Design, Construction and Analysis of an Ag Equipment Trailer

by

Connor McKean

Agricultural Systems Management

BioResource and Agricultural Engineering Department

California Polytechnic State University

San Luis Obispo, CA

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TITLE	:	Design, Construction and Analysis of an Ag Equipment Trailer
AUTHOR	:	Connor McKean
DATE SUBMITTED	:	6/5/13

Dr. Mark Zohns

Senior Project Advisor

Signature

6-11-14

Date

Dr. Art MacCarly

Department Head

Signature

4/3/2015

Date

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ABSTRACT

For this project a trailer was built to transport agricultural equipment. The equipment to be transported ranged between many different styles of three-point bars, such as cultivators, listers and planters, and combine headers. The trailer was designed and built successfully and is now used extensively at McKean Farms. The intentions of this trailer is to increase the safety and efficiency of the transportation of agricultural equipment.

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INTRODUCTION

Modern Agricultural Equipment has become increasingly larger to achieve greater efficiencies. With the advent of these larger pieces of equipment transporting them from field to field is also increasingly difficult. McKean Farms, a diversified farming operation located in Riverdale California is also experiencing difficulties transporting many of these pieces of equipment. McKean Farms would like to be able to transport everything from a combine header to a thirty-foot wide cultivator bar. Some of the pieces of equipment that will need to be transported will be as heavy as 8,000lbs. The trailer will need to be able to transport these various large pieces of equipment with operator ease, efficiency and safety in mind.

LITERATURE REVIEW

As seen in figure 1, the width and sheer size of modern agriculture equipment is far larger than the current California road structure can handle. This presents an extreme challenge to many growers. This hurdle can be overcome with the proper equipment.

Figure 1. A Combine Harvester during Transport.

Traditional Methods

As traditional farm equipment has progressively become larger and more cumbersome, the means of transporting equipment between applications has not developed as quickly. The majority of the traditional methods for transporting large and wide agricultural equipment consists of simply just transporting equipment down the road at wide widths, heavy weights and slowly. This is very unsafe and causes many problems.

The routes must be manipulated to avoid large amounts of traffic, narrow roadways and bridges. Safety is a very big concern. Schools need to be avoided at certain times of the day with large equipment. Likewise, freeways are off limits to most traditional farm equipment and some overpasses and freeway crossings are off limits or very

restrictive to large farm equipment. Also, many local rural roads can be poorly maintained and narrow. Many rural roads are not maintained by counties and have been abandoned. Many of these roads are not at consistent widths as well. Some of these rural roads are very narrow, while others can be very wide with well-maintained shoulders and very little roadside obstructions such as mailboxes, signs and power poles. Lastly, many of these small rural agricultural areas, particularly in California, have many ditches and canals crisscrossing them. This results in another hazard for moving agricultural equipment. Bridges are often another constraint with equipment width, but more so an issue with weight and height clearance. These small rural bridges have very specific weight restrictions and large agricultural equipment can exceed these weight restrictions. With the ability to disconnect a portion of the weight of the total weight by detaching the implement or header from the tractor or combine header from the combine you have the ability to redistribute weight over more axles and reduce point loads on small weight limited structures. Lastly many small rural bridges have small safety guardrails. Small guardrails are directly on the outsides of the bridge. This presents a constraint for implements that do not have enough vertical clearance to pass over these guardrails. While the tractor or combine harvester's wheel width may be able to clear the bridge guardrails the implements/headers vertical clearance may not be able to cross over the bridge's guardrails.

Many times this adds time in between fields and more time on the road. A very long route must be taken sometimes to avoid these obstacles, sometimes added double or more of the amount of time to the transport. This added time on the road reduces efficiency and increases the possibility of danger. With the extreme costs of many pieces of modern agricultural equipment it is very important to keep these pieces of equipment in the field and operating rather than transporting from field to field.

Review of Current Agricultural Equipment to be Transported

Many pieces of modern agricultural equipment have become very wide. Because many operations in modern agriculture have to be done in specific order, equipment is generally engineered to become wider rather than longer. Some modern agricultural equipment, especially with tillage, can become longer while incorporating many tillage passes. Although this is possible, most equipment has become wider therefore covering a wider swath with every pass, but only accomplishing one task. This makes more sense to the grower, in many cases due to the timing of various tasks and many other uncontrollable factors that are encountered by most production agriculturalists. As seen in Figure 2, this is a 26' wide 10 x 30" cultivator which is a very typical wide implement for California row crop farms.

Figure 2. A Typical 10 x 30" Cultivator, Which is Approximately 26' Wide.

Equipment manufacturers have come up with various ways of overcoming overall width constraints when transporting. Some equipment manufacturers have decided to fold equipment with vertical wings as seen in Figure 3 and 4. Costs are increased as you add pivot points and hydraulic cylinders to fold the implement. Lastly when folding these implements vertically, height restraints can be encountered with power lines and overpasses. Notice the height of the field cultivator in Figure 3.

Figure 3. A Traditional Field Cultivator with Four Folding Axes.

Figure 4. A Modern Folding Corn Header.

Other equipment can "stack fold" which allows for the outside "wings" of a bar type implement to stack the wing portion parallel and above the center section of the bar with a parallel linkage as seen below in Figure 5. Again this design requires extra hydraulics, pivot points and a reduction of rigidity. Also, with this design a large amount of weight is added to the equipment. Notice in the image below, rear "helper" casters must be added to assist in lifting the bar due to its excessive weight.

Figure 5. A Stack Fold Bingham Brothers Single Pass Bar.

Lastly, one more way of transporting wide agricultural equipment is to turn the wide piece of equipment 90 degrees so the width of the piece of equipment is parallel with the road and the depth of the piece of equipment is perpendicular with the road. This technique has gained popularity with many equipment manufacture's here in California because of the width of equipment, but more so because many pieces of equipment in California are not very deep so it can be transported with ease. As seen in Figure 6 many implements in have incorporated a second hitch that allows for the implement to be transported 90 degrees relative to the hitch used for field use. Many pieces of equipment like this are not very deep because of the increase of passes with less action due to the popularity of rows that require irrigation and aeration. Rather than open, flat fields that are naturally rain fed and well aerated by natural conditions.

Figure 6. A 26' Rome Finish Disc.

Towing Trailers

The solution to this problem will be to design and build a trailer to overcome the challenges of transporting these large pieces of equipment, sideways down the road.

Although the rules for normal commercial vehicles are stated above, agricultural vehicles have many special exceptions. Most agricultural equipment falls under the category of "implements of husbandry". Under DMV code **VEHICLE CODE SECTION 36600-36627** many of these "implements of husbandry" are exempt from many size and weight restrictions. See the attached Implements of Husbandry Exemptions in Appendix D for more information. The implements of husbandry category, largely refers to a very special set of exemptions for agricultural equipment, farmers and agricultural equipment dealerships.

Current Equipment

Presently, combine headers are usually transported on specifically built combine header trailers. Most modern combines headers are specifically designed to quickly detach from their combine so ease of transport from field to field maximizes efficiency. For this application there is a specifically designed trailer usually to be pulled behind the combine or a pick-up truck at lower speeds. These trailers are usually small and very simple in design. The other style of header trailer is a highway style trailer. These trailers are designed more so for custom harvesting and a farmer that is transporting headers long distances on freeways or larger, busier roads. Road style header trailers usually have higher strength chassis, more axles with heavier capacities, lights and brakes. Another important design feature that road style header trailers have is a steering pivot point and tongue out in front of the trailer with one or more axles underneath the main header. This design can be seen in Figure 7 below. Although these header trailers are designed very well for hauling headers, they are not able to haul traditional three point "bar" equipment without modification and interchangeable parts and brackets that can be cumbersome and slow down efficiency.

Figure 7. A Road Style Combine Header Transport Trailer.

An existing piece of equipment called the Retriever SLT made by Bestway Manufacturing based in Hiawatha Kansas. Bestway has created a device that has the capabilities of lifting and transporting equipment such as combine headers and three-point tool bars. The Bestway Retriever SLT can be seen in Figure 8 below. This piece of equipment has been proven to be very effective, but is very costly. The Retriever SLT 20B has the ability to load a piece of equipment by itself using its own power source and then tilt and turn the piece of equipment sideways. The Retriever also has a capacity of 20,000lbs. The retriever has two axles with a capacity of 10,000lbs (torsion) each. The total weight of the trailer is 6,720lbs. The retriever has a bumper pull hitch and can be towed with either a tractor or truck. The Bestway Company advertises the Retriever SLT moving small and large grain header platforms, cultivator bars, planter bars, lister bars, tillage equipment and scrapers.

Figure 8. A Bestways Retriever SLT

The greatest advantage of this design is the fact that you can load a piece of equipment by yourself using the power of a small gas engine. With the option of being able to self-load a trailer with the equipment, one person with a truck and trailer would be able to load and transport multiple headers depending on the length of time that the combines would be on the road. This design is exceptional, but very intricate and therefore expensive. With the addition of a power source, hydraulics and many moving parts, the complexity of this trailer makes it hard to justify unless it is being used very frequently.

Another device used commonly in western agriculture is what is called a tool bar carrier or “tool carrier”. A tool carrier straddles the piece of implement in question and uses vertical chains to lift the implement as seen in Figure 9. The driver that intends on situating a piece of equipment under the tool carrier must perform a large sweeping turn that allows for the tool carrier to straddle the piece of equipment being lifted when finished. This requires a great amount of skill from the operator and a very large area to make the large sweeping turn. Tool carriers are popular in the western states within agriculture and are usually “homemade” pieces of equipment. The large majority of these trailers are designed and fabricated by the farm operation that intends on using them, therefore they are usually not the same and greatly vary depending on the preferences of the farm operation that built them. McKean Farms does own a tool carrier and utilizes it often. The tool carrier that McKean Farms owns is too small for the size of equipment that is transported. The tool carrier that McKean farms owns is used only on equipment that is 22’ in width or smaller, therefore not able to transport equipment such as 26’ cultivator bars or 30’ combine grain headers. The chains that are used to lift the equipment are usually wound up on a shaft to lift the equipment up. This shaft has to be powered by a small gas engine, electric motor or a geared down hand operated crank. This device relies on the piece of equipment lifted to be rigid as it is lifted because it is not supported on the underside of the implement like a trailer deck has. Therefore properly supporting a “flex” type grain header would not be possible and can possibly damage the header. The other issue with a tool carrier is the length of the total trailer that would be built and the weight that it would end up being. In order to span a distance of 30 feet the trailer would need to have a minimum of 40 feet of space to allow for efficient loading therefore locating the axles at minimum 47 feet apart which becomes a very long distance for a piece of steel to span. This span distance would require a very deep and heavy steel member(s). Also the total length of the trailer with a dolly and tongue could exceed 55’. When this much steel is required to build this trailer costs go up and so does weight. With added weight reduces efficiency and requires more safety considerations such as large capacity brakes, large capacity axles, tires and a powerful tow vehicle. But the largest constraint for the use of a tool carrier is the time taken to operate. Often times loading and unloading a tool carrier can take hours.

Figure 9. McKean Farms Custom Built Tool Carrier

A local neighboring farmer has devised a way to transport bar-type of equipment down a road, with the long axis of the 3-point bars parallel to the road. He has built 5 trailers that are 40 feet long that can accommodate 30 foot 3 point bars, shown in Figure 10. The trailers cannot lift the equipment under their own power but do have the ability to be loaded with a tractor and transported. The trailers have one central hollow HSS tubing section that spans the long axis of the trailer. These trailers are considered a wagon style with a short tongue and a long center stretch. The major downside to a wagon style trailer is they can be difficult to back up. This design is very simple and cheap, therefore optimum for transporting wide equipment. The only restraint for this style trailer is the fact that you will need a different trailer for each different style bar, as you can see in figure 11. The farm in question has built five trailers with only two that have the same receiver bracket that accommodates the same type of bar. Therefore a receiver bracket must be individually designed for each bar or in the case of this farmer, an individual trailer was built specifically for that implement, which is costly and inefficient. Lastly, this style trailer does not have the ability to transport combine headers.

Figure 10. All Five Different Trailers for Transporting Bars.

Figure 11. Notice the Different Receiver Brackets.

PROCEDURES & METHODS

The procedures and methods for the design and build of the trailer first started with a wide variety of consultations within McKean Farms Staff and also people outside of the staff. With that knowledge CAD drawings were assembled. The CAD drawings assembled where completed with the intention of formatting a rough idea of materials to acquire before construction. Construction of the trailer was done at McKean Farms in Riverdale CA. Testing and modifications were also performed at McKean Farms.

Design Considerations

As stated above in the Literature Review the design that was decided on was a low bed trailer. The trailer would be require a minimum deck length of 31.5' to accommodate for a 30' long combine header. This is currently the largest piece of equipment that will need to be transported. With the addition of a ridged rear axle and a steerable front axle with a hitch and tongue the trailer reached a rough length of 45' to 50' very quickly. This length of a trailer with the addition of a tow vehicle brings the total rough length to approximately 65' to 70'. With a trailer this long turning and maneuverability would be very important to the overall functionality of the trailer.

The trailer will have to have a narrow front axle that would allow for tight turning. This type of narrow front axle is capable of pivoting at angles greater than 200 degrees. This allows for the trailer to be pivoted around an entire 360 degrees about one of the rear wheels by an experienced operator. The main downside to this design is the fact that a narrow axle reduces the total stability of the trailer. Essentially the points of contact that the trailer experiences with the ground is now three in the shape of a triangle, rather than four points of contact, in the shape of an rectangle.

The deck width must be as wide as the total depth of a 10 x 30's cultivator, which is the deepest three-point bar that is intended to be transported. (Depth translates to width when loaded on the trailer sideways) While the physical depth of the cultivator is larger, the points of contact that the cultivator will experience with the trailer are 98". This is the measurement from the gauge wheels in the front of the trailer to the shoes or shanks in the rear of the trailer. Greater width in this case would allow for greater utility of the trailer but keeping the trailer width closer to the parameters of the implements depth allowed for easier transport and maneuverability when towed.

The most pivotal constraint for this project was the deck height of the trailer. The trailer must be low enough to allow for a tractor to lift the implement above the deck of the trailer and lower it down to detach and reattach. Combine headers are easily lifted to 36" off the ground, therefore they do not provide much of an issue for the height of the trailer. The trailer was designed based on the worst possible conditions for implement clearance, which in the case of McKean Farms a John Deere 7230 with 72" tall rear tires. Relative to most other tires the height of the tires are shorter making the tractor lower to the ground, which also puts the lowest point of the three-point bars that are intended on being backed over the trailer at 15" off of the ground. This translates into a deck that has to be at minimum 15" off of the ground. While that normally would not be an issue on a car hauler or "jump" trailer, a trailer that has a deck span of 31.5' this low of a deck height is

a major issue. The main two constraints on such a low deck are; first the issue of finding a structural member that will be strong enough while still having a low vertical profile to fit under the 15" and still provide clearance, and secondly the fact that this low of a trailer will have issues getting over uneven terrain such as ditches, railroad tracks and speed bumps. Addressing the first issue is the major design constraint of this project. And to address the issue of dragging is first the area that the trailer will be operating in is a relatively level and flat are with no hills or speed bumps. But also the trailer will be designed with a slick bottom to allow for it to drag across a surface if the belly of the trailer does come into contact with the ground or road. This will allow for it to act as a sled and distribute weight evenly when dragging along the ground.

An airbag or hydraulic assisted system that would lift the trailer at the front and back was considered but due to the added complexity and reduced ease of use, the idea was discarded. While an airbag system would add some suspension to the load it would also require a power source or air source and more time to operate. A hydraulic system would require either an electric over hydraulic source or access to a tractor or combine at all times to lift the deck. Another issue with a height adjusting deck is the need for more moving parts, more steel and more complex construction.

Another consideration for the trailer was inserting a notch into the side of the trailer to allow for a tractor to back up and have the gauge wheels contact the trailer deck rather than hang over the edge of the trailer deck when dropped on the deck. The dimensions of the notch are centered on the left side of the deck. The notch is 16" deep and 192" wide. This allows for a tractor with wide rear dual tires to back up into the notch and drop an implement on the trailer.

Tongue length was determined by estimating a length based off of other trailers and the distance from the outside of a standard truck bumper to the hitch which would allow for enough clearance for a truck to make a sharp turn without the truck bumper contacting the trailer. It was considered to make the hitch long enough for a tractor with rear duals to be able to perform this sharp turn without contacting the trailer with the outside of the rear dual tire contacting the trailer, but in order for this to happen the hitch would have to be considerably longer. With a hitch that long the total length of the trailer would increase by approximately 5 feet, which is not very conducive for a trailer that is already extremely long. Therefore the hitch was determined to be 54" long, from pin to pin.

