Final Report: Sooner/Exiss Trailers Jig Design

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Tanisha Hamm

Kevin Roehm

Kaden Wanger

Prepared for: Sooner/Exiss Trailer

Contents

Customer Requirements & Quantitative Specifications

KTK Engineering Solutions compiled a list of customer requirements for Sooner/Exiss Trailer's new welding jigs. The most important requirement is that the jig increases the quantity of trailers manufactured from 7 trailers to 10 trailers per day. Another important requirement is that the welders using it like it, and that the ergonomics are pleasing. Sooner/Exiss needs the jig to be long enough to accommodate their longest trailers, which are 42', but it must also be capable of manufacturing trailer sides as short as 16'. The jig must also accommodate different heights, ranging from 5'6" to 8'2" tall. In addition, the jig must accommodate all 72 different trailer side designs which Sooner/Exiss has in production.

After speaking with the welders at Sooner/Exiss, their requirements were that the new jig be shorter in height than it is now, but be able to accommodate the tallest trailers. Currently, the welders have to climb on the jig; after the redesign this requirement will be eliminated. However, the welders want dedicated footholds to prevent slipping and easily accessible clamps. Additional horizontal cross members on the jig were another specification, purely for the welders to easily clamp aluminum tubing to during placement.

KTK thinks that the requirements from both management and wage workers at Sooner/Exiss can be accommodated with the exception of climbing which is clearly undesirable. The budget for the redesign can be up to $20,000, according to management. KTK also had ideas for a jig that has powered or manual rotation designs which can accommodate Sooner/Exiss funding requirements.

KTK used rectangular steel tubing to build the jig, with it being adequately supported to prevent the jig from sagging and therefore building sag into the sides of the trailer. The jig was built to last, using quality materials and engineering design.

Statement of Work

Background

KTK Engineering Solutions was tasked to redesign a welding jig at Sooner/Exiss Trailer. Sooner/Exiss needed to increase trailer production by 30% per day. The jig needed to be ergonomic for workers while improving their safety. The jig needs to limit the number of handheld measurements, which leads to inconsistencies in trailer manufacturing, resulting in reworks.

Current Setup

Sooner/Exiss Trailer currently uses four fixed jigs to manufacture side walls. KTK Engineering made two visits to observe workers and daily work. Figure 1 shows Sooner/Exiss Trailer's current jig setup. The figure also demonstrates the unsafe climbing which commonly required of welders in order to reach higher welds. The danger of this action is increased by the opaque welder's helmets which prevents the workers from seeing to catch themselves in the event of a fall. Eliminating climbing is one of the requirements the new jig will meet.

Figure 1- Sooner/Exiss Current Jig Setup

Scope of Work

The scope of work only included the redesign and possible fabrication of a new jig which will be used in trailer side production. The engineers of KTK researched relevant patents, and spoke to experienced engineers whom had also previously worked on the project. The general manager at Sooner/Exiss wanted a jig that would not require workers to climb on the jig. KTK needed to make sure the jig did not deflect when a trailer side was being constructed. The jig needed to increase accuracy of framing posts, window, and door placement so fewer trailers would need to be reworked.

Physical Location

The construction of the project occurred in the Oklahoma State University Biosystems and Agricultural Engineering (BAE) laboratory in Stillwater, OK and at the Sooner/Exiss Trailers factory in El Reno, OK. Solidworks models were used to communicate ideas between Sooner/Exiss Trailer and KTK Engineering. Design work was performed at Oklahoma State University, also in Stillwater, OK.

Period of Performance

KTK Engineering Solutions' engineers began the redesign of the jig in the Fall Semester of 2012. Design work was to be completed by December of 2012, and the final design review was completed in the weeks of December 3^{rd}-14^{th}. The project was completed in April of 2013. The final design was presented and the prototype delivered to the client on April 25, 2013.

Delivery Requirements

Table 1 – Delivery requirements by date and day of week

Monday	10/29/12	SOW Due
Friday	11/2/12	WBS Due
Monday	11/5/12	Task List Due
Monday	11/12/12	Engr Design Concepts Due
Monday	11/19/12	1^{st} Draft Report Due
Monday-Friday	12/3-12/14/12	Technical Presentation
Friday	12/7/12	Report due to Sooner/Exiss
Monday	4/22/2013	Project Complete

Detailed Work

KTK began the redesign in the fall semester of 2012.

The jig needed to accommodate trailers between 5'6" and 8'6" tall and between 16' and 42' long. The jig needed to be structurally sound as to not deflect when in a horizontal position. The jig also needed to accommodate the available floor space in the factory in El Reno.

The design selected is a table type jig with vertical and horizontal square tube for workers to clamp to. The jig will rotate using an electrically powered DC motor. The jig will be balanced to aid ease of movement. The jig will have a braking system utilizing a worm gear for workers to be able to stop the jig in a desired position. The jig will rotate past horizontal to the backside for welders to weld the top rail in place without having to climb on the jig. The jig will allow workers to place components and weld without needing tape measures by incorporating a measurement system into the jig. The welders will be able to weld in an ergonomic position, without having to weld over their heads. The jig will accommodate moving welding hoses up off the floor, eliminating trip hazards. The jig will also have a bottom rail or fixed toggle clamps for welders to place the bottom rail of the trailer.

KTK spent time on this list of actions for the redesign.

- Brainstorming for ideas for the redesign
- Developing a scope of work
- Drawing ideas in Solidworks
- Calculating deflection in main center pipe
- Calculating torsional deflection in center pipe
- Selecting appropriate materials based on calculations
- Developing different ideas for measurement system
- Analyzing cost difference between different systems
- Designing a 15' prototype as a proof of concept piece
- Production and testing of the prototype
- Modification of the prototype based upon testing

Incorporating manager and wage workers wants and needs resulted in several design options. Appendix 3 contains a chart of design options. This chart assisted KTK throughout the design process.

Task List

KTK developed this task list to help organize thoughts and find the direction to pursue for the redesign.

1) Jig Prototype
    a. Redesign
        i. Determination of Rotation Mechanism
            1. Hydraulic
            2. Counterweight
            3. Manual Crank
            4. Electric DC motor
        ii. Create Alternative Measurement Solutions
            1. Laser measurement
            2. Laser projection

        3. Adhesive 'tape measure'
    iii. Engineering Calculations
        1. Material Determination
        2. Deflection
        3. # of pinions
        4. Torsion
        5. Tipping
        6. Buckling
    iv. Determine clamping locations
        1. Type of clamp
        2. Number of clamps
    v. Solidworks Drawings
        1. Create 3D model
        2. Stress analysis
        3. Deflection analysis
        4. Create Standard Engineering Drawings
    vi. Scale Model
        1. Deflection Testing
        2. Material Validation
        3. Determine Number of Supports needed
  b. Purchasing
    i. Price Lasers/Measurement Systems
        1. Design System suitable
    ii. Center Pipe Material
    iii. Table Materials
    iv. Clamps
    v. Measurement System

Work Breakdown

1) Jig Prototype
  a. Redesign
    i. Scale Model
        1. Deflection Testing
        2. Material Validation
        3. Number of Supports needed
    ii. Solidworks Drawings
        1. Stress analysis
        2. Deflection analysis
    iii. Engineering Calculations

1. Material Determination
2. Deflection
3. # of pinions
4. Torsion
5. Tipping
6. Buckling

iv. Determine clamping locations
1. Type of clamp
2. Number of clamps

b. Rotation Jig
i. Rotation Mechanism
1. Hydraulic
2. Counterweight
3. Manual Crank
4. Electric DC Motor

c. Price Lasers/Measurement Systems
i. Design System suitable

d. Alternative Solutions
i. Everything that may not be financially feasible or practical

Payment Schedule

KTK did not receive compensation for the design work or the manufacturing of the jig. All materials were purchased by Sooner/Exiss. Sooner/Exiss set a ceiling of $20,000 for all expenses.

Acceptance Criteria

Sooner/Exiss required a jig that can produce at least 10 trailers per day, a 30% increase in manufacturing, while being ergonomic and pleasing for workers. The jig must also improve worker's safety; the workers must not be required to climb on the jig, reducing injuries from stepping down off the older version of the jig. In addition, welding cords need to be moved off the ground, or away from walking spaces, reducing trip hazards.

Special Requirements

Due to the nature of the project, KTK was required to travel to Sooner/Exiss when a site visit was necessary. Don Lake, Applications Engineering Extension Agent for Oklahoma State University was accommodated by meeting half way, and meeting at times convenient to him when he was in Stillwater, OK, KTK's base location. In addition, KTK collaborated with Mike Raymond with the Oklahoma Manufacturing Alliance, and Aaron Cain and Dr. Robert Taylor, both with the New Product Development Center at Oklahoma State University. Biweekly, conference calls were arranged with KTK, Dr. Paul Weckler, Larry Zahasky, Don Lake, and Mike Raymond to discuss the progress being made on the project.

Technical Analysis

Existing jigs for trailer side framing consist of steel square and round tube welded into a table-like apparatus. For example, Featherlite trailers has a set of jigs very similar to those found at Sooner/Exiss Trailer's manufacturing plant. However, Featherlite has positioning jigs (Figure 2). It is worth mentioning that Featherlite does make use of a robotic welding system, which precision welds the frame for the gooseneck. The pieces are placed upon a rotating jig with clamps them in place before the robot welds them (Featherlite, 2009)

Figure 2 - Featherlight trailer side frame jig (Featherlite, 2009)

The jigs are made of heavy steel tube which is welded together. Considering this, there should not be any maintenance costs associated with the jig, unless a cutting operation or other activity performed by a welder was to damage it by melting or annealing the metal. Considering the melting point of steel is greater than that of aluminum, (2600-2800 ^{o}F for steel, vs. 660 ^{o}F for aluminum) it is unlikely that any welding or cutting operations should involve high enough temperature to damage the jig. In addition, steel does not transform into austenite below 738 ^{o}C

(1360.4 ^{o}F), which provides evidence that the steel jig should not be in danger of annealing (assuming cold rolled steel is used to build the jig). Due to these factors, KTK engineers chose to use mainly steel components in the construction of the new welding jig.

It would be possible to create a framing jig which can rotate and translate, but only found one working example of a jig which takes advantage of this ability. The example can be found in Figure 3. It should be noted that any jig which incorporates moving components will require more maintenance. At the very least, grease will need to be pumped into the collars holding the rotating shaft.

Figure 3 - Hydraulic, movable trailer framing jig (http://www.mrtrailer.com/t_pic/titan157.jpg)

According to Sooner/Exiss Trailers employees, they did have a rotating jig that was in use at one point in the past. However, the jig had unacceptable deformation when in the horizontal position. Additionally, the jig was unpowered and had to be rotated by hand. The cost of production and the space required to accommodate a jig which rotates is also an issue.

Several safety concerns have been associated with the current jigs in use. First, the welders are often required to weld over their heads leading to rotator cuff injuries. Secondly, it creates the potential for sparks to fall into the face of the welder. In addition, the welders must climb onto the frame itself to reach some weld points, creating a hazard when stepping off the jig, as seen on a site visit when KTK was told about an employee who suffered a broken foot from just this hazard.

Any powered jig design will have to incorporate a solution to the trip hazard created by any hoses or cords which provide power to the jig, unless it uses manual rotation. Along the same lines, any pinch points and moving components of the jig will require shielding to prevent injury to the welders and a failsafe will be required to prevent accidental operation of the jig (for example, a cover over the operation switch might add protection against accidental contact).

Patent Searches

KTK found several relevant patents. The first is a patent for rail box car under frames which uses clamps attached to the jig table to secure the side sills to the center sill. One of the most relevant points made is that the non-fixed clamps used in design of the jig allow the rail car frame to be removed despite expansion in the metal caused by the welding operations. This will need to be a consideration which is examined, should any fixed dimension jigs be designed by KTK (Shipley, 1951).

The second patent, by Sellers, L. (1979), filed for a jig to fabricate side walls for houses. Included in the patent are designs for movable, U-shaped guides which can be used to place studs at the desired center distances. This could help KTK to design a system by which the trailer side ribs can be placed at the desired center to center intervals quickly and precisely. This would help KTK to meet one of the clients most fervently expressed design goals: reduction in the use of measuring tapes and hand measurement.

The third patent found describes a hand-held jig which can be adjusted using a bolt and wing-nut assembly to place framing studs at the proper center distances. This offers KTK a possible alternative method for placing the trailer ribs which may or may not appeal more to the manufacturing personnel at Sooner/Exiss Trailers. However, it is possible that any design produced by KTK which was similar could violate the patent as it was issued in 1997 and is therefore still in effect (Bingham and Stone, 1997).

Engineering Calculations

Weight

The weight of each component and the overall jig weight were calculated based on known specific weights for each component, the values were then checked with Solidwork’s mass properties tool, the hand calculations can be seen in Table 2 and

Table 3.

