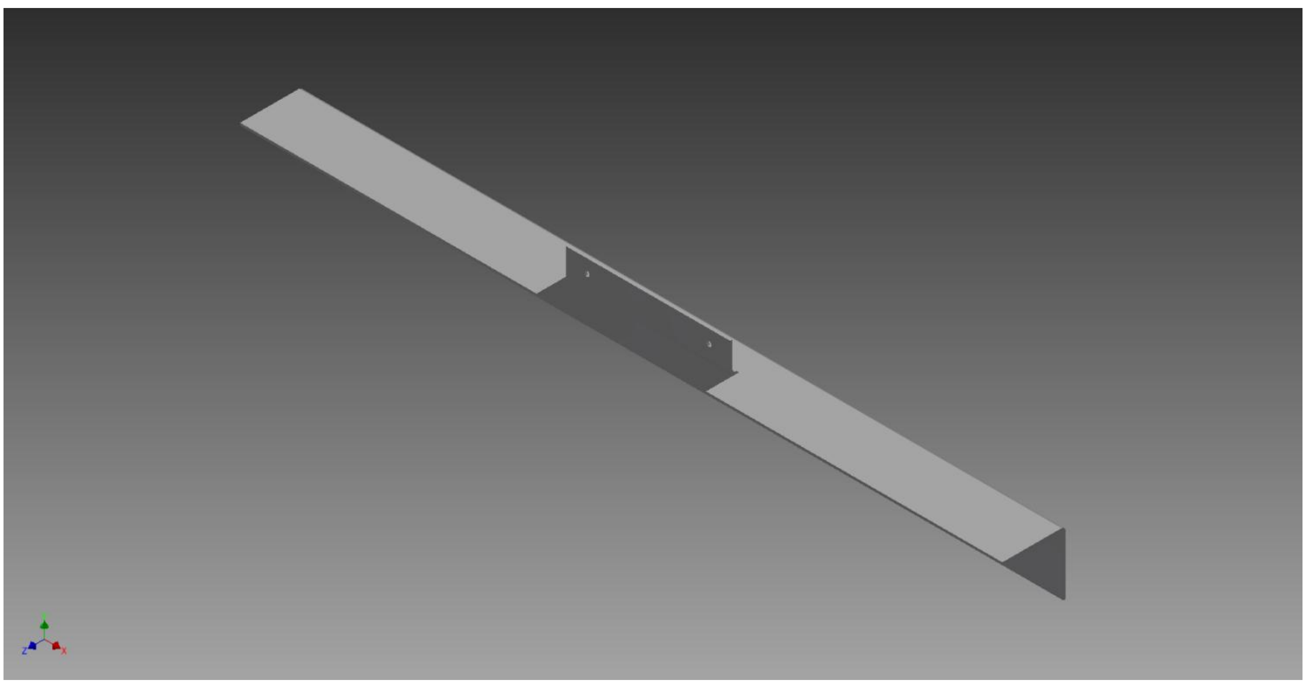
15.1 Detailed Engineering Drawings of All Parts

