Modification of a Draw Bar Type Arena Harrow to Three Point Mounted Type Harrow

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I'd like to first thank Rodeo Coach Ben Londo proposing this idea to me and making this senior project possible.

I'd like to thank my Advisor Gary Weisenberger for his advice and expertise that made the design of this project much better and closer to industry standards.

I'd like to thank Dr.Zohn for his help during the Construction of my project, as well as Vergil Threlkel.

ABSTRACT

This senior project will be the design, and construction of a three point hitch to be attached to a draw bar type spike tooth harrow. Currently used by the Cal Poly Rodeo Team to cultivate their arena before performances, and practices.

The attachment will allow the harrow to be pulled in both directions to create different types of soil affects.

Also the fabrications has a minimal budget so the majority of the materials will be scrap material already in position of the rodeo team or donated to the project.

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INTRODUCTION

In the past there have been many designs of three point drawn implements used to level and create a desirable soils processes for different applications. These implements usually consist of some sort of leveling mechanism to drag dirt and fill holes, as well as the components often seen in a spring tooth or fixed tooth harrow. With a type of packing or rolling apparatus directly behind the teeth.

At the moment the Cal Poly Rodeo Club is utilizing a Massey Ferguson 245 tractor, a 35 drawbar horsepower tractor, to pull a three row fixed tooth drag which requires more horsepower than the tractor is capable of delivering to be pulled at the rate of speed needed by the Rodeo Club to work the entire arena. For this reason the end result of the soil worked using the drag and tractor combination isn't efficient enough for the Rodeo Club.

It is also important that the implement level the ground without creating significant grooves, or leaving large clods as these can be dangerous for both the animals used and for the competitor if the animal should stumble, or loose footing because of bad soil conditions.

For this project I will be modifying a fixed tooth harrow already owned by the Rodeo Club from a draw bar pull type to a three point mounted harrow. The Massey Ferguson 245 tractor in the possession of the Cal Poly Rodeo Team will be used to drag this harrow. This drag will have to meet several criteria for the outcome of the soil and performance of the tractor.

- Implement must be sized so as to be pulled at a desired pace specified by the Rodeo Club.
- It must be versatile enough to be used to not only decrease the density of the soil and level, but to also increase the density if desired by the operator.
- The Drag must be versatile and usable on more than just the Massy Ferguson tractor.

LITERATURE REVIEW

Tractor Types

One of the most important aspects of any production agriculture is the selection of the correct sized tractor and implement to perform tillage or harvesting practices required by a crop or operation. The wrong sized tractor and implement can be very costly and not time efficient. Tractors can be generalized into three basic groups: 2-wheel drive, 4-wheel assisted drive, and 4-wheel direct drive.

Selecting a Tractor

Before selecting a tractor one must consider the type of terrain the tractor is going to be used in, two wheel drive tractors perform very well in dry upland situations. The main advantage of a 2-wheel drive tractor is a smaller turning radius however they require 80% of the weight to be over the rear tires. Along with the small front steering tires commonly used, this gives them less tire surface area traction which is often problematic in situations when traction is not perfect. 4-wheel assisted tractor has smaller tires on the front than the back and transfers some of the power to drive the front tires as well as the rear. This allows them to deliver up to 10% more horsepower than a 2-wheel drive tractor. This allows them to have better traction in slippery soil conditions while remaining more maneuverable than a 4 wheel direct drive tractor. A 4-wheel direct drive tractor is most commonly used when maximum draw bar horsepower is needed. They can usually deliver 55-60% of the horsepower to drawbar. These tractors have the highest weight to horsepower ratio of all three types (Summer and Williams).

Tractor Size

A tractor's size can be based on several different types of horsepower. Horsepower is defined in terms of the rate at which work is done. By definition one horsepower is the amount of energy needed to move 33,000 pounds one foot in one minute, or can be also interpreted as the amount of energy needed to move one pound 33,000 feet in one minute(Summer and Williams).

$$1\ Horsepower = \frac{33{,}000\ lb*1ft}{1\ minute} \quad (1)$$

The horsepower of a tractor measures the tractors ability to move a load. There are different ways of describing a tractor's horsepower: Brake horsepower is the amount of horsepower delivered by an engine with no alterations. This is usually only valuable when sizing stationary engines. Power Take Off horsepower or PTO horsepower is the amount of power delivered by the PTO shaft of a tractor which is very useful when sizing

a tractor to power equipment that utilizes the PTO shaft as its method of power transfer. Draft or Draw bar horsepower is the amount of horsepower transferred by the tractor when pulling a load. According to the Nebraska Tractor Test draft horsepower will be approximately 50-55% of the tractors engine horsepower (Summer and Williams).