Table 2 – Weight breakdown for the prototype section jig (note: sheet metal components, the gussets and sheet metal in the stands have a specific weight in lb/ft^2 and the length field is the area in ft^2)

Type	Specific Weight (lb/ft)	Length (ft)	Weight (lb)
SCALE PROTOTYPE			
Table (x1)			
6x2x3/16 St. Tube	9.42	88.7	835
gusset	7.5	2.44	18.27
Total			**853.27**
Stand (x2)			
2x2x3/16 St. Tube	4.32	23	99.4
Girdle			
Half pipe (8" sch 40)	28.55	1	28.6
sheet metal	7.5	1.36	10.2
Total			**138.2**
Center Shaft (6" sch 40)	18.97	15	284.55
TOTAL			**1276**

Table 3 – Weight breakdown for the full jig (note: sheet metal components, the gussets and sheet metal in the stands have a specific weight in lb/ft^2 and the length field is the area in ft^2)

Type	Specific Weight (lb/ft)	Length (ft)	Weight (lb)
FULL JIG			
Table (x1)			
6x2x3/16 St. Tube	9.42	248.7	2342
gusset	7.5	6.09	45.66
total			**2387.66**
Stand (x5)			
2x2x3/16 St. Tube	4.32	23	99.4
Girdle			
Half pipe (8" sch 40)	28.55	1	28.6
sheet metal	7.5	1.36	10.2
total			**138.2**
Center Shaft (6" sch 40)	18.97	42	796.7
TOTAL			**3323**

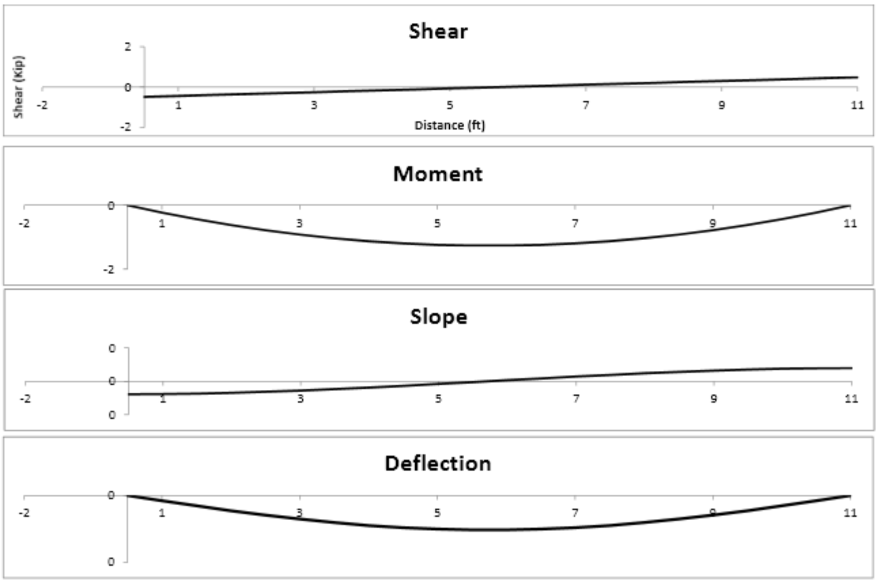
Deflection

Deflection within the main beam was calculated to ensure that the jig would not sag more than 1/32” which satisfied the requirement that sidewalls built in a lay-flat configuration would not exhibit unacceptable deformation from the welding jig. Equation 1, found in Appendix 1, was used to simulate deflection in any free span of the jig as a simply supported beam with a distributed load.

Microsoft Excel was then used to create an optimization sheet which would allow the user to determine the maximum span of material which would not result in more than the maximum allowed deflection (Figure 4).

Values		
Fixed		
E =	4176000	Kip/ft^2
ρ =	490.752	lb/ft^3
Variable		
L =	42	ft
A =	0.038759	ft^2
num sec =	4	
W =	**0.09213**	kip/ft
I =	**0.001357**	ft^4
L act =	**10.5**	ft

OD =	6.625	in
t =	0.28	in
A =	5.581354	in^2
I =	28.14218	in^4
w =	15.7	lb/ft



Allowable Deflection =	0.002604	ft	0.03125	
Maximum Deflection =	**0.0026**	ft	0.030873	in
Factor of "saftey"	1.012202			

Figure 4 - Output of deflection optimization calculation

As can be seen above, the run resulted in a 10 ft span meeting the 0.0026 ft (1/32 in) maximum deflection allowance with a calculated deflection of 0.0022 ft within each 10 ft span.

Torsion

The torsion of the center pipe was calculated by hand and using computer software based finite element analysis (FEA). Hand calculations showed that the torsional deflection of the center pipe would be .988 degrees with a 250 pound point load on the top outer corner of the table, assuming one side fixed with a brake. This torsional deflection relates into a 1.655 inch deflection total at the outmost post of the table. Half of that deflection is the top of the table rotating down due to the point load, and the other half is the bottom of the table rotating up. This torsional deflection is considered worst case scenario, with a 42’ trailer being put on the table and a worker climbing on the jig. Equations to find the torsional deflection can be found in Appendix 1. Solidworks was utilized to do a secondary analysis on the torsional deflection. A simplified model was used, shown in Figure 5. The results from Solidworks are 1.1 inch total deflection, half from the top, half from the bottom. This value was similar to that found by the hand calculations.

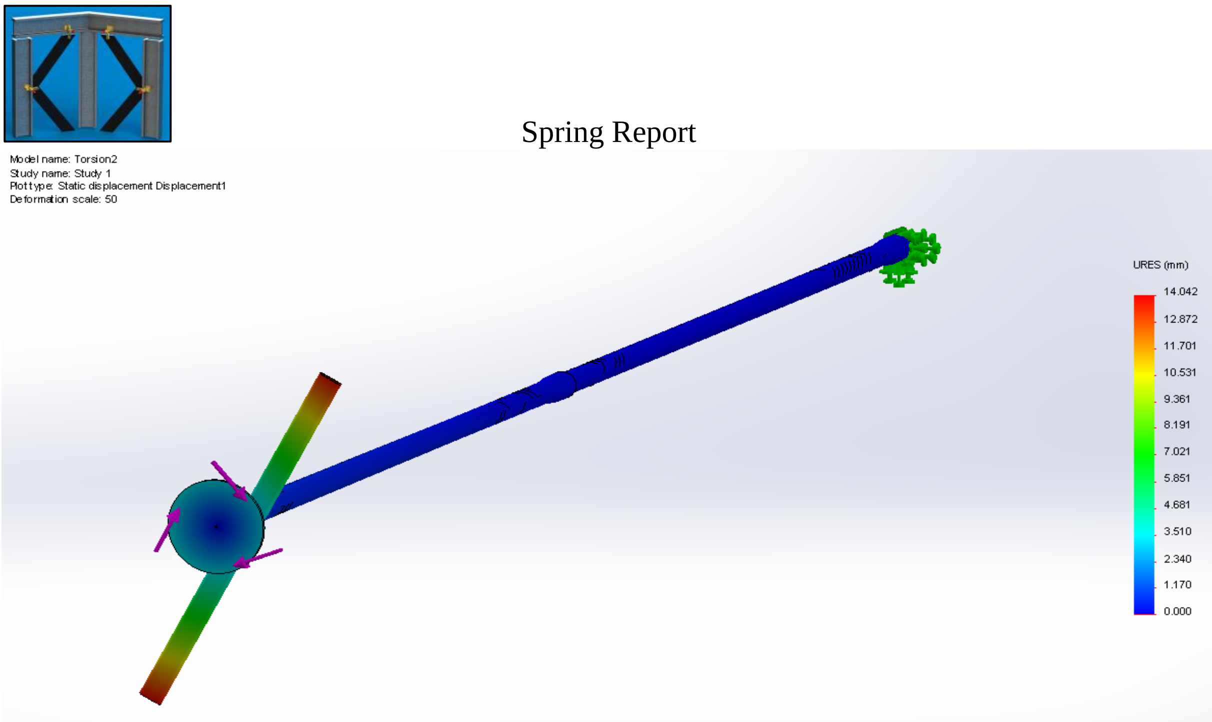


Figure 5 - FEA of Torsional Deflection

Tipping

A calculation was performed to examine the jig's tipping potential. The worst case scenario, in which the table center of mass created the greatest moment, was examined. A table angle of 30^{o} with respect to vertical met this condition. Figure 6 shows the results of the tipping calculation which was placed into an excel spreadsheet. The equations used in calculating the tipping can be found in Appendix 1. Based upon the calculations performed, a force of 1,200 lb would be required to tip the jig. However, in reality, at this point along the rotation of the jig, the table should be resting upon the ground, indicating that the point about which the table must tip is actually further from the center of mass, creating a larger moment and requiring an even larger force to actually cause tipping. The designers chose to assume the table was not quite touching the ground in an effort to determine if the jig might tip and cause damage during rotation.

TIPPING CALCULATION

Ws =	1620	lb (includes the weight of the stands)
Wt =	2384	lb
N1 =	4003	lb
N2 =	0	lb
L1 =	6.313	in
L2 =	6	in
Ls =	3	ft
r =	3.313	in
hj =	32.88	in
theta =	30	degrees
x =	1.912	in
Lt =	46.23	in
Lh =	7.289	in

$$\sum M_{center} = -P(L_t + h_j) - W_t(L_h) + N_1\left(\frac{L_s}{2}\right) = 0$$

$$P = \frac{N_1\left(\frac{L_s}{2}\right) - W_t(L_h)}{L_t}$$

P = 1,182.94 lb

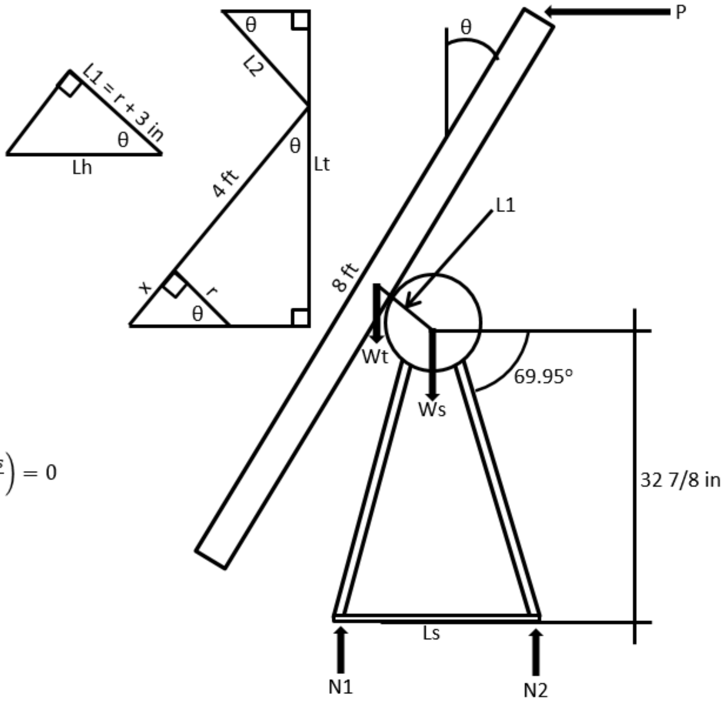
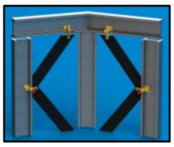


Figure 6 – Tipping calculation. Summing the moments around the center of mass of the combined stands and center shaft allowed the force P required to cause the jig to tip to be calculated. N2 was assumed to be zero in accordance with a 'just tipping' condition.

Buckling

Buckling in the upright member of the stand was also examined. The calculations and equations can be seen in Figure 7. The member was determined to be an strut. The critical load to buckle the member was determined to be 31.9 kip. In addition, based upon purely axial loading, the yield load was determined to be 6590 psi factor of safety for the member was found to be 4.5.



Buckling Calculation

Material Properties

E =	3.00E+07	psi
Sy =	3.00E+04	psi (Assuming 1020 HR Steel)

Pipe Information

D =	2	in
OD =	2.375	in
ID =	2.07	in
t =	0.15	in
k =	2.474	in
A =	1.065	in^2
I =	0.661	in^4
F =	200.156	lb
theta =	20.05	degrees
L =	41.44	in
P =	188.0248	lb
C =	1.2	(fixed/fixed)
L/k =	16.7476209	

Euler Column Check

$$\left(\frac{L}{k}\right)_1 = \left(\frac{2\pi^2 CE}{S_y}\right)^{\frac{1}{2}}$$

$(L/k)_1$= 153.90598

Use Euler Column equation when $l/k > (L/k)_1$

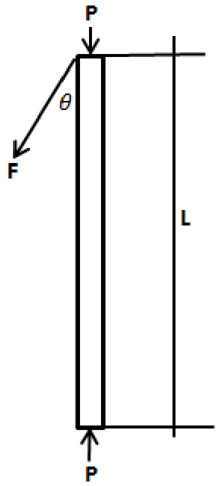
Strut Check

$$\left(\frac{L}{k}\right)_2 = 0.282\left(\frac{AE}{P}\right)^{\frac{1}{2}}$$

$(L/k)_2$ = 116.23

Consider column a strut if $l/k < (l/k)_2$

If $(l/k)_2 < (l/k) < (l/k)_1$ consider column as intermediate



Euler Calculation

$$P_{cr} = \frac{(\pi^2 EI)}{L^2}$$

Pcr = 113,888 lb

Intermediate Calculation

$$\frac{P_{cr}}{A} = S_y - \left(\frac{S_y}{2\pi}\frac{1}{k}\right)^2 \frac{1}{CE}$$

Pcr = 31,943 lb

Strut Calculation

$$\sigma_c = \frac{P}{A} + \frac{My}{I}$$

sigma c = 5,289 psi

factor of saftey = 5.67

Figure 7 – Buckling calculations.

New Stand Deformation

The new girdle design was examined using FEA. The base of the stand was fixed and then a distributed load of 328 lb directly downwards over the half pipe at the bottom of the girdle was applied (the force applied can be seen in Figure 8.

Figure 8 – Fixture (left) and load (right) conditions applied to examine girdle yielding.

