Design and Construction of a

Race Team Equipment Box

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ABSTRACT

This senior project discusses the design and construction of a race team equipment box. This equipment box was located on the rear of a modified golf cart. The rear half of the golf cart was modified by creating framework around the rear so that the equipment box would rest on top and be able to detach from it. The equipment box was able to hold all necessary equipment that is needed in the pits. Each items location was placed ergonomically so they can be reached with ease in an efficient manner. Located on both sides of the equipment box were tires holders. These tire holders swivel 360 degrees so the tires can be sanded. The equipment box has one shelf in it so that there are two areas to store parts. Once the project was completed, a "fit check" was done to make sure the equipment box could hold all that it needed. It was found that the equipment box met all specifications put into place and exceeded expectations. The equipment box was able to hold over 500 lbs. of equipment and still function properly. It also had an area for a third tire to be held. The tire holders worked well and were able to hold the tire while also being able to swivel to the four different positions.

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INTRODUCTION

There are over 1,900 dirt oval tracks in the United States and each of these tracks have around 20 local race teams that compete each racing season (National Speedway Directory 2013). This means that there are around 38,000 dirt oval race teams in the United States. Each one of these race teams have equipment for their race car that is needed for pit stops. In any type of auto racing, there are always pit stops. Pit stops occur when a race car needs to have something done to it; which can consist of a tire change, chassis adjustment, fuel refill, and/or anything else.

One type of auto racing, NASCAR, has individual pit stalls for each race car and are located on the track in an area called “pit road”. Unlike NASCAR, dirt oval track racing does not have individual pit stalls for race cars to come in and fix and/or adjust the car. Usually, the tracks have a specified area where pit crew members are allowed to bring their tools, tires, fuel, and whatever else they think they may need during the night. Sometimes these areas are inside of the race track, and others are right outside of the track. Either way, the pit crews have to bring all of the equipment from the car trailer to this area. As of now, crew members use whatever they can find in order to make carrying everything easier. Some use pull along wagons, ATVs, golf carts, or even put the equipment on the back of the race car and have it driven to the area and dropped off. These methods work, but not very well. Trying to bring two stock car tires, a floor jack, a battery powered impact, and a few tools takes up a lot of room and is difficult to fit onto an ATV or a golf cart.

Something needs to be created for race teams to transport their pit equipment easily. This new product, called the Race Day Transport (RDT), will have an area for tools, shocks, springs, a floor jack, battery powered impact, fuel jugs, air tank, and two areas to hold tires. Each tire holder will be able to swivel so that tire sanding can be done. This project will need to be able to attach/detach to the back of a golf cart easily and be able to hold all equipment necessary. After the design and build of this prototype, a cost analysis will be made of the material and labor.

LITERATURE REVIEW

A search was done to find information about materials that will be used as part of the equipment box for the project.

DSM Manufacturing Company produces high precision sheet metal products. This includes different types of aluminum, steel, and stainless steel sheet metal products. For this project, aluminum sheet metal will be used for the shell of the equipment box, so the correct type needs to be chosen. DSM has four types of sheet metal including 1100-H14 (commercially pure aluminum), 3003-H14 (general purpose manganese alloy), 5052-H32 (main alloy is magnesium), and 6061-T6 (alloyed with magnesium and silicon). The type that will be used for the project is the 1100-H14, which is commercially pure aluminum. This aluminum is easily worked and welded, ductile enough for deep draws, but has the lowest strength aluminum alloy. While this aluminum has the lowest yield at only 17,000 psi, the formability of it was great. It was rated an "A", compared to the other three that were rated either "B" or "C". The formability will allow for ease of bending and cutting of the material when it is being used to cover the equipment box.

OnlineMetals.com has information about mild steel tubing. They currently stock six grades of steel in various shapes and sizes. This includes 1018 steel, A36 steel, 1144 steel, 12L14 steel, and more. The steel needed to complete this project however, is the round rod 1018 cold-rolled steel. It has a good combination of all of the typical traits of steel, such as strength, some ductility, and comparative ease of machining. Online Metals.com also shows minimum properties of the 1018 Mild steel which is good to know for the strength and durability of the equipment box frame. The 1018 Mild steel has an ultimate tensile strength of 63,800 psi, yield strength of 53,700 psi, and a Rockwell hardness of B71. Knowing the strengths of the steel tubing will allow for the determination of which grade of tubing should be used.

The text book *Introduction to Welding Engineering* gave a lot of knowledgeable information about gas metal arc welding, which is the method the frame of the equipment box will be welded with. There are four types of metal transfer modes. They are short circuiting transfer, globular transfer, spray transfer, and pulsed spray transfer. Each of these methods are used for different purposes. For the project of welding 1018 mild steel tubing, short circuiting transfer is required. Short circuiting transfer can either use flux or some type of a shielding gas, which can either be 100% CO_2, or 75% Ar-25% CO_2. *Introduction to Welding Engineering* stated that short circuiting gas metal arc welding is used for welding of steel sheet metal and thin plate, usually <1/4" thick, in all positions.

PROCEDURES AND METHODS

Golf Cart Deconstruction Procedure

The following figures show the deconstruction procedure of the golf cart.

Figure 1. Golf Cart Before Deconstruction

A golf cart was obtained, in this case an electric EZ GO golf cart, and the bodywork of the rear half of the golf cart was removed. The first step was to take off the canopy and the canopy supports. From there, the seat, back rests, two rear fenders, and all the other additional pieces were removed until there was no longer any bodywork left. The only thing that was visible on the rear half were the frame rails, engine, wiring, rear end, and tires.

Figure 2. Deconstruction Process

Figure 3. Removing Excess Mounts

Once all of the bodywork was removed from the rear of the golf cart, the material removal process began (Figure 2). For this process, an electric sawzal and an electric grinder were used (Figure 3). All of the mounts attached to the rear frame rails were cut off except for the mounts for the shocks. The removed mounts consisted of the back support mounts, fender mounts, and other tabs used to bolt parts on. After these mounts were removed, the grinder was used to grind the excess material from the removed mounts so that the area was flush with the base material.

Design Procedure

Framework. The material that was chosen for the framework was 1 ½ inch, 0.095 inch wall thickness steel square tubing. This was chosen due to the weight that the framework needs to be able to hold. The framework needs to be able to hold two or three 28 inch diameter stock car tires, a floor jack, a battery powered impact gun, a portable air tank, and miscellaneous tools and parts. These items add up to approximately 200 lbs. This is the minimum amount of weight that the framework should be able to hold, so an extra 200 pounds was added to this so that it could hold extra equipment. This meant that the steel chosen needed to be able to hold at least 400 pounds without failing. The framework design was done in AutoCAD simultaneously to each piece measured on the golf cart so that the dimensions would be accurate. The framework design and dimensions of this project depend on the brand of golf cart acquired. As stated previously, for this specific project an electric EZ GO golf cart was used.

The first step towards designing the framework was to measure the width of the golf cart. The width was measured as 43 ¼ inches. This width was used as the width of the framework that was added onto the rear of the golf cart. The rear of the golf cart had very little to its frame; there were only two pieces of rectangular tubing that ran from the center of the golf cart to the rear. These are called “frame rails”. Since there were only two frame rails, support mounts were added onto the frame rails so that the framework for the equipment box would be strong.

Figure 9 through Figure 12 show where measurements were taken for the framework. The red color represents the pre-existing material, the blue color represents the added framework, the green color represents the equipment box, and the pink color represents the tire holders.

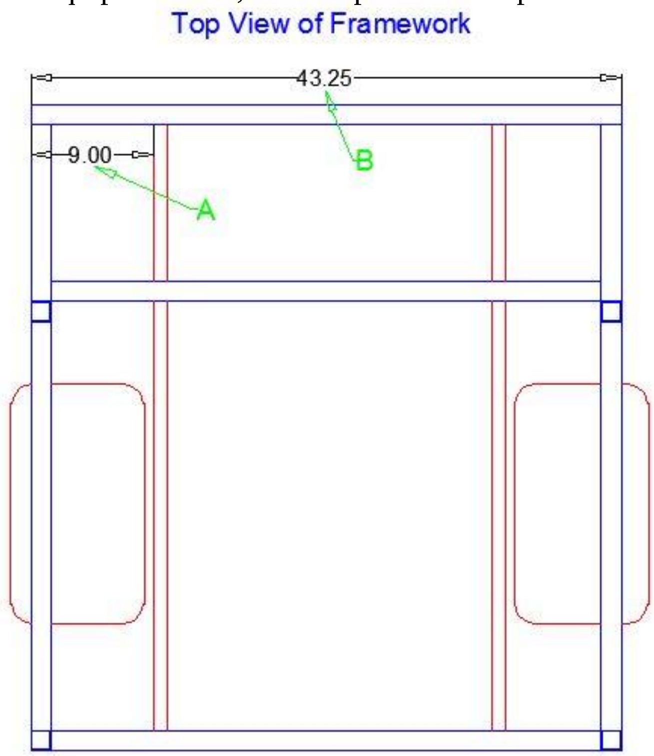


Figure 4. Left Side Support

A measurement was taken from the left frame rail to the outside edge of the left side of the golf cart (Figure 4 (A)). The measurement was 9 inches. This measurement was one horizontal corner support piece for the left side of the golf cart.

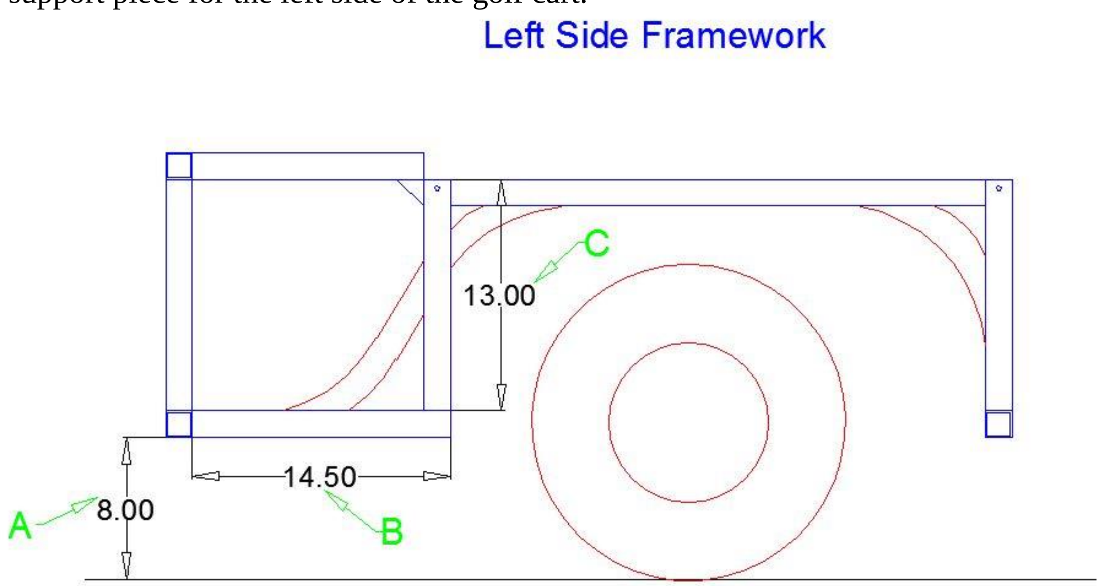


Figure 5. Height of Support

A measurement from the ground to the bottom of the golf cart frame rail was also taken; and it was 8 inches (Figure 5 (A)). This measurement determined the height of the horizontal corner support piece. These measurements were taken again for the right side corner support piece. The length of the right side horizontal piece was 8 ½ inches and the height of the right side horizontal piece was 8 inches. The measurement from the outside edge of both of these pieces is the same as the width of the golf cart measured previously, which is 43 ¼ inches (Figure 4 (B)).

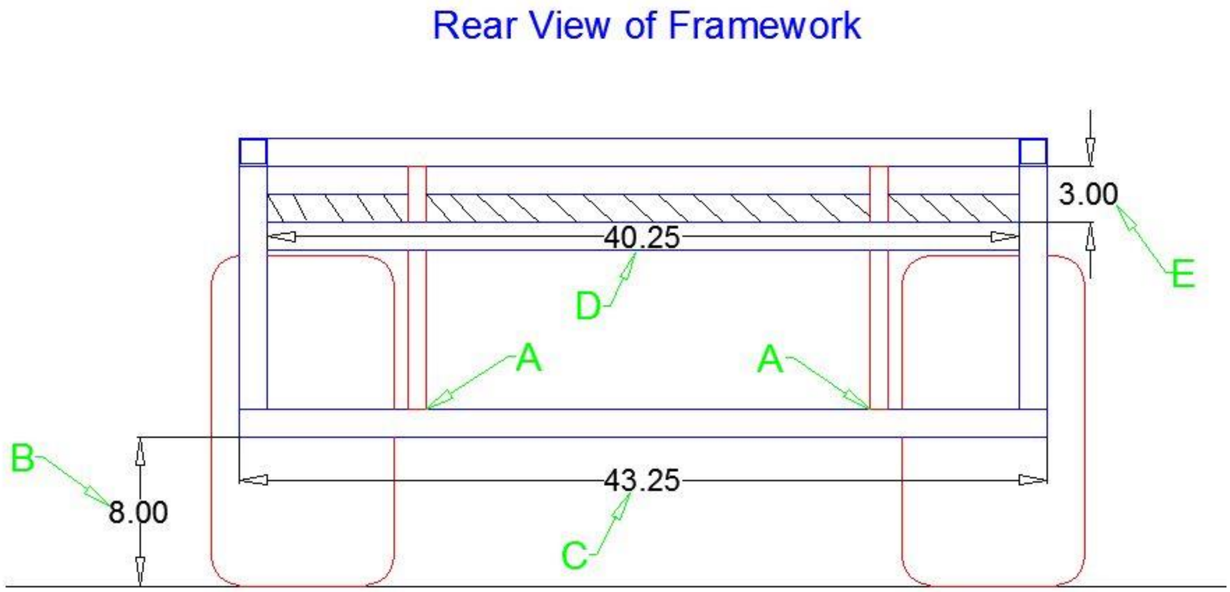


Figure 6. Determination of Rear Framework Bar

The rear of the framework for the equipment box was determined by where the frame rails ended (Figure 6 (A)). This was determined to be the back of the framework. The back of the framework was set to be the same height as the two horizontal corner pieces so that they would be level with each other. The height of the back bar was 8 inches above the ground (Figure 6 (B)). The length of the rear horizontal piece was the width of the golf cart, which was 43 ¼ inches (Figure 6 (C)). Doing so insured that the framework would stay square.

From the left front horizontal piece, a measurement was taken back 14 ½ inches towards the left rear tire so that the framework would not be too close to the tire (Figure 5 (B)). The same was done on the right side. This measurement was also 14 ½ inches.