Determining Horsepower Requirements

When determining the horsepower required for your operation, first it is important to determine how quickly you need your operation to be completed. This and also the area you need to perform your operation on, this area is most commonly measured in acres, and one acre is equal to 43,560 ft^2. The speed at which you can perform your operation is commonly determined by the type of operation you are performing, Table 1 shows a list of common operations and the speeds at which they can be performed (Summer and Williams).

Table 1. Default Values for Speed, Field Efficiency, and Draft Requirements(Edwards).

Equipment Name	Speed (mph)	Draft (lb.per unit of width) Average	Range
Tillage			
Moldboard plow (16 in. bottom, 7 in. deep)			
Light soil	5.0	320	220 - 430 per foot
Medium soil	4.5	500	350 - 650 per foot
Heavy soil	4.5	800	580 - 1,140 per foot
Clay soil	4.0	1200	1,000 - 1,400 per foot
Chisel-plow			
(7-9 in. deep)	5.0	500	200 - 800 per shank
Disk			
Single gang	5.5	75	50 - 100 per foot
Tandem	5.5	200	100 - 300 per foot
Heavy or offset	5.0	325	250 - 400 per foot
Field cultivator	5.0	300	200 - 400 per foot
Spring-tooth harrow	5.0	200	70 - 300 per foot
Spike-tooth harrow	6.0	50	20 - 60 per foot
Roller or packer	5.0	100	20 - 150 per foot
Cultivator			
Field (3-5 in. deep)	5.0	250	60 - 300 per foot
Row crop	4.5	80	40 - 120 per foot
Rotary hoe	7.5	84	30 - 100 per foot
Subsoiler (16 in. deep)			
Light soil	4.5	1500	1,100 - 1,800 per tooth
Medium soil	4.5	2000	1,600 - 2,600 per tooth
Heavy soil	4.5	2600	2,000 - 3,000 per tooth
Planting			
Planter only	5.0	150	100 - 180 per row
Planter with attachments	5.0	350	250 - 400 per row
Grain drill	5.0	70	30 - 100 per foot
No-till drill	5.0	200	160 - 240 per foot
Applying Chemicals			
Anhydrous ammonia applic.	4.5	425	375 - 450 per shank

Source: Hunt, Donnell. Farm Power and Machinery Management. 9th Edition.

The next factor you need to determine if one's equipment will be capable of performing your operation in the time given is the width of the implement used. This is usually determined based on the horsepower of the tractor used and is needed when determining the amount of area that the implement can cover in a given amount of time. The width an

implement can be in most cultivation practices is determined by the draft per foot the implement applies. Table 1 also lists of a few examples of these values for different cultivation implements. Once an implement width is selected for a tractor the rate at which it can perform its task can be calculates.

$$Area\ per\ hour\ covered = \frac{Area\ to\ be\ cultivated}{Time\ to\ do\ Operation} \quad (2)$$

Types of Implements

When selecting an implement for an operation like leveling and texturing soil it is important to select the implement that is suited for the soil type being used. In the average Rodeo Arena the soil type most desired for use is that of coarse sand, this is because of its ease of manipulation, and large particles which reduce the amount of air born particles produced during manipulation. The most common types of implements used to create a desirable soil surface texture are usually a combination of a soil harrow, perhaps some sort of leveling devise, and so sort of soil pulverizing device to break up any clods present. Figure 1 is a common example, and is the type currently used by the Cal Poly Rodeo Team.

Figure 1. Lucas Ground Hog.

These implements often require substantial horsepower in order to perform at a desired speed needed. This is usually a factor of how many different operations they perform at once. As seen in figure 1 the Ground Hog has four different operation preformed at once: the front has a row of ripper teeth, followed by a leveling or float bar, then a spike tooth type harrow, and lastly a type of soil pulverizing device. These all add up to the total horsepower needed to pull the implement. These are provided on Lucas' website and are shown in figure 2 ("Horsepower").