The results of the simulation using these conditions are as follows (Figure 9 and Figure 10):

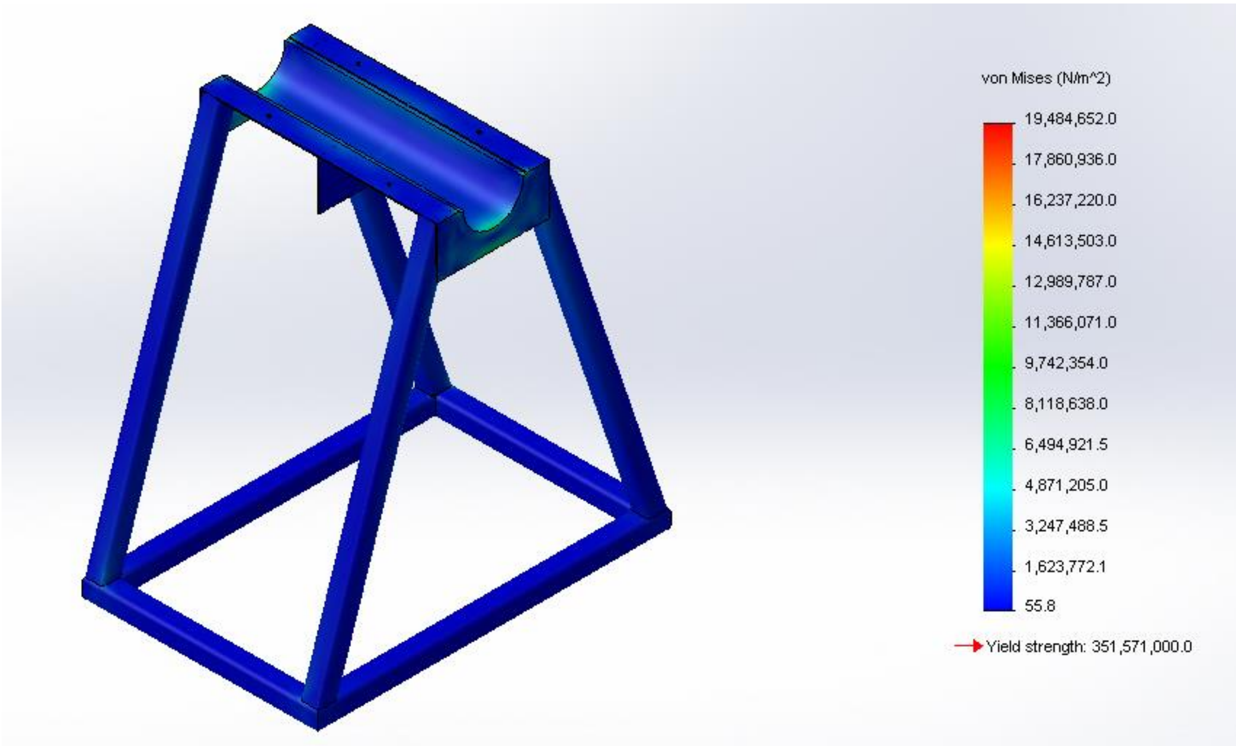


Figure 9 – Simulation stresses found in the stand, max stress is 19.5 MPa (2.83 ksi)

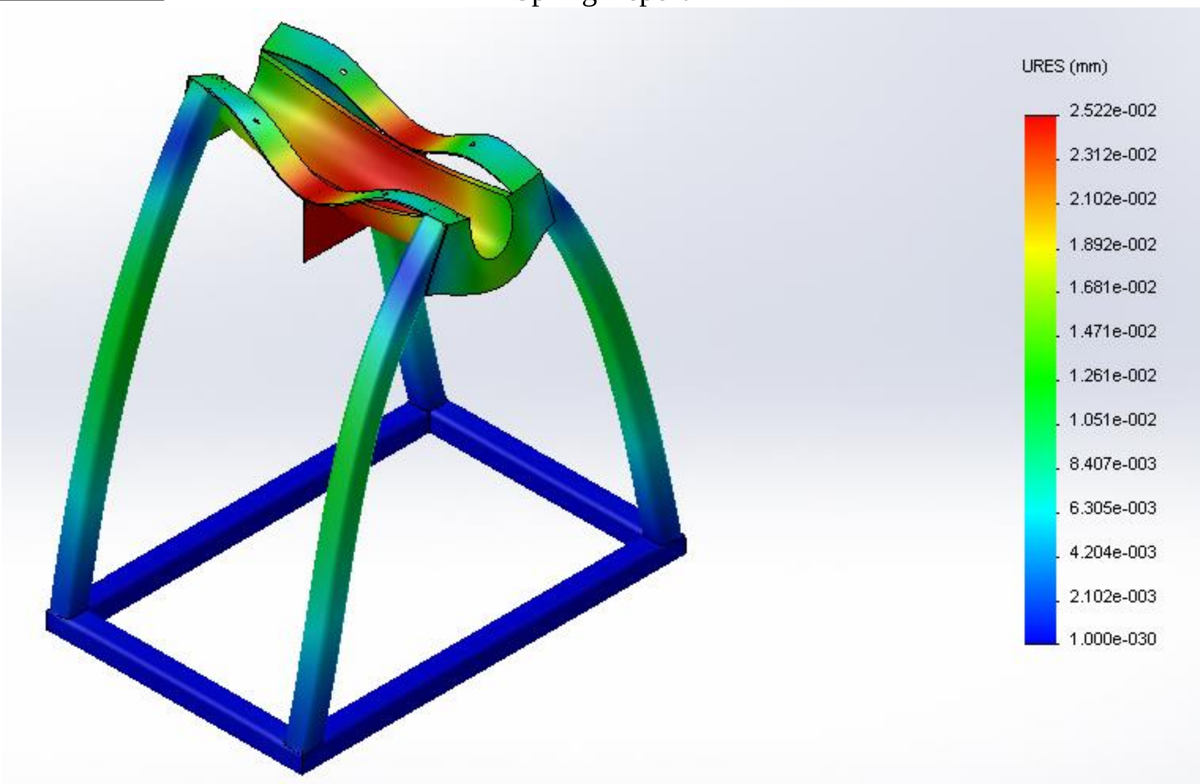


Figure 10 – Simulated deformation within the stand. Deformation is at a scale of 3910.24:1. The maximum deformation is 0.025 mm ($9.84x10^{-4}$ in).

The maximum calculated stress was 2.83 ksi, well below the yield stress for steel (~30 ksi for 1020 HR, a mild, hot rolled steel). Moreover, the simulation results showed a deflection of 0.025 mm or 0.000984 in. In addition, our results demonstrated the middle plate shown in the analysis above did not significantly aid in reducing deformation. Therefore, it was removed in the subsequent design.

Current Design

Figure 11 displays the design that KTK Engineering has created for the base model jig. Dimensions are 42' long by 8' wide. The table is made out of 2"x 6" x 3/16" rectangular steel tubing. The stands are made out of 2" x 2" x 3/16" square tubing, welded together. The table will be welded to the main rotating shaft, which will be 6" Schedule 40 pipe. There will be fixed toggle clamps on the bottom of each vertical support. The table will rotate to the ground in the front, and approximately 20 degrees past horizontal in the back. The back of the jig will have a steel stop that prevents further rotation. The jig is powered by a DC electric motor and worm gear.

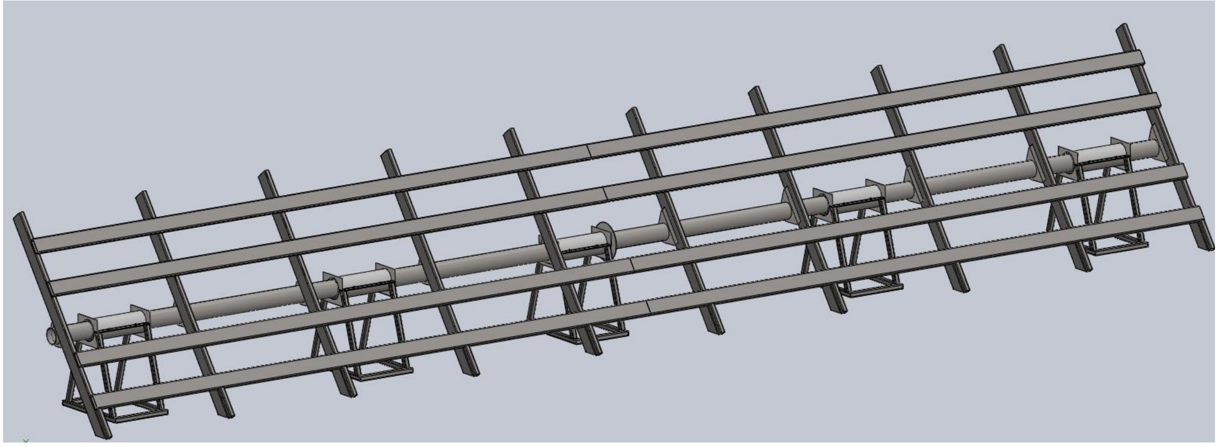


Figure 11 - View of Rotating Jig Design

Prototype Design

KTK Engineering is producing a prototype in order for Sooner/Exiss to make an executive decision to build a full scale jig. The prototype jig will be built to full length jig specifications, but will only be 15 foot long, as opposed to 42 foot. The jig will be fully rotational. After it is built it can be used in Sooner/Exiss's facility to manufacture doors and windows, if desired.

Prototype Manufacturing

Base materials for the prototype were ordered by Sooner/Exiss through their distributor and were shipped to Biosystems machine lab for assembly as shown in Figure 12.

Figure 12- Center shaft and tubing

Custom designed parts were flame cut out of a 48”x96” piece of 3/16” steel plate. As you can see in Figure 13, the half plates and gussets for the prototype were are all cut from sheet metal. Figure 14 shows the completed gusset pieces cut from the sheet metal.

Figure 13- View of Cut out material

Figure 14- Cut out material

The supporting stands for the welding table are made out of 2”x2” square tubing. The tubing for the base is welded into a 24”x36” rectangular base with angled vertical tubing members welded to the bottom girdle. The top and bottom girdles are attached by four UNF 3/8” hex bolts. Figure 15 depicts the completed stand fabrication.

Figure 15- Initial stand height

The welding table is made out 2”x 6’x 3/16” rectangular tubing. The 15’ pieces of tubing were placed on the ground and the distance between them were measured to drawing specifications. The 8’ pieces of tubing were placed perpendicular to the 15’ pieces and measured to drawing specs. The pieces were squared and tacked into place. Figure 16 shows the center shaft with the gussets premounted being measured and tacked into place.

Figure 16- Laying out the center shaft into table

After the table was tacked and welded to specifications, it had to be lifted using an overhead crane, as shown in Figure 17.

Figure 17- Finished Table

Figure 18 shows the Ultra High Molecular Weight (UHMW) polyethylene that was used in the center pipe for a bushing. This material makes the jig rotate smoothly.

Figure 18- Material used for bushing

Figure 19 shows how the UHMW used for the bushing was form fitted to the center pipe stand. The UHMW was heated such that it would form to the stand. The UHMW was then pressed down with a pipe of the same size diameter of the center shaft. After the UHMW cooled the sample center shaft was removed to place the full center shaft in.

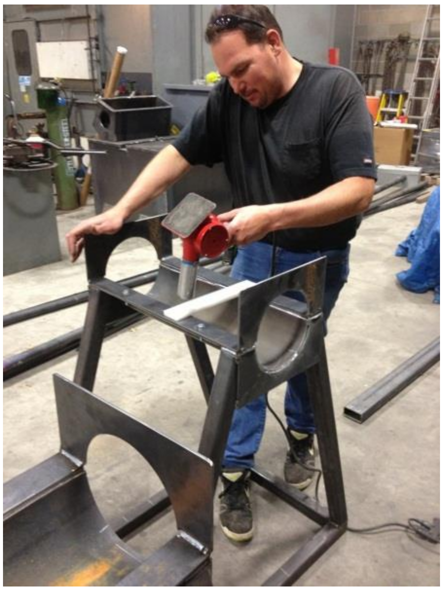


Figure 19- Form fitting bushing to stand

Figure 20 depicts the sample center shaft holding the bushing material in place during cooling.

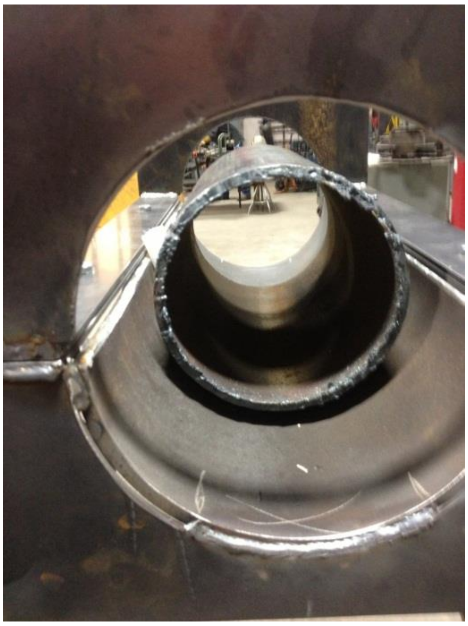


Figure 20- Initial bushing test

After the bushing cooled, the sample center shaft was used to determine how easily the center shaft would rotate. Figure 21 shows that the bushing material would work, and the rest of the stands were fitted with bushings.

Figure 21- Bushing analysis

Figure 22 depicts the stands and tables being fitted together.

Figure 22- Attaching table and stands

Figure 23 shows an error that was not diagnosed before manufacturing. The material of the stands had been changed from pipe to tubing, and the same dimensions were used, making the stands too tall. This was later fixed using simple engineering calculations.

Figure 23- Initial stand height comparison. 5'3" girl vs table height.

Figure 24 shows that the stands had been modified from the previous dimensions, to an acceptable height. This modification required the stand legs to be notched at a 60 degree angle to preserve the integrity of the degree of the table when it is sitting on the ground.

Figure 24- Modified legs of the table

Figure 25 depicts the table integrity while another senior design project needed to be worked on. The table has been used for welding, before it was attached to the stands. The table showed no visible deformation.