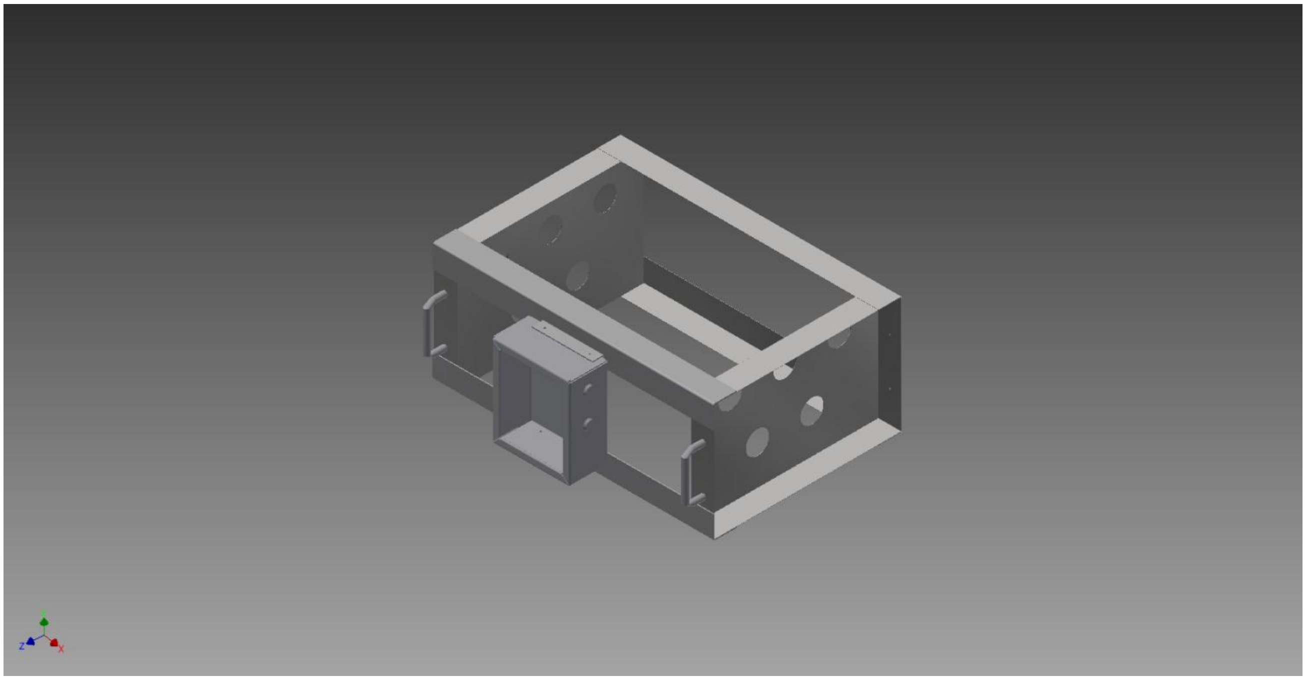
Inventor Pro Sheet Metal Application

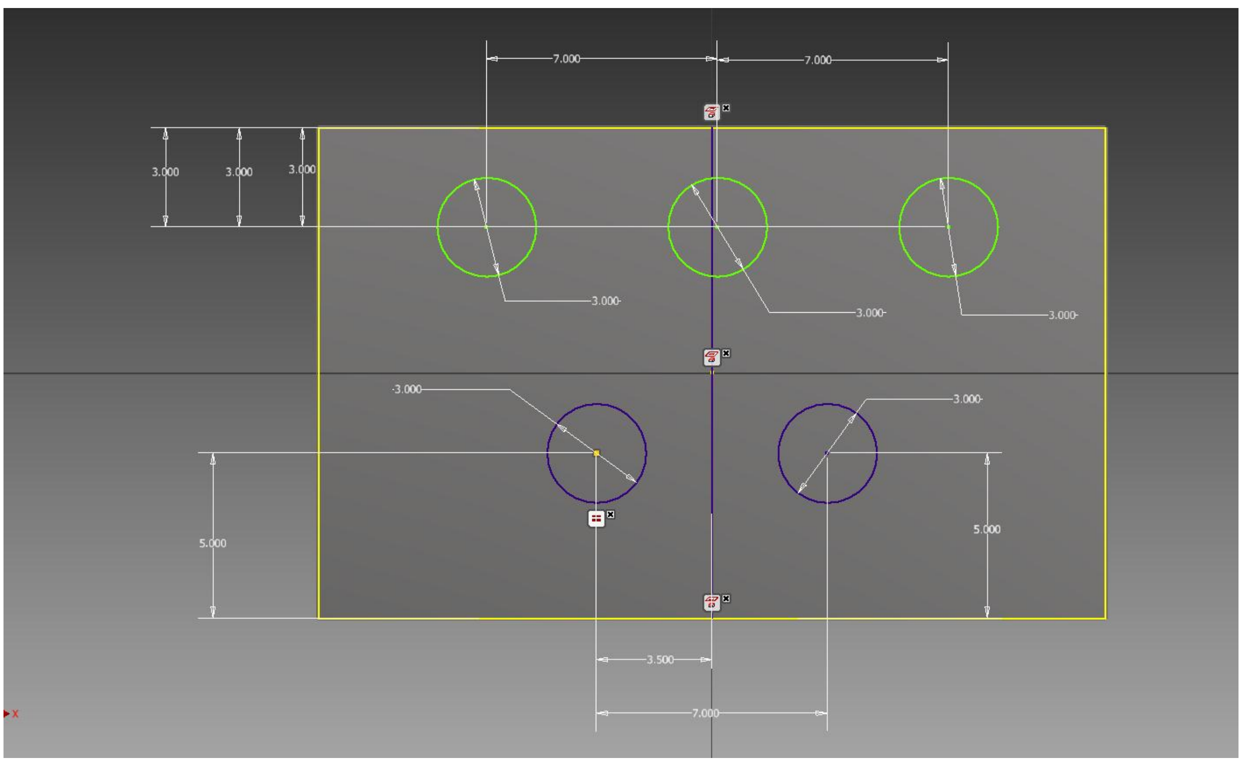











7.000
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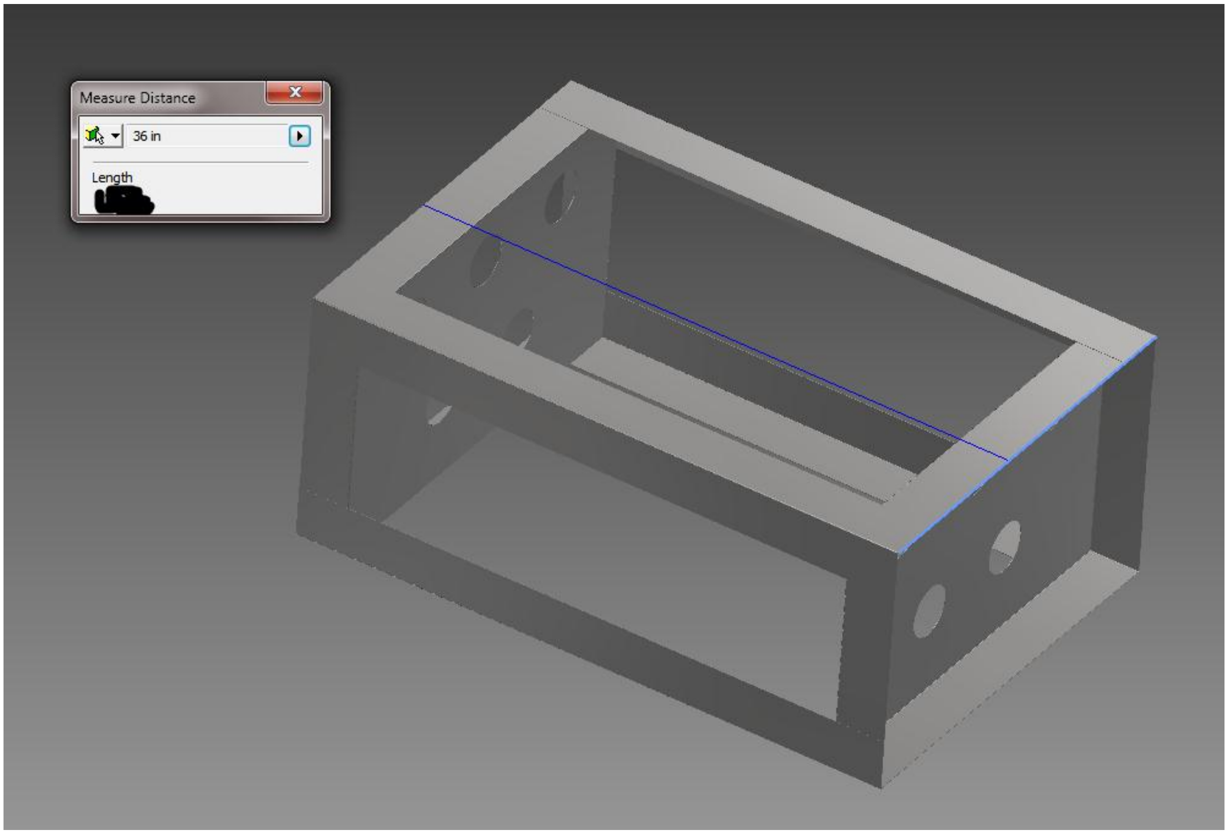
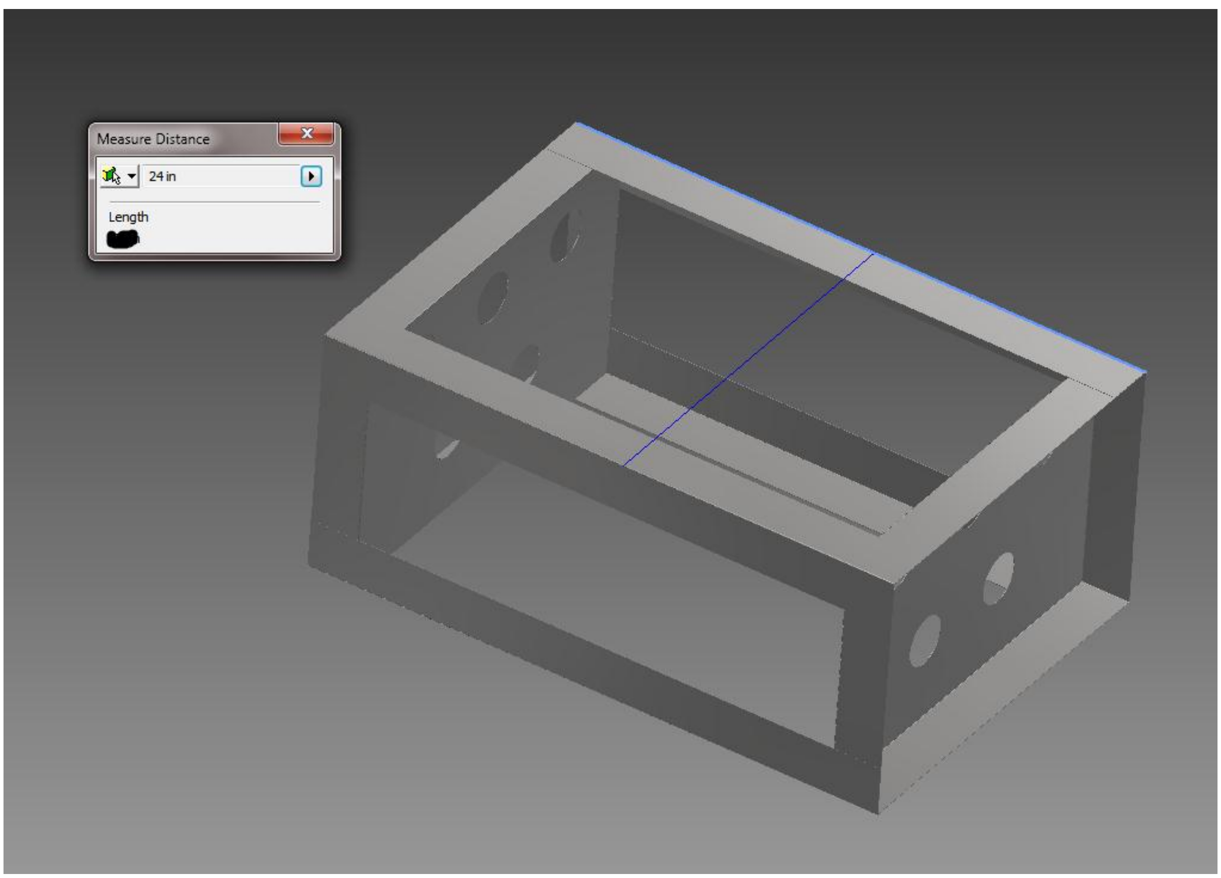
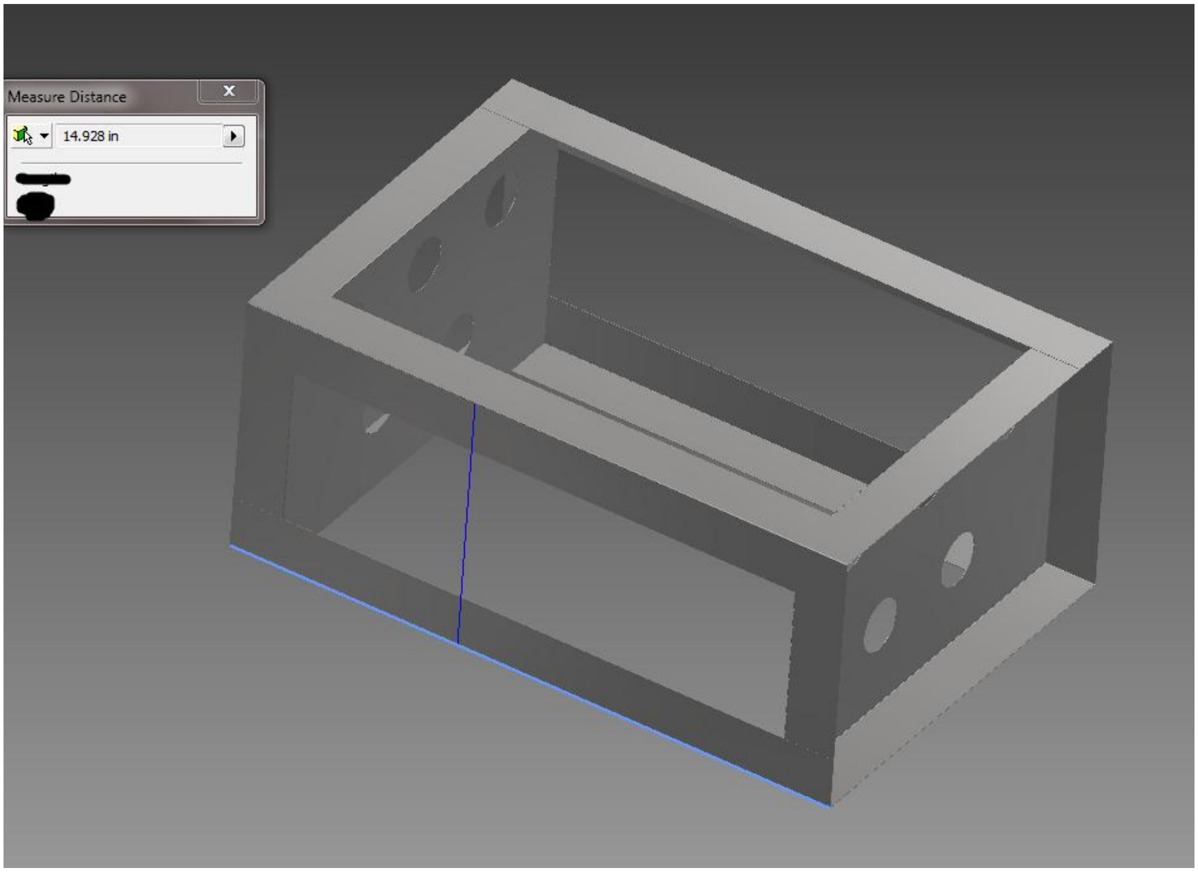
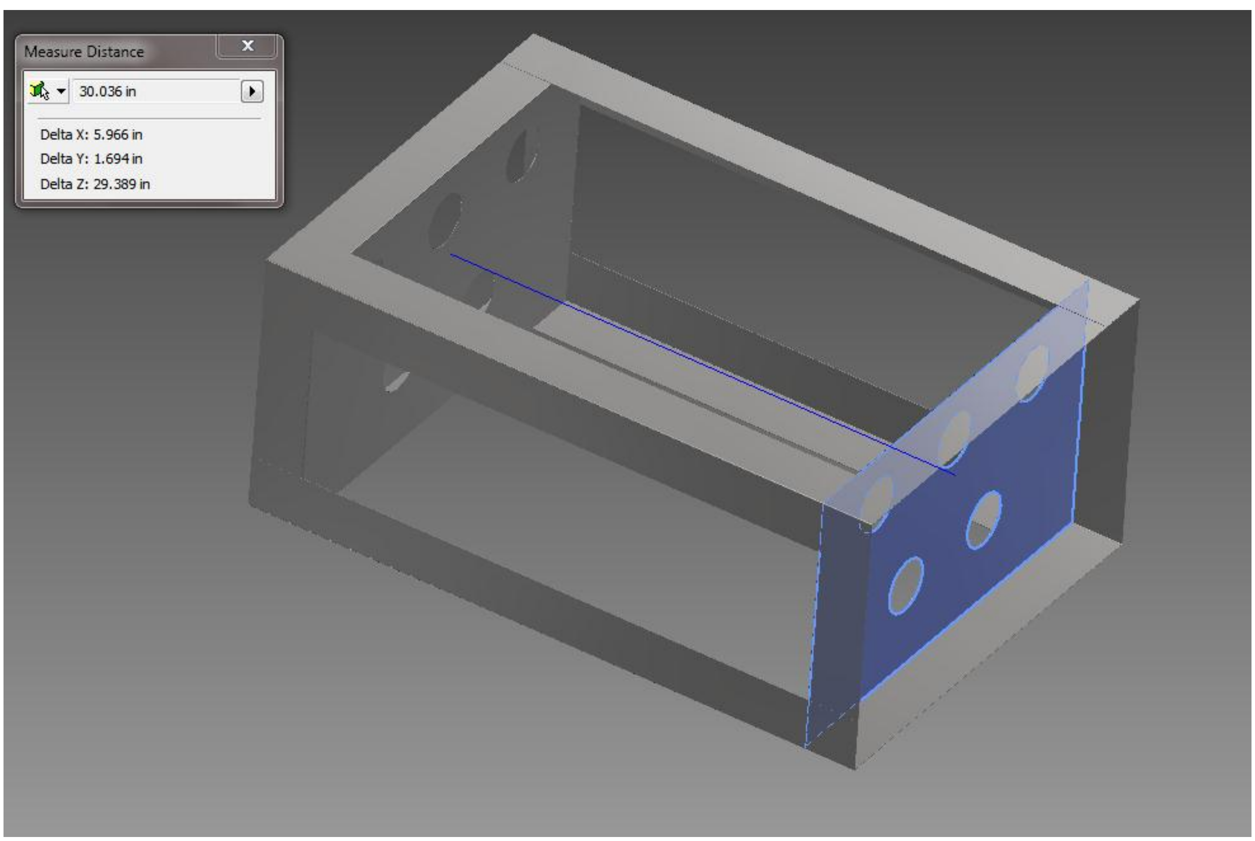
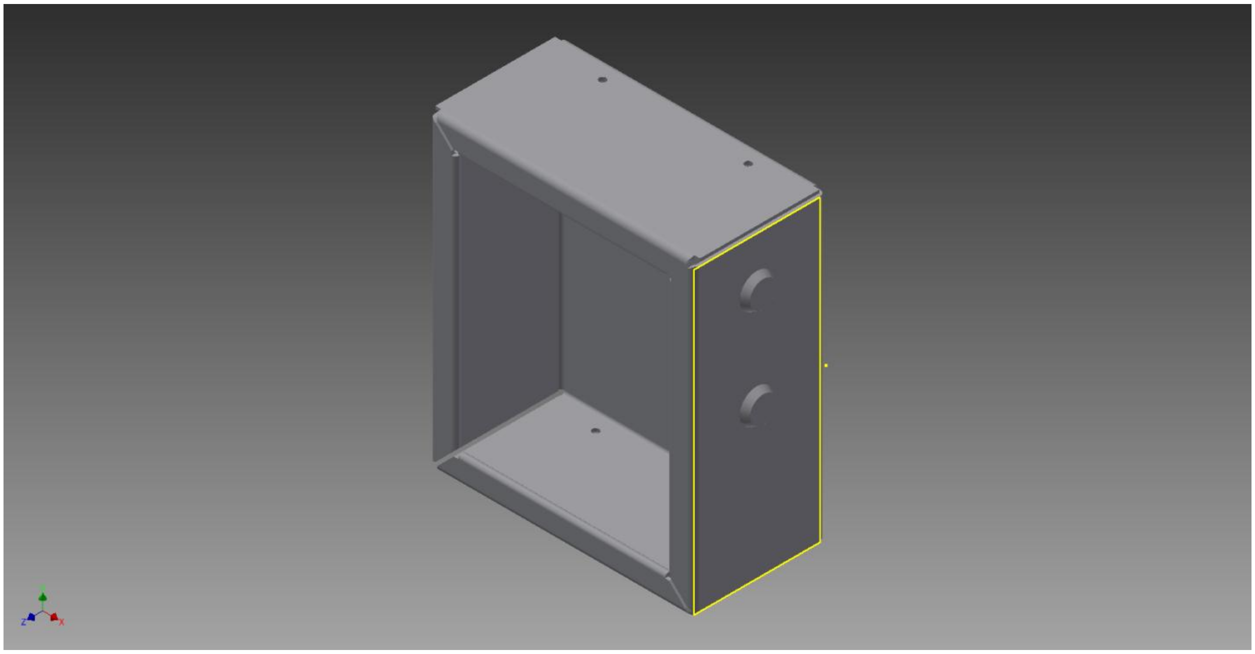
7.000


