

MEAT SMOKER

by

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ABSTRACT

This Senior Project consists of designing and building a meat smoker. The design of this meat smoker incorporates knowledge of control systems, programming, hardware, and materials manufacturing. This smoker is made to allow the user an easy experience of smoking food. The smoker provides the user with a programmable temperature and timer. It also has an automatic wood chip loader as deemed necessary to keep the correct amount of smoke distributed. Lastly, this smoker has an automatic application of the user's choice of liquid to the meat. By designing a smoker with these capabilities, an untrained person desiring to smoke meat will now have the capabilities to make a desirable meat. Smoking meat has been in the past a "sport" due to its difficult nature; with this smoker design, an average person can now participate. Also, this smoker will solve the problem of time constraint people may have. A deliciously smoked piece of meat can take more than 12 hours to finish. Prior to the design of this smoker, this implies a person would have to continuously be monitoring the meat, therefore inhibiting their normal daily activities. By creating this smoker, the user only has to touch the smoker upon startup. This allows required daily activities to still be met by the user.

INTRODUCTION

People have been consuming meat for many generations. As a result of humans' love for meat, humans have devised many different ways to make meat more delicious and pleasing to the taste buds. One of these ways humans have created is the method of smoking meat. The theory behind smoking meat is to take a tough cut of meat, slowly cook this meat at a low temperature for a long period of time, and impart the flavor of wood chips from the smoke created by the wood chips coming into contact with a hot surface. However, because this cooking process is a long and slow method, it can take all day to finish cooking and require a person's absolute attention.

The meat smoking process is not only difficult because of the time constraint, but also because of the difficulty in transforming a tough cut of meat into a delicious, juicy cut of meat. This difficulty is part of the reason meat smoking competitions are famous and why there are even television shows dedicated to meat smoking. People devote their time into perfecting different ways to smoke meat. For example, some people use the periodic application of liquid onto the meat to create a more tender meat. The Meat Smoker is designed to make this long and difficult process as easy as possible to any untrained person who also may not have the time availability to spend all day cooking meat.

BACKGROUND

This project solves the problem of time and the degree of difficulty imposed on people desiring to smoke meat. The Senior Project smoker uses two methods of heat: smoldering wood chips and an oven component. This provides maximum energy use, as well as provides optimal quality of taste according to a programmable, stable temperature.

To this date, other smoker companies attempt to solve the problems of time, cost and degree of difficulty by using a remote control that allows them to walk away about a hundred of feet from the smoker in order to resume their daily activities while still monitoring the smoker. Another alternative companies use to solve the time consumption is by making a smoker that automatically loads wood chips based off of a pre-set timer into the smoker. While these existing solutions help solve the time constraint and difficulty, they do not completely resolve these issues without compromising a delicious piece of meat. Many smokers only include one of these existing solutions and not all possible solutions. An example of one of the most famous existing meat smokers, the Traeger Texas Grill, is shown below in Figure 1. This Traeger meat smoker, automatically feeds wood chips into the chamber through the use of an auger and also automatically turns on heat to maintain a desired temperature. The Meat Smoker will include and improve the Traeger meat smoker's existing solutions, as well as add a new solution.



Figure 1: Traeger Texas Grill and Smoker

In order to smoke a delicious, juicy piece of meat, the meat must be sprayed intermittently with a liquid of choice, such as apple juice. The existing smokers make it easier for an average person to smoke meat; however, they compromise the taste of the meat by not supplying a way for the meat to be spritzed with liquid. By dismissing the liquid application, the existing smokers revoke their time-saving boasts by still requiring the user to be on stand-by to spray the meat with liquid and thereby still retaining another degree of difficulty. This project will address these unmet problems by adding a liquid sprayer that will intermittently moisten the meat throughout the smoking process. This spray setting will be adjustable to either spray or be turned off depending on the user's desire. Table I below demonstrates the advantageous characteristics met by one of the most popular and recognized existing meat smokers, Traeger Texas Grill Smoker, compared to this senior project's smoker. This table also addresses disadvantages by bringing to attention what many existing smokers lack.

Table I: Desired Smoker Capabilities

| | | Traeger Texas Grill Smoker | Senior Project Meat Smoker |
|----------------------|---|-----------------------------------|-----------------------------------|
| Advantages | Maintains Desired Temperature | ✓ | ✓ |
| | Sets a Timer for the Meat | | ✓ |
| | Signals upon Time Finished | | ✓ |
| | Loads Chips Automatically | ✓ | ✓ |
| | Sprays the Meat with Liquid | | ✓ |
| | Fully User-Controlled | | ✓ |
| Disadvantages | Does not have a Well-Known or Advertised Name | | ✓ |
| | High Price | ✓ | ✓ |

The advantages and disadvantages in comparing existing smokers with the Meat Smoker are summarized above. The only two disadvantages the Meat Smoker has are that it lacks a well-known name to provide a recommendable name among customers and the smoker is costly. The lack of a well-known name has the potential to change over time as this smoker would be shared either by advertising or word of mouth. Also, while the Meat Smoker does have a high price, it is definitely comparable to the existing smokers on the market. This price is also not set in stone; in the market place, prototypes often cost more than the product when it comes off of the mass production line. This fact is because, over time, efficiency in manufacturing is increased, and parts or materials tend to cost less when purchased in bulk. Therefore, the Meat Smoker does have the potential to become priced much lower than existing smokers. When the benefits of the Meat Smoker are compared with existing meat smokers' benefits, the Meat Smoker has the potential to far outperform existing meat smokers.

REQUIREMENTS AND SPECIFICATIONS

The requirements and specifications for the Meat Smoker are shown in Table II.

Table II: Requirements and Specifications for the Meat Smoker

| Marketing Requirements | Engineering Specifications | Justification |
|--|---|--|
| 1,7 | Should connect to a standard three-prong wall outlet of 120V _{AC} . | This connection provides easy-accessibility to use the smoker anywhere with a standard outlet. |
| 1,2,6 | Liquid will intermittently spray on the meat according to user specification. | The spraying of liquid keeps the meat moist and desirable to the user. The automatic, timed spray makes the smoker able to maintain itself. |
| 1,2,5 | Wood chips will automatically load into the smoker according to user specification. | This ensures an even smoke distribution process. This also saves the user time by not requiring them to load the wood chips. |
| 1,2 | A meat temperature probe will display the internal meat temperature on the user interface. | This makes the process to check the meat's internal temperature simple by constantly displaying the temperature in real-time on the user display. |
| 1,2,3,7 | The air temperature within the meat smoker should be within $\pm 5^\circ$ of specified temperature. | This keeps the meat smoking process as accurate as possible. This tailors the meat to the user's desire. |
| 1,2,4 | A countdown timer may be set by the user. | This timer helps the user keep track of how long the meat smoker has been on, and how much time is left. |
| 1,2,4,6 | The wood chip feeder and spray mechanism should be controlled both manually and automatically. | This provides the user with multiple options to control the smoking process. The manual application provides an override of the programmed spray and wood chip feed. |
| Marketing Requirements <ol style="list-style-type: none"> 1. Easy to use. 2. The product can be left alone after initialization until the meat is ready. 3. Maintains a desired temperature. 4. Keeps a user-specified count of time. 5. Loads wood chips automatically. 6. Automatically sprays the meat with desired liquid. 7. Safe to use. | | |

The requirements and specifications table format is provided by the *Design for Electrical and Computer Engineers*, Chapter 3.

DESIGN

The first step in designing this meat smoker is to address the mechanical aspect of the project. This project is built around the concept of heat and food. Therefore, the material used to build the inside of the oven chamber must both be able to conduct heat in order to speed up the oven heating process and must also be able to meet food grade standards. The best type of metal that meets both of these requirements is type 304 stainless steel. This type of metal is used to line the inside of the box because of its common use in the food industry, such as in pots and pans. It is also commonly used because of its resistance to corrosion and oxidation which helps guard against the acidity found in food. Lastly, it is also extremely tough for a large range of temperatures and is easily cleaned, which is a necessity as smokers become coated with grime after each use.

The chamber needs to be insulated in order to keep a steady internal chamber temperature. Fiberglass is chosen to act as an insulator for this chamber. Q Corporation regularly creates Temperature Humidity Test Chambers that must be able to withstand high temperatures and therefore, need to be insulated. These humidity test chambers require the same insulation as the meat smoker, and so, High Temperature Fiberglass is used to insulate the meat smoker chamber.

A bin is also needed in this meat smoker to hold the wood chips that will create the smoke. In order to create smoke, these wood chips need to come into contact with a high heat surface that will cause the wood chips to smolder. The metal used to create this wood chip bin is the same stainless steel used to make the entirety of the meat chamber because of the possibility of the bin coming into contact with food as well as the need to conduct heat. The bin needs to

reach extremely high temperatures to cause the wood chips to smoke; therefore, the best place for the heater to sit is directly underneath the wood chip bin inside the meat chamber.

