Barrel Smoker

By

Authors of the Report:

Class of MFG 478-001 Fall 2022

For

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Toward Fulfillment of requirements for the course:

MFG 478 Industrial Organization and Functions

Sections #001

Fall 2022 Semester

December 7, 2022

Section I

Section II

Overview

During this report, our barrel smoker is introduced. This report discusses the development and manufacturing of our product. As a group, we wanted to design and build a smoker that wouldn't break the bank for an average homeowner. The total cost of the project was $425 including the materials needed to make the final product and some of the tools that were not available at first. The cost to manufacture each Barrel smoker was $40 and we plan on selling the smoker for $69.99. The selling price is about 175% more than the manufacturing price for a healthy profit for the company. The cost of our Barrel smoker is significant because of how cheap it is compared to the multi hundred-dollar ones that you can find in the market today while maintaining high end quality. This project consisted of two engineers, one supply chain manager, five machinists/assemblers, and two welders. While the workers specialized in specific divisions, the group worked together to maintain the visions, missions and goals created for the project. This report discusses the original benchmarking plans for the final production of the barrel smokers. Throughout this process we were able to keep track of quality checks and maintain the expectations of our gallon drum smoker.

Vision Statement

We envision a portable smoker to cook delicious meats for small-to-medium sized social gatherings.

Mission Statement

Our mission is to design and build a portable smoker using raw materials of $50 or less. We will construct and report upon the smokers by December 2, 2022.

Product Name

Barrel Smoker

Goals and Objectives

The goals and objectives to produce the Barrel Smoker were as follows:

- Goal 1: As a group, decide on a final design using CAD models based on the group's vision statement and mission statement by October 1st.
    - Objective 1.1: Design engineer produces 3D and 2D models/drawings of final design.
    - Objective 1.2: Make a bill of materials for tools and materials needed to produce the barrel smoker.
    - Objective 1.3: Determine the team members that will confirm the final design matches the vision and mission statements.
- Goal 2: Develop quality requirements, manufacturing plan, and complete all purchase orders by November 10th.
    - Objective 2.1: Determine the team members that specialize in quality.

- Objective 2.2: Determine the team members that produce the manufacturing plan and smoker assembly guide.
- Objective 2.3: Purchase and collect all parts and tools needed for final production.

- Goal 3: The completion of the 11-barrel smokers while staying below out and the final report by December 2nd.
  - Objective 3.1: Finish production and quality checks on final product.
  - Objective 3.2: Determine what team members are working on specific sections of the report.
  - Objective 3.3: Review final report and final barrel smoker.

Organizational chart

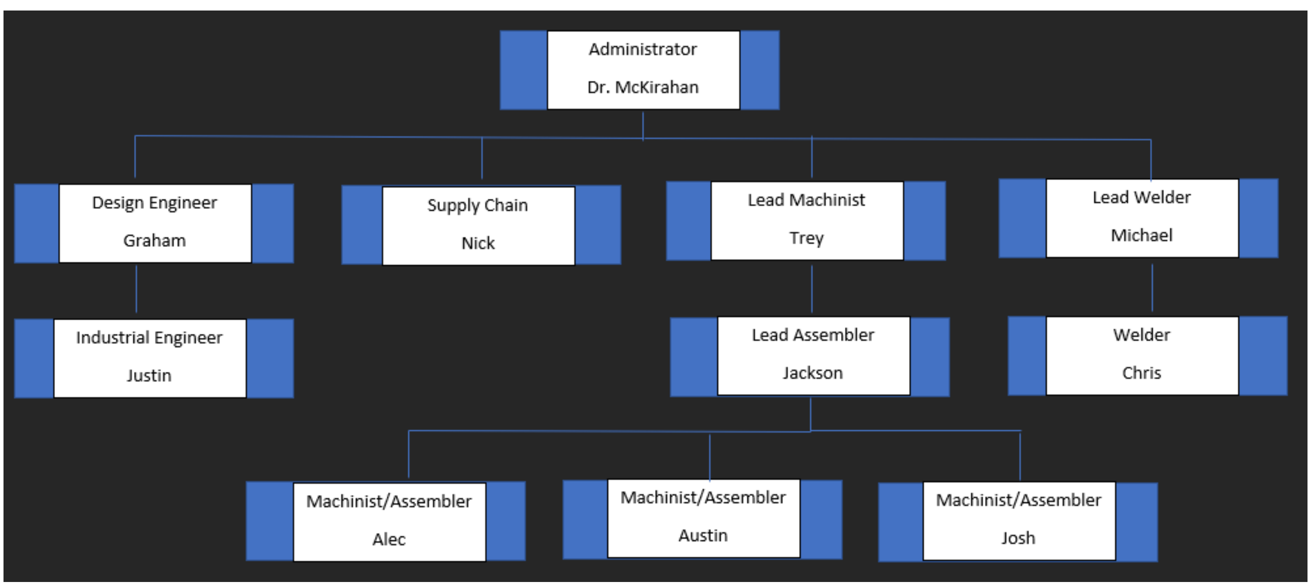


Figure 1: Organizational Chart

During the production of the 55-gallon drum smokers, we had 4 unique divisions: Engineering, Supply Chain, Machinist/Assembler, and Welder. The positions were assigned via the experience someone had in a specific skill. While the machinist/assembler division was the biggest, we had to rely on each other for the success of the project. Nick was the head of the supply chain division and without his ability to obtain the 55-gallon drums we would not have been able to produce the final product. The engineering team would not have been able to work effectively without the communication between the machinist/assembler and the welding division about their knowledge and skillsets. Regardless of the hierarchy, records show members of each division doing smaller projects throughout different divisions. For example, both welders would assist the machinists/assemblers to manufacture the final project. The organizational chart displays supply order and hierarchy to the project but during sections of the project we all worked as one to produce the best smoker on the market.

Product Function

We designed and built our smokers to be cost-effective, material-efficient, and durable by using industrial grade materials and bought items. By incorporating thick handles, welded feet and L-brackets, and bolted thermometers, assembled items should not come lose or move under normal use.

Lid Assembly

Starting from the top, we have the lid, handle, and thermometer assembled to form one piece. This subassembly is lifted vertically from its resting position above the bottom half of the barrel. It seats along a ridge that was changed post-cutting into two. Inside is the grate and smoke plate, resting on four riveted and tack welded L-brackets. This is how the meat will be rested on the grate surface and monitored via the thermometer on the lid.

Below is the bottom half of the barrel, as mentioned previously. It houses the chip chamber that is accessed from a small door on one side. The door has a Z-shaped handle and two hinges, making access simple and easy to clean. A small rotating tab is used to keep the door shut while in use. Finally, the smoking surface area is roughly 530 in^2 and smoking volume is approximately 6,902 in^3 on and above the grate surface, respectively.

Bottom Assembly

Finally, three feet are welded 120° apart, making the final assembly stable on any relatively flat surface.

Feet

How it is Useful

Our smokers give someone on a tighter budget a simple, yet efficient way to smoke any meat. It brings simplicity and functionality together into one product. The handles make lifting and replacing the large upper lids easy to do. The thermometer is placed in such a way that it is easy to see and interpret as well. There is ample space to cook and clean with no obstructions, and easy-to-access ports of entry for both the cooking space and chip storage.

Suggested Sell Price

When selling these smoker barrels, you have to combine the total cost of the labor and the materials used to manufacture the product and then add the standard 170% markup to it to find an accurate sell price. The total labor cost, minimum wage for wages, is $1,196 (10 workers, 16.5 hours worked, 7.25 per hour), and the total cost of the material is $425, for a total of $1,621 dollars for eleven smoker barrels. By dividing the $1,621 by eleven to get the total cost for one barrel and after adding a 70% markup to it, the suggested retail price would be $250.52.

GANTT Chart

The GANTT Chart below takes our overall goals and distributes them into 22 specific objectives, as well as outlines deadlines for which weeks we had planned to complete each item. The first half of the semester was focused on planning, goal-setting, and delegating tasks to each group member. On week 10, we began production on the smokers, which was comprised of a multitude of different jobs. Production finished right before Thanksgiving break on week 14, then the last week was spent finalizing our report and making a presentation. We cut out week 16 of the semester from the chart, as we planned to complete everything by study week.

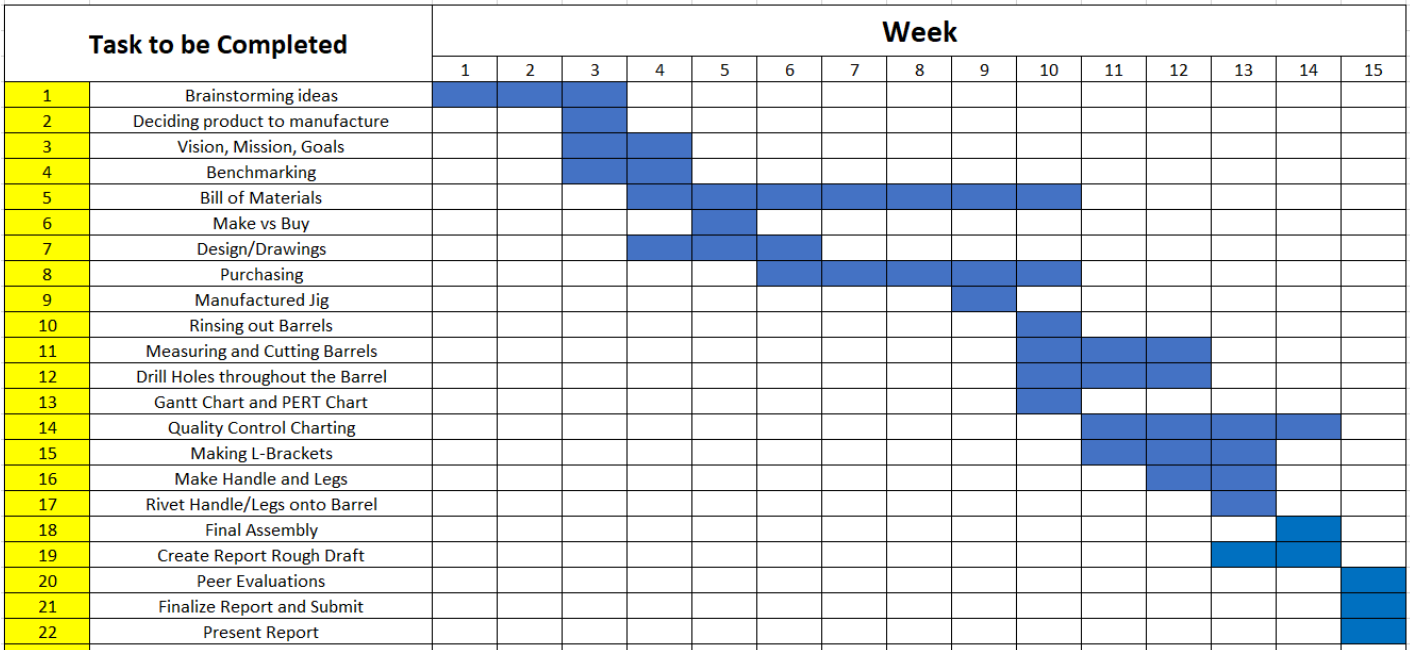


Figure 2: GANTT Chart

Section III

Product Name

Our group's new product is called The Barrel Smoker.

Product Budget

The group was given a budget of $50 a person with an assumed $50 extra if needed, with having 11 members, the maximum total budget was $550. This budget was to be used for the purchase of raw materials, equipment, and parts needed. In total the group spent $425 with 11 smokers built, so the price per product was $38.64. After the production of 11 smokers, the teams' remaining budget was $125. For more detailed information about the budget please refer to the Bill of Materials in section IV.

Benchmarking Ideas

When choosing products to benchmark, they wanted to find smokers that would be good representations of our visualized product. To find this, the benchmarked smokers needed the following components: a thermometer, dimensions around 3’ x 2’, woodchip or charcoal fueled, enough cooking space for a medium-sized cookout, an air vent, meat loading door, fuel loading door, and grease trap. Examples of some products we benchmarked are as follows:

Product Benchmarking Checklist	Wants and Needs in our product? (Charactersitics, Performance, Variables and Attributes)	Competitor 2's Product: Outsunny 20" Mini Small Smoker	Picture of Competitor 1's Product
1	$50	$60	
2	3' height x 2' diameter	19.7" L x 13.8" W x 15.4" H	
3	lightweight	6.6 lbs	
4	portable, on wheels(?)	portable & compact	
5	Handle material	wooden handles	
6	black(?)	black	
7	Body material	steel	
8	woodchip fueled	charcoal fueled	
9	adjustable top air vent	side air vent	
10	sits on ground	elevated	
11	built-in thermometer	1.6" diameter thermometer	
12	cooking space	2 grates (charcoal & cooking)	
13	Cooking grate material (rebar?)		

Dyna-Glo Signature Series Vertical Charcoal Smoker	Picture of Competito 2's Product	Char-Broil® Bullet Charcoal Smoker	Picture of Competitor 3's Product
$189		$151	
26.8 × 23.1 × 44.2 in		21.1"D x 21.75"W x 39.1"H	
73.7 lbs		41 lbs	
Large with wheels		medium-large sized	
Metal handle		dual-carry steel handles	
black powder coat		black, porcelain coated	
steel		steel	
charcoal fueled		charcoal fueled	
adjustible vent on top		adjustable 3 hole bottom vent	
elevated		elevated stand	
'stainless temperature gauge'		lid-mounted temperature guage	
3 grates (681 sq inches)		2 grates(388 sq inches)	
chrome-plated		removable ash and water pan	
		side doorway w/handle	
		top cover/lid w/handle	

Figure 3.1: Group 1 Benchmarking

Product Benchmarking Checklist	Wants and Needs in our product? (Charactersitics, Performance, Variables and Attributes)	Competitor 1's Product	Picture of Competitor 1's Product	Competitor 2's Product	Picture of Competitor 2's Product	Competitor 3's Product	Picture of Competitor 3's Product
1	dimensions	Depth 18.9 in, width 20.8, height 27.8 , 24.9 lb lbs		20.25Dx18.25wx20.25h		H=31.496in W=21.654 D=19.134	
2	grate size	390 square inches		20" round + hooks above		395 sq. inches	
3	Material Used	2 chrome-plated cooking grates, steel for body		steel and stainless steel		2 porcelain coated steel racks. Steel	
4	Portablility?	Doesn't mention anything, no wheels		Disassembled into small parts		Has 3 handles. Under 20lbs	
5	temperature control	Adjustable base and lid dampers. Heat Thermometer		adjustable vent on lid		adjustable vent and built in thermometer	
6	coating/surface treatment	paint		paint		paint	
7	Venting System	Vent holes on the bottom		small adjustable vent on lid		adjustable vent on lid	
8	Price/ Budget	82		$160		$89.99	
9	Loading Method	Top down and from side door		top-down		top-down & side door	
11	Fuel type	Charcoal		charcoal		charcoal	

Figure 3.2: Group 2 Benchmarking

Product Benchmarking Checklist	Wants and Needs in our product? (Charactersitics, Performance, Variables and Attributes)	Competitor 1's Product	Picture of Competitor 1's Product
1	Drum-Like	Drum	
2	25-35 Gal Vol	30 Gal	
3	Black	Stainless Steel Handle	
4	Portable	Charcoal Basket	
5	Enclosable	3-Point Barrel Stand	
6	Grate	Standard Grill Grate	
7	Temp Montering	Steel Hanging Rods	
8	Vent	Wooden Hook Remover	
9	Handle	Porcelain Enamel Coating	
10	Food Safe	Dimensions: 36" Tall x 25" Wide	

Competitor 2's Product	Picture of Competitor 2's Product	Competitor 3's Product	Picture of Competitor 3's Product
21 1/2 Inch Diameter		Two 10-inch wagon wheels allow mobility	
Steel		Airflow control system and a sealed lock help keep in the smoky flavor	
27.5" x 27.5" x 43"		Cooking grate offers 284 square inches of space for smoking	
Freestanding		Product height (in.): 43.3	
Vertical		Product depth (in.): 25.4	
center-mounted 3-inch custom dial thermometer		Fuel type: Charcoal	
100 to 500 degrees		Product weight (lb.): 133	
Removable fire basket holds 8-10 pounds of lump charcoal		Built-in thermometer	
removable caster wheels		Converts into a charcoal grill	
quality paint that can withstand temperatures up to 1000 degrees Fahrenheit		Product weight (lb.): 133	

Figure 3.3: Group 3 Benchmarking

The yellow section is where the group listed the variables that were determined to be most important in finding a smoker like the desired product. After comparing each smokers’ specifications to the group's ideal specifications, the group based their design on the Dyna-Glo Signature Series Vertical Charcoal Smoker, the first one listed in green, and the Big Bad Barrels Smoker, which is the second one listed in green.

