Design Report

The Smoke Sentry

Team 12: Automeated Solutions

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ENGR 339/340 Senior Design Project

Calvin College

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Executive Summary

The project that Team 12 decided to study, design, and build is a device that can be inserted into a gas grill to automate the smoking process of meat so someone can walk away from the grill. The team performed research on automated devices for alternative smoking methods such as charcoal and electric grills. The senior design group met with Smokehouse professionals and others with smoking expertise in order to learn about challenges and to gain perspectives for a gas grill, smoking device. The team then decided on methods to implement with the device to maintain gas flow, regulate and measure temperature, and provide the correct amount of wood pellets and smoke. The team has built a prototype Smoke Sentry and has tested and refined the prototype design.

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1.6 Introduction

Smoking of meat is a process that allows flavors to permeate meat and makes meat more tender. The person smoking the meat chooses a type of wood flavoring to imbue into the meat. The chips from this wood flavor are soaked in water to extend their life in the heat and increase the smoke released. The chips are gradually inserted into the smoker over time to keep a consistent smoke content. The smoke and heat in the smoking device cook and flavor the meat. When the meat reaches the desired internal temperature, the process is finished. This means that the process takes a large amount of time and careful attention to temperature and smoke fuel. Therefore, it is a good process to automate since it is intensive and time consuming. In addition to the nature of smoking to be arduous, it is also not easily available as a way of cooking meat for many people. Many of these people have gas grills and there is no readily available, automated way to smoke meat on a gas grill. With this in mind, the team decided to focus on automated gas grill smoking for the project.

Team 12 consists of two mechanical engineers, Jon Sager and Jordan Swets, and two electrical engineers, Ethan Oosterman and Dain Griffin. The goal of the senior design course is to apply the knowledge learned in engineering classes to a real-world project. It is a capstone course to highlight the skills of senior engineers through an open-ended project. The engineering department at Calvin College seeks to provide students with the ability to handle challenges and requirements that they face in real scenarios. Calvin College is a liberal arts college that aims to provide students with the skill set to face the work environment.

1.7 Project Management

1.7.1 Team Organization

The team is divided into two groups. The mechanical engineers on the team are responsible for the design and construction of the majority of the system's hardware. This includes the gas valve, chip feed, and food rack devices. These members of the team are also tasked with determining how best to use these components to keep the system in thermodynamic balance.

The team's electrical engineers are responsible for the control systems needed to adjust the devices used for the process and how to relay this to the user. They are to design and build the system's electrical control panel as well as program the system's microcontroller to operate a grill without constant user input.

Team members' duties may be adjusted when high-priority project tasks require immediate attention. In the event that an essential part of the project is behind schedule, additional time may be allocated to this task from other tasks of less importance.

Before a team member makes a decision that affects the other members' work, that team member shall notify the others and explain the rationale for the decision to ensure all team members have complete knowledge of relevant parts of the project.

Team members are expected to be present at all meetings. Should a team member be unable to attend a meeting, that member should give advance notice to the other members if possible.

The team chose Jordan to be the team leader and contact with the faculty team advisor. Dain was chosen to be in charge of finances and budget.

Team Advisor:	Professor Mark Michmerhuizen
Class Instructors:	Professor Leonard DeRooy
	Professor Renard Tubergen
	Professor Mark Michmerhuizen
	Professor Ned Nielsen
	Professor Jeremy VanAntwerp
Industrial Consultant:	Eric Walstra (Gentex Corp.)
Project Mentor:	Randy Newsome (Intralox LLC)

1.7.2 Schedule

Scheduling for the team is usually decided a week in advance. The tasks needed to be performed are discussed over the weekend. Each workday, the schedule is reviewed and edited on the team's whiteboard as deemed necessary. This is then updated with the work breakdown schedule. The project schedule can be seen in the Appendix as the work breakdown schedule. Each team member is expected to work at least eight hours outside of class-allotted time per week on the project. The team members who do not achieve this are expected to make up for lost time on their own time.

1.7.3 Budget

The main use of the budget will be for electrical components needed for the device. Most mechanical components are available from the machine shop and will not need to be purchased. Donors (as seen in Acknowledgements) have provided meat for testing. A grill has been offered for use during testing as well (as seen in Acknowledgements).

1.7.4 Method of Approach

For this project, research was needed on alternative solutions, recipes, the smoking process in general, and electrical control devices. These research topics were split evenly amongst the group. The device was then designed based on initial research, then modified as tests were performed in order to achieve better results. This process of optimization after initial design was how the team achieved a working prototype.

1.8 Requirements

1.8.1 Prototype Requirements

1.8.1.1 Smoke Fuel Feed System

(1) The prototype shall input chips into the chip tray.

(2) The prototype should be capable of inputting a minimum of 30 chips every 30 minutes.

(3) The weight of the smoke fuel feed system prototype shall be less than 20 pounds.

(4) The size of the smoke fuel feed system prototype should not exceed 225 square inches.

(5) The smoke fuel feed system prototype shall hold its integrity while exposed to temperatures up to 250 degrees Fahrenheit.

(6) The smoke fuel feed system prototype shall not permanently alter the existing gas grill system

1.8.1.2 Commentary on Smoke Fuel Feed System

(1) Smoking meats requires the burning of soaked chips inside the chamber where the meat is cooked. This provides the flavor for the meat.

(2) Chips need to be input into the system often enough to continue to provide smoke for the meat. This requirement is a benchmark, chips may not need to be inputted this often.

(3) The smoke fuel feed system needs to be within the weight range that is comfortable for the typical consumer to pick up and move around. However, it needs to be heavy enough to be stable.

(4) The smoke fuel feed system needs to fit on the side tray that is on all gas grills. This will be the most convenient for customers.

(5) The smoke fuel feed system will be exposed to hotter than ambient temperatures due to its proximity to the grill.

(6) For the convenience of the consumer, the "smoke sentry" should be an attachment to any existing grill as opposed to be an entire system.

1.8.1.3 Gas Flow Control System

(1) The prototype shall control the flow of propane into the system.

(2) The weight of the gas control system prototype shall be less than 20 pounds.

(3) The size of the gas control system prototype should not exceed 120 square inches.

(4) The gas flow control system shall not permanently alter the existing gas grill system.

1.8.1.4 Commentary on Gas Control System

(1) Controlling the amount of propane into the system is the method by which temperature is controlled within the system.

(2) The gas control system needs to be within the weight range that is comfortable for the typical consumer to pick up and assemble. However, it needs to be heavy enough to be stable.

(3) The gas control system needs to be small enough to not be an inconvenient obstacle to consumers.

(4) For the convenience of the consumer, the “smoke sentry” should be an attachment to any existing grill as opposed to be an entire system.

1.8.1.5 System Controller

(1) The system controller shall be capable of manually controlling the gas flow system.

(2) The system controller shall be capable of autonomously controlling the gas flow system

(3) The system controller shall be capable of manually controlling the smoke fuel feed system.

(4) The system controller shall be capable of autonomously controlling the smoke fuel feed system.

(5) The system controller shall be accessible via a local web server.

1.8.1.6 Commentary on System Controller

(1) If the customer would like to manually change the gas flow, the system controller should accommodate this customer

(2) If the customer would like to leave the system while still controlling the gas flow, the system controller should accommodate this customer

(3) If the customer would like to manually change the smoke fuel feed, the system controller should accommodate this customer

(4) If the customer would like to leave the system while still controlling the smoke fuel feed, the system controller should accommodate this customer

(5) For the purpose of this prototype, a local web server is sufficient for accessing the controls

1.8.1.6 Temperature Sensor

(1) The temperature sensor shall measure temperature with an accuracy of +/- 2 [F]

(2) The temperature sensor shall hold its integrity while exposed to temperature of 300 degrees Fahrenheit

1.8.1.7 Commentary on Temperature Sensor

(1) Temperature needs to be measured within this accuracy to be reliable for the system controller.

(2) The inside of the system will reach a maximum temperature of 300 degrees Fahrenheit.

1.8.1.10 Safety

(1) The gas control system shall not contain any leaks

(2) The system should not expose any surface exceeding 100 degrees Fahrenheit.

1.8.1.11 Commentary on Safety

(1) Gas leaks are a danger to the safety of the customers

(2) Any surface exceeding that temperature could harm the customer if they should contact it. However, a normal propane grill exposes surfaces hotter than 100 degrees Fahrenheit so this requirement is not binding.

1.8.2 Product Requirements

1.8.2.1 Smoke Fuel Feed System

(1) The product shall input chips into the chip tray. (Same as Prototype [SAP])

(2) The product shall be capable of inputting a minimum of 30 chips every 30 minutes for up to 9 hours.

(3) The weight of the smoke fuel feed system product shall be less than 20 pounds. SAP

(4) The size of the smoke fuel feed system product should not exceed 225 square inches. SAP

(5) The smoke fuel feed system product shall remain its integrity while exposed to temperatures up to 250 degrees Fahrenheit. SAP

1.8.2.2 Commentary on Smoke Fuel Feed System

(1) Smoking meats requires the burning of soaked chips inside the chamber where the meat is cooked. This provides the flavor for the meat.

(2) Chips need to be input into the system often enough to continue to provide smoke for the meat. This requirement is a benchmark, chips may not need to be inputted this often.

(3) The smoke fuel feed system needs to be within the weight range that is comfortable for the typical consumer to pick up and move around. However, it needs to be heavy enough to be stable.

(4) The smoke fuel feed system needs to fit on the side tray that is on all gas grills. This will be the most convenient for customers.

(5) The smoke fuel feed system will be exposed to hotter than ambient temperatures due to its proximity to the grill.

(6) This is an accommodation for consumers who want to manually control the system.

(7) The system should be capable of being left alone and performing its functions.

1.8.2.3 Gas Flow Control System

(1) The product shall control the flow of propane into the system. SAP

(2) The weight of the gas flow control system product shall be less than 20 pounds. SAP

(3) The size of the gas flow control system product should not exceed 120 square inches. SAP

1.8.2.4 Commentary on Gas Flow Control System

(1) Controlling the amount of propane into the system is the method by which temperature is controlled within the system.

(2) The gas flow control system needs to be within the weight range that is comfortable for the typical consumer to pick up and assemble. However, it needs to be heavy enough to be stable.

(3) The gas flow control system needs to be small enough to not be an inconvenient obstacle to consumers.

1.8.2.5 System Controller

(1) The system controller shall be capable of manually controlling the gas flow system. SAP

(2) The system controller shall be capable of autonomously controlling the gas flow system. SAP

(3) The system controller shall be capable of manually controlling the smoke fuel feed system. SAP

(4) The system controller shall be capable of autonomously controlling the smoke fuel feed system. SAP

(5) The system controller shall be accessible via a local Wi-Fi connection. SAP

1.8.2.6 Commentary on System Controller

(1) If the customer would like to manually change the gas flow, the system controller should accommodate this customer

(2) If the customer would like to leave the system while still controlling the gas flow, the system controller should accommodate this customer

(3) If the customer would like to manually change the smoke fuel feed, the system controller should accommodate this customer

(4) If the customer would like to leave the system while still controlling the smoke fuel feed, the system controller should accommodate this customer

(5) For the product design, a Wi-Fi connection is the most convenient for system control for the customer.

1.8.2.7 Temperature Sensor

(1) The temperature sensor shall measure temperature with an accuracy of +/- 1 [F]

(2) The temperature sensor holds its integrity while exposed to temperature of 310 degrees Fahrenheit.

1.8.2.8 Commentary on Temperature Sensor

(1) Temperature needs to be measured within this accuracy to be reliable for the system controller. An increased level of accuracy is required for the actual production of this design

(2) The inside of the system will reach a maximum temperature of 300 degrees Fahrenheit. However, if this product were to go into design, there would need to be a safety factor to accommodate the customers as well as the shareholders.

1.8.1.11 Safety

(1) The product shall comply with UL standards.

(2) The product shall comply with CE standards.

(3) The product shall have an emergency shutdown switch

(4) The product shall detect and warn the user of any malfunction

(5) The gas control system shall not contain any leaks

(6) The system shall not expose any surface exceeding 100 degrees Fahrenheit.

1.8.1.12 Commentary on Safety

(1) By complying with these standards, it provides the shareholders, as well as customers, that safety considerations have been met.

(2) By complying with these standards, it provides the shareholders, as well as, customers that safety considerations have been met. In addition, the product will be able to circulate internationally.

(3) In the case of a potential gas leak or similar malfunction, the customer needs a quick and easy method of turning the system off.

(4) The customer should be made aware of any potential threats that a malfunctioning product could pose.

(5) Gas leaks are a danger to the safety of the customers

(6) Any surface exceeding that temperature could harm the customer if they should contact it.

1.9 Research

While investigating how to accomplish the proposed solution, the team found other similar systems on the market. The "Big Green Egg" (biggreenegg.com) is its own device and grill combination that runs on charcoal. The CyberQ (bbqguru.com) is a device that monitors and regulates temperatures in a grill or smoker, but only in systems that use charcoal. The PitmasterIQ (pitmasterIQ.com) also monitors temperatures in grills while barbecuing, but again, only charcoal-based systems.

These products are all based around devices that use charcoal and do not address systems that use gas. The solution strives to be more versatile and user friendly than the other products mentioned. The CyberQ and the PitmasterIQ are simply parts of the solution that the team will create. Although the device will also monitor and regulate temperature, it will also transform a current gas grill that is used by the average consumer into an automated smoking experience. This is not in the scope of the CyberQ and the PitmasterIQ devices.

In addition, the team was able to tour a smokehouse in Portage called "Barrett's Smokehouse". The owner of the smokehouse, Tim Barrett, showed the team numerous methods of smoking different types of meats. The takeaway from this tour was the common method of "low and slow". This refers to a timing and temperature controlling technique where the chef starts at the lowest temperature to increase the porosity of the meat. He then adds smoke to the system to fill the pores with the flavor of the wood. When the pores are filled, the temperature is increased again to further increase the porosity and smoke absorbed by the meat. The smoking process is finished when the meat can take no more smoke because it cannot increase its porosity and the appropriate core temperature has been reached.

See References in section 1.19.

1.10 **Task Specifications and Schedule**

The tasks were split up into their mechanical and electrical concentrations. For example, designing the structure of the proposed system is to be drawn in a 3D modeling package such as SolidWorks and is to be done by either of the Mechanical Engineers on the team. In addition, any thermal or force FEA on the system will also be done by Jon who is a Mechanical Engineer. However, designing the circuit diagram for the proposed architecture is to be done by the electrical engineers.

After the system is modeled and the circuit diagram is created, the materials can be ordered, the prototype can be built and wired and testing, retesting, and debugging can begin. A more complete list of tasks and scheduling can be seen in Appendix A.

1.11 **System Architecture**

The system's hardware consists of five major components to be attached to an existing gas grill. The first of these is a custom-made rack for smoking food with an attached tray underneath to hold the required wooden chips. The tray is designed to be small enough to fit inside any grill a customer may wish to use, yet large enough to hold a reasonable amount of food.

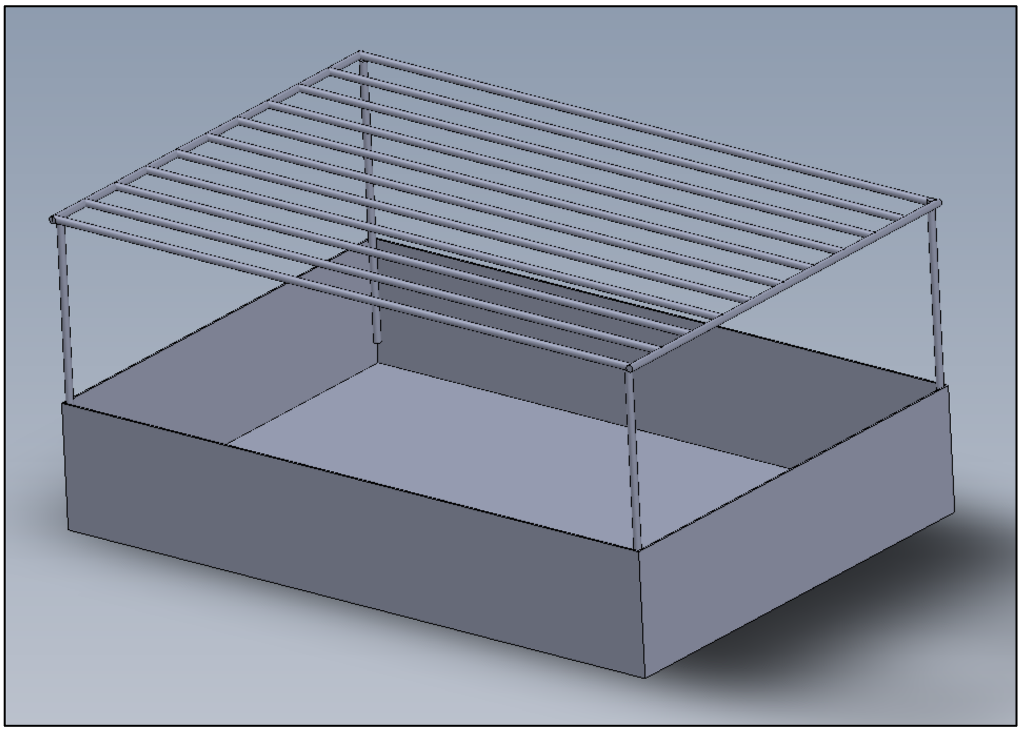

Figure 1.11.1. Tray concept for wood chips

The second component is a system used to transport chips into the tray as needed throughout the smoking process. An auger is controlled by a stepper motor in order to move chips into a chute that leads to the chip tray. As chips are consumed during the smoking process, the system slowly feeds more into the tray as needed. A model of the design's auger system is displayed in Figure 1.11.2. The auger is attached to a stepper motor. This motor receives signals for its operation from the control system and rotates the auger accordingly. The auger then pushes the chips down the tube to then fall into the chip tray, burn, and provide the smoke in the system. The rate at which wood chips are added to the flame must be regulated to ensure that the food receives the proper amount of smoke.