The heater must also be able to withstand any acidity from the food as well as has the capability to heat an entire meat smoker chamber. Two 500 W Incoloy Sheathed Heaters by Watlow will be used to heat the chamber. The Incoloy Sheathed aspect of the heater means that this heater will resist corrosion and oxidation, similar to how the stainless steel material performs in the smoker chamber in order to protect from food acid. Also, the total of 1,000 Watts will be able to generate a great amount of power to heat the entire chamber. Lastly, in regards to the mechanical design, the liquid canister and wood chip feeder will be built out of copper metal. Both the canister and wood chip feeder are located outside of the meat smoker chamber in order to provide easy access during the meat smoker process and because there is no need to have these holders heated. The use of copper to build these holders are chosen because copper is not toxic to the body in small doses. Also, leaching of the copper into the liquid or onto the wood chips will be minimal because these holders will, again, not be heated.

After the mechanical design is completed, the electrical design of the meat smoker is necessary. The basic design of what the Meat Smoker must accomplish using electrical circuitry is shown in the Level 0 Hardware Block Diagram. The Meat Smoker is designed to be user controlled, and therefore must be manually controlled by a user's input through buttons, switches, and a PID controller. Each of the inputs shown in the Level 0 Hardware Block Diagram, excluding the Type-K thermocouple, are buttons or switches activated by the user. The outputs of the Level 0 Hardware Block Diagram are the responses needed to the user's input. More detailed descriptions of each of the hardware inputs and outputs of the Meat Smoker are shown in Table III.

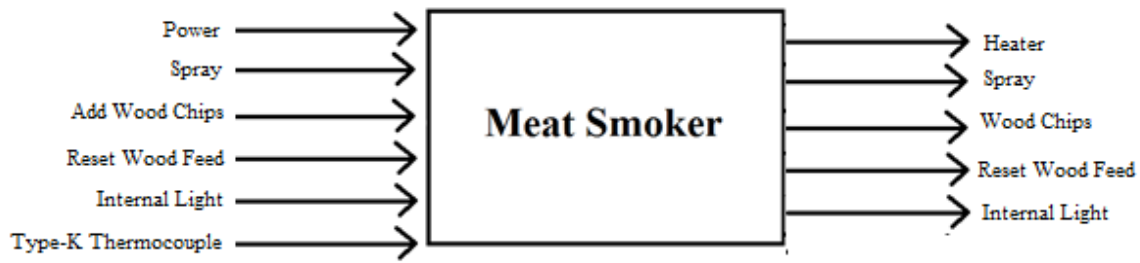


Figure 2: Level 0 Hardware Block Diagram

Table III: Level 0 Hardware Functional Description

| Module | Meat Smoker |
|----------------------|---|
| Inputs | Power- manual switch to turn on/off the power to the system Spray- manual button used to command the smoker when to disperse spray onto the meat Add Wood Chips- manual button used to add the desired amount of wood chips to the chamber Reset Wood Feed- manual button used to set the wood chip holder to the position needed in order to refill with wood chips Internal Light- light switch used to turn on the light bulb in the meat smoker Type-K Thermocouple- used to provide feedback in order for the heater to properly adjust heat provided |
| Outputs | Heater- used to heat the chamber to the desired temperature Spray- used to provide moisture on top of the meat Wood Chips- maintains the smoke level within the meat smoker Reset Wood Feed- the disc inside of the wood chip holder is pulled back in order to allow more room for wood chips to be refilled Internal Light- light is provided to the inside of the meat smoker chamber |
| Functionality | The meat smoker is a self-sufficient smoker in which the temperature is set by the user and the outputs allow for the smoker to easily produce a desirable smoked meat. |

There are three main control loops that make up the Meat Smoker. These control loops may be seen in Figure 3. The most important control loop is a closed-loop temperature control. This circuit must be able to set a user-desired temperature, turn on the heater to reach this set temperature, and then maintain this heat once the Type-K thermocouple indicates the air temperature inside the chamber matches the set point temperature. This control is set up using a PID controller that receives feedback from a Type-K Thermocouple and adjusts its output. The

way this heater circuit functions is, first, the Meat Smoker receives power through an AC power outlet. This power runs directly to a 25 Amp circuit breaker. This circuit breaker would cause power to shut off if the amperage drawn by the meat smoker ever exceeds 25 Amps; this is a protection against any fire hazards. The circuit breaker then connects to the contact, then to a solid state relay, to the heater and then back to neutral in order to complete the circuit. A more detailed diagram of this circuit is shown in Figure 4.

A contact is used in this circuit to act as another protection against fire hazards. This circuit, in itself, draws about 9 Amps and must therefore be guarded against any dangers. A contact is used rather than just a solid state relay in this circuit because of the manner in which a contact fails. A contact always fails open as it is a mechanical device, which would guarantee the circuit would no longer be completed if the device failed. However, a solid state relay uses TTL logic and may fail either open or closed. This does not assure that in a device failure, the circuit would be broken. Also, a contact must be used in conjunction with a solid state relay because a contact cannot handle the speed and the number of times this circuit would be turned on and off by the PID controller. Also, the PID controller and the solid state relay both communicate via TTL logic and therefore, provide an easy device connection. As soon as the user changes the position of the Power On switch, the circuit is completed and this heater circuit begins functioning.

The second control loop in the Meat Smoker electrical design is the wood chip feeding circuit. This circuit is an open-loop circuit that releases wood chips into the wood chip bin according to the user's push of a button. The length that this "Add Wood Chips" button is pressed determines how long the wood chips will be fed into the wood chip bin. This circuit functions by the use of an air piston pushing a disc inside of the chip feeder's tube. Therefore,

when this disc receives air pressure, it pushes the wood chips out of the tube and forces them to fall into the wood chip bin. The main usage of air to feed these wood chips is one of the reasons why an air compressor is used in the Meat Smoker. A tube filled with pressurized air from the compressor runs to a dual air valve and then up to the back end of the air piston connected to the wood chip feed tube. When this side of the dual air valve is activated by the press of the “Add Wood Chips” button, the pressurized air is sent up to the piston to push wood chips out.

This same exact circuit set up is used to “reset” the wood chip feeder. The only differences between the “Add Wood Chips” circuit and the “Reset” circuit are that they use two different inputs to the dual air valve and the pressurized air no longer runs to the back end of the air piston, but to the front end. This placement of the pressurized air forces the disc to be pushed back into its original position before wood chips were released into the wood chip bin. This allows more wood chips to be reloaded into the wood chip feeder.

The last control circuit is also an open-loop control system. This is the liquid spray circuitry. This is also extremely similar to the wood chip feeder circuit. The container that holds the liquid to be sprayed is constantly pressurized by the air compressor. Instead of controlling when the pressurized air is to be released, the release of the liquid needs to be controlled. This is performed by the use of a liquid valve, or more specifically a solenoid. When the “Spray” button is pressed, the circuit allowing AC power to the solenoid is completed and the pressurized liquid is able to spray out of the nozzle located within the meat chamber. These three control loops are shown in Figure 3 below. The complete wiring diagram of the Meat Smoker is shown in Figure 4.