Design Procedure

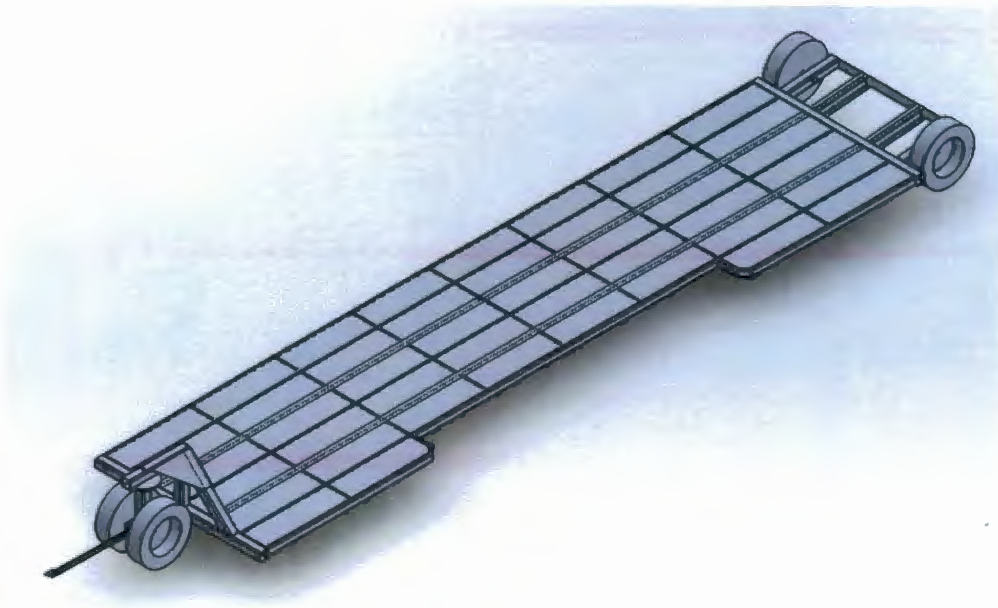

Figure 12. Full Assembly of Trailer

After the general dimensions and design considerations had been covered the entire trailer was "mocked up" using the Cal Poly BRAE Department Solid Works design software. The drawing was do as an assembly with many components. The main components where broken up into the deck frame, deck top plate, rear axle assembly, front gooseneck assembly, front axle assembly, hitch and wheels. The assembly was broken up into these pieces because the same steel was used for each one of these components. If a different size, type or wall thickness of steel was needed a different size part drawing was used. Whenever possible the drawings where done using the weldments capabilities of solid works.

The main trailer beams will need to support a dead load of 8,000lbs and a live load of approximately 4,395lbs. The total length of the trailer is 31.5'. The weight per foot of the trailer is 393lbs per foot. Assuming an allowable stress of 30,000lb-in^2 for mild steel the section modulus needed will be 19.5in^3. The allowable stress is calculated as 0.6 of the yield stress, which is 50,000lb-in^2. The calculations can be seen in Appendix B.

The main deck frame was designed using two W6 x 16 beams and 4" x 2" x 1/4" tubing as seen below in Figure 13. The two wide flange beams run the whole 31.5'. The main tubing members (4) run a length of 31.5'. The fifth tubing member does not run the full length due to the notch in the left side of the deck. Seven cross members connect the tubing members together and add total rigidity.

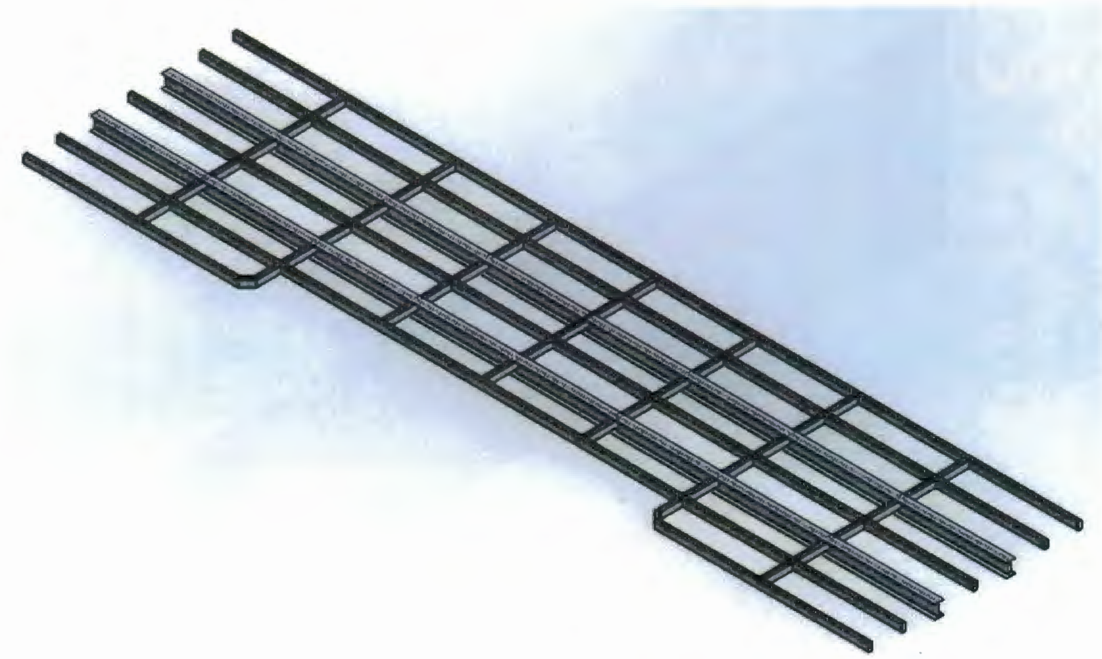

Figure 13. Main Deck Frame.

The deck was set to be ¼" diamond plate steel as seen below in Figure 14 (not simulated on Solid Works). This diamond plate steel was oversized in thickness with the anticipation of many large point loads that could have the potential of puncturing the top of the deck. These point loads will be a result of the various shoes and shanks that are sharp and bare a large portion of the total weight of the implement often.

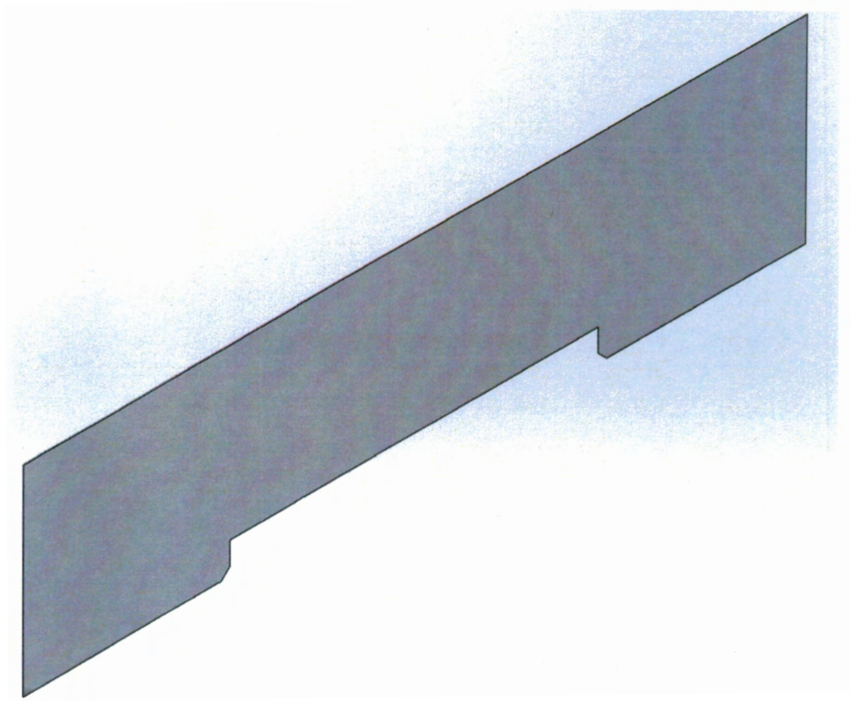

Figure 14. Deck Top.

The rear axle assembly was created in solid works using 5" x 5" x 3/8" square steel tubing as seen in Figure 15. Without accurately sizing the wheels and tires at the point of the SolidWorks drawings the height and angle of the horizontal member that would support the rear axle, the drawing was based on a 31" tire which is a common size. Spindles for the rear axle where intended to be "hard-mounted" to the rear horizontal members. The rear horizontal members where intended to be as wide as possible while still allowing for the profile of the tires in order to keep the rear wheel base as wide as possible and ultimately the trailer as stable as possible.

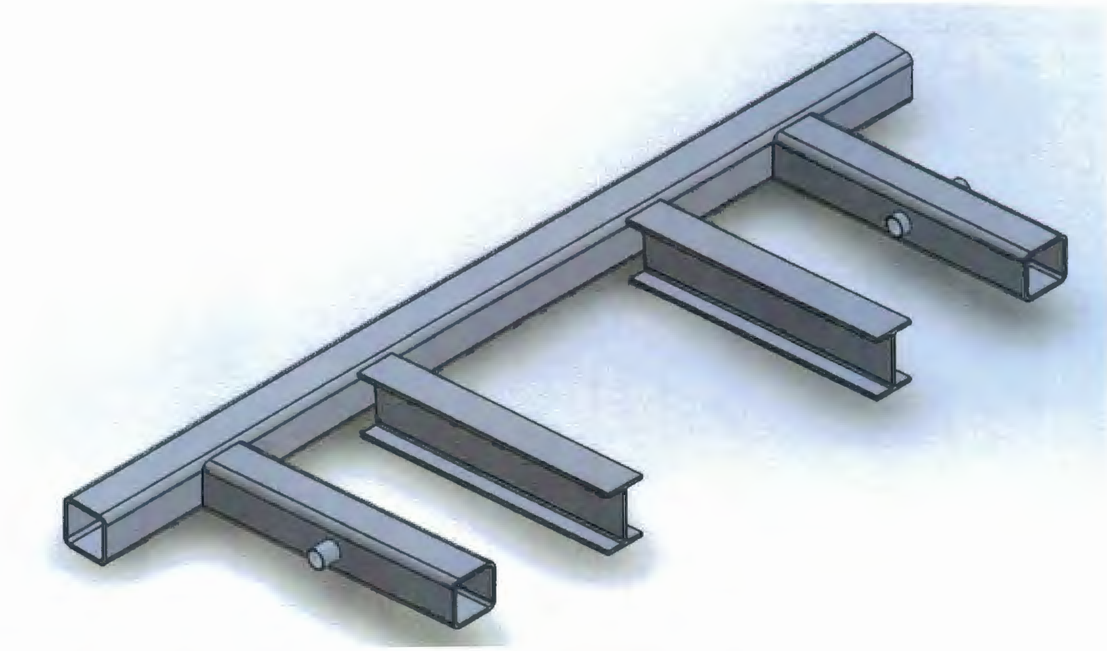

Figure 15. Rear Axle Assembly.

The original Gooseneck member was to be made of 5" x 5" x 3/8" steel tubing as seen in Figure 16. The gooseneck was designed to have one vertical member and two members creating a triangle to increase the overall stability and reduce the possibility of failure due to torsion. The pivot point of the front axle was to be positioned below the front most portion of the horizontal member. Braces will be added depending on the amount of scrap steel left and the final design.

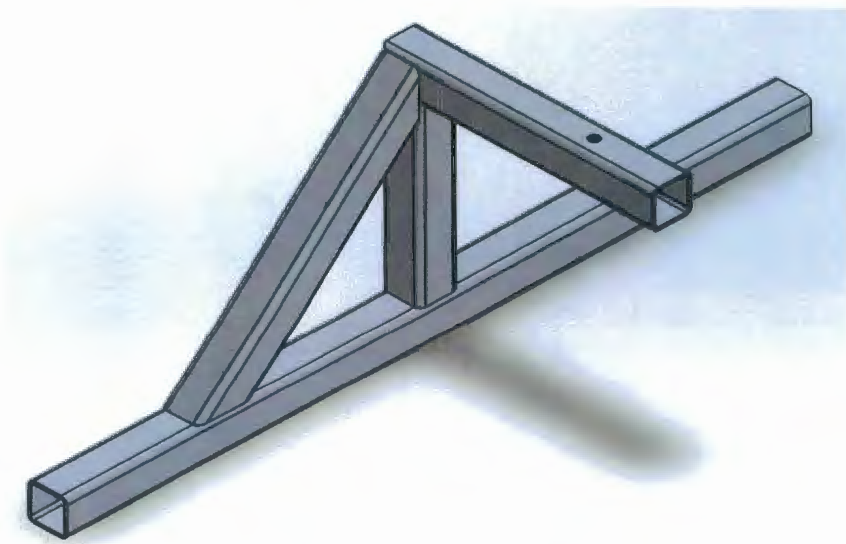

Figure 16. Gooseneck Member.

The front axle was designed to attach to the gooseneck with a vertical column as seen in Figure 17. A turntable will allow for the front axle to turn. The spindles will be mounted through the square tubing. On the front most face of the tubing a clevis will be added to accept the tongue. A ridged tongue to axle structure was discussed with the pivot point of the gooseneck being slightly in front of the axle to add some tongue weight to the towing vehicle. The addition of tongue weight would increase the overall stability when towed and increase the traction of the tow vehicle. Due to the complexity of the loading and ease of hitching this design feature was scrapped.

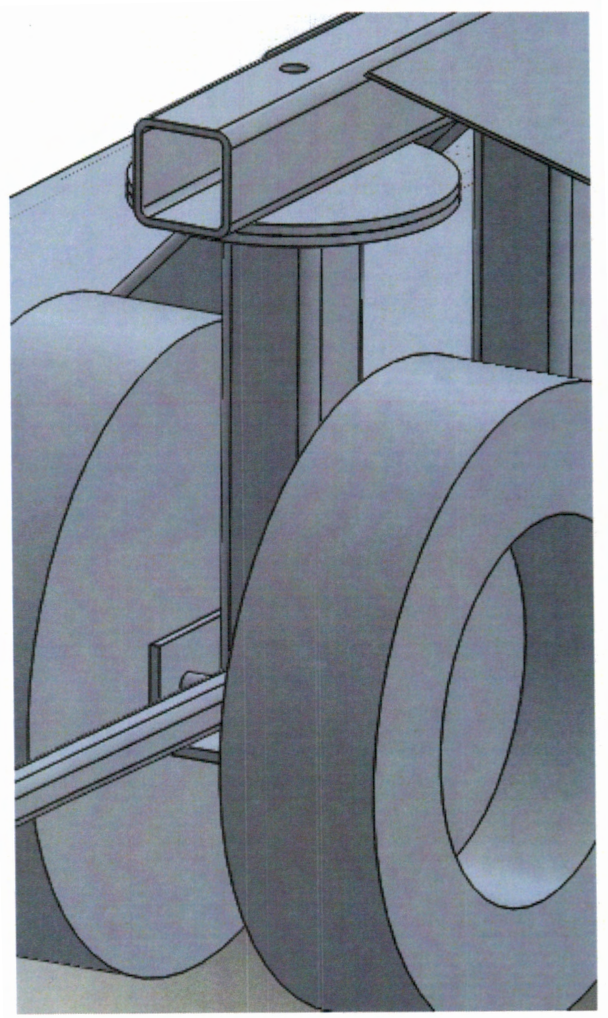

Figure 17. Steering Column and Turntable.

The hitch was determined to be 5" x 5" square tubing with a bushing on one side to mate to the front axle and a single clevis tongue in the front of the hitch as seen in Figure 18. A thick single tongue was chosen with the intentions of greater versatility and ease of hitching. A hitch jack and safety chains where intended to be added.

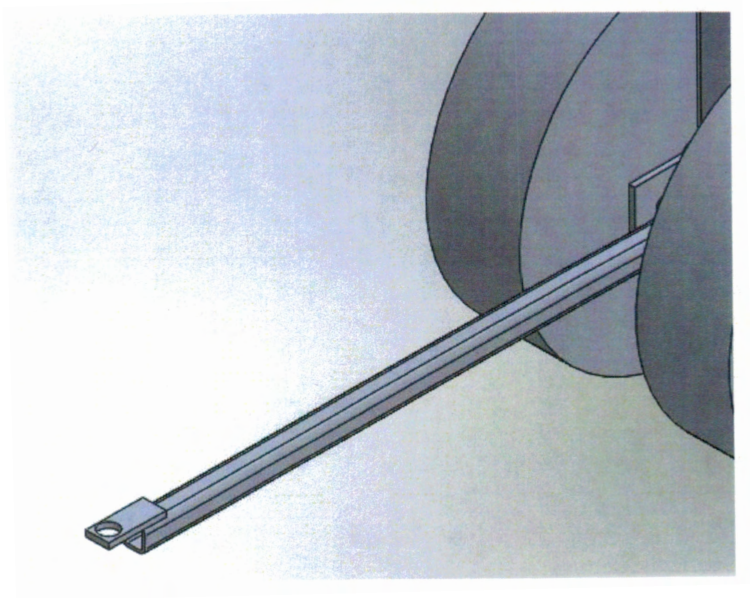

Figure 18. Hitch and Tongue.

Materials Acquisition

A cut list was next formed based upon the solid works drawings that where completed and can be seen below in table 1. Due to the fairly limited different types of steel used the cut list was fairly simple. The front gooseneck, rear axle assembly and the front axle was all the same 5" x 5" x 3/8" steel so it was lumped together when ordering the steel. The 4" x 2" x 1/4" pieces of steel where ordered as 40' pieces therefore butt welding smaller pieces was not necessary to complete the large 31.5' spans for the main deck.

Table 1. Estimated Cut List.