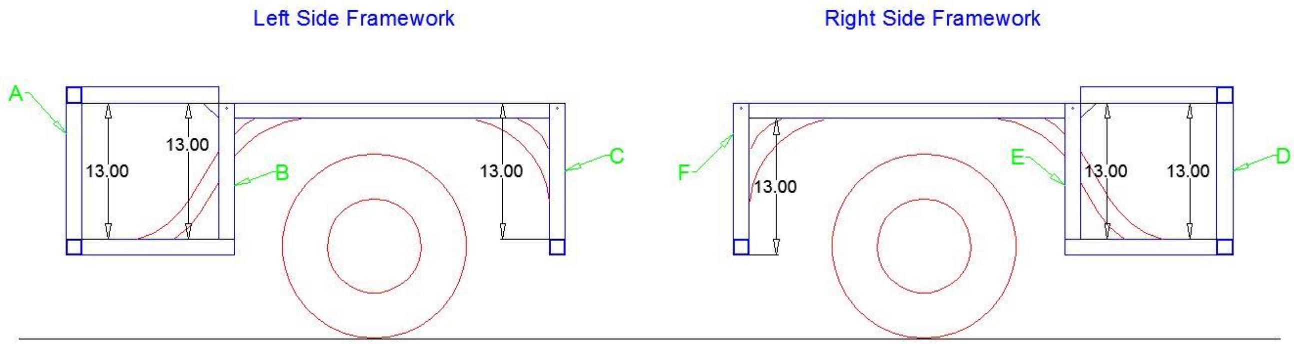


Figure 7. Six Uprights

A measurement from the left front corner horizontal piece up to the golf cart frame rail was measured as 13 inches (Figure 5 (C)). This was the height of the six uprights. One was on the left front corner (A), one on the right front corner (D), one on the left side middle (B), one on the right side middle (E), one on the left rear corner (C), and one on the right rear corner (F) (Figure 7).

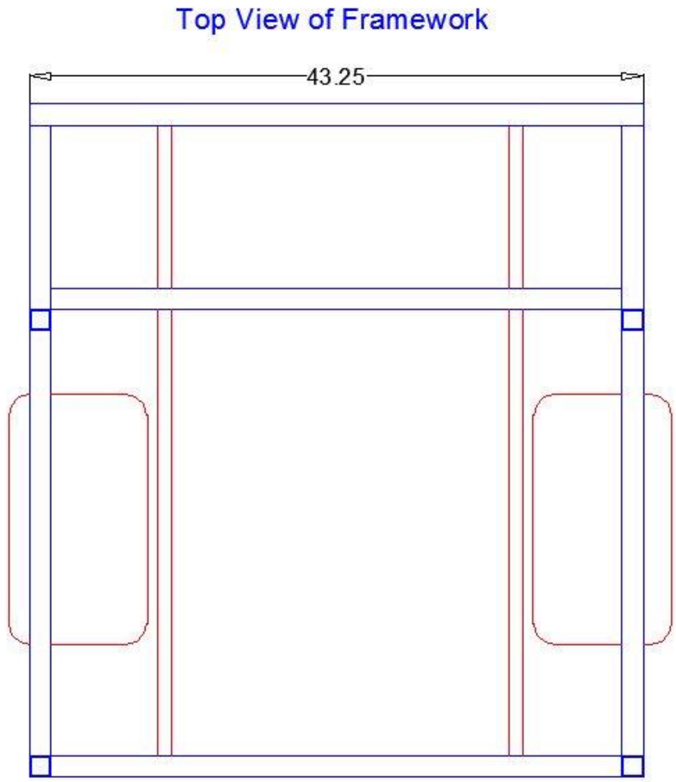


Figure 8. Front Bar of Seat

A horizontal piece that was the same width of the golf cart, 43 ¼ inches, was designed to sit on top of the two front uprights (Figure 8). This was the front part of the seat.

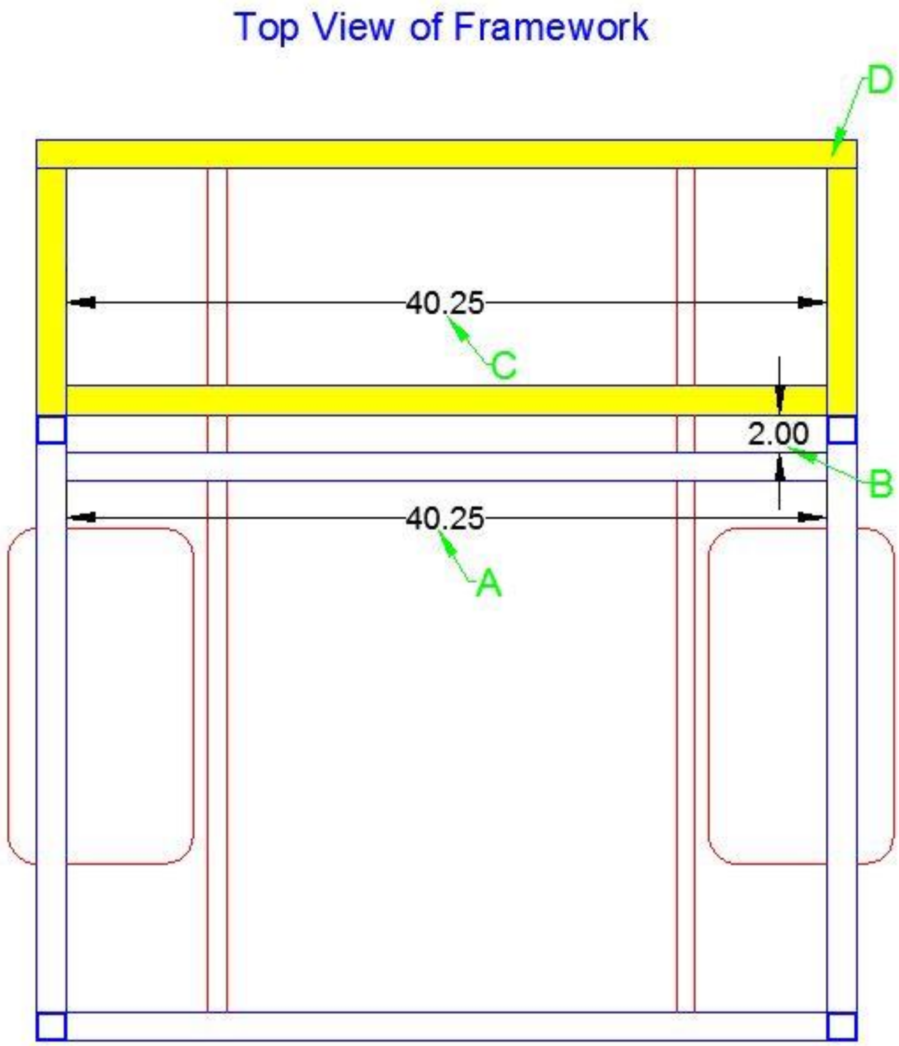


Figure 9. Middle Support Member

A measurement was taken between the two rear uprights (Figure 6 (D)). This measurement was 40 ¼ inches. This piece was placed down 3 inches from the top of the rear upright so that it would also tie into the frame rails (Figure 6 (E)). The same dimension, 40 ¼ inches, was also used for the piece that was placed between the two middle uprights (Figure 9 (A)). This piece was moved two inches towards the rear of the golf cart until it could be tied into the frame rails (Figure 9 (B)). This allowed for more of the new framework to be tied into the golf cart's frame rail.

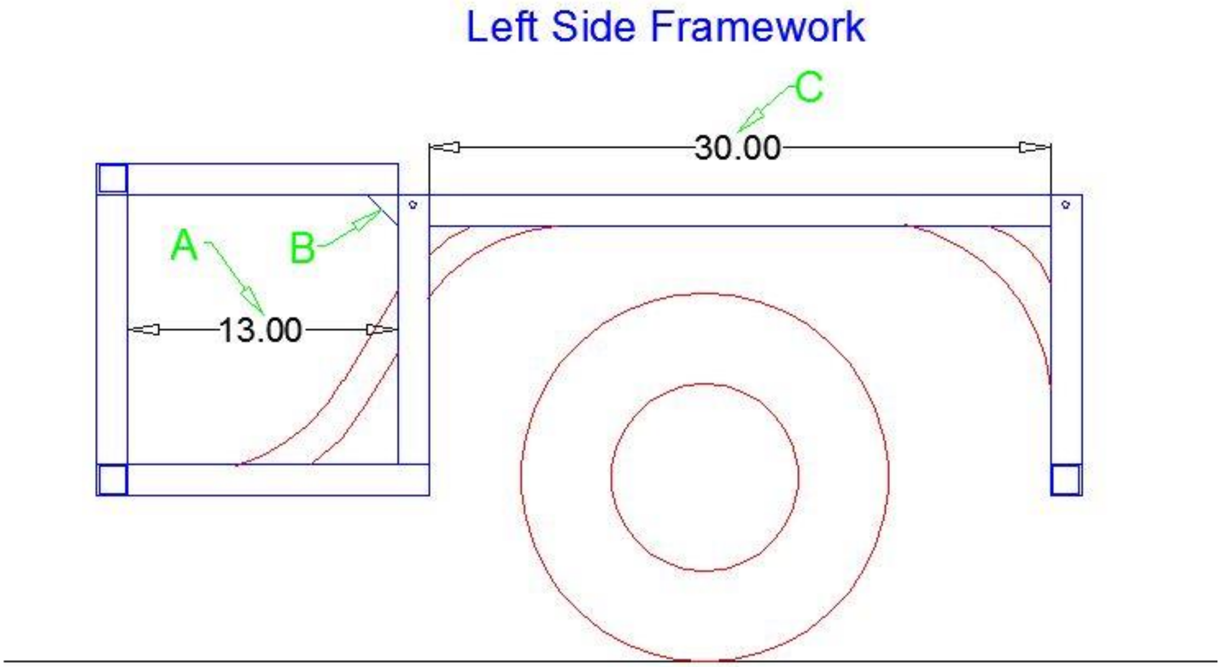


Figure 10. Left Side Framework

A measurement was taken from the back side of the front horizontal piece back to the front part of the left middle upright (Figure 10 (A)). This measurement was 11 ½ inches. This was the same dimension on the right side. Another measurement was taken between those two horizontal pieces (Figure 9 (C)). The measurement was 40 ¼ inches. This rectangular area was the seat frame (Figure 9 (D)). Two triangular gussets were placed on both the right side and left side middle uprights attached to the horizontal pieces of the seat running towards the rear of the golf cart for support (Figure 10 (B)). There were two horizontal pieces, 30 inches long, that fit in between the middle uprights and rear uprights that run towards the rear of the golf cart (Figure 10 (C)).

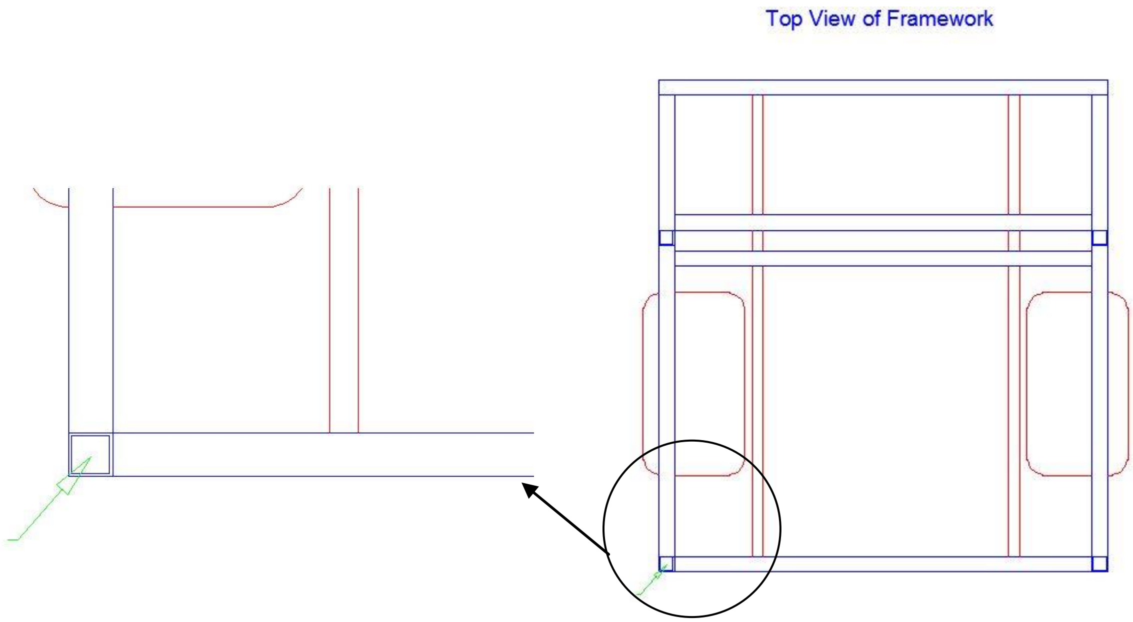


Figure 11. Open Ended Upright

Rather than sitting on top of the uprights, these pieces fit level with the top of the uprights so that both the acquired height was kept and it would allow the two middle uprights and two rear uprights to have an open end (Figure 11). These open ends were purposefully left that way so that the equipment box mounts would be able to slide in.

Equipment Box. Figure 12 through Figure 17 show where measurements were taken for the equipment box.

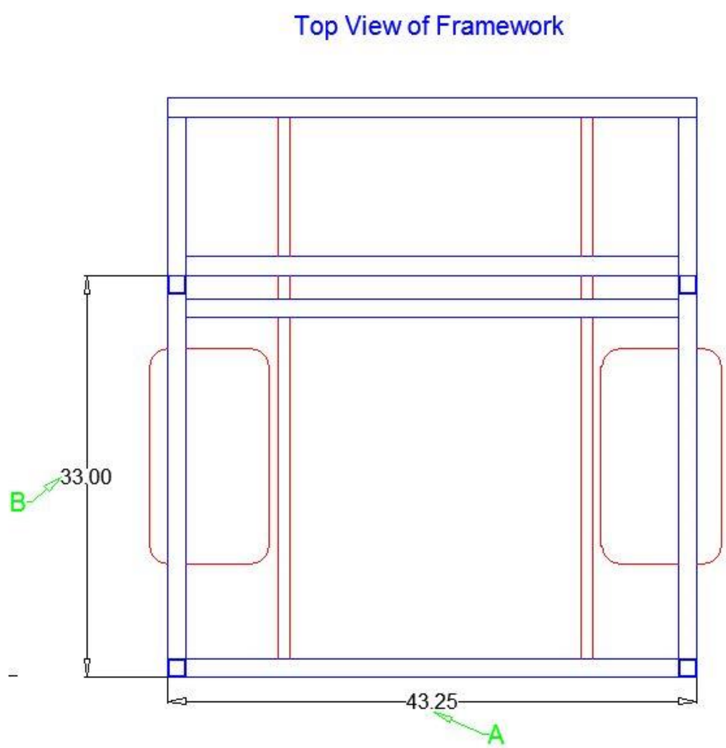


Figure 12. Equipment Box Width and Length

The width of the equipment box was designed to be the same width of the golf cart and the framework, which was 43 ¼ inches (Figure 12 (A)). The length of the equipment box was measured from the rear of the seat frame to the rear of the framework (Figure 12 (B)). This measurement was 33 inches.