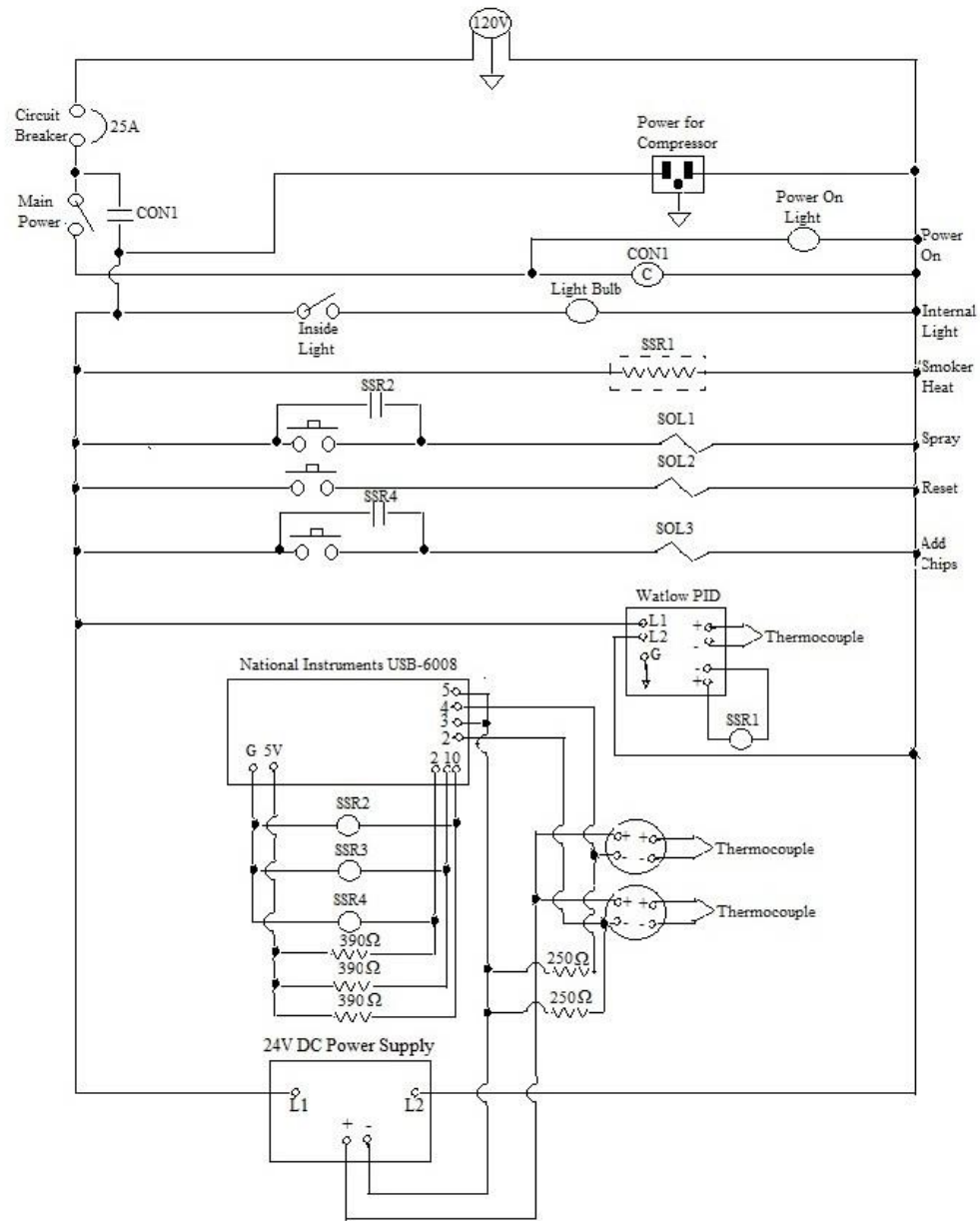


Figure 4: Electrical Wiring Diagram

At this stage in the design process, a fully functional meat smoker is available. However, this would not completely set the Meat Smoker apart from all other meat smokers that exist. The Meat Smoker needs to be a completely automatic meat smoker. In other words, the user needs to be able to just initialize the meat smoker to their desired settings, and then may walk away and

know their meat is being perfectly cooked. Therefore, a LabVIEW user interface needs to be created in order to communicate with the Data Acquisition System. The software design inputs and outputs are shown below in Figure 5 and described in Table IV.

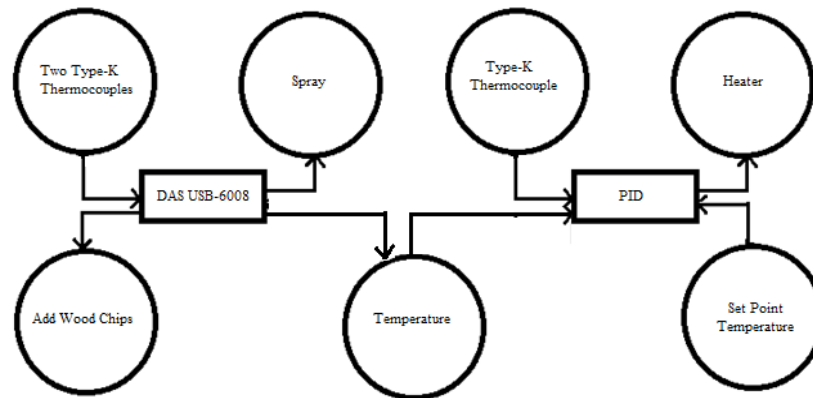


Figure 5: Software Level 0 Block Diagram

Table IV: Level 0 Software Functional Description

| Module | Meat Smoker |
|----------------------|--|
| Inputs | <p>Two Type-K Thermocouples- used to display to the user the internal meat temperature through use of the DAS.</p> <p>Temperature- used to output the desired temperature using the user interface to the PID controller</p> <p>Type-K Thermocouple- used to provide feedback to the PID controller to direct how much heat to add to the chamber</p> <p>Set Point Temperature- used to input directly onto the PID controller the desired set temperature</p> |
| Outputs | <p>Spray- used to spray the meat chamber with liquid according to the desired user settings</p> <p>Add Wood Chips- used to add wood chips to the chamber according to the desired user settings</p> <p>Temperature- used to communicate the desired user temperature for the chamber</p> <p>Heater- used to heat the chamber to a set temperature according to the PID controller's feedback loop</p> |
| Functionality | <p>The meat smoker is a self-sufficient smoker in which the temperature is set by the user and the outputs allow for the smoker to easily produce a desirable smoked meat by using a PID controller and a DAS USB-6008.</p> |

The way the design of the user interface is addressed is to focus on what the user desires or needs most in a meat smoker, in other words, what the user sees as the most important aspect

for a meat smoker. This most important aspect is the meat itself. The user needs a simple way to tell when the meat is done. This is performed by reading the temperature in from two different thermocouples that are to be used as meat probes. This reading ability through an interface allows both the heat to be maintained within the chamber and makes it easier on the user by not having to open the door in order to take the meat temperature. The meat temperature readings are shown in Figure 6 as Meat Probe 1 and Meat Probe 2. An option also exists for the user to view the temperature as a gauge, which is labeled in Figure as “Actual Temperature [F]” and also has a reading beneath it. Also, the “Thermometer” displays the temperature reading. These are just more ways to view the temperature and have no bearings on the actual function of the readings or the Meat Smoker.

The meat probe temperatures are read in by the use of a Data Acquisition System, more specifically a National Instruments DAS USB-6008. This DAS acts as the communicator between LabVIEW and the Meat Smoker’s functions. The DAS communicates in terms of a 4-20mA current or a 2-10V voltage. Therefore, in order to receive the temperature from the thermocouples as inputs, the thermocouple output must be translated into a current or voltage. Two wire transmitters, commonly known as “hockey pucks” in the industry, are used to convert the thermocouple outputs into a 4-20mA current based off of the read temperature. The wire transmitter outputs are then wired to the DAS as two different inputs. LabVIEW then can use this 4-20mA current range to scale the readings back into a temperature reading.

Next, the user also needs a timer to set in order to keep track of how long the meat has been in the oven. This timer may be set directly on the LabVIEW user interface and then, will countdown and display the “Cook Time Left” as seen in Figure. When this time runs out, a light is illuminated on the interface. Also, there is a “Progress” bar seen in Figure 6. This bar slowly

increases with a red solid color as time passes. This timer function does not communicate with the Meat Smoker at all. It is merely a function intended to visually help the user.

The ability to set the chamber temperature using LabVIEW is another function the user needs. This would give the user the ability to both set the oven temperature using the PID controller interface and the LabVIEW interface. The user may set the oven temperature using the “Set Oven Temperature” slider shown in Figure 6. The DAS then outputs a voltage to the PID controller that has been scaled according to the temperature. The PID controller then receives this voltage as an input and scales it back into a temperature reading.

The next functions the user interface needs to address are the Spray and Feed Wood Chips functions. The circuitry is already created for the actual spray and wood chip feed applications; however, the DAS needs to communicate via voltage to activate the solenoids. This is performed by using solid state relays. As previously discussed, solid state relays use TTL logic and therefore are a perfect match to use for Data Acquisition Systems. These solid state relays receive a voltage from the DAS when spray or wood chip feeds are needed; when they receive this voltage, the circuit is completed. The valves are then able to open in order to let liquid or pressurized air through. Two different solid state relays are used for the wood chip feed and the spray so they may be separately commanded by the user. Because these processes function by circuit completion, the duration of their activation to feed wood chips or spray may be controlled by the user. This is shown in Figure 6 by the “Spray Duration (ms)” and the “Wood Chip Duration (ms)”.

The Meat Smoker is meant to be able to run on its own and continue spraying and feeding wood chips when the user is not there. For this reason, a “Spray Interval (min)” and a “Wood Feed Interval (min)” setting needs to exist on the user terminal in Figure 6. These

interval specifications are based off a timer. For example, if the user entered 40 into the “Spray Interval (min)” and 1000 in the “Spray Duration (ms)”, liquid would spray every 40 minutes for 1 second. There are a few other settings that correspond to the spray and wood chip feed. Both of these functions have a light to illuminate when their action is occurring. Also, there are two buttons, “Activate Spray” and “Activate Chip Feed” that need to be pressed in order for the spray or wood chip feed cycles to begin. Also, there is a “STOP” button that is used for a quick exit from both the wood chip feed and spray cycles. Lastly, there is a “Force Spray” and “Force Chips” button seen in Figure 6. These are used to activate spray or the wood chip feed outside of the automatic cycle. However, due to time constraint, these last two mentioned buttons, “Force Spray” and “Force Chips”, were never implemented in the circuitry; all other discussed functions are implemented. These buttons are created to make an easier, more controlled Meat Smoker for users.

LabVIEW creates a user interface terminal based off of the actual code created to communicate with the Data Acquisition System. The entirety of the code created in LabVIEW is shown in Figure 7. A closer look, or a “zoomed-in” version, of the code may be seen in Figures 8 and 9. These code functions are all labeled according to how they are shown on the user interface terminal.