HORSEPOWER REQUIREMENTS

Ground Hog Arena Tool Size	5'	6'	7'	8'	9'	10'	12'
Weight of Unit	1200 lbs.	1300 lbs.	1475 lbs.	1775 lbs.	1850 lbs.	2060 lbs.	2275 lbs.
Horsepower Required	30 HP	35-40 HP	40-50 HP	50-60 HP	60-70 HP	80-100 HP	100+ HP
Category of Tractor Attachment	1 & 2	1 & 2	1 & 2	2	2	2	2

Figure 2. Ground Hog Horsepower Requirements.

The more operations an implement performs the more draft horse power that will be needed to operate it. Often other forms of horsepower are also used by an implement. For example some arena drags utilize a tractors auxiliary hydraulic system or the Power Take Off, to run some types of agitators to pulverize the soil and create the desired particle density and finish. One good example of this is the RotoGroomer made by Reist Industries shown in figure 3.

Figure 3 Reist Industries RotoGroomer("Equestrian").

Now these implements can be very complicated and require more horse power per foot of width than normal Agricultural implements. However, they all consist of combinations of the original implements, and by using the different average forces per foot of width for these and adding all of them together, one can get a relatively close estimate to the amount of horsepower, draft or other form, needed to power them. Some are relatively simple which allows for a smaller tractor with optimal width allowing the implement to have a fast rate of operating, translating to more area covered in less time. One example of this type of implement is the Roto Harrow made by Gibbs Manufacturing shown in figure 4.

Figure 4. Roto Harrow made by Gibbs Manufacturing ("Roto").

The majority of arena drags are 3 point mounted, this allows them to be easily maneuvered by the tractor in operation, and allows them to be lifted up when driving over surfaces such as roads, and other miscellaneous objects without causing damage to the drag or surface being driven over. The size of hitch is determined by the amount of draft needed to pull the implement.

A three point hitch consists of commonly two lower arms which attach to the implement directly, and a top cleaves attachment which uses a turnbuckle type connecting rod to attach the center of the hitch to the tractor. Hydraulic cylinders power the lower arms allowing the implement to be raised and lowered. As shown in figure 5.

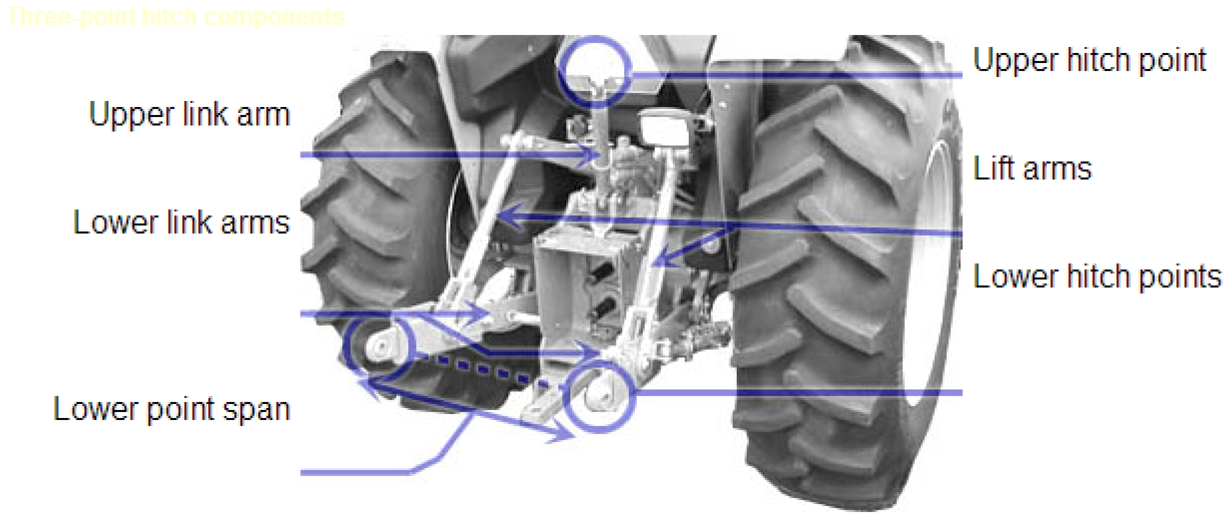

Figure 5. Three Point Hitch Example ("Three").