Metal	Estimated Inches	Estimated Feet	# of Sticks	# of 4'x8' Sheets	Amount of Scrap
Gooseneck					
5"x5"x3/8" tube	224"	20.6'	1 @ 20'		None
Tail					
5"x5"x3/8" tube	192"	16'	1 @ 20'		4' to be used on Gooseneck
Deck Structure					
4"x2"x1/4" tube	2514"	209'	5 @ 40'		None
Deck Surface					
1/4" diamond plate	34776 sq-in	241.4 sq-ft		8	15'^2
Metal Strap					
48"x48"x1/2" strap	2,304 sq-in	16 sq-ft		0.5	
W-Flange Beam					
W6 x 16 beam	776"	70	2 @ 35'		15'

The other items needed for the completion of the trailer where acquired through various local businesses that McKean farms has charge accounts for with the miscellaneous components such as lights, wheels, tires, hubs, spindles and D-rings.

Fabrication

The fabrication was all done at McKean Farms, where access to Solid Works software is not possible, therefore screen-shots and dimensioned models where used to construct the trailer. This was a hurdle, and did lead to many of the dimensions and components to change from the models to the actual finished product. Also, key parts such as wheels and spindles where acquired after the models were completed, therefore many items had to be mocked during construction.

To start the fabrication all parts where cut to size according to cut list. Once all pieces for the main deck where cut the correct size the main four members that run the full 31.5' were laid out with the cross members connecting them. They were shimmed level and tacked together as seen in Figure 19.

Figure 19. Shims and Tack Welds for Rough Fit-Up.

Once the main frame was tacked together the end caps of 5" x 5" x 3/8" were tacked on. When adding the end caps braces where added to provide more strength to the frame end cap connection as seen in Figure 20. Outside straps where used to strengthen the connection between the 4" x 2" and the 5" x 5" members as well as to cap the 5" x 5" tubes.

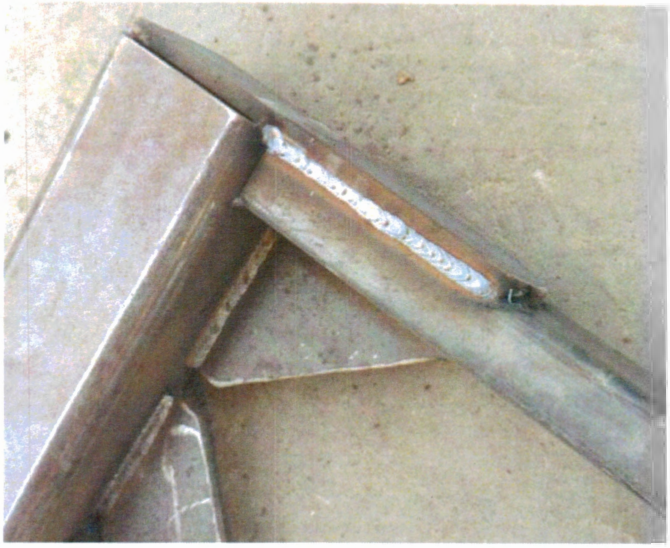

Figure 20. Braces and Strap Cap Added.

The 15" deep notch was added to the left side of the trailer as seen in Figure 21. A bevel was added to the corners of the notch for aesthetic purposes. Later the sheet metal that will be added to the top of the deck will follow the profile of the notch.

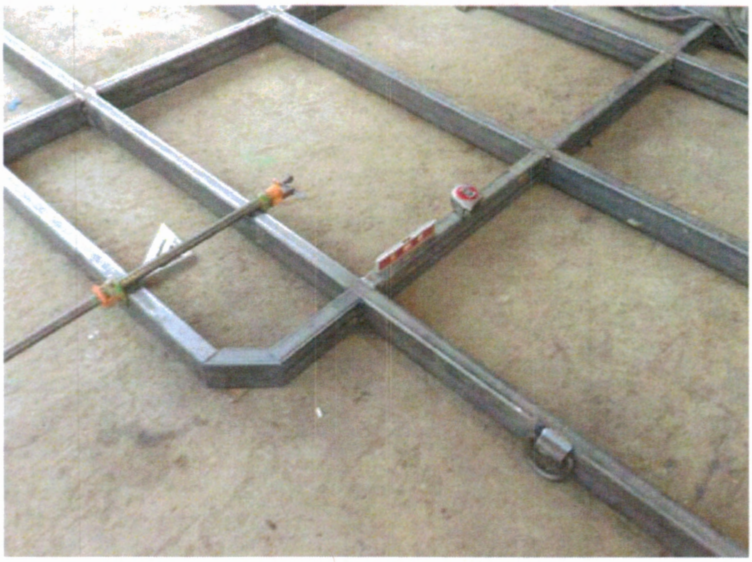

Figure 21. Notch with Bevel.

Once all members of the frame and end caps where tacked together and everything was re measured and determined to be square. All of the members where welded together as seen in Figure 22. All top and bottom welds where completed first, then the welds on the sides of the frame once the frame was flipped vertical. A staggered approach to all of the welding was very important to not warp the frame of during the heating and cooling of the welding on the frame.

Figure 22. Welding of the Frame.

The frame was pre-arched when the deck top was tacked on. The deck top used is 1/4" thick diamond plate steel. This thick of steel was going to add a large portion of weight but does have the ability to add structural stability to the total frame. With this much weight across a 31.5' span though the trailer was bound to sag in the center of the span. It was decided to pre-arch the structural members across the span when the deck top was added. The reason for doing this is to essentially use the top deck in compression to add rigidity to the total frame. The frame would be pre-arched to be 6" higher than that outside caps when the deck top was added as seen in Figure 23. The pre-arch height determination was an estimation based on possibility of deflection. The process that was used involved 6" blocks in the center of the span and a forklift and truck on either end to compress the plate and frame together and the frame to the ground. The deck top was tacked on from the outside in. Once that process was complete the frame was flipped over and the deck was fully welded to the frame. Once all of the welding was complete the deck top was trimmed to fit the profile of the main frame.

Figure 23. Deck Top Being Added to Frame While Pre-Arched.

Next was the addition of the rear axle portion of the trailer. First the wheels, tires, hubs and spindles where acquired to perform a mockup of the dimensions of the axle placement as seen in Figure 24. Originally the rear axle portion of the trailer consisted of a two vertical members that came up 4" with two horizontal members that protruded rearwards to support each wheel with at connecting member as the rear bumper. After some thought and contemplation it was determined to scrap the vertical member and have the two horizontal members that protrude rearwards to be pitched up at a slight angle to accommodate for the ultimate height of the trailer. The angle needed was 6 degrees. This angle puts the rear axle square in the center of the horizontal 4" x 4" member at 32.5" from the frame caps. This gives a level deck height of 15" off of the ground. The determination of this dimension was done by setting the trailer at level using jacks 15" above a level surface and using paper templates to determine the proper angle needed. Once the template determined the angle needed, this angle was transposed onto the 4" x 4" member. The members where cut and tacked in place to do a visual mockup.

Figure 24. Rearward Axle Members Tacked in Place.

Next a hole was pierced in both of the end caps with a cutting torch and a steel wire was ran from the front of the trailer frame to the rear of the trailer frame as seen in Figure 25. This was done with the intentions of using this wire to pull electrical wires through the frame later once the general construction is finished.

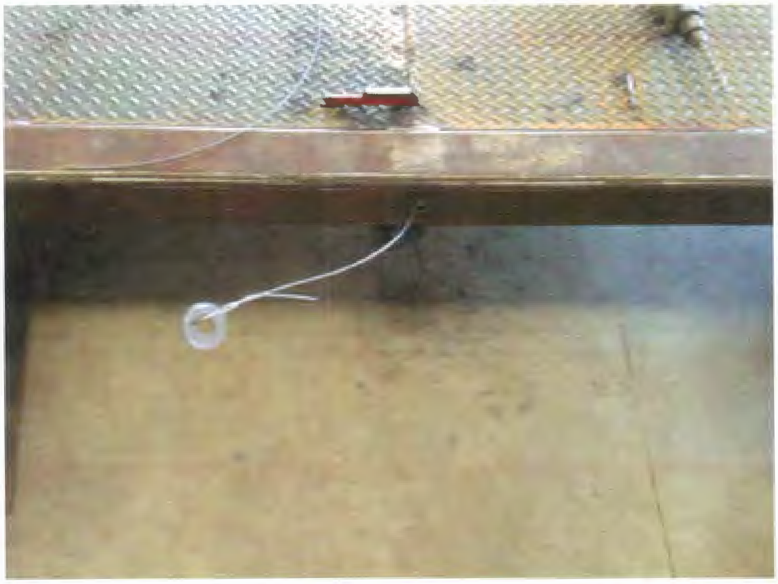

Figure 25. A Wire to Pull Tail Light Wires Through Later.

The front axle portion of the trailer was next to be mocked up as seen in Figure 26. The vertical member was cut to size allowing for plenty of clearance for the front wheel to clear the turntable. Next the horizontal member was cut to size. The joint between the vertical and horizontal member is a 45-degree miter joint, which will add extra strength. The 90-degree turn in the gooseneck joint was slightly greater than 90 degrees to add a slight rake to the front axle to aid in the straight tracking of the front axle and reduce the chance of the trailer wanting to "swim" as it is being towed.

Figure 26. Mock-Up of the Gooseneck.

Once the gooseneck portion of the trailer is tacked in place the next item to work on was the turntable and vertical member to drop down to the axle. First a turntable was cut to size as seen in Figure 27. The turntable is made out of ½" thick plate with one 1 1/4" hole in the center for the main pin and two small holes to accommodate grease zerks. The plates where rough cut by hand with a torch then tack welded together and cleaned up with a torch and then grinder to ensure uniformity. Once they looked uniform a hole was drilled through both plates in the center of the circle. Then the plates where broken apart and the holes for the zerks where drilled and tapped.

Figure 27. Turntables Cut to Size.

Next the vertical member was cut to the span the distance between the axle and the turntable. This again was 5" x 5"tubing. Once the tubing was cut, using a floor jack the tubing was put into place as seen in Figure 28.

Figure 28. Turntable and Vertical Member Mock-Up.

Next, using the existing pieces available the turning clearance was checked by turning the vertical tubing approximately 45 degrees and placing the wheels the intended distance away from the vertical member as seen in Figure 29. All clearances check out as expected.

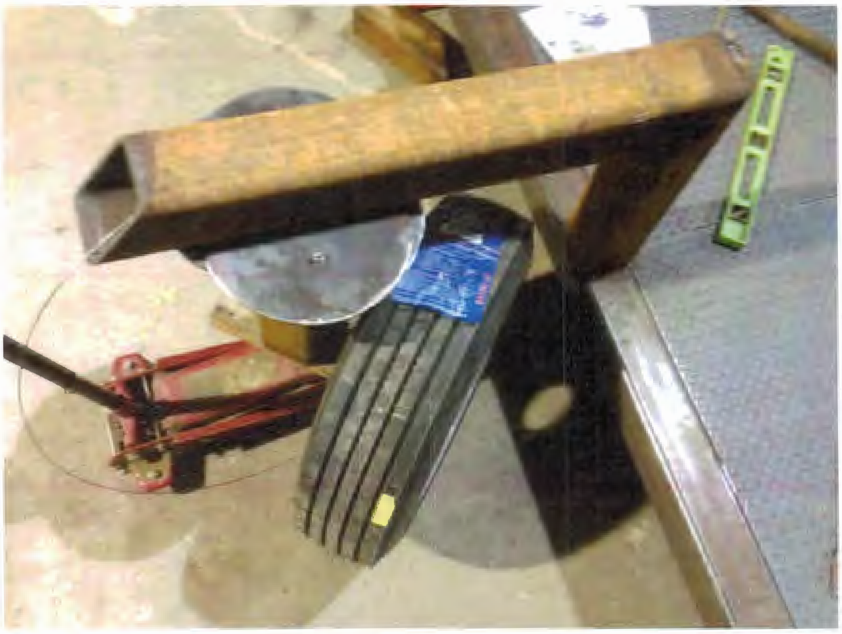

Figure 29. Checking Clearances for Turning.

Once all clearances looked good the two rear axle horizontal members, the horizontal gooseneck member and the vertical front axle member where all removed. The tacks where removed so all of these pieces can be transported to a local machine shop, where Mike Acquistapace was to install DOM tubing bushings to accept the spindles and front axle pivot pin. The intended design allowed for all four spindles to be installed using set screws to hold the spindles in the DOM tubing. For the front axle both spindles will be butted against each other within the DOM tubing with a grease zerk between both of them to assist in pushing the spindles out of the DOM tubing if they ever need to be removed. The first step of this whole process started with large holes needed to accept the DOM tubing as seen in Figure 30. First a center hole was drilled on an end mill then widened out with a criterion boring bar. The criterion boring bar was used to bore out a large enough hole to accept the O.D. of the DOM tubing as seen in Fig 30.

Figure 30. Criterion Boring Bar Boring Out Holes to Accept DOM Spindle Tubes.

Next the DOM tubing that is intended to accept the spindles had to be bored out. Mike Aquistapace bored out the inner diameter of the DOM tubing to accept the spindles with a small amount of clearance. Mike used a boring bar on a lathe to provide the correct ID to the DOM tubing as seen in Figure 31.

Figure 31. Lathe Mounted Boring Bar.

Next Mike added a flat face to all four spindles. The flat face on the spindles is used to secure the spindles inside the DOM tubing that they are inserted in. Note the spindle fit-up in Figure 32. A pair of set screws will be tightened against the flat face that is milled on the spindle as seen in Figure 33. This allows for the spindles to be removed if they are ever damaged. The front axle tube will house both spindles butted together. A grease zerk will be inserted between the two spindles to aid in pushing the spindles out if they ever do need to be removed. The location of the set screws will be on the bottom of the tubing. The reason for the location of the set screws on the bottom is to hold the spindles up against the top of the DOM tubing, therefore taking the majority of the force. All three pieces of the DOM tubing will be welded on both sides of the 5" x 5" members. The tubing was next welded in place and the spindles installed.

Figure 32. Spindle Tubing and Spindle Installed.

Figure 33. Set Screws on the Underside of the Spindle Tubing (rear).

Gussets were then added to support the horizontal members for the rear axle along with the welds to join both pieces of 5" x 5" tubing as seen below in Figure 34. The strap show

in the Figure below is ½" thick steel plate that is a remnant of other plate that was later used.

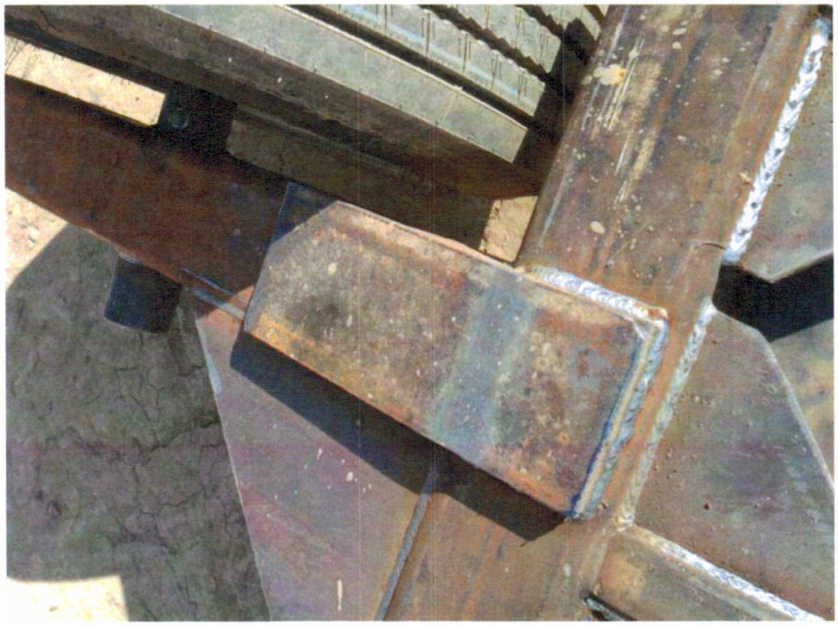

Figure 34. Final Welding and Gussets for the Rear Axle Members.

Next the front axle DOM tubing was welded in place and the spindle inserted and tightened down. The lower turntable was welded onto the vertical member with the pivot pin welded ridged through the center of the plate. Gussets were added to the turntable plate and vertical 5" x 5" member. At this point the vertical member was ready to be inserted into the gooseneck portion of the trailer.

The gooseneck vertical member and horizontal member was joined together next with by a complete weld around all four sided of the miter joint. Then 45 degree angle gussets where added as seen in Figure 34 to add strength to the gooseneck portion. Next the DOM tubing used to accommodate the pivot pin was inserted into the bored holes in the horizontal gooseneck member and welded in place. A fitting was added to the side of the DOM tubing to accommodate a tube extension for a grease zerk. The upper turntable plate was also welded in place and gusseted against the 5" x 5" member.

Figure 35. 45 Degree Angle Gooseneck Braces Added.

Next the lower portion of the gooseneck assembly and the rigid portion of the gooseneck assembly where mated together. The pin was lifted through the DOM pivot tubing using a floor jack and the castle nut was tightened on the pivot pin and a pin was applied to the castle nut. A castle nut was used to eliminate the chance of the nut coming loose when the turntable is moved as seen in Figure 36. Note, the grease zerk protruding out of the 5" x 5" tubing that connects to the DOM pivot tubing also seen in Figure 36.

Figure 36. Assembled front gooseneck.

Next the front hitch tubing was determined to be 50" long and was be made out of the same 5" x 5" tubing. A scrap of ¾" thick strap was used as the hitch pivot. A 1.25" hole was drilled in the plate and the corners of the plate were beveled to allow for the tongue turning in the tow vehicle's hitch clevis. An insert was cut out of the hitch tubing to allow for a larger welded area when the tongue and hitch are jointed together as seen in Figure 37. The tongue and hitch was then welded together.