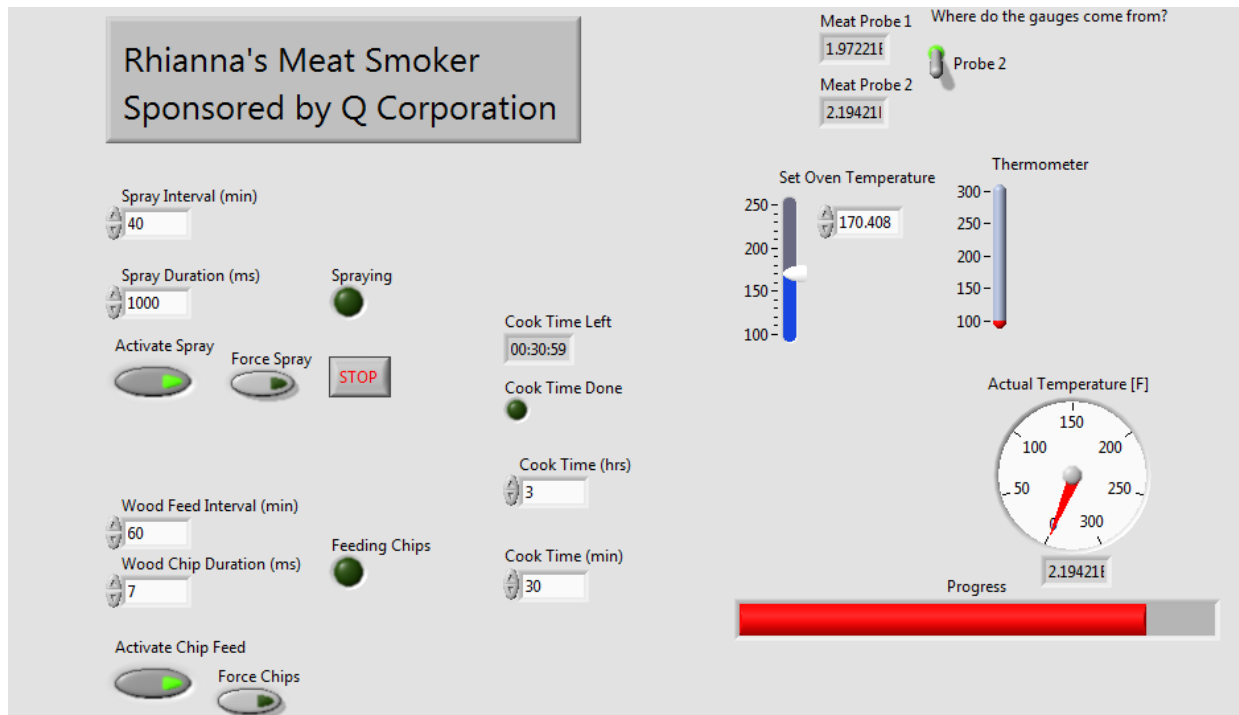


Figure 6: Meat Smoker User Terminal

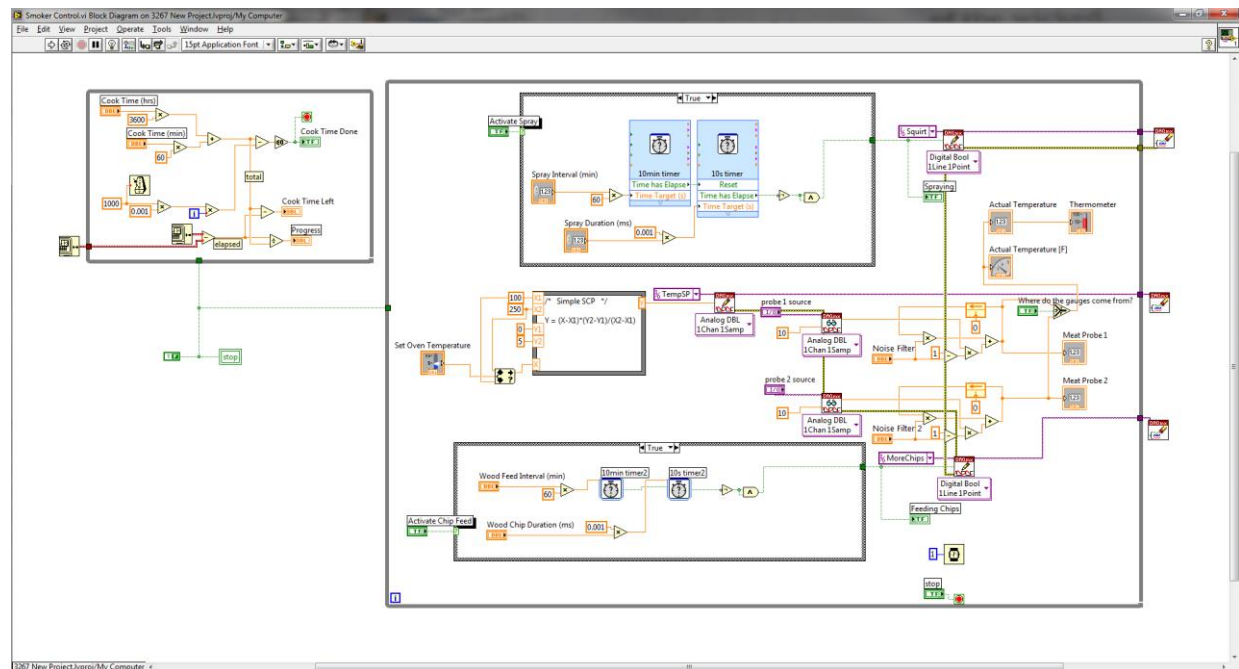


Figure 7: Meat Smoker LabVIEW Code

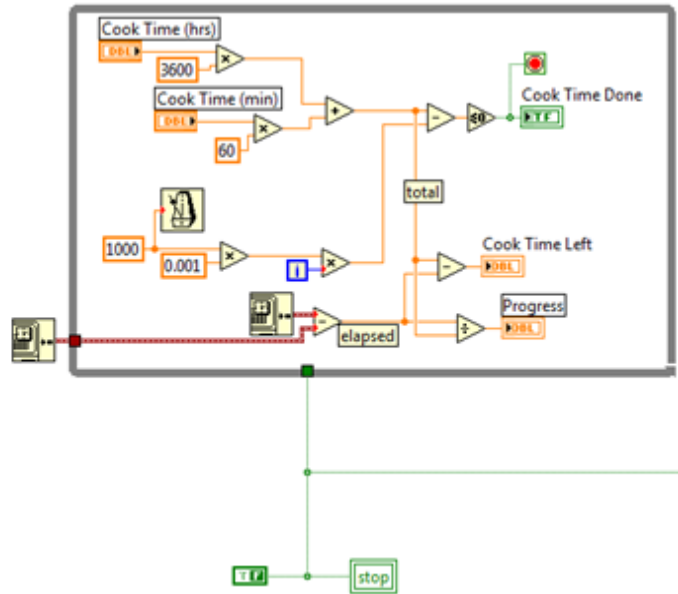


Figure 8: Closer View of LabVIEW Timer Code

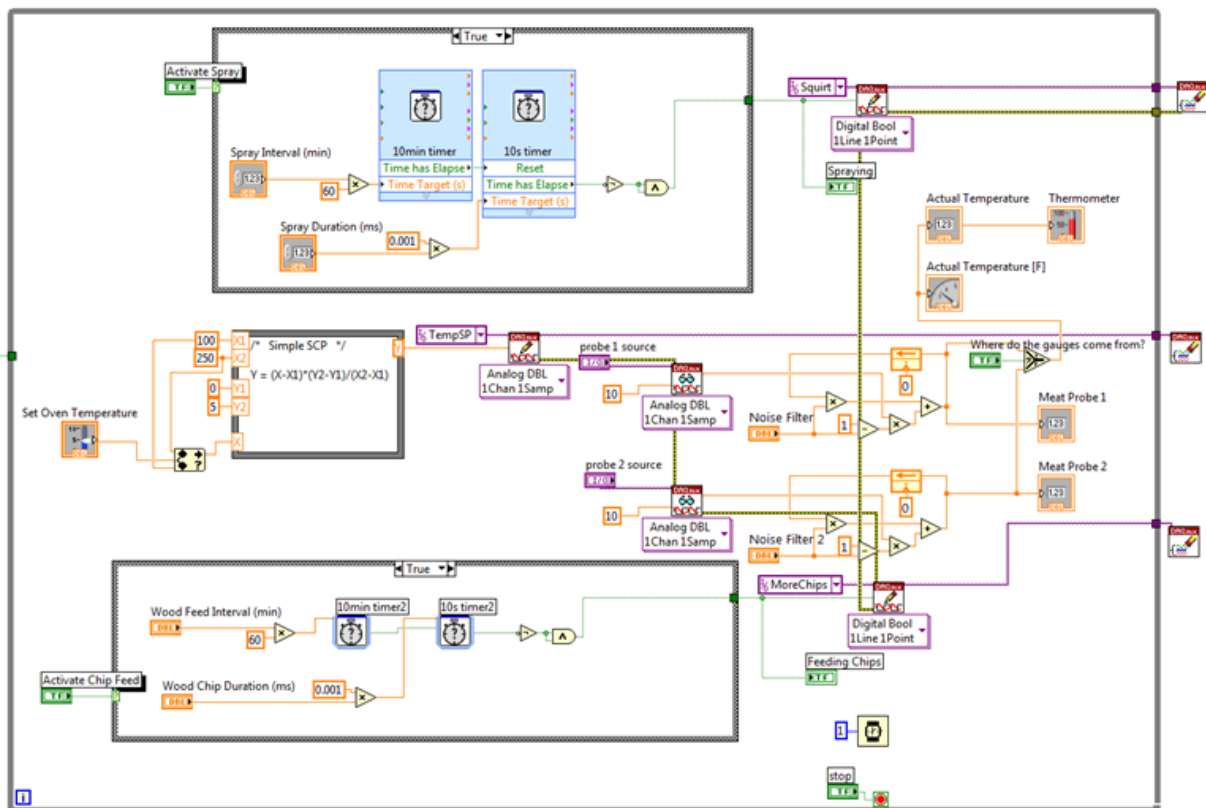


Figure 9: Closer View of LabVIEW Temperature, Spray, and Wood Chip Feed Code

DEVELOPMENT AND CONSTRUCTION

The construction of the Meat Smoker began with building the Meat Smoker's structure. All manufacturing of the structure was performed using Q Corporation facilities and equipment with the help and supervision of Q Corporation employees. The first step performed in creating the Meat Smoker's box is to bend and weld 18 gauge, food grade, type 304 stainless steel together to form the basic structure. Also, this stainless steel is welded using a TIG Miller Synchrowave 250 machine. The stainless steel interior of the box at this stage in the development is shown in Figure 10, and the stainless steel interior of the door is shown in Figure 11.

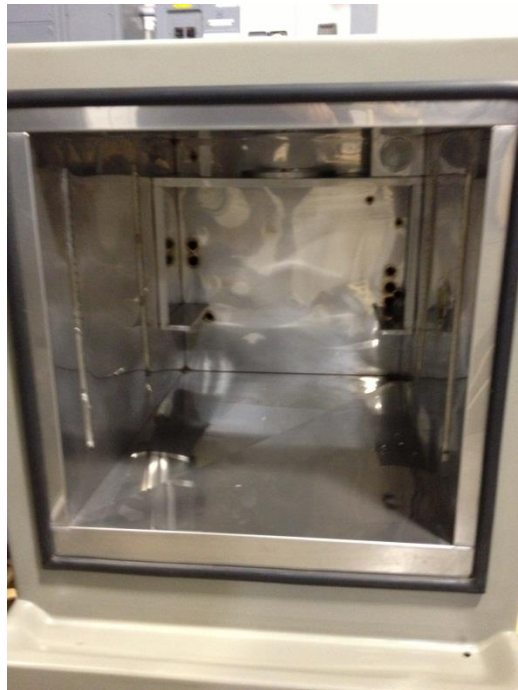


Figure 10: Inside View of the Meat Smoker



Figure 11: Inside View of the Door to the Smoker Chamber

Next, four inches of High Temperature Fiberglass is added to the outside of the stainless steel interior. This layer helps protect the consumer from burning themselves on the meat smoker; this stops heat transfer to the exterior of the meat smoker box. The next step in creating the meat smoker box is to mold a fiberglass exterior on to it. This was performed using molds for Q Corporation's standard Temperature Humidity Test Chambers. Next, holes are drilled from the exterior to the interior of the box in order to provide a place for the liquid sprayer, thermocouples, and wood chips to be fed through. The exterior of the meat smoker box at this stage in development are shown in Figures 12-14.



Figure 12: Front View of the Meat Smoker Chamber



Figure 13: Top View of the Smoker Chamber



Figure 14: Rear View of the Smoker Chamber