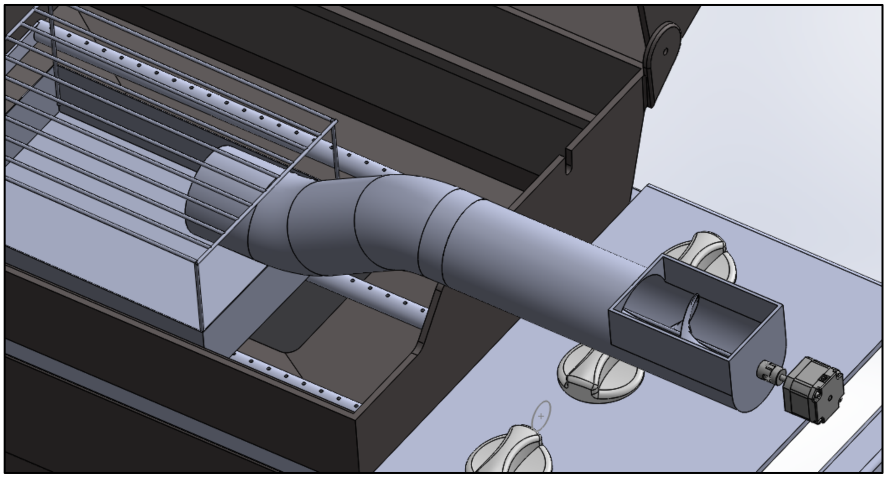

Figure 1.11.2. Auger concept for chip transport

The third component is an apparatus that is attached to the grill's gas tank. This system contains an external gas valve that is connected via a pulley to a stepper motor to control the gas flow into the grill. The flow is adjusted as necessary while smoking to ensure that the grill stays at the desired temperature. Temperature regulation is directly related to the gas input into the system. The team designed a method of controlling the gas input into the system that can be seen in Figure 1.11.3. As seen in the figure, there are two pulleys attached by a synchronous belt. One of the pulleys is attached to a valve on the propane tank. The other pulley is attached to a step motor. The step motor will receive temperature data signals from the control system and twist the pulley accordingly. When the pulley attached to the step motor is twisted it will then twist the pulley on the gas valve which will either increase or decrease the amount of gas into the system.

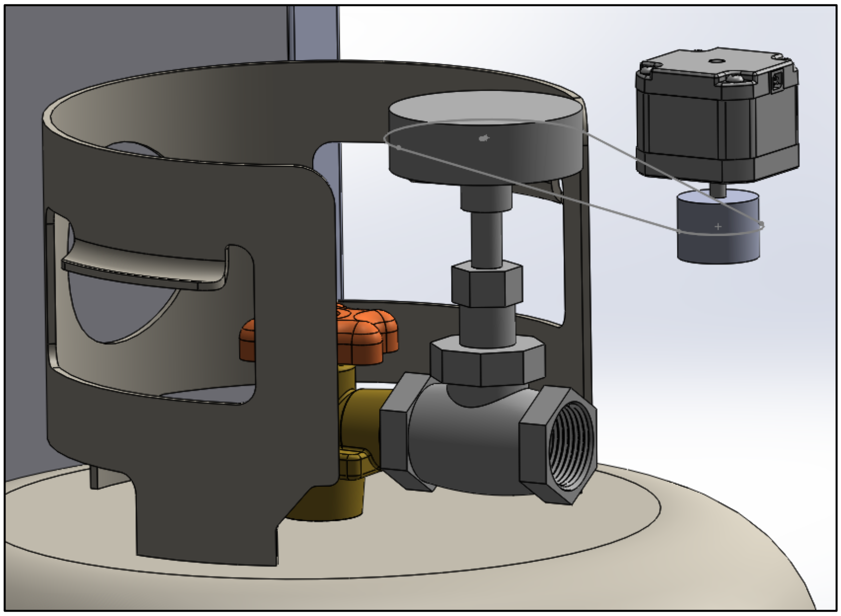

Figure 1.11.3 Gas flow control apparatus concept

The fourth component is a network of sensors that are used to monitor the environment within the grill and ensure that it operates as intended. The system shall contain two thermocouples in order to measure both the ambient temperature inside the grill and the internal temperature of the food being smoked. A flame sensor is also utilized to check whether the gas flowing into the grill is igniting. This allows the system to prevent potential gas leaks by closing the valve if the gas is not burning.

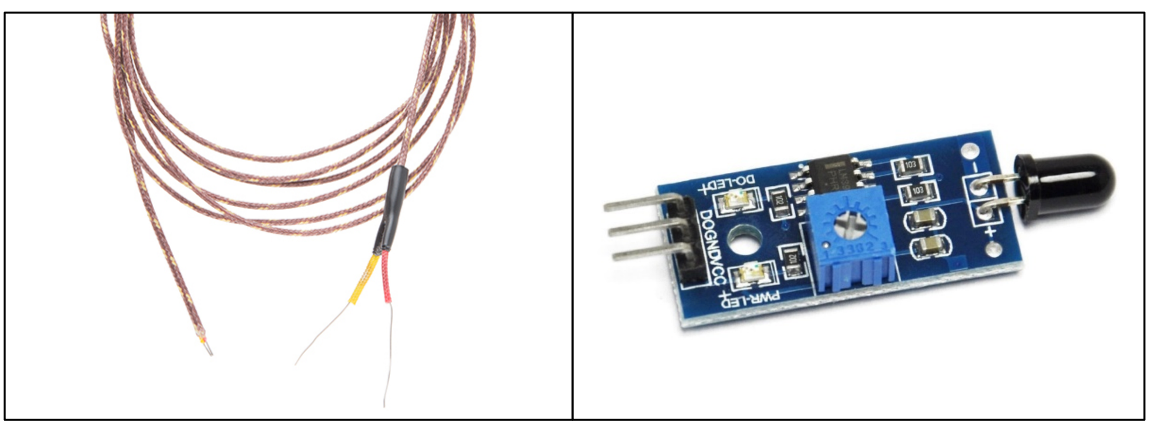

Figure 1.11.4. Thermocouple and infrared flame sensor

The fifth and final hardware component is an electrical panel which contains a microcontroller, a circuit board for handling inputs and outputs, and a power supply. The prototype system utilizes a Raspberry Pi to run the software which controls the autonomous operation of the Smoke Sentry. The Raspberry Pi is connected to the thermocouples and flame sensor to monitor the state of the grill. It then processes the information gathered from these sensors to determine when and how to operate the system's stepper motors. The Raspberry Pi interacts with the motors through an Adafruit Motor HAT, a circuit board containing additional necessary circuitry to power and control stepper motors. Both the Raspberry Pi and the Adafruit Motor HAT are also connected to the panel's power supply.

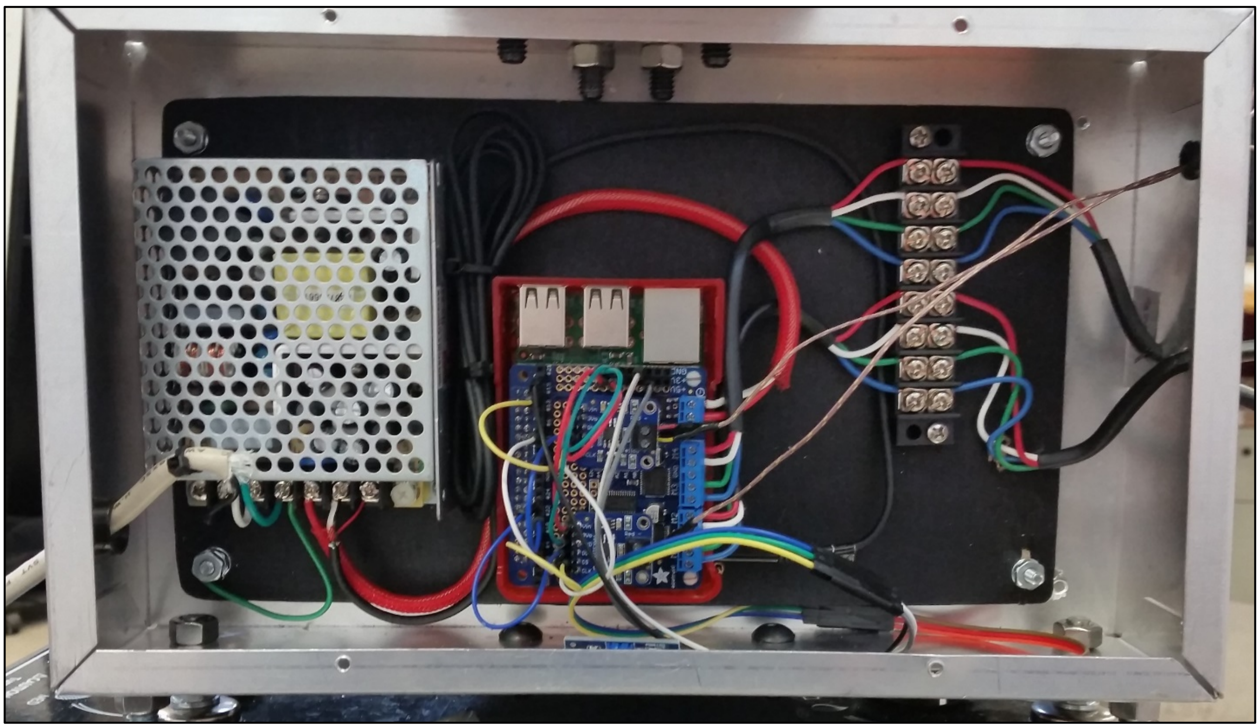

Figure 1.11.5. Electrical component panel inside enclosure

In addition to monitoring the system's inputs and outputs, the software within the Raspberry Pi also runs a web server to allow for a user to set parameters for operation via an internet connection. The server can be accessed from any browser on the same network and provides the user with an interface for controlling the machine's outputs.

A diagram of the overall system is shown in Figure 1.11.6 below.

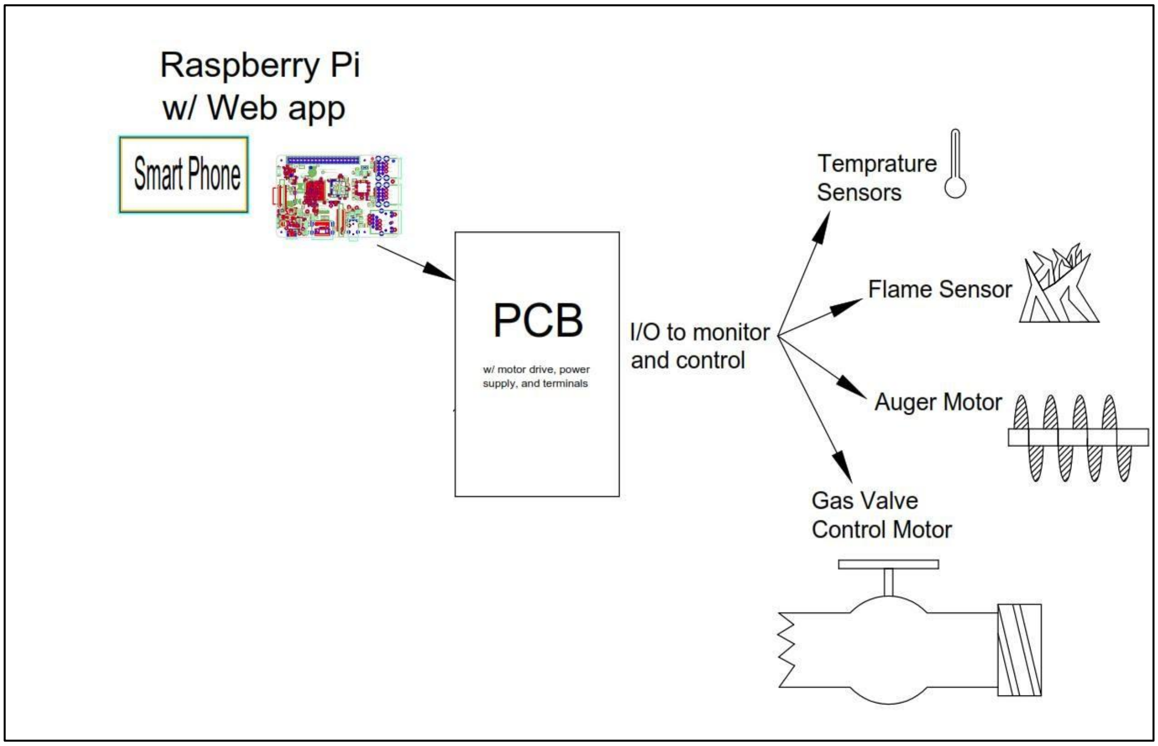

Figure 1.11.6. System diagram for Smoke Sentry components

1.12 **Design Norms**

This design focuses primarily on three design norms: transparency, integrity, and caring. The system will be transparent in that it will communicate the temperature to the user in a clear and concise way to ensure awareness of the smoking process. Additionally, integrity is to be shown through honest communication of the data displayed to the user. All information sent shall be accurate and honest. Finally, the idea of caring for the user is essentially the entire basis for this design. This product is intended to make the smoking process easier and less stressful for the user, improving the user's quality of life.

A tension that the team faces is the inherent purpose of the project. The team is using gas to cook meat. Using propane gas for multiple hours continuously is not being stewards of the earth that was given to us. In essence, the team is sacrificing the use of more gas for tastier meat. This is not evidence of Christians who are stewards of this earth. This is an unsolvable tension that exists within the nature of the project.

1.13 Design

1.13.1 Smoke Fuel Feed System

1.13.1.1 Design Criteria and Alternatives

In order for the system to have sufficient smoke for flavoring the meat, the system is required to have a means of delivering wood chips or pellets in to the cooking compartment. The criteria chosen for this part of the system are as follows: the system must have a high capacity of chips or pellets in a compact space for long cooks, it must be inexpensive, and must be easily programmable. The high capacity is necessary to impart trust that the Smoke Sentry will continue to provide smoke while the user is away, the inexpensive criteria is important because the team seeks to reduce waste. If a user were to buy another product, they would be buying more material than if they bought the Smoke Sentry which attaches to an existing system thus being more of a steward of resources. The simplicity of programming is for the sake of designing and minimizing design time and effort. The two alternatives for this as proposed by the team were a shovel that pushes small piles of chips down a chute through use of an actuator or an auger that turns chips down a chute through use of a rotating motor.

1.13.1.2 Design Decision

The decision was made to use an auger with a motor driving it. Both systems could make use of a hopper for high capacity in a compact area so in that regard, they were equivalent. The main reason for the auger over the actuator was due to simplicity of programming. The auger is easily controlled by a stepper motor that is told to turn at specific intervals over the duration of a cook. The code for this is simple compared to the actuator that has to be told to move forward and backward to pick up more chips or pellets and push them a certain distance. Finally, the stepper motor was a lot less expensive option over the actuator.

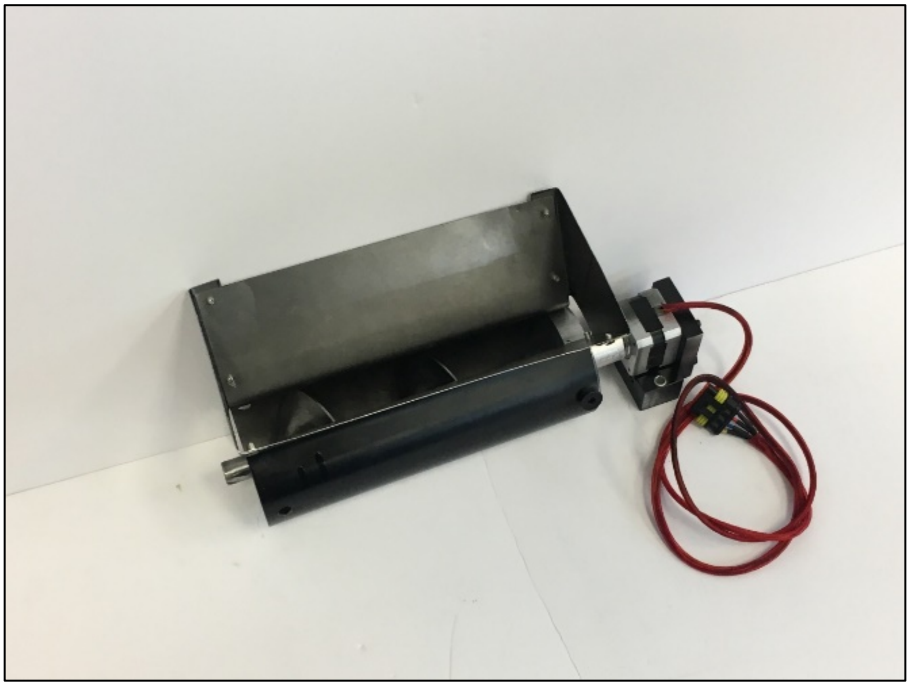

Figure 1.13.1. Final smoke fuel feed design

1.13.2 Gas Flow Control

1.13.2.1 Design Criteria and Alternatives

The project requires that temperature be controlled in order to cook the meat. For the Smoke Sentry, with its scope being confined to gas grills, temperature regulation must occur through altering the flow of gas to the system. The criteria assigned to this is that the flow control has to safely seal and close the gas line, it has to be easily automated, and it has to attach to the existing system without modifying the grill. Safety is inherent in the trust users have in the Smoke Sentry. The flow control is required to fully close to prevent gas leaks so fuel leakage does not pose a threat to users. It also must completely close so no propane is wasted which is important for stewards of resources just as no modifications to the grill adheres to stewardship.