Figure 25- Testing

Cost Analysis

KTK performed an analysis of the materials costs for both the 15’ prototype jig (**Table 4**) and the full 42’ final jig (Table 5). The full price for the prototype components came out to just over $1,300.00 and the full jig material cost came up to $3,100.00, both significantly under the original $20,000.00 budget.

Table 4 - Price of all materials for the 15' prototype

Base and Table Prototype

Original Materials

Parts List	Quantity (ft)	Price/ft	Total
2x6in Rectangular Tubing	92	$5.10	$469.20
6-5/8in Drill Stem Pipe	15	$40.00	$600.00
Drawn over mandrel Pipe	4	$48.90	$195.60
2-3/8in Pipe	47	$1.90	$89.30
1/2in Steel Rod	15	$0.78	$11.70
HH-225D Toggle Clamp	4	$25.00	$100.00
UHMW Plastic	16	$9.68	$154.88
40 Roller Chain	10	$3.53	$35.30
80 Tooth Sprocket	1	$74.22	$74.22
Idler Sprocket	1	$27.68	$27.68
Adhesive Backed Ruler	2	$29.70	$59.40
Total			$1,817.28

New Materials

Parts List	Quantity (ft)	Price/ft	Total
2x6in Rectangular Tubing	92	$5.10	$469.20
2x2in Square Tubing	47	$2.25	$105.75
6in Schedule 40 Pipe	15	$11.24	$168.60
8in Schedule 40 Pipe	2	$16.43	$32.86
3/16x48x96in Steel Plate	1	$101.00	$101.00
HH-225D Toggle Clamp	4	$25.00	$100.00
UHMW Plastic	16	$9.68	$154.88
40 Roller Chain	10	$3.53	$35.30
80 Tooth Sprocket	1	$74.22	$74.22
Idler Sprocket	1	$27.68	$27.68
Adhesive Backed Ruler	2	$29.70	$59.40
Total			$1,328.89

Table 5 – Price of all materials for the full jig

Base and Table Full Jig

Original Materials

Parts List	Quantity (ft)	Price/ft	Total
2x6in Rectangular Tubing	248	$5.10	$1,264.80
6-5/8in Drill Stem Pipe	42	$40.00	$1,680.00
Drawn over mandrel Pipe	10	$48.90	$489.00
2-3/8in Pipe	120	$1.90	$228.00
1/2in Steel Rod	42	$0.78	$32.76
HH-225D Toggle Clamp	10	$25.00	$250.00
UHMW Plastic	TBD		
40 Roller Chain	10	$3.53	$35.30
80 Tooth Sprocket	1	$74.22	$74.22
Idler Sprocket	1	$27.68	$27.68
Adhesive Backed Ruler	2	$79.20	$158.40
Total			$4,240.16

New Materials

Parts List	Quantity (ft)	Price/ft	Total
2x6in Rectangular Tubing	248	$5.10	$1,264.80
2x2in Square Tubing	120	$2.25	$270.00
6in Schedule 40 Pipe	42	$11.24	$472.08
8in Schedule 40 Pipe	5	$16.43	$82.15
3/16x48x96in Steel Plate	2.5	$101.00	$252.50
HH-225D Toggle Clamp	10	$25.00	$250.00
UHMW Plastic	27	$9.68	$261.36
40 Roller Chain	10	$3.53	$35.30
80 Tooth Sprocket	1	$74.22	$74.22
Idler Sprocket	1	$27.68	$27.68
Adhesive Backed Ruler	2	$79.20	$158.40
Total			$3,148.49

Recommendations

KTK recommends that Sooner/Exiss Trailer purchase two basic jigs for their production line. We also recommend that the jigs be motorized with adhesive rules and toggle clamps.

Modifications

After prototype demonstrations Sooner/Exiss recommended that some modifications be made to the jig. They recommended that the stands be made vertically taller to increase the angle of the jig when it is resting on the ground. The adhesive backed rules need to be recessed into the jig itself to protect against abrasive damage from the trailer sides. The toggle clamps and bottom vertical members should be recessed to allow for easy installation of the bottom rail.

References

Bingham, G. A. and V. C. Stone. 1997. Adjustable framing jig. U.S. Patent No. 5628119.

Featherlite Factory Tour, Ahead of the Curve. 2009. Mr. Truck. Available at http://www.mrtrailer.com/featherlite_factory.htm. Accessed 12 October 2012.

Sellers, L. 1979. Wall component fabricating jig. U.S. Patent No. 4154436

Shipley, T. G. 1951. Welding Jig for car underframes. U.S. Patent No. 2553947

http://www.universaltrailer.com/

http://www.soonertrailers.com/

http://www.exiss.com/

Appendix 1

Equations Used:

Horizontal Deflection

$$y = \frac{Wx}{24EI}(2lx^2 - x^3 - l^3)$$

y = deflection

W = distributed load

E = Young's modulus

I = Moment of inertia

x = location along beam

l = total length

Torsional Deflection

$$\theta = \frac{Tl}{JG}$$

G=Modulus of Rigidity

θ= Torsional Deflection

T=Torque

l=length

J=Polar moment of Inertia

Tipping

$$\sum M_{center} = -P(L_t + h_j) - W_t(L_h) + N_1\left(\frac{L_s}{2}\right) = 0$$

$$P = \frac{N_1\left(\frac{L_S}{2}\right) - W_t(L_h)}{L_t}$$

P= Force

N_1 = Normal Force

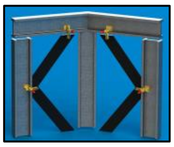
$L_s = Stand\ Width$

$L_h = W_t\ Moment\ Arm$

$L_t = P\ Moment\ Arm$

$W_t = Table\ Weight$

$W_s = Weight\ of\ stands + center\ shaft\ pipe$



Spring Report

Buckling

Euler

$$P_{cr} = \frac{(\pi^2 El)}{L^2}$$

Intermediate

$$\frac{P_{cr}}{A} = S_y - \left(\frac{S_y}{2\pi}\frac{1}{k}\right)^2 \frac{1}{CE}$$