Next, the wood chip bin is manufactured and the pipe that directs the wood chips after they drop into the bin is built into the Meat Smoker. The interior of the meat chamber with these additions are shown in Figure 15. Next, the heater must be screwed onto the bottom of the wood chip bin. This is shown in Figure 16. The actual wood chip feeder must then be manufactured as well as the liquid canister. These are shown in Figures 17-19.



Figure 15: Inside View of the Meat Smoker with the Wood Chip Bin



Figure 16: Heater on the Underside of the Wood Chip Bin

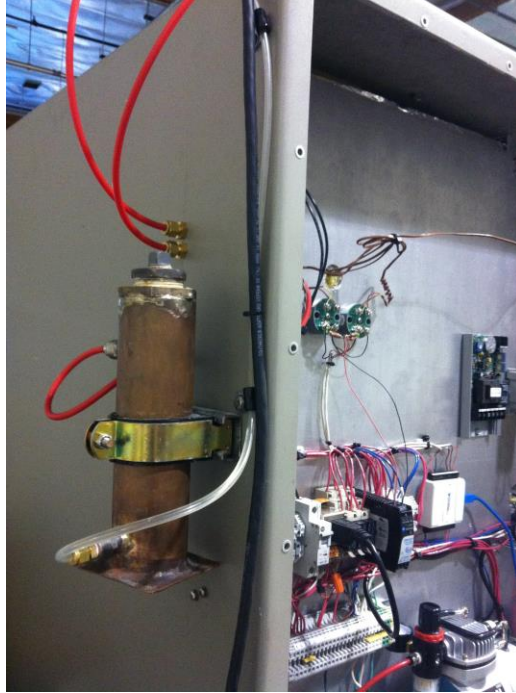


Figure 17: Finished View of the Spray Mechanism



Figure 18: Finished View of the Wood Chip Feeder and Spray Solenoid



Figure 19: Top View of the Wood Chip Feeder

After these parts have been manufactured, the electrical wiring and circuitry may be connected. These are shown in Figures 20 and 21.

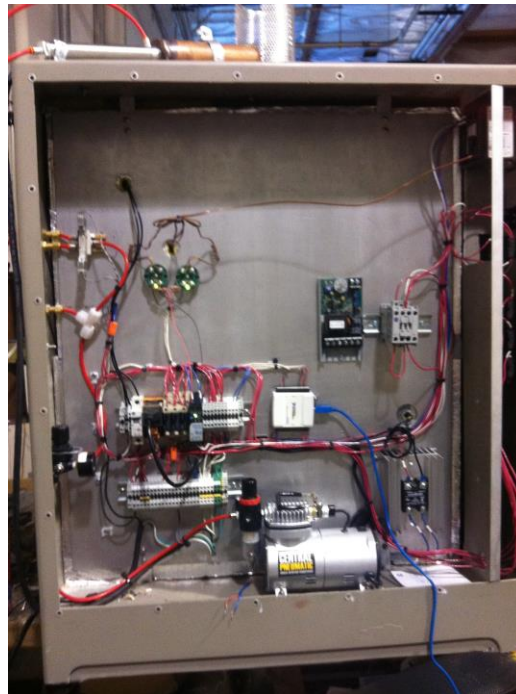


Figure 20: Finished View of the Wiring



Figure 21: Side View of the Manual Control and PID Controller

TESTING

The main testing that occurs to view the function of the Meat Smoker is to observe the whether the wood chip feed, spray, and temperature work both manually and automatically. When this is confirmed, the Meat Smoker is functioning properly. Therefore, there is no set, standard way to test the Meat Smoker. The wood chip feed and spray is therefore tested by manually pressing the buttons commanding their activation, and observing that wood chips are fed or spray is dispersed. The other method to test these processes is to initialize these functions on LabVIEW and observe they respond according to the user times set. Both of these tests were passed. These functions work correctly. Lastly, the stability of the temperature of the chamber is tested by observing the speed at which the chamber heats as well as if the Meat Smoker maintains the set point temperature. The speed at which the chamber heats up is recorded below in Figure 22. This demonstrates that the Meat Smoker heats up by about 2.5°F per minute. This also demonstrates the accuracy of the Meat Smoker to maintain the set point temperature within $\pm 5^\circ$.