The three point hitch comes in several standard sizes, these are all based on horsepower of the tractor, and also in relation to the amount of horsepower needed for an implement. The higher the category the hitch the larger the tractor needs to be to operate the implement correctly this is a factor of the design of the implement and its horsepower requirements. The categories are numbered starting with the smallest being a 0 ranging to the largest being a category 4. The dimensions of the mounting hardware increases accordingly. Table 2 gives the specifications used by standard three point hitches.

Table 2. Three Point Hitch Dimensions and Horsepower

Category	Hitch pin size		Lower hitch spacing	Tractor drawbar power
	upper link	lower links		
0	17 mm (⅝")	17 mm (⅝")	500 mm (20")	<15 kW (<20 hp)
1	19 mm (¾")	22.4 mm (⅞")	718 mm (26")	15-35 kW (20-45 hp)
2	25.5 mm (1")	28.7 mm (1 ⅛")	870 mm (32")	30-75 kW (40-100 hp)
3	31.75 mm (1 ¼")	37.4 mm (1 7⁄16")	1010 mm (38")	60-168 kW (80-225 hp)
4	45mm (1 ¾")	51 mm (2")	1220 mm (46")	135-300 kW (180-400 hp)

PROCEDURES

Design Procedures

The design of this project was somewhat of a challenge because the 3 point attachment was to be constructed from scrap material. And the attachment was to be built so that it could be easily remove and re attached to the other side of the harrow so that it could be drug both directions to create different effects on the soil. For this to be possible, an attachment system needed to be designed that would handle the various loads placed on the harrow as well as be removable. For this reason I went with U bolt type attachment for the bottom of the "A" frame portion of the hitch, and a bolt assembly type center support member.

Figure 6 Side view of Hitch

The Attachment

For the 3 point attachment itself I was able to procure the 3/8" plate and ¼" plate needed was donated by the BRAE department. The material was cut on the automated plasma cutter. The links that were to pin to the tractor three point hitch were constructed of 3/8" plate which is the standard in the industry. The attachment was to be constructed to the

standard category one type three point hitch. This was done because many category 2 tractors are able to be sleeved down, or have adjustments to attach to a category one implement, but it is not possible for a tractor with only category 1 tractor to attach to a category 2 implement correctly due to the fact that the pin holes of a category 2 implement would be larger than the pins needed by the tractors attachment. So for that reason I decided it would be best for the Rodeo Club, even though the Massey Ferguson currently used by the Club is a category 2 hitch type tractor, if the implement had category 1 type attachments. These attachment sizes are listed in the Literature Review of this report.

Figure 7 Plasma Cutting Process

The structural members to be used for the link part of attachment was 2.5”x2.5” 1/8”, this was smaller walled tubing than I would have liked to have used for durability purposes, but due to the low amount of force placed on the link potion of the attachment this served the purpose. Also it would have made fabrication of the link part of the attachment much easier if the tubing had been 3”x3” because the lower links of the attachment are required to be 3” wide to meet standards for a category one three point attachment. However this was overcome during fabrication by placing two pieced of ¼” plate between the links and the tubing to give it the added ½” needed to make the links 3” wide.

Center Support

The center support of the three point hitch is the member running from the top if the link portion of the attachment down to the back or middle of the implement and is what gives the three point its ability to keep the implement level during operation from front to rear. This is the member which experiences the most loading during operation. For this reason the tubing used for the link portion of the attachment was too small to handle such loads. The member was constructed of 2-7/8” diameter schedule 80 pipe, commonly known as “oil rig pipe” that was procured from the Rodeo Club as a piece of scrap left over from the construction of their arena. This structural member provided the strength and bearing

area needed for the center support because it needed to be strong in tension and compression.

The center support was attached to the harrow using a bolt type system so as to allow it to be removed and placed in the opposite direction when the drag was pulled in the opposite directions. These links were built out of 3/8” steel in order to have the same strength as the link portion attached to the tractor. The bolts used were ¾” bolts with half thread, this added some shear strength by increasing the minor diameter of the bolts in the shear plane where no threads were present.