Strut

$$\sigma_c = \frac{P}{A} + \frac{My}{I}$$

$P = Force\ on\ column$

$P_{cr} = critical\ force$

$E = Young's\ Modulus$

$I = Area\ Moment\ of\ Inertia$

$L = Length$

$A = area$

$S_y = yield\ stress$

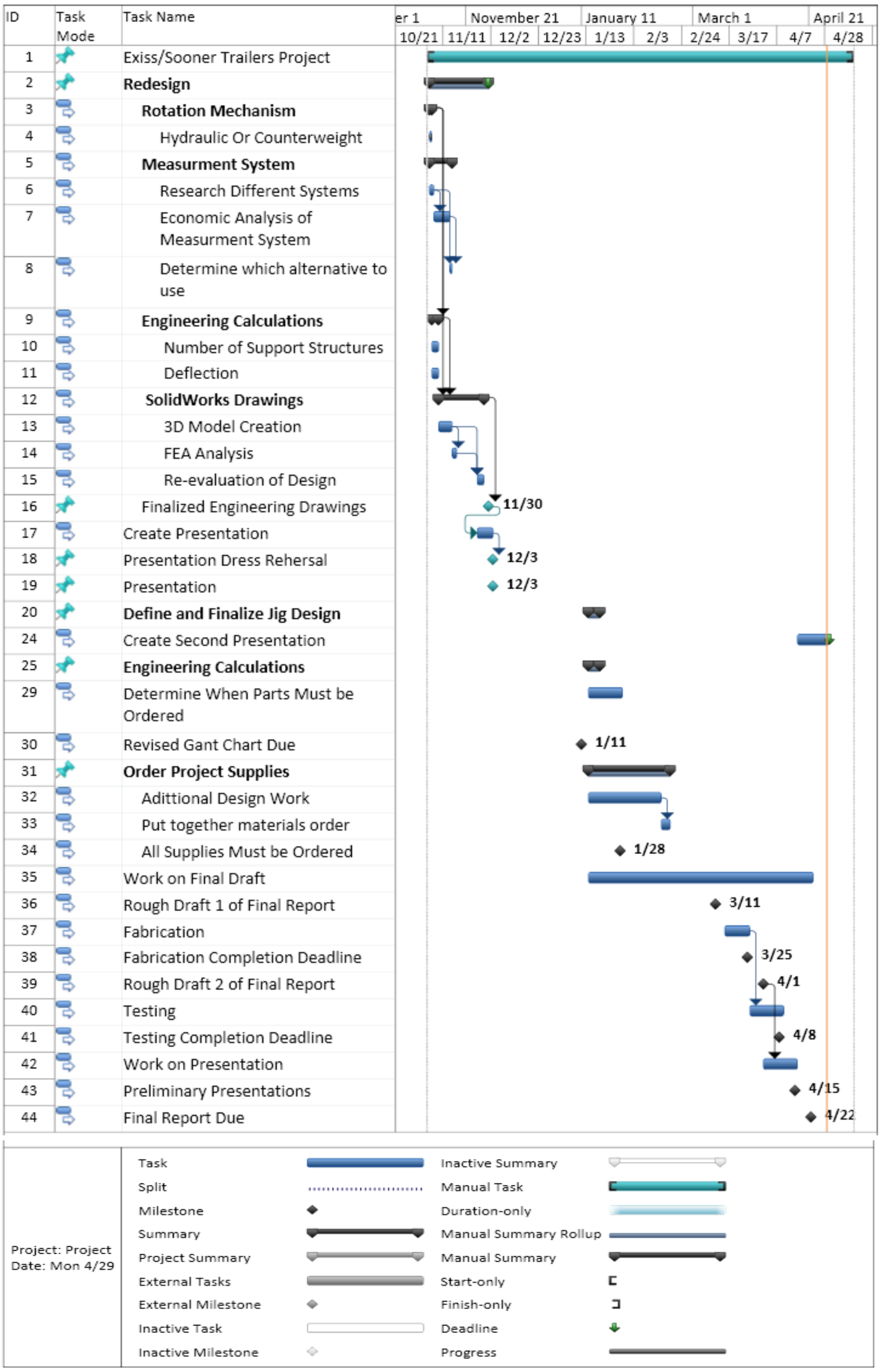
$\frac{L}{k} = slendernes\ ratio$

$C = End\ Conditions$

$M = Moment$

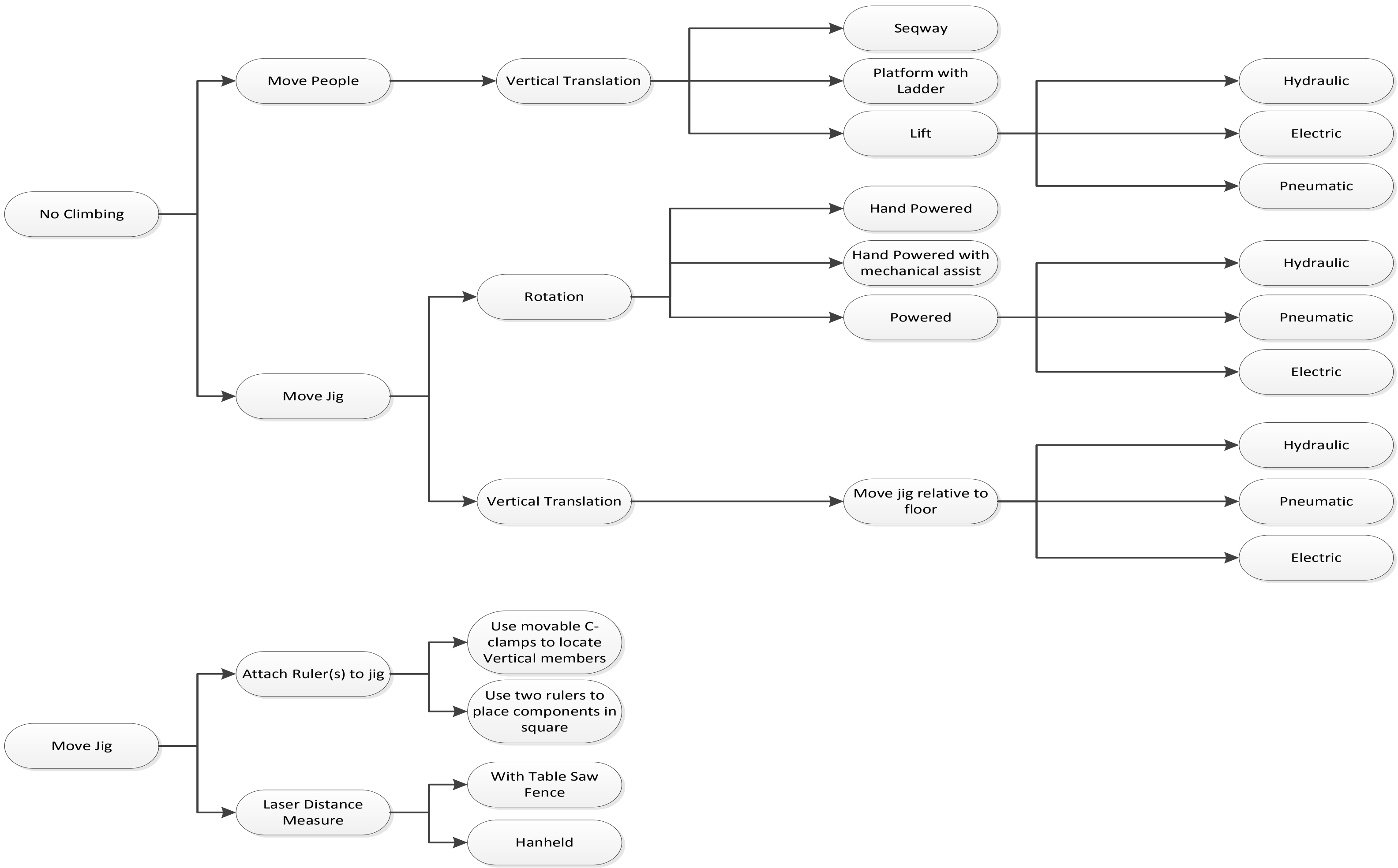
Appendix 2

Gantt Chart- Microsoft Project



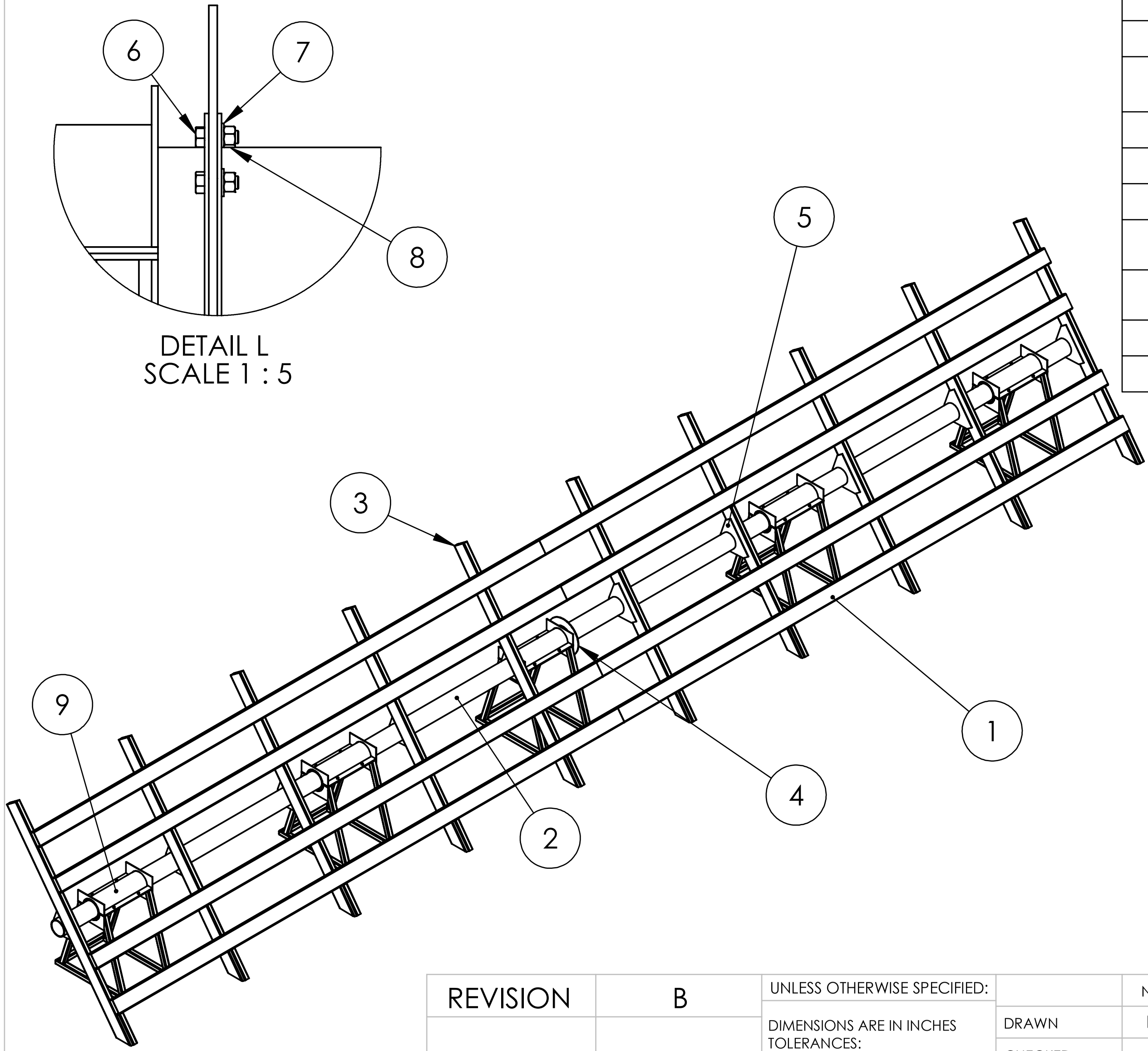
Appendix 3

Flow Chart of Generated Design Options



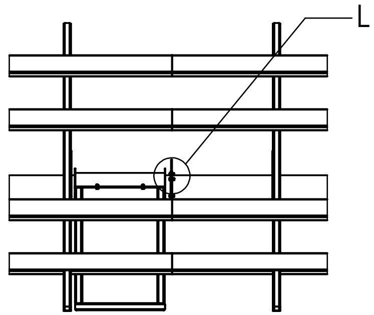
Appendix 4

CAD Drawings:



ITEM NO.	PART NUMBER	QTY.
1	Stand	5
2	6.625 in x ~21 ft Center Pipe	2
3	table	1
4	Sprocket	1
5	gusset	10
6	UNF 3/8-24 1"	5
7	3/8" FLAT WASHER	5
8	UNF 3/8-24 LOCKNUT	5
9	Bushing	5

UNLESS OTHERWISE SPECIFIED:
- ALL MATERIALS ARE MILD HOT
- ROLLED STEEL
- PIPE IS SCHEDULE 40



FRONT VIEW

REVISION	B
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APPLICATION	

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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KDR	2/3/13
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ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

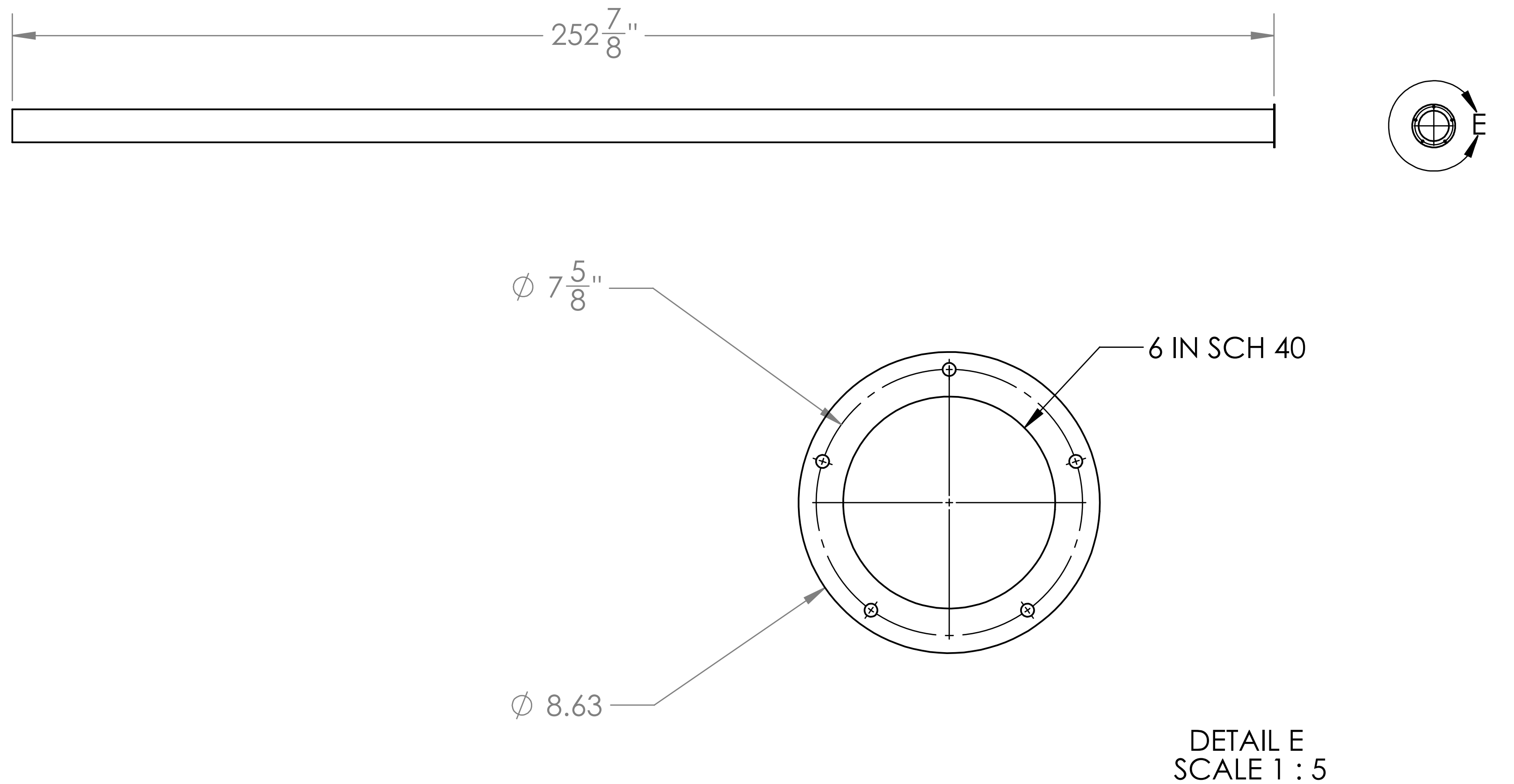
TITLE:

JIG - SINGLE SECTION

SIZE	DWG. NO.	REV
A		

SCALE: 1:128 WEIGHT: SHEET 1 OF 20

5 4 3 2 1



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TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

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MATERIAL

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	NAME	DATE
DRAWN	KDR	2/3/13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

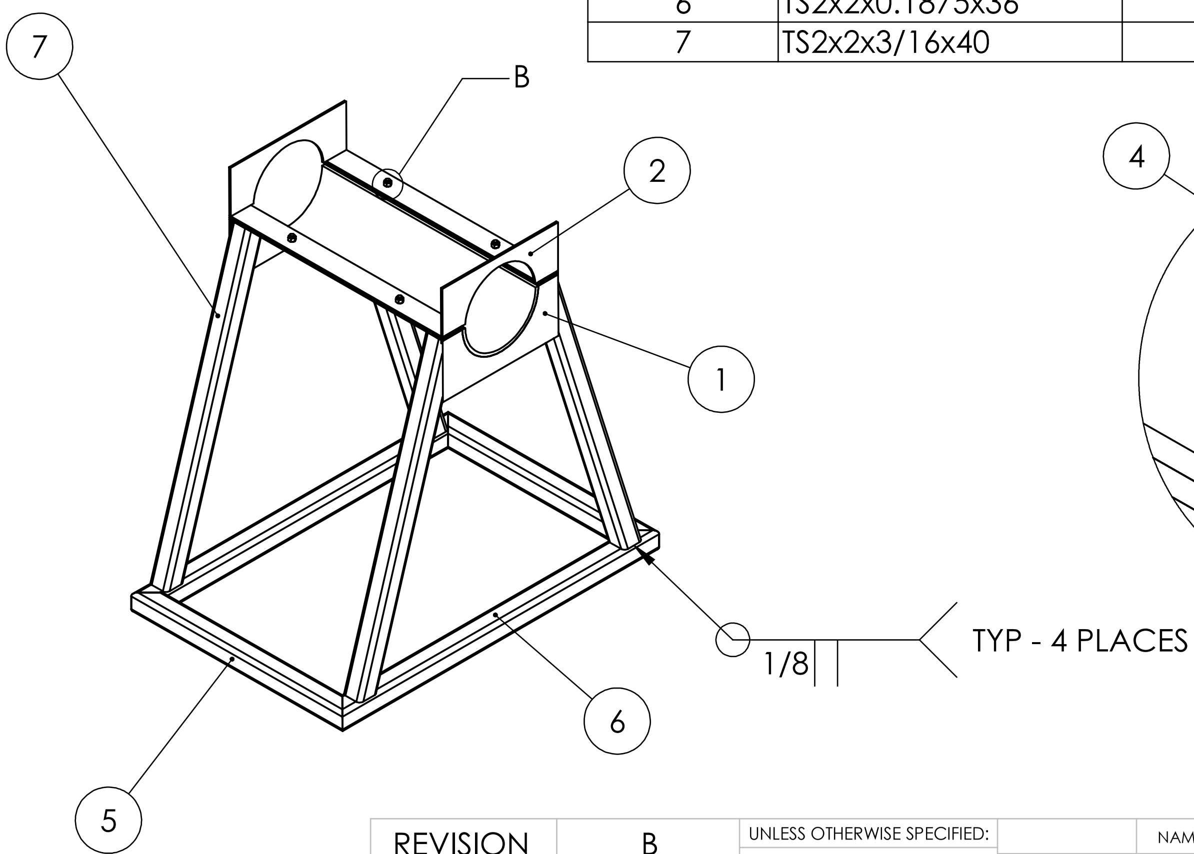
CENTER SHAFT

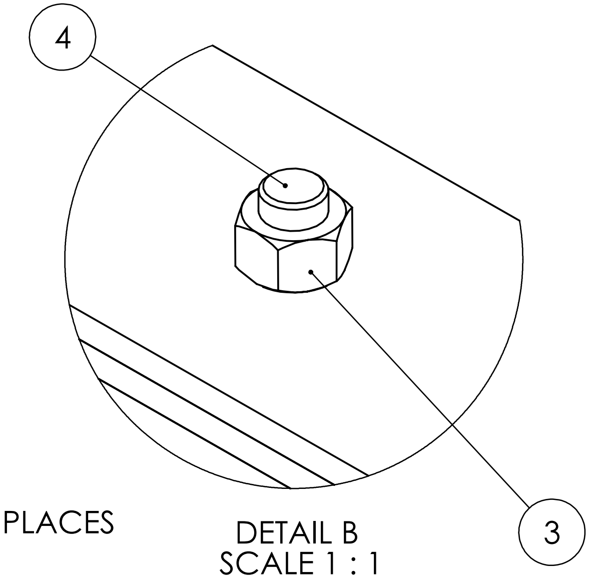
SIZE	DWG. NO.	REV
A		

SCALE: 1:64 WEIGHT: SHEET 2 OF 20

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Girdle	SUBASSEMBLY	1
2	Top_Girdle	SUBASSEMBLY	1
3	UNF 3/8-24 HEX BOLT		4
4	UNF 3/8-24 HEX NUT		4
5	TS2x2x3/16x24		2
6	TS2x2x0.1875x36		2
7	TS2x2x3/16x40		4