Measure Distance
36 in
Length
[redacted]

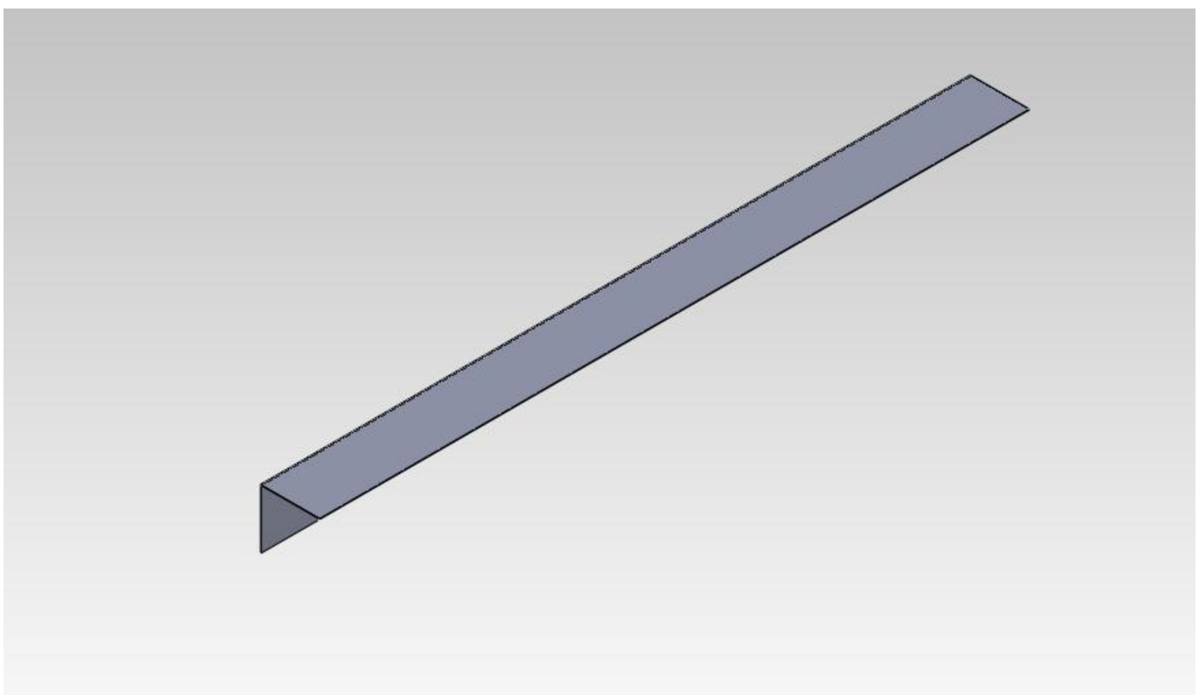

Measure Distance
24 in
Length
[redacted]

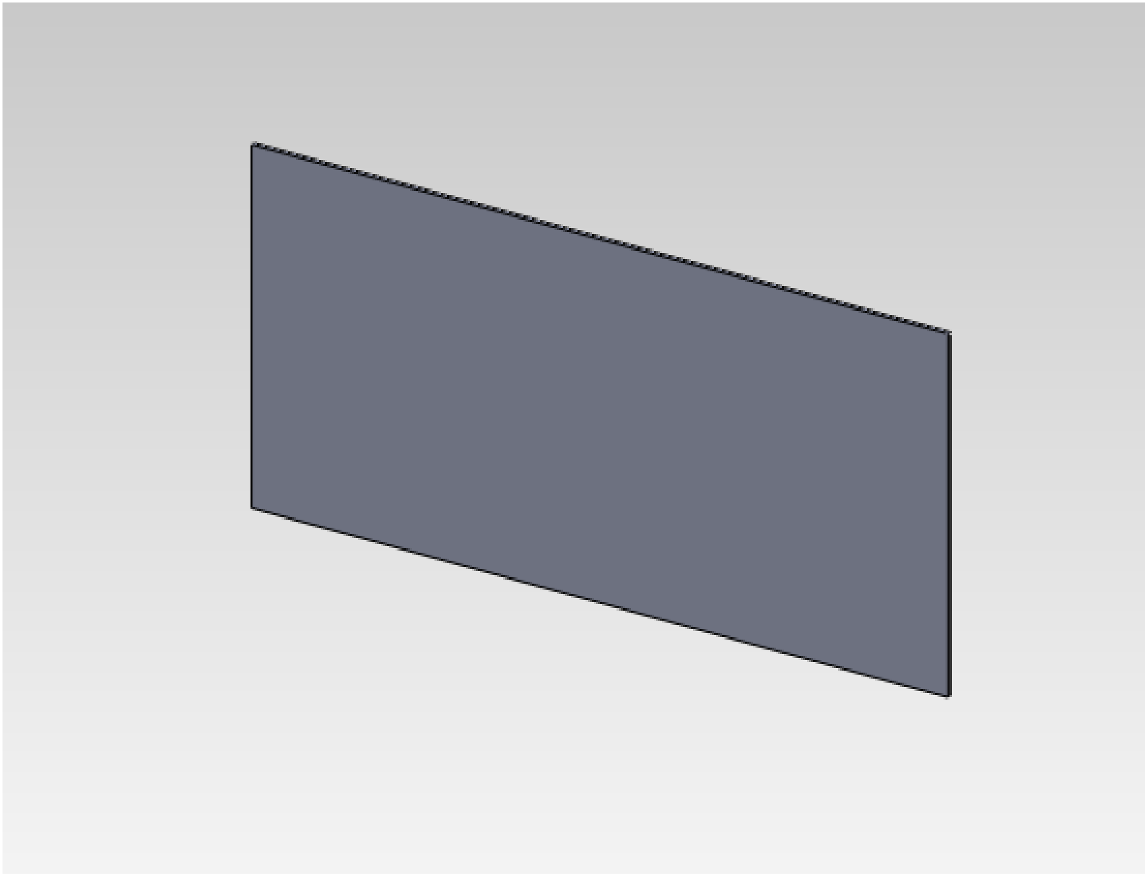

Measure Distance
14.928 in
[redacted]

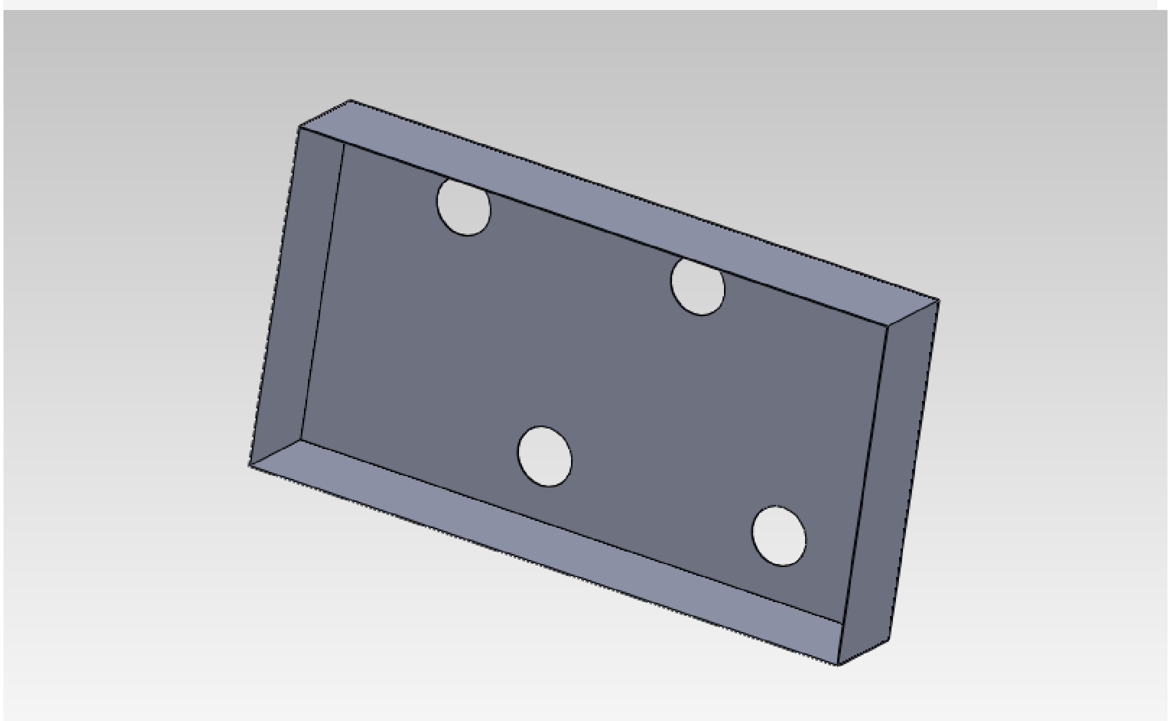

Measure Distance
30.036 in
Delta X: 5.966 in
Delta Y: 1.694 in
Delta Z: 29.389 in