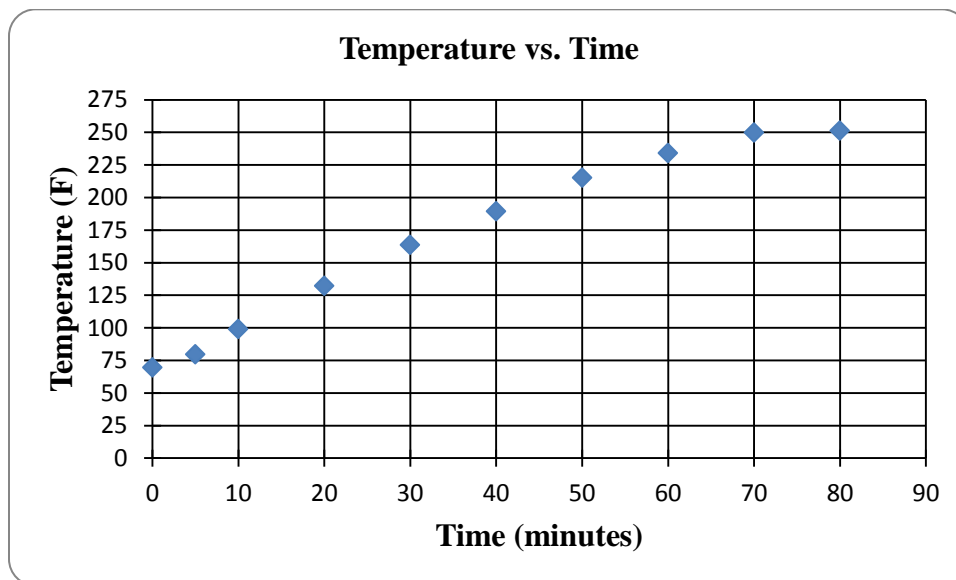


Figure 22: Temperature of the Meat Chamber (set to 250°) vs. Time

Another way in which the Meat Smoker is tested is by actually using the Meat Smoker to make a delicious piece of meat. Instructions to recreate this Brisket test are shown below.

Pictures of this test are shown in Figures 23-25.

1. Set the Meat Smoker temperature using the PID Controller to 225°F.
2. Mix together the ingredients of a rub to coat the beef brisket with. Recommended rub is:
 - i. ½ c. crushed black pepper
 - ii. 2 tbsp. cumin
 - iii. 2 tbsp. red chili flakes
 - iv. 2 tbsp. cinnamon
 - v. Pinch of ground mustard
 - vi. ½ c. instant espresso
 - vii. 1 tsp. salt
 - viii. 2 tbsp. garlic powder
 - ix. 2 tbsp. onion powder

This amount of rub will vary depending on the size of the beef brisket.



Figure 23: Brisket with the Rub Before Being Cooked

3. Once the rub is prepared, coat the brisket with yellow mustard and generously apply the rub onto the meat.
4. Next, load the wood chip holder with the desired flavor of wood chips. If the disc inside the feeder is not already at the bottom, hold the “Reset Wood Chips” button on the smoker until the disc has reached the end of the tube. Now, the wood chip feeder can be loaded. Also, load the spray canister with the desired liquid by unscrewing the top of the canister. Make sure this lid is screwed back on tightly. Recommended wood chips and liquid are: Apple Wood Chips and Apple Juice.



Figure 24: Recommended Apple Wood Chips

5. Next, initialize the wood chip feed and spray times on the LabVIEW interface according to one's own preference. Recommended settings for the wood chip feed are:
 - i. 45 min. Wood Feed Interval and 1 ms. Wood Chip Duration

Recommended settings for the spray mechanism are:

- ii. 60 min. Spray Interval and 500 ms. Spray Duration
6. Set the timer on the LabVIEW interface to the desired amount of time. Recommended set time is: 1 hr. and 15 min. for every 1.5 lbs. of beef brisket.
7. Place the beef brisket inside of the heated Meat Smoker and place both meat probes into the deepest, thickest parts of the brisket.
8. Press the “Run Continuously” button on the LabVIEW interface in order to start the timer, meat probe readings, the wood chip feed, and the spray mechanism.
9. As soon as the timer reads about 45 min. left of cook time or when the meat probe reads about 180°F, take the beef brisket out of the meat smoker and wrap the brisket in foil.
10. Turn off the heat on the meat smoker using the PID Controller, stop the wood chip feed and spray mechanism by pressing “STOP” on the LabVIEW interface, and place the brisket back into the Meat Smoker for another 15 min.
11. Once the 15 min. has finished, remove the beef brisket from the oven, slice it into even pieces, and enjoy.



Figure 25: Cooked Brisket

CONCLUSION AND RECOMMENDATIONS

The Meat Smoker project has accomplished all that was intended to be in the Meat Smoker. It is completely automatic and may be left alone for the users to continue their normal days without being tied down to watching their meat. It is also completely set apart from all other meat smokers not only for being fully automatic, but for having a spray mechanism to keep the meat moisturized. Each time this smoker has been used to make meat, the meat always comes out tasting delicious.

If this project was to be repeated, there are a few changes to be made. First of all, the placement of the wood chip feeder should be changed. Now, the hole placement for wood chips to drop through are on the top of the Meat Smoker. This allows heat to escape as it rises, making the PID controller work harder to keep the chamber at a steady temperature. This hole placement should be moved to the side of the Meat Smoker. Also, a window on the door of the Meat Smoker is not necessary. This window becomes extremely grimy and filthy while smoking meat that the inside of the Meat Smoker is no longer visible. This window just increased the cost of the Meat Smoker and is not beneficial. These are the only changes to be recommended. This is a Meat Smoker that meets all users' desires, and therefore, should be recreated by all who enjoy meat.

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APPENDICES:

APPENDIX A- SENIOR PROJECT ANALYSIS

Project Title: Meat Smoker

Student's Name: Rhianna Topp

Advisor's Name: Art MacCarley

Summary of Functional Requirements:

The Meat Smoker is designed to, foremost, deliciously cook any piece of meat. Its second main capability is to be self-sufficient. In other words, this meat smoker can be left alone after being initialized by the user of their own desires. For example, the meat smoker can be set to cook at 250°F, and then based off of the user's input during initialization, the user interface will count down how much time is left on a user-specified timer. As part of the Meat Smoker's self-sufficiency, the Smoker itself will also spray the meat with liquid when it needs moisturized, as well as feed wood chips in to the chamber when specified. For example, the user may initialize on the user interface that every 30 minutes, wood chips will be added to the meat chamber, and every 45 minutes, the meat will be sprayed with liquid. This Meat Smoker is intended to be left alone to cook a delicious piece of meat on its own.

Primary Constraints:

This project is difficult as it requires the knowledge that comes with a mechanical engineering, electrical engineering, and computer programming engineering Bachelors of Science degree. The computer programming skills are demonstrated programming a user interface, created on LabVIEW, integrated with a data acquisition system module and the PID

Controller. The mechanical engineering skills possessed are the skills to design and manufacture the box, or basic shape, of the Smoker, the automatic wood chip feeder, liquid canister, and the correct materials to use in each of these cases. Lastly, the electrical engineering skills consist of that which corresponds to designing and the applying a control system. Also, any wiring and integration of the parts for both software and hardware are performed with an Electrical Engineering mindset or skills.

Economic:

The economic impacts that result from this project are that of monetary gain. This Smoker is yet another item placed on the market to be purchased by end-users. This will cause more spending to result and therefore, help boost the economy. As this is another item that needs to be manufactured, more jobs will be created for people to monitor the machines that will produce this meat smoker.

The costs will accrue throughout the project's lifecycle as it nears the programming stage of its life. The PID controller and data acquisition system will both cost a significant amount of money. This project is funded/sponsored by Q Corporation. Q Corporation is a company that designs and manufactures testing equipment. This equipment includes control, refrigeration, responsive heating, and many other systems. After completing an internship this past summer with Q Corporation, they agreed to sponsor the Meat Smoker project. The manufacturing of the project will cost about \$2,287. The cost of each component is shown in Table V below. As a comparison, the original estimated cost is shown in Table VI. However, the cost to manufacture this prototype will not be the same price of the meat smoker if manufactured on a large-scale basis. This fact is because, often, when manufacturing occurs on a large-scale basis, efficiency increases and the cost of materials decrease. Also, efficiency not only increases in

manufacturing, but also in the design of the meat smoker's circuitry. Expensive components could be rid of by replacing them with less expensive circuit designs. For example, the function of the PID controller could be programmed into LabVIEW rather than buying a PID controller.

Table V: Cost Breakdown of the Meat Smoker

| Components | Prices | Total Number of Components |
|-----------------------------------|---------------|----------------------------|
| Alton-Bradley 24V DC Power Supply | \$ 85.00 ea. | 1 |
| Watson PID Controller | \$ 450.00 ea. | 1 |
| Central Pneumatic Air Compressor | \$ 80.00 ea. | 1 |
| ALCO Actuation Solenoid | \$ 55.00 ea. | 1 |
| ALCO Air Dual Valve | \$ 210.00 ea. | 1 |
| Alton-Bradley Circuit Breaker | \$ 25.00 ea. | 1 |
| Alton-Bradley Contact | \$ 10.00 ea. | 1 |
| Crydom Solid State Relay | \$ 35.00 ea. | 4 |
| National Instruments DAS USB-6008 | \$ 267.00 ea. | 1 |
| Wire Transmitter | \$ 85.00 ea. | 2 |
| Thermocouple | \$ 8.00 ea. | 3 |
| Switch | \$ 12.00 ea. | 3 |
| Button | \$ 12.00 ea. | 3 |
| Metal and Wiring Materials | \$ 600.00 | - |
| Power Outlet for Air Compressor | \$ 6.00 ea. | 1 |
| Light Bulb | \$ 3.00 ea. | 1 |
| Watlow 500W Heater | \$ 45.00 | 2 |
| Total | | \$ 2287.00 |

Table VI: Original Estimated Cost Breakdown for the Meat Smoker

| Components | Prices |
|-------------------------------|--------------|
| PID Controller | \$30 |
| Heat Component | \$50 |
| Fan Component | \$20 |
| Temperature Sensor | \$10 |
| Spray Mechanism | \$5 |
| Metals, Screws, miscellaneous | \$50 |
| Speaker | \$3 |
| Total | \$168 |

As of now, no individuals or parties profit from this project. However, it can be claimed that I profit from being able to have a fully functional, automatic meat smoker at the completion of this project. Smokers last users about ten years as they are built for heavy duty wear and tear by temperature and meat grime. The only operation costs that exist are the cost of the liquid to be sprayed onto the meat, the wood chips to be fed into the smoker, and the meat itself. There are no maintenance costs this meat smoker requires apart from any breakdown of the product. I would expect the first devices to fail on the Meat Smoker would be the solid state relays; however, this would be a quick fix.