One alternative proposed by the team was a clamp that would attach to the hose fuel line existing on the grill that would squeeze and loosen around the hose to restrict and open gas flow.

The other alternative was a motor-driven pulley system with a belt attached to a new valve that would open and close the valve.

1.13.2.2 Design Decision

The team decided on the pulley system with an extra valve to control the flow of gas. This system was found to be the safest as clamp systems were shown to be both inefficient and difficult to manage through research. The valve system allows for complete closure of the valve and thus complete gas flow stoppage. This was chosen as the safest solution to gas flow. Additional sealing was required for the extra valve as new components were chained to the existing system. These components met the gas rated sealing requirements for the USA from UL and CE. The valve, when sealed as such does not leak gas.

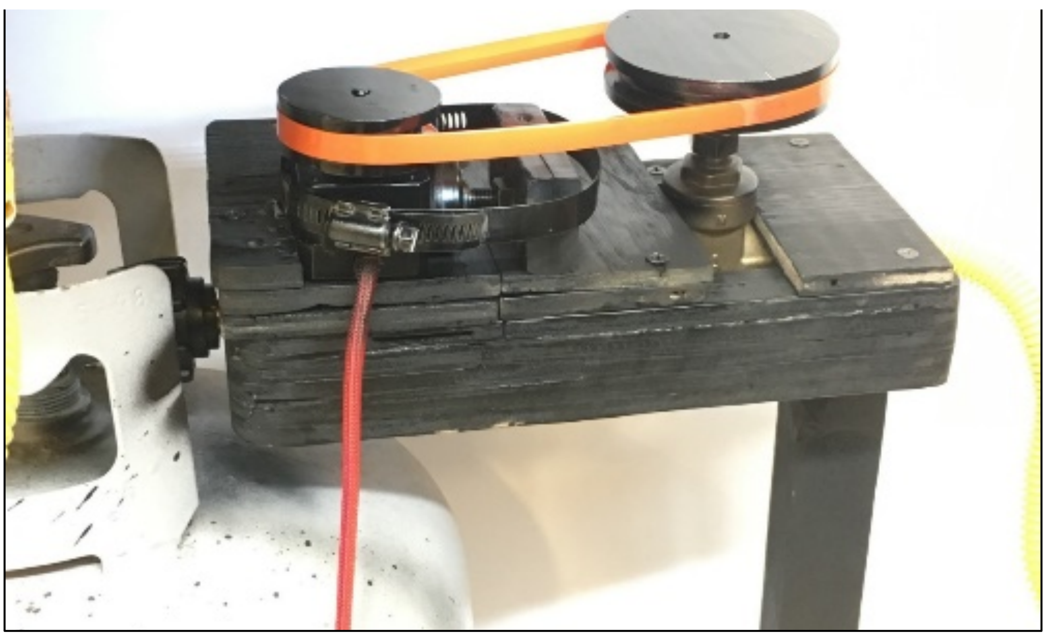

Figure 1.13.2 Final gas flow control design

1.13.3 System Controller

1.13.3.1 Design Criteria and Alternatives

The criteria for evaluating a system controller are that it has to be inexpensive and easy to program for the given requirements of the valve and auger.

The system's controller offers a great deal of design alternatives. For the purposes of this project, the choice has been narrowed down to a Raspberry Pi or an Allen-Bradley Micrologix 820 PLC. Both offer their own unique advantages and disadvantages. The Raspberry Pi is advantageous in that it is cheaper by an order of magnitude (tens rather than hundreds of dollars) and it offers more freedom of choice in software development for the system. A Raspberry Pi can be programmed in a number of different languages, while a MicroLogix 820 has a much more limited selection. The Raspberry Pi also offers more in the way of connectivity to external devices through Bluetooth or Wi-Fi. Nevertheless, the MicroLogix PLC has advantages of its own. While the PLC must be programmed with proprietary software, this software greatly simplifies the process and allows for easier development of complicated control system functions than does a coding language. The Raspberry Pi would require a far greater amount of work to achieve the same results as a PLC. Additionally, the MicroLogix PLC has native support for analog signals, which would be required for the system's inputs and outputs. A Raspberry Pi does not, and would require converters from analog to digital and vice-versa.

1.13.3.2 Design Decision

Based on the aforementioned design criteria, the Raspberry Pi is the better choice for the system controller. While it is more difficult to program for this type of controller over a PLC, the lower price and added connectivity features make it the more suitable candidate for the job.

1.13.4 Temperature Sensor

1.13.4.1 Design Criteria and Alternatives

The criteria for the temperature sensor is that it has to measure temperature in the environment of a smoke-filled grill and that it must be inexpensive.

The temperature sensor also offers two alternatives. One is a thermocouple, while the other is an infrared sensor.

The thermocouple must be connected by a wire to the area at which the temperature must be measured, while the infrared sensor allows for temperature detection from a distance. On the other hand, since a thermocouple does not rely on light for its temperature reading, it is unhindered by the presence of heavy smoke in the grill. A thermocouple is also less expensive than an infrared sensor.

1.13.4.2 Design Decision

The thermocouple is the better choice for the system's temperature sensor. The lower price combined with the reliability in smoke-filled environments make this option more effective than the relatively expensive infrared sensor.

1.13.5 Auger Housing

1.13.5.1 Design Criteria and Alternatives

The criteria for the housing for the auger is that it cannot bind on the wood pellets or chips, and it has to support the motor and auger shaft easily. The average thickness of a woodchip exceeds 1/8 inches. This means that the space between the narrowest diameter of the auger and the widest part of the housing must be less than this to allow chips to move through without getting caught. The auger chosen was a 3 inch diameter auger made of steel. As such, the motor needed to be mounted in a way that could support the weight of the auger and the torque of the auger in the housing.

The two designs chosen between were a U-shaped channel made of sheet metal with a block that the motor connects to on one side and a plastic tube supported by angle iron with a seat for the motor to be attached to. These can be seen in Figure 1.13.3 and 1.13.4.

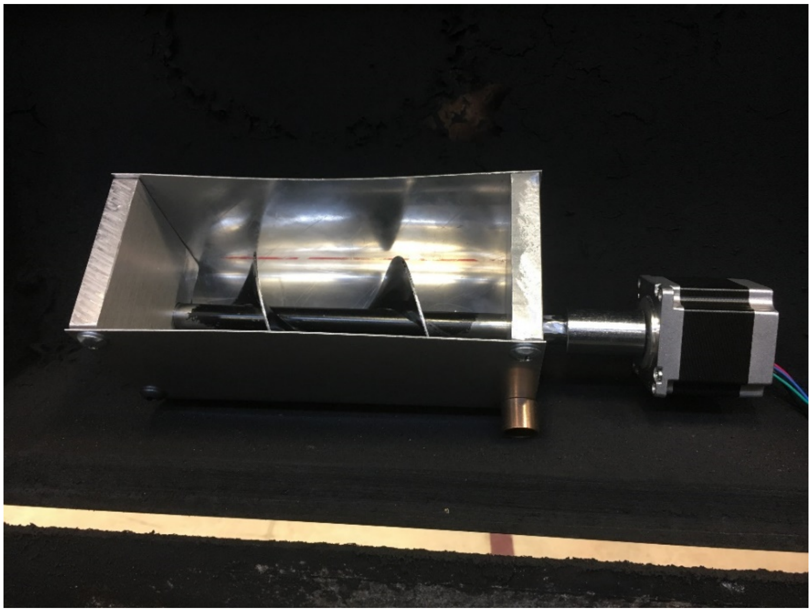

Figure 1.13.3. U-channel auger housing design

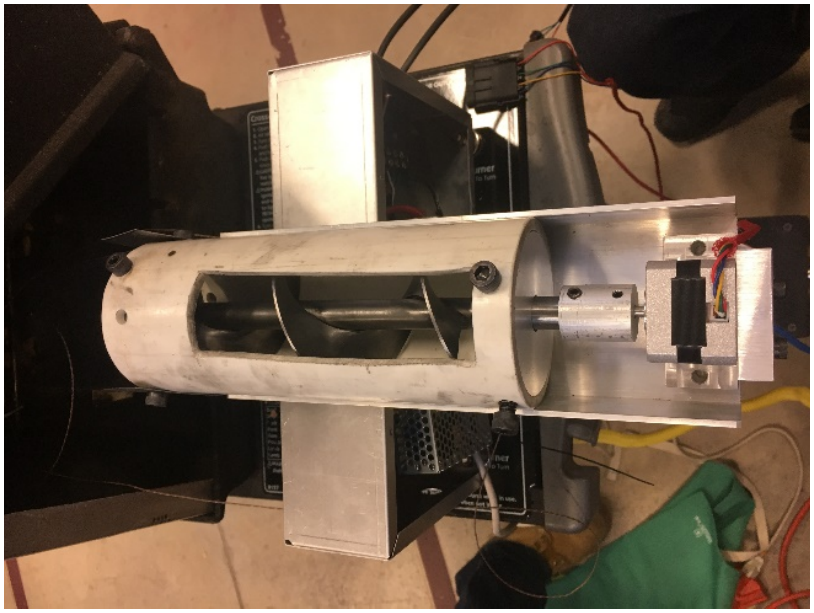

Figure 1.13.4. Tube auger housing design

1.13.5.2 Design Decision

The design chosen after both housings were built was the plastic tube supported by angle iron. The sheet metal, given the equipment in the machine shop at Calvin College, was too difficult to work with to achieve a reasonable circular radius for the auger to sit in. The tools often created oblong arcs which allowed chips to get caught between the wall and the blade of the auger. The plastic tube was rigid and already had a close tolerance with the diameter of the auger. As such, it was much harder for chips to get trapped between the blade and the wall. The auger was ground down slightly so that the maximum gap between wall and auger was close to 0.030 inches. As the tube was not perfectly cylindrical, the tolerance on this gap is +/- 0.015 inches which is still under the needed maximum gap for the tube. The plastic tube housing also allowed for easier support for the weight of the auger since it was more rigid and required only one supporting block internally as opposed to two with the sheet metal housing. The motor was attached to one of these supporting blocks on the sheet metal housing. This made the plastic tube more desirable as the location of the motor was more easily adjustable along the length of the supporting angle iron. Figure 1.13.4 shows the design chosen for the prototype. The design was re-optimized after testing. See section 1.14.1 for test results and conclusion.

1.13.6 Auger and Enclosure Location

1.13.6.1 Design Criteria and Alternatives

The criteria for the location of the auger and enclosure were that they had to be close to the gas flow controller to allow for easy wiring, they had to be easily supported on any grill, and they had to not be a hazard to the user of the Smoke Sentry as safety is a driving factor of users' trust in the team's design.

The alternatives for the auger location were mounting it on its own to the grill, or attaching it directly to the enclosure. The alternatives for the enclosure location were hanging off a grill table or platform to the side of the cooking compartment or setting on top of the table or platform to the side of the cooking compartment. Figure 1.13.5 shows the two location designs for the auger and enclosure location.

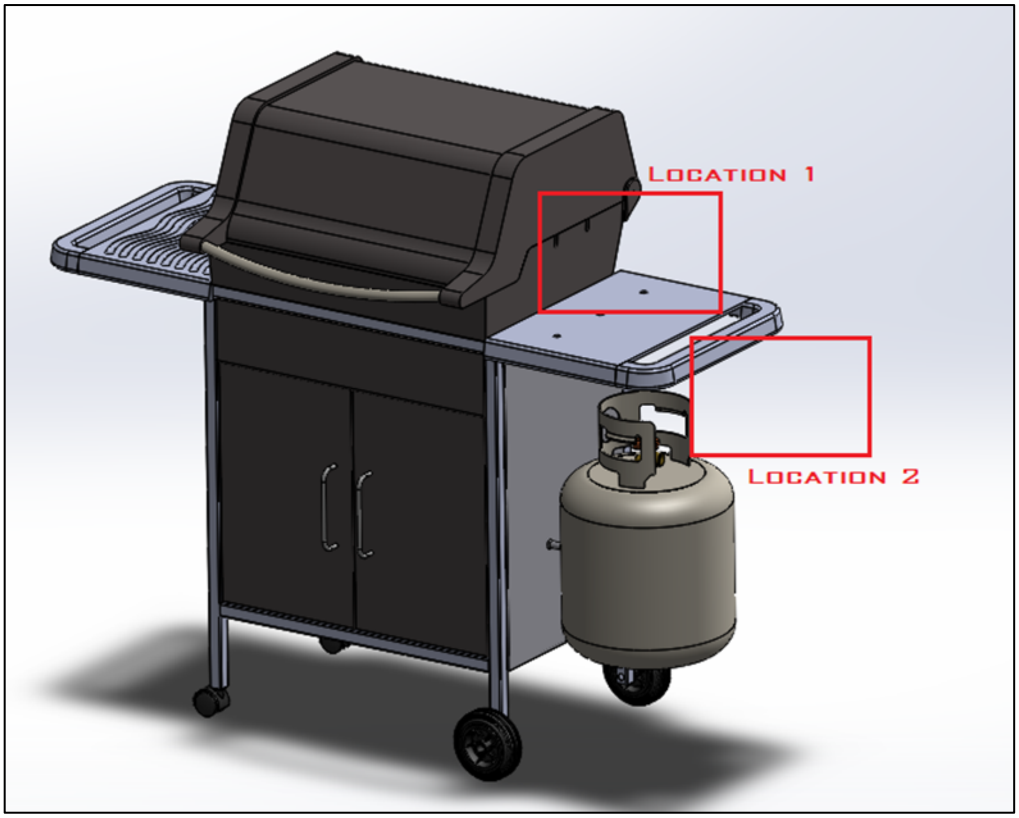

Figure 1.13.5. Possible locations for auger and enclosure.

1.13.6.2 Design Decision

The location of the auger was chosen to be rigidly attached to the enclosure. This allowed a more stable support for the auger since the enclosure would then be relatively fixed to the auger system. This allowed for easier wiring of the auger motor as well and provides a way to keep the auger system close to the gas flow control since the enclosure needed to be placed there. The location of the enclosure was decided to be setting on top of the platform of the grill. This allowed for more stability as a hanging enclosure would need extensions for the auger and would be unsafe for users as the whole system weighs around 8 kg or a little less than 20 lbs. The stability is planned to be better in a production-grade Smoke Sentry through the use of adjustable-height feet that screw in and out of the enclosure. The decision of the attachment of the auger to the enclosure led to another design decision about the stability of the enclosure.

1.13.7 Auger Orientation for Attachment to Enclosure

1.13.7.1 Design Criteria and Alternatives

The auger system, when attached to the enclosure had three criteria, it must be balanced with the enclosure, it had to be far enough away from the hot cooking chamber, and it needed to allow for easy adjustments for electrical components within the enclosure. The two alternatives were the auger sitting parallel to the narrowest side of the enclosure without a counterweight or sitting perpendicular to the narrowest side of the enclosure with a counterweight as seen in Figure 1.13.6.

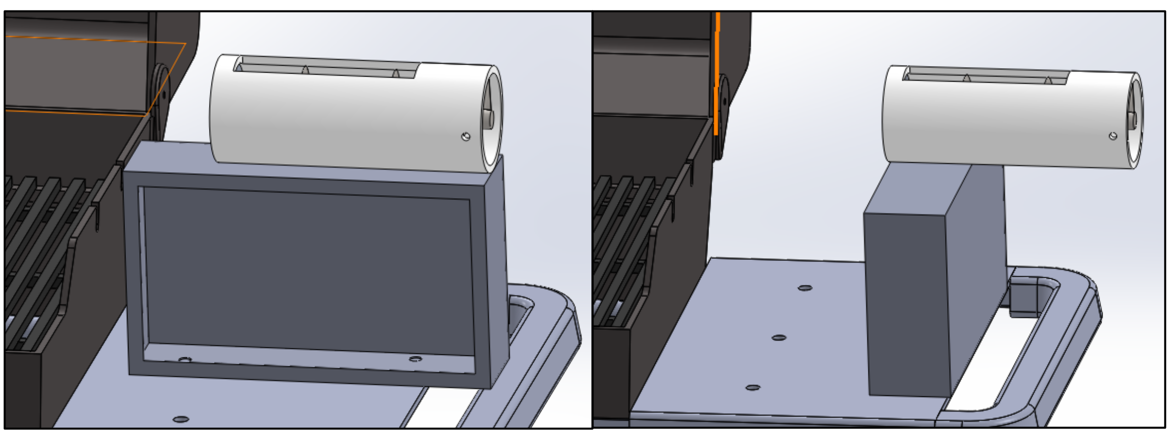

Figure 1.13.6. Orientations for auger attachment to enclosure showing parallel (left) and perpendicular (right) attachment alternatives

1.13.7.2 Design Decision

The alternative chosen for the orientation was perpendicular to the narrowest side of the enclosure. After a thermal FEA model (See section 1.14 for test results) of the plastic tubing, the plastic auger housing needed to be at least 12.5 centimeters away from the metal outside of the grill lid. This eliminated the parallel orientation of the auger because the mounting for this would put the plastic too close as the enclosure would be too wide for the average platform on the grill. The perpendicular orientation with angle iron allowed for the distance required as the enclosure would require less space on the platform. This can be seen in Figure 1.13.6. The balancing system for this orientation required a counterweight as the auger and its motor became a moment arm extending from the enclosure. To find the weight necessary for the counterbalance, a moment balance was done for the enclosure. An equivalent mass of the arm and the motor with its mounting blocks was found and a distance was set for the location of the counterweight. From this, the needed weight was calculated to be approximately 2 kg. Balancing weights were made to this scale and attached to the enclosure. The calculations for this can be seen in Appendix D.

1.13.8 Motor Size

1.13.8.1 Design Criteria, Alternatives, and Decision

The motor for the system has to provide sufficient torque for the auger, needs to be the same for both the auger and the gas flow valve, and needs to be easily programmed to progress in steps. The alternatives for this are a large 3.2V motor and a smaller 12V motor. The larger motor provides less torque than the smaller motor as it provides less power. The small motor also has smaller steps to progress through (i.e. a higher resolution). The small motor also operates well for both the auger and the valve system.