Product Benchmarked

The class used this benchmarking process to help visualize what their final product would be. The class split into three groups of three to four people; each group finding three products to benchmark. To be sure that the benchmarked smokers would be useful to the project before the groups split up, some necessary variables were decided upon. The smokers benchmarked needed: to have a way to get a temperature reading, ways to load both food and fuel, an air vent, and the capability to produce enough food for a medium-sized cookout (cooking space). With these needs being set, each group showed their benchmarked products, compared the aspects of each product with the predefined needs and the Dyna-Glo Signature Series Vertical Charcoal Smoker, and the Big Bad Barrel Smoker were the closest options to what was visualized. These chosen smokers to imitate and the ideas that were generated from them are shown below:

Dyna-Glo Signature Series Vertical Charcoal Smoker	Picture of Competitor 2's Product
$189	
26.8 × 23.1 × 44.2 in	
73.7 lbs	
Large with wheels	
Metal handle	
black powder coat	
steel	
charcoal fueled	
adjustible vent on top	
elevated	
"stainless temperature gauge"	
3 grates (681 sq inches)	
chrome-plated	

Competitor 2's Product	Picture of Competitor 2' Product
20.25Dx18.25wx20.25h	
20" round + hooks above	
steel and stainless steel	
Disassembled into small parts	
adjustable vent on lid	
paint	
small adjustable vent on lid	
$160	
top-down	
charcoal	

Figure 4: Product Benchmarked

The team decided to use both smokers as both had aspects we wanted to replicate. They liked the wheel and handle design of the dynamic-glo smoker; this design would allow the large smoker to remain portable, although it was decided to make it stationary later on. They also liked the top loading feature of the big bad barrel smoker and decided this design would be the best way to load the 55-gallon drum smoker.

Mechanical Properties

With the team's product being a smoker that needs to cook at high temperatures the main property they focused on was heat resistance. The material the team used needed to be able to withstand temperatures up to 500 ^{o}F. The group decided to go with carbon steel tight head 55-gallon drums. The barrels use carbon steel that has a melting point of 2600 ^{o}F. Since the material of the barrel was well over the required heat resistance, the group used extra barrels to create the fuel loading door and smoke plate that required the same heat resistance. The team also needed to find a grate with just as much heat resistance and landed on a porcelain-coated carbon steel grate, the melting point of the carbon steel being 2600 ^{o}F and the melting point of porcelain being 3725^{o}F. Also, due to the high temperatures of a running smoker, we needed to elevate the smoker to prevent the bottom of the barrel from scorching the ground. To do this we welded three feet to the bottom of our smoker, elevating it 2.5 inches. However, we recommend keeping it on a concrete platform or a similar non-flammable material. Also, be aware that during use the body, handles, and fuel port are likely to be extremely hot.

PERT Chart

The PERT Chart below references the GANTT chart previously displayed. It takes all tasks in the GANTT chart and visualizes the order in which they were completed, portraying a variety of different paths that can be taken when executing this project. The numbers on the arrows in between represent how many class periods we spent completing each specific task. The critical path is the shortest possible path through the PERT chart that can be taken. It is highlighted in red and sums up to 31 class meetings. While this is about the length of a full semester at over 15 weeks, in many cases, multiple jobs were completed simultaneously as the responsibilities were delegated to different class members.

We started with the brainstorming process at step 1, for which we generated several ideas and finally decided on a product to manufacture (2). From there, we were ready to both start benchmarking other products (4) and determine our vision, mission, and goals (3). After choosing a product to benchmark, we began to plan our specific design, which required creating a bill of materials (5) that included a make vs buy determination (6). After deciding the necessary parts, it was time to make designs and illustrate drawings (7). From there, some students worked on purchasing (8) while others manufactured a jig to use for cutting the barrels (9).

At this point, we were finally ready to commence production. After rinsing out the barrels (10), we measured and cut the tops off using an angle grinder (11), and then drilled holes through the barrels (12). From here, the class split up to complete different tasks simultaneously. We had to create GANTT and PERT charts (13) to schedule our timeline, while continuing production by using scrap metal to make L-brackets (15), handles, and legs (16) for the smokers. Once the handles, legs, and brackets were finished, we used rivets to attach them to the product (17). Finally, once everything was ready, we put everything together in a final assembly (18). Now that production was finished, we could make measurements for quality control charting (14), as well as starting the paper rough draft (19). Then, we finalized the report, made our final edits, and submitted it (21), while completing peer evaluations during the same week (20). The final step was to present the report, completing our project for good (22).

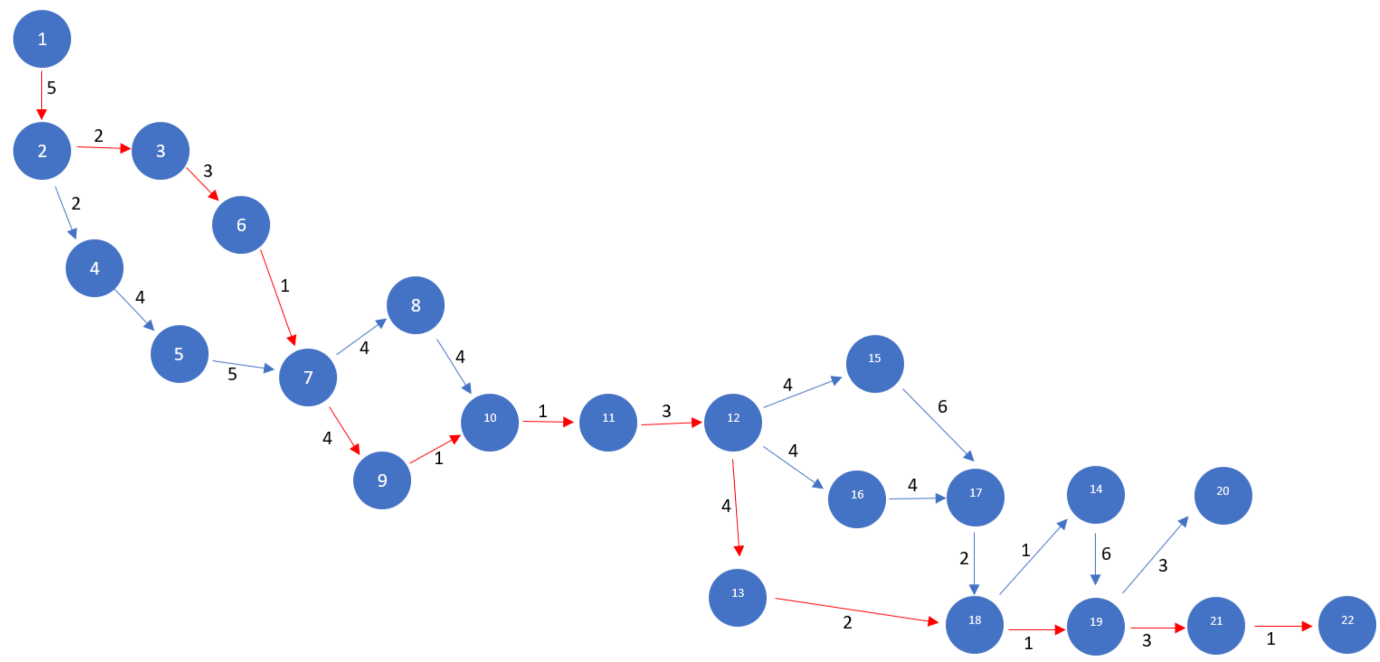


Figure 5: PERT Chart

Section IV

Engineering Model

The engineering model we used for the smoker drum is the concurrent model. The reasoning it's concurrent and not traditional is because our plan(s) on how we were going to fabricate parts changed once we found that the current method(s) were talking too much time and less efficient compared to other methods. One example of this during our project would be that initially we were going to try, and angle grind the tops and bottoms off the spare drums for the smoke plates. However, after we used the angle grinder to cut the barrels during our first step, we realized how slow that process was and decided we had to find another method when it came to cutting through the steel on the barrel. The solution we ended with was using the plasma cutter due to the amount of time saved and we were also able to save some of the cutting wheels by switching processes.

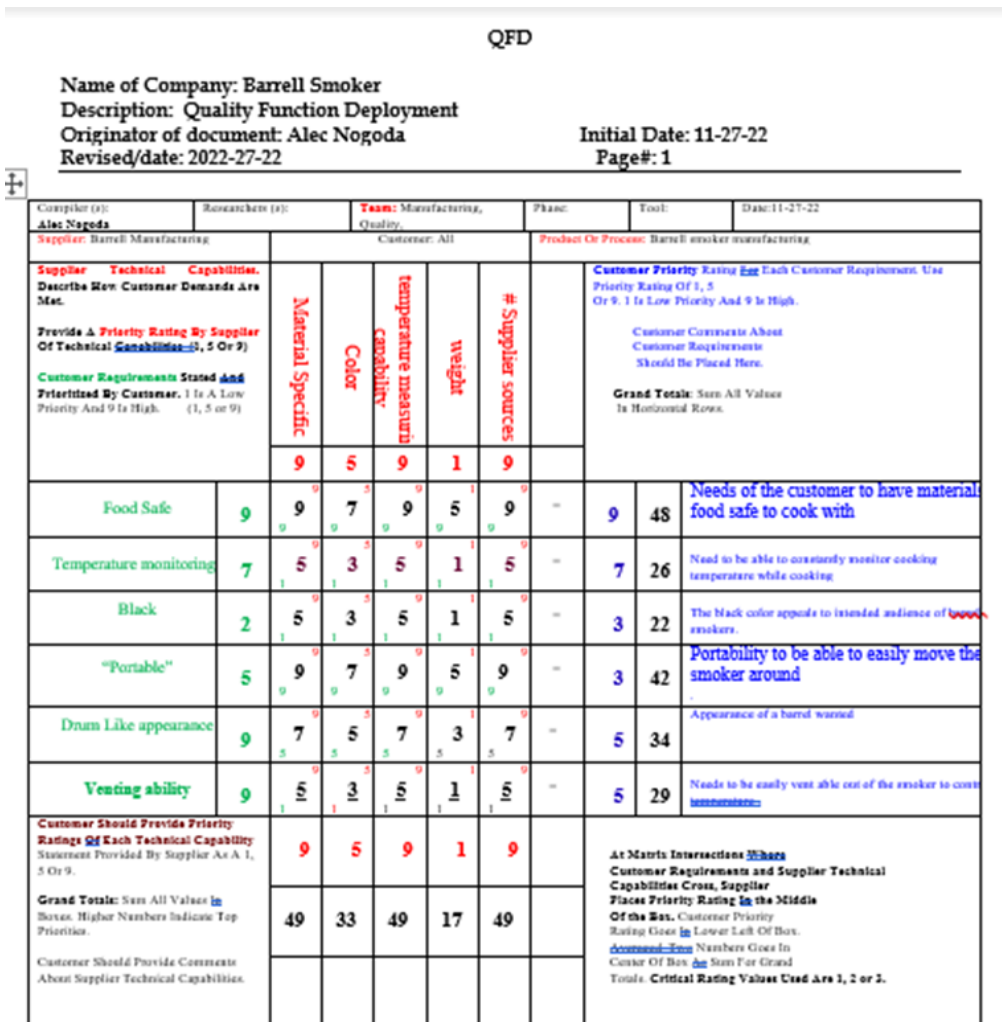
Product Function

Our product is designed to work and function like a normal store-bought smoker, allowing the consumer to cook food at a lower temperature for a longer amount of time and to allow for the food to acquire a smokey flavor. On the top section of our product there is a thermometer which allows the consumer to view if the internal temperature is accurate to what it needs to be for the food to be sufficiently cooked. Additionally, there is a handle, made from ¼'' steel, allowing the consumer to put food into the drum to be cook as well as to retrieve it out after it has been thoroughly cooked. Inside the drum there is a 21" grill grate allowing for 350 square inches of cooking surface area, and below the grate is our smoke plate, which is made from the tops and bottoms of scrap barrels, which slows the heat from reaching the cooking surface. At the base of the drum there is a fuel door, made from the scrap barrels, and latch, made from the ¼'' steel, which allows for fuel (charcoal, pellets, wood) to be inserted into the bottom. On the base of our product, we have 3 feet made of ¼'' steel 120° apart from which makes it so the base doesn't scorch the ground underneath it.

QFD Model

QFD stands for Quality Functional Deployment. This is where the customer's voice is used to manufacture a product to service all a customer's needs and wants. This method is used to create a product to fulfill the needs of the niche customer market defined by the customer's wants. This Model uses the House of Quality Matrix in three matrices look at customer needs, requirements, and the requirements defined by the process and technical aspects. The first matrices look at the Nees and wants of the customer through reviews interviews and surveys to get a better idea of the customer's needs. The second matrices are used to look at the actions required by the design and requirements of the product meaning the product specification and characteristics. The third matrices are used to develop the quality specifications to regulate the quality of the product and the needs of the production process. These are used to create measurable features in each matrix. The following is the usage of these matrices against competing products to gage the ability of our product to fulfill the desires of the customers and keep the quality acceptable.

QFD Chart



QFD

Name of Company: Barrell Smoker
Description: Quality Function Deployment
Originator of document: Alec Nogoda Initial Date: 11-27-22
Revised/date: 2022-27-22 Page#: 1

Compiler (s): Alec Nogoda | Researchers (s): | Team: Manufacturing, Quality. | Phase: | Tool: | Date: 11-27-22

Supplier: Barrell Manufacturing | Customer: All | Product Or Process: Barrell smoker manufacturing

Supplier Technical Capabilities. Describe How Customer Demands Are Met. Provide A Priority Rating By Supplier Of Technical Capabilities (1, 5 Or 9). Customer Requirements Stated And Prioritized By Customer. 1 Is A Low Priority And 9 Is High. (1, 5 or 9)

Customer Priority Rating For Each Customer Requirement. Use Priority Rating Of 1, 5 Or 9. 1 Is Low Priority And 9 Is High. Customer Comments About Customer Requirements Should Be Placed Here. Grand Totals: Sum All Values In Horizontal Rows.

		Material Specific	Color	temperature measuring capability	weight	# Supplier sources				
		9	5	9	1	9				
Food Safe	9	9	7	9	5	9	-	9	48	Needs of the customer to have materials food safe to cook with
Temperature monitoring	7	5	3	5	1	5	-	7	26	Need to be able to constantly monitor cooking temperature while cooking
Black	2	5	3	5	1	5	-	3	22	The black color appeals to intended audience of barrel smokers.
"Portable"	5	9	7	9	5	9	-	3	42	Portability to be able to easily move the smoker around
Drum Like appearance	9	7	5	7	3	7	-	5	34	Appearance of a barrel wanted
Venting ability	9	5	3	5	1	5	-	5	29	Needs to be easily vent able out of the smoker to cont temperature.
Customer Should Provide Priority Ratings Of Each Technical Capability Statement Provided By Supplier As A 1, 5 Or 9.		9	5	9	1	9				At Matrix Intersections Where Customer Requirements and Supplier Technical Capabilities Cross, Supplier Places Priority Rating In the Middle Of the Box. Customer Priority Rating Goes In Lower Left Of Box. Accumed Tree Numbers Goes In Center Of Box As Sum For Grand Totals. Critical Rating Values Used Are 1, 2 or 3.
Grand Totals: Sum All Values In Boxes. Higher Numbers Indicate Top Priorities. Customer Should Provide Comments About Supplier Technical Capabilities.		49	33	49	17	49				

Figure 6: Quality Functional Deployment

The chart above shows the QFD's most important requirements of smokers. The most important needs of the customer come down to the ability of the product to be food safe and the measurability of the internal temperature of the smoker. This helps to prioritize the manufacturing process and quality department to make economical and strategical choices during the manufacturing and marketing process. Through the QFD process it was found that the most important things to the customer are their safety, portability, and functionality of the smoker. Using these as key factors to Make our smoker the best fit for the market of customers we intend to seek. This will make our product more likely to be chosen over competitors' products.