The center support was attached to the harrow in the middle of the implement. This allowed for the center support to not be completely removed when the three point attachment is placed on the opposite side of the implement.

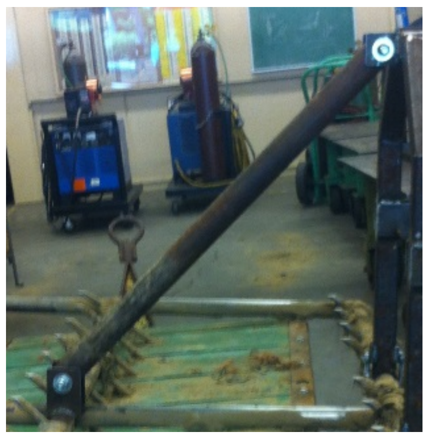

Figure 8

Center Support Close up

RESULTS

The finished product was just what the Rodeo Club needed. The new three point attachment allowed them to make tighter turns on the tractor without leaving wheel makes. As well as lift the drag to back it in to the roping boxes to work and level the ground inside of them as well. This makes the drag much more user friendly and enable the Club to create the desired soil process to ensure safety of the animals and contestants during their rodeo activities.

The drag was pulled in both methods of operation with the harrow, so that the teeth pointed backwards, and forwards. Due to the way the drag works with the new method of attachment, it was found that it deepened the ground too much with the teeth pointed forward. For this reason the drag should be used with the teeth pointed backwards until the ground becomes too shallow then used with the teeth pointed forward to deepen the ground, which this harrow can now do, thanks to the modification of the hitch. This is a huge advantage to the harrow. Before, whenever the ground became too shallow the Rodeo Club would have to unhook this harrow, and use the Ground Hog type harrow they also have, which requires more horsepower than the Massey Ferguson Tractor can deliver, and for this reason a much slower speed was needed to operate with this tractors available horsepower.

With the new three point type attachment for the harrow it also levels the ground much better than before since now, some down pressure is applied to the rear of the drag causing it to also drag soil when in operation. Before the rear of the drag would simply float the ground.

Figure 9

Finish Harrow in Operation

DISCUSSIONS

This project was built completely from donated materials that were either currently in the Rodeo Clubs possession or generously donated by the BRAE department. Also all fabrication was done in the BRAE departments labs.

If it would have been possible, with the limited budget the Rodeo Club had, to build the drag with stronger material this probably would have made the drag more durable. Not that the steel members will yield under normal conditions, but if the drag were to hit a fence, or be backed into something there is a good chance the steel members making up the "A" portion of the three point attachment would yield and bend. However due to the fact that the this is not an implement the Rodeo Club plans to use indifferently it was the most economical fix to their problems until they can raise the money to purchase a tractor big enough to pull the Ground Hog drag they currently have as well.

Hypothetical Costs of Materials

The cost of building this exact three point attachment again from materials not donated would have been as follows:

Table 3. Hypothetical Cost of Materials

Number of Item	Item	Cost Per Item ($)	Total Cost
1	2.5 HSS Square Tubing	$ 10.42	$ 10.42
1	12"x24"x3/8" Hot Rolled Carbon Plate	$31.16	$31.16
1	4' 2 1/2" sch 80 pipe	$ 35.00	$ 35.00
		total	$ 76.58

So the cost of building something like this would be about $76.58 dollars in materials. It took approximately 4 hours to build at $80 dollars and hour prevailing wage. The modification to this implement would cost about $396.58 to build from scratch with the tools we have here at Cal Poly.

RECOMMENDATIONS

The drag works great for the tractor the Rodeo Club currently uses. If they should get another tractor, they need to be sure the tractor is a category 1 or 2 type three point hitch so that this implement will still be usable with the new tractor. If at all possible they should look for a four wheel assisted drive tractor since in sandy conditions four wheel assisted drive tractors turn much easier and experience less wheel slip then a two wheel drive tractors.