The original estimated schedule for this project is shown in the Gantt chart below in Figure 26.

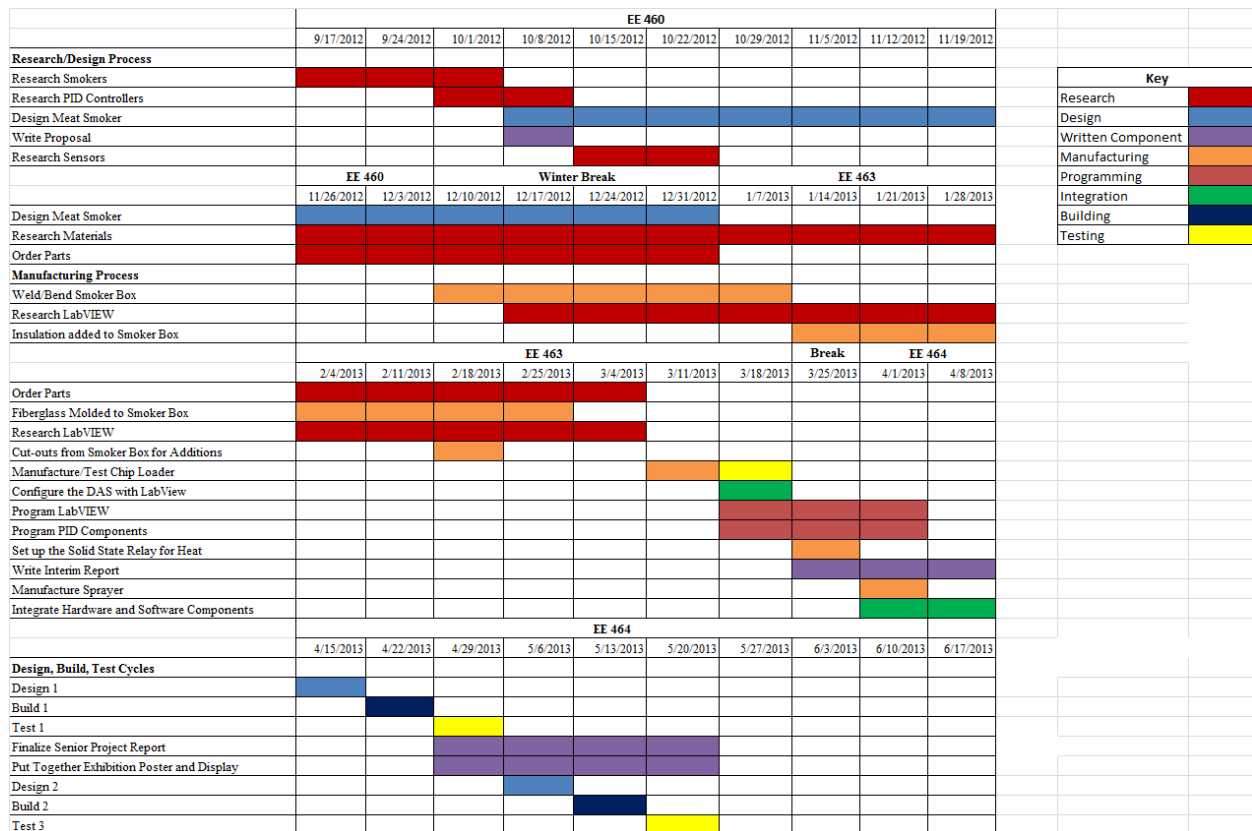


Figure 26: Original Planned Schedule

The actual schedule of this project is shown in Figure 27.



Figure 27: Updated Estimated Schedule

After this project ends, Q Corporation and I will no longer have any connection in regards to the Meat Smoker. Later in life, I may desire to patent this meat smoker; however, as of now, this is not in my plans. I will use this meat smoker as my own whenever I desire to make delicious meat.

The benefits from this project come from not only the knowledge gained throughout the process of building the Meat Smoker, but also the possibility of eventually selling this project. Also, the customers will benefit from this Meat Smoker over time as they will have the perfect piece of meat every time they smoke, as well as the Meat Smoker itself will age correctly, as the more times it is used, the better flavors the Smoker will develop.

If manufactured on a Commercial Basis:

If this product is manufactured on a commercial basis, the estimated number of devices sold per year would be about 100 units. The manufacturing cost for each unit would be about \$1,500. The decrease in cost would be due to the money saved by buying each part in bulk, rather than individually. The estimated purchase price for each device would be about \$2,000, which would then lead to a profit of about \$50,000 for the first year of selling 100 units. The estimated cost for the user to operate the device is about \$25 per use. This cost in itself is to purchase the flavored wood chips needing to be loaded into the Smoker, the liquid to be sprayed, and the actual meat to be smoked.

Environmental:

The environmental impacts of this project only exist in regards to the purchase of meat the user will have, the wood chips that are needed to produce smoke and flavor, as well as the smoke that will be emitted by use. However, these are not undesirable environmental effects; by promoting the devouring of meat, the animal life cycle will continue to be established. The natural resources this project uses are stainless steel and copper, which are used in the manufacturing of the basic structure, as well as the wood chips that are needed to initially pack the unit. This unit is mostly made out of metals, and therefore is one of the only natural resources used, apart from the silicon on the electronics.

Manufacturability:

There are no issues or challenges with the materials manufacturing of the meat smoker. Difficulty in the manufacturing of the meat smoker will present itself in the programming of each PID controller. However, if the PID controller, in the future, is programmed in the

LabVIEW software, this meat smoker will be able to be reproduced quickly and easily.

Sustainability:

The device is created to maintain itself after initial programming by the user. Therefore, this device only needs to be maintained upon the first couple minutes of use, as well as the final cleaning of the grime produced from smoking the meat. However, the project will eventually, over time, degrade due to the use of metal materials and just due to normal “wear and tear” of electrical components too. The project will impact the sustainable use of resources by allowing and encouraging the consumption of nature’s provided meat. Upgrades that may improve the design of the project include perhaps making the Smoker’s user-interface touch-screen or Bluetooth controlled. The challenges that would come with these upgrades exist only in the challenge of designing and programming these upgrades. Also, the challenge would also be to integrate these upgrades with the PID controller. However, it is suspected that in the future, these “challenges” would be minimal.

Ethical:

There are no ethical implications relating to the design, manufacture, use, or misuse of the project. This is a smoker intended to cook animal meat; therefore, the only injury that may occur would be due to electrical misuse of providing power to the smoker. However, this is performed using a basic 3-prong outlet connection, and due to conjecture, there exists no ethical implications. However, PETA, the organization that defends animal cruelty, may be disturbed by the creation of the Meat Smoker as it encourages the feasting upon animal meat. While PETA may be upset with the creation of this meat smoker, consuming meat in itself is not an ethical

dilemma. Meat has been consumed for generations and it's consumption is, therefore, a normal non-ethical part of everyday life.

Health and Safety:

There are few health and safety concerns associated with the design, manufacture or use of the project. There is of course the concern that the Meat Smoker is another form of an oven. Therefore, it is extremely possible that people may burn themselves when using this meat smoker. Also, because this product encourages the consumption of meat, people may choose to eat more than the recommended healthy amount of red meat. Also, the power provided to the Meat Smoker is done using a standard 3-prong AC outlet connection. If the product is mishandled, this high voltage could prove to be a safety concern. However, these few risks are the only health and safety concerns.

Social and Political:

There are not any political issues associated with the design, manufacture and use of this product. However, this project, as previously mentioned, may upset PETA through the encouragement of the consumption of animal meat, which they consider to be morally wrong. However, this is only a small group of people that may become upset even though the Meat Smoker is not breaking any political, ethical, or social laws. This project impacts the general public who enjoy consuming meat, as well as saving themselves the time of smoking meat. This project is not targeted toward any specific stakeholder. It can be claimed the stakeholders are those who consume meat, and the indirect stakeholders are family members of those who consume meat. Also, this project will only benefit stakeholders and will cause no harm to them. This project does not create any inequities and will only encourage a boost in economy as

previously discussed. Each of the resources needed for every use of this smoker is readily available to all in the United States. Almost every grocery store carries meat and liquid and almost every hardware store carries wood chips to be smoked. Also, the Meat Smoker is designed to be user friendly and therefore, special knowledge or skills are not needed to make this Meat Smoker function.