Make vs Buy Chart

Item Name	Make vs Buy	Units	Cost	Cost per unit
55 Gallon Drum	Buy	17	170	10
Smoke Plate	Make	11	0	0
Lid Handle	Make	11	0	0
L Brackets	Make	44	0	0
Feet	Make	44	0	0
Fuel Door	Make	11	0	0
Fuel Door Latch	Make	11	0	0
Fuel Door Hinges	Buy	24	14	7

Thermometer 2 Pack	Buy	12	10.59	64
Grill Grate	Buy	11	13.34	147
1/8" x 3/8" Rivet Pack	Buy	1	2.22	2.22
1/4" x 1/2" Rivet Pack	Buy	1	8	8

Figure 7: Make vs Buy

The “Make vs Buy Chart” above provides a detailed listing of the components in this product. Seventeen drums were purchased, with eleven converted into functional smokers while the remaining 6 were used to manufacture parts for use in the drums converted into smokers. Those parts being the smoke plates and fuel doors. We were able to obtain ¼” steel plate from Grate Dane for free which allowed us to manufacture many of our components rather than buy them. The parts we were able to manufacture from the ¼" steel include the L brackets, fuel door latch, lid handle, and feet. We made those 4 parts by utilizing many manufacturing methods (bending, cutting, grinding, drilling). We purchased 2 sets of rivets, 1/8" x 3/8" and 1/4" x 1/2" to hold the L brackets, fuel door, and handles onto the drum. Also, we purchased six two packs of thermometers to get an accurate reading of the temperature inside of the drum to ensure there is enough heat for the food inside to cook. We also purchased eleven sets of two hinges to secure the fuel door to the drum. On top of that we also decided to buy grill grates rather than manufacturing our own due to the amount of manufacturing that would be required vs the cost of buying them.

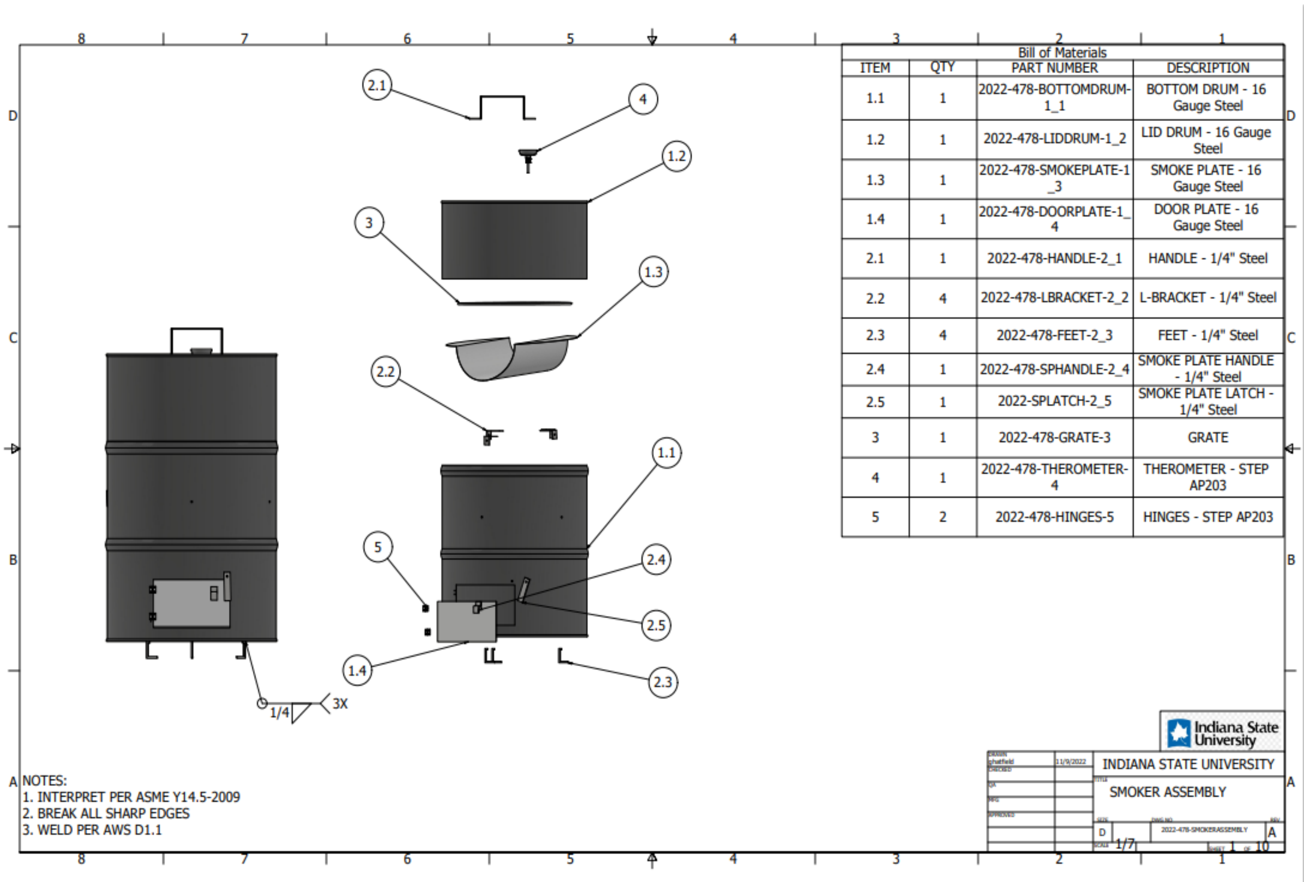
Bill of Materials/Parts List

Part Number	MFR PN/LINK	Description	Make vs. Buy	Material	Supplier	Quantity	Unit Price	Total Price
		Final Assembly	Make					$0
1	Link	55 Gallon Drum	Buy	16 Gauge Steel	Karen Shank-Kinney	17	$10.00	$170
2022-478-BOTTOMDRUM-1.1		55 Gallon Drum - Bottom	Make	16 Guage Steel	Karen Shank-Kinney	11	$0.00	$0
2022-478-LIDDRUM-1.2		55 Gallon Drum - Lid	Make	16 Gauge Steel	Karen Shank-Kinney	11	$0.00	$0
2022-478-SMOKEPLATE-1.3		Smoke Plate	Make	16 Gauge Steel	Karen Shank-Kinney	11	$0.00	$0
2022-478-DOORPLATE-1.4		12" x 7" Smoke Door Plate	Make	16 Gauge Steel	Karen Shank-Kinney	11	$0.00	$0
2		Steel Scrap	Buy	1/4" Steel	Great Dane		$0.00	$0
2022-478-HANDLE-2.1		Handle	Make	1/4" Steel	Great Dane	11	$0.00	$0
2022-478-LBRACKET-2.2		L-Bracket	Make	1/4" Steel	Great Dane	44	$0.00	$0
2022-478-FEET-2.3		Feet	Make	1/4" Steel	Great Dane	44	$0.00	$0
2022-478-SPHANDLE-2.4		Smoke Plate Handle	Make	1/4" Steel	Great Dane	11	$0.00	$0
2022-478-SPLATCH-2.5		Smoke Plate Latch	Make	1/4" Steel	Great Dane	11	$0.00	$0
2022-478-GRATE-3	Link	Grate	Buy	Purch	Char-Broil (Menards)	11	$13.34	$147
2022-478-THEROMETER-4	Link	BBQ Thermometer (2 pack)	Buy	Purch	YOTOM (Amazon)	6	$10.59	$64
2022-478-HINGES-5	Link	Jersvimc 12Pcs 1in Hinge	Buy	Purch	Jersvimc (Amazon)	2	$6.99	$14
6								
7	Link	1/8" x 3/8" Rivets	Buy	Purch	Sontax (Menards)	1	$2.22	$2
8	Link	1/4" x 1/2" Rivets	Buy	Purch	Grip Fast (Menards)	1	$8.00	$8
9	Link	Cutting Wheels	Buy	Purch	Performax (Menards)	20	$1.01	$20
								$0
Assembly Final		(max cost)				11	$50	$550
Total Cost								$425
Remaining Budget								$125

Figure 8: Bill of Materials/Parts List

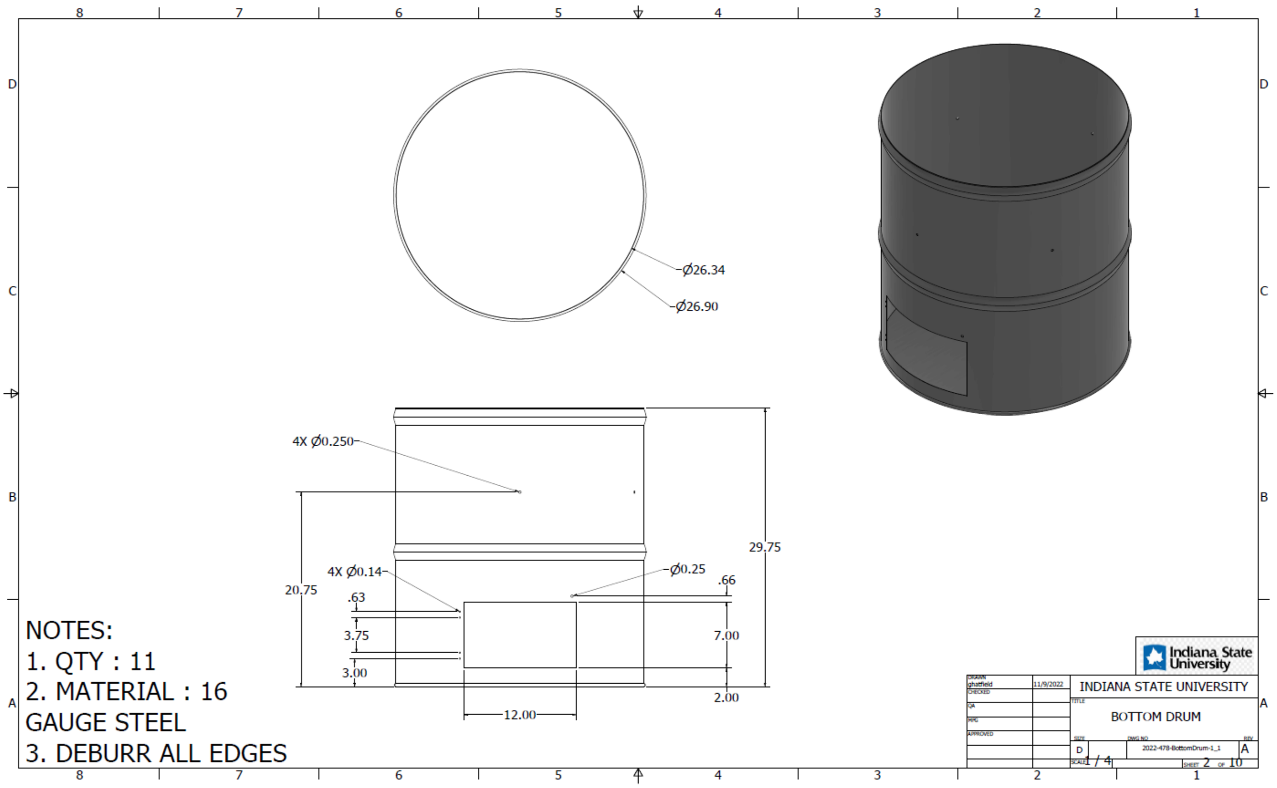
Isometric and Multiview Drawings

The engineering drawings provided below are each manufactured parts for the assembly of the Smoker. All the drawings were precisely hand-machined and assembled for the final product. The bill of materials shows whether a part was made in the shop by our welders/ machinist or was bought online. The parts that we were able to make in house were either bought from Karen Shank-Kinney or was gifted by Great Dane including the 55-gallon drums and 3 scrap sheets of ¼" mild steel. The 55-gallon drum smoker consists of nine manufactured parts and three pre-made parts that we outsourced for constant quality. The first drawing listed is the final assembly drawing and the exploded view of the smoker. The drawings of the individual parts of the smoker are displayed after the smoker assembly/exploded view drawing.



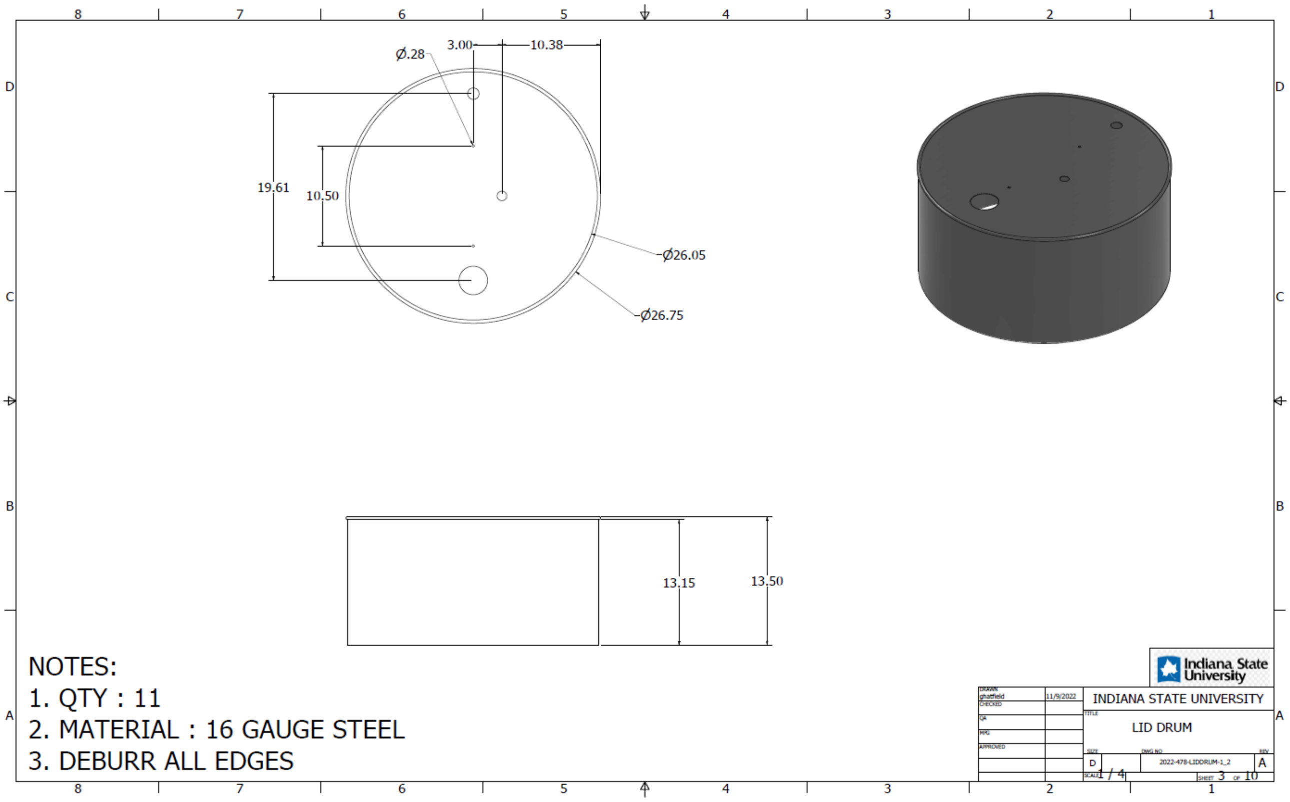
Drawing 1: Smoker Assembly Drawing

In drawing 1: Smoker Assembly Drawing, the final assembly of the smoker along with the exploded view is shown. The Barrel Smoker assembly consists of 12 unique parts including 9 parts that we manufactured from various types of scrap metal from Great Dane and extra 55-gallon drums that we purchased.