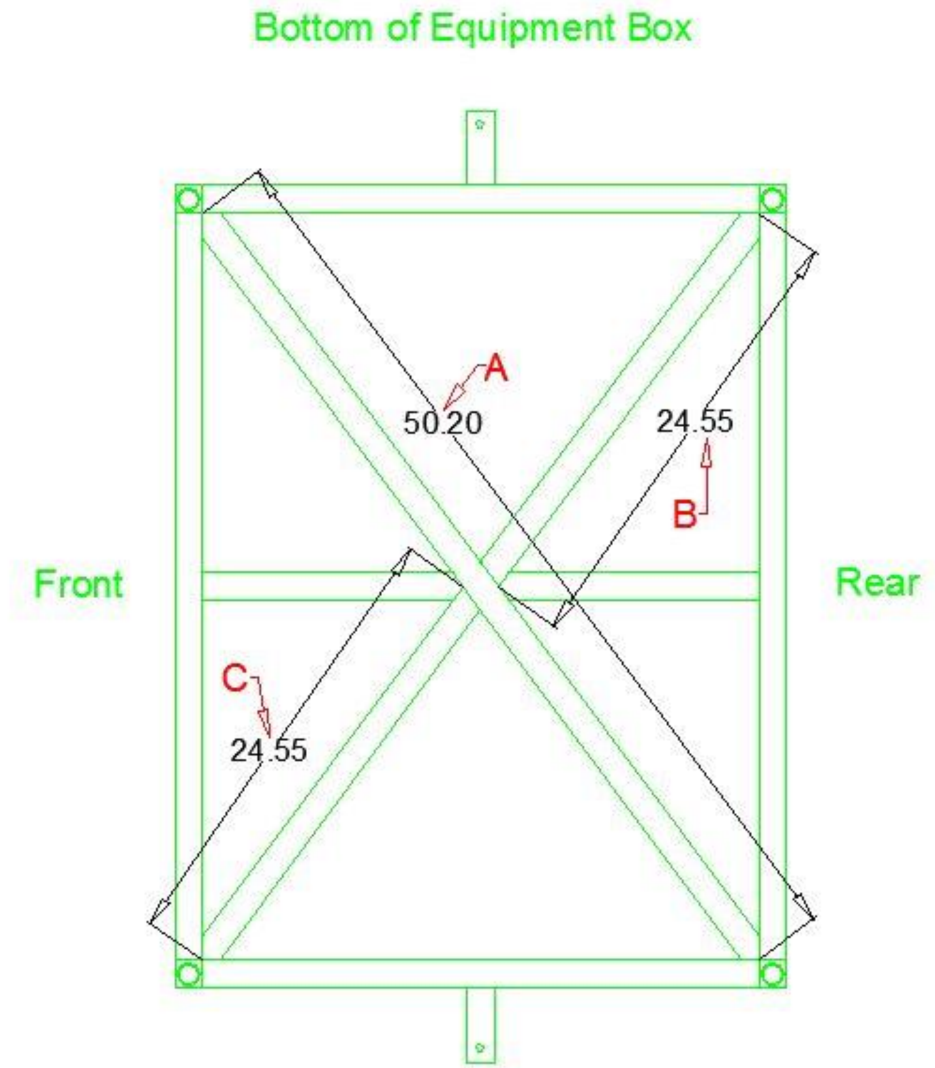


Figure 13. Equipment Box "X"

To give the equipment placed in the equipment box more support, an "X" was added (Figure 13). One part of the "X" running from the right rear corner to the left front corner was 50 3/16 inches (A), and the other part of the x was measured as 24 9/16 inches for one piece (B) and 24 9/16 inches for the other piece (C) (Figure 13).

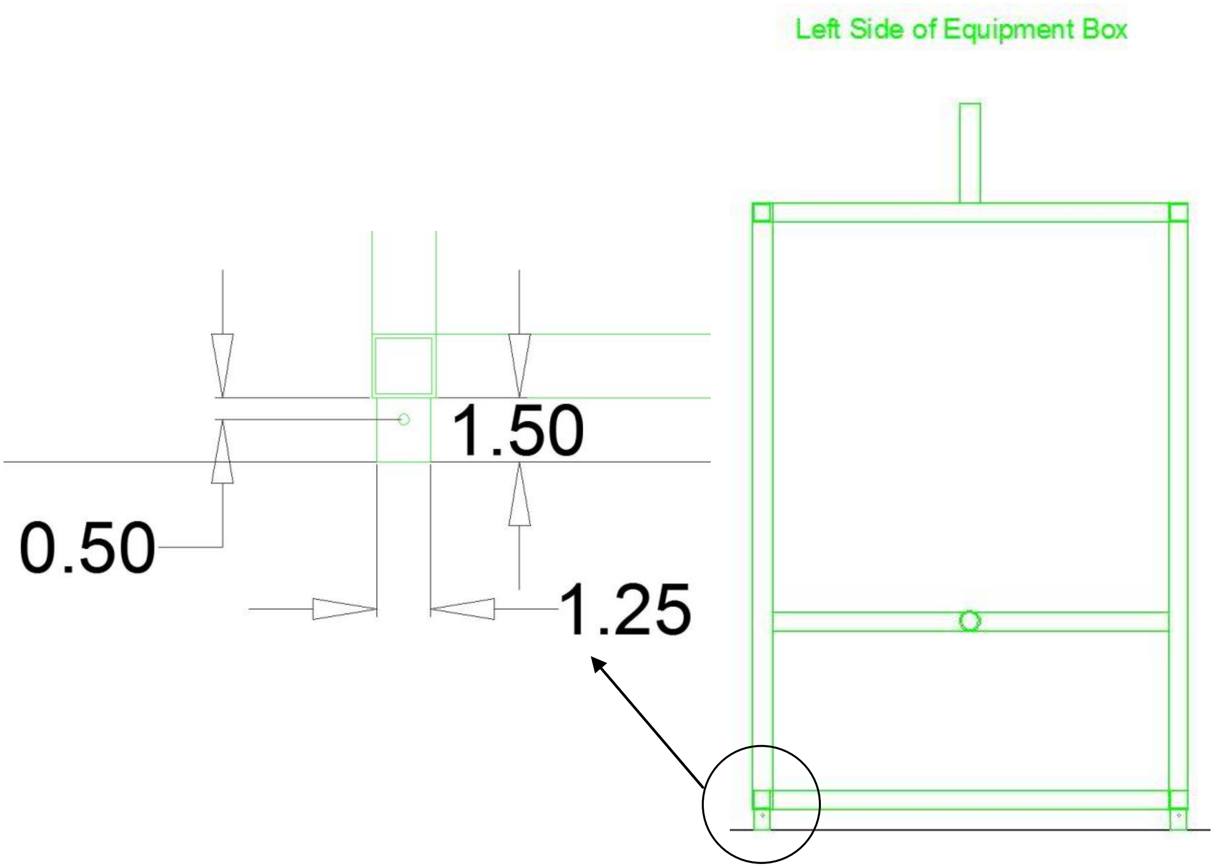


Figure 14. Equipment Box Mounts

At the bottom of each corner, a 1 ½ inch long piece of 1 ¼ inch round tubing was added as equipment box mounts so that the equipment box would slide into the four uprights of the base frame and was secured by two ¼ inch holes that were bolted to the framework (Figure 14).

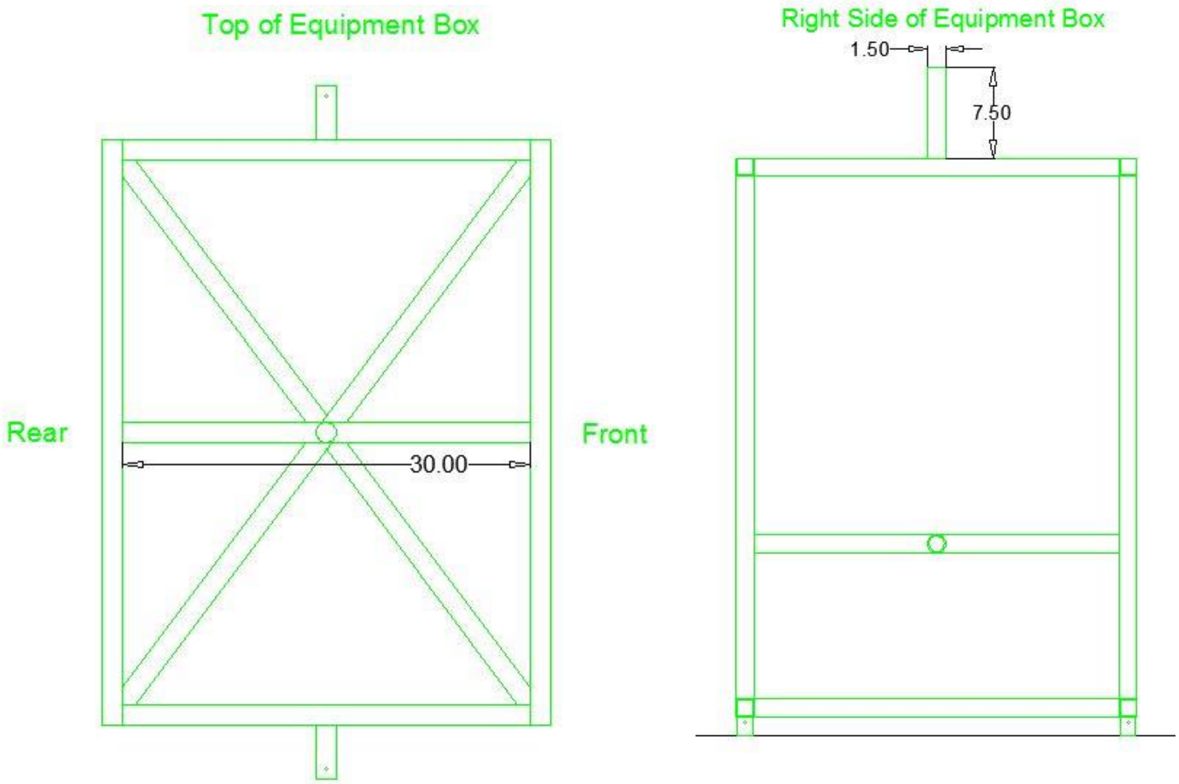


Figure 15. Center Tire Support

The same dimensions, excluding the "X", were used for the top rectangular piece of the equipment box; with the width being 43 ¼ inches and the length being 33 inches. The top rectangular frame piece of the equipment box had an additional member going from the center of the left piece to the center of the right piece (Figure 15). This piece was 30 inches. In the center of that member, there was a 7 ½ inch long capped piece of 1 ½ inch round tubing going straight up (Figure 15). This was used as a spot for a tire to be held.

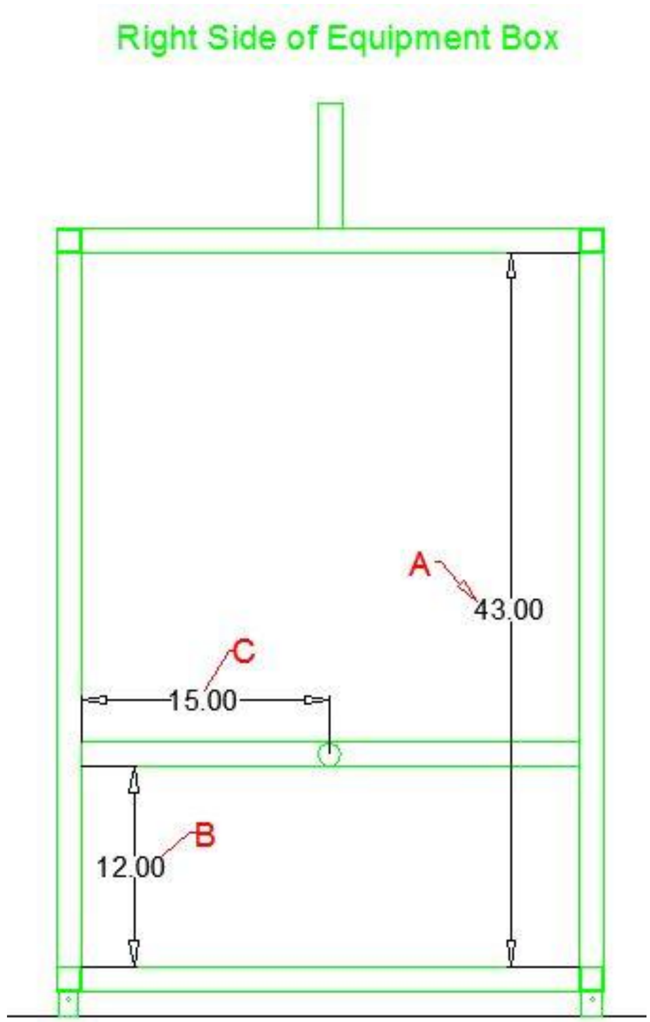


Figure 16. Equipment Box Height

The height of the equipment box was designed so that the height of a piece of aluminum sheet metal could cover the height of the equipment box. The dimensions of one sheet of aluminum sheet metal are 48 inches by 120 inches. Therefore the height of the equipment box was 46 inches tall, with 2 inches of play. All four vertical beams were 43 inches because they sat on the bottom rectangular framework piece and the top rectangular piece sat on the top of the vertical pieces (Figure 16 (A)). A 30 inch long straight horizontal beam of square tubing was added between the left front and left rear vertical beam, and another 30 inch long straight horizontal beam was added between the right front and right rear vertical beam. The bottom of this horizontal beam of tubing on both sides were placed 12 inches up from the bottom of the vertical beam (Figure 16 (B)). A 4 inch long piece of 1 ½ inch round tubing was placed in the center of the left side horizontal piece 15 inches from the edge (Figure 16 (C)). A duplicate piece was on the right side horizontal piece with the same dimensions. These pieces were one component of the tire holders.