1.13.9 Power

1.13.9.1 Design Criteria and Alternatives

The criteria for powering options were that the choice needed to be inexpensive and efficient. Efficiency with power relates to stewardship in the design norms for this project.

Inexpensive methods applies to the business plan and market study for keeping the Smoke Sentry in competition with its market.

The two alternatives for power were battery power and a 100-240V wall plug-in. The battery powered Smoke Sentry would be more mobile whereas the wall plug-in Smoke Sentry would require an accessible socket.

1.13.9.2 Design Decision

The team decided to use a wall socket plug-in for the Smoke Sentry as a battery required for the duration of a smoked meat cook would be very large and expensive. The battery would also be less efficient at delivering energy to the system as power would be lost due to inefficiencies from charging the battery and cooking the meat whereas a wall plug-in only has inefficiency with power delivery when cooking the meat.

1.13.10 Thermocouple Amplifier

1.13.10.1 Design Criteria and Alternatives

The criteria for the thermocouple amplifier is that it needed to amplify the voltages output by the thermocouples. Another criterion is minimizing the thermocouple amplifier cost.

There are two alternatives for the thermocouple amplifier. Fist, the team can purchase a thermocouple amplifier from Adafruit. Second, the team can perform the basic function of a thermocouple amplifier through the means of extending the existing code for the temperature sensors.

The first alternative is the simplest and easiest to implement. However, the second alternative could offer an easy solution to spending needless budgetary money.

1.13.10.2 Design Decision

The first alternative is the better solution. If purchased at Adafruit, the thermocouple amplifier would only cost $20. However, if the team were to create code to implement a thermocouple amplifier, it would take roughly 5-10 hours of work from an electrical engineer. Assuming a salary of $60/hr, to implement this code would cost about $300-600.

1.13.11 Programming language

1.13.11.1 Design Criteria and Alternatives

The criteria for the web application is the program needs to be accessible through the users network and allow them to access it via their smart phone or computer, along with being user-friendly and have easy navigation. As a control standpoint, the program needs to be able to relay real-time feedback to the user so information can be received and viewed with little weight time so the user can make critical cooking decisions.

The alternatives for language are Ruby and Python.

1.13.11.2 Design Decision

When choosing programming languages to code, Ruby was chosen in the beginning because of its ease-of-use to create a network and web application to control the system. Later as components were being selected to build the system, there were pre-existing drivers for the motor HAT and the thermocouple amplifiers that were written in Python. To get the Python code to communicate with the web application, two servers need to be created. The first was in Ruby, running Sinatra. The second was in Python, running Flask. The two servers that needed to communicate together to send and receive data to get real-time feedback of the system variables that were being displayed within the web application.

1.13.12 Material Selection:

Table 1.13.1 lists the components for the system, the material selected, the reason for the material chosen, and any alternative choices considered.

Table 1.13.1. Material selection design decisions

Component	Material	Reason	Alternatives (and considerations for production)
Auger	Steel	Inexpensive and easily available	Aluminum or heavy plastic to reduce weight for production Smoke Sentry
Auger housing	PVC	Extremely inexpensive and easily available	Any heat resistant plastic to reduce space needed between grill and enclosure for production Smoke Sentry
Auger support	Aluminum angle iron	Easily available and to reduce weight	Iron was not chosen due to its weight
Counterweight	Steel	High density	Aluminum was not chosen due to insufficient density
Motor mounting blocks	Aluminum	Low density	Steel was not chosen due to its high density
Gas flow valve	Brass	Easily available	none
Valve support	Wood	Easily available and easily formed	Plastic or aluminum were considered for a production Smoke Sentry as they are more aesthetic
Chip chute	Steel	Easily available	Stainless steel would be preferred due to heat resistance and sanitation
Chip tray and grate	Stainless steel	Sanitary and heat resistant	none
Pulleys	Aluminum	Easily machined and lightweight	Plastic could be used for the production Smoke Sentry to reduce weight
Valve pulley belt	Urethane	Easily available for small sizes	Rubber belting was less available than urethane belting

1.14 Integration, Test, Debug

1.14.1 Auger Housing Tests

The team conducted a series of pass/fail tests on the auger housing to determine if the proposed designs were feasible.

The first design was an aluminum enclosure as show in Figure 1.14.1. The design was tested by turning the auger by communicating with the Raspberry Pi and seeing if it successfully pushed the chips through the enclosure. This design failed because the chips would get stuck in the housing and would jam the auger.

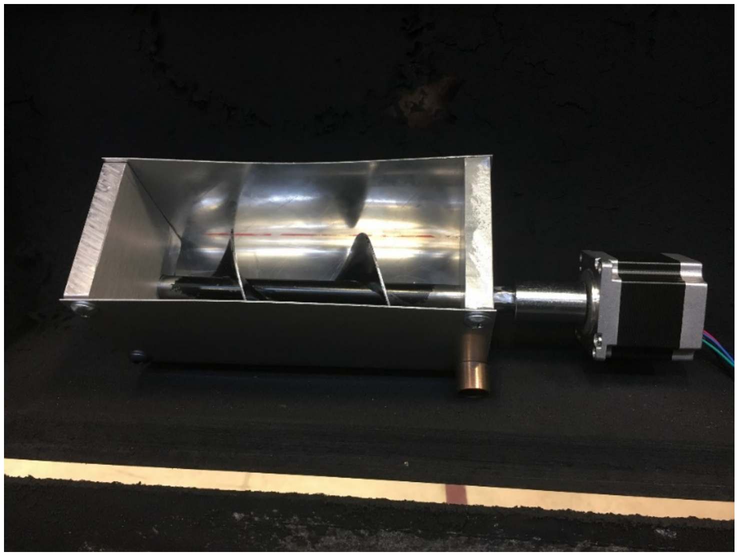

Figure 1.14.1. U-channel, aluminum housing

The second design was a portion of PVC pipe as seen in Figure 1.14.2. This design was tested in two manners. The first manner was to observe if the chips would get stuck in the housing. This design did pass this test. The stepper motor would successfully turn the auger and push the chips through the housing. The second manner was to observe the effect of heat from the grill on the pipe. The team performed a thermal FEA on the system and produced the result that can be seen in Figure 1.14.3.

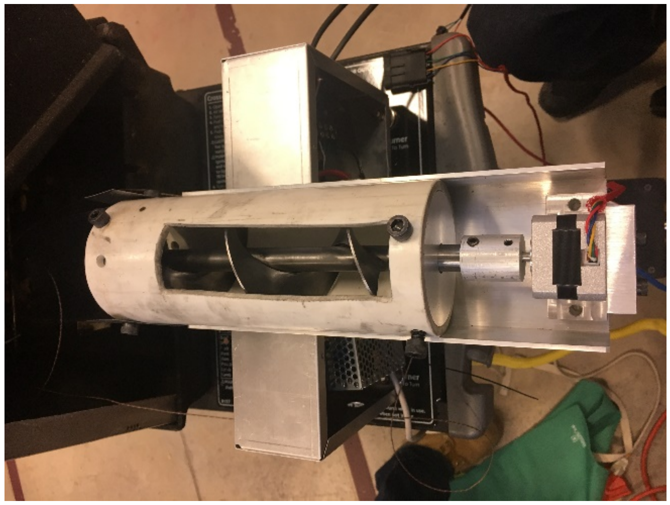

Figure 1.14.2. PVC housing

Although the test showed that the Pipe's surface would reach about 170 F and would deform, the team wanted to see its performance when the grill was on. The team ran a test with the grill at the usual temperature and the enclosure at the typical distance away from the grill. This design failed this test when the pipe began to deform and melt.

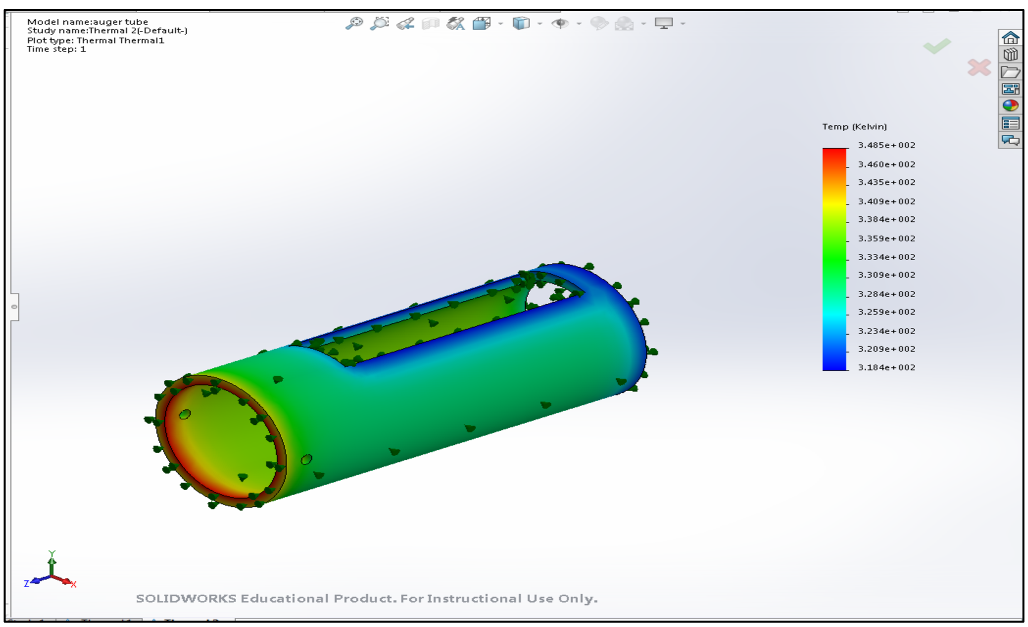

Figure 1.14.3. PVC thermal FEA

The third design was also a sheet metal housing as seen in Figure 1.14.4. The accuracy of manufacturing was improved by using thinner steel than the aluminum sheet metal for the first housing. This design was tested by filling the housing with chips and turning the stepper motor. The enclosure successfully held the chips and the auger did not get stuck. In addition, the heat did not deform the housing. In the end, this design was successful.

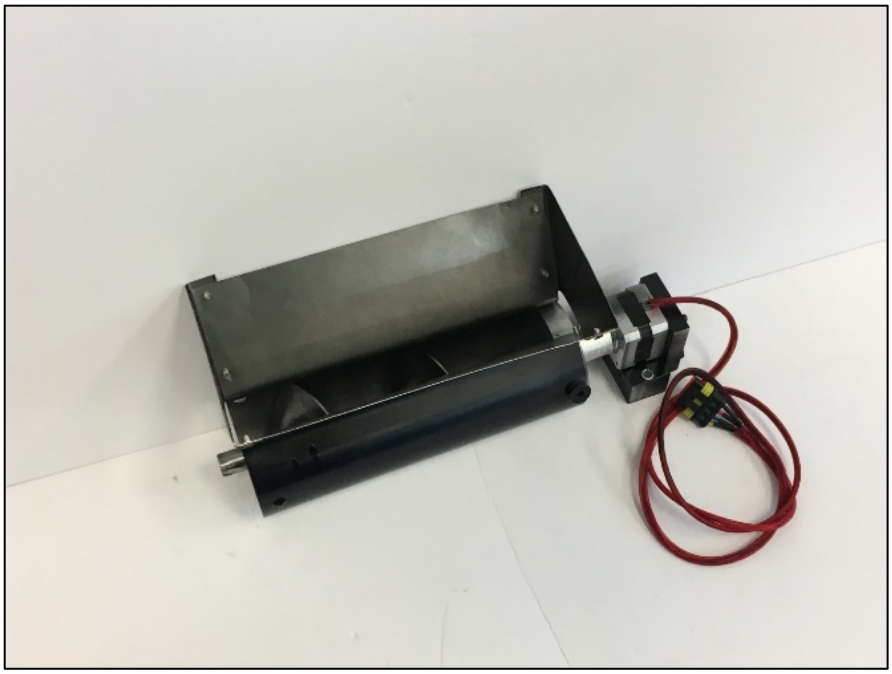

Figure 1.14.4. Steel sheet metal housing

1.14.2 Chip Chute Tests

The team conducted a series of pass/fail tests to see if the proposed designs for the chip chute were feasible.

The first design was made from aluminum and can be seen in Figure 1.14.5. Chips were pushed down from the step motor turning the auger and observed as they travelled down the chute. The chips got stuck half-way down the chute and did not make it to the chip tray. Therefore, this design failed.

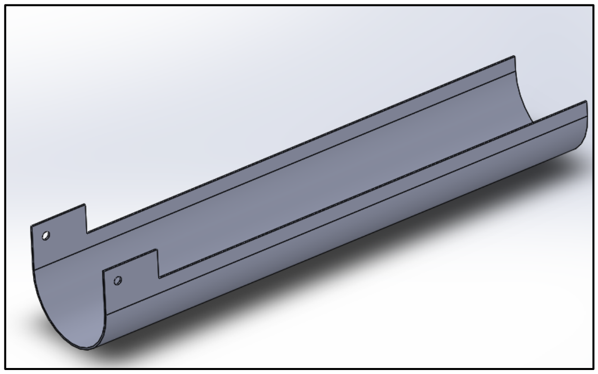

Figure 1.14.5. Chip chute CAD design

The second design was made from steel and was like the first design. However, parts of it were trimmed to make it perform at a steeper angle and it was polished to reduce friction. The same test was conducted and this design passed.

1.14.3 Chip Tray Tests

The team conducted a series of pass/fail tests to observe if the chip tray designs were feasible

The first design can be seen in Figure 1.14.6. Chips were set in the tray and heated to see if the tray enabled the chips to smoke. This design failed to create smoke.

Figure 1.14.6. Open tray for smoking wood chips

The second design featured an enclosed tray where the chips were enclosed and were not exposed to the ambient air. Chips were set in the tray and heated to see if the tray enabled the chips to smoke. This design did create smoke and passed the test.

1.14.4 Gas Control Tests

The team conducted a series of pass/fail tests to observe if the gas control designs were feasible

The first design featured two pulleys housed in a wooden shell, which can be seen in Figure 1.14.7. The gas was opened and the step motor was turned to see if the gas flow was reduced or increased. This design successfully altered the flow of gas.

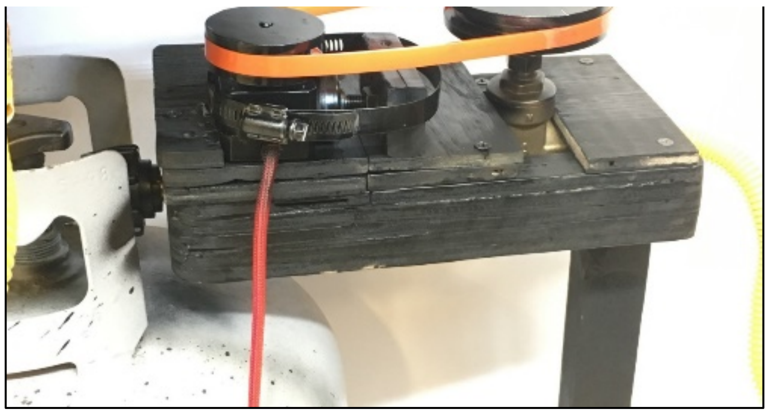

Figure 1.14.7. Gas flow control system

1.14.5 Grill Seal Tests

The team conducted a series of pass/fail tests to observe if the grill seal designs were feasible.

The first design can be seen in Figure 1.14.8 and featured a three-sided aluminum encasing. The grill was heated up and filled with smoke and the team observed if the temperature remained consistent to within +/- 10 F. This design passed this test.

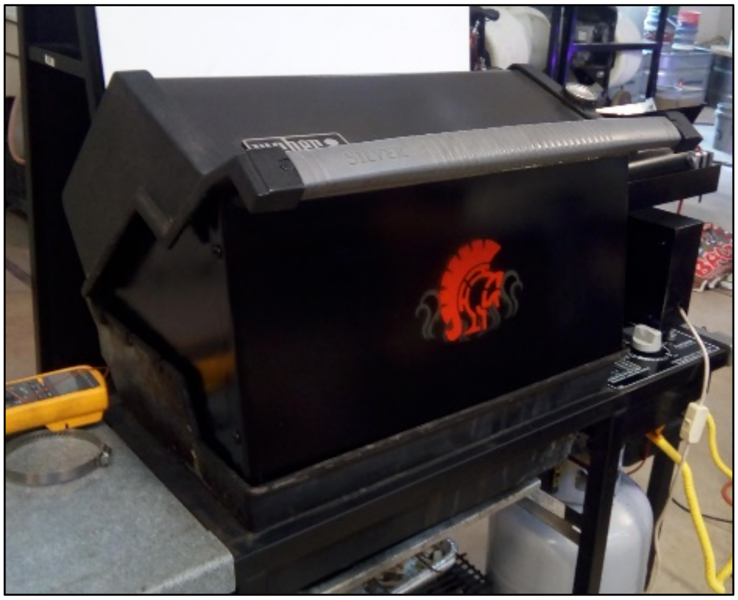

Figure 1.14.8. Grill seal and heat shield shown placed inside main chamber of grill (sporting the Smoke Sentry logo)

1.14.6 Thermal Response Test

The team conducted a test to observe the thermal response time of the smoke sentry.

The system was sealed and the gas was opened and the ambient temperature of the system was recorded every second for 1709 seconds. The team produced Figure 1.14.9 from this recorded data.