I did not remove the excess teeth from the top of the harrow at the request of the Rodeo Club, but these do create somewhat of a safety issue if someone was to trip on one of the protruding spikes, or fall on the drag. These could cause injuries. It would be beneficial to the harrow, to remove these for safety reasons. Another reason for removing the excess teeth is when the drag is operated with the teeth pointing backwards there is a chance the teeth will hit the tire when the implement is lifted, which could damage the tire.

Also the drag leaves some dirt clods when working in moist sand. This could be mitigated by the addition of another conditioning device designed to break up the clods at the rear of the harrow.

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APPENDIX A

HOW PROJECT MEETS REQUIREMENT FOR THE ASM MAJOR

HOW PROJECT MEETS REQUIREMENT 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 involves the application of Ag machinery design, horsepower management, and fabrication technologies.

Application of Business and/or Management Skills. In this project the Client, the Rodeo Club, were very involved and had a big hand in suggestions for the design of the implement. Without customer relations skills this would have been a difficult process. Also the materials needed had to be obtained through donations which requires being able to present yourself and project well.

Time management played a major role in this project since the build needed to be completed so that the implement could be used during Poly Royal of 2014. The design had to be approved in time to fabricate the implement before Poly Royal. Also some testing and modification time had to be allowed before the drag was needed as well.

Quantitative, Analytical Problem Solving Since this project was designed to a set of standards set for Agriculture implements limited stress calculations were needed since with these standards many of the forces involved in the operations are already factored in.

Since the build was from scrap or donated materials there was no cost for its construction. However, I have included a hypothetical cost analysis of the project if build with purchased materials.

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 129 Lab Skills/Safety
- BRAE 133 Engineering Graphics
- BRAE 151 AutoCAD
- BRAE 142 Machinery Management

- BRAE 301 Hydraulic/Mechanical Power Systems
- BRAE 321 Ag Safety
- BRAE 343 Material Analysis
- BRAE 418/419 Ag Systems Management

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. This project involves creating an attachment that will be pulled by a tractor with certain abilities and requirements. In order for this implement to function correctly it must attach to this tractor correctly and be adjustable by the operator to create the desired soil modifications.

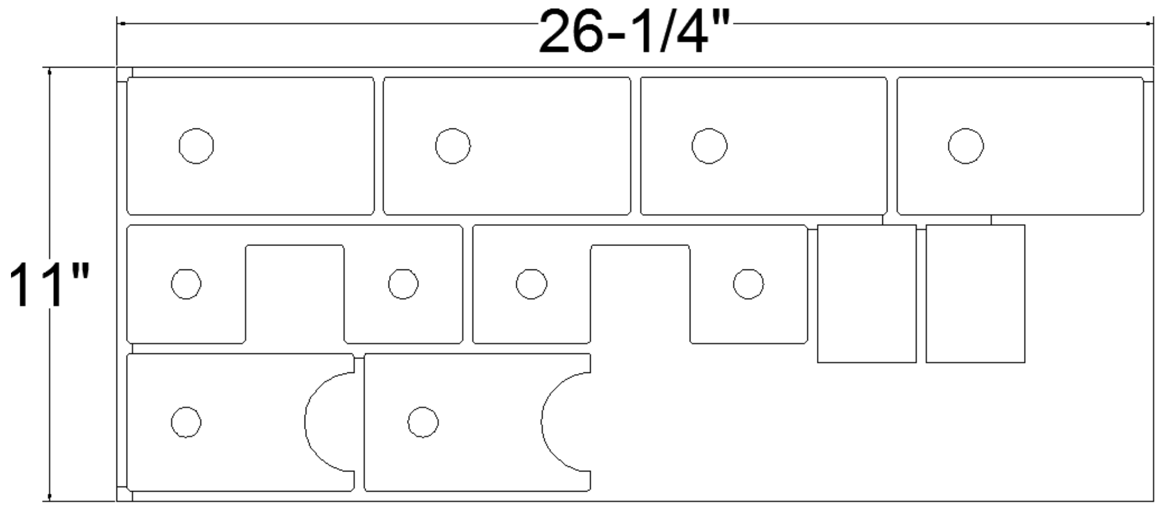
Interdisciplinary Features. This project involves horsepower management as well as fabrication with constraints. It also must be easily adjustable by someone with limited mechanical ability.