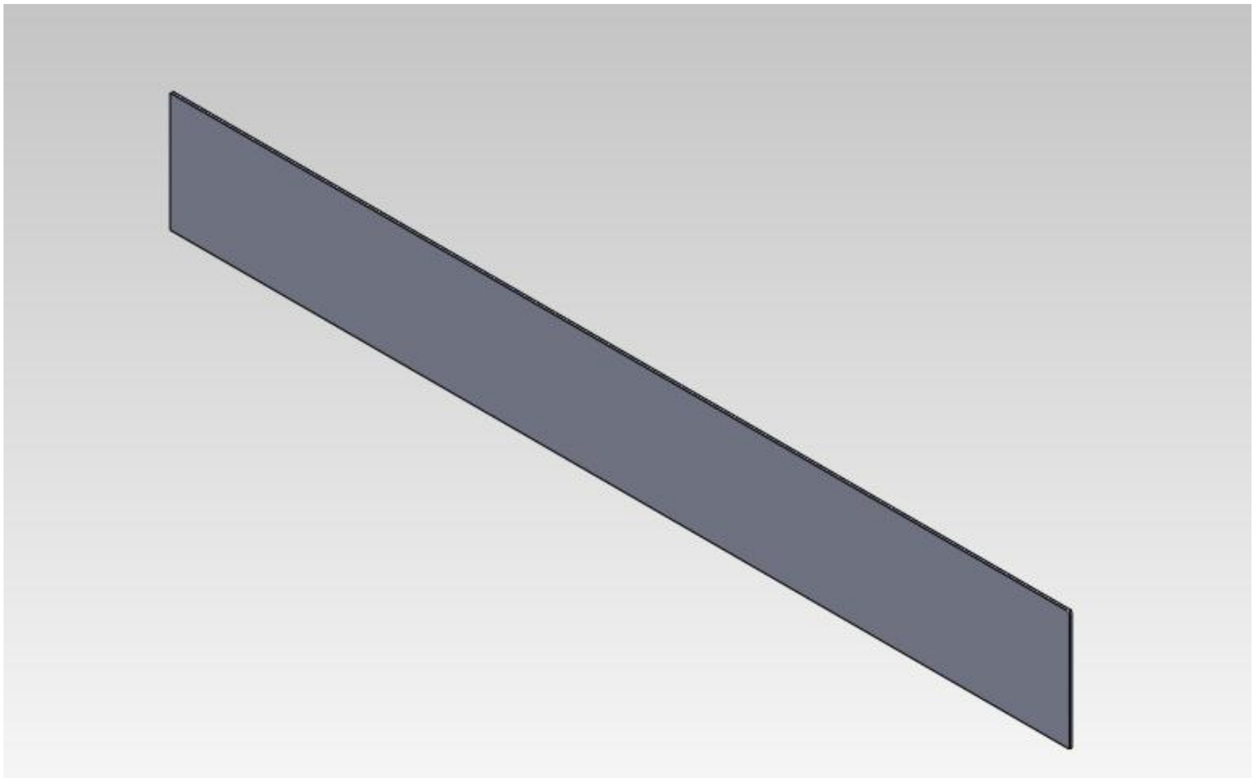


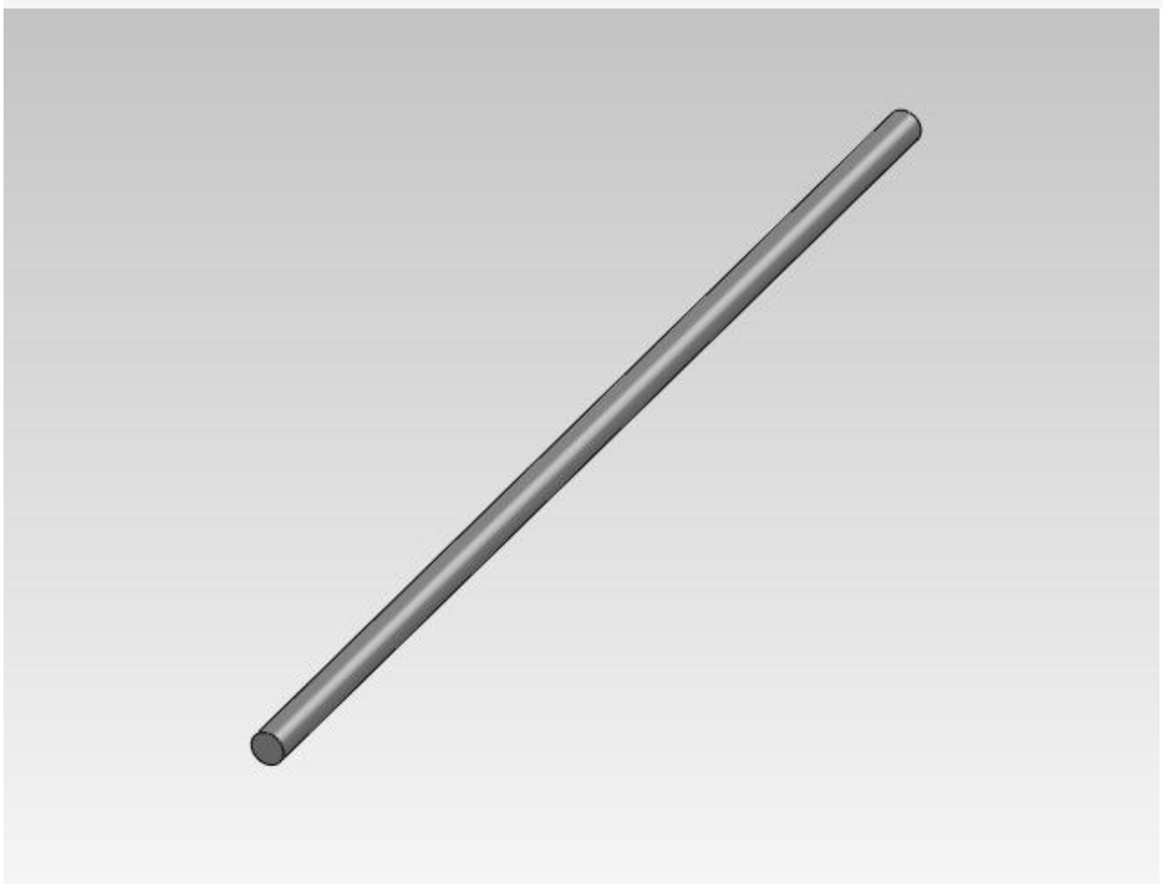
SolidWorks parts for finite element Analysis

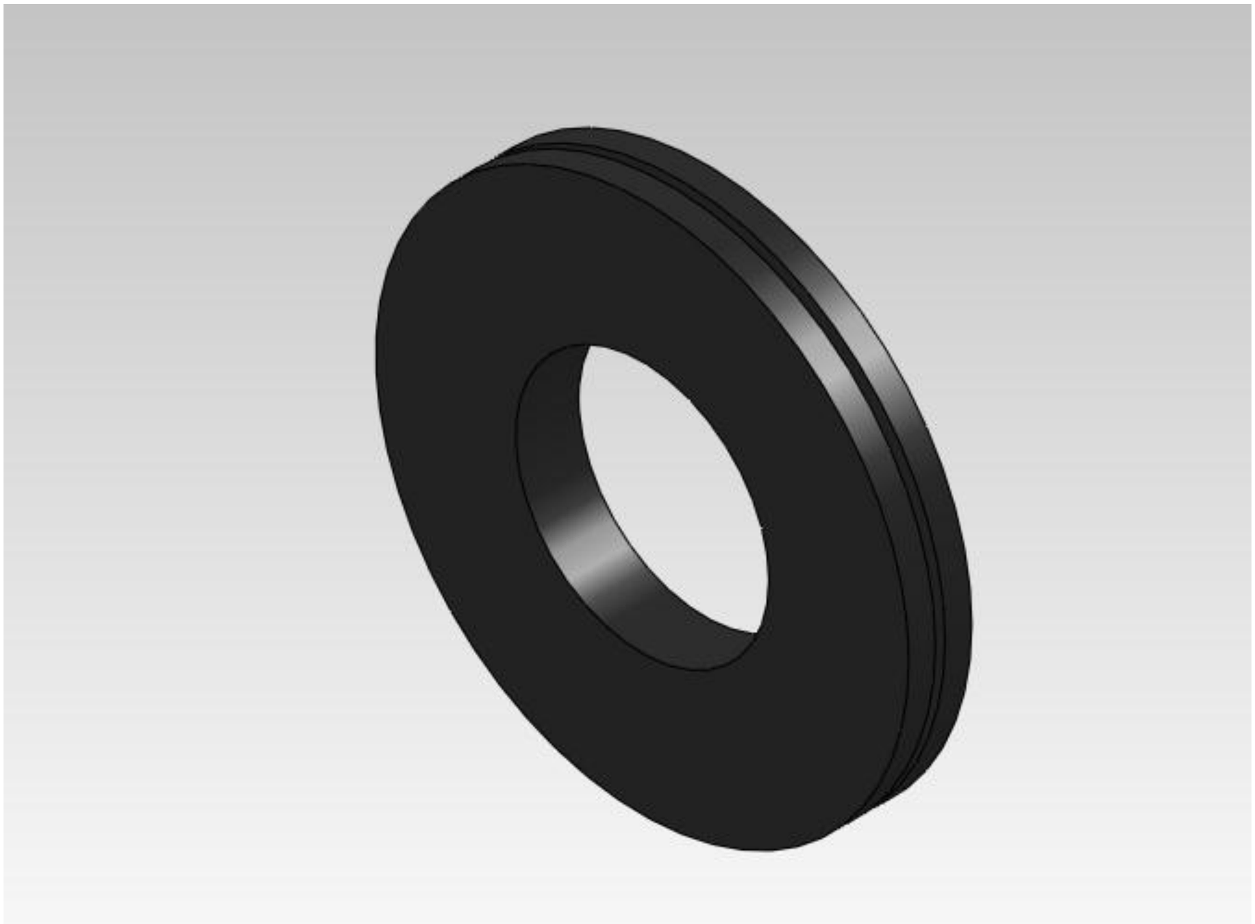












15.2 Appendix B. Detailed Raw Design Calculations and Analysis

$$f = \frac{62.20}{Re} = \frac{62.20}{72346.9} = .00086$$

$$N_u = 72346.9$$

$$N_u = \frac{(f/8)(Re-1000)Pr}{1+12.7(f/8)^{1/2}(Pr^{2/3}-1)}$$

$$= \frac{\left(\frac{.00086}{8}\right)(72346.9-1000)\cdot(.702)}{1+12.7\left(\frac{.00086}{8}\right)^{1/2}\left((.702)^{2/3}-1\right)}$$

$$N_u = 5.36$$

Surface Temperatures

Air properties

@65°C ⇒ 338 K

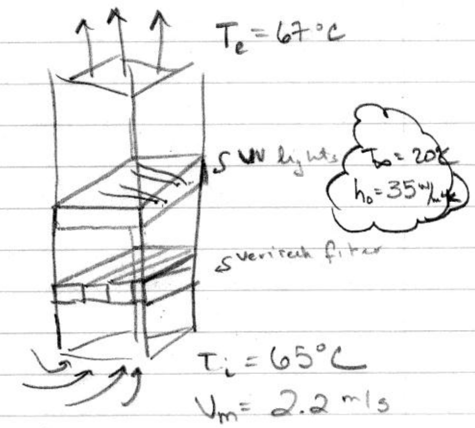
$\rho = 1.035\ kg/m^3$

$\nu = 1.971 \times 10^{-5}\ kg/m \cdot s$

$C_p = 1.008\ kJ/kg \cdot °C$

$K = .0291\ W/m \cdot °C$

$Pr = .702$



$T_i = 65°C$

$V_m = 2.2\ m/s$

1500 cfm

36" x 19.8" base

$1500\ ft^3/min = 42.4753\ m^3/min \times \frac{1\ min}{60\ secs} = .7079\ m^3/s$

$\dot{V} \cdot \rho = \dot{m}$

$(.7079\ m^3/s)(1.035\ kg/m^3) = .7327\ kg/s = \dot{m}$

$$D_h = \frac{4A_c}{P} = \frac{4((.9144m)(.502m))}{2(.9144) + 2(.502)} = .648929$$

$$Re = \frac{V_m D_h}{\nu} = \frac{(2.2)(.648929)}{(1.971 \times 10^{-5})} = 72432.5 \text{ ; } \therefore \text{turbulent}$$

$$Nu = \frac{h D_h}{k} = .023\, Re^{.8} \cdot Pr^{.3} = .023(72432.5)^{.8}(.702)^{.3} = 159.8$$

$$h = \frac{k}{D_h} \cdot Nu = \frac{(.0291)}{(.648929)} \cdot (159.8) = 7.17\ W/m^2 \cdot °C$$

$$q''_s = \frac{T_e - T_\infty}{\frac{1}{h} + \frac{1}{h_o}} = \frac{67 - 20}{\frac{1}{7.17} + \frac{1}{35}} = 279.693\ W/m^2$$