Development:

The most significant new tool I learned throughout the course of this project was my knowledge of LabVIEW and programming with a DAS. These turned out to be extremely effective tools for communicating via interface to control systems and also made programming in a higher level language quite simple. Of course, every program has its drawbacks, but for the most part, I would recommend LabVIEW to others in the future. My research for this project is shown below in the Bibliography.

APPENDIX B- PARTS LIST AND COSTS

Table V: Cost Breakdown of the Meat Smoker

| Components | Prices | Total Number of Components |
|-----------------------------------|---------------|----------------------------|
| Alton-Bradley 24V DC Power Supply | \$ 85.00 ea. | 1 |
| Watson PID Controller | \$ 450.00 ea. | 1 |
| Central Pneumatic Air Compressor | \$ 80.00 ea. | 1 |
| ALCO Actuation Solenoid | \$ 55.00 ea. | 1 |
| ALCO Air Dual Valve | \$ 210.00 ea. | 1 |
| Alton-Bradley Circuit Breaker | \$ 25.00 ea. | 1 |
| Alton-Bradley Contact | \$ 10.00 ea. | 1 |
| Crydom Solid State Relay | \$ 35.00 ea. | 4 |
| National Instruments DAS USB-6008 | \$ 267.00 ea. | 1 |
| Wire Transmitter | \$ 85.00 ea. | 2 |
| Thermocouple | \$ 8.00 ea. | 3 |
| Switch | \$ 12.00 ea. | 3 |
| Button | \$ 12.00 ea. | 3 |
| Metal and Wiring Materials | \$ 600.00 | - |
| Power Outlet for Air Compressor | \$ 6.00 ea. | 1 |
| Light Bulb | \$ 3.00 ea. | 1 |
| Watlow 500W Heater | \$ 45.00 | 2 |
| Total | | \$ 2287.00 |

APPENDIX C- SCHEDULE: TIME ESTIMATES

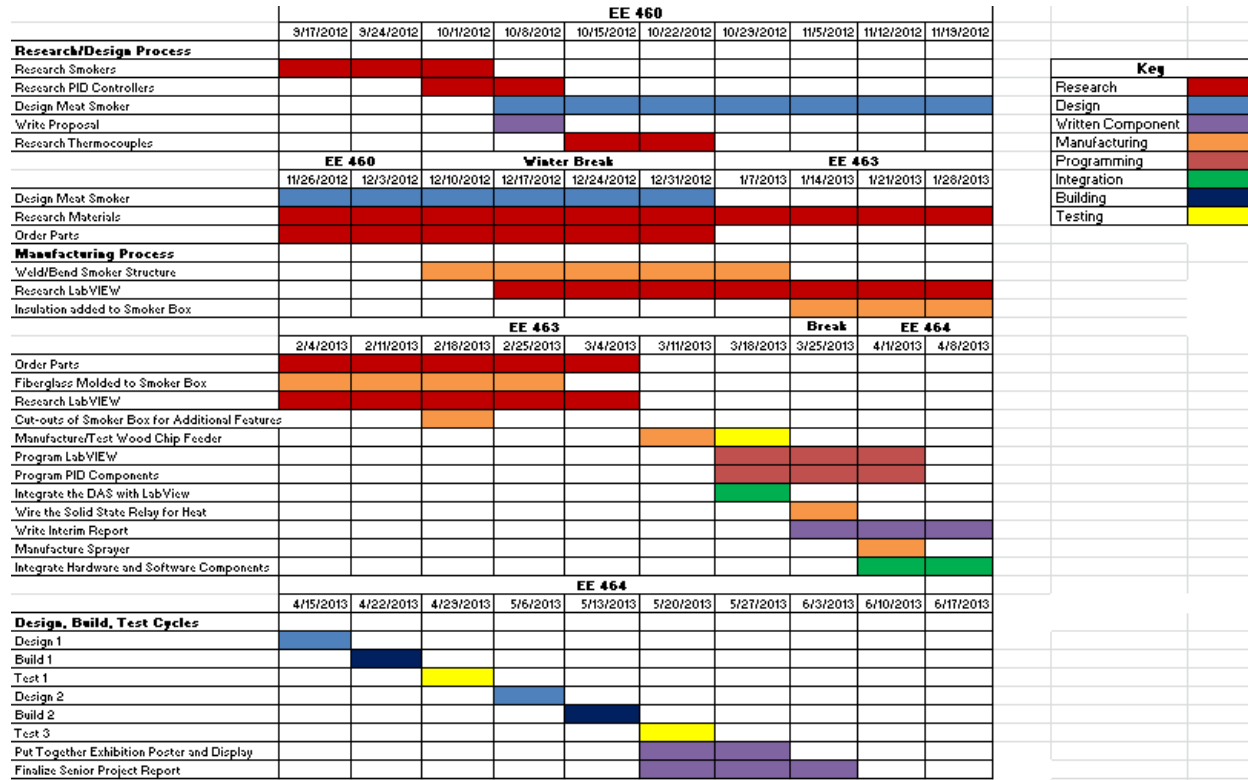


Figure 27: Updated Estimated Schedule

APPENDIX D- WIRING SCHEMATIC

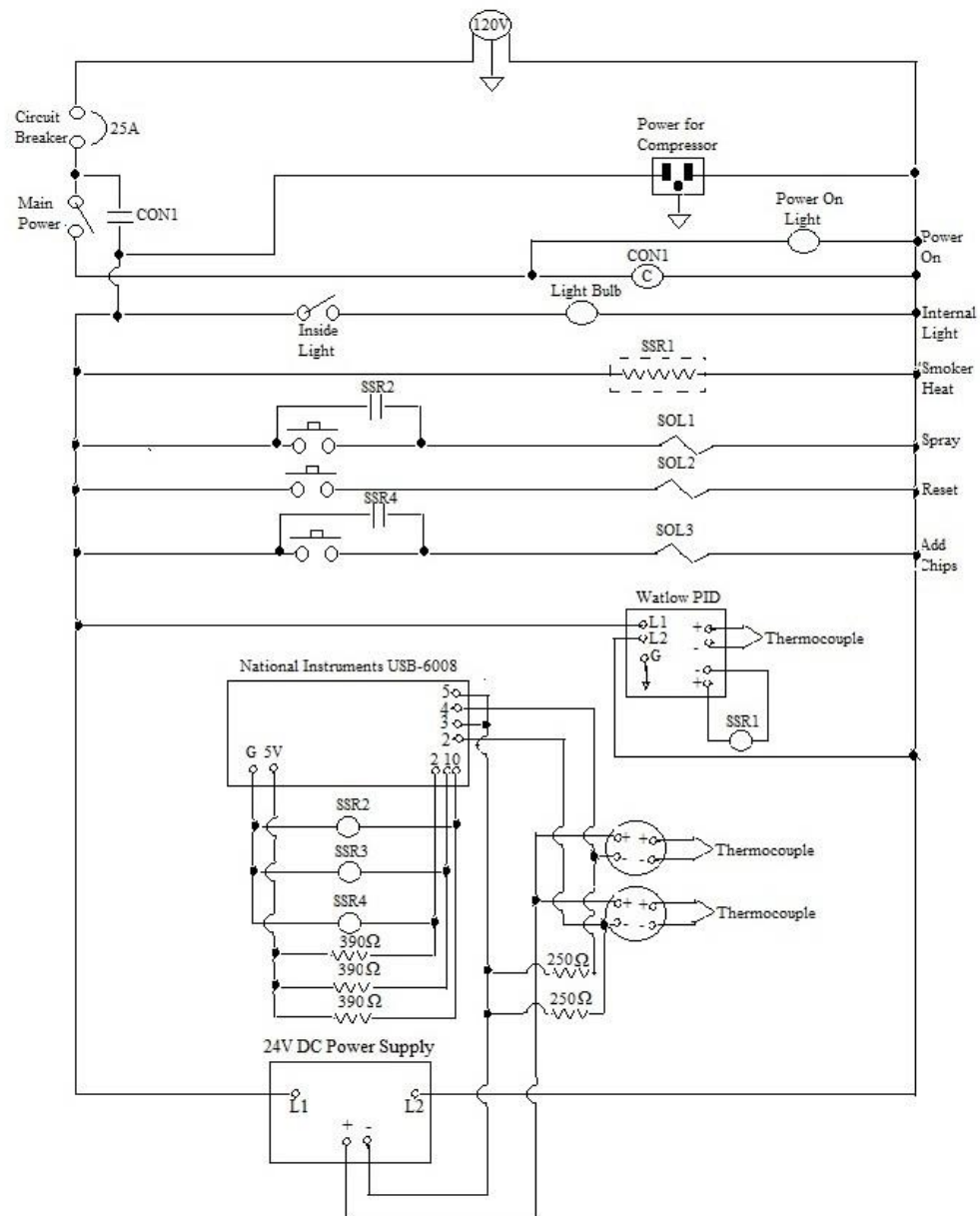


Figure 4: Electrical Wiring Diagram