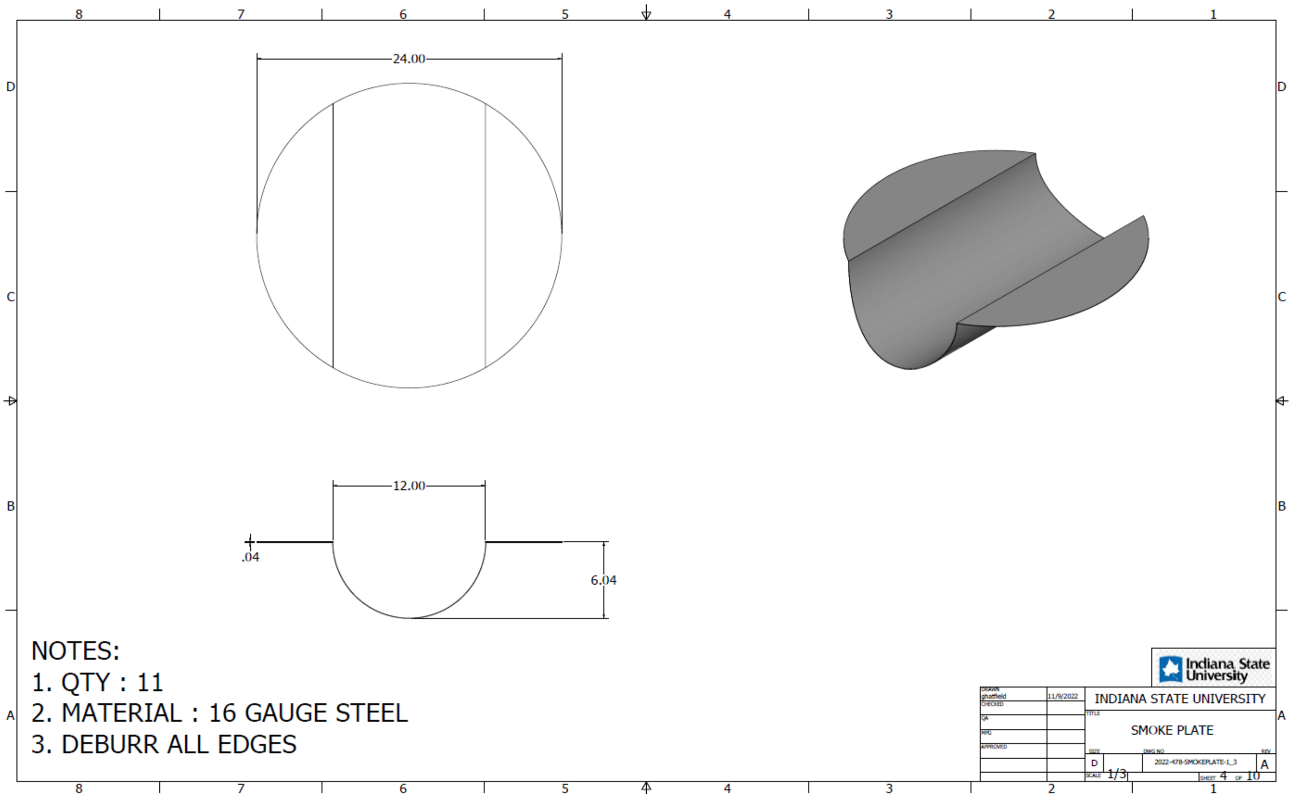
Drawing 2: Bottom Drum Drawing

In drawings 2: Bottom Drum, corresponds with part number 2022-478-BOTTOMDRUM-1_1. Per unit, the Bottom Drum has a quantity of 1 making it the main structure of the total assembly. We started the manufacturing of the Bottom Drum with a typical 43.34" tall 55-gallon drum. We cut the 55-gallon drum slightly above the tallest rib of the drum for plenty of room for 2022-478-GRATE-5, and 2022-478-SMOKEPLATE-1_3. The total height of the Bottom Drum is 29.75 inches while the outside diameter is 26.90 inches across. The bottom drum is made of 16-gauge steel (0.063" thick). We used an acetylene torch to cut out a 12"x7" rectangle for an opening to apply or take out fuel for the smoker. The opening is going to be opened and close with the help of part 2022-478-DOORPLATE-1_4, 2022-478-HINGES-5, AND 2022-478-SPLATCH-2_5. There were 4 holes that are 0.25" in diameter that we drilled 20.75" from the bottom of the bottom drum for riveting the 2022-478-LBRACKET-2_2 on the inside of the bottom drum.



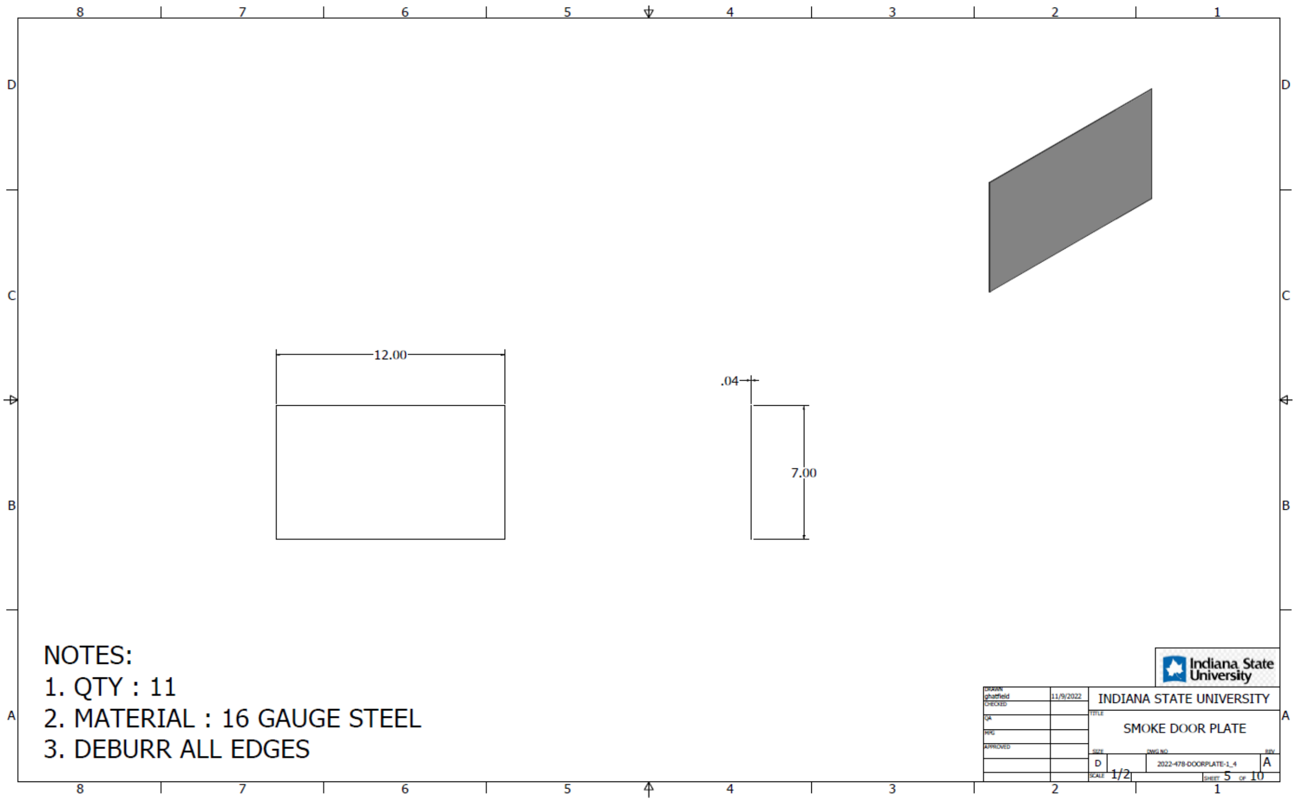
Drawing 3: Lid Drum Drawing

In drawing 3: Lid Drum, corresponds with part number 2022-478-LIDDRUM-1_2. Per unit the Lid Drum has a quantity of 1 making it the cover for the parts that are located inside of the Bottom Drum. The Lid Drum also is the result of the 55-gallon drum being cut, because the Lid Drum is from the original 55-gallon drum, the thickness of the Lid Drum is 16-gauge steel (0.063" thick). The Lid Drum has 3 additional holes drilled in for the riveting of 2022-478-HANDLE-2_1 AND 2022-478-THERMOMETER-4. The overall height of the Lid Drum is 13.59" and the outside diameter is 26.90. The diameter of the Bottom Drum and Lid Drum is the same for easy lift off and placement.



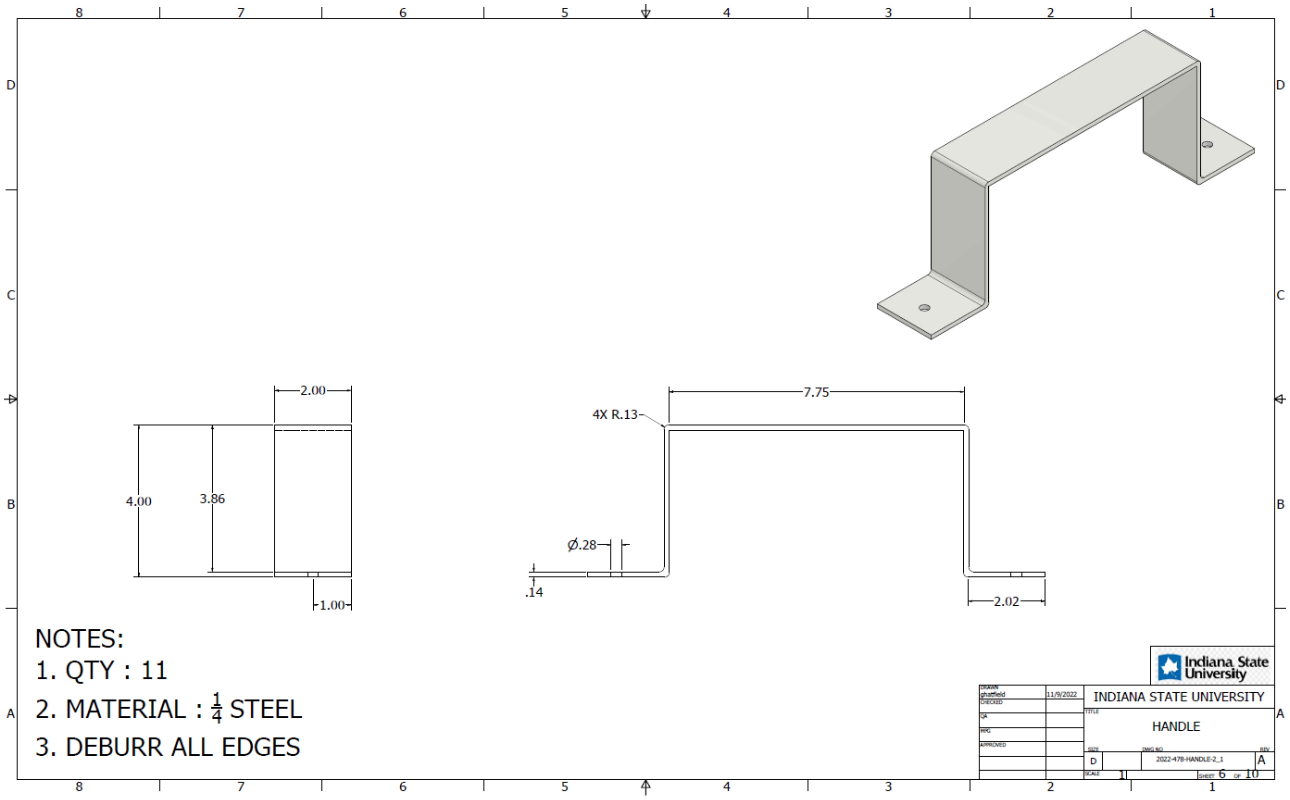
Drawing 4: Smoke Plate Drawing

In drawing 4: Smoke Plate, corresponds with part number 2022-478-SMOKERPLATE1-_4. Per unit the Smoke Plate has a quantity of 1 making it the Seperator between the fuel and 2022-478-GRATE-3. The Smoke Plate is made from the extra 55-gallon drums that we purchased. Using the piranha press we were able to make the bends to provide a section for the oil and grease to land without going into contact with the flame. The Smoke Plate will be placed inside of the Bottom Drum and will be stationary with the help of 2022-478-LBRACKET-2_2. The overall diameter of the Smoke Plate is 24" across and has a height of 6.04" to maintain the original purpose of the Smoke Plate of blocking the flame and only letting smoke having contact with whatever food is on 2022-478-GRATE-3.



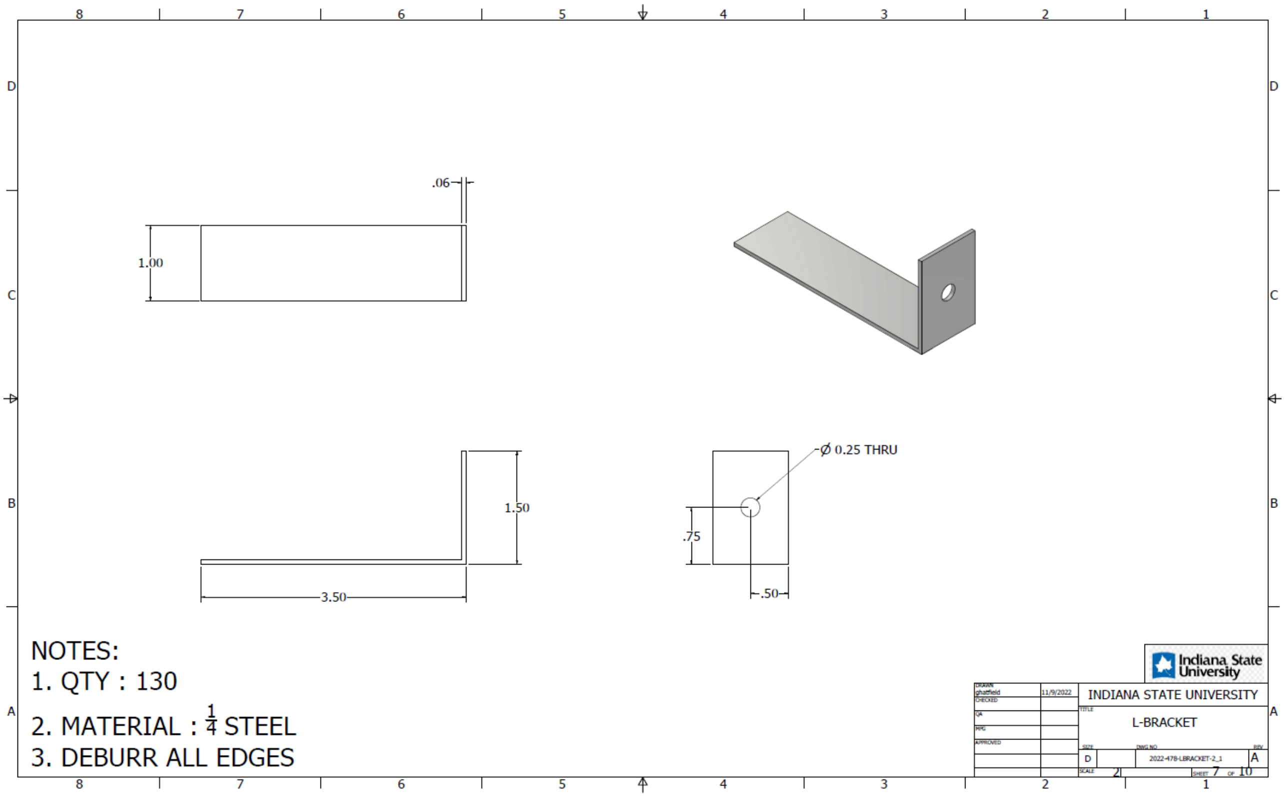
Drawing 5: Smoke Door Plate Drawing

In drawing 5: Smoke Door Plate, corresponds with 2022-478-DOORPLATE-1_4. Per unit the Door Plate has a quantity of 1 making it correspond with the 12”x7” rectangular cut out at the bottom of the Bottom Drum. The Smoke Plate will be paired with 2022-478-HINGES-5 and 2022-478-SPLATCH-2_5 to have the ability to open and close for access of oxygen into the Barrel Smoker and access to adding or removing fuel. The Smoke Plate was also manufactured from the extra 55-gallon drums that were bought for extra scrap material. The Smoke Plate has simple dimensions of 12”x7”x0.4” for a lightweight but sturdy door.