DETAIL B
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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KDR	2/3/13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

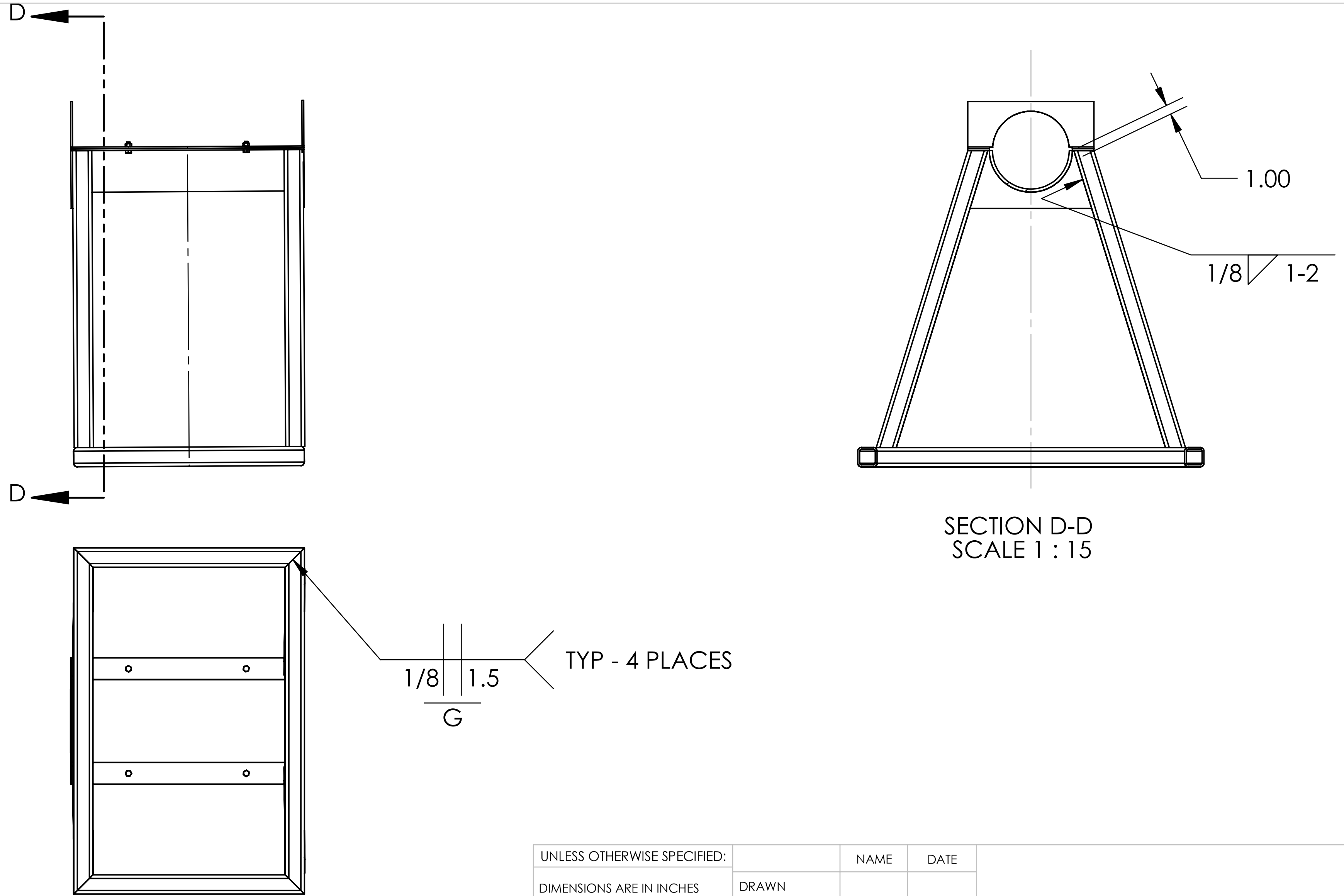
TITLE:

STAND

SIZE A | DWG. NO. | REV

SCALE: 1:24 | WEIGHT: | SHEET 3 OF 20

5 4 3 2 1



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FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

STAND

SIZE **A** DWG. NO. REV

SCALE: 1:24 WEIGHT: SHEET 4 OF 20

NEXT ASSY	USED ON
APPLICATION	

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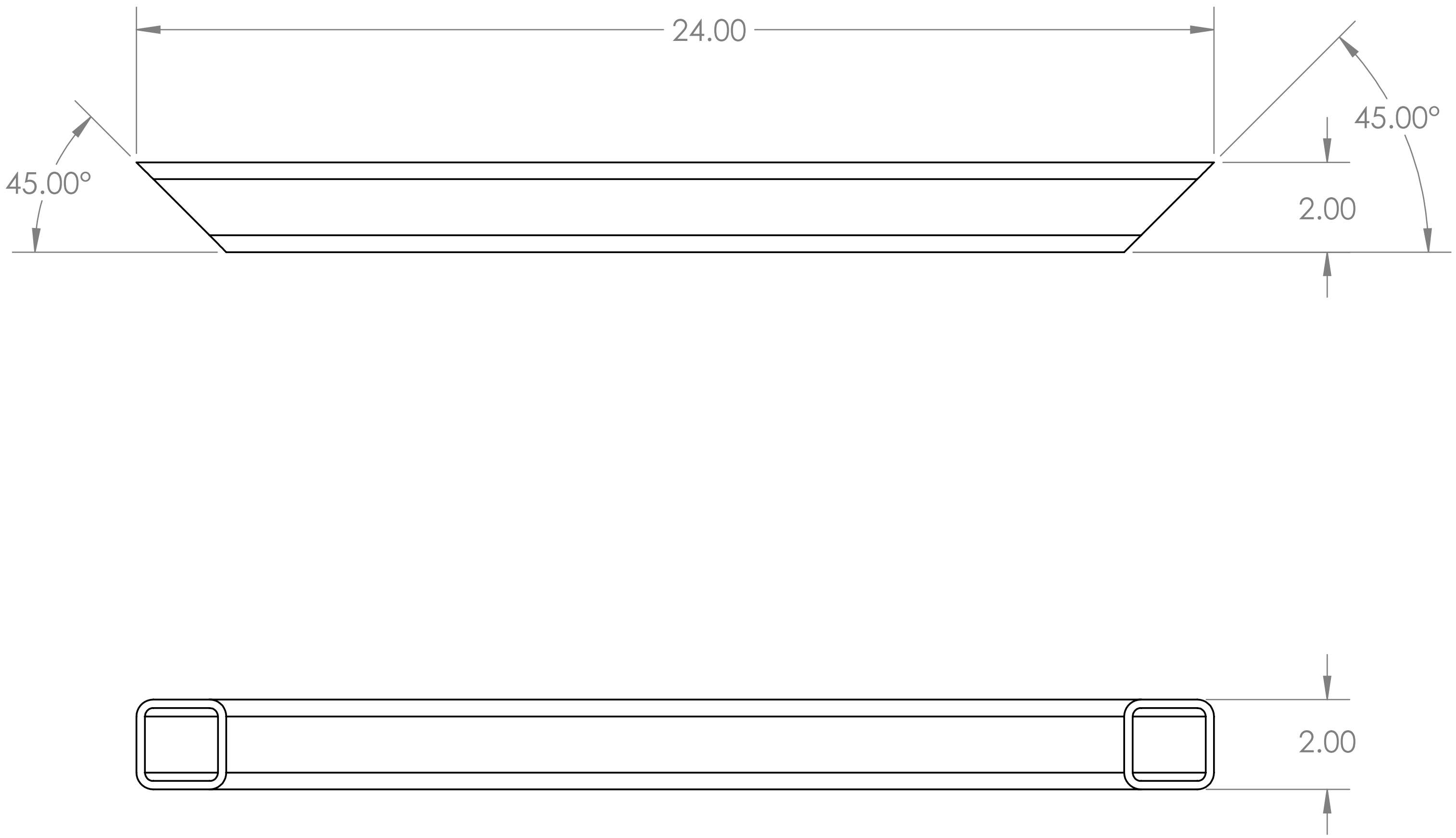

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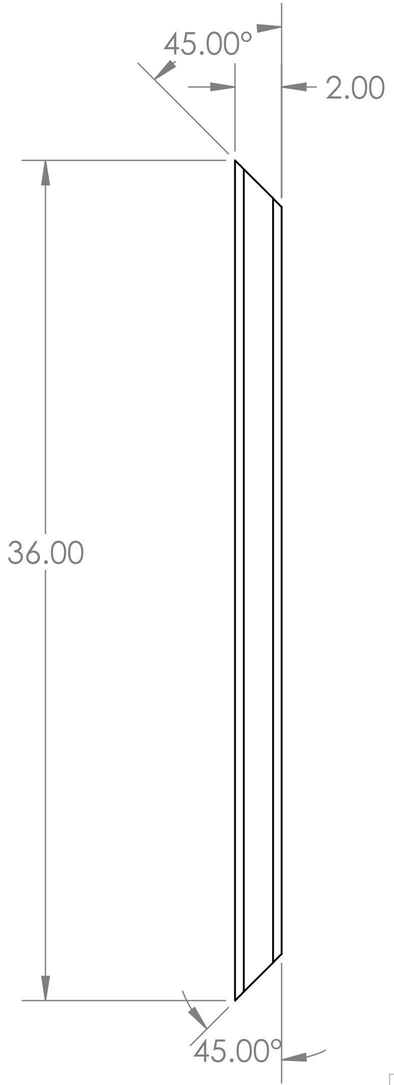
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

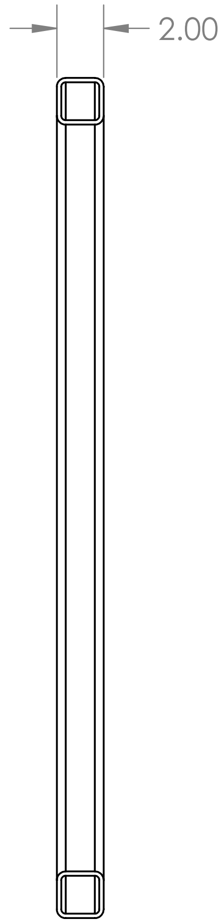
TITLE:

TS2x2x0.1875x24

SIZE	DWG. NO.		REV
A			
SCALE: 1:8	WEIGHT:	SHEET 5 OF 20	

5 4 3 2 1





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			ENG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	MFG APPR.		
		MATERIAL	Q.A.		
NEXT ASSY	USED ON	FINISH	COMMENTS:		
APPLICATION		DO NOT SCALE DRAWING			

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TITLE:

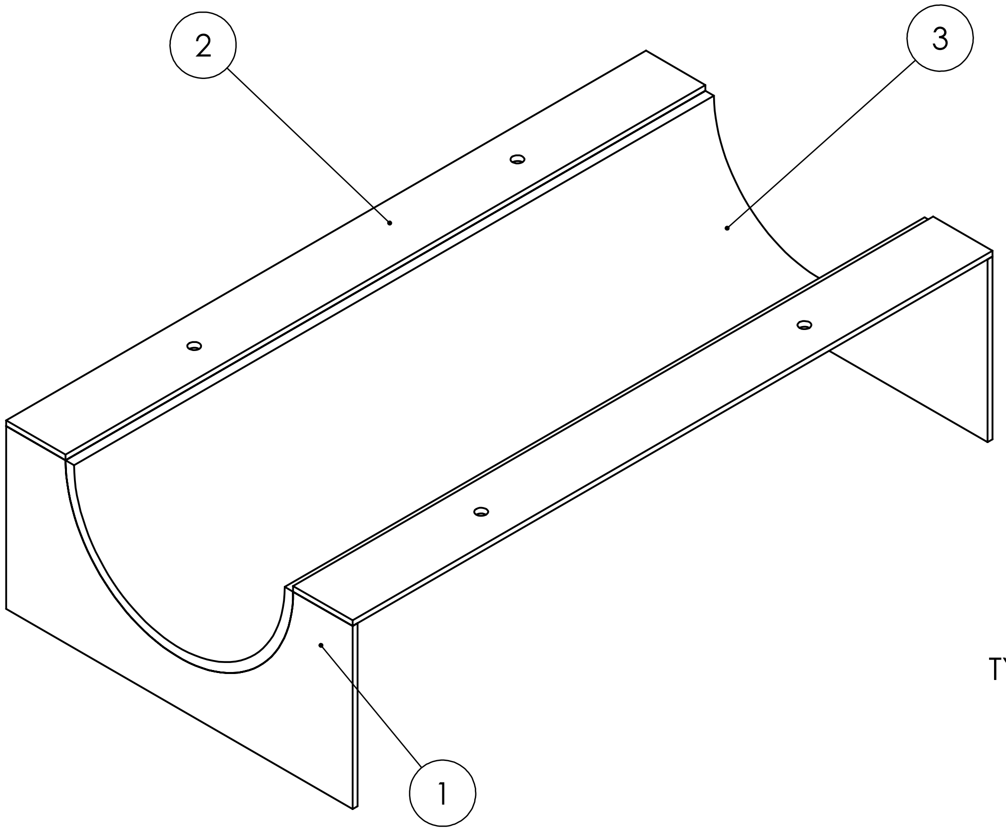
TS2x2x0.1875x36

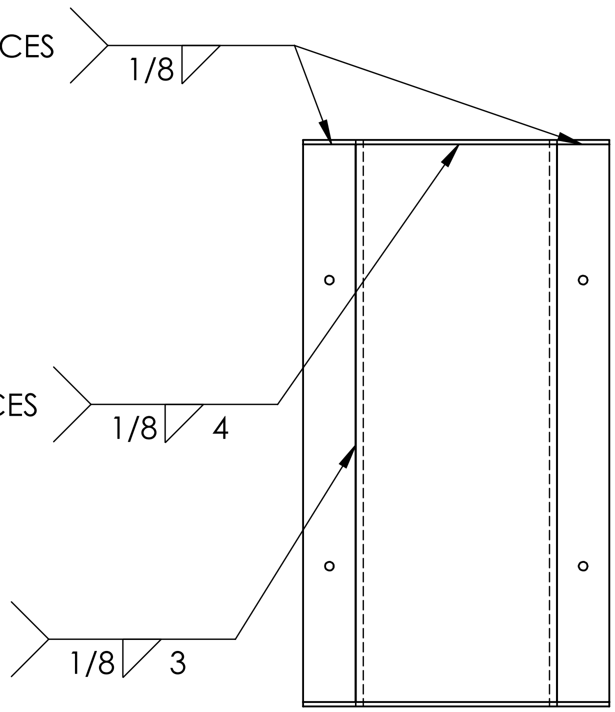
SIZE	DWG. NO.	REV
A		

SCALE: 1:12 WEIGHT: SHEET 6 OF 20

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Half Plate		2
2	STRAP		2
3	half pipe	1020 HR SCH 40 8" PIPE	1