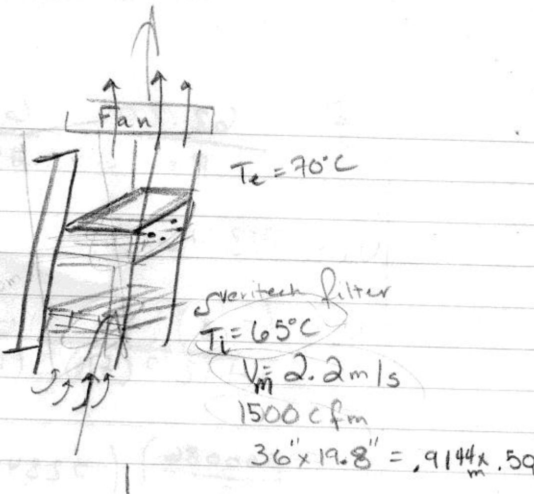
$$T_s = T_e - \frac{q_s''}{h}$$

$$= 67 - \frac{279.693}{7.17}$$

$$= 28.499\ °C$$

The surface temperature of the oven hood will be $\approx 29°C \Rightarrow 83.°F$

Air properties
@ 65°C ⇒ 338 K
$\rho = 1.035$
$\nu = 1.971 \times 10^{-6}$
$C_p = 1.008$
$k = .0291$
$P_r = .702$



$1500 \ ft^3/m = .708 \ m^3/s$

$\dot{V} \times \rho = \dot{m}$

$.708 \ m^3/s \times 1.035 \ kg/m^3 = .733 \ kg/s$

$Re_y = \frac{V_m D_h}{\nu} = \frac{(2.2)(.6483)}{(1.971 \times 10^{-5})} = 72346.9$ ~~2.85167x10^6~~

$D_h = \frac{4 A_c}{P} = \frac{4((.9144)(.508))}{2(.914) + 2(.508)} = \frac{1.83612}{.28378} = .648163$

$Re_y = 2.85167 \times 10^6$ ⇒ therefore turbulent ✓

$Nu = \frac{h D_h}{k} = .023 Re^{.8} Pr^{.3} = .023(72346.9)^{.8}(.702)^{.3}$
$= 159.649$

$h = \frac{k}{D_h} \cdot Nu = \frac{(.0291)}{(.648163)}(159.649) = 7.1676$

$T_e = T_s - (T_s - T_i) e^{-hA/\dot{m}c_p} = 250$

Air Properties		
Evaluated at 65 C => 338 K		
r	1.035	kg/m^3
v	1.97E-05	kg/m*s
C_p	1.008	kJ/kg*C
k	0.0291	W/m*C
Pr	0.702	

	Known						Assumed	
dV/dt	1500	CFM	>	0.7327	kg/s		Ti	65
Vm	2.2	m/s					Te	70
Length	19.8	in	>	0.502	m			
Width	36	in	>	0.9144	m			
Height	3	m						
Perimeter	111.6	in	>	2.8328	m			
T∞	20	C						
h0	35	W/m^2*C						

Calculations		
Dh=	4 Ac/p=	0.648162666
Re=	Vm*Dh/v =	72346.92364
Nu=	.023*Re^.8*Pr^.3=	159.648567
h=	k/Dh*Nu=	7.167603972
q"s=	(Te-T∞)/(1/h+1/h0)=	297.4631179
Surface Temperature		
Ts=	Te-q"s/h=	28.49894622

15.3 Appendix C. Copies of Commercial Catalogs

VFD Switches and Current Sensors

Variable Frequency Drive Monitoring and Control

CURRENT MONITORING

DESCRIPTION

Hawkeye 904, 934, and 720 microprocessor-based current status switches provide a unique solution for accurately monitoring status of motors controlled by variable frequency drives.

The H904 and H934 store the sensed amperage values for normal operation at various frequency ranges in non-volatile memory. This information allows the device to distinguish between a reduced amp draw due to normal changes in the frequency and an abnormal amp drop due to belt loss or other mechanical failures. The relay on the H934 is isolated from the current switch, and all relay connections are externally accessible on the device.

The H720 analog output corresponds to current in the monitored conductor from 10 to 80 Hz.

APPLICATIONS

- Monitoring positive status on motors controlled by variable frequency drives
- Replacing pressure switches
- Measuring current and load trending

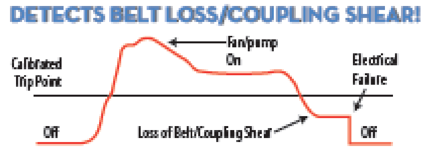
FEATURES (H720)

- Superior to Hall effect and metal core sensors...frequency tolerant 10-80 Hz
- Accurate to 0.5% of full scale
- Suitable for load side monitoring of VFDs
- Adjustable zero and span for precise scaling
- Adjustable mounting bracket for easy placement

FEATURES (H904 and H934)

- Microprocessor-based...real labor saver...No need to calibrate to detect belt loss on VFDs
- Self-adjusting trip point...factory programmed to detect belt loss undercurrent conditions
- Provides accurate status for VFD loads...prevents costly long-term failures
- Automatically compensates for the effects of frequency and amperage changes associated with VFDs
- Nuisance Reduction feature...provides a secondary setpoint option of 50% of the originally measured current
- LED indicates normal and alarm conditions...rapid troubleshooting
- Huge labor savings...no need to calibrate in live starter enclosures... install and go
- Available with a relay (H934)...status and control in one package, saving time and space
- Bracket can be installed in three different configurations...added flexibility
- Monitors both frequency and amperage...distinguishes normal drops in amperage due to frequency changes from abnormal drops due to mechanical failure
- Split-core design is ideal for retrofits...no need to remove conductor
- 5-year warranty

DETECTS BELT LOSS/COUPLING SHEAR!



Now you can easily detect when drive belts slip, break, or pump couplings shear. In fact, a typical HVAC motor that loses its load has a reduction of current draw of up to 50%. That's why our sensors are the industry standard for status.

SPECIFICATIONS

5 Year Warranty

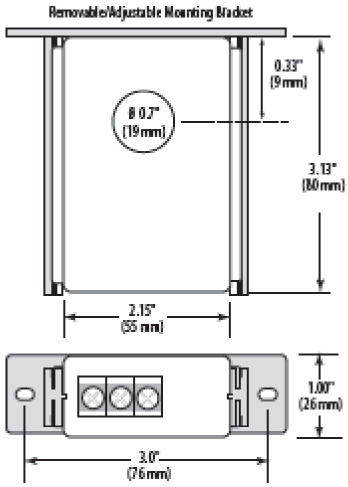
Sensor Power	H904/H934: Induced from monitored conductor H720: 12-30VDC
Insulation Class	600VAC RMS
Frequency Range	34 to 75 Hz (belt loss indication); 20 to 34 Hz (on/off status)
Temperature Range	-15° to 60°C (5° to 140°F)
Humidity Range	10-90% RH non-condensing
Off Delay	0 sec to 2 min.

800.354.8556 +1 503.598.4564 www.veris.com

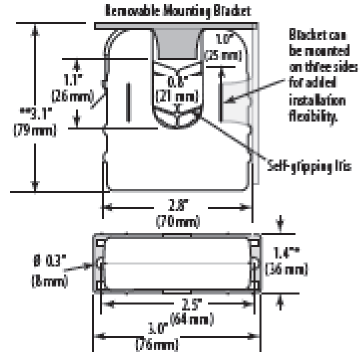
VERIS INDUSTRIES

DIMENSIONAL DRAWINGS

H720



H904/934

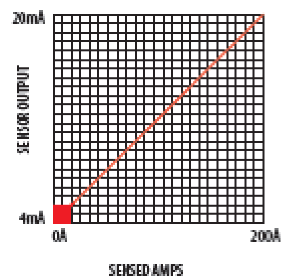


* Terminal block may extend up to 1/8" over the height dimensions shown.

EXAMPLE LINEAR OUTPUT (H720)

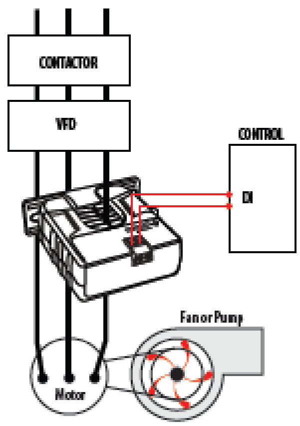
Scale software as shown

Requires 12-30VDC for sensor power



APPLICATION/WIRING DIAGRAM (H904)

Monitoring Fan/Pump Motors for Positive Proof of Flow



NOTE: The H904 is not intended for use in staged pump or variable inlet vane applications.

H934 RELAY CONTACT RATINGS

Resistive	5A@250VAC, 30VDC

TYPICAL COIL PERFORMANCE

Voltage	AC	DC
24V	10mA	10mA

CURRENT MONITORING

ORDERING INFORMATION

MODEL	AMPERAGE RANGE	STATUS OUTPUT	MIN. TRIP POINT	RELAY TYPE	HOUSING	STATUS LED	RELAY POWER LED	UL
H720	200A, 10-80 Hz	4-20mA	n/a	none	Solid-core			●

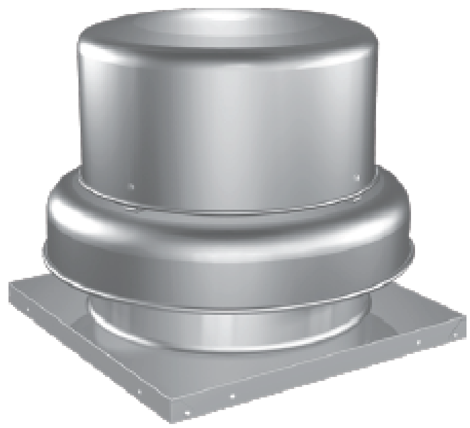
GREENHECK
Building Value in Air.

PN 471558

Downblast Centrifugal Roof Exhaust Fans

Installation, Operation and Maintenance Manual

Please read and save these instructions. Read carefully before attempting to assemble, install, operate or maintain the product described. Protect yourself and others by observing all safety information. Failure to comply with instructions could result in personal injury and/or property damage! Retain instructions for future reference.



Model G Direct Drive

Model G is a direct drive downblast centrifugal exhaust fan. These fans are specifically designed for roof mounted applications exhausting relatively clean air. Performance capabilities range up to 4,300 cfm *(7,305 m³/hr)* and up to 1 in. wg *(249 Pa)* of static pressure. The maximum continuous operating temperature is 180°F *(82°C)*. G models are available in 27 sizes with nominal wheel diameter ranging from 8 to 24 inches *(203 to 610 mm)* (060 - 243 unit sizes). Each fan shall bear a permanently affixed manufacturer's engraved metal nameplate containing the model number and individual serial number. All fans are UL/cUL listed Standard 705.

Model GB Belt Drive

GB Model Fans are belt drive downblast centrifugal exhaust fans. These fans are specifically designed for roof mounted applications exhausting relatively clean air. Performance capabilities range up to 44,700 cfm *(75,950 m³/hr)* and up to 2.5 in. wg *(623 Pa)* of static pressure. The maximum continuous operating temperature is 180°F *(82°C)*. GB models are available in twenty sizes with nominal wheel diameters ranging from 11 to 54 inches *(279 to 1372 mm)* (071-540 unit sizes). Each fan shall bear a permanently affixed manufacturer's nameplate containing the model number and individual serial number. All fans are UL/cUL listed Standard 705.