Figure 37. Front Hitch and Tongue before Welding.

Next a bushing was added to the rear of the hitch to accommodate a pin that connects the hitch to the front axle. The bushing was welded on both sides. Then two ¾" thick plates were welded on either side of the vertical member to accept the pin as seen in Figure 38. This design does require a wheel to be removed if the pin needs to be removed, but this pin should rarely ever be removed.

Figure 38. Front Hitch Attachment to the Front Axle Member.

Lastly various gussets where added to the front gooseneck portion of the trailer to aid in the rigidity of the gooseneck as it will experience high loads. Note the gussets in Figure 39. The gussets added where do increase the weight and seem like overkill but this was done per request of McKean Farms.

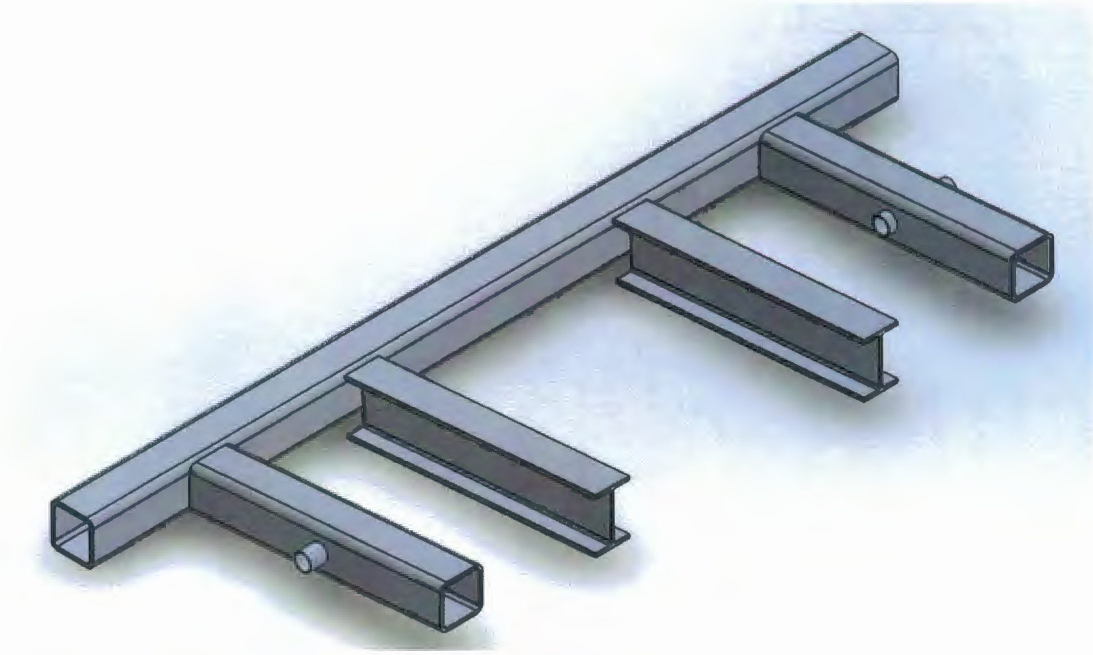

Figure 15. Rear Axle Assembly.

The original Gooseneck member was to be made of 5" x 5" x 3/8" steel tubing as seen in Figure 16. The gooseneck was designed to have one vertical member and two members creating a triangle to increase the overall stability and reduce the possibility of failure due to torsion. The pivot point of the front axle was to be positioned below the front most portion of the horizontal member. Braces will be added depending on the amount of scrap steel left and the final design.

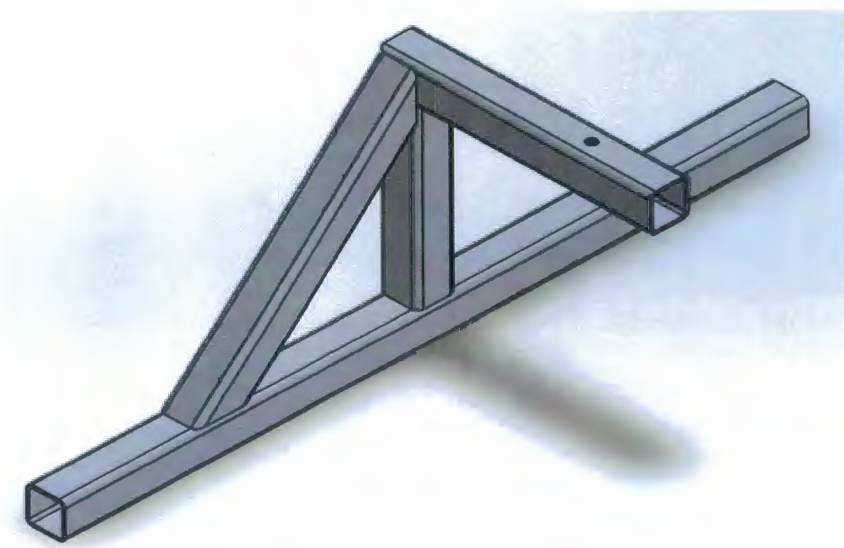

Figure 16. Gooseneck Member.

The front axle was designed to attach to the gooseneck with a vertical column as seen in Figure 17. A turntable will allow for the front axle to turn. The spindles will be mounted through the square tubing. On the front most face of the tubing a clevis will be added to accept the tongue. A ridged tongue to axle structure was discussed with the pivot point of the gooseneck being slightly in front of the axle to add some tongue weight to the towing vehicle. The addition of tongue weight would increase the overall stability when towed and increase the traction of the tow vehicle. Due to the complexity of the loading and ease of hitching this design feature was scrapped.

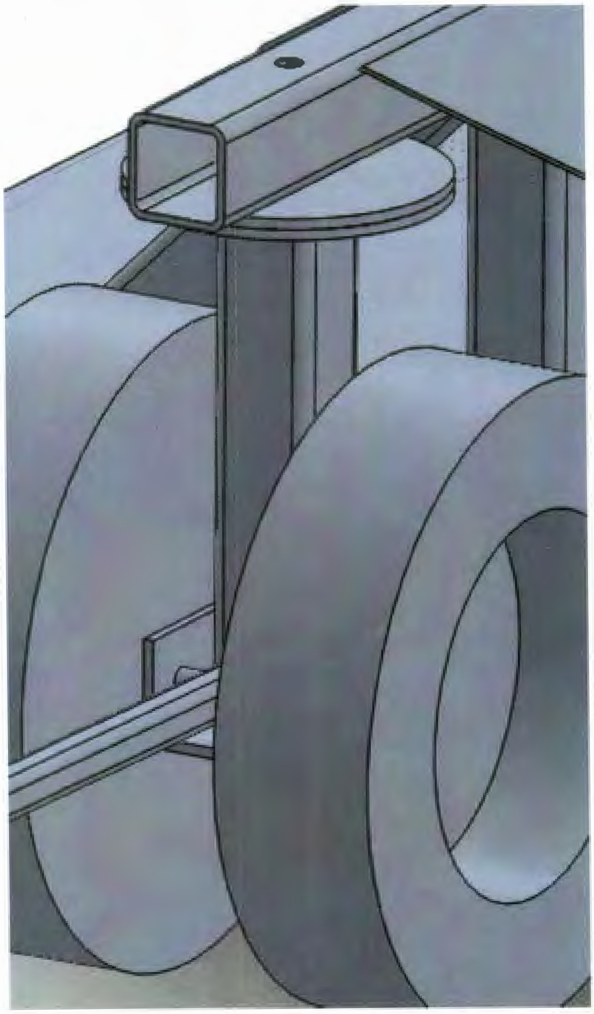

Figure 17. Steering Column and Turntable.

The hitch was determined to be 5" x 5" square tubing with a bushing on one side to mate to the front axle and a single clevis tongue in the front of the hitch as seen in Figure 18. A thick single tongue was chosen with the intentions of greater versatility and ease of hitching. A hitch jack and safety chains where intended to be added.

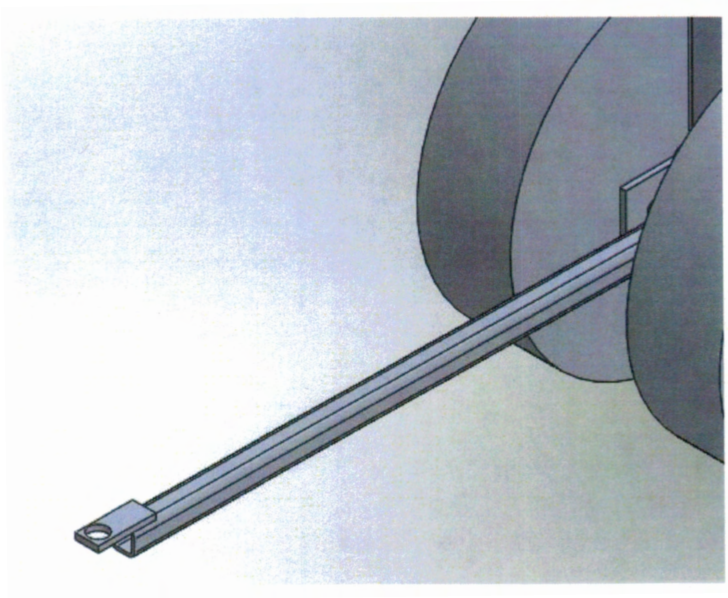

Figure 18. Hitch and Tongue.

Materials Acquisition
A cut list was next formed based upon the solid works drawings that where completed and can be seen below in table 1. Due to the fairly limited different types of steel used the cut list was fairly simple. The front gooseneck, rear axle assembly and the front axle was all the same 5" x 5" x 3/8" steel so it was lumped together when ordering the steel. The 4" x 2" x 1/4" pieces of steel where ordered as 40' pieces therefore butt welding smaller pieces was not necessary to complete the large 31.5' spans for the main deck.

Table 1. Estimated Cut List.

Metal	Estimated Inches	Estimated Feet	# of Sticks	# of 4'x8' Sheets	Amount of Scrap
Gooseneck					
5"x5"x3/8" tube	224"	20.6'	1 @ 20'		None
Tail					
5"x5"x3/8" tube	192"	16'	1 @ 20'		4' to be used on Gooseneck
Deck Structure					
4"x2"x1/4" tube	2514"	209'	5 @ 40'		None
Deck Surface					
1/4" diamond plate	34776 sq-in	241.4 sq-ft		8	15'^2
Metal Strap					
48"x48"x1/2" strap	2,304 sq-in	16 sq-ft		0.5	
W-Flange Beam					
W6 x 16 beam	776"	70	2 @ 35'		15'

The other items needed for the completion of the trailer where acquired through various local businesses that McKean farms has charge accounts for with the miscellaneous components such as lights, wheels, tires, hubs, spindles and D-rings.

Fabrication
The fabrication was all done at McKean Farms, where access to Solid Works software is not possible, therefore screen-shots and dimensioned models where used to construct the trailer. This was a hurdle, and did lead to many of the dimensions and components to change from the models to the actual finished product. Also, key parts such as wheels and spindles where acquired after the models were completed, therefore many items had to be mocked during construction.

To start the fabrication all parts where cut to size according to cut list. Once all pieces for the main deck where cut the correct size the main four members that run the full 31.5' were laid out with the cross members connecting them. They were shimmed level and tacked together as seen in Figure 19.

Figure 19. Shims and Tack Welds for Rough Fit-Up.

Once the main frame was tacked together the end caps of 5" x 5" x 3/8" were tacked on. When adding the end caps braces where added to provide more strength to the frame end cap connection as seen in Figure 20. Outside straps where used to strengthen the connection between the 4" x 2" and the 5" x 5" members as well as to cap the 5" x 5" tubes.

Figure 20. Braces and Strap Cap Added.

The 15" deep notch was added to the left side of the trailer as seen in Figure 21. A bevel was added to the corners of the notch for aesthetic purposes. Later the sheet metal that will be added to the top of the deck will follow the profile of the notch.

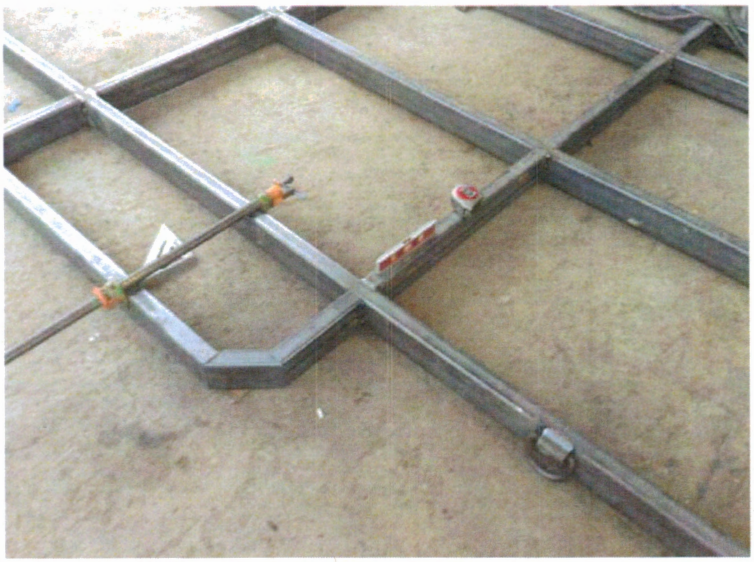

Figure 21. Notch with Bevel.

Once all members of the frame and end caps where tacked together and everything was re measured and determined to be square. All of the members where welded together as seen in Figure 22. All top and bottom welds where completed first, then the welds on the sides of the frame once the frame was flipped vertical. A staggered approach to all of the welding was very important to not warp the frame of during the heating and cooling of the welding on the frame.

Figure 22. Welding of the Frame.

The frame was pre-arched when the deck top was tacked on. The deck top used is 1/4" thick diamond plate steel. This thick of steel was going to add a large portion of weight but does have the ability to add structural stability to the total frame. With this much weight across a 31.5' span though the trailer was bound to sag in the center of the span. It was decided to pre-arch the structural members across the span when the deck top was added. The reason for doing this is to essentially use the top deck in compression to add rigidity to the total frame. The frame would be pre-arched to be 6" higher than that outside caps when the deck top was added as seen in Figure 23. The pre-arch height determination was an estimation based on possibility of deflection. The process that was used involved 6" blocks in the center of the span and a forklift and truck on either end to compress the plate and frame together and the frame to the ground. The deck top was tacked on from the outside in. Once that process was complete the frame was flipped over and the deck was fully welded to the frame. Once all of the welding was complete the deck top was trimmed to fit the profile of the main frame.

Figure 23. Deck Top Being Added to Frame While Pre-Arched.

Next was the addition of the rear axle portion of the trailer. First the wheels, tires, hubs and spindles where acquired to perform a mockup of the dimensions of the axle placement as seen in Figure 24. Originally the rear axle portion of the trailer consisted of a two vertical members that came up 4" with two horizontal members that protruded rearwards to support each wheel with at connecting member as the rear bumper. After some thought and contemplation it was determined to scrap the vertical member and have the two horizontal members that protrude rearwards to be pitched up at a slight angle to accommodate for the ultimate height of the trailer. The angle needed was 6 degrees. This angle puts the rear axle square in the center of the horizontal 4" x 4" member at 32.5" from the frame caps. This gives a level deck height of 15" off of the ground. The determination of this dimension was done by setting the trailer at level using jacks 15" above a level surface and using paper templates to determine the proper angle needed. Once the template determined the angle needed, this angle was transposed onto the 4" x 4" member. The members where cut and tacked in place to do a visual mockup.

Figure 24. Rearward Axle Members Tacked in Place.

Next a hole was pierced in both of the end caps with a cutting torch and a steel wire was ran from the front of the trailer frame to the rear of the trailer frame as seen in Figure 25. This was done with the intentions of using this wire to pull electrical wires through the frame later once the general construction is finished.

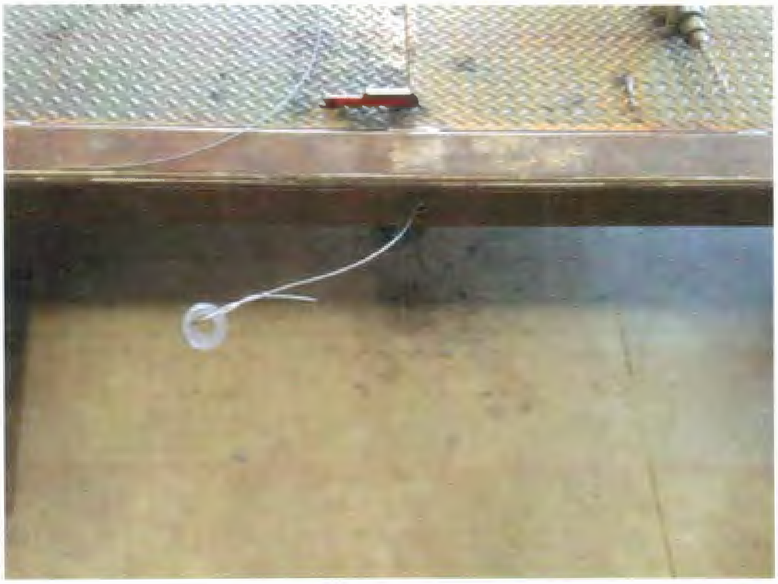

Figure 25. A Wire to Pull Tail Light Wires Through Later.