REVISION	B
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KDR	2/3/13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

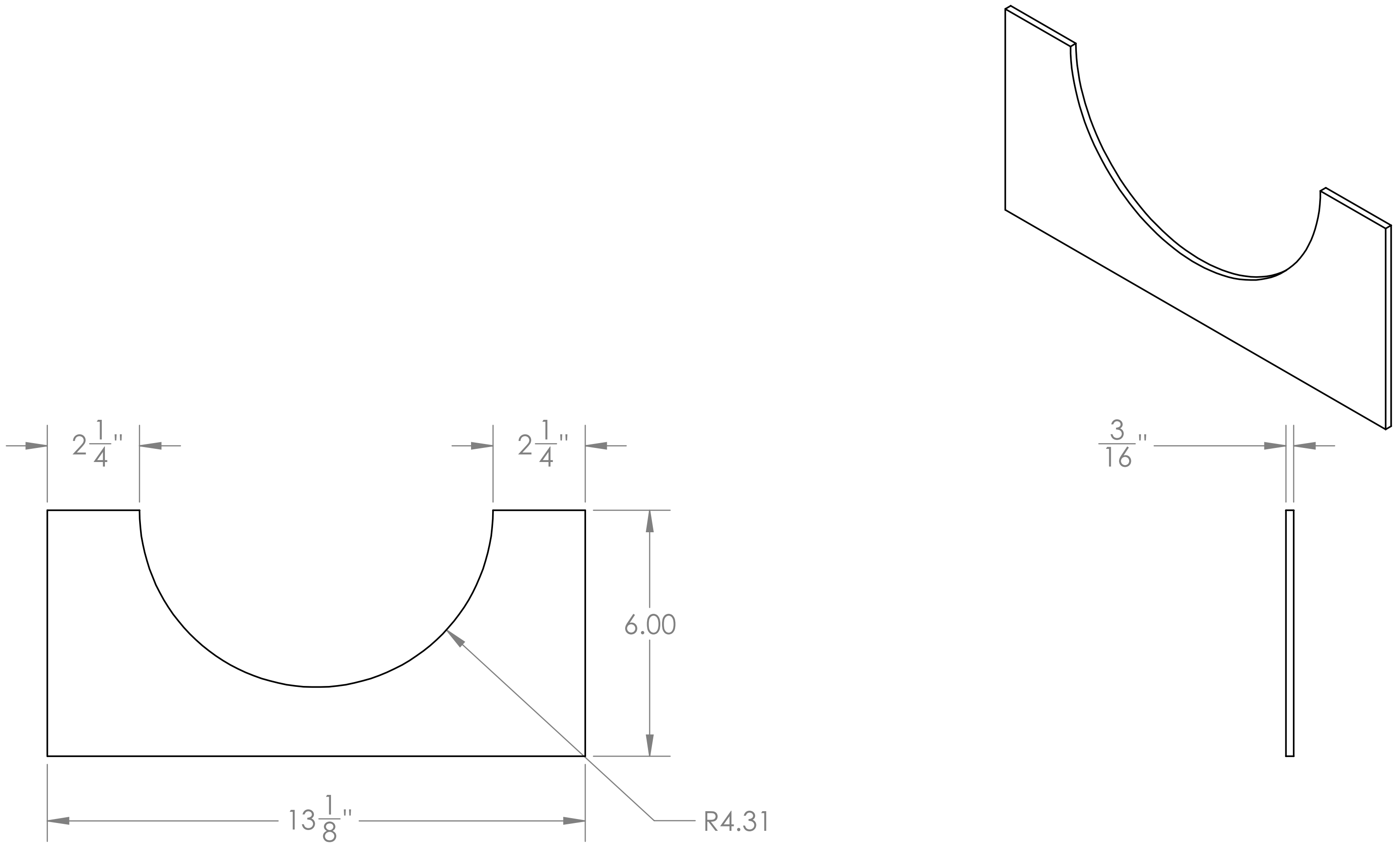
TITLE:

GIRDLE

SIZE A | DWG. NO. | REV

SCALE: 1:8 | WEIGHT: | SHEET 7 OF 20

5 4 3 2 1



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NEXT ASSY	USED ON
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UNLESS OTHERWISE SPECIFIED:

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FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KDR	2/3/13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

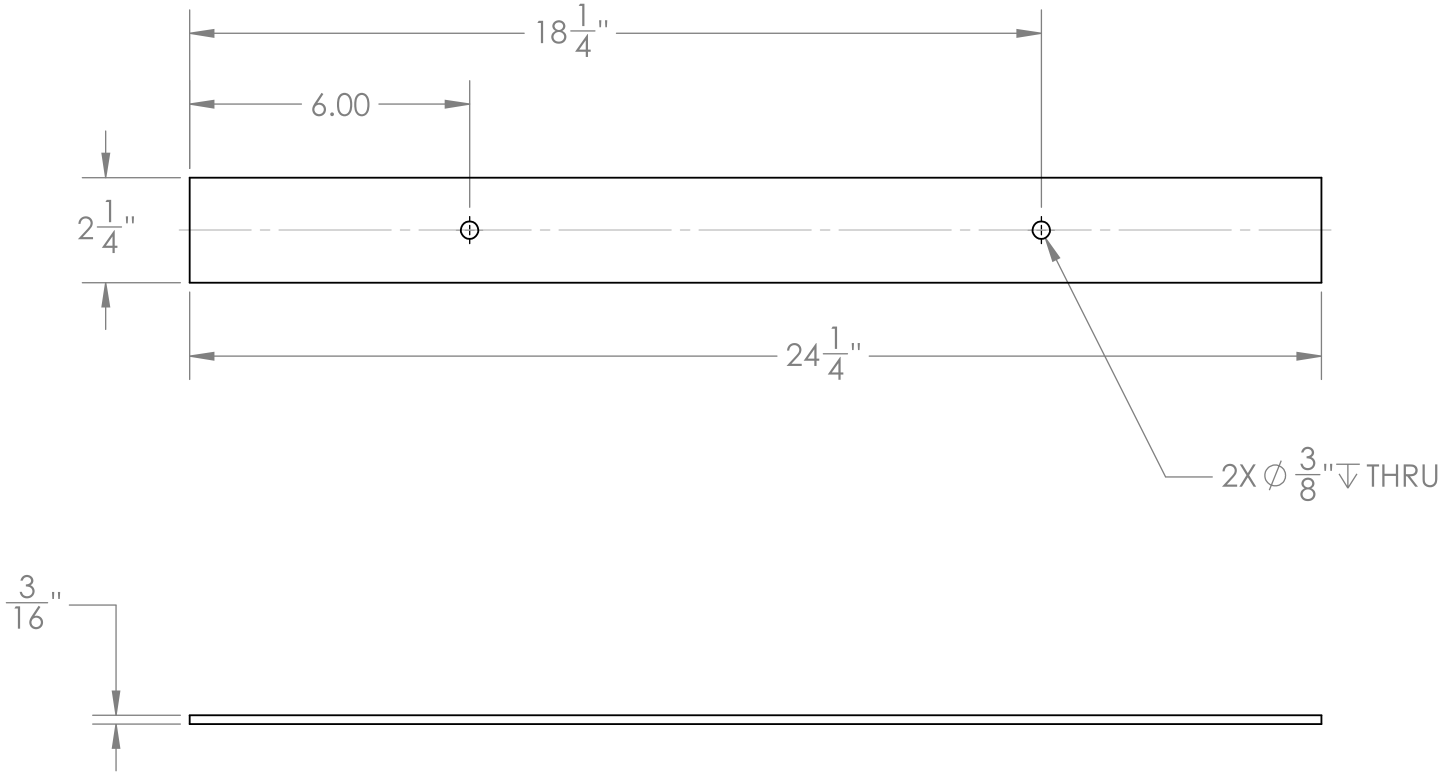
TITLE:

HALF PLATE

SIZE A | DWG. NO. | REV

SCALE: 1:4 | WEIGHT: | SHEET 8 OF 20

5 4 3 2 1



REVISION	B	UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	KDR	2/3/13
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

STRAP

SIZE	DWG. NO.	REV
A		
SCALE: 1:8	WEIGHT:	SHEET 9 OF 20

5 4 3 2 1

REVISION	B	UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	KDR	2/3/13
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

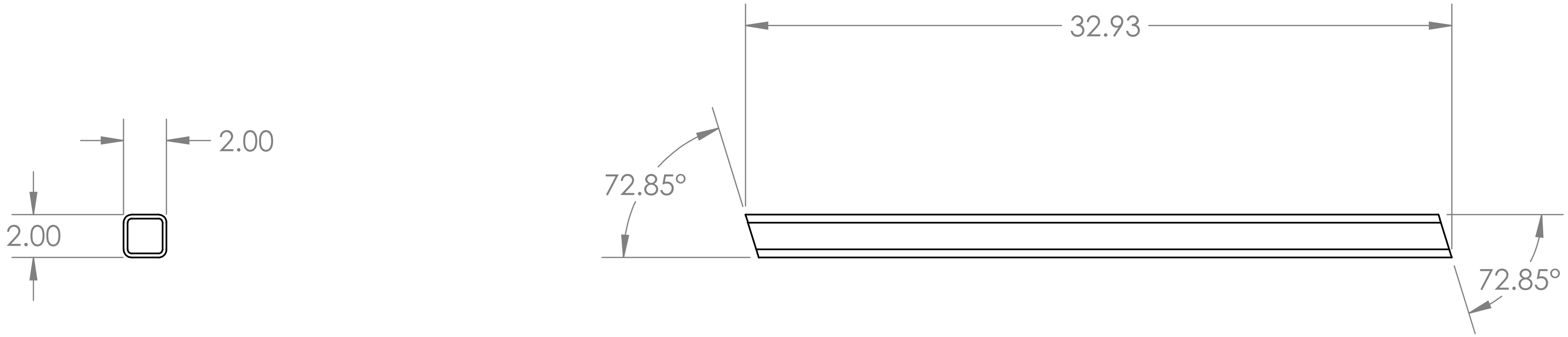
TITLE:

HALF PIPE

SIZE	DWG. NO.	REV
A		

SCALE: 1:8 | WEIGHT: | SHEET 10 OF 20

5 4 3 2 1



REVISION	B
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KDR	2/3/13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