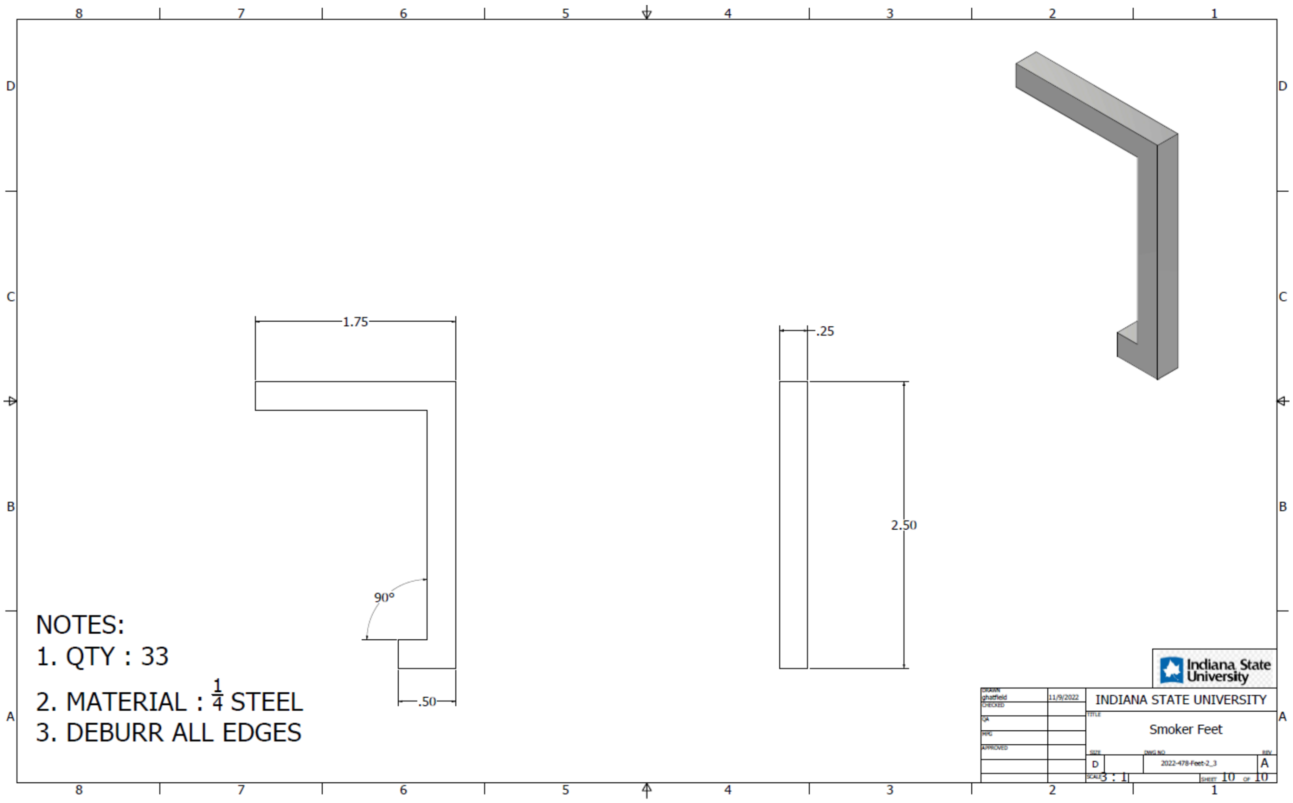
Drawing 6: Handle Drawing

In drawing 6: Handle, corresponds with 2022-478-HANDLE-2_1. Per unit the Handle has a quantity of 1 making it the best way to lift the Lid Drum up for access to the inside of the Bottom Drum. The Handle was made from the scrap ¼" steel that was obtained from Great Dane. The Handle was manufactured by using the TorchMate and then using the piranha press the shape of the handle was formed. The Handle has 2 (¼") holes that is used to rivet the Handle to the Lid Drum. The location where someone would place their hand is 7.75” long and 0.14” thick to provide a good grip.



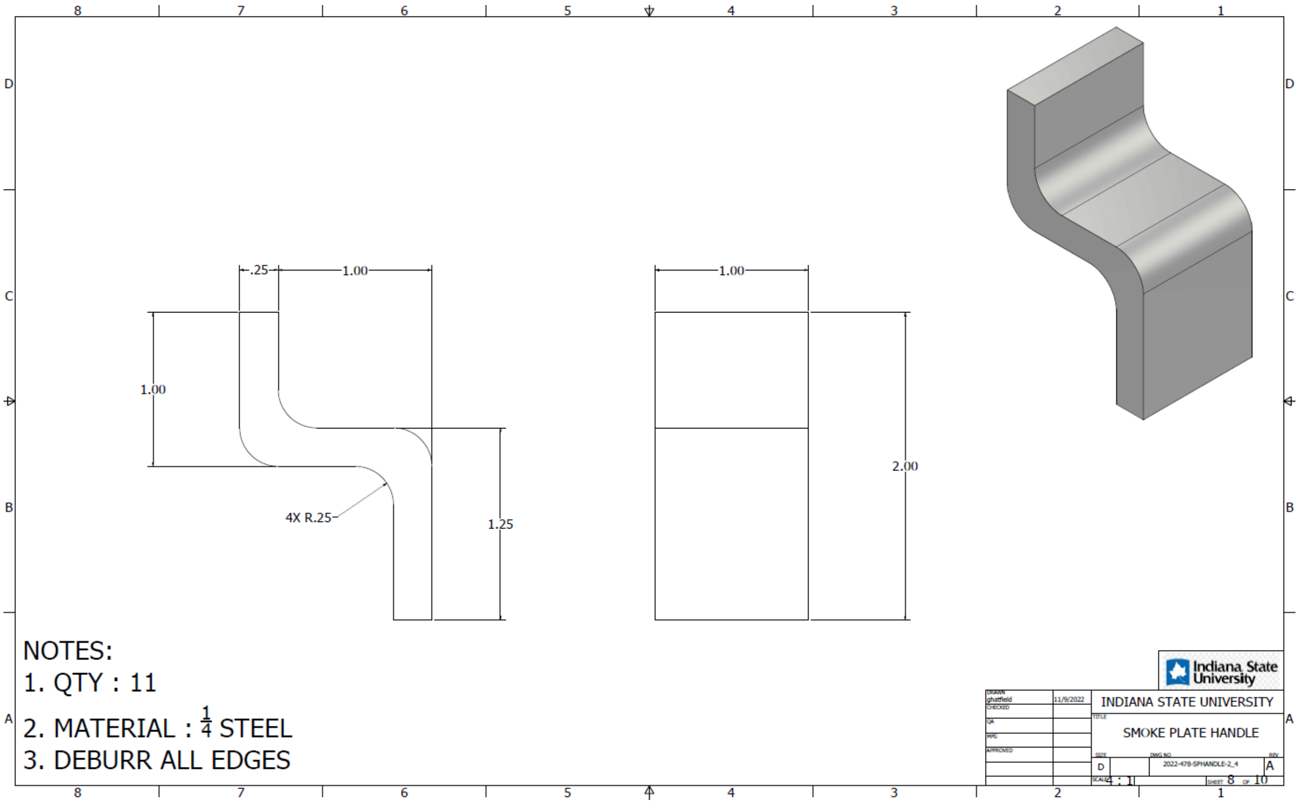
Drawing 7: L-Bracket Drawing

In drawing 7, L-Bracket, corresponds with 2022-478-LBracket-2_2. Per unit the L-Bracket has a quantity of 4 making it the placement for 2022-478-SMOKEPLATE-1_4 and 2022-478-GRATE-3. The L-Bracket was originally from scrap metal provided by Great Dane and was cut into shape by the TorchMate and bent to get specific measurements needed. The L-Bracket is located inside of the Bottom Drum and is riveted using the 0.25” diameter hole that was drilled into the 1.50” section of the L-Bracket.



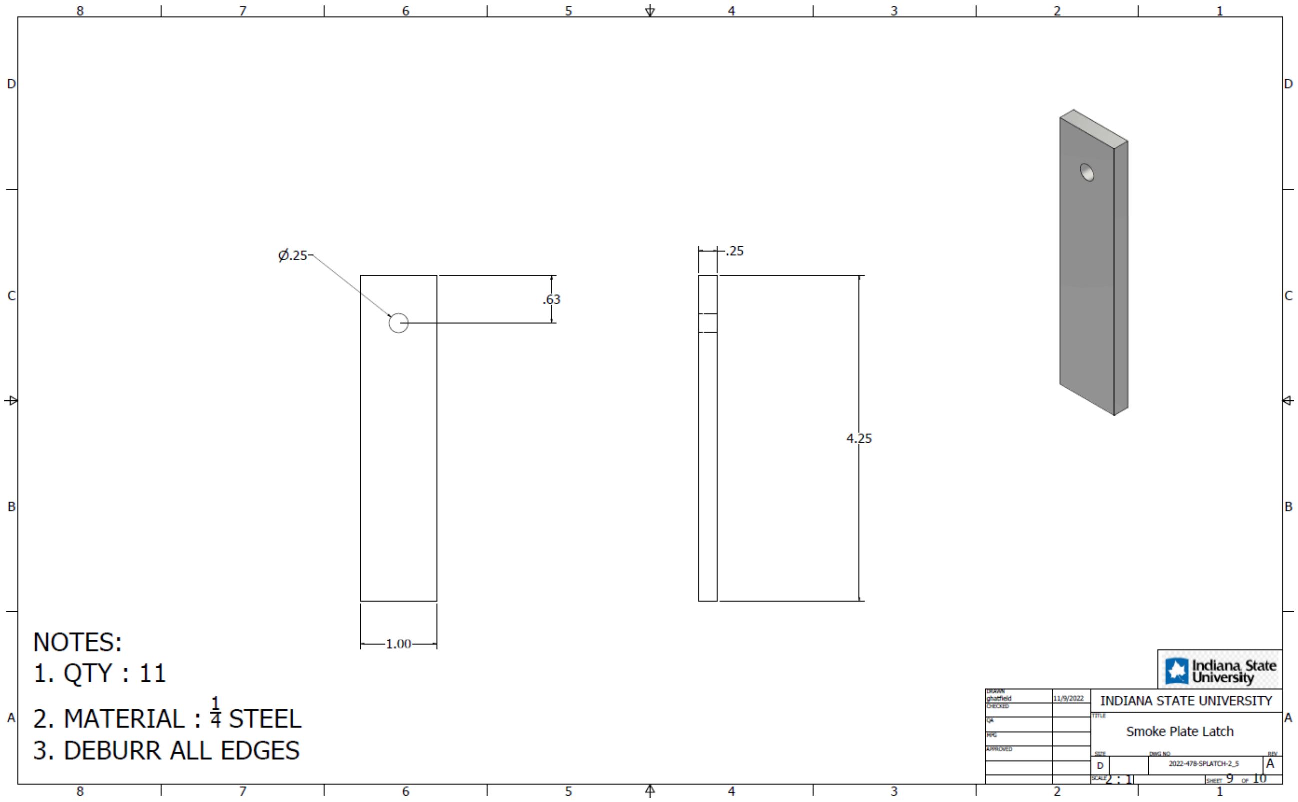
Drawing 8: Smoker Feet Drawing

In Drawing 8: Smoker Feet, corresponds with 2022-478-FEET-2_3. Per unit the Smoker Feet has a quantity of 4 making the Bottom Drum not touch the ground. Also, the Feet has a lifted design so a person cooking wouldn't have to bend over as much. This design improves the overall heigh of the Barrel Smoker by 2.50" and having a 0.75" thickness to the feet wouldn't break or bend because of the weight of the Barrel. The Feet was originally from scrap metal provided by Great Dane and was cut into shape by the TorchMate and bent to get specific measurements needed.



Drawing 9: Smoke Plate Handle Drawing

In Drawing 9: Smoke Plate Handle, corresponds to 2022-478-SPHANDLE-2_4. Per unit the Smoke Plate Handle has a quantity of 1 making the Smoke Plate have a handle for an easier way to open and close the Smoke Plate. The Smoke Plate Handle was originally from scrap metal provided by Great Dane and was cut into shape by the TorchMate and bent to get specific measurements needed. The dimensions were selected to make sure that the operator of the smoker can open and close the Smoke Door without issue but to not make it bulky, so the operator does not hit his/her shin on the Smoke Plate Handle.



Drawing 10: Smoke Plate Latch Drawing

In drawing 10: Smoke Plate Latch, corresponds to 2022-478-SPLATCH-2_5. Per unit the Smoke Plate Latch has a quantity of 1 making it the locking mechanism for the Smoke Plate. The design of the Smoke Plate Latch is a simple 4.25”x2”x0.25” rectangle that is riveted to the outside of the Bottom Drum. The single rivet holes give the Smoke Plate Latch the ability to rotate around to lock and unlock the Smoke Plate. The Smoke Plate Handle was originally from scrap metal provided by Great Dane and was cut into shape by the TorchMate and then drilled a ¼" hole for the ability for the rivet.

Section V

Organizational Chart

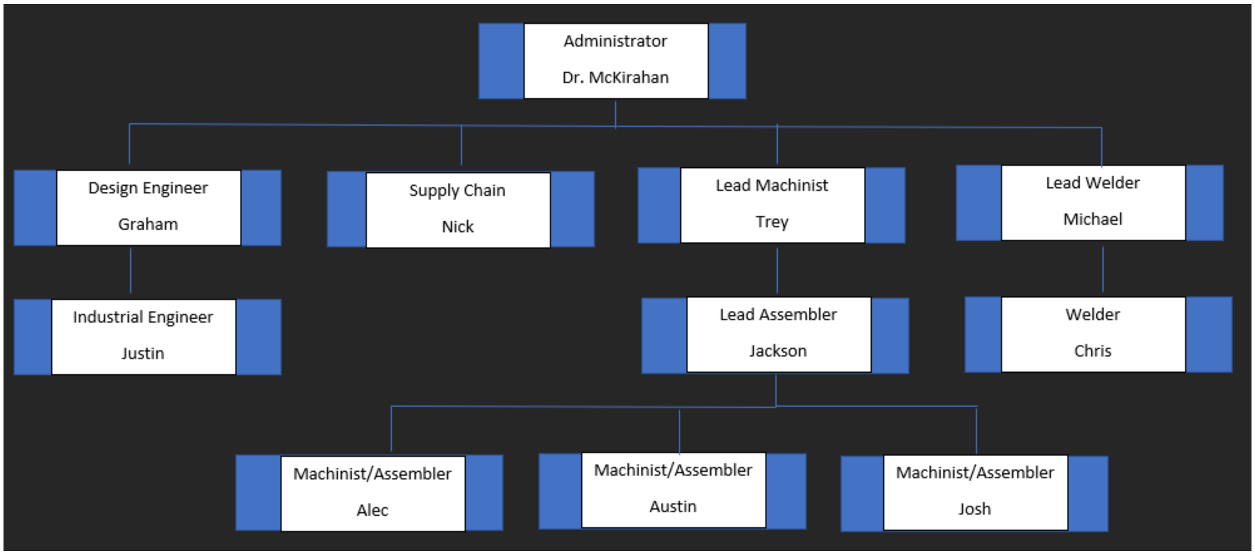


Figure 9: Organizational Chart

Here is a reminder of the organizational chart defined at the beginning of this report.