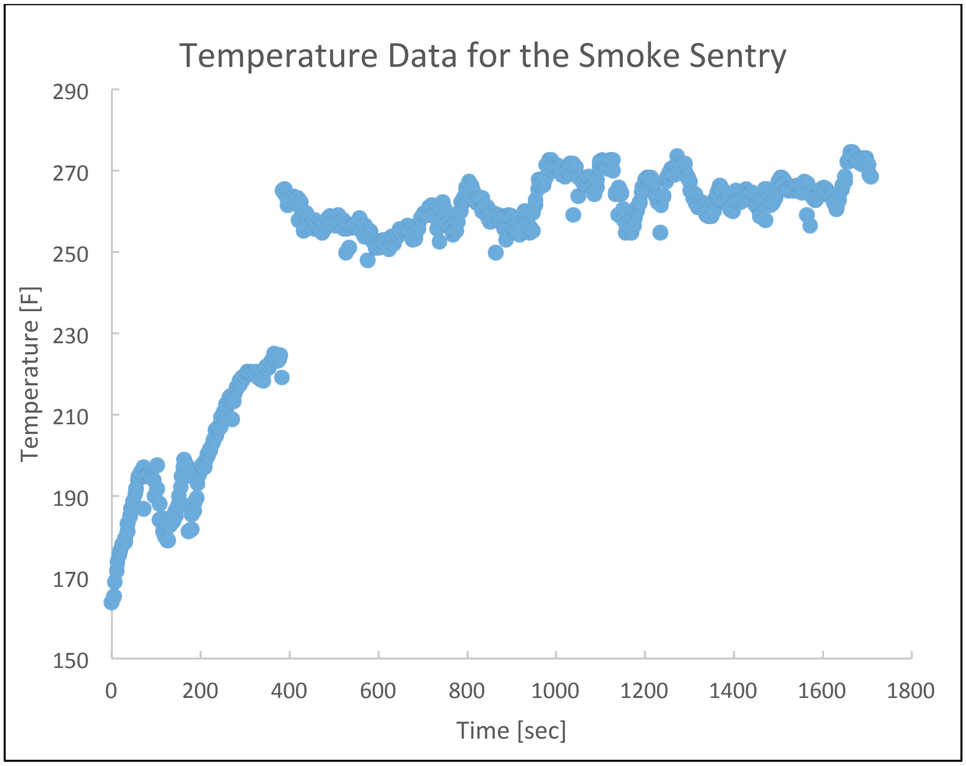

Figure 1.14.9. Temperature data recorded from Smoke Sentry after the device was set at a certain temperature

The system appears to approach an average final temperature of 265 [F]. Knowing this and that the time constant is the time at which the temperature is 63% of the final temperature, the team created Figure 1.14.10 and found a time constant of **312 seconds**. In other words, the smoke sentry takes roughly 5 minutes to reach the temperature that the user inputs into the system.

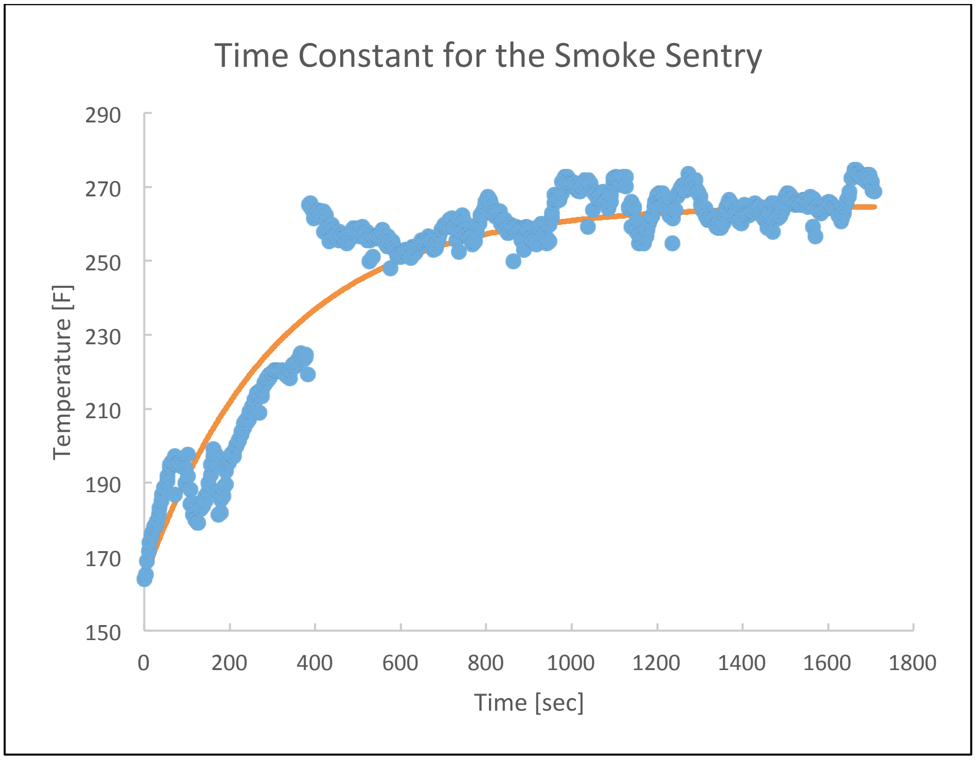

Figure 1.14.10. Temperature data with calculated time constant fit

1.14.7 Manual Control Button Tests

The team conducted a series of pass/fail tests to develop the functionality of the web application's buttons for manual control of the auger and gas valve motors.

The initial design featured a series of buttons coded to send specific commands via Javascript to the main Ruby program, which was then intended to immediately send motor-controlling commands to the Python program. The first test of the code failed, as the motors were unresponsive.

The team then modified the code to fully match the required syntax of the programming languages used. Once these changes were made, the motors began to turn when the web application's relevant buttons were pressed, resulting in a passed test.

1.14.8 Real-Time Web Application Updates Tests

The team conducted a series of pass/fail tests to ensure that the web page continuously requested and received important data.

The first design included Javascript code that periodically requested data from the main Ruby program, including the current temperature inside the grill and the operational status of the automatic smoking mode. The request for temperature data was then to be directed to the Python code to be taken from the system's thermocouples. The first test was a failure, as the requests received errors from the programs to which they were trying to connect.

The team then updated the code to change the format of the returned data from strings to JSON, a type specifically designed for use with Javascript. The implementation of this code resulted in successful communication between the programs, and the test conducted with this new iteration was a success.

1.14.9 Web Application Target Temperature Submission

The team conducted a series of pass/fail tests to check that the program received and used a desired target temperature set by the user from the web page.

The initial web application design included a field in which a user could input a desired target temperature for the grill to maintain. The first test of this field was a failure, as the "submit" button would redirect the user to a different version of the web page rather than properly submit the data.

The team revised the code to utilize a different method of communication between the Javascript and the main Ruby program. This new method allowed the target temperature to send successfully, resulting in a passed test.

1.14.10 PID Loop for the Automated Control Tests

The team conducted a series of pass fail/tests to check to see if the PID loop was acting accordingly and calculating the correct values so that the system could adjust the gas valve accordingly.

The first step was to take the "target_temp" and subtract it by the "current_temp" to get the error. Then, that error was used to make the proper adjustments as seen in Figure 1.14.11.

```ruby
#--This is where the Temperatures are called to calculate the error--
  current_temp = $temp_sensor.get_current_temp
  target_temp = $temp_sensor.get_target_temp
  puts "  Current temp: #{current_temp}, Target temp: #{target_temp}"

#--This is where the Error and Accum error are calculated--
  error = target_temp - current_temp
  $accum_ierror += error * delta_pid_time.to_f

  $accum_ierror = 0 if $accum_ierror > 200.0
  $accum_ierror = 0 if $accum_ierror < -200.0

  puts "  Error: #{error} degrees"
  puts "  Accum Error: #{$accum_ierror} "

#--This is where the PID is calculated--
  _p = C_p * error
  _i = $accum_ierror * C_i
  _d = 0
  pid = _p + _i + _d
```

Figure 1.14.11 Calculations in the PID Loop in pid.rb

Once the calculations were set, the proportional and integral coefficients (C_p and C_i) needed to be dialed in to adjust the tuning process of the controller. This was a guess and check test until the proper coefficients were found in the system and it reached a steady-state at or near the target temperature. The coefficients seen in Figure 1.14.11 were deemed to be satisfactory and the testing completed as a pass.

1.15 Business Plan

1.15.1 Marketing Study

When looking at what is on the market when it comes to different types of smoking apparatuses, there are multiple varieties to choose from. Charcoal smokers, full wood-burning smokers, combination electric and wood smokers, and even gas smokers are all potential options depending on what type of resources a consumer would like to use. With the market being so diverse, it could be thought that an automated system would have been developed for each of these. Nevertheless, research indicates that automated temperature control systems seem to have only been created for charcoal grills to turn them into smoker systems. There are complete automated systems for each variation, but most systems are expensive and not aimed towards the do-it-yourself customer.

For this reason, the design's focus was narrowed down to an apparatus that will fit a generic gas grill and convert it into an automated smoker system.

1.15.1.1 Competition

As competitors go, there are not many automated temperature regulating systems designed for gas smoking for the everyday consumer. Companies like Charbroil and the Big Green Egg have automated systems that focus on charcoal smoking and have created full systems for purchase, but not something that can attach to an already owned grill. This allows for the development of a system that can attach to a gas grill without too much competition and allows for price variability as long as there is a demand for the product.

1.15.1.2 Market Survey

With the market being devoid of any particular smoking system that can attach to a gas grill, a survey of the do-it-yourself smoking community was required. After talking to multiple smoker enthusiasts, the conclusion was reached that an attachment to a gas grill would be desirable. Beyond just the idea of simply creating an attachment, more research is needed in variables like cost and functionality to make sure that this product is a success.

1.15.2 Cost Estimate

1.15.2.1 Development

Within the development process of the Smoke Sentry there have been variable changes after new research has been brought to the table. With this being a system that relies on temperature variation depending on recipes, a prototype needs to be constructed in the near future to allow for rigorous testing as seen in the Appendix. With different meats needing different temperatures and times at those temperatures testing will be crucial in the development of the system having an accurate automated program.

1.15.2.2 Production

1.15.2.2.1 Fixed Costs

With looking at the amount of time put into research the estimate so far is about 60 to 80 hours. Finding the proper components and sensors for the system took some time along with assembling a system that will work in theory. The development time for the Web app and control program will be where most of the fixed cost will go. So far 45 hours have gone into R&D for the code and programming, and there was more development needed to complete the main program infrastructure. It is estimated there will be an additional 120 hours of development time needed to complete the programming side of the system. Although the team has a working system there is more fine-tuning to the program that is necessary. First, the user interface needs to be cleaned up so that it is easier to navigate around the web app. Second, a customized recipe should be added to allow for various cook times and temperature control so that the user can have free range of how they want to smoke their food.

With an engineer roughly costing $100 per hour as required, in a real-world situation the overhead of this project would be somewhere in the $15,000 range.

1.15.2.2.2 Variable Costs

The components that will be used to construct the Smoke Sentry; the microcontroller, temperature sensors, fan and motor, gas regulator and assorted metal hardware to create the inner box; will all be considered variable cost. With the cost of materials for the prototype being around the $500 budget, having an affordable product for customers is looking attainable with the product being manufactured on a larger scale. The possible starting target is 10,000 units produced in the first manufacturing term.

With the Smoke Sentry being in its prototype phase at this time, the cost of the system is much higher than anticipated the commercial product to be. When making this a commercial product it will be considered necessary to construct the own microcontroller system since the Raspberry Pi is more powerful than necessary. With this in mind, the team could fabricate a board that would have the bare minimum of what is neededus

including the thermocouple amplifier, motor HAT and drivers along with Wi-Fi capabilities. This would allow a simpler device that would cost less and be able to manufacture on a mass scale.

1.15.2.2.3 Summary Financials

As seen in Table 1.15.1, the total cost of parts for the prototype are estimated to be under $300. With a budget from Calvin of $500, this is substantial evidence the project is viable and will be moved forward with the build of the prototype. For full finances of the project, including parts that were obsoleted or deemed unusable, see Appendix 1.19.5.

Table 1.15.1: Part costs and totals for Smoke Sentry prototype

Parts List for The Smoke Sentry			
Electrical Part Description	Qty	Cost per Unit	Total Cost
Adafruit DC & Stepper Motor HAT for Raspberry Pi - Mi	1	$ 22.50	$ 22.50
Raspberry Pi 3 - Model B - ARMv8 with 1G RAM	1	$ 39.95	$ 39.95
12v Stepper Motor with Cable, Bipolor	2	$ 14.95	$ 29.90
Thermocouple Type-K - Glass Braid Insulated (Bare Wi	2	$ 12.56	$ 25.12
IR Flame Sensor Module Detector Smartsense For Temperature	1	$ 7.00	$ 7.00
Thermocouple Amplifier MAX31855 breakout board	2	$ 14.95	$ 29.90
8-pin terminal block	1	$ 7.00	$ 7.00
4-wire 18-awg cable	10	$ 0.33	$ 3.30
Mounting Hardware	1	$ 7.00	$ 7.00
			$ 171.67
Metal Part Description	Qty	Cost per Unit	Total Cost
Auger	1	$ 35.00	$ 35.00
Grill Grate and Tray*	1	$ 8.35	$ 8.35
Chip Feeder*	1	$ 12.81	$ 12.81
Metal Tubing*	1	$ 11.47	$ 11.47
Gas Valve	1	$ 12.99	$ 12.99
Enclosure 12"x7"x3"	1	$ 20.00	$ 20.00
Motor Mounting Blocks*	1	$ 15.00	$ 15.00
Metal Chute*	1	$ 7.00	$ 7.00
			$ 122.62
*cost is estimated from material weight and operations done			
		Total Cost	$ 294.29

1.16 Conclusion

The team discovered a number of ways to improve upon the initial design since the idea's inception, from simplifying the set of variables controlled within the grill to developing an internet-based method of interfacing with the system. Because this is just a prototype, physical buttons on the system are being overseen at the present, but if this was to become a commercial product, certain safety standards like UL and NEMA certifications need to be considered. The team has finished building the prototype of the smoke Sentry and has tested the durability and accuracy of the sensors and hardware and will continue to do so to make sure the product can endure multiple uses. With more time the smoke Sentry has other variables that could be optimized to either create a smaller more compact system, or be able to become more versatile to work with a wider range of gas grills that are on the market. Overall the system has promise to become an actual marketable product that people will enjoy and use on a daily basis.

1.17 Acknowledgements

Professor Mark Michmerhuizen:

Faculty advisor

Randy Newsome:

Employee at Intralox LLC

Randy is a former professor at West Michigan University and enjoys helping student groups. He was instrumental in narrowing our focus of device design. He also helped set up a tour of Barrett's Smokehouse.

Barrett's Smokehouse:

Restaurant in Portage, MI.

Helped the group understand first-hand the smoking process and what it entails

Phil Jasperse

Machine Shop Technician

Helped the group with welding on the device and other machine shop needs

Bob DeKraker

Engineering Lab Manager

Helped with various technical and location problems and needs

Louise Earl Butcher

Butcher shop on Wealthy Street in Grand Rapids

Provided Team 12 with meat for test runs

The Swets Family

Donated a gas grill for use on Team 12's project

1.18 References/Bibliography

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1.19 Appendix

1.19.1 Appendix A: Gantt Chart

1.19.2 Appendix B: Electrical Schematics

1.19.3 Appendix C: SolidWorks Drawings

1.19.4 Appendix D: EES Calculations

1.19.5 Appendix E: Final Budget Document

1.19.1 Appendix A: Gantt Chart

	Task Name	Durati	Start	Finish	Pre	Resource Names
1	Research	2 days	Mon 10/10/16	Wed 10/12/16		Jordan,Jon,Dair
2	Find Current Recipes	1 day	Wed 10/12/16	Thu 10/13/16	1	Jordan
3	Look At Alternatives	1 day	Wed 10/12/16	Thu 10/13/16	1	Dain,Ethan
4	Decide Scope	1 day	Wed 10/12/16	Thu 10/13/16	1	Dain,Ethan,Jon,
5	Relavent Thermodynamic Principles	1 day	Wed 10/12/16	Thu 10/13/16	1	Jon
6	Relavent Control System Principles	2 days	Wed 10/12/16	Fri 10/14/16	1	Dain,Ethan
7	Features Needed	2 days	Wed 10/12/16	Fri 10/14/16	1	Jordan
8	Determine Requirements (interface, functional, performance)	3 days	Mon 10/17/16	Thu 10/20/16	2,3,4,	Dain,Ethan, Jon,Jordan
9	Design System Architecture	3 days	Mon 10/17/16	Thu 10/20/16	2,3,4,	Dain,Ethan
10	Develp Design Norms	2 days	Mon 10/17/16	Wed 10/19/16	2,3,4,	Jon
11	List design alternatives	1 day	Mon 10/17/16	Tue 10/18/16	2,3,4,	Jordan
12	List design decisions	2 days	Tue 10/18/16	Thu 10/20/16	11,2,3	Dain,Ethan,Jon,
13	Write PPFS Draft	16 days	Thu 10/20/16	Thu 11/17/16	12,11,	Dain,Ethan,Jon,
14	Sections 1.1-1.9, 1.18	16 days	Thu 10/20/16	Wed 11/16/16	12,11,	Jordan
15	Sections 1.10-1.12	16 days	Thu 10/20/16	Wed 11/16/16	12,11,	Jon
16	Sections 1.13-1.16	16 days	Thu 10/20/16	Wed 11/16/16	12,11,	Ethan
17	Sections 1.17,1.18.2-1.19	16 days	Thu 10/20/16	Wed 11/16/16	12,11,	Dain
18	Write PPFS	16 days	Thu 11/17/16	Thu 12/15/16	13	Dain,Ethan,Jon,
19	3D model	1 day	Thu 12/15/16	Fri 12/16/16	18	Jordan
20	Circuit Design	1 day	Thu 12/15/16	Fri 12/16/16	18	Dain,Ethan
21	Material selection	1 day	Mon 12/19/16	Tue 12/20/16	19	Dain,Jon,Jordar
22	Build Prototype	64 days	Tue 12/27/16	Mon 4/17/17	18	Dain,Ethan,Jon,
23	Build Physical System	64 days	Tue 12/27/16	Mon 4/17/17		Jon,Jordan
24	Build Auger System	14 days	Tue 12/27/16	Thu 1/19/17		Jon,Jordan
25	Build Chip Tray	7 days	Fri 1/20/17	Thu 2/2/17	24	Jon,Jordan
26	Build Chute	6 days	Thu 2/2/17	Mon 2/13/17	25	Jon,Jordan
27	Additional Research on Valve	5 days	Mon 2/13/17	Wed 2/22/17	26	Jon,Jordan
28	Build Valve	12 days	Wed 2/22/17	Wed 3/15/17	27	Jon,Jordan
29	Design Enclosure for Electrical Components	12 days	Wed 3/15/17	Wed 4/5/17	28	Jon,Jordan
30	Build Auger Holder	4 days	Wed 4/5/17	Wed 4/12/17	29	Jon,Jordan
31	Design and Build Counterbalance	4 days	Wed 4/12/17	Wed 4/19/17	30	Jordan
32	Design Control System	64 days	Sun 1/1/17	Thu 4/20/17		
33	Research Components Necessary for Control	12 days	Sun 1/1/17	Thu 1/19/17		Dain,Ethan
34	Schematic Drawings Layout	5.7 days	Fri 1/20/17	Mon 1/30/17	33	Dain
35	Order Components	2 days	Tue 1/31/17	Thu 2/2/17	34	Dain
36	Research Programming Languages	20 days	Thu 1/19/17	Thu 2/23/17	33	Ethan
37	Research Network Communications	10 days	Thu 2/23/17	Tue 3/14/17	36	Ethan
38	Motor Control Language and programming	20 days	Thu 2/2/17	Thu 3/9/17	35	Dain
39	Build Sub-panel	4 days	Thu 3/9/17	Thu 3/16/17	38	Dain
40	Implement PID loop	6 days	Mon 4/10/17	Wed 4/19/17	39,41	Dain,Ethan
41	Web Application Development	15 days	Tue 3/14/17	Mon 4/10/17	37	Ethan
42	Safety Procedures	7 days	Wed 4/19/17	Tue 5/2/17	40	Dain,Ethan