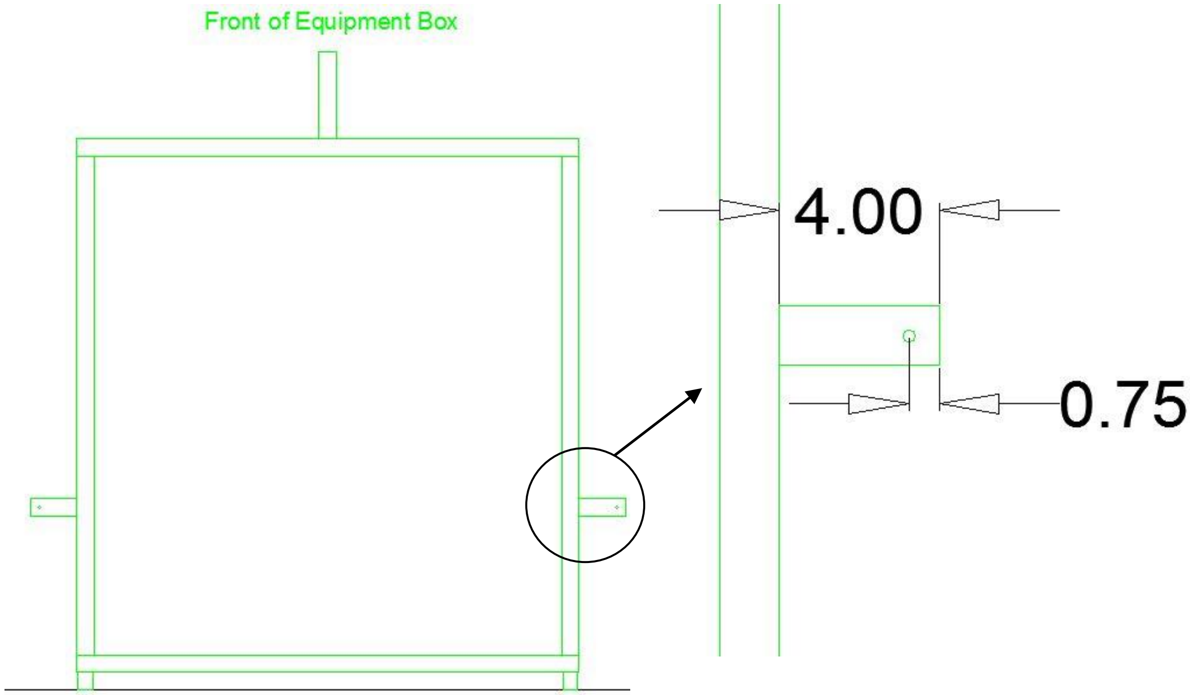


Figure 17. Component of Tire Holder

These two round tube pieces had four 5/16 inch holes that were ¾ inch from the outer edge inward (Figure 17). Two holes are perpendicular to the horizontal beam, and two holes are parallel to the beam (Figure 17).

Tire Holders. Figure 18 and Figure 20 show measurements for the tire holders.

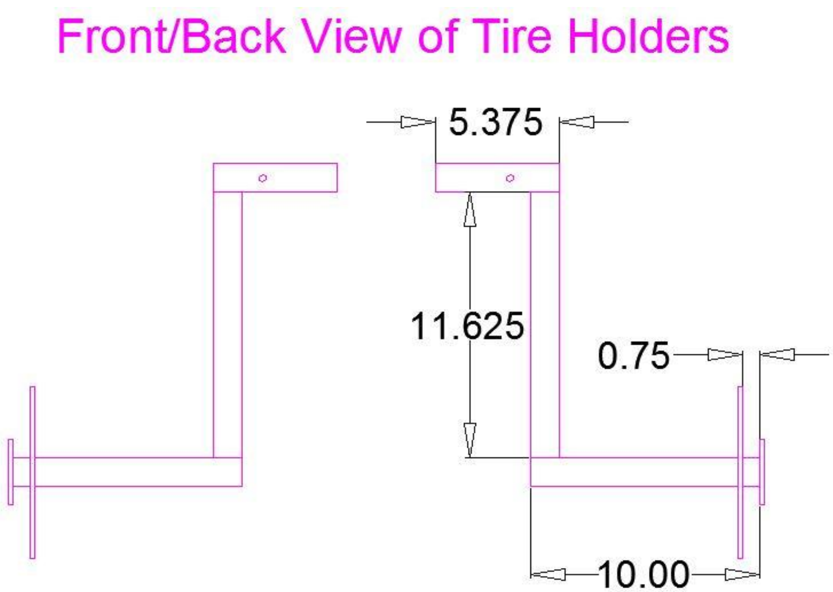


Figure 18. "S–Shaped" Component of Tire Holder

The first component of the tire holders were the round tubing pieces attached to one of the horizontal beams on the equipment box discussed above. The second component of the tire holder was "s-shaped" (Figure 18). This "s-shaped" piece starts with a piece of 1 ¼ inch round tube designed to slide into the 1 ½ inch round tube attached to the equipment box so that it would be able to spin (Figure 18 (A)). The length of this piece was designed to be 5 3/8 inches long so that the tire, when mounted, will stick out far enough so that tire sanding can be complete. Another piece of 1 ¼ inch tubing was added to the end of the first one at a 90 degree angle (Figure 18 (B)). This piece was set at 11 5/8 inches so that when the tire mount was set to the lowest position, the tire will be at a height of a typical person's waist. Another piece that was 10 inches long was added to that piece at a 90 degree angle in the opposite direction of the 5 3/8 inch piece (Figure 18 (C)).

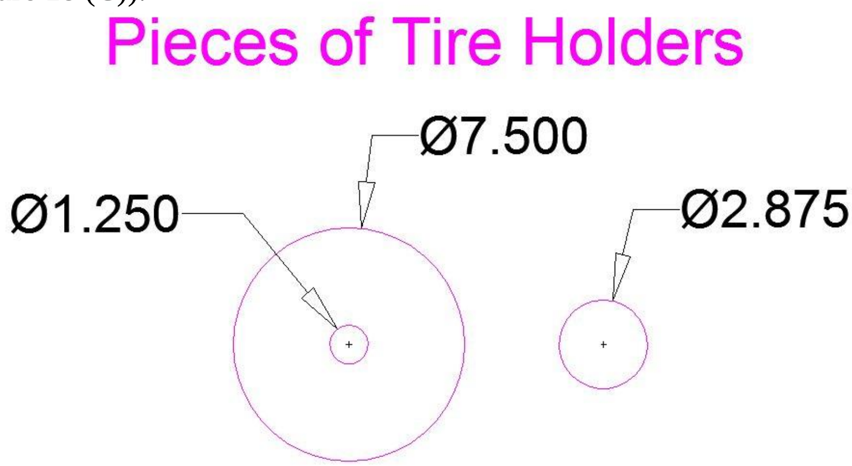


Figure 19. Circular End Caps

A 7 ½ inch diameter "donut" shaped piece of 3/16 inch steel plate with a 1 ¼ inch diameter circle cut from the center was designed to slide onto the 10 inch long piece (Figure 19). It was located ¾ inches from the edge of the 10 inch long piece (Figure 18). Also located on the end of the 10 inch long piece was a 2 7/8 inch diameter circular piece of 3/16 inch steel plate was attached to cap the round tubing (Figure 19). The circular piece was designed to have a diameter of 2 7/8 inch so that it was slightly smaller than the diameter of the tires rim hole (Figure 20). The tires rim hole is shown below.

Figure 20. Rim Hole

This allowed for the tire to be slid over the circular piece while preventing it from sliding off. The two circular pieces were designed so that the tire does not slide off the edge or towards the golf cart. The rims of the stock car tires are not balanced directly in the center because there are different offsets. The tire will not balance perfectly when sitting on top of a piece of round tubing. The two circular pieces “pinch” the rim in between the two and prevents it from falling over.

Cabinet Doors. A 23 ¾ x 47 ¾ inch piece of ¾ inch thick wood was used for the rear cabinet doors because it was easier to construct and design than a sheet metal door would be. It was much simpler to use wood because it did not need framework to strengthen it like sheet metal did. Wood was also easy to work with because screws were used to attach each component rather than bolting or pop riveting.

The following Figure shows the dimensions of the cabinet door with all the proper components.

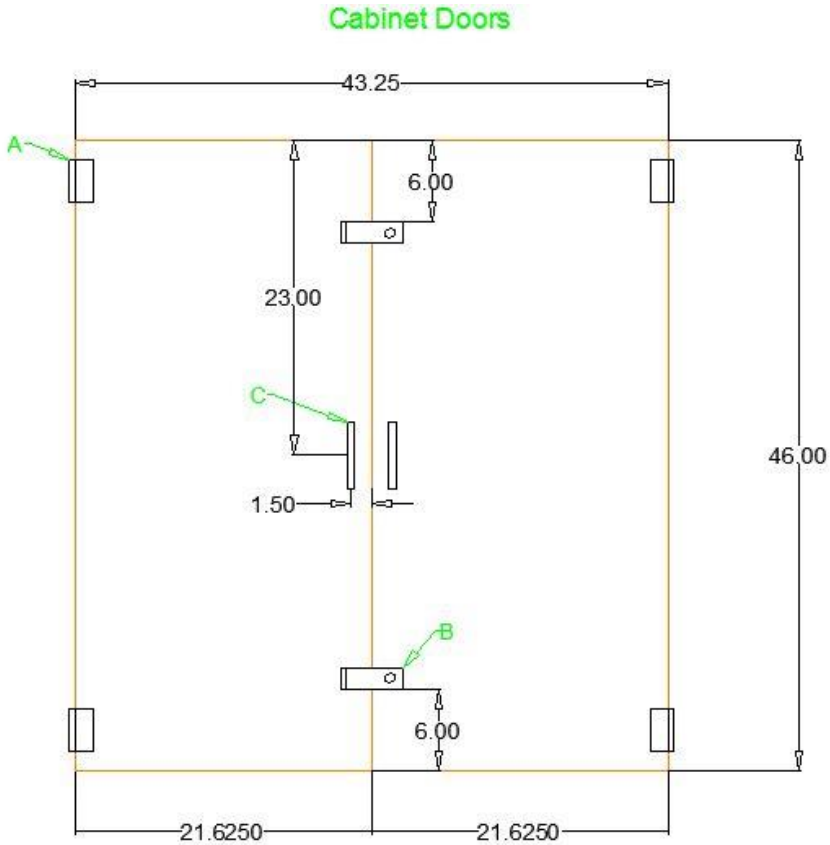


Figure 21. Cabinet Doors with Components

The equipment box has two doors located on the rear that open from the center outward (Figure 21). On each corner, 1 ½ inches down from the top, there was a 3 inch by 5/8 inch door hinge with one half of it attached to the equipment box frame and the other half attached to the cabinet door for a total of four hinges (Figure 21 (A)). The door on the left was 46 inches long and 21 5/8 inches wide. The door on the right was also 46 inches long and 21 5/8 inches wide. At the bottom and top of the cabinet doors located 6 inches down from the top/bottom, a 4 ½ inch latch was mounted. The hinge side of the latch was mounted on the left door (Figure 21 (B)). The small square piece was mounted on the equipment box's right cabinet door. Two 4 ¾ inch by ½ inch door handles were added, one on each door. The door handle was located 23 inches down from the top and 1 ½ inches over from where the two doors met (Figure 21 (C)).

Fabrication Procedure

Framework and Equipment Box. The project fabrication consisted of cutting all the square tubing with an electric metal cut off saw. Excluding the "X" that was needed for the base of the equipment box, every piece of square tubing was cut at a 90 degree angle, perpendicular to the cut off saw blade. Cutting each one of these pieces at a 90 degree angle allowed for each piece to butt up against another piece with a 90 degree angle.

The following picture shows the "X" pieces that were cut out to fit the base of the equipment box.

Figure 22. "X" Component of Equipment Box

The only pieces that were cut at an angle were the three pieces that formed the "X" of the equipment box. The piece that ran from the right rear corner to the left front corner of the equipment box was originally cut at a 90 degree angle to the desired length of 50 3/16 inches (Figure 22).

The following picture shows the chop saw that was used to cut all of the square and round tubing.

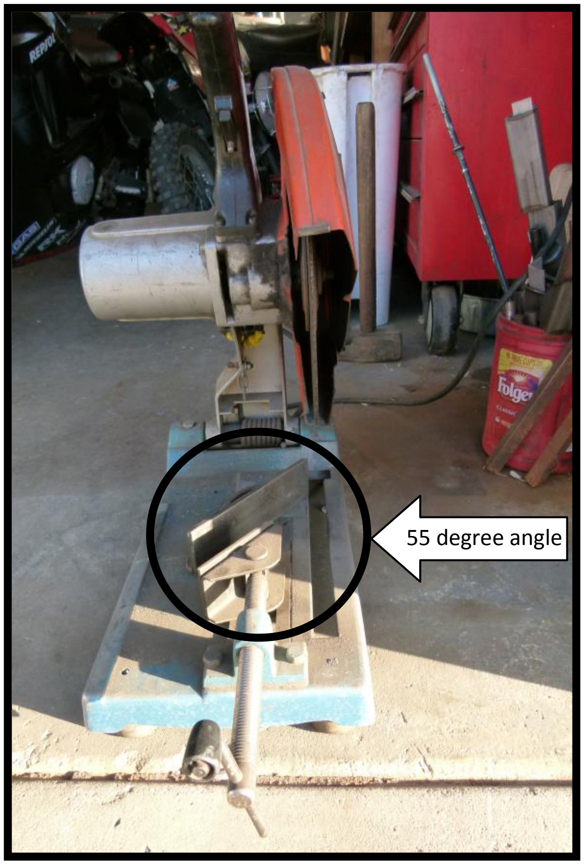


Figure 23. Chop Saw with 55 Degree Angle

From this point, the cut off saw vice was turned to a 55 degree angle (Figure 23). It was turned to a 55 degree angle because this piece fit in the corner of the lower rectangular part of the equipment box, so the corners needed to be cut off. The 50 3/16 inch piece was placed into the vice so that the blade of the cut off saw would cut off the corners of the square tubing. Once this was done, the end of the square tube had a point. This same procedure was done on both sides. The length of the piece after the cuts was still 50 3/16 inches from point to point. The other two pieces of the “X” were 24 9/16 inches in length (Figure 1). Each piece should have one corner that has a 55 degree cut, exactly like the long piece of the “X”. The other end, since it does not go to the other corner, has a different angled cut. The angle of this end was 18 degrees.

The following image shows a round tube that has been coped to fit on another round tube.

Figure 24. Round Tubing Coping

The “s-shaped” tire holder pieces were cut at a 90 degree angle, but one edge of each piece was “coped” so that it fit on the other piece of round tubing without big gaps. These pieces of round tubing were coped by using an electric depressed center wheel grinder. This was done by grinding the edge of the round tubing until it looked like an arc (Figure 24).

The following figure shows the two circular components of the tire holders.

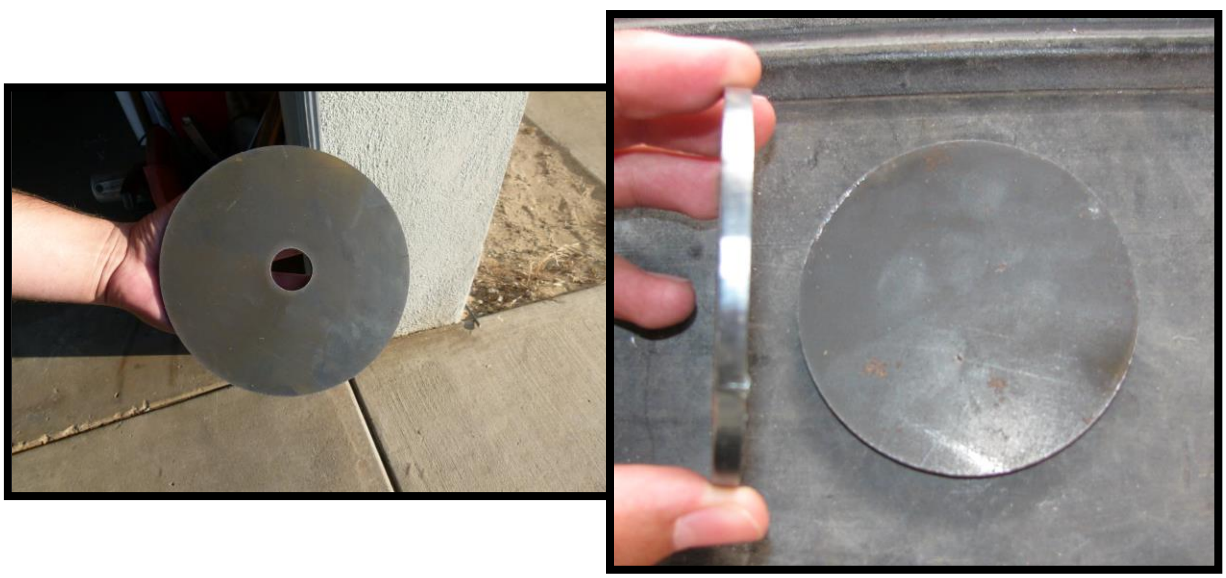


Figure 25. Tire Holder End Pieces

Another component of the tire holders were the circle pieces that go on the ends. The two 7 ½ inch diameter “donut” shaped pieces and two 2 7/8 inch diameter circles were cut from a plasma cutter to achieve a precise cut (Figure 25).