Specialized Agricultural Knowledge. This project applied many skills pertaining to fabrications as well as ergonomics and functionality of agricultural implements. As well as design skills involving creating a system not over complicated but adjustable in many aspects.

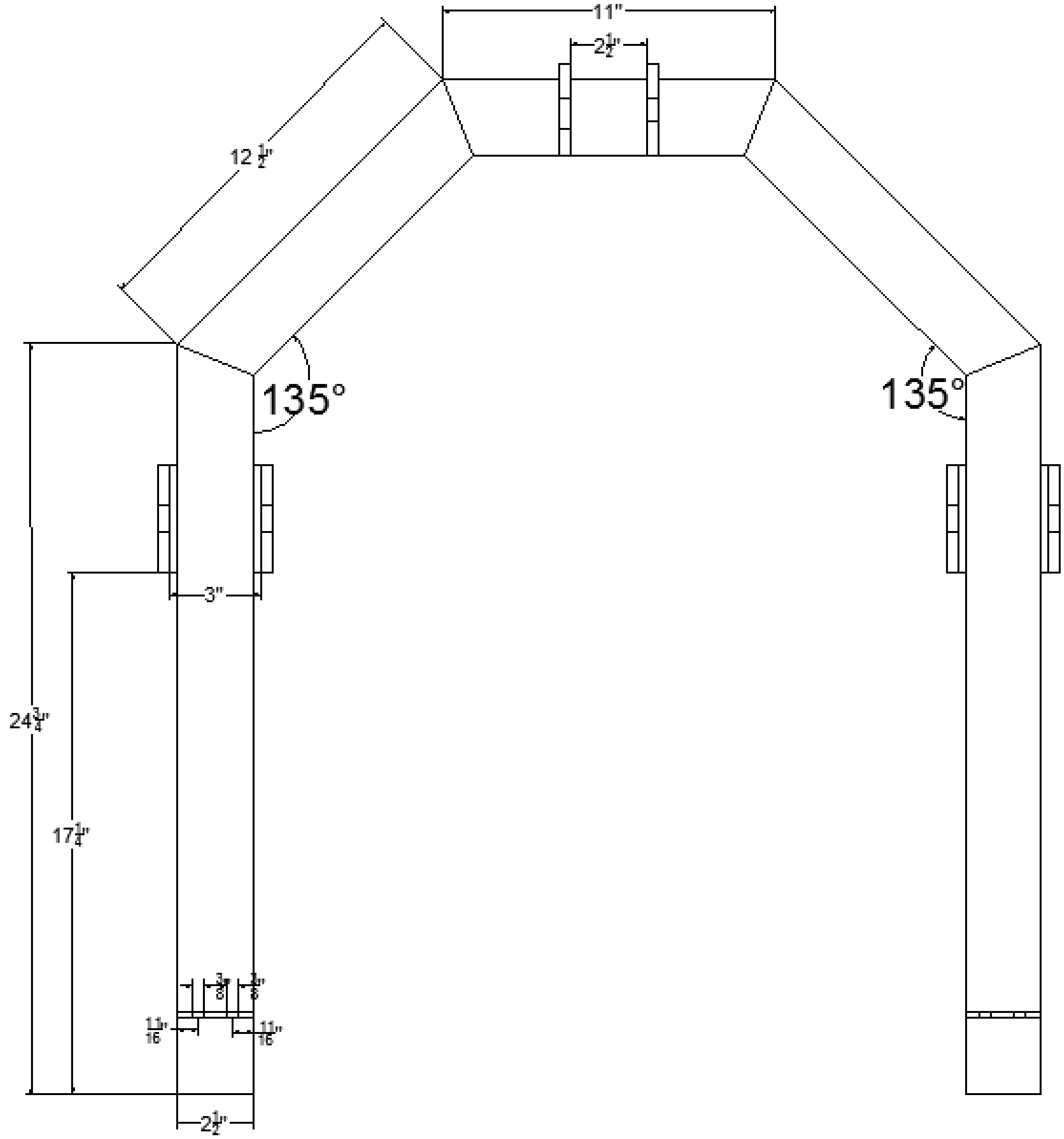
APPENDIX B

AutoCAD Drawings

LINK CUT DRAWING



FRONT VIEW OF HITCH



SIDE VIEW OF HITCH