General Safety Information

Only qualified personnel should install this fan. Personnel should have a clear understanding of these instructions and should be aware of general safety precautions.

1. Follow all local electrical and safety codes, as well as the National Electrical Code (NEC) and the National Fire Protection Agency (NFPA), where applicable.

Receiving

Upon receiving the product, check to make sure all items are accounted for by referencing the bill of lading to ensure all items were received. Inspect each crate for shipping damage before accepting delivery. Notify the carrier if any damage is noticed. The carrier will make notification on the delivery receipt acknowledging any damage to the product. All damage should be noted on all the copies of the bill of lading which is countersigned by the delivering carrier. A Carrier Inspection Report should be filled out by the carrier upon arrival and reported to the Traffic Department. If damaged upon arrival, file a claim with carrier. Any physical damage to the unit after acceptance is not the responsibility of Greenheck Fan Corporation.

Unpacking

Verify that all required parts and the correct quantity of each item have been received. If any items are missing, report shortages to your local representative to arrange for obtaining missing parts. Sometimes it is not possible that all items for the unit be shipped together due to availability of transportation and truck space. Confirmation of shipment(s) must be limited to only items on the bill of lading.

Handling

G Direct Drive

Lift unit on to the roof utilizing hooks under the lip of the shroud. Evenly space the hooks around the shroud using a minimum of four lifting straps. Use a spreader bar to ensure the straps do not come in contact with the unit (see Figure 1).

Figure 1

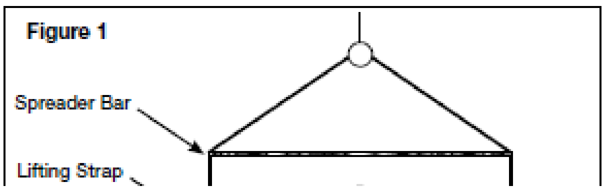


Figure 2

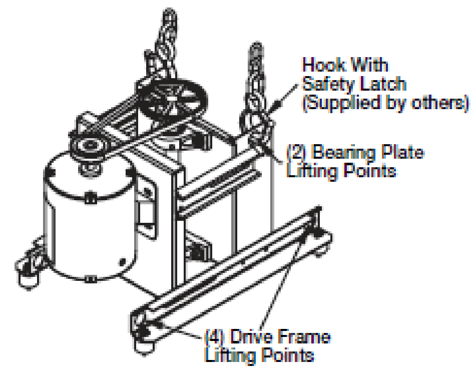
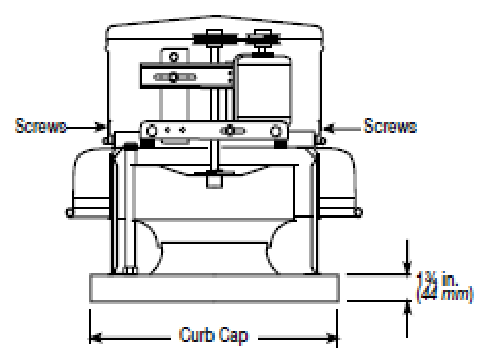


Figure 3



GB Belt Drive

When lifting the unit on to the roof, use either the four lifting points on the drive frame or the two lifting points on the bearing plate if present (see Figure 2 for lifting points). Access to the drive frame is accomplished by removing the screws pointed out in Figure 3. The cover can then be removed and placed on a flat surface in an area protected from strong winds.

When G/GB unit is on the roof, move fan to desired

G - Direct Drive

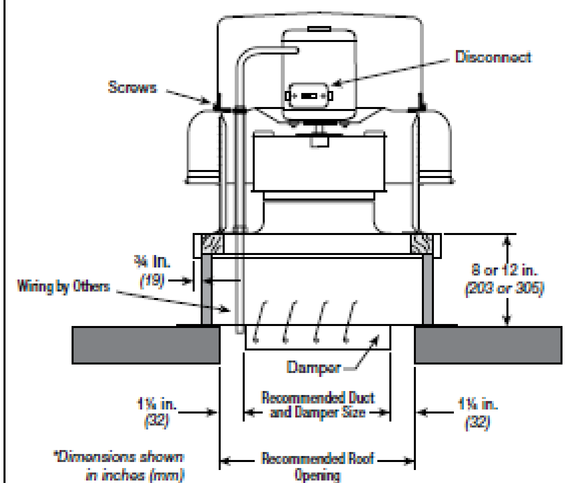
Model	Curb Cap	Damper	Roof Opening	*Approx. Weight
G 060, 065, 070, 075	17 *(432)*	8 *(203)*	10½ *(267)*	18 *(8)*
G 080, 085, 090, 095	17 *(432)*	10 *(254)*	12½ *(267)*	26 *(12)*
G 97, 98, 99	19 *(483)*	12 *(305)*	14½ *(368)*	57 *(26)*
G 103, 103 HP	19 *(483)*	12 *(305)*	14½ *(368)*	62 *(28)*
G 123	19 *(483)*	12 *(305)*	14½ *(368)*	65 *(30)*
G 133	19 *(483)*	12 *(305)*	14½ *(368)*	66 *(30)*
G 143, 143 HP	22 *(559)*	16 *(406)*	18½ *(470)*	76 *(35)*
G 163, 163 HP	22 *(559)*	16 *(406)*	18½ *(470)*	80 *(36)*
G 183, 183 HP	30 *(762)*	18 *(457)*	20½ *(521)*	119 *(54)*
G 203, 203 HP	30 *(762)*	18 *(457)*	20½ *(521)*	130 *(59)*
G 223/243, 223/243 HP	34 *(864)*	24 *(610)*	26½ *(673)*	150 *(68)*

GB - Belt Drive

Model	Curb Cap	Damper	Roof Opening	*Approx. Weight
GB 071, 081, 091	19 *(483)*	12 *(305)*	14½ *(368)*	58 *(26)*
GB 101, 101HP	19 *(483)*	12 *(305)*	14½ *(368)*	63 *(29)*
GB 121	19 *(483)*	12 *(305)*	14½ *(368)*	66 *(30)*
GB 131	19 *(483)*	12 *(305)*	14½ *(368)*	67 *(30)*
GB 141, 141HP	22 *(559)*	16 *(406)*	18½ *(470)*	83 *(38)*
GB 161, 161HP	22 *(559)*	16 *(406)*	18½ *(470)*	89 *(40)*
GB 180, 180HP	30 *(762)*	18 *(457)*	20½ *(521)*	125 *(57)*
GB 200, 200HP	30 *(762)*	18 *(457)*	20½ *(521)*	138 *(63)*
GB 220, 220HP, 240, 240HP	34 *(864)*	24 *(610)*	26½ *(673)*	158 *(72)*
GB 260	40 *(1016)*	30 *(762)*	32½ *(826)*	305 *(138)*
GB 300, 300HP	40 *(1016)*	30 *(762)*	32½ *(826)*	320 *(145)*

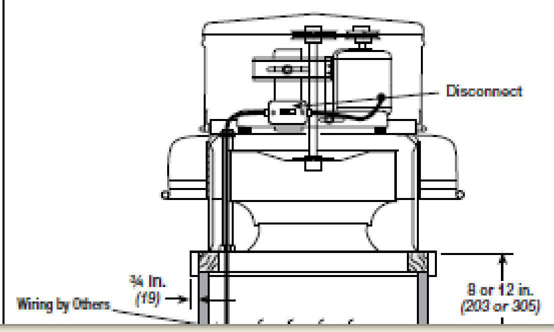
G Direct Drive

Figure 5 - Typical Roof Mounting Installation



GB Belt Drive

Figure 6 - Typical Roof Mounting Installation



Pre-Starting Checks

1. Check all fasteners and set screws for tightness. The wheel should rotate freely and be aligned as shown in Figure 7 below.
2. Wheel position is preset and the unit is test run at the factory. Movement may occur during shipment and realignment may be necessary.
3. Only G unit - Centering height alignment can be accomplished by loosening the set screws in the wheel and moving the wheel to the desired position.
4. Only GB unit - Centering can be accomplished by loosening the bolts holding the drive frame to the shock mounts and repositioning the drive frame.
5. Only GB unit - Wheel and inlet cone overlap can be adjusted by loosening the set screws in the wheel and moving the wheel to the desired position.
6. Only GB unit - Fan RPM should be checked and verified with a tachometer.
7. Check wheel rotation (viewing from the shaft side) by momentarily energizing the unit. Rotation should be clockwise as shown in Figure 8 and correspond to rotation decal on the unit. If wheel rotation is incorrect, reverse two of the wiring leads or check motor wiring for single phase.

Wheel Overlap and Gap Dimensions

Model			G - Overlap In. (mm)	H - Gap In. (mm)
G		060-095	–	3/32 (2)
G		97-163	¼ (6)	–
	GB	071-161	¼ (6)	–
G		183-243	⅜ (10)	–
	GB	180-240	⅜ (10)	–
	GB	260-540	½ (13)	–

Wheel Rotation

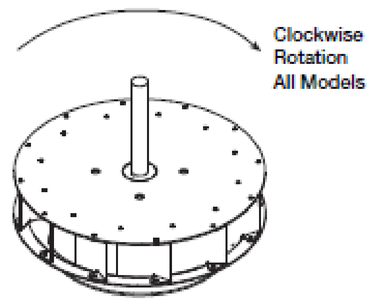


Figure 8

WARNING

Correct direction of wheel rotation is critical. Reversed rotation will result in poor air performance, motor overloading and possible burnout.

WARNING

The fan has been checked for mechanical noises at the factory prior to shipment. If mechanical noise should develop, suggested corrective actions are offered in the Troubleshooting section.

IMPORTANT

Over tightening will cause excessive bearing wear and noise. Too little tension will cause slippage at startup and uneven wear.

Model GB
Pre-Starting Belt Tension Checks

8. Always loosen tension enough to install belts without stretching, see Figure 9.

Belts

Mc-Master Catalog

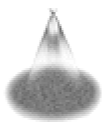
For information about spray nozzles and pipe size, see page 2082.

Full Cone Spray Nozzles

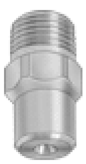
An excellent choice for cooling as well as dust- and foam-control applications. They provide a uniform distribution of droplets.

Spray nozzle fittings and manifolds are also available.

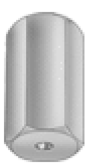
Full Cone Spray Nozzles



Full Cone



Male



Female

The full cone spray pattern and low flow rates of these nozzles make them good for distributing fluids, cooling, washing, and rinsing. Maximum pressure is 400 psi. Brass nozzles have a maximum temperature of 450° F. Type 303 stainless steel nozzles have a maximum temperature of 800° F.