The front axle portion of the trailer was next to be mocked up as seen in Figure 26. The vertical member was cut to size allowing for plenty of clearance for the front wheel to clear the turntable. Next the horizontal member was cut to size. The joint between the vertical and horizontal member is a 45-degree miter joint, which will add extra strength. The 90-degree turn in the gooseneck joint was slightly greater than 90 degrees to add a slight rake to the front axle to aid in the straight tracking of the front axle and reduce the chance of the trailer wanting to "swim" as it is being towed.

Figure 26. Mock-Up of the Gooseneck.

Once the gooseneck portion of the trailer is tacked in place the next item to work on was the turntable and vertical member to drop down to the axle. First a turntable was cut to size as seen in Figure 27. The turntable is made out of ½" thick plate with one 1 1/4" hole in the center for the main pin and two small holes to accommodate grease zerks. The plates where rough cut by hand with a torch then tack welded together and cleaned up with a torch and then grinder to ensure uniformity. Once they looked uniform a hole was drilled through both plates in the center of the circle. Then the plates where broken apart and the holes for the zerks where drilled and tapped.

Figure 27. Turntables Cut to Size.

Next the vertical member was cut to the span the distance between the axle and the turntable. This again was 5" x 5"tubing. Once the tubing was cut, using a floor jack the tubing was put into place as seen in Figure 28.

Figure 28. Turntable and Vertical Member Mock-Up.

Next, using the existing pieces available the turning clearance was checked by turning the vertical tubing approximately 45 degrees and placing the wheels the intended distance away from the vertical member as seen in Figure 29. All clearances check out as expected.

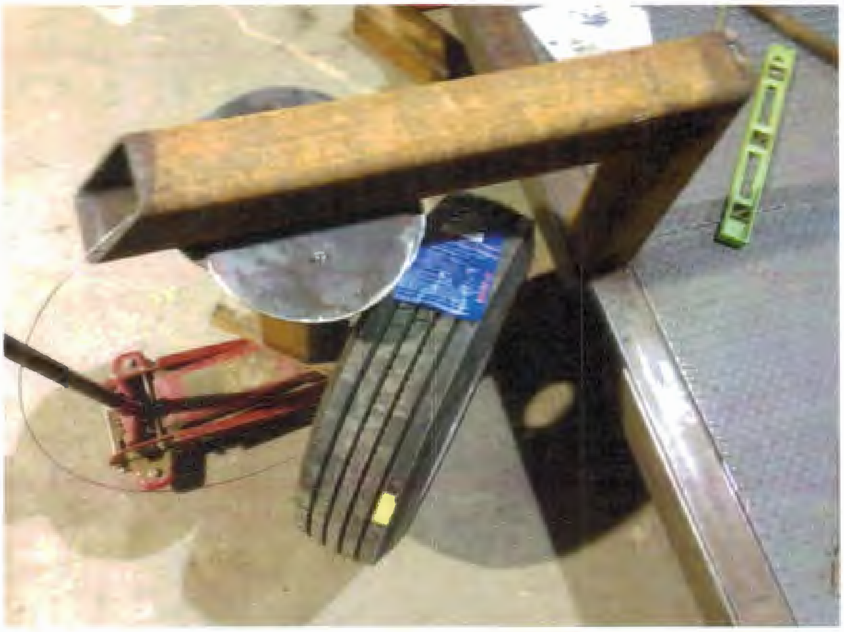

Figure 29. Checking Clearances for Turning.

Once all clearances looked good the two rear axle horizontal members, the horizontal gooseneck member and the vertical front axle member where all removed. The tacks where removed so all of these pieces can be transported to a local machine shop, where Mike Acquistapace was to install DOM tubing bushings to accept the spindles and front axle pivot pin. The intended design allowed for all four spindles to be installed using set screws to hold the spindles in the DOM tubing. For the front axle both spindles will be butted against each other within the DOM tubing with a grease zerk between both of them to assist in pushing the spindles out of the DOM tubing if they ever need to be removed. The first step of this whole process started with large holes needed to accept the DOM tubing as seen in Figure 30. First a center hole was drilled on an end mill then widened out with a criterion boring bar. The criterion boring bar was used to bore out a large enough hole to accept the O.D. of the DOM tubing as seen in Fig 30.

Figure 30. Criterion Boring Bar Boring Out Holes to Accept DOM Spindle Tubes.

Next the DOM tubing that is intended to accept the spindles had to be bored out. Mike Aquistapace bored out the inner diameter of the DOM tubing to accept the spindles with a small amount of clearance. Mike used a boring bar on a lathe to provide the correct ID to the DOM tubing as seen in Figure 31.

Figure 31. Lathe Mounted Boring Bar.

Next Mike added a flat face to all four spindles. The flat face on the spindles is used to secure the spindles inside the DOM tubing that they are inserted in. Note the spindle fit-up in Figure 32. A pair of set screws will be tightened against the flat face that is milled on the spindle as seen in Figure 33. This allows for the spindles to be removed if they are ever damaged. The front axle tube will house both spindles butted together. A grease zerk will be inserted between the two spindles to aid in pushing the spindles out if they ever do need to be removed. The location of the set screws will be on the bottom of the tubing. The reason for the location of the set screws on the bottom is to hold the spindles up against the top of the DOM tubing, therefore taking the majority of the force. All three pieces of the DOM tubing will be welded on both sides of the 5" x 5" members. The tubing was next welded in place and the spindles installed.

Figure 32. Spindle Tubing and Spindle Installed.

Figure 33. Set Screws on the Underside of the Spindle Tubing (rear).

Gussets were then added to support the horizontal members for the rear axle along with the welds to join both pieces of 5" x 5" tubing as seen below in Figure 34. The strap show

in the Figure below is ½" thick steel plate that is a remnant of other plate that was later used.

Figure 34. Final Welding and Gussets for the Rear Axle Members.

Next the front axle DOM tubing was welded in place and the spindle inserted and tightened down. The lower turntable was welded onto the vertical member with the pivot pin welded ridged through the center of the plate. Gussets were added to the turntable plate and vertical 5" x 5" member. At this point the vertical member was ready to be inserted into the gooseneck portion of the trailer.

The gooseneck vertical member and horizontal member was joined together next with by a complete weld around all four sided of the miter joint. Then 45 degree angle gussets where added as seen in Figure 34 to add strength to the gooseneck portion. Next the DOM tubing used to accommodate the pivot pin was inserted into the bored holes in the horizontal gooseneck member and welded in place. A fitting was added to the side of the DOM tubing to accommodate a tube extension for a grease zerk. The upper turntable plate was also welded in place and gusseted against the 5" x 5" member.

Figure 35. 45 Degree Angle Gooseneck Braces Added.

Next the lower portion of the gooseneck assembly and the rigid portion of the gooseneck assembly where mated together. The pin was lifted through the DOM pivot tubing using a floor jack and the castle nut was tightened on the pivot pin and a pin was applied to the castle nut. A castle nut was used to eliminate the chance of the nut coming loose when the turntable is moved as seen in Figure 36. Note, the grease zerk protruding out of the 5" x 5" tubing that connects to the DOM pivot tubing also seen in Figure 36.

Figure 36. Assembled front gooseneck.

Next the front hitch tubing was determined to be 50" long and was be made out of the same 5" x 5" tubing. A scrap of ¾" thick strap was used as the hitch pivot. A 1.25" hole was drilled in the plate and the corners of the plate were beveled to allow for the tongue turning in the tow vehicle's hitch clevis. An insert was cut out of the hitch tubing to allow for a larger welded area when the tongue and hitch are jointed together as seen in Figure 37. The tongue and hitch was then welded together.

Figure 37. Front Hitch and Tongue before Welding.

Next a bushing was added to the rear of the hitch to accommodate a pin that connects the hitch to the front axle. The bushing was welded on both sides. Then two ¾" thick plates were welded on either side of the vertical member to accept the pin as seen in Figure 38. This design does require a wheel to be removed if the pin needs to be removed, but this pin should rarely ever be removed.

Figure 38. Front Hitch Attachment to the Front Axle Member.

Lastly various gussets where added to the front gooseneck portion of the trailer to aid in the rigidity of the gooseneck as it will experience high loads. Note the gussets in Figure 39. The gussets added where do increase the weight and seem like overkill but this was done per request of McKean Farms.

Figure 39. Gussets Added to the Gooseneck.

A tool box in the rear of the trailer was also added to accommodate various chains, binders and other tools needed. The tool box has a simple latch and two gas springs to aid in lifting the door as seen in Figure 40.

Figure 40. Tool Box in the Rear of Trailer.

Lights and Paint

Lights have been added to the rear of the trailer to aid in warning other drivers when slowing down on the road as seen in figure 41.

Figure 41. Lights Added to the Rear of the Trailer.

The trailer has not been painted yet due to the trailer being used often during the spring listing and planting season.

Testing

The trailer was tested by putting a cultivator on the deck. Loading of multiple types of bars and combine headers was completed and all pieces of equipment fit on the trailer well. Once loaded the trailer was driven for approximately an hour. Despite the trailer being very low to the ground the belly did not sag on the ground. The trailer proved to turn well and handled very well.

RESULTS

The results of this senior project are a fully functioning implement transport trailer that meets the original requirements.

Final Design

The trailer was flipped back over and loaded with the same cultivator and the results were far better the trailer sags less than a ½" when loaded as seen below in Figure 42. The clearance below the deck of the trailer only at 8.5" from the ground along the length of the trailer.

Figure 42. The Trailer Loaded.

At the current time, McKean farms is very pleased with the trailer and its functionality. The trailer has been used extensively during the spring of 2014. The implement trailer has now hauled a planter, two different types of listers, a grain drill and two types of cultivators. The trailer is easily hooked up and many of the tractor operators are becoming very quick at loading and unloading bar equipment on and off of the trailer. A combine header has not been tested on the trailer yet, but with the small grain harvesting season approaching quickly it will see plenty of use.

Weight Analysis

As seen in Table 2 the total weight of the trailer should be slightly greater than 6,528lbs. This weight estimation is based off of purely the steel used during construction. This amount does not account for the other miscellaneous components on the trailer such as the spindles, hubs, wheels, tires, pins and bushings. All of these other components do add up to increase the overall weight of the trailer. The actual weighed weight of the trailer came out to be 7,120 lbs. The original weight of the trailer before the addition of the two wide-flange beams would have be approximately 6,000lbs. The addition of the two wide flange beams increased the total weight of the trailer by 1,120 lbs. The addition of the two beams did greatly increase the weight of the trailer but it was well worth the sacrifice in weight for the increased rigidity.

Table 2. Weight Analysis of Implement Trailer

Metal	Estimated Inches (")	Estimated Feet(')	Lbs/ft (lbs)	Lbs/square ft (lbs)	Total (lbs)
Gooseneck					
5"x5"x3/8"	224"	18.67	22.37		417.65
Tail					
5"x5"x3/8"	192"	16	22.37		357.92
Deck Structure					
4"x2"x1/4"	2514"	209	8.81		1841.29
Deck Surface					
1/4" Diamond Plate	34776"^2	241.4^2		10.21	2464.69
Metal Strap					
48"x48"x1/2"	2,304"^2	16^2		20.42	326.72
W-Flange Beam					
6 1/4" x 16	776"	70	16		1120.00
				Total	6528.27

Cost Analysis

Table 3 show the cost of the steel that was purchased to build the trailer. Note the added cost of the two wide flange beams added at the end of construction.

Table 3. Cost of Steel.

Metal	Estimated Inches	Estimated Feet	# of Sticks	# of 4'x8' Sheets	Cost
Gooseneck					
5"x5"x3/8"	224"	20.6'	1 @ 20'		$ 360.25
Tail					
5"x5"x3/8"	192"	16'	1 @ 20'		$ 360.25
Deck Structure					
4"x2"x1/4"	2514"	209'	5 @ 40'		$ 1,437.50
Deck Surface					
1/4" Diamond Plate	34776"^2	241.4'^2		8	$ 1,695.74
Metal Strap					
48"x48"x1/2"	2,304"^2	16^2		0.5	$ 280.46
W-Flange Beam					
6 1/4" x 16	776"	70	2 @ 35'		$ 753.32
				Total	$ 4,887.52

Table 4 shows the cost of materials to construct this trailer. All costs seen above are actual costs. Note the labor hours are estimated. Also note that the paint and electrical work is not finished yet so they do not have costs (at this point). The machine work labor from Mike Aquistapace was settled at a flat rate of $300.00.

Table 4. Total Costs of Project.

Item	Units	Cost/Unit	Total
Steel			$ 4,887.52
DOM tubing			$ 56.25
Pins, Bolt and Castle Nut			$ 26.20
Hubs	4	$ 44.85	$ 179.40
Spindles	4	$ 26.73	$ 106.92
Wheels & Tires	4	$ 378.93	$ 1,515.73
Fenders	2	$ 25.49	$ 50.98
Lights (unknown at this point)			
Paint (unknown at this point)			
Jack	1	$ 58.82	$ 58.82
Shop Supplies/Consumables			$ 100.00
Miscellanious Hardware/Steel			$ 25.00
Machine Shop Labor			$ 300.00
Total Estimated Labor	100(hrs)	$ 80.00	$ 8,000.00
		Total Costs=	$ 15,306.82

DISCUSSION

Weight Considerations

The ultimate weight of the trailer ended up being 7,120 lbs according to a local semi scale. The total weight in steel was determined to be 6,528 lbs. The difference in weight was made up by the other components of the trailer. This project did not have a weight budget at the start of construction. This trailer was most likely over built though. The reason for this trailer being over built was due to the preference for overbuilt equipment that McKean farms has. The cost in steel was well worth the fact that the trailer was overbuilt in the opinion of the owners of McKean Farms. With that being said this trailer is designed for a total capacity of 8,000lbs (evenly distributed load) and has a total static weight of 7,120lbs. The ratio of the trailer weight vs. trailer capacity is relatively low, but this result is due to the design features of this trailer. The stretched design and low profile of the trailer does not allow for a light weight trailer.

Costs vs. Benefits Considerations

Due to this trailer not having any direct payback, weighing the actual costs vs. the benefits is very difficult. The costs can be determined and come out to a total of $11,306.82. Although the costs can be determined but the benefits cannot really be determined. The variation in many factors of how the trailer is utilized does not allow for any type of concrete quantification of the benefits of the trailer. The main two benefits of the use of the trailer is first increased efficiency and reduced downtime and second, increased safety. The implement trailer allows for more accessibility to various implements in different places. This is very important to McKean farms due to the fact that McKean farms usually runs tractors day and night and many times the implements on these tractors are switched as much as three times during a shift. The ability to bring implements to the tractors rather than the tractors having to get the implements greatly increases efficiency. Secondly reducing the amount of road transporting with these wide implements greatly reduces the chances of accidents and therefore increases safety. This increase in overall safety is very valuable due to the chance of a serious accident. With current transportation methods an accident is very possible. The cost of tractor vs. vehicle accidents can range in severity and cost, but do have the ability to exceed millions of dollars.

RECOMMENDATIONS

The main recommendations that should be considered for this project is to perform a deflection calculation as well as a stress calculation. As discussed above the stress's that this trailer endures is relatively small compared to the strength of the materials used, but the deflection was very high due to the extreme span covered. If this trailer was to be built again, the main two improvements to make would be to first; reduce two 4" x 2" members that span the trailer deck with the wide flange beams rather than add the wide flange beams afterwards. Second; would to possibly add a simple device that would allow for the deck to be lifted and lowered relative to the axles. This would increase the trailers versatility but also increase the complexity of the trailer.

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APPENDIX A:

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

Major Design Experience

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. This project involves the application of mechanical systems, design and fabrication.

Application of Business and/or Management Skills. This project involves applications of business and/or management skills in the areas of machinery logistics, safety and operational efficiencies.

Quantitative, Analytical Problem Solving. Quantitative, analytical problem solving includes design, construction, testing and analysis.

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 151 CAD for Agricultural Engineering
- BRAE 152 3-D Solids Modeling
- BRAE 142 Agricultural Power and Machinery Management
- BRAE 203 Ag Systems Analysis
- BRAE 301 Hydraulic and Mechanical Power Systems
- BRAE 321 Agricultural Safety
- BRAE 324 Principles of Ag Electrification
- BRAE 343 Mechanical Systems Analysis
- BRAE 418/419 Ag Systems I & II

APPENDIX B:

DESIGN CALCULATIONS

Analysis of the deck structure.

Solve:
Solve for the section modulus value needed for the deck structure.

Assume:
A uniformly distributed load of 8,000lbs
Dead load of 4,395lbs (weight of deck, evenly distributed)
A deck span of 31.5' or 378"
Load per foot= $\frac{12{,}395\#}{31.5\,ft} = 393\frac{lbs}{ft}$
Allowable stress is calculated the Yield stress of $50{,}000 lb/in^2 \; x \; 0.6 = 30{,}000 lb/in^2$
Therefore assume Allowable stress of $30{,}000 lb/in^2$ for mild steel
Below is a screen shot of a SolidWorks screen shot showing the section properties of a cross section of the deck structure. The I and C values can be found in Figure 42 below.