Overview of Manufacturing

Throughout the manufacturing of our smokers, we spent a lot of time troubleshooting our process to make the most efficient and quality-induced process possible. The barrel was first cleaned and cut in two. Following the splitting of the barrel was deburring the edges. While this was underway the blanks for the handles and door latch were being cut on the laser cutter. Once the handle blanks were cut, they were drilled and then sent to the press to be formed. While the handles were being formed the grease catcher was being cut out and formed while the vent door was also being cut and installed with the hinges. Then the brackets and handles were riveted onto the barrel, followed by the addition of the grease tray grill grate onto the bottom half of the barrel. Then holes for the thermostats were drilled and installed onto the lid of the smoker. This can be seen in the bellow Block diagram. This running of the assembly line is a poor representation of what could be accomplished with this type of product because much of the time produced was wasted. This means that a lot of the time was spent moving parts and pieces back and forth through the manufacturing lab. With our current knowledge, there could have been a better process put into place to balance the operation and production line.

SIPOC

SIPOC Charts (Suppliers, Inputs, Processes, Outputs, and Customers) are a form of organizational chart that allows users to visualize what it takes to complete a given task, how that task will be completed, and what the outcomes will be. Also included are details about where items come from, how they will be assembled or used, and who will be the end user of those items. For our project, the SIPOC Chart, shown below, outlines what it takes to build a single smoker from the first design/benchmarking stages to testing the final product. This allows any individual wanting to know how this process unfolds to get a general idea of what all must happen, how it must happen, and who will receive those end products. Our suppliers include all vendors for this project's purchased items, electricity, plumbing, and tools used. Inputs include mainly those purchased items and tools, and processes involve how they all came together step-by-step. Outputs include the smokers that were manufactured and wastes, whether in time or physical. Finally, customers include those who receive the outputs, including the class, scrap yard, landfill, etc.

SIPOC Chart

	SUPPLIERS	**INPUTS**	**PROCESSES**	**OUTPUTS**	**CUSTOMERS**
	Who supplies the process inputs?	**What inputs are required?**	**What are the major steps in this process?**	**What are the process outputs?**	**Who receives the outputs?**
1	Facebook Marketplace	Barrels	Benchmarking/ Design	Barrel Smokers	Students/ Instructor

2	Great Dane	1/4" Mild Steel Sheet	Order/Pick Up Materials	Excess/Unused Materials	Scrap Yard
3	Char-Broil (Menards)	Grill Grates	Check Inventory Upon Arrival	Scrap Materials	Water Refinery
4	YOTOM (Amazon)	Thermometers	Cut Barrels & Mat'ls From 1/4" Steel	Water Waste	Landfill
5	Jersvimc (Amazon)	1" Hinges	Deburr/Drill/ Bend/Weld	Trash	Hospital
6	Sontax (Menards)	Ø1/8" Rivets	Assemble Components	A Crushed Finger	
7	Grip Fast (Menards)	Ø1/4" Rivets	Test Functionality	Learning Experiences	
8	Performax (Menards)	Ø4-1/2" Cutting Wheels			
9	Pittsburgh Tools (Harbor Freight)	Rivet Tool			
10	Local electric, water	Electricity, Water			
11	Lincoln Electric	Plasma Table Programming			
12		Weld Wire			
13		Drill Bits			
14		Wire Wheels			
15		Grinding Wheels			

Figure 10: SIPOC

Our Organizational Structure

The organizational structure used to carry out the process was the hybrid or matrix structure; as can be seen in the organizational chart in Figure 9. This structure was used because of how flexible it is and how easily one could manage each workstation in the area. A more decentralized approach as to how decisions were made was utilized because the workers closer to the actual issues could more easily devise a solution to their own problems. In this hybrid organization, there was a CEO, who would supervise each workstation until each worker became safe and consistent with their results. Then, he would pass that duty on to individual project managers that would direct how each operation was meant to run. Between each operation, there were floaters that would transport each finished product to the next workstation and be available for any small outside projects, like wiping down parts and sweeping up work areas. This approach to the organizational structure helped to mass-produce the product safely and efficiently while having multiple workers at each station to make decisions.

Integration Type

The integration type used was a forward, vertical integration method. First, we obtained raw materials, some pieces were purchased online such as the barrels and grates while the sheet metal used to make the L-brackets was obtained from scrap metal at Great Dane trailer company. Next, we manufactured the parts separately and then assembled them together to produce a finished product. Ultimately the students distribute the smokers themselves and are also the end consumers. Below is an example of our integration type:

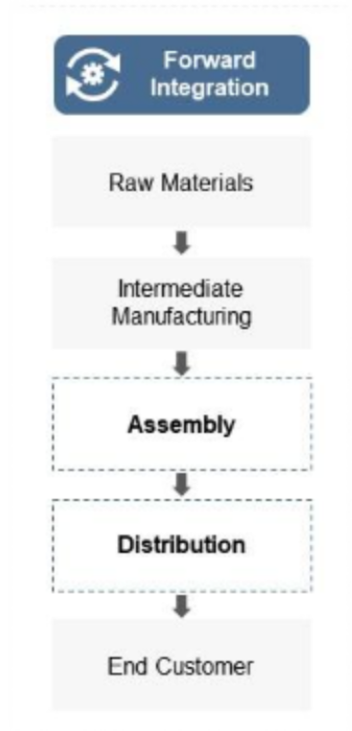


Figure 11: Integration Type

Block Diagram

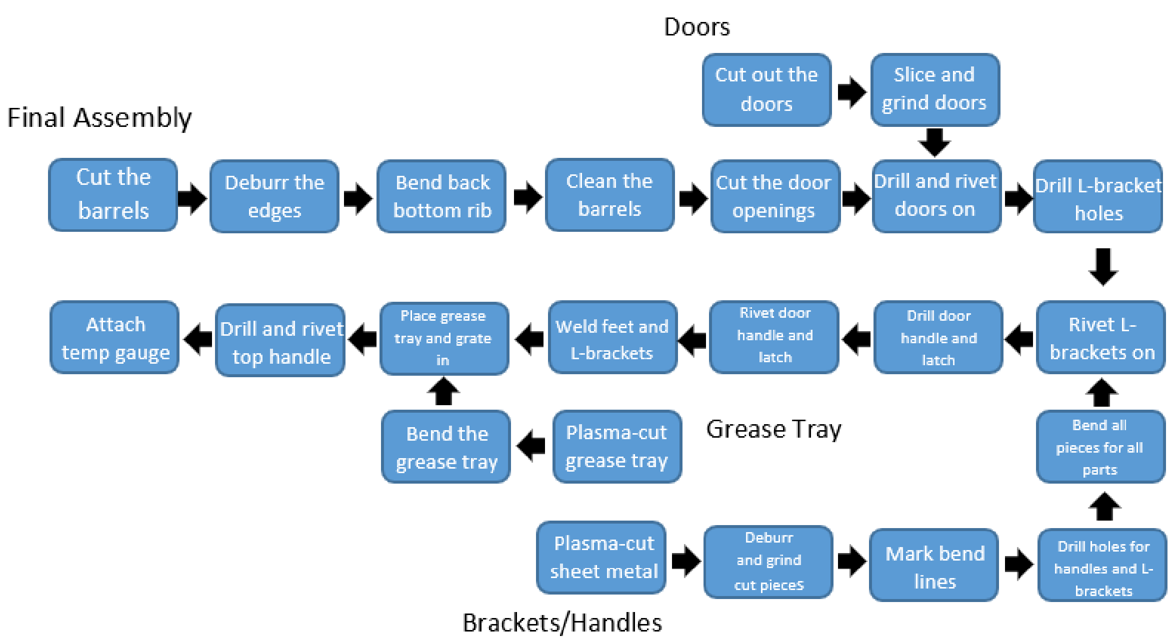


Figure 12: Block Diagram

The final smoker assembly follows a step-by-step linear production flow along with three sub-assemblies in the same step-by-step linear flow. Each sub-assembly dealt with the meat of the smoker. For example, the brackets held up the grease tray and grate, feet, latch, and doors. The final assembly primarily dealt with the skin and bones of the smoker; one example being managing the barrel itself and adding all the external parts from the sub-assemblies and purchased items. Each steps' descriptions can be seen in the block diagram as well as the beginnings of each sub-assembly.

Flow Chart

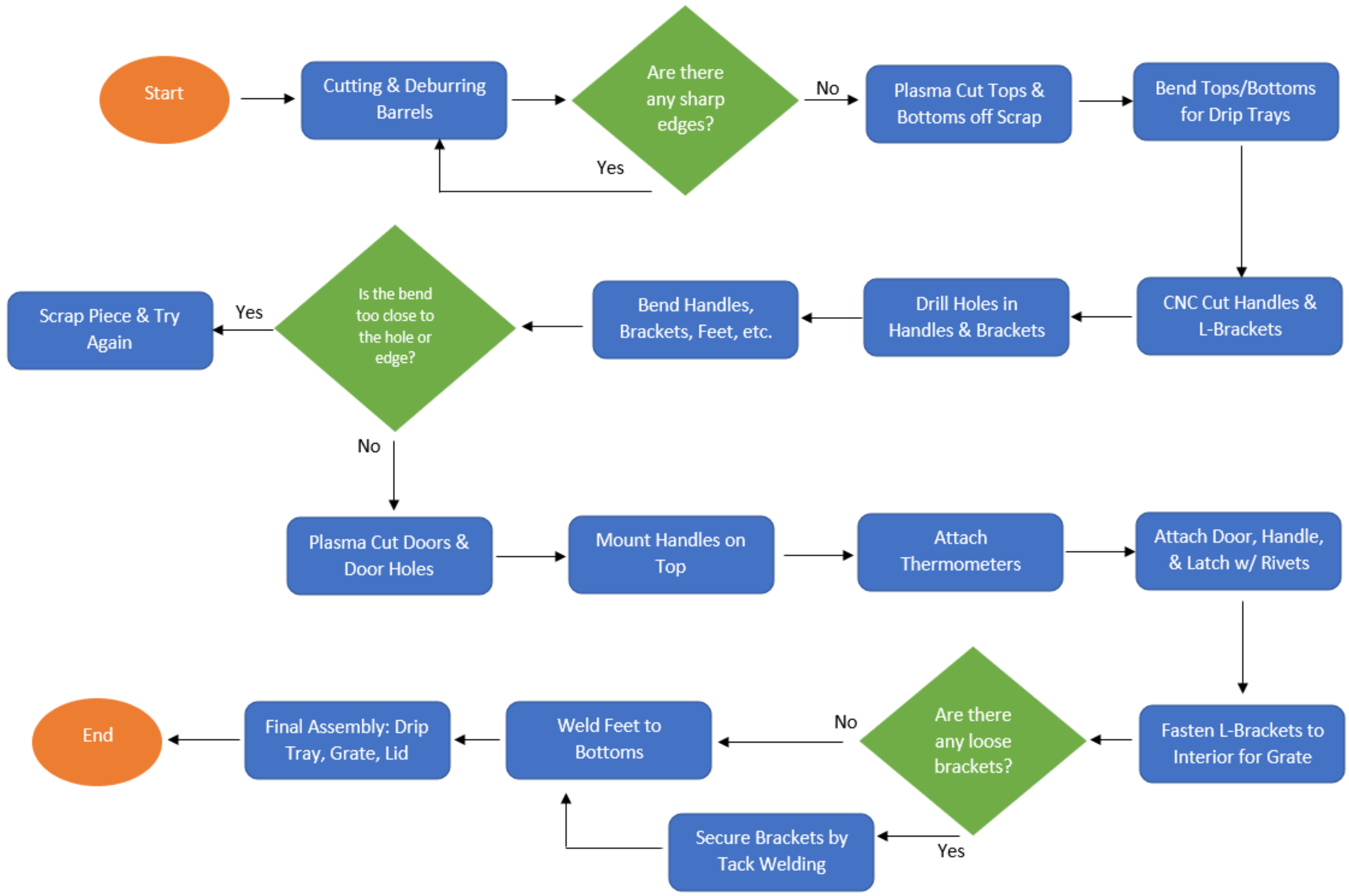


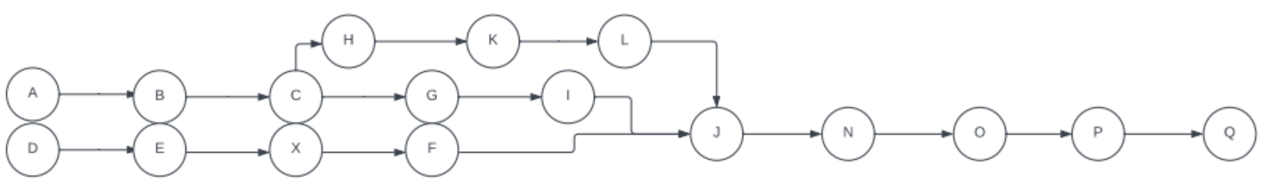
Figure 13: Flow Chart

The flow chart above was used to visualize all steps of manufacturing in an orderly, linear manner. The orange ovals signified the beginning or the end of the whole process, while the blue squares represented a specific task or action to be completed. The green diamonds were used to depict a decision to be made and offered two different conditional paths depending on the answer to the question. Whether the answer was yes or no, it could determine if a different path needed to be taken, or if the previous step needed to be repeated.

Work Layout

The diagram below shows the work area used to manufacture the smokers. This diagram shows the many different steps in making our finished product. There are multiple areas where pervious steps need to be completed to continue with the following steps. In some areas of the process, certain operations need to have multiple operations happening within the same time slots. This helps with keeping the process from stalling on one operation. This process has an assorted number of operations happening where equipment is used multiple times in the process, and there needs to be space in the same areas to complete all operations. There are many tools used to complete this smoker. Some of the tools include an angle grinder, MIG welder, plasma cutter, laser cutter, wire wheel, manual rivet tool, press brake, drill press, cordless drill, pliers, and a grinder.

Work Layout Chart and Table



A – Clean barrels B – Cut barrels into top and bottoms C – Deburr edges of barrel cut D – laser cut blanks (handles, door latch, brackets) E – Drill blanks for rivets X – Measure for forming F – Forming of parts (handles, door latch, brackets) G – Cut lower vent hole H – Cut vent doors	I – Drill vent door and barrel for rivets J – Rivet vent door to hinge and hinge to barrel, Rivet L brackets K – Cut grease blanks L – Form grease traps N – Weld feet onto bottom of barrel O – Drill and rivet handle to lid, Drill hole for thermometer P – Install thermometer in lid Q – Install grease trap, grill grate, and lid

Figure 14: Work Layout

Ergonomic and Human Risks

There were many different factors that had safety factors and put certain risks on the students. There was an accident that occurred with a student using the Pirahna cutting and bending machine. The student got his finger stuck in the bending portion of the machine and it severed the tip of his finger. There were many safety percussions that were taken to help keep students safe such as wearing safety glasses the whole time in the lab. Wearing face shields while using a grinder or cutting the barrels. Some of the ergonomic risks was the noise. There were many processes that were very loud such as cutting the barrels and using the grinder to debur the edges. There were also many times we had to bend over to work on the barrels and lots of lifting and carrying. Some of the human risks were pinch points on the machines and sharp edges on the barrels. Some of the PPE we used were face shields, safety glasses, and gloves. There were some students that wore ear plugs which should have been required while cutting the barrels and deburring them. Lab coats were also worn when we were welding and grinding due to the sparks coming from this process. Gloves should have been worn when transporting the barrels before they were deburred and really after as well as the cut part was very sharp.