Pipe Size	Flow Rate, gpm 20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		Each 1-9	10-Up
Brass NPT Male											
1/8"	0.1	0.2	0.3	0.7	60°	0.04"	7/16"	7/8"	32885K711	$8.90	$7.99
1/8"	0.1	0.2	0.3	0.7	90°	0.04"	7/16"	7/8"	32885K113	8.90	7.99
1/8"	0.1	0.2	0.3	0.7	120°	0.04"	7/16"	7/8"	32885K111	8.90	7.99
1/8"	0.3	0.5	0.7	1.4	60°	0.05"	7/16"	7/8"	32885K721	8.90	7.99
1/8"	0.3	0.5	0.7	1.4	90°	0.05"	7/16"	7/8"	32885K115	8.90	7.99
1/8"	0.3	0.5	0.7	1.4	120°	0.05"	7/16"	7/8"	32885K121	8.90	7.99
1/8"	0.5	0.7	1.1	2.2	60°	0.07"	7/16"	7/8"	32885K731	8.90	7.99
1/8"	0.5	0.7	1.1	2.2	90°	0.07"	7/16"	7/8"	32885K117	8.90	7.99
1/8"	0.5	0.7	1.1	2.2	120°	0.07"	7/16"	7/8"	32885K131	8.90	7.99
1/4"	0.7	1.0	1.5	2.9	60°	0.08"	9/16"	1 1/16"	32885K143	9.54	8.53
1/4"	0.7	1.0	1.5	2.9	90°	0.08"	9/16"	1 1/16"	32885K119	9.54	8.53
1/4"	0.7	1.0	1.5	2.9	120°	0.08"	9/16"	1 1/16"	32885K141	9.54	8.53
1/4"	1.0	1.5	2.3	4.4	60°	0.10"	9/16"	1 1/16"	32885K153	9.54	8.53
1/4"	1.0	1.5	2.3	4.4	90°	0.10"	9/16"	1 1/16"	32885K101	9.54	8.53
1/4"	1.0	1.5	2.3	4.4	120°	0.10"	9/16"	1 1/16"	32885K151	9.54	8.53
3/8"	1.4	2.0	3.0	5.9	60°	0.12"	11/16"	1 1/4"	32885K163	12.20	10.86
3/8"	1.4	2.0	3.0	5.9	90°	0.12"	11/16"	1 1/4"	32885K103	12.20	10.86
3/8"	1.4	2.0	3.0	5.9	120°	0.12"	11/16"	1 1/4"	32885K161	12.20	10.86
3/8"	2.1	3.0	4.6	8.8	60°	0.15"	11/16"	1 1/4"	32885K761	12.20	10.86
3/8"	2.1	3.0	4.6	8.8	90°	0.15"	11/16"	1 1/4"	32885K105	12.20	10.86

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
3/8"	2.1	3.0	4.6	8.8	120°	0.15"	11/16"	1 1/4"	32885K171	12.20	10.86
3/8"	2.8	4.0	6.1	11.8	60°	0.18"	11/16"	1 1/4"	32885K183	12.20	10.86
3/8"	2.8	4.0	6.1	11.8	90°	0.18"	11/16"	1 1/4"	32885K107	12.20	10.86
3/8"	2.8	4.0	6.1	11.8	120°	0.18"	11/16"	1 1/4"	32885K181	12.20	10.86
1/2"	3.6	5.0	7.6	14.8	60°	0.20"	7/8"	1 1/2"	32885K771	14.16	12.61
1/2"	3.6	5.0	7.6	14.8	90°	0.20"	7/8"	1 1/2"	32885K123	14.16	12.61
1/2"	3.6	5.0	7.6	14.8	120°	0.20"	7/8"	1 1/2"	32885K191	14.16	12.61
1/2"	4.3	6.0	9.2	17.7	60°	0.21"	7/8"	1 1/2"	32885K213	14.16	12.61
1/2"	4.3	6.0	9.2	17.7	90°	0.21"	7/8"	1 1/2"	32885K125	14.16	12.61
1/2"	4.3	6.0	9.2	17.7	120°	0.21"	7/8"	1 1/2"	32885K211	14.16	12.61
1/2"	5.0	7.0	10.8	20.7	60°	0.22"	7/8"	1 1/2"	32885K223	14.16	12.61
1/2"	5.0	7.0	10.8	20.7	90°	0.22"	7/8"	1 1/2"	32885K127	14.16	12.61
1/2"	5.0	7.0	10.8	20.7	120°	0.22"	7/8"	1 1/2"	32885K221	14.16	12.61
3/4"	5.7	8.0	12.3	23.6	60°	0.23"	1 1/8"	1 3/4"	32885K234	29.71	26.56
3/4"	5.7	8.0	12.3	23.6	90°	0.23"	1 1/8"	1 3/4"	32885K235	29.71	26.56
3/4"	5.7	8.0	12.3	23.6	120°	0.23"	1 1/8"	1 3/4"	32885K236	29.71	26.56
3/4"	8.6	12.0	18.5	35.4	60°	0.31"	1 1/8"	1 3/4"	32885K254	29.71	26.56
3/4"	8.6	12.0	18.5	35.4	90°	0.31"	1 1/8"	1 3/4"	32885K255	29.71	26.56
3/4"	8.6	12.0	18.5	35.4	120°	0.31"	1 1/8"	1 3/4"	32885K256	29.71	26.56
1"	10.8	15.0	23.1	44.3	60°	0.32"	1 3/8"	2 3/16"	32885K264	37.35	33.40

Catalog Page|BookmarkBookmarked

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up

Top of Form

Bottom of Form

Full Cone Spray Nozzle Brass, 1" NPT Male, 15 GPM @ 40 PSI, 60 Deg Angle

Please complete the specification for this item.

Each

Usually ships in 2 weeks.

1"	10.8	15.0	23.1	44.3	90°	0.32"	1 3/8"	2 3/16"	32885K265	37.35	33.40
1"	10.8	15.0	23.1	44.3	120°	0.32"	1 3/8"	2 3/16"	32885K266	37.35	33.40
1"	14.4	20.0	30.8	59.0	60°	0.37"	1 3/8"	2 3/16"	32885K274	37.35	33.40
1"	14.4	20.0	30.8	59.0	90°	0.37"	1 3/8"	2 3/16"	32885K275	37.35	33.40
1"	14.4	20.0	30.8	59.0	120°	0.37"	1 3/8"	2 3/16"	32885K276	37.35	33.40

Brass NPT Female

1/8"	0.1	0.2	0.3	0.7	60°	0.04"	9/16"	1 1/8"	32885K712	8.90	7.99
1/8"	0.1	0.2	0.3	0.7	90°	0.04"	9/16"	1 1/8"	32885K114	8.90	7.99
1/8"	0.1	0.2	0.3	0.7	120°	0.04"	9/16"	1 1/8"	32885K112	8.90	7.99
1/8"	0.3	0.5	0.7	1.4	60°	0.05"	9/16"	1 1/8"	32885K722	8.90	7.99
1/8"	0.3	0.5	0.7	1.4	90°	0.05"	9/16"	1 1/8"	32885K116	8.90	7.99
1/8"	0.3	0.5	0.7	1.4	120°	0.05"	9/16"	1 1/8"	32885K122	8.90	7.99
1/8"	0.5	0.7	1.1	2.2	60°	0.07"	9/16"	1 1/8"	32885K732	8.90	7.99
1/8"	0.5	0.7	1.1	2.2	90°	0.07"	9/16"	1 1/8"	32885K118	8.90	7.99

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
1/8"	0.5	0.7	1.1	2.2	120°	0.07"	9/16"	1 1/8"	32885K132	8.90	7.99
1/4"	0.7	1.0	1.5	2.9	60°	0.08"	11/16"	1 3/8"	32885K144	9.54	8.53
1/4"	0.7	1.0	1.5	2.9	90°	0.08"	11/16"	1 3/8"	32885K109	9.54	8.53
1/4"	0.7	1.0	1.5	2.9	120°	0.08"	11/16"	1 3/8"	32885K142	9.54	8.53
1/4"	1.0	1.5	2.3	4.4	60°	0.10"	11/16"	1 3/8"	32885K154	9.54	8.53
1/4"	1.0	1.5	2.3	4.4	90°	0.10"	11/16"	1 3/8"	32885K102	9.54	8.53
1/4"	1.0	1.5	2.3	4.4	120°	0.10"	11/16"	1 3/8"	32885K152	9.54	8.53
3/8"	1.4	2.0	3.0	5.9	60°	0.12"	7/8"	1 1/2"	32885K164	12.20	10.86
3/8"	1.4	2.0	3.0	5.9	90°	0.12"	7/8"	1 1/2"	32885K104	12.20	10.86
3/8"	1.4	2.0	3.0	5.9	120°	0.12"	7/8"	1 1/2"	32885K162	12.20	10.86
3/8"	2.1	3.0	4.6	8.8	60°	0.15"	7/8"	1 1/2"	32885K762	12.20	10.86
3/8"	2.1	3.0	4.6	8.8	90°	0.15"	7/8"	1 1/2"	32885K106	12.20	10.86
3/8"	2.1	3.0	4.6	8.8	120°	0.15"	7/8"	1 1/2"	32885K172	12.20	10.86
3/8"	2.8	4.0	6.1	11.8	60°	0.18"	7/8"	1 1/2"	32885K184	12.20	10.86
3/8"	2.8	4.0	6.1	11.8	90°	0.18"	7/8"	1 1/2"	32885K108	12.20	10.86
3/8"	2.8	4.0	6.1	11.8	120°	0.18"	7/8"	1 1/2"	32885K182	12.20	10.86
1/2"	3.6	5.0	7.6	14.8	60°	0.20"	1 1/8"	2"	32885K772	14.16	12.61
1/2"	3.6	5.0	7.6	14.8	90°	0.20"	1 1/8"	2"	32885K124	14.16	12.61
1/2"	3.6	5.0	7.6	14.8	120°	0.20"	1 1/8"	2"	32885K192	14.16	12.61
1/2"	4.3	6.0	9.2	17.7	60°	0.21"	1 1/8"	2"	32885K214	14.16	12.61
1/2"	4.3	6.0	9.2	17.7	90°	0.21"	1 1/8"	2"	32885K126	14.16	12.61

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
1/2"	4.3	6.0	9.2	17.7	120°	0.21"	1 1/8"	2"	32885K212	14.16	12.61
1/2"	5.0	7.0	10.8	20.7	60°	0.22"	1 1/8"	2"	32885K224	14.16	12.61
1/2"	5.0	7.0	10.8	20.7	90°	0.22"	1 1/8"	2"	32885K128	14.16	12.61
1/2"	5.0	7.0	10.8	20.7	120°	0.22"	1 1/8"	2"	32885K222	14.16	12.61
3/4"	5.7	8.0	12.3	23.6	60°	0.23"	1 3/8"	2 1/8"	32885K231	29.71	26.56
3/4"	5.7	8.0	12.3	23.6	90°	0.23"	1 3/8"	2 1/8"	32885K232	29.71	26.56
3/4"	5.7	8.0	12.3	23.6	120°	0.23"	1 3/8"	2 1/8"	32885K233	29.71	26.56
3/4"	8.6	12.0	18.5	35.4	60°	0.31"	1 3/8"	2 1/8"	32885K251	29.71	26.56
3/4"	8.6	12.0	18.5	35.4	90°	0.31"	1 3/8"	2 1/8"	32885K252	29.71	26.56
3/4"	8.6	12.0	18.5	35.4	120°	0.31"	1 3/8"	2 1/8"	32885K253	29.71	26.56
1"	10.8	15.0	23.1	44.3	60°	0.32"	1 5/8"	2 3/8"	32885K261	37.35	33.40
1"	10.8	15.0	23.1	44.3	90°	0.32"	1 5/8"	2 3/8"	32885K262	37.35	33.40
1"	10.8	15.0	23.1	44.3	120°	0.32"	1 5/8"	2 3/8"	32885K263	37.35	33.40
1"	14.4	20.0	30.8	59.0	60°	0.37"	1 5/8"	2 3/8"	32885K271	37.35	33.40
1"	14.4	20.0	30.8	59.0	90°	0.37"	1 5/8"	2 3/8"	32885K272	37.35	33.40
1"	14.4	20.0	30.8	59.0	120°	0.37"	1 5/8"	2 3/8"	32885K273	37.35	33.40

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
Stainless Steel NPT Male											
1/8"	0.1	0.2	0.3	0.7	60°	0.04"	7/16"	7/8"	32885K811	$27.38	$24.39