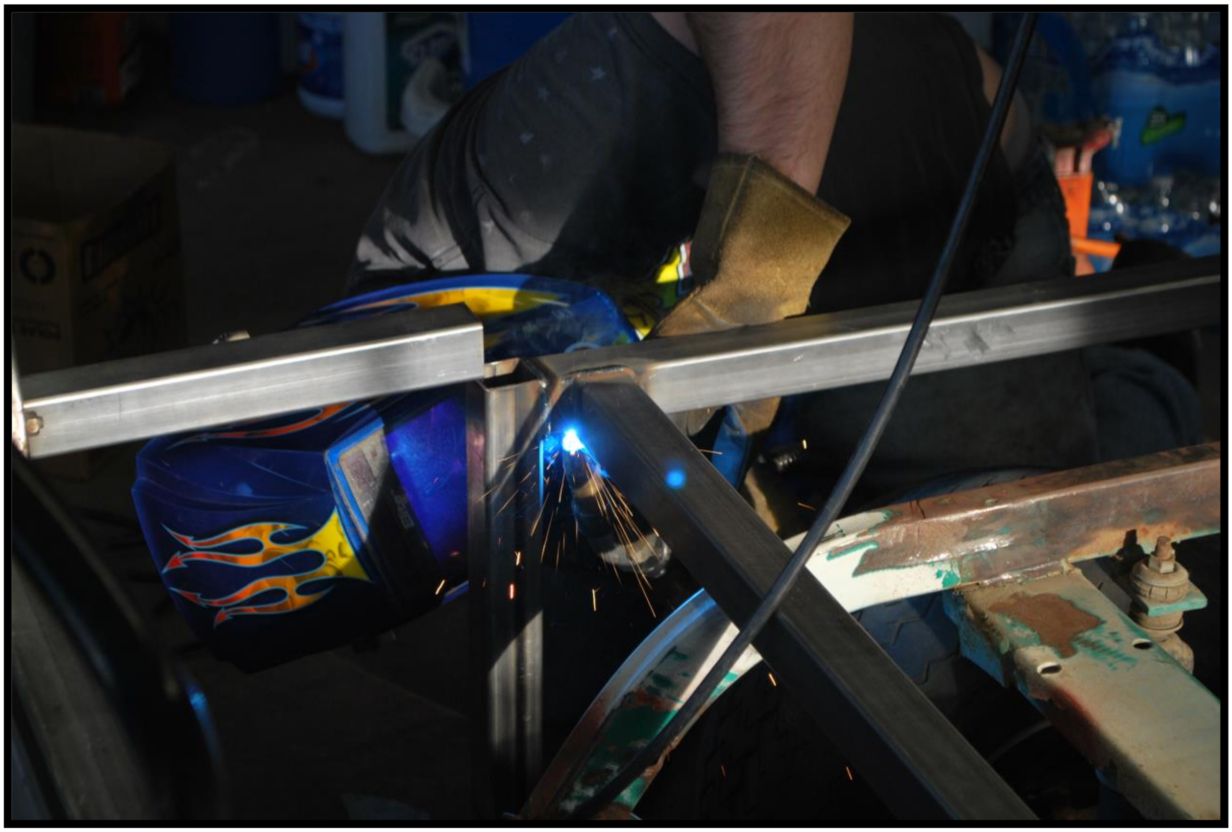


Figure 26. Pieces Mocked Up Being Welded

Once all pieces were cut out to the correct lengths, they were then mocked up to be welded. The AutoCAD drawings were referred to so that the correct length pieces were welded together in the correct position (Figure 26). For this project a Lincoln Electric 110 MIG welder was used. However, other methods of welding such as arc welding or TIG welding could also be used. To find the amperage and wire speed needed, look at the suggested amperage and wire speed table that is located on your welder, in the welder manual, or online, based on the thickness of the material being welded and the wire size. When welding components together, make sure that they are square to each other by using a square. This makes sure that each component welded will turn out level and square to each other.

Figure 27. Cabinet Door Hinge

The equipment box cabinet doors used a total of four hinges, two door handles, and two latches. Each door handle was placed in the correct position, 23 inches from the top and 1 ½ inches over from the center edge. They were then screwed into place. Each hinge was placed in the correct location, 1 ½ inches down from the top, and firmly clamped. Half of the hinge was drilled and pop riveted into the square tubing. This was done on all four corners. The left cabinet door was placed up against the hinging part of the hinge and was then screwed in (Figure 27). The left side door was then able to open and close. The right side cabinet door was done the same so that when closed fits flush with the left side door. The latches were then laid out six inches from the top and six inches from the bottom. Once they were in the correct position, they were screwed into place. The cabinet doors were then able to open, close, lock, and unlock.

Paint. The following image shows the resulting paint job on the framework and equipment box.

Figure 28. Painted Framework and Equipment Box

Once all of the framework and the equipment box were complete, the painting process began. Before the actually painting took place, both the framework and equipment box were wiped down with paint thinner to get off all of the oil and grease on the metal. A slight sanding with 180 grit sandpaper was done to slightly scratch the surface of the metal so the paint would stick better. The metal was then wiped down with paint thinner a second time to do the final cleaning. When all of the metal was free of dirt, grease, oil, and everything else, a coat of black primer was sprayed on. Any color primer could be used however. This primer was left to dry for approximately 30 minutes, in which the final painting process was ready to begin. Satin black was the color of choice, and it took two spray cans to complete the entire paint job (Figure 28). After the painting was complete, it was left to dry for one day before it was worked on again.

Woodwork. Five pieces of wood were used; one for the seat, one for the equipment box base, one for the equipment box shelf, one for the left cabinet door, and one for the right cabinet door.

Figures 29 through 31 show each piece of wood that were cut out.

Figure 29. Wood Seat Piece

The seat was cut out from ¾ inch cabinet grade plywood. It was a rectangular shape with dimensions of 12 ¾ inches by 43 3/16 inches (Figure 29).

Figure 30. Equipment Box Shelf and Base Board

The equipment box shelf was also cut out from ¾ inch cabinet grade plywood. The equipment box shelf was rectangular, with dimension of 32 5/8 inches by 42 5/8 inches. However, for the shelf piece, a 1 ¾ inch x 1 ¾ inch square piece was cut out of each corner so that the shelf piece wouldn't hit the uprights of the equipment box (Figure 30 (one on left)). The equipment box base piece was cut the same dimension as the shelf piece, including the 1 ¾ inch x 1 ¾ inch square pieces cut from each corner. However, this piece was only 3/8 inch ply wood instead of ¾ inch ply wood. A thinner material was used for the base piece because it did not need to be as strong due to the support from the equipment box X member (Figure 30 (one on right)).

Figure 31. Two Cabinet Door Wood Pieces

The last two pieces of wood cut were from a ½ inch thick board. Each piece was cut into a 21 5/8 inch by 46 inch rectangle that was used for the rear cabinet doors (Figure 31).

Sheet Metal. Sheet metal was cut and bent by a local sheet metal fabricator, Johnny "Fab" Kuma. One sheet of aluminum is 48 inches by 120 inches, so each side of the framework and equipment box was laid out in AutoCAD to determine which pieces would be able to fit in one sheet of aluminum with the smallest amount of waste. It took two sheets of aluminum to do all of the pieces with very little scrap. The dimensions and list of which pieces were to be cut out on the same sheet were sent to Johnny Fab in which they were cut and bent to the correct dimensions. The left side piece and front side piece of sheet metal each had a one inch 90 degree bend on one side so that it would wrap around the square tubing, leaving a nice edge. The top piece was cut so there were 1 ½ inch 90 degree bends on each side. The left and right side aluminum pieces for the framework were cut to a rectangle. They were laid up against the framework in the correct space in which a scribe was used to scribe a line to get the correct size wheel opening. It was then cut out along the scribe mark and placed up against the framework to see if it fit. From here, trimming was done until the wheel openings were large enough so that the tires would not rub. One by one, each piece of sheet metal was placed in the correct position by use of clamps.

When drilling the holes to fasten the aluminum to the framework and equipment box, the holes were laid out with a ruler and marked with a pen so that they would be the same distance apart and in a straight line. Once all holes were laid out, the drilling process began. A #11 drill bit was used so that aluminum 3/16 inch pop rivets would fit. A #11 drill bit is approximately three thousandths of an inch larger than 3/16 so the pop rivet will go into the hole easily without too much play. After drilling each hole, a fastener, called a cleko, was put into the hole to keep the aluminum panel in place. After all the holes were drilled, the clekos were pulled out, and the aluminum panels were taken off. Each hole that was drilled was de-burred so that the aluminum panels would sit flush against the square tubing. From here, the aluminum was put back onto the framework and equipment box with a cleko in every other drilled hole. Pop rivets were placed in the holes that did not have clekos and they were pop riveted in. Once all the empty holes were pop riveted, the clekos were removed from the other drilled holes and these holes were pop riveted.

RESULTS

Once the equipment box was complete, it was ready to be tested. The requirement that the equipment box had to meet included: being able to fit in a 91 inch by 53 inch truck bed, tire holders must be able to swivel 360 degrees and lock in four positions in order for ease of tire sanding, must be able to attach/detach to the back of a golf cart, must be able to hold two 28 inch diameter stock car tires, a 28 inch x 13 inch x 6.5 inch floor jack, a 14 inch x 9 inch x 4 inch battery powered impact gun, a 21 inch x 12 inch x 12 inch portable air tank, and miscellaneous tools. The equipment box successfully held all of the requirements and held up to dimension specifications. Not only was the equipment box able to hold two tires, a floor jack, an impact gun, a portable air tank, and some miscellaneous tools, but it also held a significant amount of extra equipment. The figure below shows what was held in the equipment box.

Figure 32. All Items Held in Equipment Box

The following table lists each item shown in the picture and their approximate weights.

Table 1. Items Placed in Equipment Box

Equipment Box Equipment	
Items	**Weight (lbs.)**
Tire 1 (Left Rear)	40
Tire 2 (Right Front)	40
Tire 3 (Right Rear Beadlock)	45
Spring 1	10
Spring 2	10
Spring 3	10
Spring 4	10
Spring 5	10
Spring 6	10
Spring 7	10
Spring 8	10
Air Tank	10
Fuel Jug 1 (5 gallons)	40
Fuel Jug 2 (5 gallons)	40
Fuel Funnel	2
Impact Gun	10
Floor Jack	50
Small Box of Miscellaneous Parts 1	5
Small Box of Miscellaneous Parts 2	10
Timing Light Box	5
Water Container	12
Big Hammer	10
Flashlight	1
Spindle	10
Shock	5
Coil Over	15
Coil Over Eliminator	15
Pull Bar	20
Tire Sander	10
Tool Box	70
Total	**545**

As shown above, the equipment box was able to hold a third tire and much more. In total, the equipment box was able to hold approximately 545 lbs. without any problems. The lower compartment of the equipment box was able to hold the springs, pull bar, and other parts that aren't used often. The shelf held items that would frequently be used such as the tool box, fuel jugs, impact gun, etc.

The equipment box was designed so that it would attach/detach from the golf cart with ease. It successfully did so by have four bolts that were located on each lower corner holding it in place. Once the four bolts were removed, the equipment box pulls strait up and off of the rear of the golf cart. The length of the golf cart with the equipment box and the width are also within the specification. The total length is 90 inches, and the total width is 43 ¼ inches. These dimensions are both within the specifications of fitting in a truck bed of 91 inches by 53 inches.

The equipment box was also designed so that two tires would be located on a 360 degree swivel arm so that it could be sanded easily. This swivel arm worked very well and was at the proper height so that an average height person could sand the tire easily (Figure 33). The following image shows the tire sanding in action.

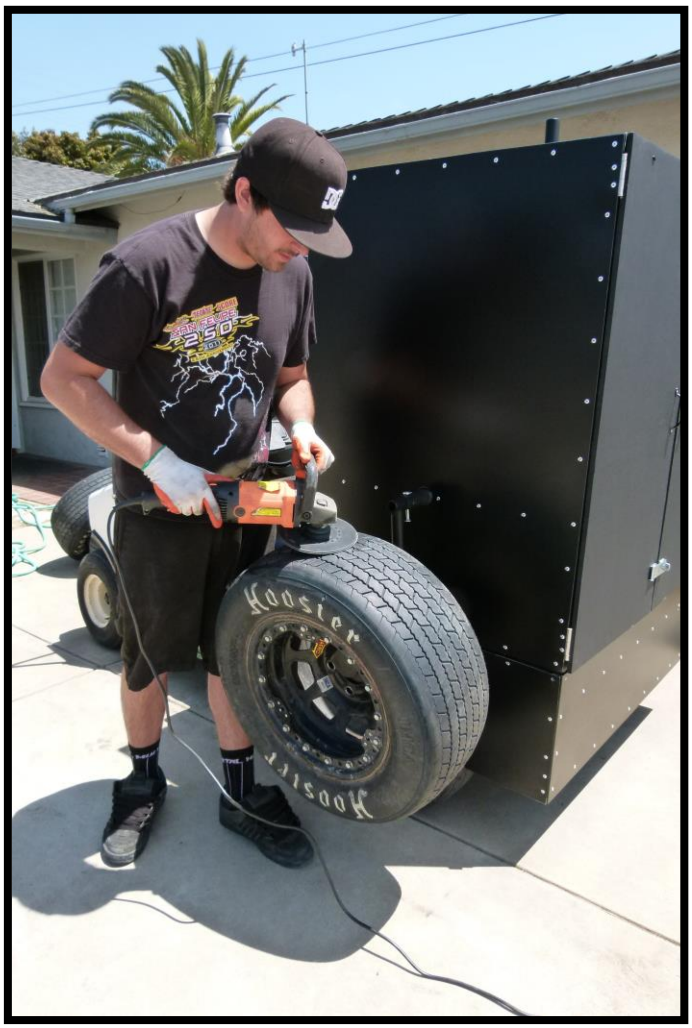


Figure 33. Sanding Tire on Tire Holder

The four different locking positions of the tire swivel arm worked as they were supposed to (Figure 34). The tires were in the lowest position when tire sanding needs to be done. The tires can then swivel to the highest point or to the left or right position so that it clears the bed of the truck when loaded up for transportation. The following figures show the tire in the four different positions.