Figure A1. Gantt Chart Task List

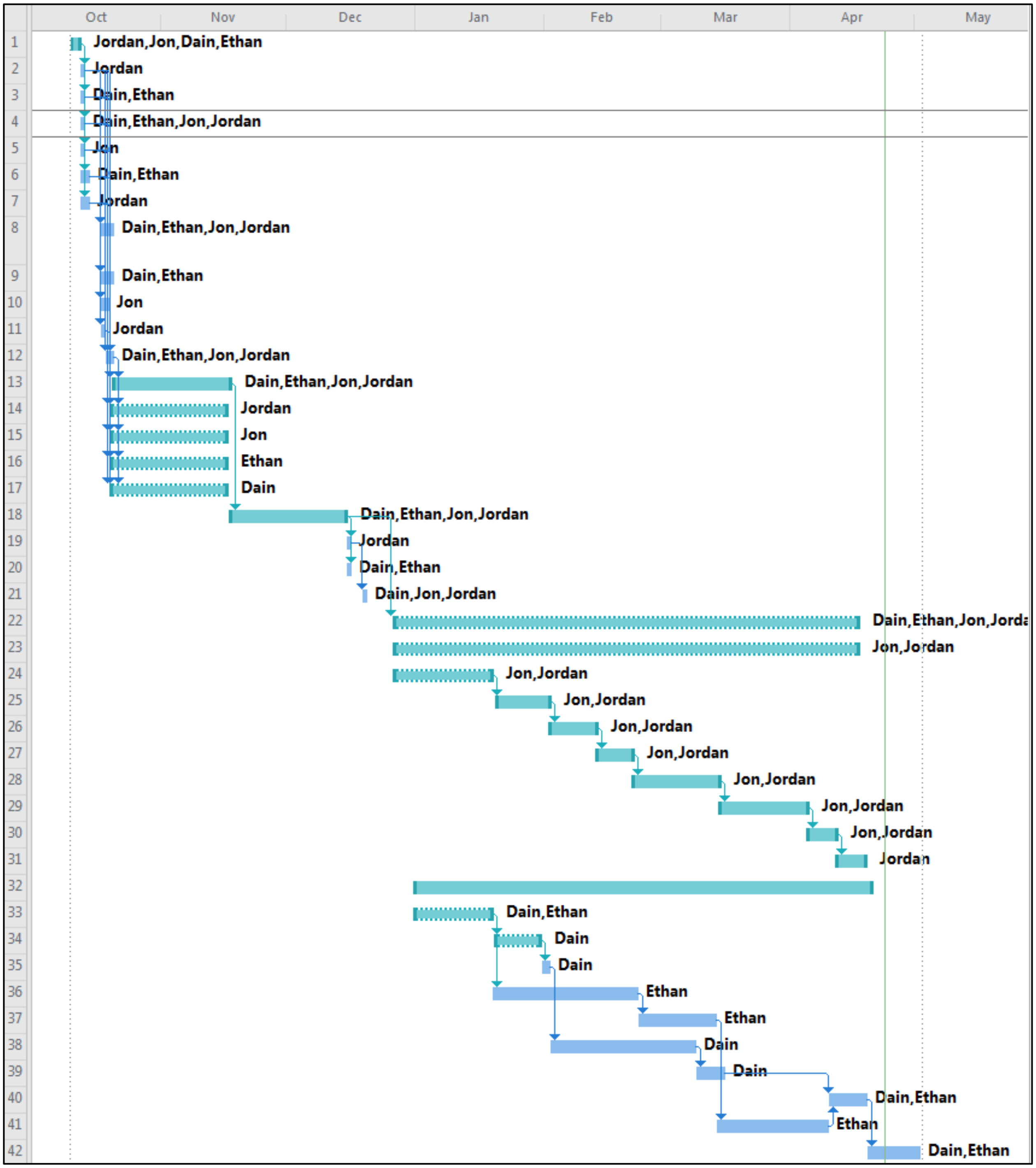

Figure A2. Gantt Chart Task Schedule

1.19.2 Appendix B: Electrical Schematics

SMOKE SENTRY
AUTOMATED MEAT SMOKER

MACHINE IDENTIFICATIONS	
CUSTOMER	CALVIN COLLEGE
DISTRIBUTOR	-
PROJECT #	-
SERIAL NUMBER	-
MANUFACTURED YEAR	2017

UTILITY SPECIFICATIONS	
3-PHASE, +EARTH	-
MAIN LINE VOLTAGE	-
CONTROL VOLTAGE	-
TOTAL MOTOR FULL LOAD	-
FULL LOAD CURRENT	-
COMPRESSED AIR	-

WIRE REFERENCE FORMAT		
WIRE NUMBER	PAGE	LINE
0102	01	02

ELECTRICAL DRAWING INDEX

DRAWING #	FILE TITLE	DETAILS
SS-E00	SS_SCHEMATICS	DRAWING INDEX
SS-E01	SS_SCHEMATICS	INCOMING POWER AC, RASPBERRY PI POWER
SS-E02	SS_SCHEMATICS	AUGER AND GAS VALVE MOTOR CONTROL
SS-E03	SS_SCHEMATICS	RASPBERRY PI GPIO LAYOUT
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
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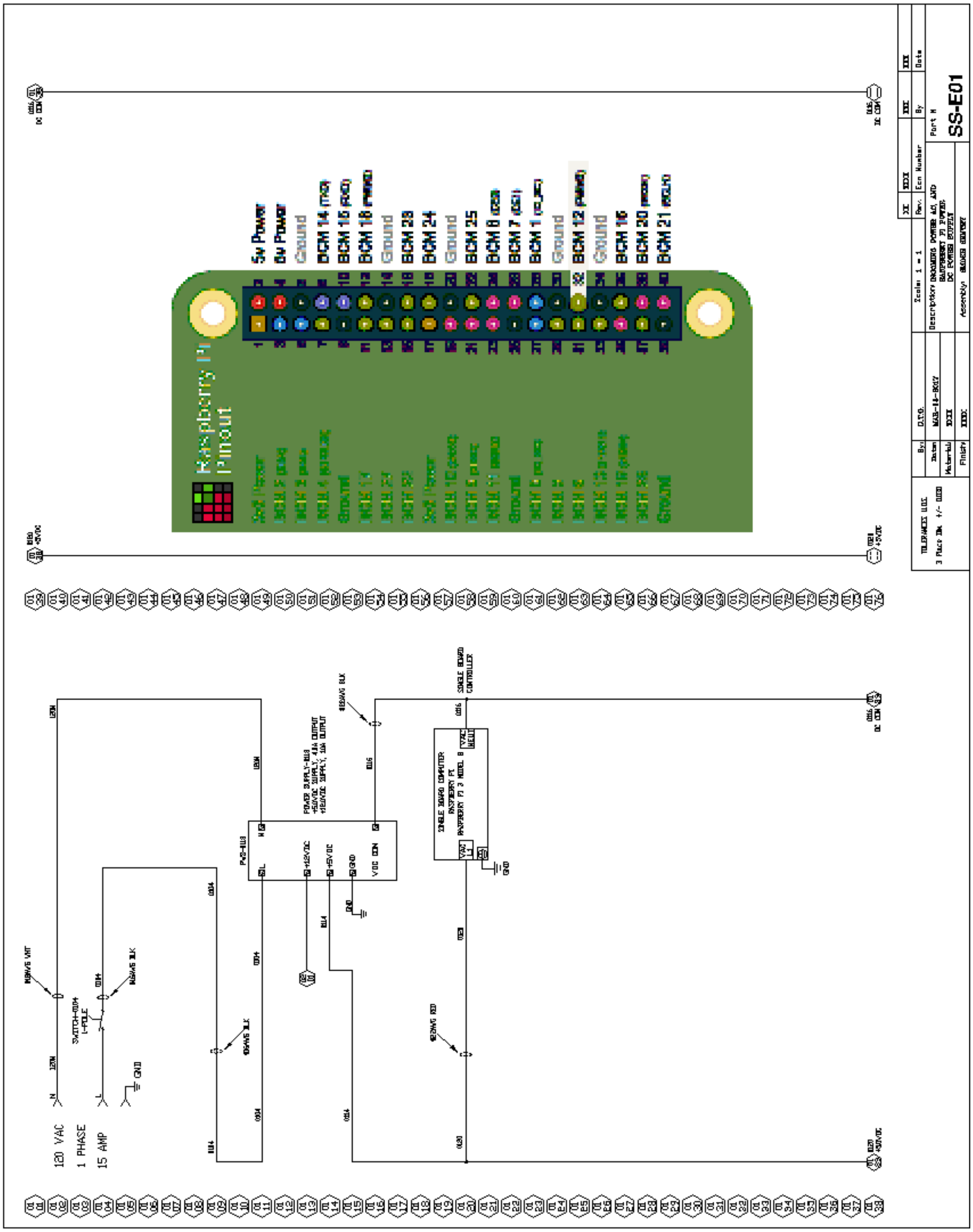
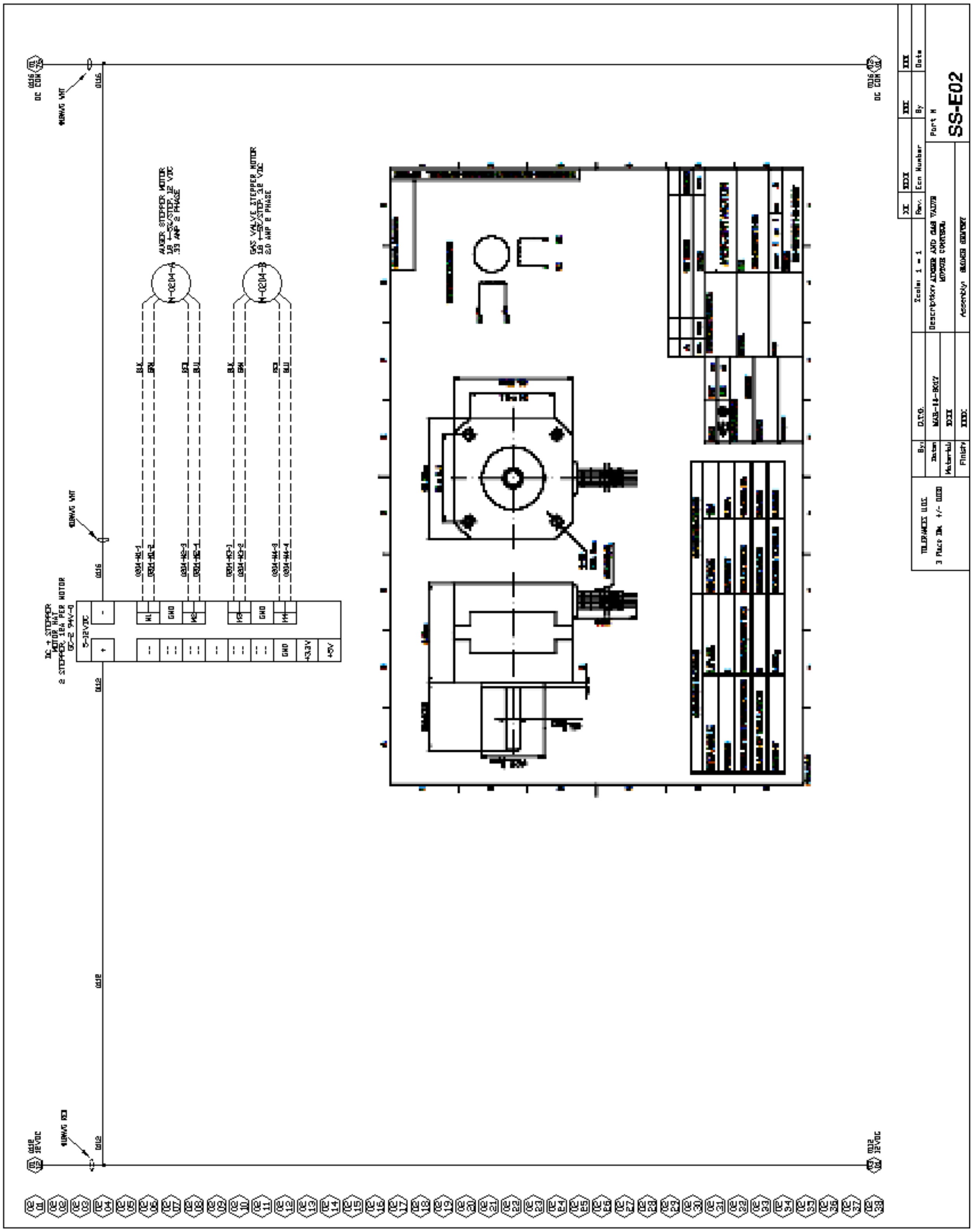
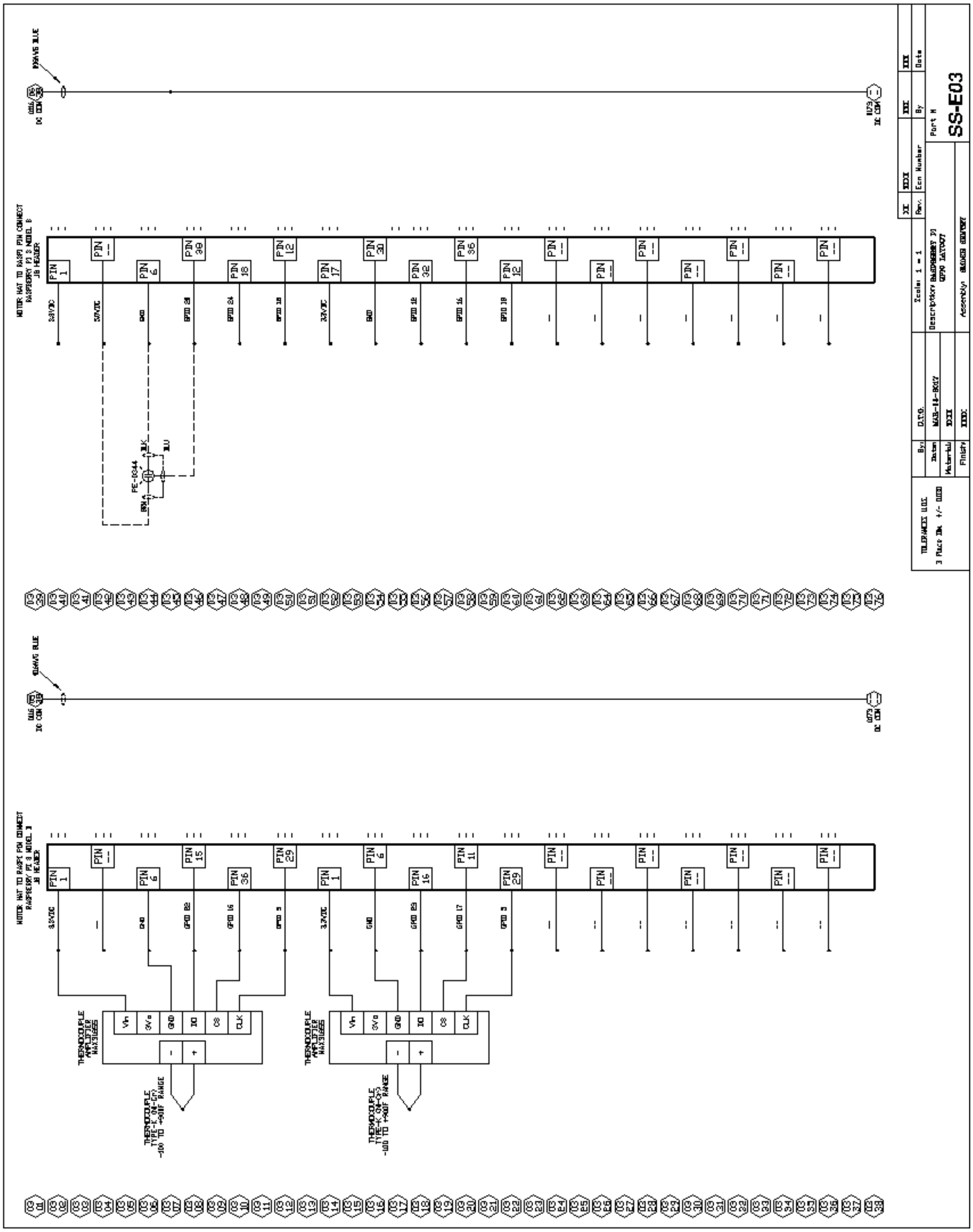
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
SS-SP	SS_ENCLOSURES	ELECTRICAL ENCLOSURE, SUB-PANEL COMPONENTS LAYOUT
SS-PB1	SS_ENCLOSURES	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-