Time Study Data

Task	Average Time
Cutting Barrels	3:46
Deburring Barrels	1:22
Plasma Cut Tops	1:06
Bending Barrel Lips	1:48
CNC Cut Handles	0:35
CNC Cut L-Brackets	0:56
Drill Handle Holes	2:17
Drill L-Bracket Holes	0:44
Bending Handles	1:38
Bending L-Brackets	1:45
Bending Drip Trays	2:28
Cutting Door Holes	0:45
Cutting Doors from Scrap	0:19
Mounting Handles	1:20
Attaching Doors	7:16
Riveting Handles/Latches	3:32
Welding Feet to Bottoms	2:16
Final Assembly	0:30
Total Transition Time	9:00
TOTAL	**19:23**

Figure 15: Time Study Data

Above is a chart that displays all the specific manufacturing tasks that were carried out and the average time to complete one of these tasks. These values were calculated by making repeated measurements of classmates performing a job and averaging the measurements. Therefore, these values are not the start-to-finish time of completing every single iteration of a task. For example, it took just under 4 minutes to cut one barrel, but much longer to cut all 11 of them. Since there were constantly multiple operations in progress concurrently, multiplying these times by the total items produced and summing the times would not decide the total start-to-finish time of the whole project.

The total time of 19 minutes and 23 seconds DOES represent the estimated start-to-finish time of completing ONE smoker through all of the manufacturing steps without any delay or waiting time. This can also be referred to as the cycle time. The cycle time is different from the takt time (mentioned below) as the takt time represents how often a completed product rolls off the assembly line. Multiplying the cycle time by 11 yields a total time of about 3.6 hours if each smoker was produced individually. The transition time was calculated by estimating about 30 seconds to move the incomplete product from one station to the next. What this table does not include is the significant delay that resulted from any issues we ran into that required collaborative problem solving from the whole group. Additionally, it took some time for us to figure out how to use new tools or machines before we got into a rhythm completing a certain task.

Takt Time Analysis

The Takt Time can be calculated using the following equation:

$$\text{Takt Time} = \text{Daily Operating Time} / \text{Desired Output per Day}$$

In total, 5 weeks or 10 class periods were used for physically manufacturing the smokers. Not counting setup and cleanup times, we completed about an hour and 15 minutes of work per class period (75 minutes). Therefore, about 750 minutes or 12.5 hours of work were required to fully produce all 11 of our barrel smokers.

$$\text{Takt Time} = 1.25 \text{ hours per day} / 1.1 \text{ smokers per day} = 1.14 \text{ hours}$$

Takt Time = 12.5 total hours / 11 total smokers = 1.14 hours

Using a couple of different units, the Takt Time equates to 1.14 hours. Theoretically, this would mean we would be completing a smoker about every 1 hour and 8 minutes. However, with our production strategy, we completed a full step for every smoker before moving on to the next step, and therefore finished all 11 of our smokers in the last class period of Week 14. For example, we cut all the barrels at once, then plasma cut all the tops at once, etc. This value contrasts the cycle time determined above, because the cycle time represents how long it takes a single smoker to be manufactured from start to finish, while the takt time looks at the operation as a whole, considering all 11 smokers.

Inventory Control Policy

Our inventory started with the receiving of the barrels. We had to make two trips to get the barrels in Illinios. We then began to order the different parts for the smokers. We had a very inefficient way of transporting the barrels once we got them in Terre Haute. We moved them into the classroom upstairs first and then moved them downstairs to the lab. This ended up making some time wasted and unneeded travel. All the other parts we received were brought directly to the lab and we had a table where we kept all our parts. Some flaws to our process were the number of times the barrels were moved around the lab. The barrels were cut outside and then moved across the lab to be deburred. After that they were moved back towards the door where they were cut and drilled for the brackets. The barrels had one more move to the welding station where the bottom brackets were welded on. The manufacturing of the brackets was a very efficient process as the metal was brought right to the plasma cutting table and the pieces were brough to the drill press and finally bent. One of our flaws was not keeping a very accurate inventory. There was no labeling of the barrels and all we did was set aside 11 for the actual smokers and set the rest for parts. The parts themselves were also not labeled. We cut extra metal bars for the brackets but didn't keep them numbered or have an exact amount that we made. Parts like the rivets were bought in bulk and we had extra of them. Overall, we were weak in the counting and inventory keeping of this project.

Section VI

TQM Plan

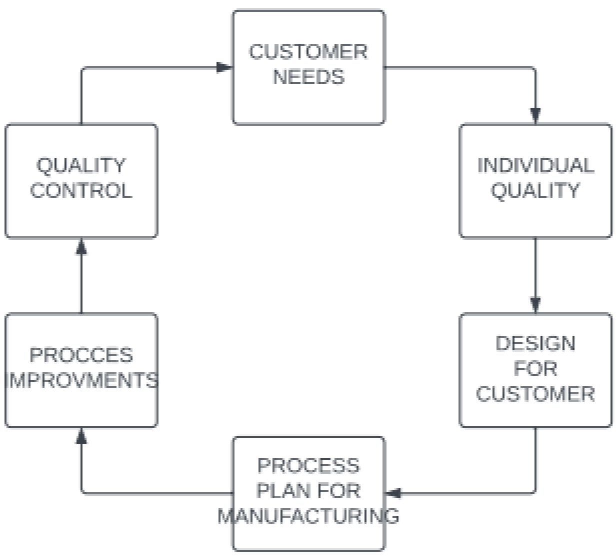


Figure 16: Total Quality Management

The TQM of the smokers was the most crucial aspect to determine the wants of the customers buying the barrels. These wants were found through class discussions, benchmarking, and reviewing similar products. The above diagram depicts the process below. This set up the design team with a lot of the critical features needed to create the design that could fit customer needs. This plan would have to include individuals' quality because of the limited number of resources involved in the production of the barrels. This would be done through ownership of each individual's work. Once the design was created, the manufacturing team worked on making a process for the prototype manufacturing of the smokers through different trials in the construction operations and overall process. Once the basic process was found for each operation of how to do the operation, the next question was: Is there a better way and how can we make it more efficient? This would be our process improvements throughout the assembly of the smokers. Lastly our quality control needed to have all our critical features measured and insured for quality.

Product Specifications

Overall, there were a few critical dimensions and criteria that needed to be held to create a usable smoker for the market we aimed for. These critical dimensions and criteria were the thermostat position 3 inches from center, Overall smoker weight below 60 lbs., the position of the vent door from the bottom of the barrel 2 inches from the bottom of the barrel. These dimensions can be seen in the drawings for reference. The thermostat position is critical to accurately measure the internal temperature of the cooking area. The overall weight is important because of the portability aspect depicted in our project goals and objectives for our customer market. Another critical dimension of the smoker was its vent door position because it needs to be used often to add fuel and air to the bottom of the smoker. Below are the measurements taken by the quality department to conduct capability studies on the critical features of the smoker. These measurements were taken with a measuring square, and an electric weighing scale. Shown also is the UCL, LCL, USL, LSL, and the overall Cp of each feature.

UCL= (mean+(3*(Standard deviation))
LCL= (mean-(3*(Standard deviation))
Cp= (USL-LSL) / (6*Standard deviation)

Using this information, we can conclude that the process is capable at our current spec limits on all features except the thermostat position. We know this because the ideal Cp is 1.33 and the current Cp of the thermostat position is below 1.33 at 1.14. This is an acceptable Cp for a first process, however there is much room for improvement in the process to be able to keep up with the current needs of the smoker. Our control limits are also calculated below for each critical feature.

Measurement Data charts of critical features

Thermometer position		
Parts	measurements	tolerance
1	10.625	+/- .500
2	10.5	+/- .500
3	10.625	+/- .500
4	10.625	+/- .500
5	10.625	+/- .500
6	10.5	+/- .500
7	10.25	+/- .500
8	10.5	+/- .500
9	10.625	+/- .500
10	10.25	+/- .500
11	10.625	+/- .500

Smoker Weight		
Parts	measurements	tolerance
1	54.6	<60
2	54.4	<60
3	54	<60
4	54.6	<60
5	54.6	<60
6	54.4	<60
7	54.2	<60
8	54.4	<60
9	54.2	<60
10	54.6	<60
11	54.2	<60

Door Position		
Parts	measurements	tolerance
1	2.25	+/- .500
2	2.125	+/- .500
3	2.25	+/- .500
4	2.25	+/- .500
5	2.125	+/- .500
6	2.25	+/- .500
7	2.125	+/- .500
8	2.125	+/- .500
9	2.125	+/- .500
10	2.25	+/- .500
11	2.25	+/- .500

UCL	10.96063293
LCL	10.08482162
CP	1.14
USL	10.88
LSL	9.88
n =	11
Sum =	115.8
Mean =	10.52272727
Std. dev =	0.145968552
Max =	10.6
Min =	10.3
Range =	0.4
STD error of mean	0.044011174

UCL	55.00849774
LCL	53.75513862
CP	7.98
USL	60
LSL	50
n =	11
Sum =	598.2
Mean =	54.38181818
Std. dev =	0.208893187
Max =	54.6
Min =	54.0
Range =	0.6
STD error of mean	0.062983666

UCL	2.389019181
LCL	1.997344455
CP	2.55
USL	2.5
LSL	1.5
n =	11
Sum =	24.1
Mean =	2.193181818
Std. dev =	0.065279121
Max =	2.3
Min =	2.1
Range =	0.1
STD error of mean	0.019682396

Figure 17: Product Specifications

Control Charting

Below are the control charts using the mean of the data sets and their individual UCL, LCL, USL, and LSL to chart the data.

Thermostat Control Charting:

Here is the Data table of the collected Data for the Thermostat position on the smokers. This shows a capable process at installation of the Critical feature.

parts	measuremnts	UCL	LCL	mean	USL	LSL
1	10.625	10.96063	10.08482	10.52273	10.88	9.88
2	10.5	10.96063	10.08482	10.52273	10.88	9.88
3	10.625	10.96063	10.08482	10.52273	10.88	9.88
4	10.625	10.96063	10.08482	10.52273	10.88	9.88
5	10.625	10.96063	10.08482	10.52273	10.88	9.88
6	10.5	10.96063	10.08482	10.52273	10.88	9.88
7	10.25	10.96063	10.08482	10.52273	10.88	9.88
8	10.5	10.96063	10.08482	10.52273	10.88	9.88
9	10.625	10.96063	10.08482	10.52273	10.88	9.88
10	10.25	10.96063	10.08482	10.52273	10.88	9.88
11	10.625	10.96063	10.08482	10.52273	10.88	9.88

Figure 18: Thermometer Control Chart

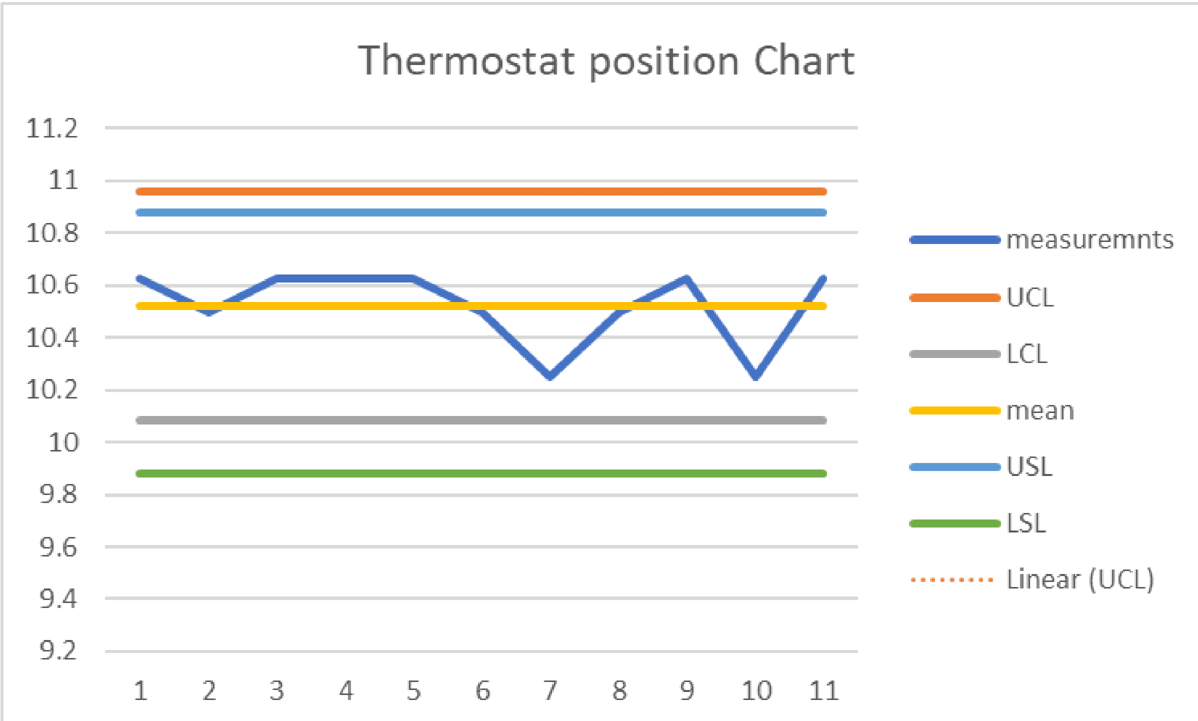


Figure 19: Thermometer Position Chart

Smoker Weight Charting

Here is the Data table of the collected Data for the weight of the smokers. This shows a capable process at installation of the Critical feature.

parts	measuremnts	UCL	LCL	mean	USL	LSL
1	54.6	55.0085	53.75514	54.38182	60	50
2	54.4	55.0085	53.75514	54.38182	60	50
3	54	55.0085	53.75514	54.38182	60	50
4	54.6	55.0085	53.75514	54.38182	60	50
5	54.6	55.0085	53.75514	54.38182	60	50
6	54.4	55.0085	53.75514	54.38182	60	50
7	54.2	55.0085	53.75514	54.38182	60	50
8	54.4	55.0085	53.75514	54.38182	60	50
9	54.2	55.0085	53.75514	54.38182	60	50
10	54.6	55.0085	53.75514	54.38182	60	50
11	54.2	55.0085	53.75514	54.38182	60	50

Figure 20: Smoker Control Chart

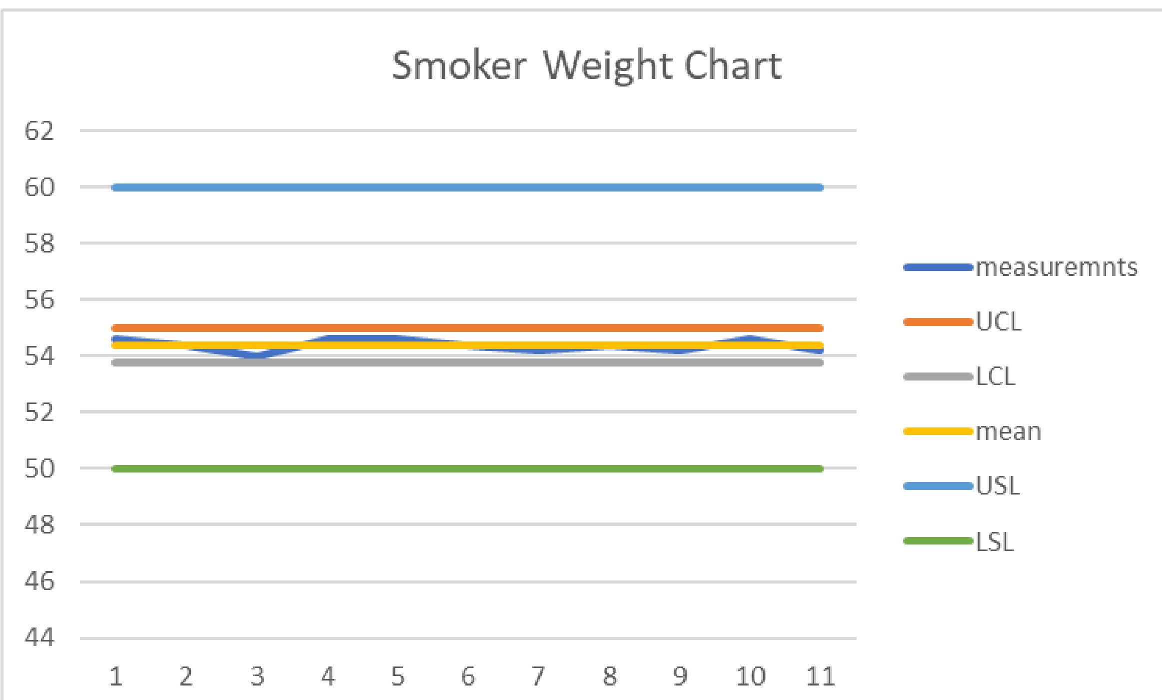


Figure 21: Smoker Weight

Smoker vent door position

Here is the Data table of the collected Data for the vent door position on the smokers. This shows a capable process at installation of the Critical feature.