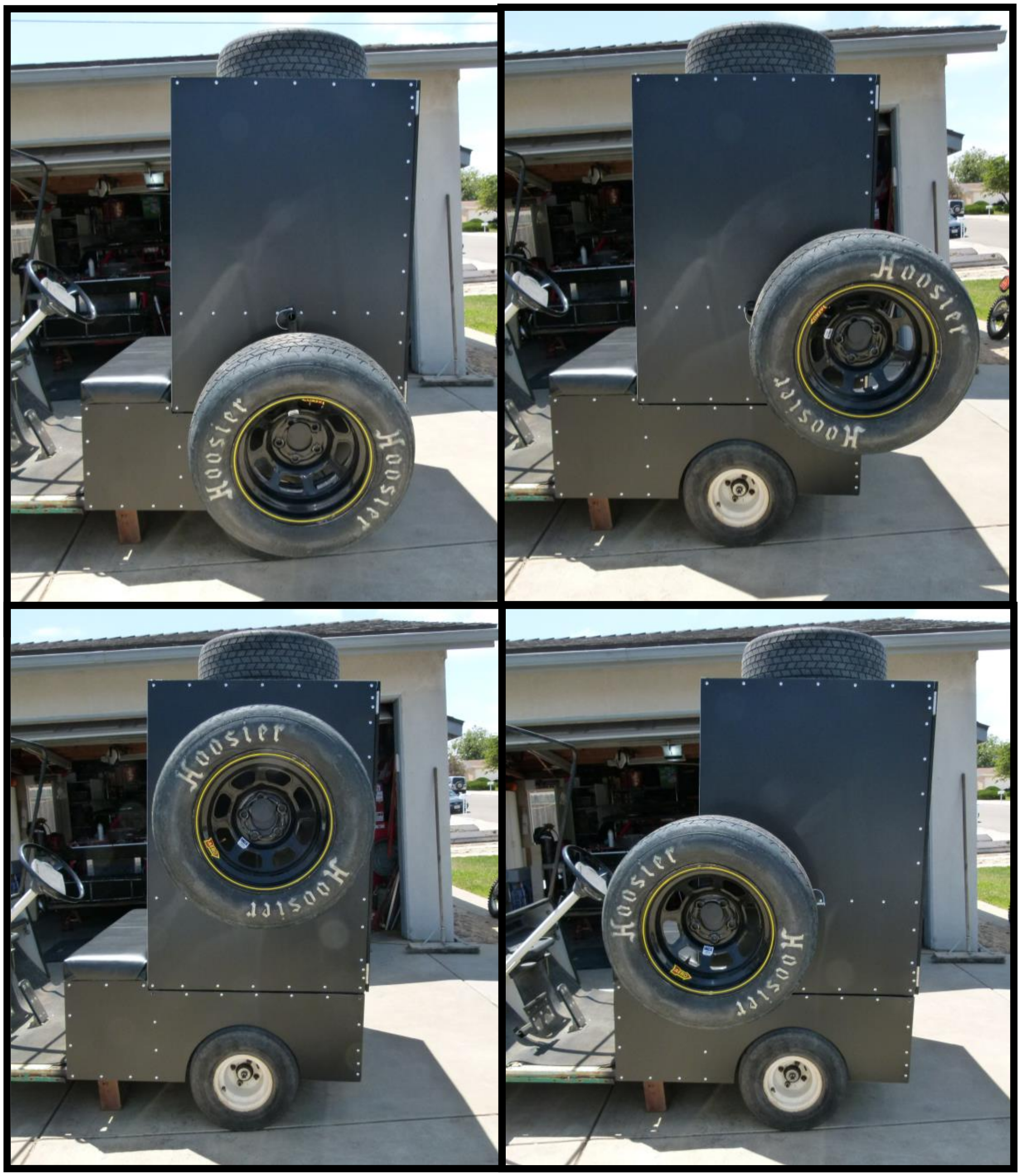


Figure 34. Four Tire Holding Positions

DISCUSSION

Framework

The framework that was added to the rear of the golf cart proved to work and hold the weight of the equipment box and all of the equipment placed in the box. It was designed the way it was with multiple things in mind. First of all, the framework needed to be able to be sturdy enough so that it could hold all of the weight. This was done by tying in the added framework to the already existing frame rails of the golf cart. Doing so made the framework sturdy enough to hold the weight. The second part of the design was to allow for a seat area, and allow for the equipment box to be detachable. The seat area needed to be wide enough so that an average size person could sit on it and not feel like they are falling off. The design of the seat was made to be the same length as the original one, but cut in half so that the equipment box could be made larger. The framework that allowed for the attachment of the equipment box was designed so that the four uprights will be "open" or "hollow" so that the round tube on each corner of the equipment box could slide in. Since there was going to be a lot of weight in the equipment box, it was best to try and get the center of gravity of the equipment box over the rear axles. This was done so that the additional weight on the rear of the golf cart does not make the front of the golf cart too light, and potentially come off the ground.

Equipment Box

The length of the equipment box was determined by where the length of the framework was. The width of the equipment box was designed so that it would be the same width as the golf cart. The golf cart width was small enough so that it would fit in the bed of a truck, so by making the equipment box the same width, it allows for the golf cart to still fit in the back of a truck bed. The height was determined by the width of a sheet of sheet metal. It would not be efficient or cost effective to make the height of the box bigger than the width of a sheet of sheet metal because another piece of sheet metal would have to be used. The tire holder location was set at a certain height so that when the tires are in the down position, a person could sand the tire comfortably. This design turned out to be very successful because it was tested and turned out to be very comfortable and easy to use.

Tire Holders

The tire holders were somewhat difficult to design. They needed to be able to swivel, hold the tire on, and the tire needed to be able to be removed quickly and easily. The tires weight was not centered on the rim, so when the tire sat on the tire holder, it wanted to fall off or lean over to the side. That is why there is small cap on the end that prevents the tire from falling off. There is a big "donut" that is 1 inch over from the cap which prevents the tire from falling over. These pieces sort of pinche the rim and prevents it from both falling off and falling over. It worked very well and does not fall off, yet it is very easy to remove the tire.

Equipment Box Enclosure

To enclose the equipment box, sheet metal was used. It was picked due to its light weight. Since there was a lot of area to cover, the sheet metal does not add much extra weight to the golf cart. It is also very easy to work with and allows for minor alterations to be made without much work. This thickness of sheet metal is relatively strong, and is not very expensive to purchase, which makes it more efficient and cost effective.

Project Duplication Time

The total amount of time it took to produce the finished project was 167 hours. The time breakdown is shown in Appendix C.

The following table shows how much time it would take to do the project a second time if someone were to order one.

Table 2. Project Duplication Time

Project Duplication Time	
Task	**Hrs.**
Deconstruction	10
Design	12
Construction	80
Material Procurement	4
Report	N/A
Preparation of Poster	N/A
Fit Check	N/A
Total	106

Each tasks amount of time ends up going down with the duplication of the initial project. This is due to the familiarity of how to set up everything and the knowledge from completing the first project. The report, preparation of poster, and fit check are all not applicable because if someone were to order one of these equipment boxes, these things would not need to be done.

Project Overhead Costs

The following table shows the overhead of the project.

Table 3. Project Overhead Costs

Overhead Expenses	
Expenses	**Cost**
Electricity	$ 25.00
Transportation (Gas)	$ 25.00
Labor	$ 3,841.00
Total	$ 3,891.00

This project consisted of many hours using electric power tools including welders, grinders, chop saws, etc. It also took multiple trips down to hardware stores to pick up parts, tools, and other necessities needed during construction. As for labor, Table 3 shows the number of hours it took to complete the project. It will cost a company around $23 per hour for a fabricator to be working on this project. This includes his hourly wage, insurance, social security, and other employee costs. This means that it would cost $3,891 to pay for the labor for this projects completion.

Total Cost For Production

Table 4. Total Cost For Production

Total Cost For Production	
Expenses	**Cost**
Overhead	$ 3,891.00
Materials	$ 460.15
Total	$ 4,351.15

After adding up all of the costs, it shows that purchasing one of these equipment boxes is not reasonable. Just one of these equipment boxes would cost $4,351.15, and that is with no profit. An additional $300 would be added to this price in order to make a profit. This brings it to a grand total of $4,651.15. The cost of the equipment box would end up costing more than the actual golf cart, which is not cost effective. The price of the equipment box would be much more reasonable if it were to sell for just the materials cost of $460.15.

RECOMMENDATIONS

The main improvement in the design of this equipment box would be to have a couple small pull out drawers for small tools and equipment. The equipment box right now has two large empty areas to store everything. This works okay, but when there are small parts and small tools, they tend to get lost and float around within the box. If there were small drawers, markers, screwdrivers, and other small tools could be stored in this specified area so that it is secure and easy to get to.

Another improvement that could be made is with the tire holders. The current tire holders work like they were supposed to, but don't keep the tire sturdy. The tire stays on the holder by being pinched together with two round plates. These plates prevent the tire from falling over, but there is a lot of slop, so the tires tend to move around quite a bit. The new improved design should be able to hold the tire stable while also allowing for easy removal in case of a pit stop.

Another improvement that could be made is to change the cabinet doors. Coming up with a design for the cabinet doors was very difficult because there needed to be two doors (because one door would have been too large) and they needed to shut flush against the framework. Aluminum sheet metal would be the ideal material used, but designing this with a locking handle would take time. The designed cabinet door would ideally be able to shut flush against the framework when locked.

REFERENCES

1. DSM Manufacturing Company. 2013. DSM Manufacturing Internet Home page. <http://www.dsmmfg.com/Pages/default.aspx,>, referenced February 12, 2013.

2. National Speedway Directory. 2013. National Speedway Directory Internet Home page. <http://speedwaysonline.com/>, referenced February 15, 2013.

3. Online Metals.com. 2013. Online Metals.com Internet Home page. <http://www.onlinemetals.com/>, referenced February 25, 2013.

4. Strahl, R. 2001. Part II Welding Processes. Kendall/Hunt Publishing Company, United States, pp. 77-196.

APPENDIX A

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

ASM Project Requirements

The ASM senior project must include a problem solving experience that incorporates the application of technology and the organizational skills of business and management, and quantitative, analytical problem solving. This project addresses these issues as follows.

Application of Agricultural Technology. The project will involve the application of fabrication and mechanical system technologies.

Application of Business and/or Management Skills. The project will involve business and management skills in the areas of machinery management, cost and productivity analyses, and time management.

Quantitative, Analytical Problem Solving. Quantitative problem solving will include the bending stress calculations and cost calculations.

Capstone Project Experience

The ASM senior project must incorporate knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge skills from these key courses.

- BRAE 342 Agricultural Materials
- BRAE 343 Mechanical Systems Analysis
- BRAE 129 Laboratory Skills and Safety
- BRAE 151 AutoCAD
- BRAE 418/419 Agricultural Systems Management
- IME 142 Manufacturing Processes: Materials Joining

ASM Approach

Agricultural Systems Management involves the development of solutions to technological, business or management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving. This project addresses these issues as follows.

Systems Approach. The project involves AutoCAD drawings of the design based on ergonomic placement of components. It also involves cutting, welding, and fabricating to build the final product.

Interdisciplinary Features. The project will involve mechanical systems, agricultural safety, and shop skills.

<u>Specialized Agricultural Knowledge</u>. The project utilizes knowledge in areas of mechanical and fabrication systems and agricultural safety.

APPENDIX B

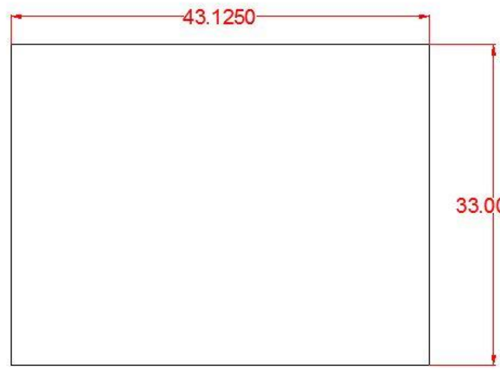
DESIGN DRAWINGS

DESIGN DRAWINGS

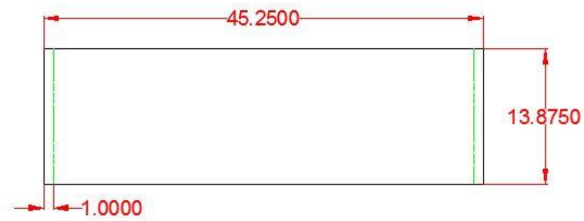
Sheet Metal Drawings

The following images are the different pieces of sheet metal used for the project. All dimensions are shown in inches. The green color shows where 90 degree bends were made.