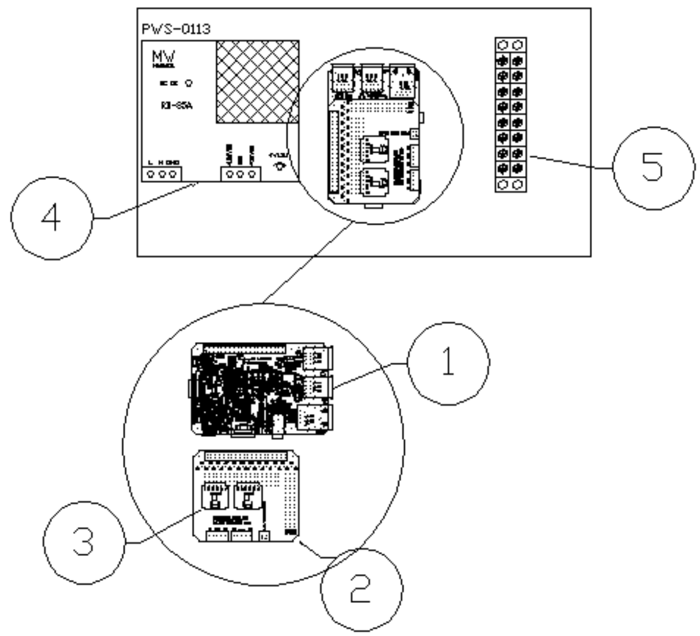
			XX	XXXX	XXX	XXX
TOLERANCES U.O.S.	By:	D.T.O.	Scale: 1 = 1	Rev. Ecn Number	By	Date
3 Place Dim. +/- 0.030	Date:	MAR-14-2017	Description: DRAWING INDEX		Part #	
	Material:	XXXX			SS-E00	
	Finish:	XXXX	Assembly: SMOKER SENTRY			


120 VAC
1 PHASE
15 AMP
SINGLE BOARD COMPUTER
RASPBERRY PI
POWER SUPPLY
SINGLE BOARD CONTROLLER
Raspberry Pi
Pinout
5v Power
5v Power
Ground
BCM 14 (TXD)
BCM 15 (RXD)
BCM 18
Ground
BCM 23
BCM 24
Ground
BCM 25
BCM 8
BCM 7
BCM 1
Ground
BCM 12
Ground
BCM 16
BCM 20
BCM 21
SS-E01


AUGER STEPPER MOTOR
GAS VALVE STEPPER MOTOR
DC + STEPPER MOTOR HAT
5-12VDC
GND
+3.3V
+5V
BLK
GRN
RED
BLU
Scale: 1 = 1
Description: AUGER AND GAS VALVE MOTOR CONTROL
Ecn Number
Part #
SS-E02


SS-E03
THERMOCOUPLE AMPLIFIER MAX31855
THERMOCOUPLE TYPE-K
Vin
3Vo
GND
DO
CS
CLK
PE-0344
Scale: 1 = 1
Rev.
Ecn Number
By
Date
Part #
Description
Assembly
Material
Finish

Ref.	Qty.	Manufacturer	Mfg. Part #	Description
1	1	Rasp PI	N/A	Raspberry PI 3 Complete Starter Kit
2	1	Adafruit	2348	Adafruit DC & Stepper Motor HAT for Raspberry PI
3	2	Adafruit	269	Thermocouple Amplifier MAX31855 breakout board
4	1	MEANWELL	RD-35A	Power Supplies 32V; 5V,4A; 12V,1A
5	1	LOVES	49439	TERMINAL BLOCK 8 POLE
6	-	-	-	-
7	-	-	-	-
8	-	-	-	-
9	-	-	-	-
10	-	-	-	-
11	-	-	-	-

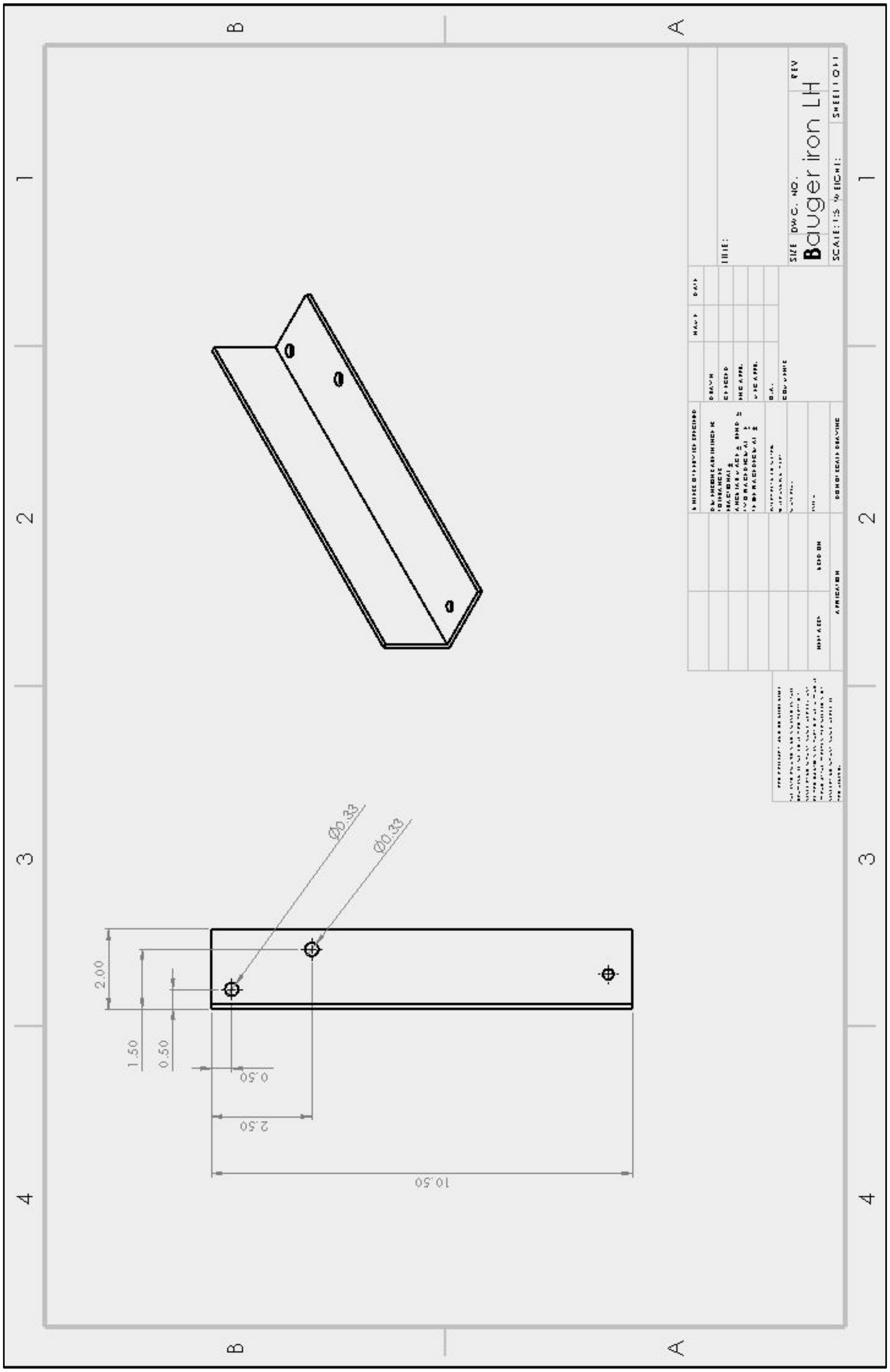


ELECTRICAL PARTS NOT SHOWN ON DRAWINGS:

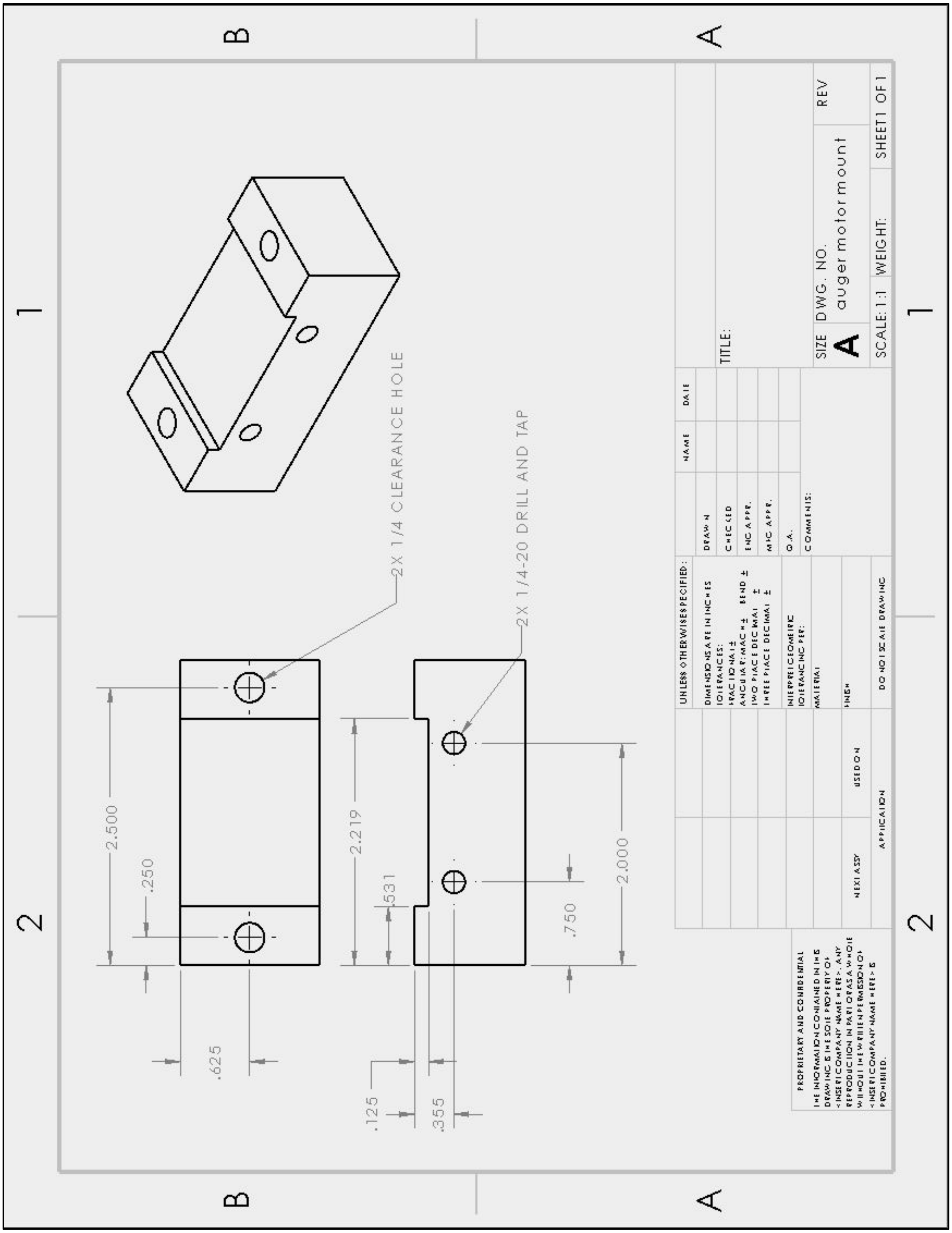
Ref.	Qty.	Manufacturer	Mfg. Part #	Description
1	1	LEVITON	L01-05410-00I	FEED-THRU CORD SWITCH IVORY
2	2	NUYI	LYSB01A6MBCDB	4 Pin Way 20-14 AWG Waterproof Connector Wire Harness
3	1	Atomic Market	N/A	IR Flame Sensor Module Detector Temperature Detecting
4	-	-	-	-

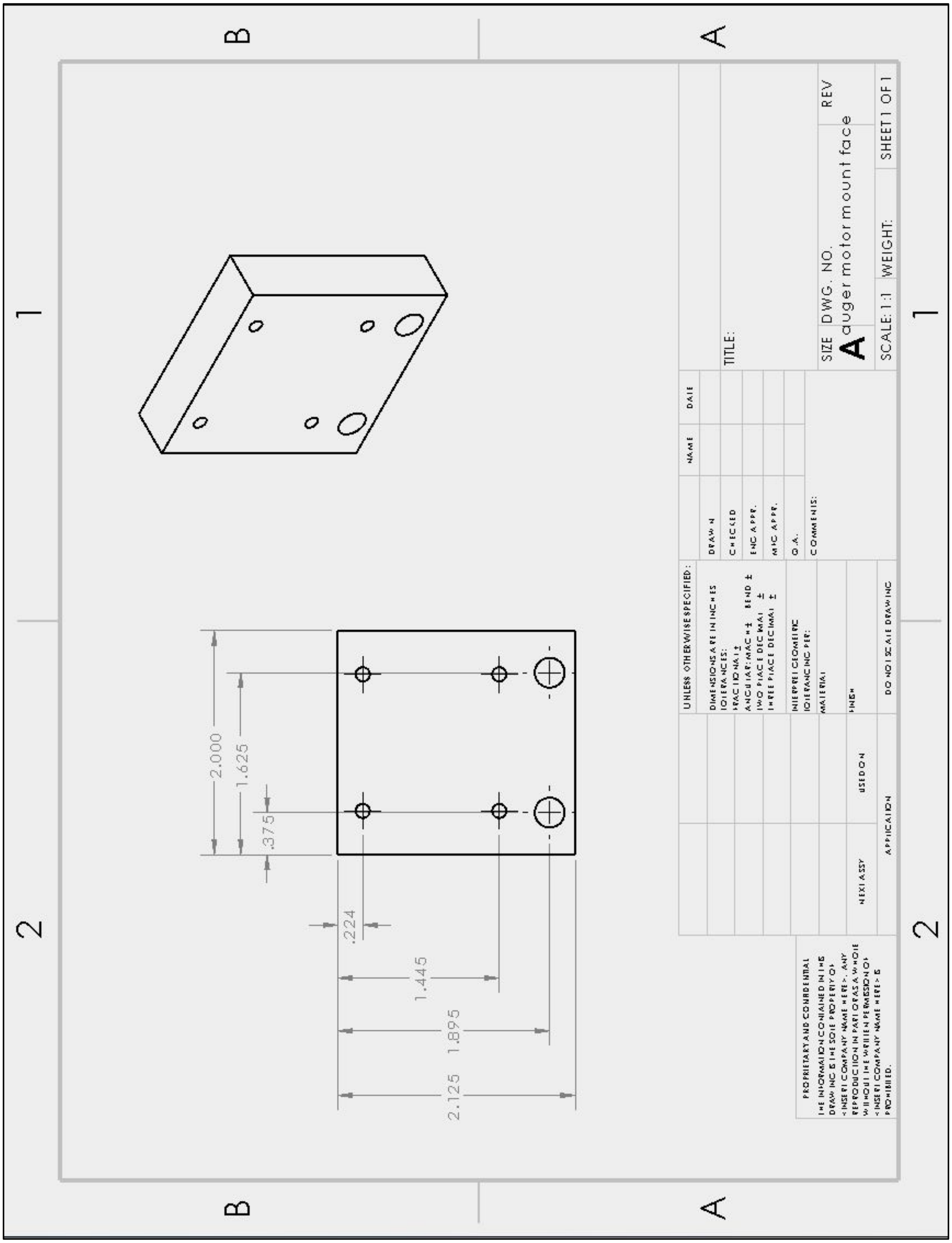
TOLERANCES U.O.S. 3 Place Dim. +/- 0.030	By:	D.T.O.	Scale: 1 = 1	Rev.	Ecn Number	By / Date
	Date:	—	Description: ELECTRICAL SUBPANEL LAYOUT	Part #		
	Material:	XXX		SmkSnty-SP		
	Finish:	XXX	Assembly: SMOKE SENTRY ENCLOSURE			