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
1/8"	0.1	0.2	0.3	0.7	90°	0.04"	7/16"	7/8"	32885K129	27.38	24.39
1/8"	0.1	0.2	0.3	0.7	120°	0.04"	7/16"	7/8"	32885K511	27.38	24.39
1/8"	0.3	0.5	0.7	1.4	60°	0.05"	7/16"	7/8"	32885K821	27.38	24.39
1/8"	0.3	0.5	0.7	1.4	90°	0.05"	7/16"	7/8"	32885K202	27.38	24.39
1/8"	0.3	0.5	0.7	1.4	120°	0.05"	7/16"	7/8"	32885K521	27.38	24.39
1/8"	0.5	0.7	1.1	2.2	60°	0.07"	7/16"	7/8"	32885K831	27.38	24.39
1/8"	0.5	0.7	1.1	2.2	90°	0.07"	7/16"	7/8"	32885K204	27.38	24.39
1/8"	0.5	0.7	1.1	2.2	120°	0.07"	7/16"	7/8"	32885K531	27.38	24.39
1/4"	0.7	1.0	1.5	2.9	60°	0.08"	9/16"	1 1/16"	32885K543	29.74	26.75
1/4"	0.7	1.0	1.5	2.9	90°	0.08"	9/16"	1 1/16"	32885K206	29.74	26.75
1/4"	0.7	1.0	1.5	2.9	120°	0.08"	9/16"	1 1/16"	32885K541	29.74	26.75
1/4"	1.0	1.5	2.3	4.4	60°	0.10"	9/16"	1 1/16"	32885K553	29.74	26.75
1/4"	1.0	1.5	2.3	4.4	90°	0.10"	9/16"	1 1/16"	32885K208	29.74	26.75
1/4"	1.0	1.5	2.3	4.4	120°	0.10"	9/16"	1 1/16"	32885K551	29.74	26.75
3/8"	1.4	2.0	3.0	5.9	60°	0.12"	11/16"	1 1/4"	32885K563	34.68	30.93
3/8"	1.4	2.0	3.0	5.9	90°	0.12"	11/16"	1 1/4"	32885K301	34.68	30.93
3/8"	1.4	2.0	3.0	5.9	120°	0.12"	11/16"	1 1/4"	32885K561	34.68	30.93
3/8"	2.1	3.0	4.6	8.8	60°	0.15"	11/16"	1 1/4"	32885K861	34.68	30.93
3/8"	2.1	3.0	4.6	8.8	90°	0.15"	11/16"	1 1/4"	32885K303	34.68	30.93
3/8"	2.1	3.0	4.6	8.8	120°	0.15"	11/16"	1 1/4"	32885K571	34.68	30.93
3/8"	2.8	4.0	6.1	11.8	60°	0.18"	11/16"	1 1/4"	32885K583	34.68	30.93

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
3/8"	2.8	4.0	6.1	11.8	90°	0.18"	11/16"	1 1/4"	32885K305	34.68	30.93
3/8"	2.8	4.0	6.1	11.8	120°	0.18"	11/16"	1 1/4"	32885K581	34.68	30.93
1/2"	3.6	5.0	7.6	14.8	60°	0.20"	7/8"	1 1/2"	32885K871	39.24	34.89
1/2"	3.6	5.0	7.6	14.8	90°	0.20"	7/8"	1 1/2"	32885K307	39.24	34.89
1/2"	3.6	5.0	7.6	14.8	120°	0.20"	7/8"	1 1/2"	32885K591	39.24	34.89
1/2"	4.3	6.0	9.2	17.7	60°	0.21"	7/8"	1 1/2"	32885K613	39.24	34.89
1/2"	4.3	6.0	9.2	17.7	90°	0.21"	7/8"	1 1/2"	32885K401	39.24	34.89
1/2"	4.3	6.0	9.2	17.7	120°	0.21"	7/8"	1 1/2"	32885K611	39.24	34.89
1/2"	5.0	7.0	10.8	20.7	60°	0.22"	7/8"	1 1/2"	32885K623	39.24	34.89
1/2"	5.0	7.0	10.8	20.7	90°	0.22"	7/8"	1 1/2"	32885K403	39.24	34.89
1/2"	5.0	7.0	10.8	20.7	120°	0.22"	7/8"	1 1/2"	32885K621	39.24	34.89
3/4"	5.7	8.0	12.3	23.6	60°	0.23"	1 1/8"	1 3/4"	32885K634	71.38	63.67
3/4"	5.7	8.0	12.3	23.6	90°	0.23"	1 1/8"	1 3/4"	32885K635	71.38	63.67
3/4"	5.7	8.0	12.3	23.6	120°	0.23"	1 1/8"	1 3/4"	32885K636	71.38	63.67
3/4"	8.6	12.0	18.5	35.4	60°	0.31"	1 1/8"	1 3/4"	32885K654	71.38	63.67
3/4"	8.6	12.0	18.5	35.4	90°	0.31"	1 1/8"	1 3/4"	32885K655	71.38	63.67
3/4"	8.6	12.0	18.5	35.4	120°	0.31"	1 1/8"	1 3/4"	32885K656	71.38	63.67
1"	10.8	15.0	23.1	44.3	60°	0.32"	1 3/8"	2 3/16"	32885K664	86.55	77.20
1"	10.8	15.0	23.1	44.3	90°	0.32"	1 3/8"	2 3/16"	32885K665	86.55	77.20
1"	10.8	15.0	23.1	44.3	120°	0.32"	1 3/8"	2 3/16"	32885K666	86.55	77.20
1"	14.4	20.0	30.8	59.0	60°	0.37"	1 3/8"	2 3/16"	32885K674	86.55	77.20

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
1"	14.4	20.0	30.8	59.0	90°	0.37"	1 3/8"	2 3/16"	32885K675	86.55	77.20
1"	14.4	20.0	30.8	59.0	120°	0.37"	1 3/8"	2 3/16"	32885K676	86.55	77.20
Stainless Steel NPT Female											
1/8"	0.1	0.2	0.3	0.7	60°	0.04"	9/16"	1 1/8"	32885K812	27.38	24.39
1/8"	0.1	0.2	0.3	0.7	90°	0.04"	9/16"	1 1/8"	32885K201	27.38	24.39
1/8"	0.1	0.2	0.3	0.7	120°	0.04"	9/16"	1 1/8"	32885K512	27.38	24.39
1/8"	0.3	0.5	0.7	1.4	60°	0.05"	9/16"	1 1/8"	32885K822	27.38	24.39
1/8"	0.3	0.5	0.7	1.4	90°	0.05"	9/16"	1 1/8"	32885K203	27.38	24.39
1/8"	0.3	0.5	0.7	1.4	120°	0.05"	9/16"	1 1/8"	32885K522	27.38	24.39
1/8"	0.5	0.7	1.1	2.2	60°	0.07"	9/16"	1 1/8"	32885K832	27.38	24.39
1/8"	0.5	0.7	1.1	2.2	90°	0.07"	9/16"	1 1/8"	32885K205	27.38	24.39
1/8"	0.5	0.7	1.1	2.2	120°	0.07"	9/16"	1 1/8"	32885K532	27.38	24.39
1/4"	0.7	1.0	1.5	2.9	60°	0.08"	11/16"	1 3/8"	32885K544	29.74	26.75
1/4"	0.7	1.0	1.5	2.9	90°	0.08"	11/16"	1 3/8"	32885K207	29.74	26.75
1/4"	0.7	1.0	1.5	2.9	120°	0.08"	11/16"	1 3/8"	32885K542	29.74	26.75
1/4"	1.0	1.5	2.3	4.4	60°	0.10"	11/16"	1 3/8"	32885K554	29.74	26.75
1/4"	1.0	1.5	2.3	4.4	90°	0.10"	11/16"	1 3/8"	32885K209	29.74	26.75
1/4"	1.0	1.5	2.3	4.4	120°	0.10"	11/16"	1 3/8"	32885K552	29.74	26.75
3/8"	1.4	2.0	3.0	5.9	60°	0.12"	7/8"	1 1/2"	32885K564	34.68	30.93
3/8"	1.4	2.0	3.0	5.9	90°	0.12"	7/8"	1 1/2"	32885K302	34.68	30.93
3/8"	1.4	2.0	3.0	5.9	120°	0.12"	7/8"	1 1/2"	32885K562	34.68	30.93

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
3/8"	2.1	3.0	4.6	8.8	60°	0.15"	7/8"	1 1/2"	32885K862	34.68	30.93
3/8"	2.1	3.0	4.6	8.8	90°	0.15"	7/8"	1 1/2"	32885K304	34.68	30.93
3/8"	2.1	3.0	4.6	8.8	120°	0.15"	7/8"	1 1/2"	32885K572	34.68	30.93
3/8"	2.8	4.0	6.1	11.8	60°	0.18"	7/8"	1 1/2"	32885K584	34.68	30.93
3/8"	2.8	4.0	6.1	11.8	90°	0.18"	7/8"	1 1/2"	32885K306	34.68	30.93
3/8"	2.8	4.0	6.1	11.8	120°	0.18"	7/8"	1 1/2"	32885K582	34.68	30.93
1/2"	3.6	5.0	7.6	14.8	60°	0.20"	1 1/8"	2"	32885K872	39.24	34.89
1/2"	3.6	5.0	7.6	14.8	90°	0.20"	1 1/8"	2"	32885K308	39.24	34.89
1/2"	3.6	5.0	7.6	14.8	120°	0.20"	1 1/8"	2"	32885K592	39.24	34.89
1/2"	4.3	6.0	9.2	17.7	60°	0.21"	1 1/8"	2"	32885K614	39.24	34.89
1/2"	4.3	6.0	9.2	17.7	90°	0.21"	1 1/8"	2"	32885K402	39.24	34.89
1/2"	4.3	6.0	9.2	17.7	120°	0.21"	1 1/8"	2"	32885K612	39.24	34.89
1/2"	5.0	7.0	10.8	20.7	60°	0.22"	1 1/8"	2"	32885K624	39.24	34.89
1/2"	5.0	7.0	10.8	20.7	90°	0.22"	1 1/8"	2"	32885K404	39.24	34.89
1/2"	5.0	7.0	10.8	20.7	120°	0.22"	1 1/8"	2"	32885K622	39.24	34.89
3/4"	5.7	8.0	12.3	23.6	60°	0.23"	1 3/8"	2 1/8"	32885K631	71.38	63.67
3/4"	5.7	8.0	12.3	23.6	90°	0.23"	1 3/8"	2 1/8"	32885K632	71.38	63.67
3/4"	5.7	8.0	12.3	23.6	120°	0.23"	1 3/8"	2 1/8"	32885K633	71.38	63.67
3/4"	8.6	12.0	18.5	35.4	60°	0.31"	1 3/8"	2 1/8"	32885K651	71.38	63.67
3/4"	8.6	12.0	18.5	35.4	90°	0.31"	1 3/8"	2 1/8"	32885K652	71.38	63.67
3/4"	8.6	12.0	18.5	35.4	120°	0.31"	1 3/8"	2 1/8"	32885K653	71.38	63.67

	Flow Rate, gpm									Each	
Pipe Size	20 psi	40 psi	100 psi	400 psi	Spray Angle	Orifice Dia.	O'all Wd. (Hex Size)	O'all Lg.		1-9	10-Up
1"	10.8	15.0	23.1	44.3	60°	0.32"	1 5/8"	2 3/8"	32885K661	86.55	77.20
1"	10.8	15.0	23.1	44.3	90°	0.32"	1 5/8"	2 3/8"	32885K662	86.55	77.20
1"	10.8	15.0	23.1	44.3	120°	0.32"	1 5/8"	2 3/8"	32885K663	86.55	77.20
1"	14.4	20.0	30.8	59.0	60°	0.37"	1 5/8"	2 3/8"	32885K671	86.55	77.20
1"	14.4	20.0	30.8	59.0	90°	0.37"	1 5/8"	2 3/8"	32885K672	86.55	77.20
1"	14.4	20.0	30.8	59.0	120°	0.37"	1 5/8"	2 3/8"	32885K673	86.55	77.20