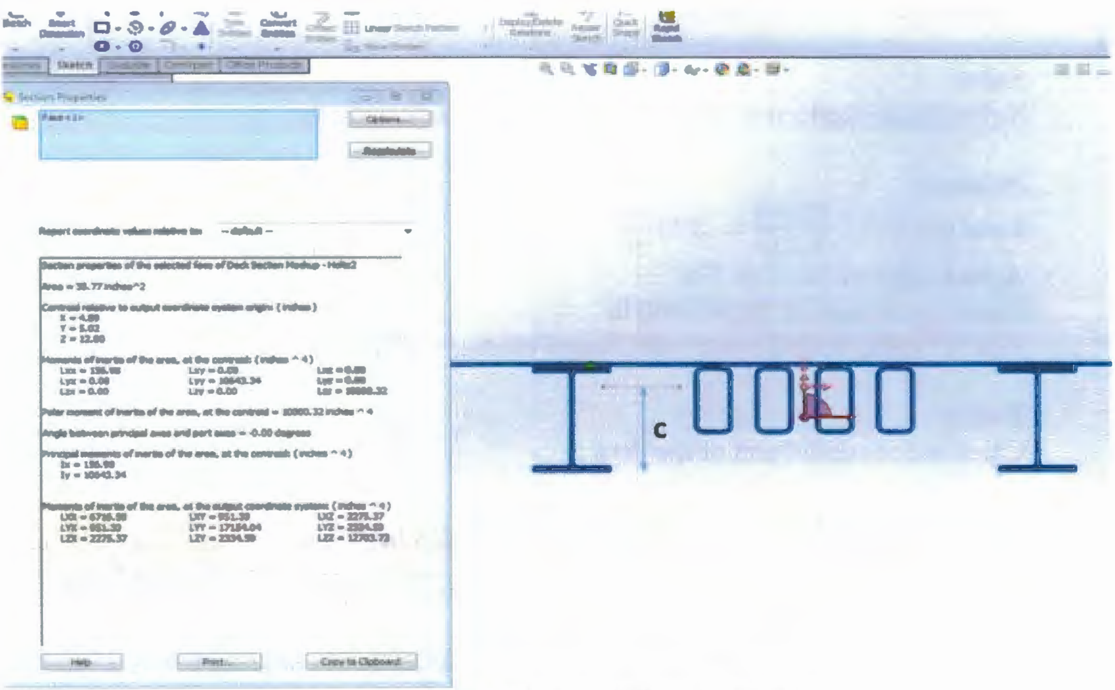


Figure 43. SolidWorks Section Analysis

Req'd:
Stress Calculation

$$Mmax = \frac{wl^2}{8} = \frac{393lb \; x \; (31.5\,ft)^2}{ft \quad\quad 8} = 48{,}744\; lb - ft$$

$$48{,}744\ lb - ft\ x\ \frac{12in}{1ft} \approx 584{,}928\ in - lb$$

$$S = \frac{M}{Fb} = \frac{584{,}928\ in - \ lb - in^2}{30{,}000\ lb} = 19.5\ in^3$$

The actual Section Modulus
I=156.98
C= 5.02

$$S = \frac{I}{C} = \frac{156.98in^4}{5.05in} \approx 31.1in^3$$

The section modulus needed to support this load would be 19.5 inches cubed. The actual section modulus is 31.1inches cubed. This gives the trailer a safety factor of 1 to 1.6 for stress. This shows that the trailer is built stronger than it needs to be with a uniformly distributed load of 8,000lbs.

Solve:
Solve for the deflection that the deck structure will undergo.

Assume:
Load per foot= $\frac{12{,}395\#}{31.5\ ft} = 393\frac{lbs}{ft}$
A deck span of 31.5' or 378"
Elasticity of steel is 29,000,000 lb
The "I" value with the two wide flange beams = 157in^4

Req'd:
Calculate the deflection of the deck.

$$\Delta = \frac{5wL^4}{384\ x\ E\ x\ I} = \frac{5\ x\ \frac{393lbs}{ft}\ x\ \frac{ft}{12in}\ x\ (378\ in)^4 - in^2}{384\ x\ 29{,}000{,}000lbs\ x\ 157in^4} = 1.91"\ of\ deflection$$

The calculated deflection is 1.91". The actual deflection is approximately 1" in the center when loaded. This is most likely due to the fact that depending on the load assuming an evenly distributed load will cause more deflection than what is more likely which is two semi point loads closer to the beginning and the end of the trailer.

APPENDIX C:

IMPLEMENTS OF HUSBANDRY EXEMPTIONS

16.020 Implement of Husbandry (CVC §36000)

A vehicle which is used exclusively in the conduct of agricultural operations.

Vehicles that are designed primarily for transportation of persons or property on a highway **are not** implements of husbandry **unless** they are specifically designated as such by other provisions of the *California Vehicle Code*.

Registration Exemption for Implements of Husbandry (CVC §36100)

- Implements of husbandry which are only incidentally operated or moved over a highway and those listed in CVC §§36005 or 36015 **are exempt** from registration.
- The owner of an implement of husbandry exempt from registration may, at the owner's option, secure a Special Equipment (SE) identification (ID) plate for the implement of husbandry vehicle (CVC §36115).

Implement of husbandry includes, but is not limited to:

- A lift carrier or other vehicle designed and used exclusively for the lifting and carrying of implements of husbandry or tools used exclusively for the production or harvesting of agricultural products, when operated or moved upon a highway (CVC §36005a).
- A trailer of the tip-bed type when used exclusively in the transportation of other implements of husbandry or tools used exclusively for the production or harvesting of agricultural products (CVC §36005b).
- A trailer or semitrailer having no bed, and designed and used solely for transporting a hay loader or swather (CVC §36005c).
- A spray or fertilizer applicator rig used exclusively for spraying or fertilizing in the conduct of agricultural operations.
    - Excluded from this definition are anhydrous ammonia fertilizer applicator rigs which have a transportation capacity in excess of 500 gallons (CVC §36005d).
- A trailer or semitrailer which has a maximum transportation capacity in excess of 500 gallons, but not more than 1000 gallons:
    - used exclusively for the transportation and application of anhydrous ammonia, if the vehicle is either equipped with operating brakes, ***or***
    - towed upon a highway by a motor truck that is assigned a manufacturer's gross vehicle weight rating of 3/4 ton or more.
- A combination of vehicles is limited to two vehicles operated one behind the other (CVC §36005e).

- A nurse rig or equipment auxiliary to the use of and designed or modified for the fueling, repairing, or loading of an applicator rig or an airplane used for the dusting, spraying, fertilizing, or seeding of crops (CVC §36005f).
- A row duster (CVC §36005g).
- A wagon or van used in both the following ways:
    - exclusively for carrying products of farming from one part of a farm to another part thereof, or from one farm to another farm.
    - solely for agricultural purposes, including any van used in harvesting alfalfa or cotton, which is only incidentally operated or moved on a highway as a trailer (CVC §36005h).
- A wagon or portable house on wheels is all of the following:
    - used solely by shepherds as a permanent residence in connection with sheep raising operations.
    - moved from one part of a ranch to another part thereof or from one ranch to another ranch.
    - which is only incidentally operated or moved on a highway as a trailer (CVC §36005i).
- Notwithstanding subdivision (f) of CVC §36101, a trap wagon, as defined in CVC §36016, moved from one part of a ranch to another part of the same ranch or from one ranch to another, which is only operated or moved on a highway incidental to agricultural operations.
    - the fuel tank or tanks of the trap wagon shall not exceed 1000 gallons total capacity (CVC §36005j).
- Any vehicle which is operated upon a highway only for the purpose of transporting agricultural products for a total distance of one mile or less from the point of origin of the trip (CVC §36005k).
- A portable honey-extracting trailer or semitrailer (CVC §36005l).
- A non-self propelled fertilizer nurse tank or trailer which is moved unladen on the highway and auxiliary to the use of a spray or fertilizer applicator rig (CVC §36005m).
- Any cotton trailer when used on the highways for the exclusive purpose of transporting cotton from a farm to a cotton gin, and returning the empty trailer to such farm (CVC §36005n).
    - an SE ID plate **is required** prior to movement on the highway (CVC §5014).

- A truck tractor or truck tractor and semitrailer combination:
  - which is owned by a farmer, ***and***
  - operated on the highways only incidental to a farming operation, not for compensation, and for a distance of **not more** than two miles (on the highway) each way (CVC §36005).

NOTE: This definition applies only to:

- Truck tractors with a manufacturer's gross vehicle weight rating **over 10,000 pounds** that are equipped with all-wheel drive and off-highway traction tires on all wheels.
- Semitrailers used in combination with such a truck tractor and exclusively in production or harvesting of tomatoes.

These vehicles **cannot** be operated in excess of 25 miles per hour on the highways.

Farm Trailer (CVC §36010)

A farm trailer is one of the following:

- A trailer or semitrailer owned and operated by a farmer in the conduct of agricultural operations, and used exclusively to transport agricultural products upon the highways to the point of first handling and return.
- A trailer or semitrailer that is all of the following:
  - equipped with rollers on the bed, with a frame not taller than 10 inches high, and with a gross vehicle weight rating of 10,000 pounds or less.
  - owned, rented, or leased by a farmer and operated by that farmer in the conduct of agricultural operations.
  - used exclusively to transport fruit and vegetables upon the highway to the point of first handling and return.
  - that was manufactured and in use prior to January 1, 1997.

NOTE: These vehicles may also be operated on the highways without a load for the purpose of delivering a rented or leased vehicle to the renting or leasing farmer's farm, or returning empty to the owner's premises.

Cotton Module Mover (CVC §§36012 and 36101)

A cotton module mover is both of the following:

- Motor truck, semitrailer, or a truck tractor in combination with a semitrailer, that is equipped with a self-loading bed.

- Designed and used exclusively to transport field manufactured cotton modules to a cotton gin.

An SE ID plate for the vehicle is optional **unless** it is a truck tractor in combination with a semitrailer.

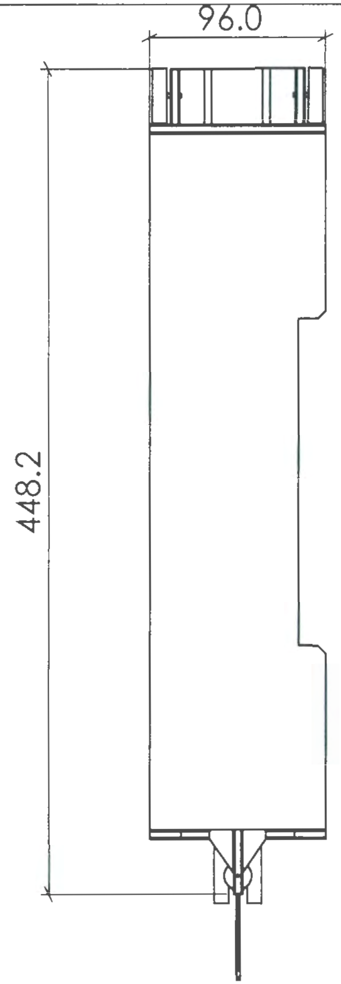
Farm Tractor Used for Towing (CVC §36015)

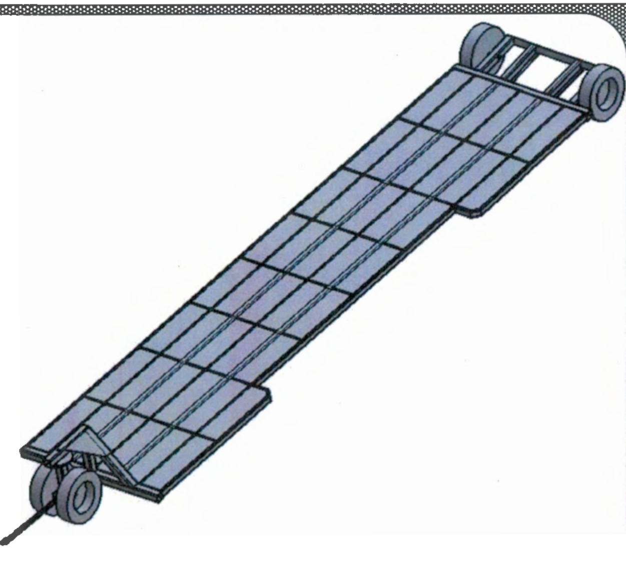
An implement of husbandry includes:

- Any farm tractor, otherwise an implement of husbandry, used upon a highway to draw a farm trailer, carrying farm produce, or to draw any trailer.
- Asemitrailer carrying other implements of husbandry, between farms, or from a farm to a processing or handling point and returning with or without the trailer.

APPENDIX D:

PART DRAWINGS





Isometric View

BRAE
bioresource and agricultural engineering

Designer:
CONNOR MCKEAN

Equipment Trailer

(Ag. Equipment Transport Trailer)

CLASS:

Senior Project
BRAE 462

Trailer Assembly

SHEET:

A-1.00

Wednesday, June 04, 2014

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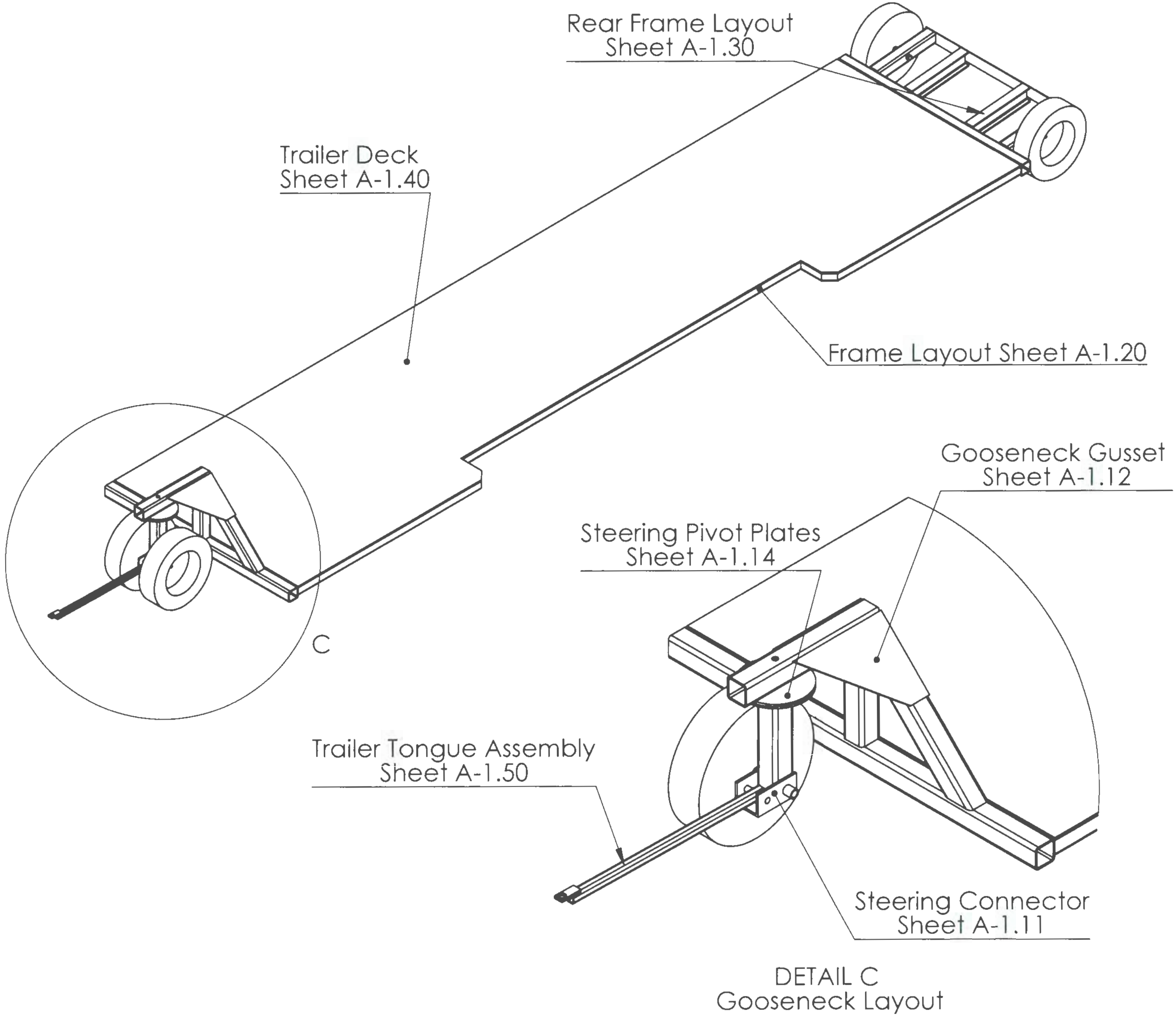


Wednesday, June 04, 2014

BRAE bioresource and agricultural engineering

Designer:

CONNOR MCKEAN

Equipment Trailer

(Ag. Equipment Transport Trailer)

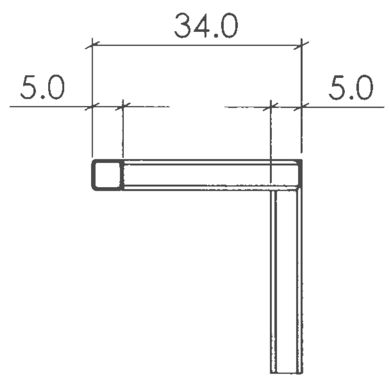
CLASS:

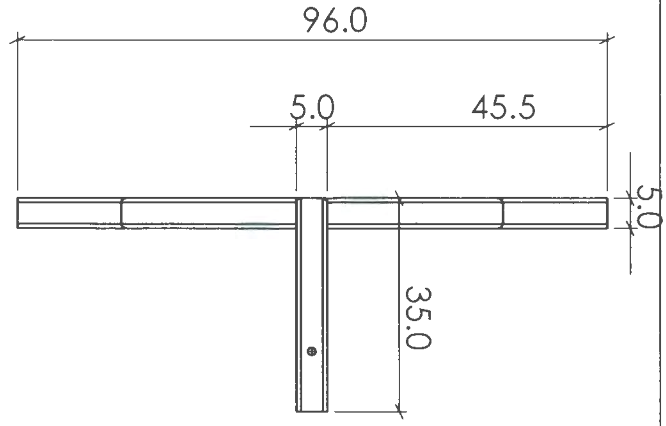
Senior Project
BRAE 462

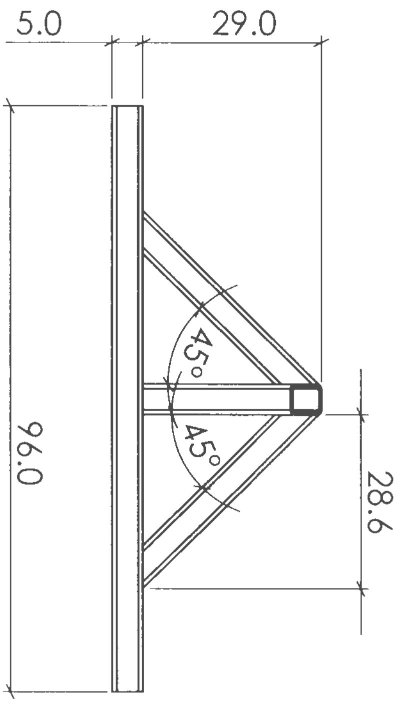
Trailer Parts Layout

SHEET:

A-1.01







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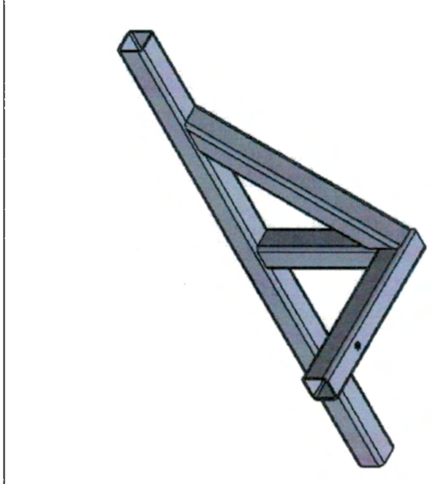


Wednesday, June 04, 2014

Equipment Trailer

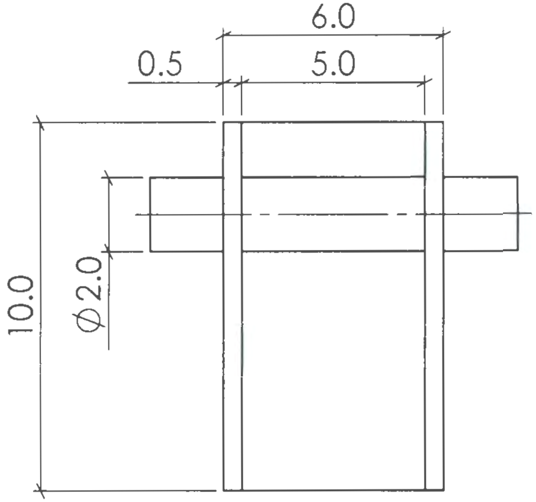
(Ag. Equipment Transport Trailer)

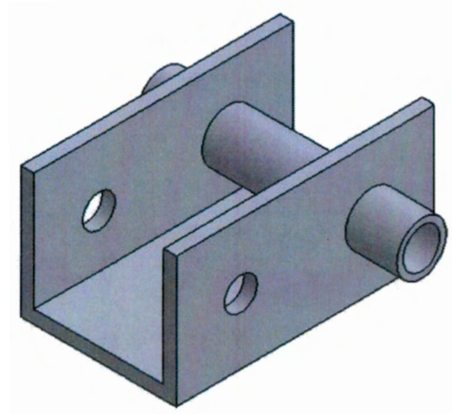
Designer:
CONNOR MCKEAN

CLASS:
Senior Project BRAE 462

Gooseneck Assembly

SHEET:
A-1.10





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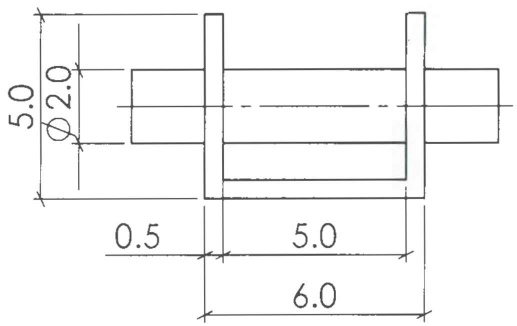

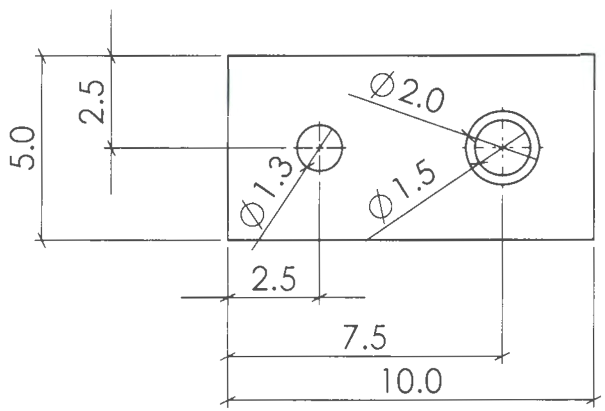

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Designer:

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Equipment Trailer

(Ag. Equipment Transport Trailer)

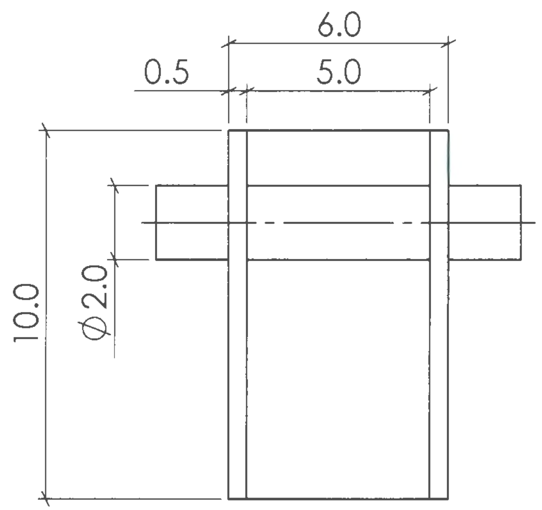
CLASS:

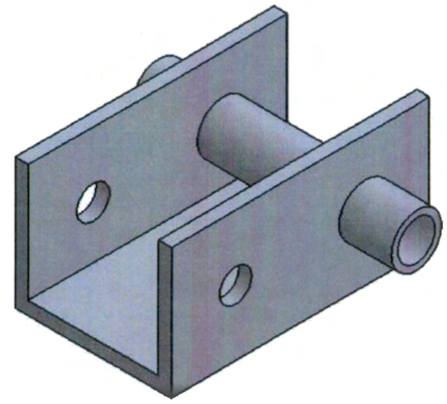
Senior Project BRAE 462

Steering Connector

SHEET:

A-1.11





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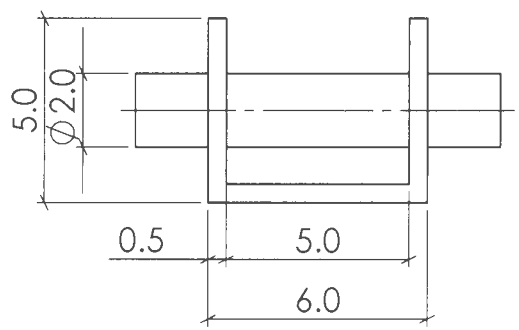
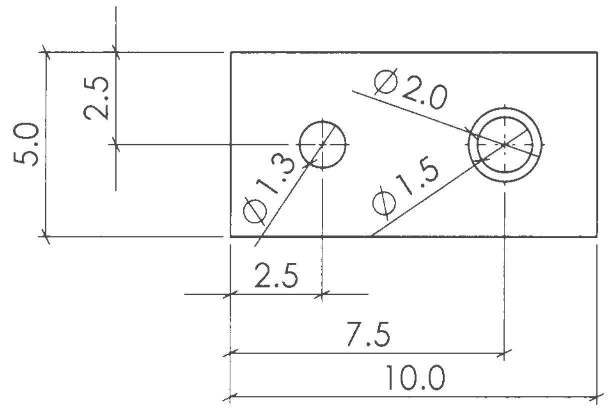




Designer:
CONNOR MCKEAN

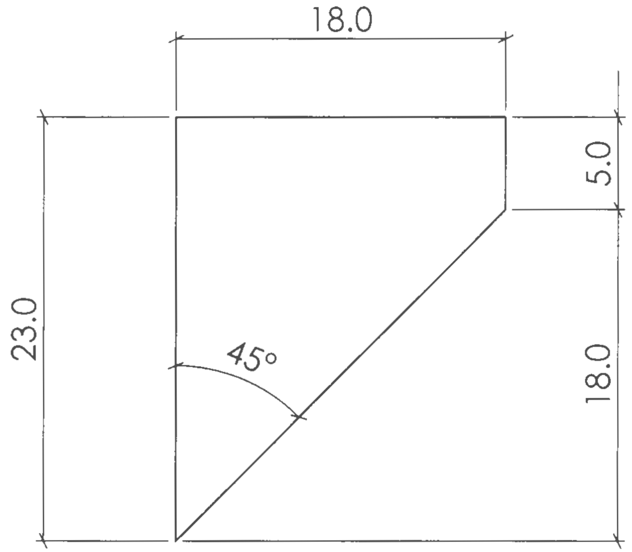
Equipment Trailer
(Ag. Equipment Transport Trailer)

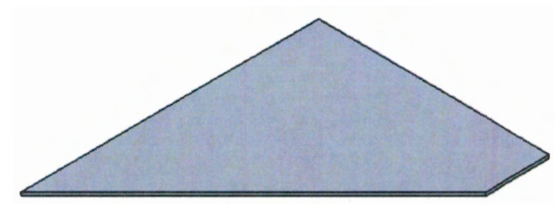
CLASS:
Senior Project
BRAE 462

Steering Connector

SHEET:
A-1.11

Wednesday, June 04, 2014





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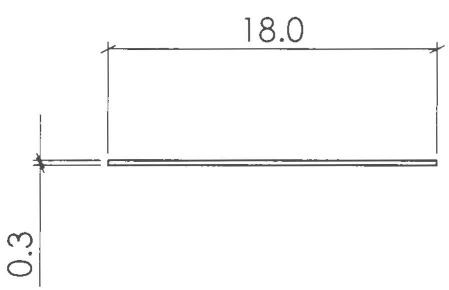

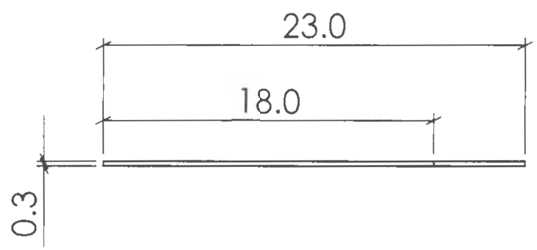

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CLASS:
Senior Project
BRAE 462

Gooseneck Gusset

SHEET:
A-1.12

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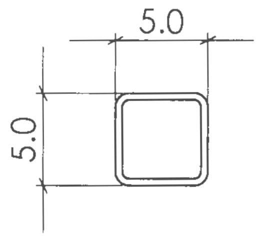

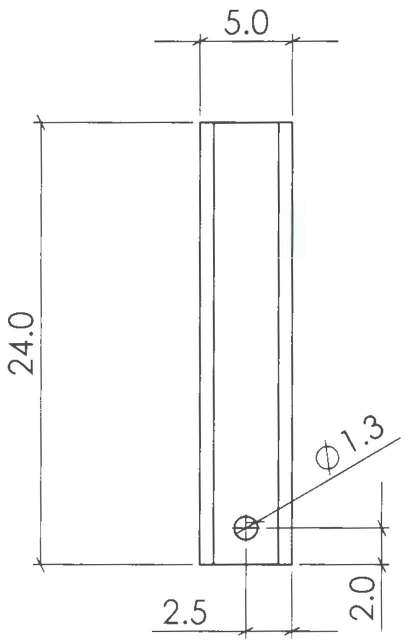

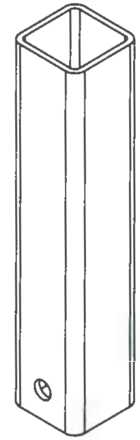

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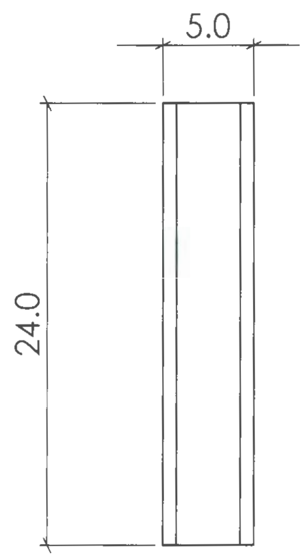

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Equipment Trailer

(Ag. Equipment Transport Trailer)

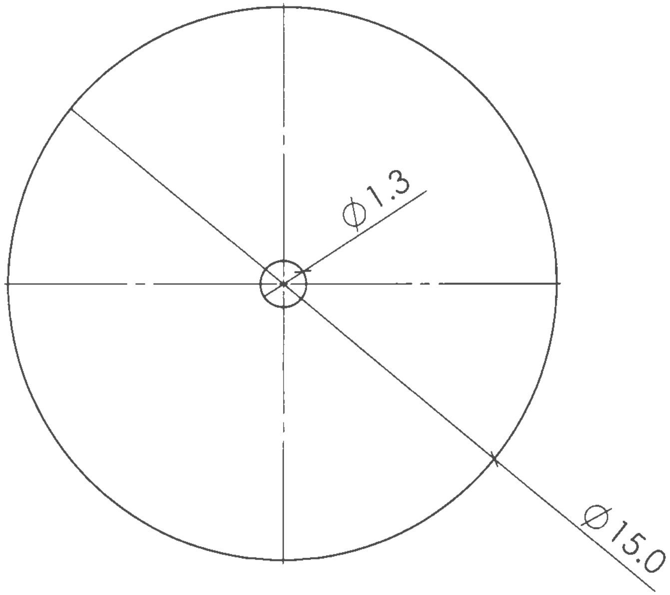
CLASS:

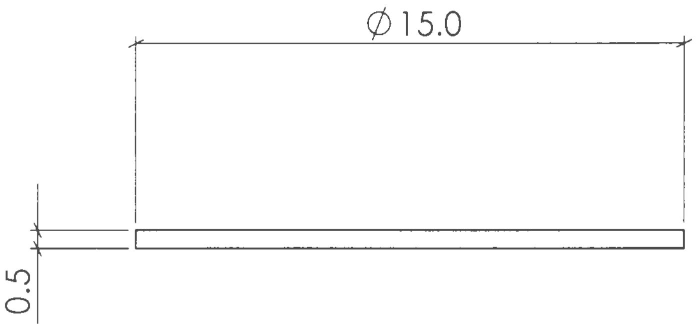
Senior Project
BRAE 462

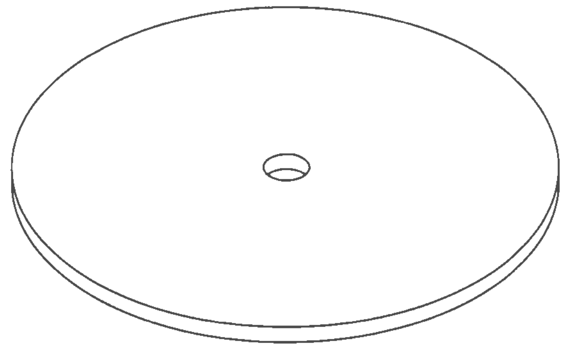
Steering Column

SHEET:

A-1.13







Isometric View

Designer:
CONNOR MCKEAN

Equipment Trailer

(Ag. Equipment Transport Trailer)

CLASS:

Senior Project
BRAE 462

Steering Pivot Plates

SHEET:

A-1.14

Wednesday, June 04, 2014

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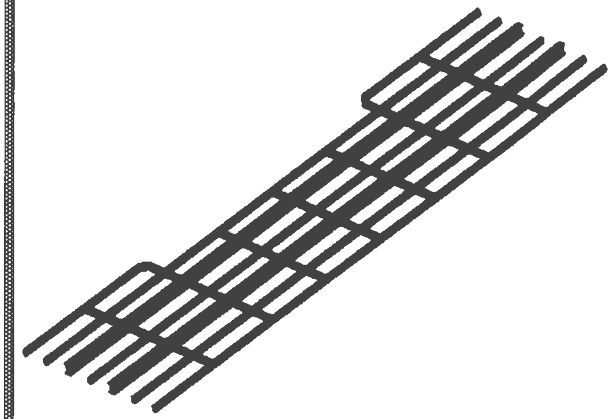