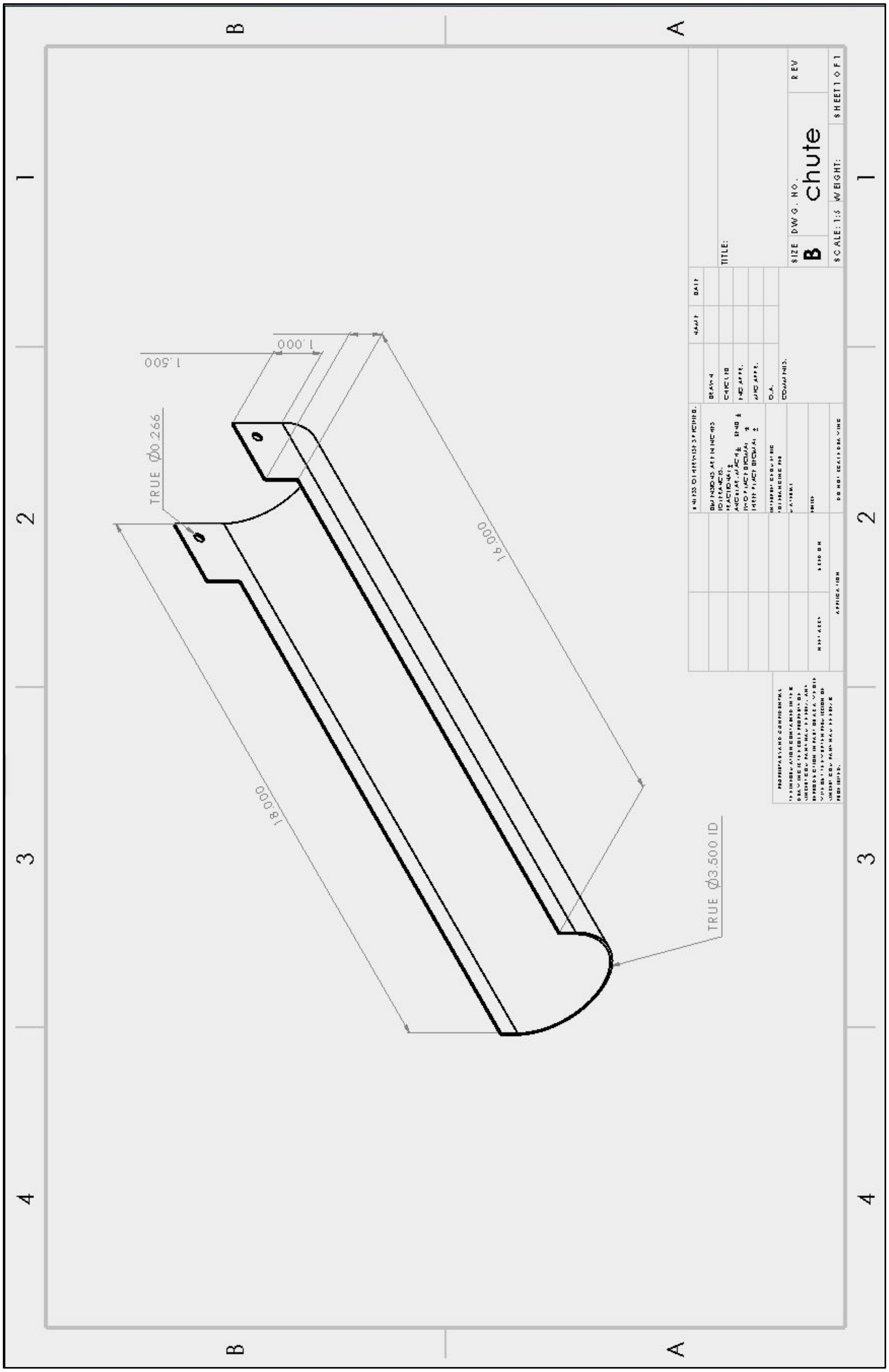
1.19.3 Appendix C: SolidWorks Drawings

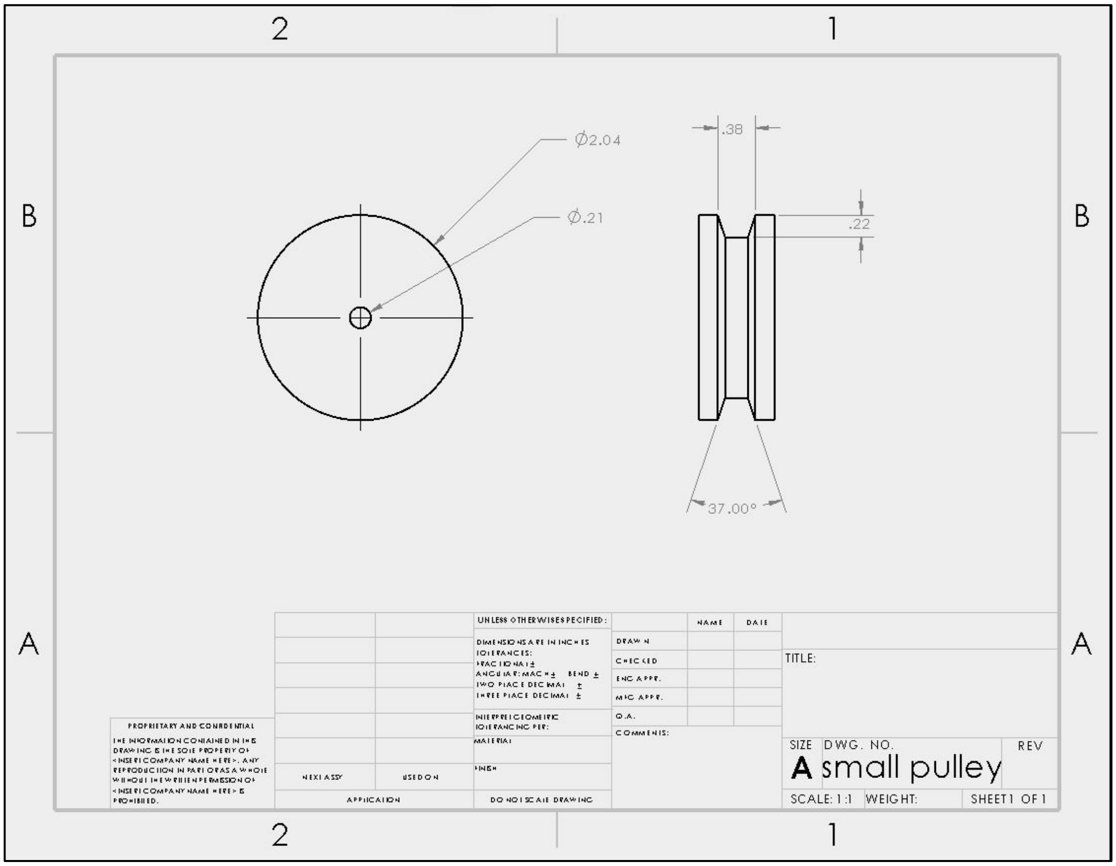


Bauger iron LH
SIZE DWG. NO.
REV
SCALE: 1:5 WEIGHT:
SHEET 1 OF 1
TITLE:
DRAWN
CHECKED
NAME
DATE
Ø0.33
Ø0.33
2.00
1.50
0.50
0.50
2.50
10.50

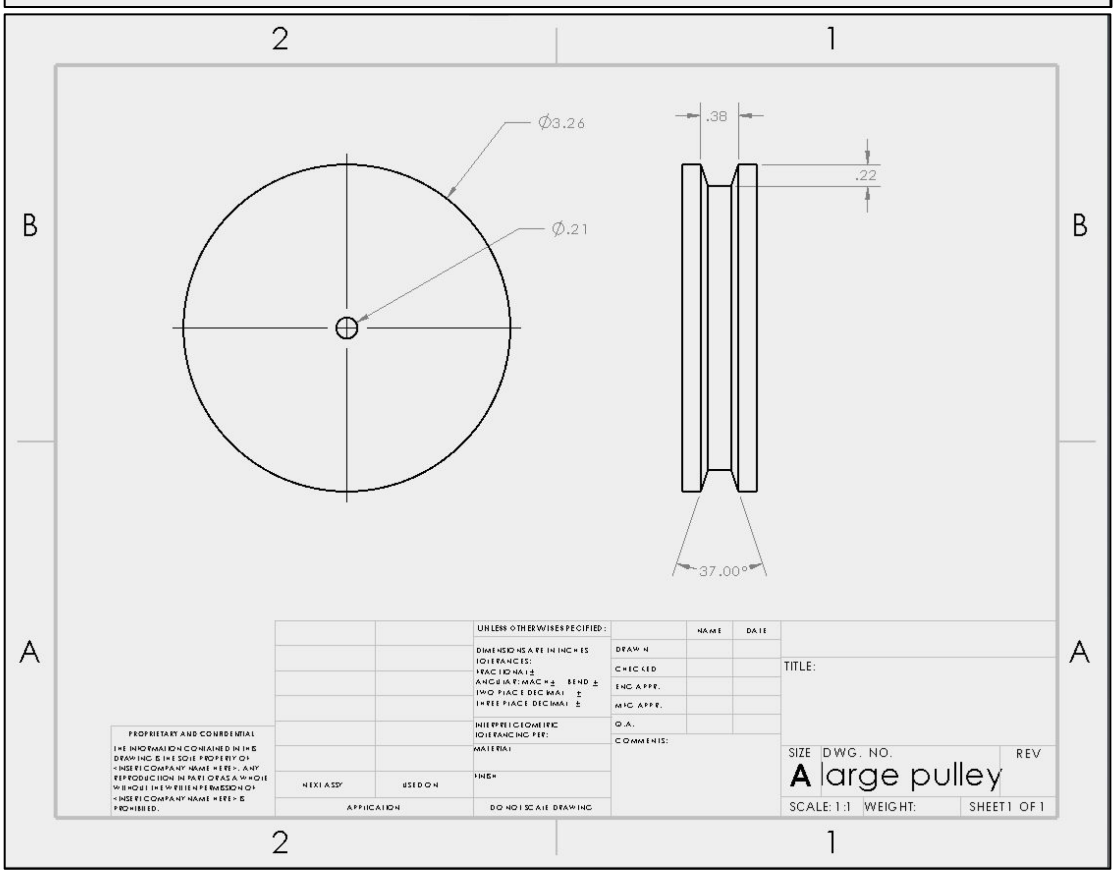

2X 1/4 CLEARANCE HOLE
2X 1/4-20 DRILL AND TAP
2.500
.250
.625
2.219
.531
.125
.355
.750
2.000
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
TITLE:
SIZE
A
DWG. NO.
auger motor mount
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL


2.000
1.625
.375
.224
1.445
1.895
2.125
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
TITLE:
SIZE
A
DWG. NO.
auger motor mount face
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL


TRUE Ø0.266
1.500
1.000
16.000
18.000
TRUE Ø3.500 ID
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
SIZE
DWG. NO.
B
chute
REV
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1



2
1
B
A
Ø2.04
Ø.21
.38
.22
37.00°
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
SIZE
DWG. NO.
REV
A
small pulley
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1



2
1
B
A
Ø3.26
Ø.21
.38
.22
37.00°
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
SIZE
DWG. NO.
REV
A
large pulley
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1

1.19.4 Appendix D: EES Calculations

"Weight on Motor Mount"

"Specifications"

L = 7.5 [in] * **convert**(in,m)
height = 0.051 [m]

m_motor = 235 [g] * **convert**(g,kg)
m_motor_seat = 225 [g] * **convert**(g,kg)
m_angle_iron = 300 [g] * **convert**(g,kg)

g = 9.81 [m/s^2]

"Mass is on the end of a cantilever beam"

m_eq = (m_motor + m_motor_seat) + 0.23 * (m_angle_iron)

F_eq = m_eq * g

"Moment balance"

F_eq * L - F_cb * height = 0

m_cb = F_cb/g

SOLUTION

Unit Settings: SI C kPa kJ mass deg

F_{cb} = 19.38 [N]	F_{eq} = 5.189 [N]
g = 9.81 [m/s^2]	height = 0.051 [m]
L = 0.1905 [m]	$m_{angle,iron}$ = 0.3 [kg]
m_{cb} = 1.976 [kg]	m_{eq} = 0.529 [kg]
m_{motor} = 0.235 [kg]	$m_{motor,seat}$ = 0.225 [kg]

No unit problems were detected.

Thermal Anaylsis on PVC Pipe

Specifications

$T_o = 294.261$ [K]

T_{inside} = **ConvertTemp** [F , K , 210]

$k_{air} = 0.035$ [W/(m*K)]

$L_{pipe} = 15 \text{ [in]} \cdot \left| 0.0254 \cdot \frac{m}{in} \right|$

$k_{pvc} = 0.05$ [W/m*K]

Temperature of PVC pipe using one-dimensional heat-transfer analysis

$$R_{air,in,pipe} = \frac{1}{k_{air} \cdot L_{pipe}}$$

$$R_{PVC} = \frac{1}{k_{pvc} \cdot L_{pipe}}$$

$$\frac{T_{inside} - T_o}{R_{air,in,pipe} + R_{PVC}} = \frac{T_{inside} - T_{pvc}}{R_{air,in,pipe}}$$

SOLUTION

Unit Settings: SI C kPa kJ mass deg

k_{air} = 0.035 [W/(m*K)]	k_{pvc} = 0.05 [W/m*K]	L_{pipe} = 0.381 [m]
$R_{air,in,pipe}$ = 74.99 [K/W]	R_{PVC} = 52.49 [K/W]	T_{inside} = 372 [K]
T_o = 294.3 [K]	T_{pvc} = 326.3 [K]	

No unit problems were detected.

1.19.5 Appendix E: Final Budget Document

Team Name Automeated Solutions

Team # 12

Senior Design Advisor: Prof. Mark Michmerhuizen

Name of student submitting THIS budget and request for reimbursement: Dain Griffin

e-mail address: dtg3 Student ID No. 1752131

Date	Team member	Description	Debit	Credit	Balance	Comments	Status
9/30/16		Beginning Balance			$500.00		
12/12/16	Dain G	Motor and Temp Sensor order - Sparkfun	85.26		$414.74	Calvin Order	Received
12/28/16	Dain G	Motor HAT- Adafruit	29.62		$385.12	Calvin Order	Received
12/28/16	Dain G	Ras Pi 3 - Amazon	73.99		$311.13	Calvin Order	Received
12/30/16	Jordan S	Auger	30.50		$280.63	Calvin Order	Received
2/27/17	Jordan S	Sleeve Bearings	8.63		$272.00	Calvin Order	Received
2/27/17	Jordan S	Valve	20.03		$251.97	Calvin Order	Received
3/16/17	Dain G	IR Flame Sensor	7.00		$244.97	Calvin Order	Received
3/17/17	Dain G	Rasp Pi case	5.00		$239.97	Calvin Order	Received
3/31/17	Dain G	12v Stepper Motors	43.08		$196.89	Calvin Order	Received
4/1/17	Jordan S	Propane Valve parts	34.50		$162.39	Jordan paid for this. Have receipt.	Received
4/1/17	Jon S	Propane Valve parts	22.51		$139.88	Jon paid for this. Have receipt.	Received
4/1/17	Dain G	AdaFruit Thermocouple Amps & hardware	47.93		$91.95	Calvin Order	Received
4/1/17	Dain G	Amazon wire sleeves and plugs	22.74		$69.21	Calvin Order	Received
4/6/17	Jordan S	McMaster V-Belt order	8.40		$60.81	Calvin Order	Received
4/7/17	Jordan S	New McMaster V-Belt order	19.50		$41.31	Calvin Order	Received
4/8/17	Jordan S	Magnetic stripping	9.53		$31.78	Calvin Order	Received
4/12/17	Jon S	McMaster CapeSleeve Bib	23.66		$8.12	Calvin Order	Received
5/3/17	Dain G	Meijer's spray paint	6.50		$1.62	Dain paid for this. Have receipt	Received

If a team reaches a negative balance situation then the Sr. Design Faculty member will need to sign below and communicate with the Department Chair the need for additional funds.

I understand that this team is overbudget and reccomend funds to cover this shortage be drawn from ______________________________

____

Signature ____

1.19.6 Appendix F: Code File Descriptions

Files are located:
DriveS@SHARED/Engineering/Teams/Team12/Smoke_Sentry_Code_Final

***hat-server.py*:**

The hat server file is where many of the Python libraries are imported. This is where flask is initialized to create a server so that Python and Ruby can communicate with one another through URI addresses. This is also where motors and thermocouples are defined so that they need be called. This file must be running on the Raspberry Pi.

***homepage.haml*:**

The homepage file uses HAML, and HTML template to create the layout of the web application. This is where titles and descriptions are written; where buttons are created and to allow them to submit calls to the JavaScript file so that information can be sent and received.

***automeated.css*:**

This is a CSS file that formats the homepage to get a more appealing GUI. We can set colors and format text and layout to make the page easier to navigate.

***smoke_sentry.js*:**

Smoke sentry JavaScript file sends and receives data from the main Ruby program main.rb to be displayed on the homepage so that the user gets real-time feedback of information.

***auger.rb*:**

This is a Ruby file that creates a class called auger and allows the main program to call that class to move the auger stepper motor forward and backward.

***gas_value.rb*:**

This is a Ruby file that creates a class called gas valve and controls the gas valve stepper motor. Within this file, the range of steps that is required to open the gas valve to full from close is established, and then turned into presented value from 0% to 100%.

***main.rb*:**

This is a Ruby file and is the main executable of the Smoke Sentry program. Here is where get and post commands are sent and received two get data from the hat server along with all the other classes that are created and controls the creation of the Sinatra server to that communicates with the flask server to send commands. This file must be running and is the main program.

***pid.rb*:**

This is a Ruby file that controls the main PID loop for the automation of the Smoke Sentry system. The Proportional and Integral are set and controlled but the Derivative is not implemented. With more time that could be implemented to the system.

***ss_control.rb*:**

This is a Ruby file that controls the main call to the automation of the PID and continually runs checks to ensure that the user gets real-time feedback. This file must be running.

***ss_process.rb*:**

This is a Ruby file that ensures that auto mode is running and sending feedback to the user along with controlling the automated auger timer to put chips in at certain intervals.

***temp_sensor.rb*:**

This is a Ruby file that calls and controls the temperature sensor information so that the main program send it to the homepage to be displayed for the user.

***temp_timer.rb*:**

This is a Ruby file that creates a timer variable that controls the target temperature so that it can be set in intervals to increase over time. This code did not get finished.