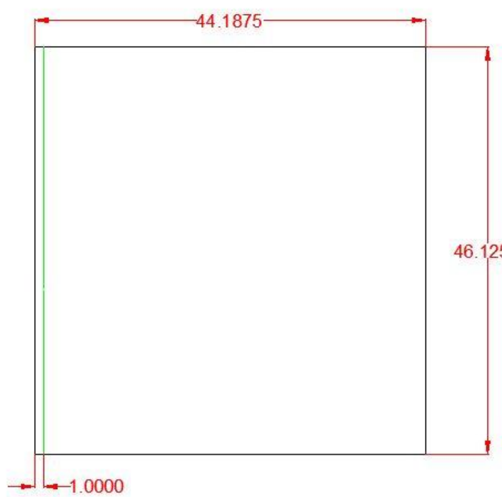
Bottom of Equipment Box



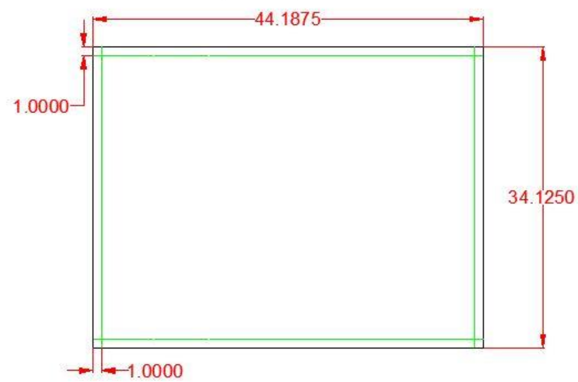
Back of Frame Work



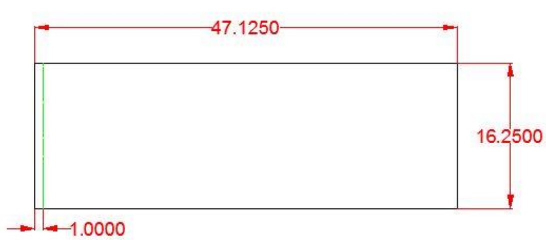
Front Side of Equipment Box



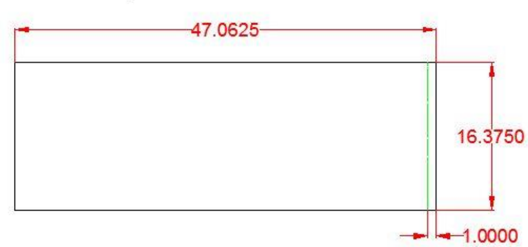
Top of Equipment Box

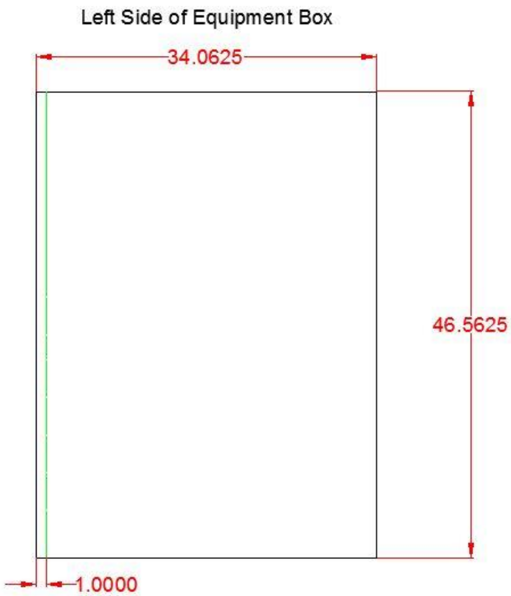


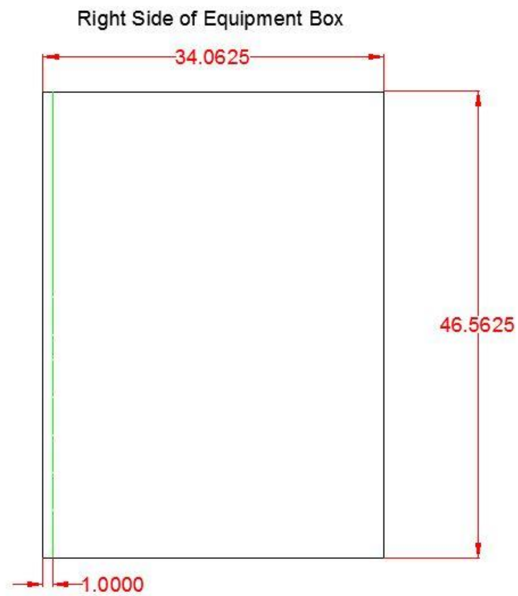
Left Side of Frame Work

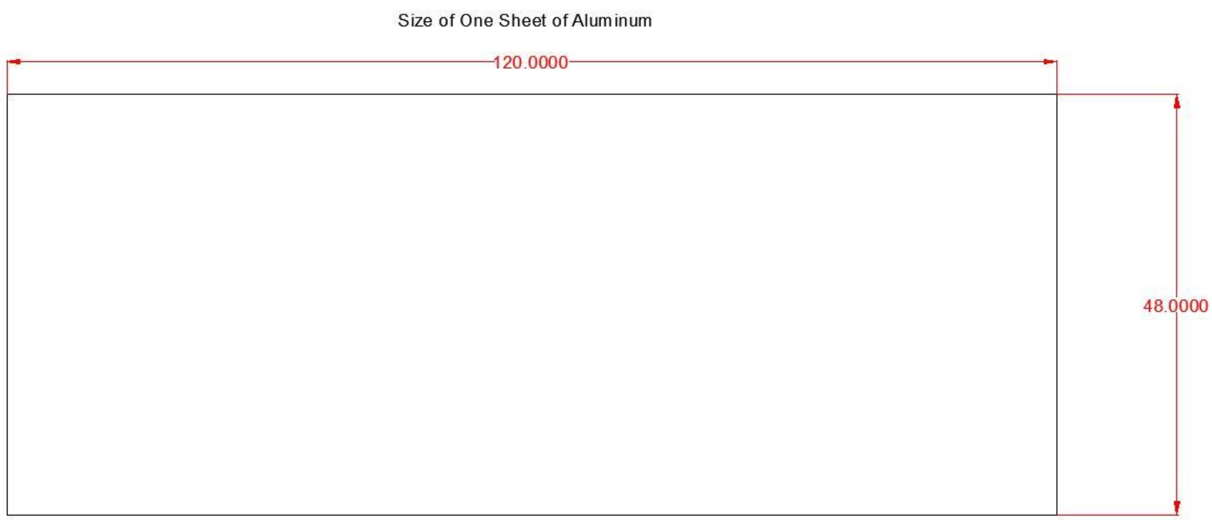


Right Side of Frame Work




Left Side of Equipment Box
34.0625
46.5625
1.0000

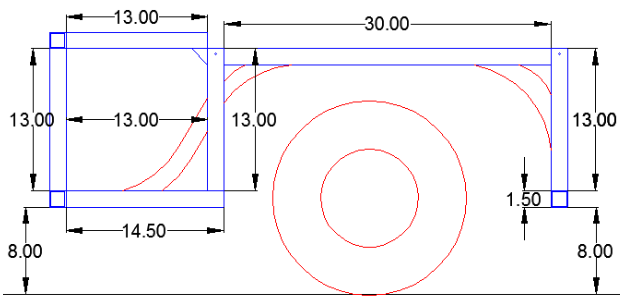

Right Side of Equipment Box
34.0625
46.5625
1.0000


Size of One Sheet of Aluminum
120.0000
48.0000

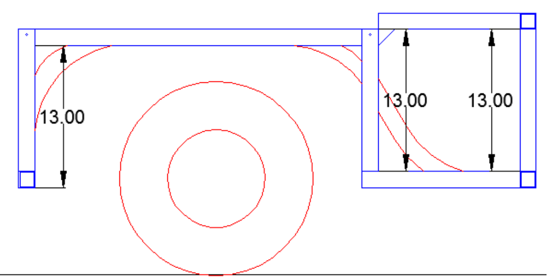
Framework Drawings

The following images are the dimensions of the framework design. All dimensions shown are in inches. The red lines are the pre-existing components of the golf cart.

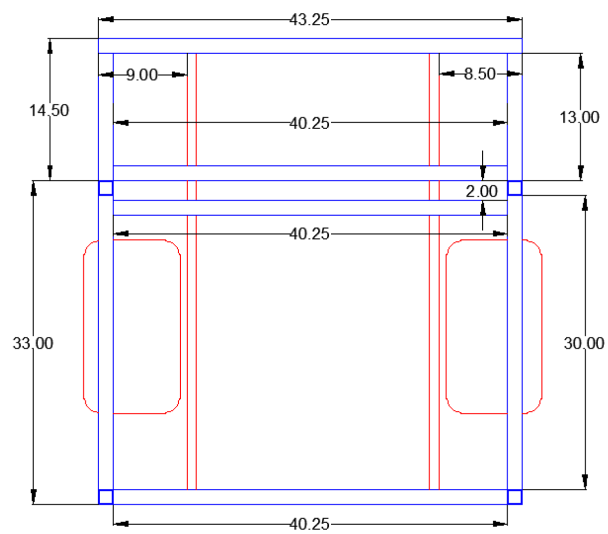
Left Side Framework



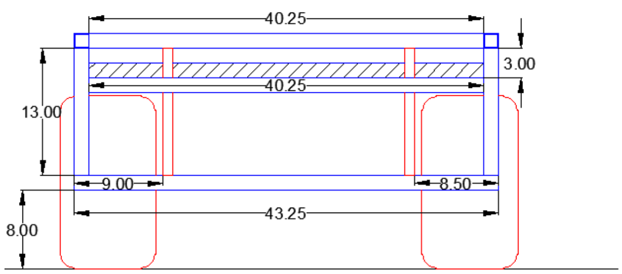
Right Side Framework



Top View of Framework

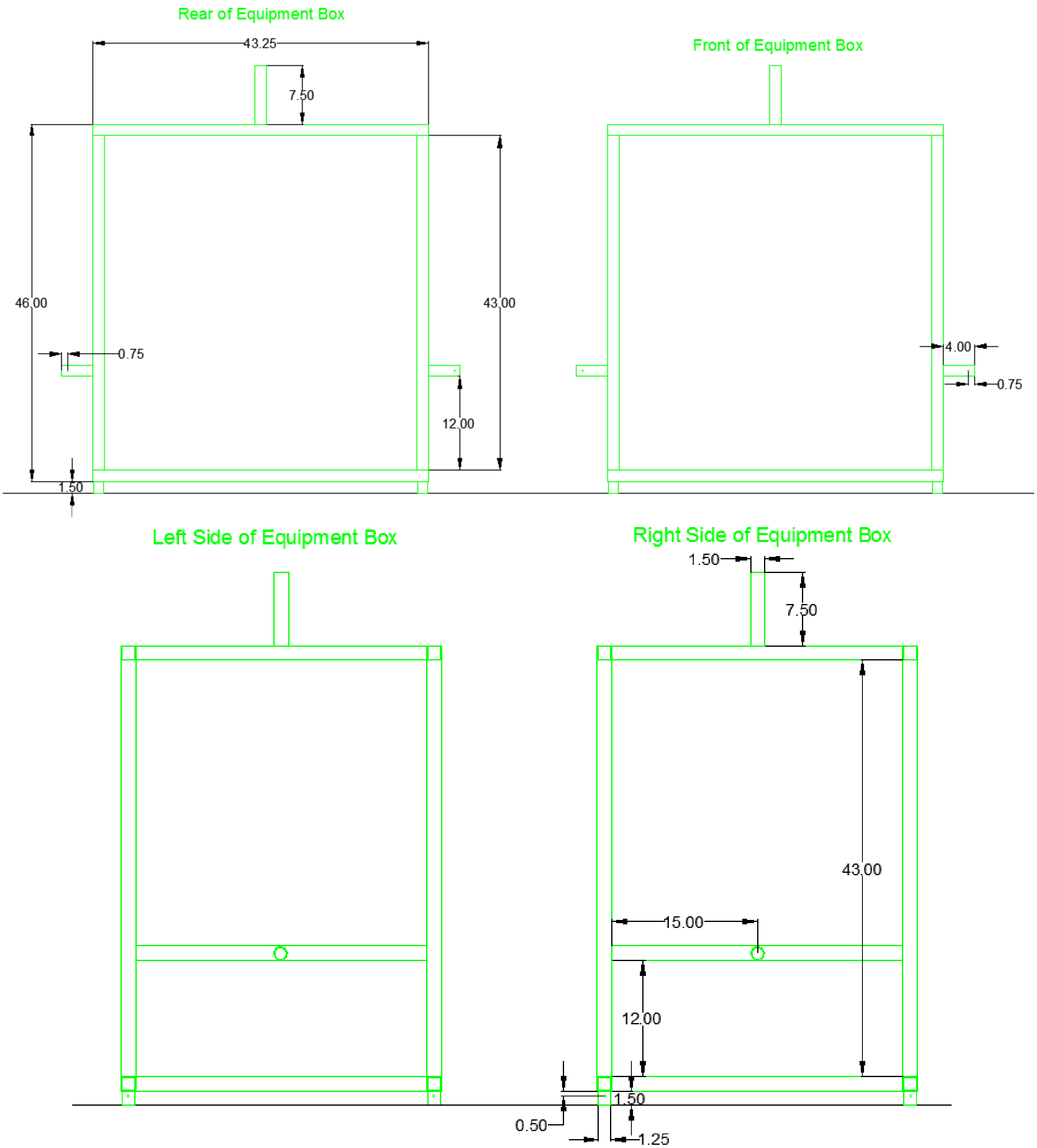


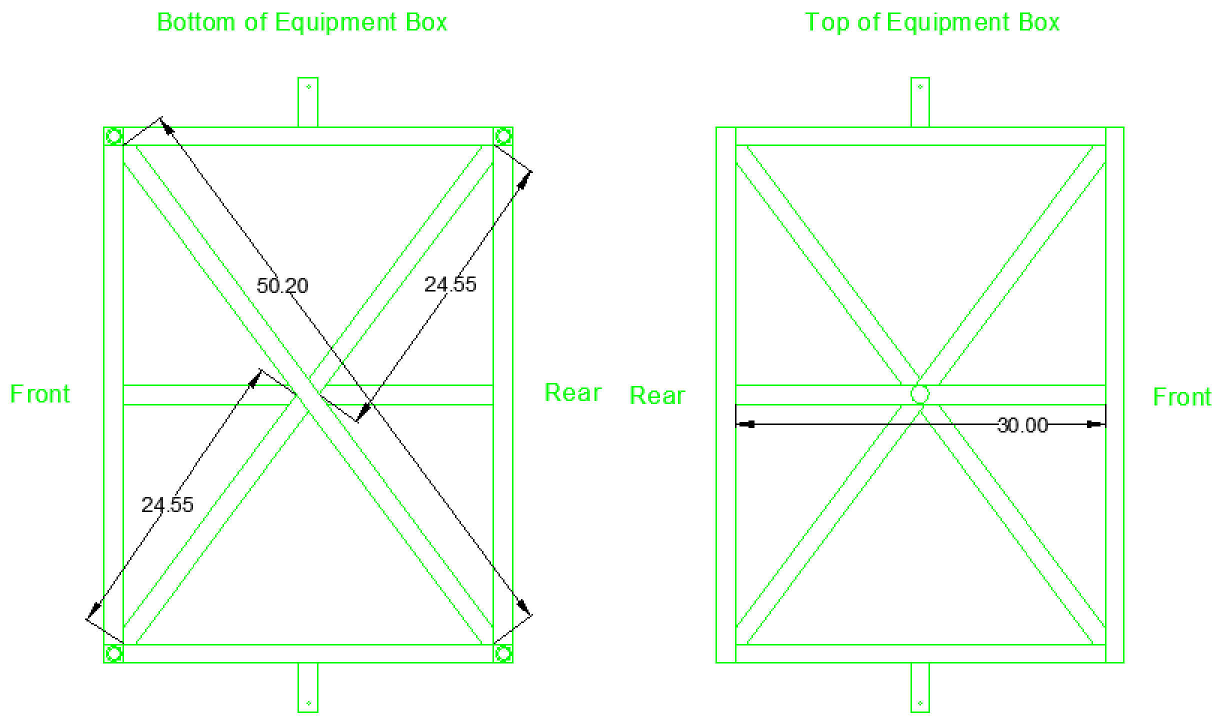
Rear View of Framework



Equipment Box Drawings

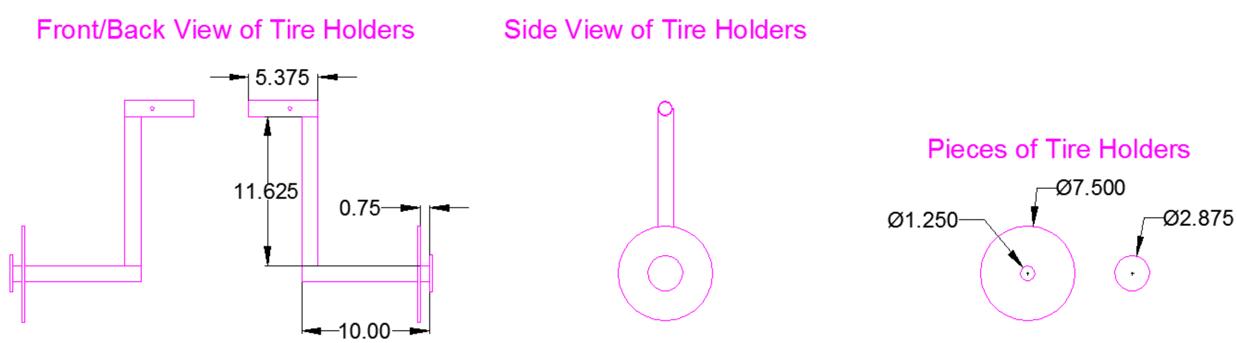
The following images are the dimensions of the framework design. All dimensions shown are in inches.