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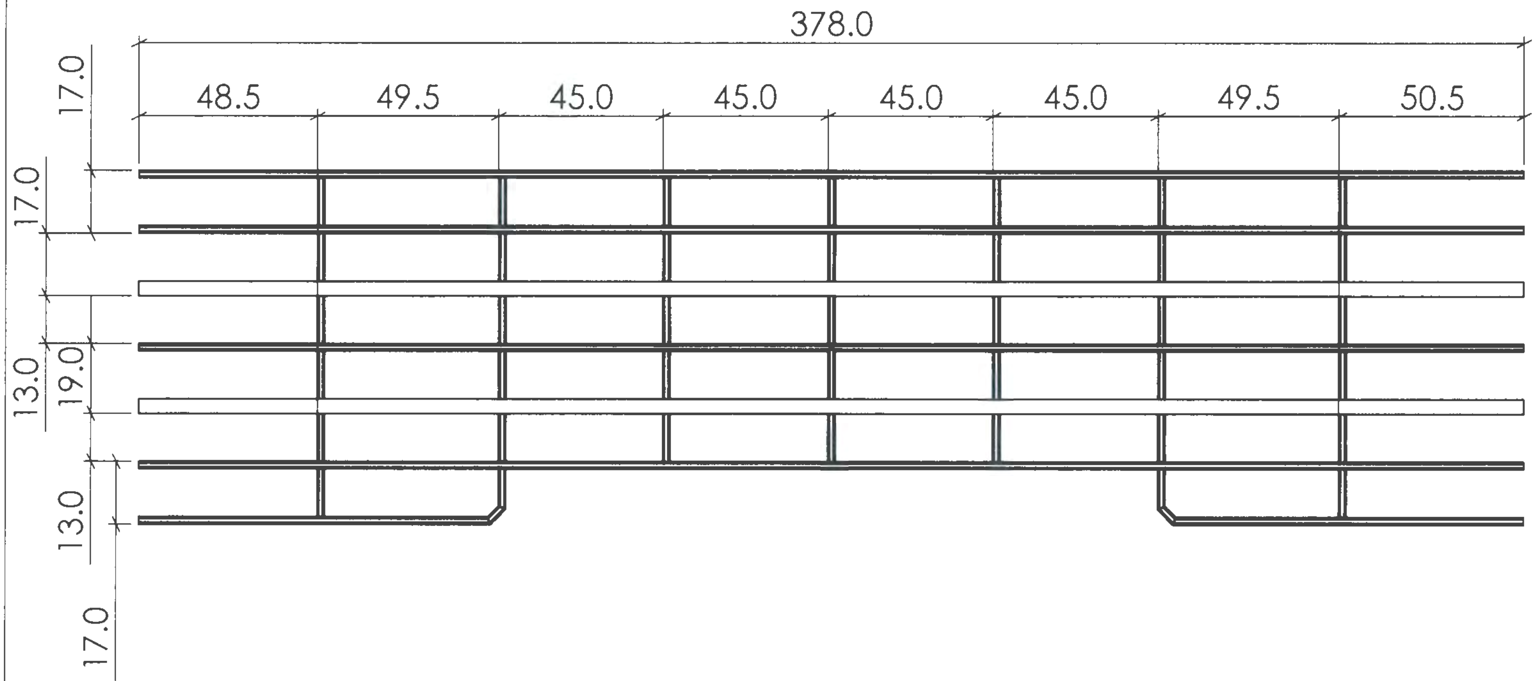

Wednesday, June 04, 2014

BRAE
bioresource and agricultural engineering

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Equipment Trailer
(Ag. Equipment Transport Trailer)

CLASS:
Senior Project BRAE 462

Frame Layout

SHEET:
A-1.20

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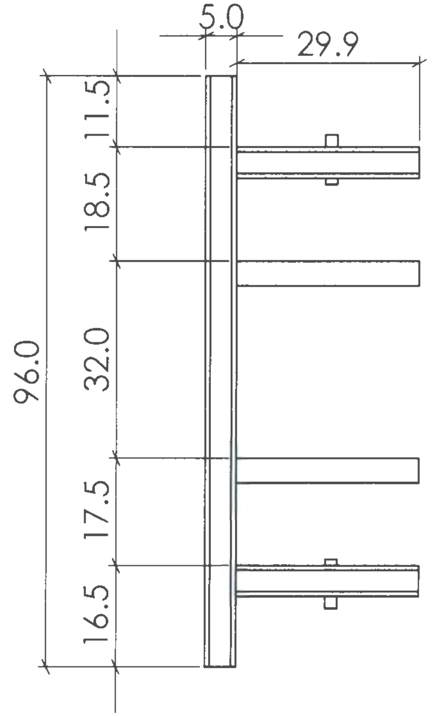

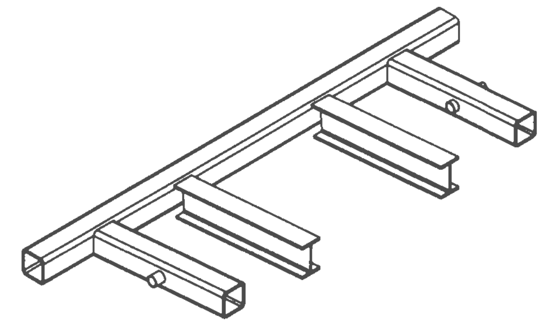

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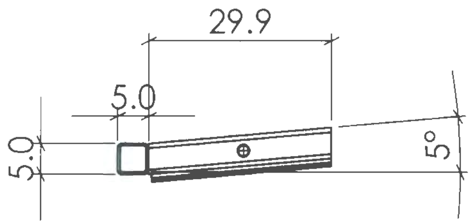
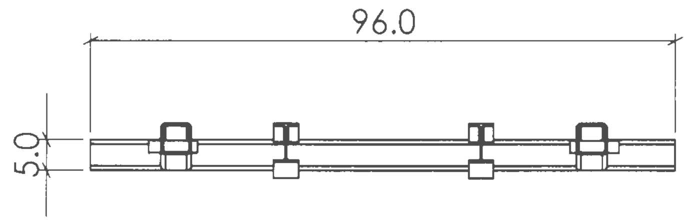




BRAE
bioresource and agricultural engineering

Designer:
CONNOR MCKEAN

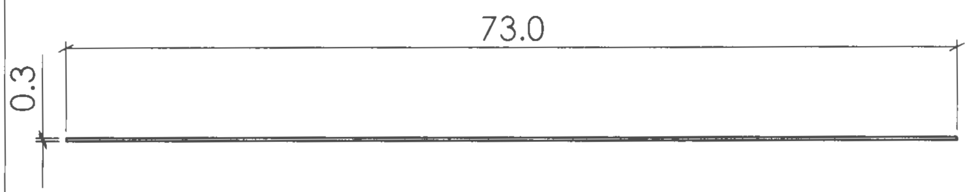
Equipment Trailer
(Ag. Equipment Transport Trailer)

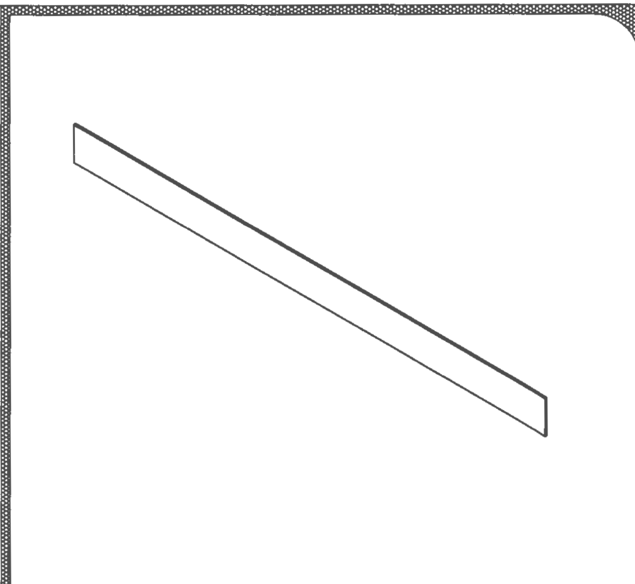
CLASS:
Senior Project BRAE 462

Rear Frame Layout

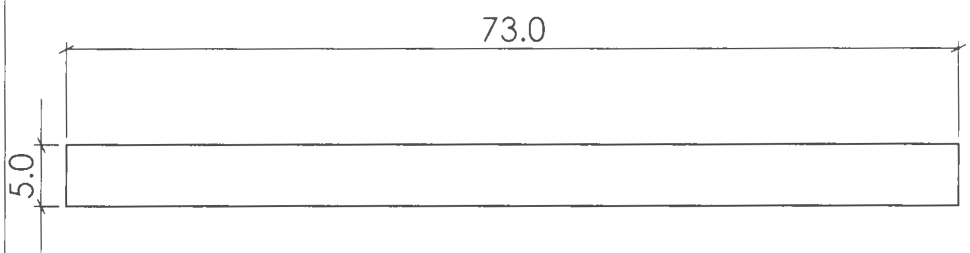
SHEET:
A-1.30

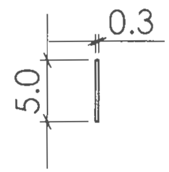
Wednesday, June 04, 2014





Isometric View





Wednesday, June 04, 2014

BRAE biorescurce and agricultural engineering

Designer:

CONNOR MCKEAN

Equipment Trailer

(Ag. Equipment Transport Trailer)

CLASS:

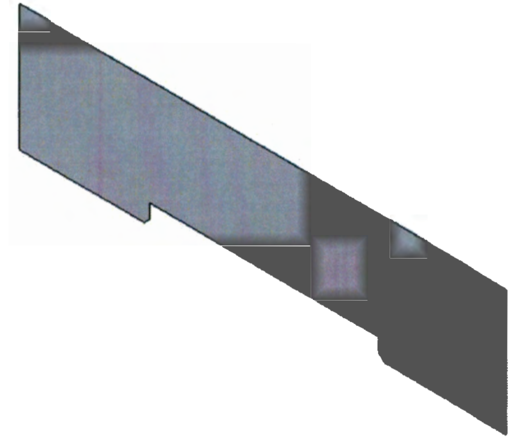
Senior Project BRAE 462

Rear Back Panel

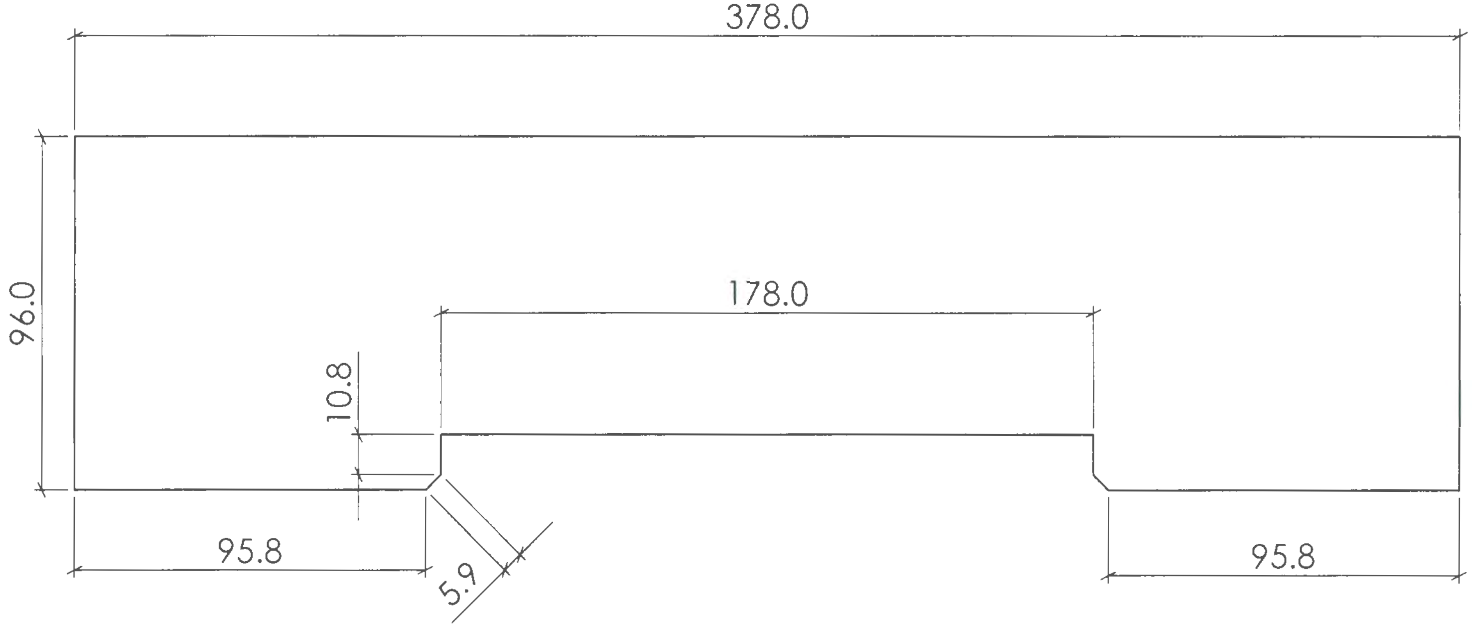
SHEET:

A-1.31

5 4 3 2 1



Isometric View



Designer:

CONNOR MCKEAN

Equipment Trailer

(Ag. Equipment Transport Trailer)

CLASS:

Senior Project BRAE 462

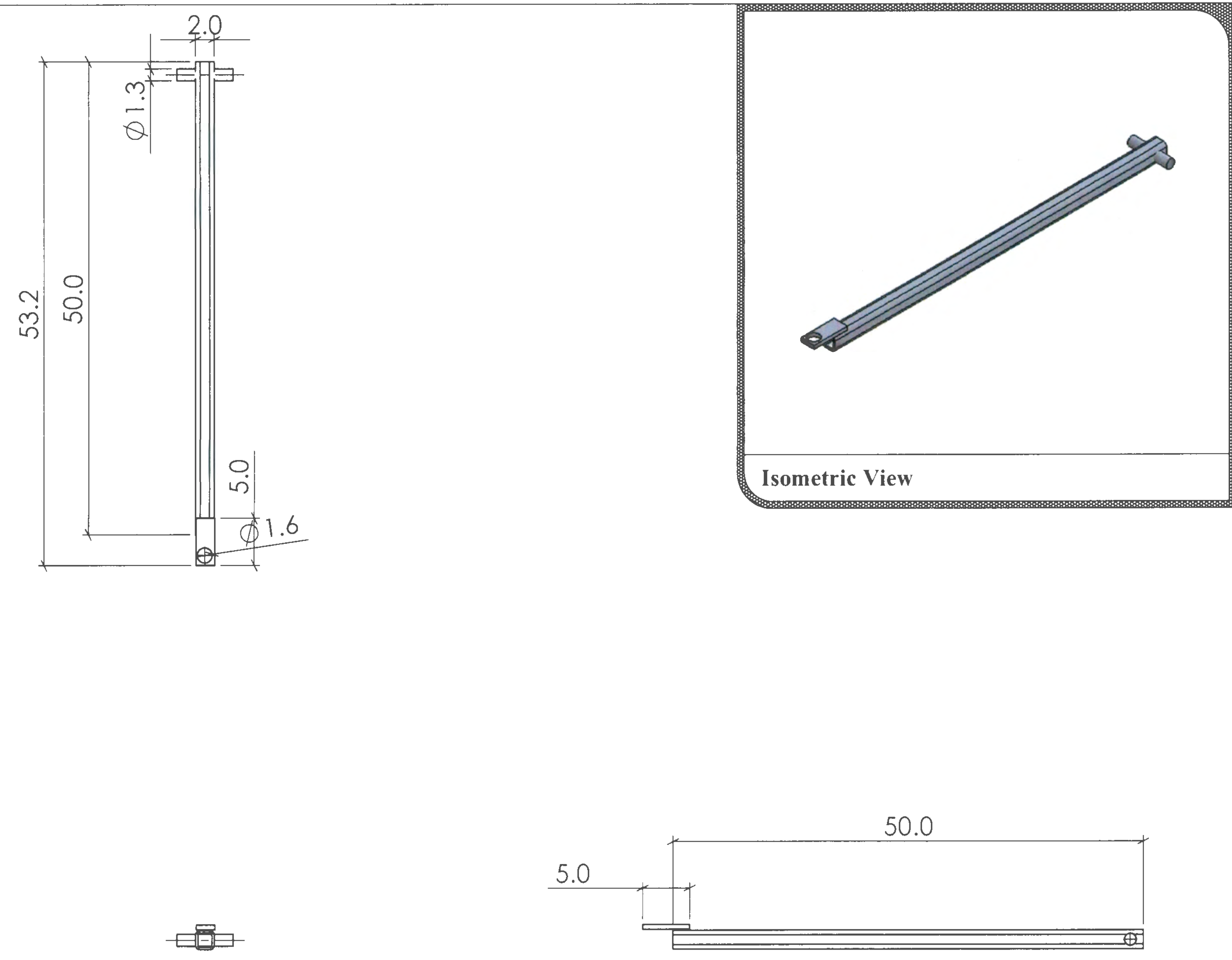
Trailer Deck

SHEET:

A-1.40

Wednesday, June 04, 2014

5 4 2 1



Designer:
CONNOR MCKEAN

Equipment Trailer
(Ag. Equipment Transport Trailer)

CLASS:
Senior Project
BRAE 462

Trailer Tongue Assembly

SHEET:
A-1.50

Wednesday, June 04, 2014

5 4 2 1