parts	measuremnts	UCL	LCL	mean	USL	LSL
1	2.25	2.389019	1.997344	2.193182	2.5	1.5
2	2.125	2.389019	1.997344	2.193182	2.5	1.5
3	2.25	2.389019	1.997344	2.193182	2.5	1.5
4	2.25	2.389019	1.997344	2.193182	2.5	1.5
5	2.125	2.389019	1.997344	2.193182	2.5	1.5
6	2.25	2.389019	1.997344	2.193182	2.5	1.5
7	2.125	2.389019	1.997344	2.193182	2.5	1.5
8	2.125	2.389019	1.997344	2.193182	2.5	1.5
9	2.125	2.389019	1.997344	2.193182	2.5	1.5
10	2.25	2.389019	1.997344	2.193182	2.5	1.5
11	2.25	2.389019	1.997344	2.193182	2.5	1.5

Figure 22: Smoker Door Control Chart

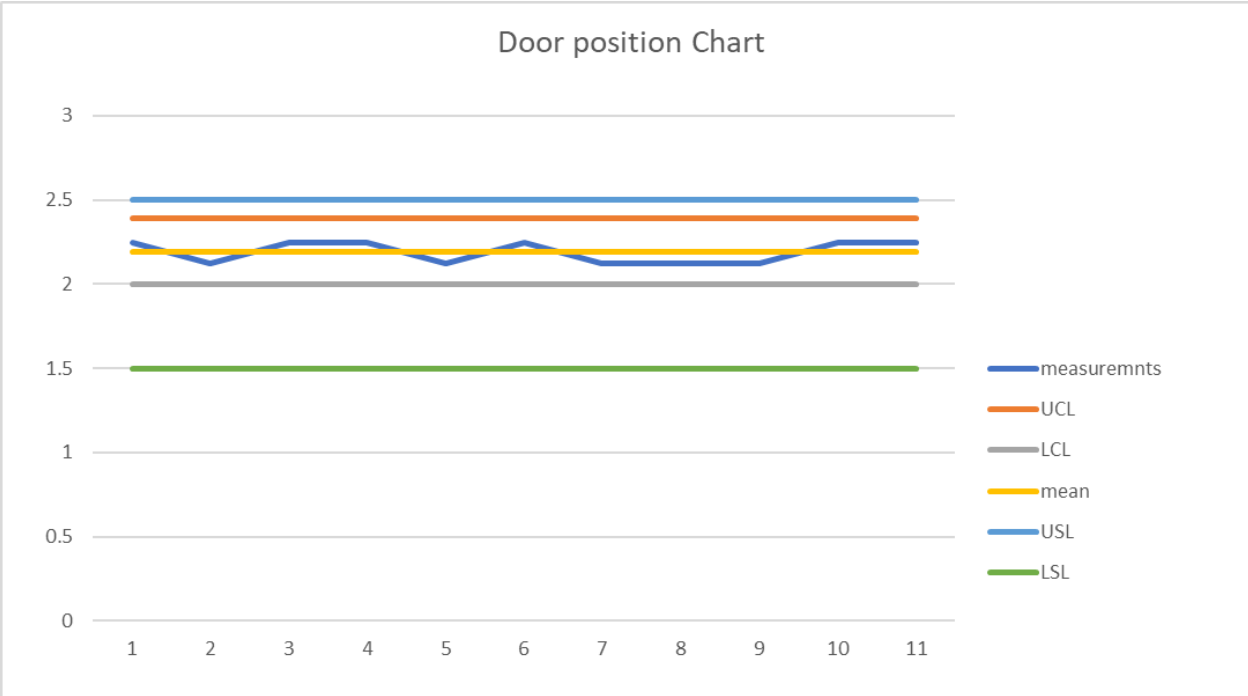


Table 15: Door Position

Overall, you can see throughout the control charts that each one of our features consistently falls between our spec limits. However, we come close to our control limits at times with our thermostat position. Which is indicated in our above Cp of 1.14.

X-Bar Chart

Because so many needed to be manufactured, we had to ensure the quality of the length of the L-Bracket stock sizes that were cut on the TorchMate CNC Plasma Table. Prior to being drilled and bent, the blanks needed to be a bit oversized to accommodate the radius that would be manufactured. That was compensated for within the program, from which the blanks were cut in sets. Shown below is the variable data taken by measuring their lengths with a Vernier caliper. Three sets of ten blanks were measured, with the mean, standard deviation, and range of the sets calculated to find the overall X-Bar-Bar and R-Bar values. The nominal length of the blanks was intended to be 4.250".

L-Bracket X-Bar Data

L-Bracket Stock Size Sample	Length 1	Length 2	Length 3	Mean	Standard Deviation	Range	
1	4.256	4.255	4.255	4.255	0.0006	0.0010	
2	4.254	4.256	4.254	4.255	0.0012	0.0020	
3	4.254	4.255	4.254	4.254	0.0006	0.0010	
4	4.253	4.255	4.254	4.254	0.0010	0.0020	
5	4.255	4.253	4.255	4.254	0.0012	0.0020	
6	4.255	4.255	4.255	4.255	0.0000	0.0000	
7	4.253	4.254	4.256	4.254	0.0015	0.0030	
8	4.254	4.255	4.255	4.255	0.0006	0.0010	
9	4.255	4.254	4.254	4.254	0.0006	0.0010	
10	4.255	4.255	4.255	4.255	0.0000	0.0000	
			Sum	42.55	0.0071	0.0130	
			X-Bar-Bar	4.25460	0.0007	0.0013	**R-Bar**

Figure 23: L-Bracket X-Bar Chart

The mean values ($\bar{X}$) were calculated with the following formula:

$$\bar{X} = \Sigma Lengths / 3$$

Standard Deviation (σ) was calculated with the following where *x = Each Length* and *N = Size of Population*:

$$\sigma = \text{Sq. Rt. } [\Sigma(x - \bar{X})\text{^}2 / N]$$

Range (R) was found with the following formula:

$$R = R_{MAX} - R_{MIN}$$

The Grand Average (X-Bar-Bar) was found by averaging the $\bar{X}$ values:

$$X\text{-}Bar\text{-}Bar = \Sigma\bar{X} / 10$$

The Grand Average Range ($\bar{R}$) value was found by averaging the R values:

$$\bar{R} = \Sigma R / 10$$

As one could quickly notice, they were running a bit long; according to the X-Bar-Bar, or grand average, roughly 4.25460" to be exact. That was not much of an issue though, as after bending most were still within tolerance per the drawing.

Next, the UCL and LCL needed to be calculated. Using Excel, this is what was found:

UCL / LCL Chart

X-Bar-Bar	4.25460
A_2	0.308
R-Bar	0.0013
UCL	**4.2550**
LCL	**4.2542**

Figure 24: UCL & LCL Chart

The formulas used were the following where A_2 = *constant for a sample size of 10*:

$$UCL_x = X\text{-}Bar\text{-}Bar + A_2\bar{R}$$

$$LCL_x = X\text{-}Bar\text{-}Bar - A_2\bar{R}$$

From these, the X-Bar Chart was able to be created for the L-Bracket stock lengths:

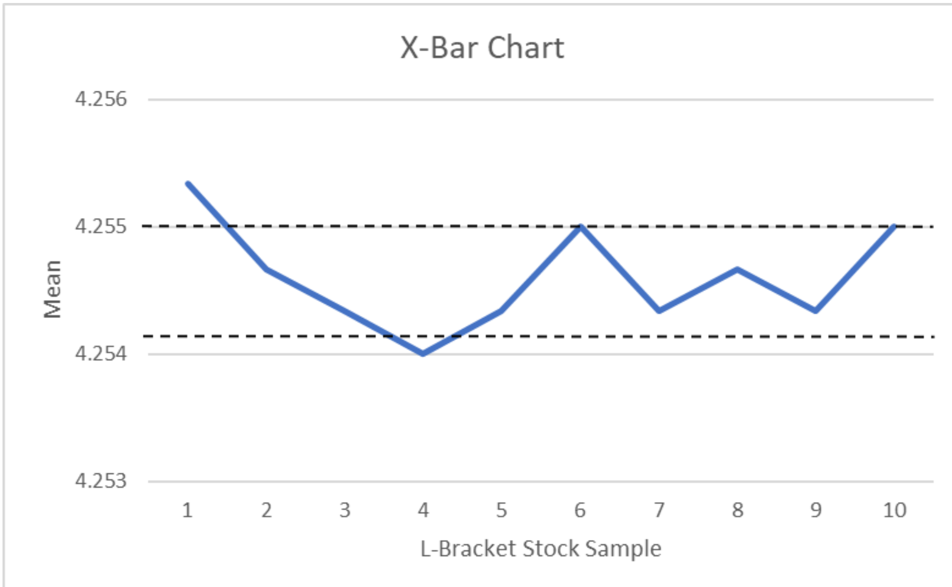


Figure 25: X-Bar Chart Graph

According to the chart, with the UCL and LCL calculated, there were four sample groups that made or crossed the boundaries of what is acceptable. Then the Shewhart Standard Deviation Value (*s*) was calculated:

s Chart

R-Bar	0.0013
d_2	3.078
s	**0.00042**

Figure 26: S Chart

The formula was the following where d_2 = *constant for a sample size of 10*:

$$s = \bar{R} / d_2$$

Finally, with the upper specification limit (*USL*) and lower specification limit (*LSL*) being 4.281 and 4.219 per the drawing, respectively, process capability (*Cp*) was able to be calculated:

C_p Chart

USL	4.281
LSL	4.219
s	0.00042
Cp	**4.36E-06**

Figure 27: Cp Chart

The formula for calculating C_p was the following:

$$C_p = (USL - LSL) / 6\sigma$$

Because a good *Cp* is found to be greater than 1.33, this calculation showed that this process was not very capable. However, for the sake of this project, it did not affect the overall. In a mass-production setting, this would need to change.

Section VII

Re-telling the Executive Summary

During this report, our barrel smoker is introduced. This report discusses the development and manufacturing of our product. As a group, we wanted to design and build a smoker that wouldn't break the bank for an average homeowner. The total cost of the project was $425 including the materials needed to make the final product and some of the tools that were not available at first. The cost to manufacture each Barrel smoker was $40 and we plan on selling the smoker for $69.99. The selling price is about 175% more than the manufacturing price for a healthy profit for the company. The cost of our Barrel smoker is significant because of how cheap it is compared to the multi hundred-dollar ones that you can find in the market today while maintaining high end quality. This project consisted of two engineers, one supply chain manager, five machinists/assemblers, and two welders. While the workers specialized in specific divisions, the group worked together to maintain the visions, missions and goals created for the project. This report discusses the original benchmarking plans for the final production of the barrel smokers. Throughout this process we were able to keep track of quality checks and maintain the expectations of our gallon drum smoker.

Discuss if Successful

Throughout the design and manufacturing of our smokers, there was a plethora of successful endeavors and unfortunate pitfalls. To start off, we had to make design changes to accommodate a lack of stocked materials from one vendor for grill grates; but in the end we were able to find a suitable replacement that both fit and functioned perfectly for our needs. Another example was cutting the L-brackets and handles on the CNC plasma table. Although there were software issues off-the-bat, we were able to find an alternate route to cutting copious amounts of each design in an efficient way by patterning each over a specified surface area. Lastly, to ensure the few loose L-brackets would remain in their correct orientations, each were both tack-welded and rivetted. Although there were some obstacles that had to be overcome along the way, we were able to successfully manufacture eleven complete smokers with ample amounts of time and money to spare.

Prototype performance/SWOT

SWOT Analysis	
Strengths	**Weaknesses**
Cheaper to produce than benchmarked products Variety of different majors in class Prior experience w/ machines, welding, CAD, etc.	Smaller class size than previous years A few non-MFG majors with less experience Most of class didn't know each other beforehand
Opportunities	**Threats**
Great Dane offering free scrap metal Finding cheap used barrels for sale Extensive machining/metal lab at our disposal	Inflating cost of materials Limited amount of time to complete project Losing a worker to injury near the end

Figure 28: SWOT Analysis

The SWOT analysis examines the four categories of factors that affect our ability to complete the project: strengths, weaknesses, opportunities, and threats. Strengths and weaknesses are internal factors that can either help us perform to our best abilities or inhibit our team from working with efficiency. Opportunities and threats, however, are external factors that we have less control over but still affect our performance. Opportunities must be found and capitalized on to assist our work, while dealing with threats involves either combatting the issue directly, using creative thinking to work around the problem, or finding an alternative solution.

Highlights/Trials/Tribulations

During the fabrication process of creating these smokers we encountered quite a few things that went quite well and several things that didn't. Some of the things during this project's execution that went well was that everyone showed excellent teamwork and work ethic. Everyone also proved to be very flexible and able to make on the spot changes to overcome the problems that came up during the fabrication process. Several of the fabrication processes also went quite well such as the plasma cutting of the access doors, riveting of the handles, and welding on the feet.

Throughout the process we did come across quite a few issues, however. There were a few design oversights such as missing a latch to hold the bottom access door closed and the grate mounting brackets only being held in with one rivet and thus allowing them to rotate. We could not get ahold of some of the types of metal stock material that we were designing around and had to improvise a lot to accommodate what we were able to acquire. There was also an issue with designing around ¼" pop rivets and found out during assembly that the rivet guns that were on hand could not accommodate rivets that large and we had to go out and buy a rivet gun that could do what we needed. Our process for making some of the cuts needed from our raw material was not ideal and added unnecessary time to the overall process. One example is using an angle grinder with cut-off wheels to separate the barrels into the top and bottom halves, using the plasma cutter would have been much faster and would have left a similar quality of cut if we were careful. The processes we used to deburr the various parts was also not ideal and took quite a long time whereas if we had researched what the most efficient way to deburr each unique type of component beforehand and utilized them, we could have saved a lot of time. The final issue was that the software that we used to operate the CNC plasma cutter did not have the ability to do on the fly nesting operations that would have allowed us the flexibility that we needed when changing the design to accommodate our material selection. This forced us to cut each part one at a time or to manually pattern and generate G-code for the parts as needed, and this took much more time than if we could nest a specific number of components on the fly.

Section VIII

What We Would Do Differently

While, overall, the project was a success, there are certainly quite a few things that we would do differently if we were to set out to do this or a similar project again in the future. First is that we would ensure that the product design is fully fleshed out and completed before we embarked on the manufacturing process as this would significantly reduce the number of on-the-fly modifications that we had to do. The fabrication process should have also been more fleshed out before we started to ensure that we were using the most efficient and effective processes in the most efficient way for each needed operation as well as our ability to perform each operation with the tools we have at our disposal. To help minimize time wasted we could have Utilized the plasma cutter more and found a more efficient way to deburr the parts as well as to lay out the overall process flow to minimize time wasted transporting the components around to the various work areas. A detailed plan of exactly who is going to do what and when beforehand would have also helped to increase efficiency and reduce the need for meetings during our assembly time. Finally, the most important thing that we would change is to be more focused on meeting the highest safety and quality standards when using the equipment instead of just going as fast as possible and neglecting the dangers of the equipment that is being used.