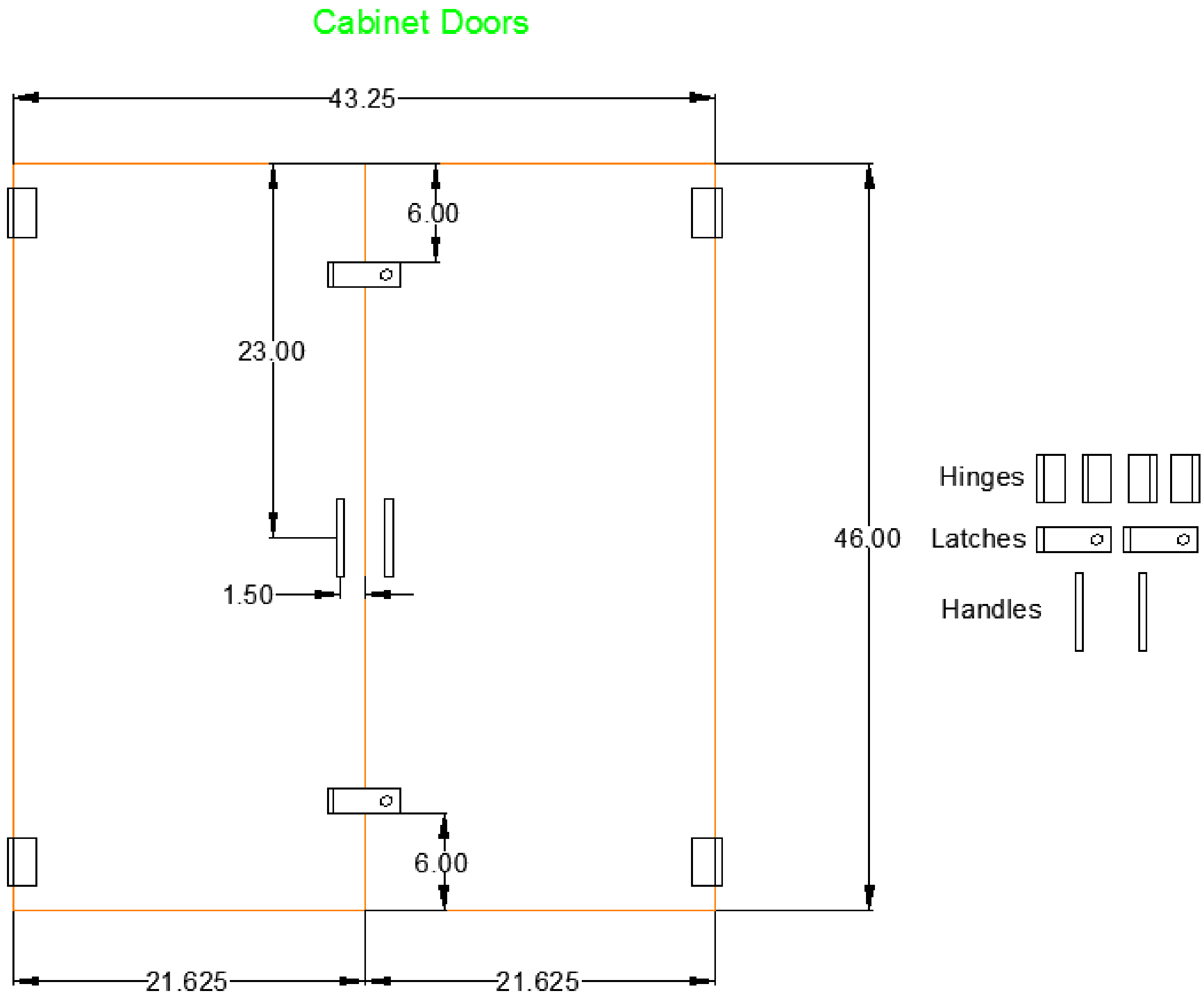
Tire Holder Drawings

The following images are the dimensions of the tire holder design. All dimensions shown are in inches.



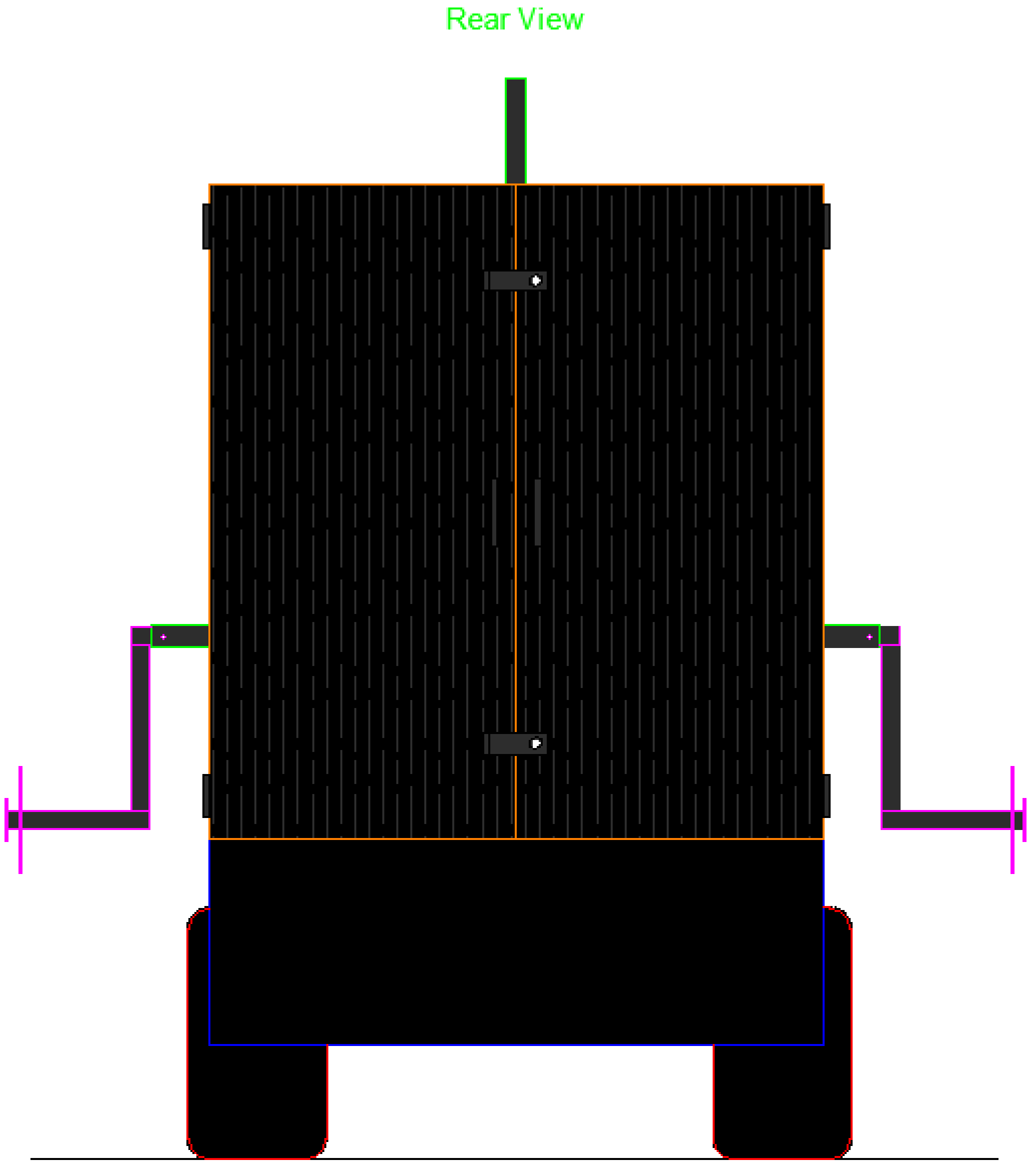
Cabinet Door Drawings

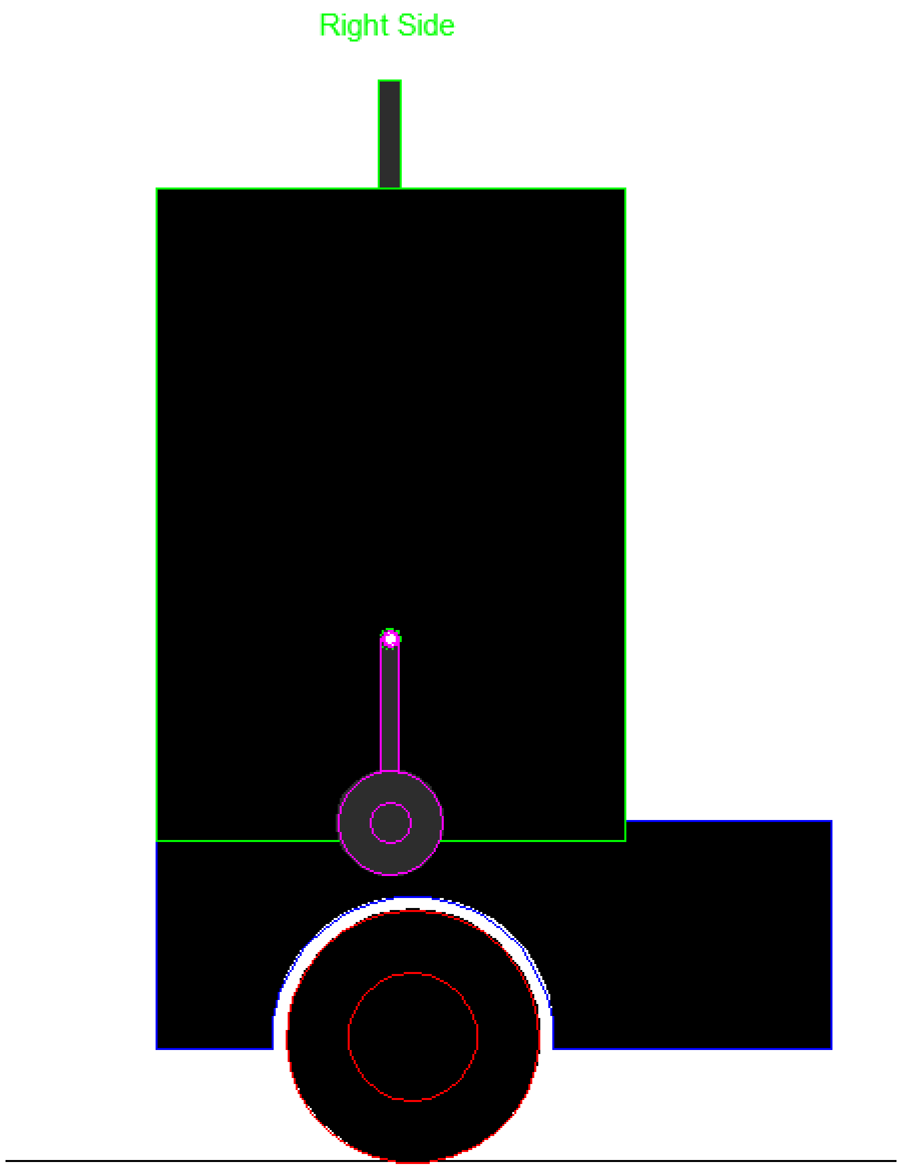
The following images are the dimensions of the cabinet door design. All dimensions shown are in inches.



Completed Project Put Together

The following images show the finished project drawings combined.




Right Side

APPENDIX C

PROJECT COMPLETION TIME

PROJECT COMPLETION TIME

The following table shows a breakdown of the time that was spent on different sections of the project.

Project Completion Time		
Task	**Sub-Task**	**Hrs.**
Deconstruction		12
Design	25	
	Framework	5
	Equipment Box	6
	Tire Holders	4
	Sheet Metal	2
	Cabinet Doors	6
	Shelves	2
Construction	91	
	Framework	20
	Equipment Box	25
	Tire Holders	10
	Sheet Metal	15
	Cabinet Doors	12
	Shelves	5
	Painting	4
Material Procurement		10
Report		21
Preparation of Poster		5
Fit Check		3
Total		167

It took approximately 167 hours to complete the project. It would not take as long if the same project were to be completed again because there wouldn't be much design work to do, and the report and preparation of poster would be excluded.

APPENDIX D

BILL OF MATERIALS

BILL OF MATERIALS

A total of two sheets of aluminum sheet metal were also purchased to develop the enclosure of both the equipment box and the framework. The wooden seat and wooden shelf were also acquired without purchase. Also purchased were the door hinges, latches, pop rivets, and other miscellaneous items.

The following table shows what items were purchased to complete the project.

Bill of Materials			
Material	**Quantity**	**Price**	**Total**
1-1/2" x 1-1/2" x 0.095" H.S.T. 20' Square Tubing	4	$ 23.60	$ 94.40
4' x 10' Aluminum Sheet Metal	2	$ 80.00	$ 160.00
3" Hinge 5/8" Radius Door Hinge	4	$ 2.58	$ 10.32
4.5" Latching Post	2	$ 6.58	$ 13.16
5/16" x 2-3/4" Round Lock Pin	2	$ 2.98	$ 5.96
0.023" - 10L Welding Wire	1	$ 29.99	$ 29.99
Black Spray Primer	2	$ 2.99	$ 5.98
Black Spray Paint	2	$ 2.99	$ 5.98
#6 x 5/8" Wood Screws	2	$ 1.19	$ 2.38
#7 x 1/2" Wood Screws	1	$ 1.09	$ 1.09
#9 x 1/2" Wood Screws	2	$ 1.09	$ 2.18
8 Piece Painters Tray Set	1	$ 9.97	$ 9.97
1 Gallon Glidden Exterior Flat Black Wood Paint	1	$ 23.97	$ 23.97
3' x 6' All Purpose Foam Pad	1	$ 19.98	$ 19.98
12 mm Sanded 23.75" x 47.75" Wood Panel	2	$ 14.55	$ 29.10
2" Four Pack Galvanized Corner Brace	1	$ 4.68	$ 4.68
4-7/8" Black Door Handle	2	$ 2.97	$ 5.94
Subtotal			$ 425.08
Tax		8.25%	$ 35.07
Grand Total			$ 460.15

As seen from table 2, it cost $460.15 for all the pieces to construct the equipment box and framework. This price is based on only the items purchased and does not include the golf cart, items that were already in possession, utilities, and transportation gas expenses.

APPENDIX E

PROJECT PICTURES

PROJECT PICTURES

Project Progression

The following images show the project as it progresses over time until completion.