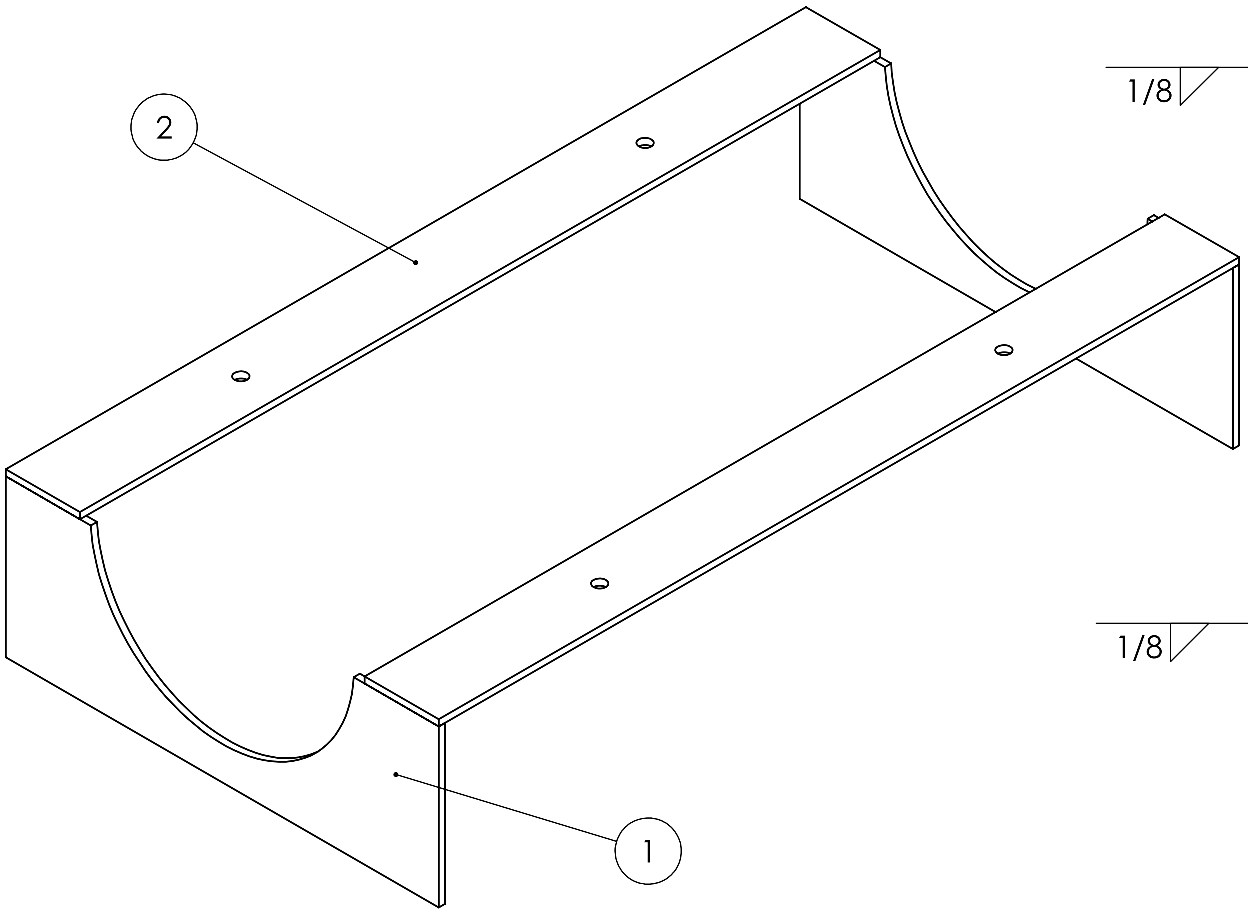
TS2x2x0.1875x40

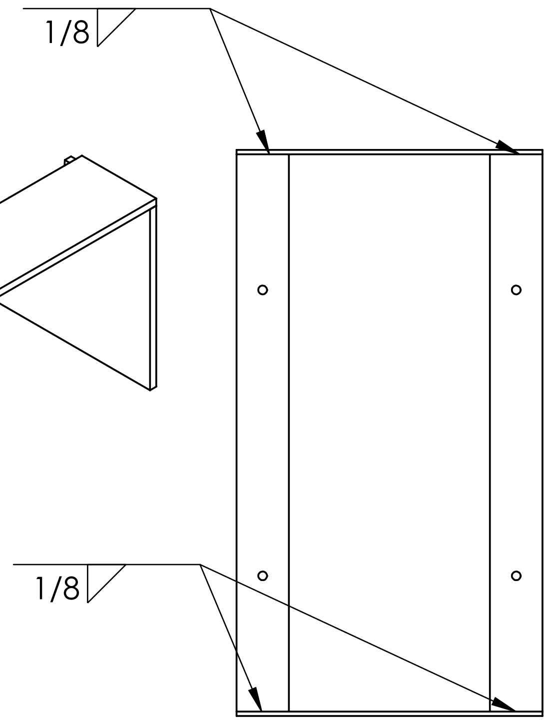
SIZE **A** | DWG. NO. | REV

SCALE: 1:8 | WEIGHT: | SHEET 11 OF 20

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Top Half Plate		2
2	STRAP		2





REVISION	B
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KDR	2/3/13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

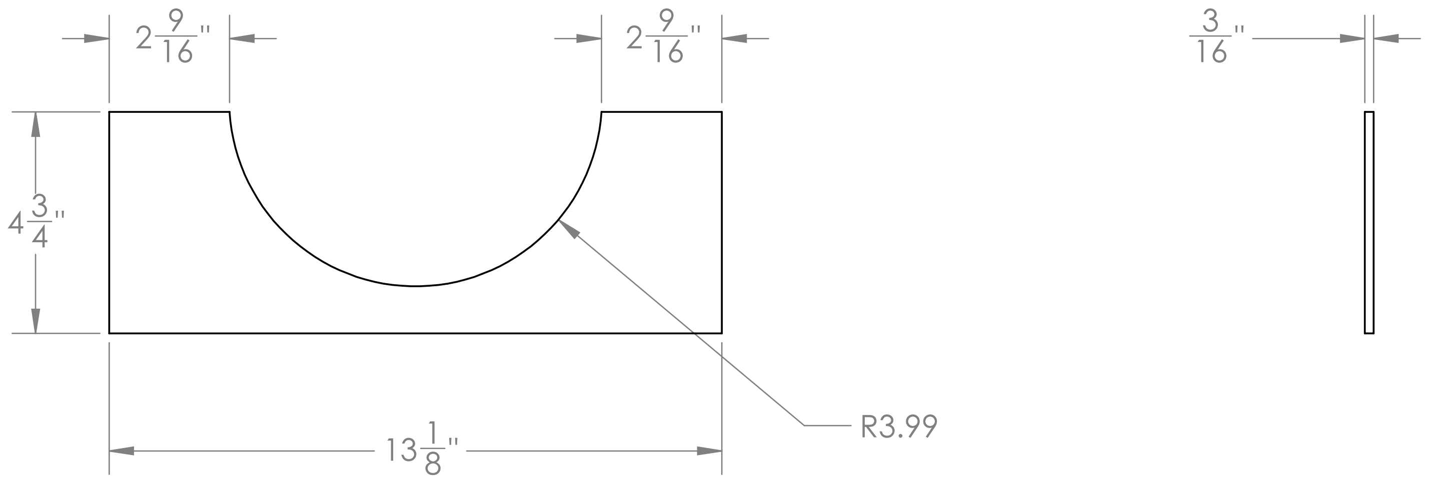
TITLE:

TOP GIRDLE

SIZE A | DWG. NO. | REV

SCALE: 1:8 | WEIGHT: | SHEET 12 OF 20

5 4 3 2 1



REVISION	B
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KDR	2/3/13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

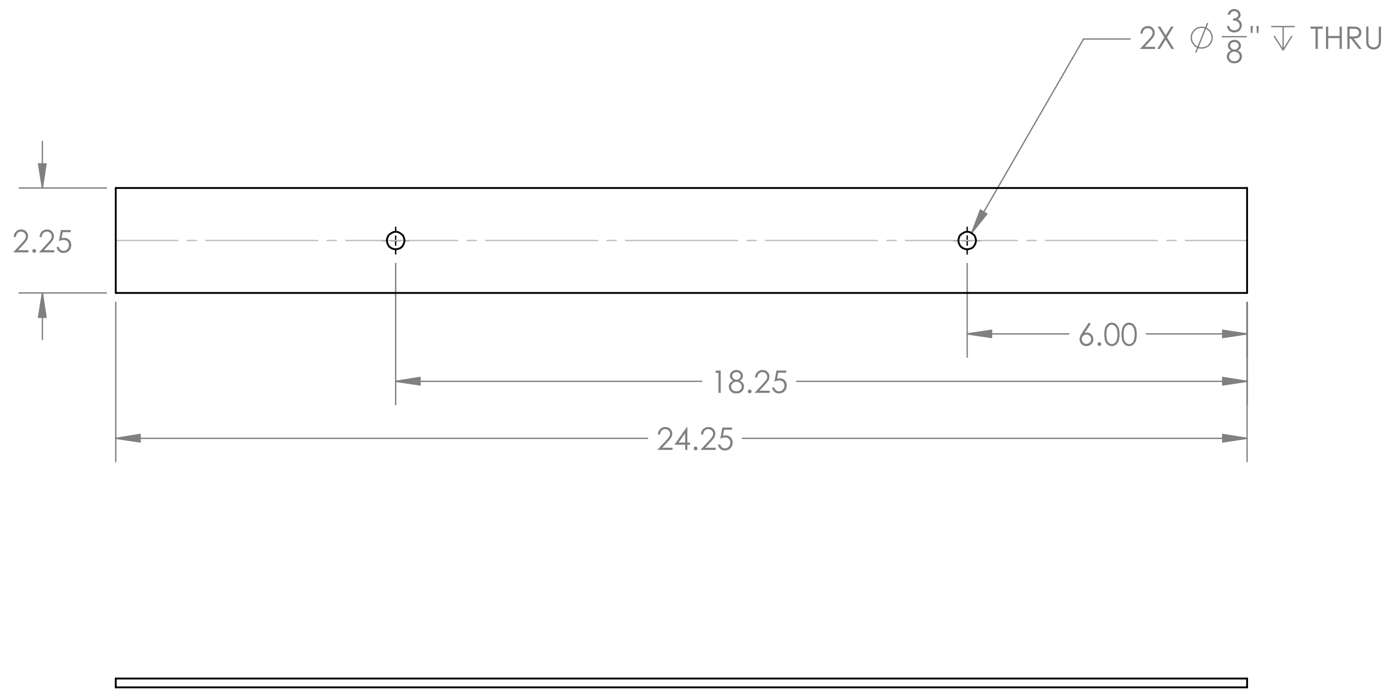
TITLE:

TOP HALF PLATE

SIZE	DWG. NO.	REV
A		

SCALE: 1:4 WEIGHT: SHEET 13 OF 20

5 4 3 2 1



TOP STRAP

REVISION	B
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KDR	2/3/13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

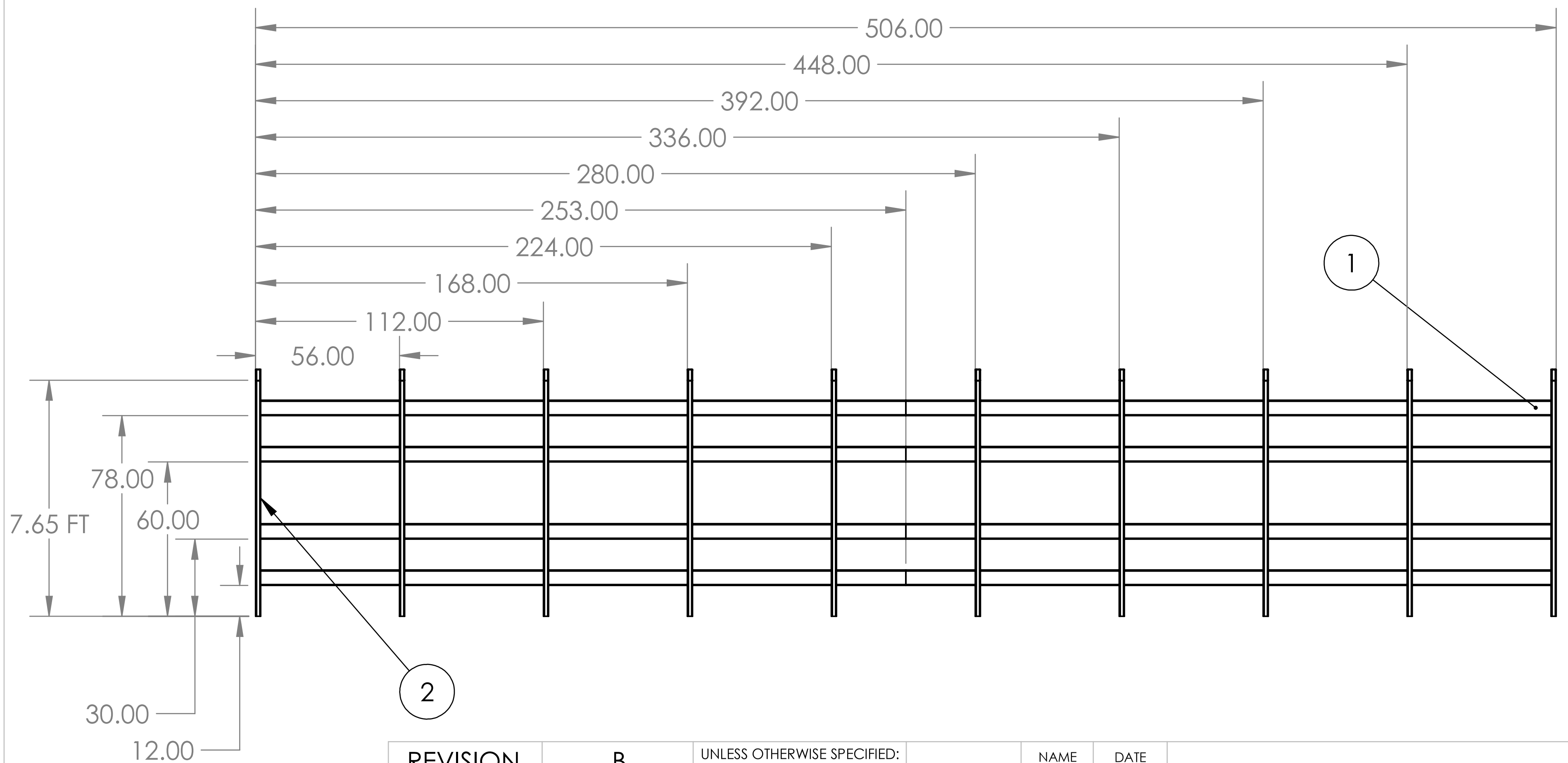
TITLE: TOP STRAP

SIZE	DWG. NO.	REV
A		

SCALE: 1:8 WEIGHT: SHEET 14 OF 20

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TR6x2x3/16x180	6X2X1/8 253 IN STEEL TUBE	8
2	TR6x2x3/16x96	6X2X1/8 8 FT STEEL TUBE	10
3	2x2 Sq Tube		10



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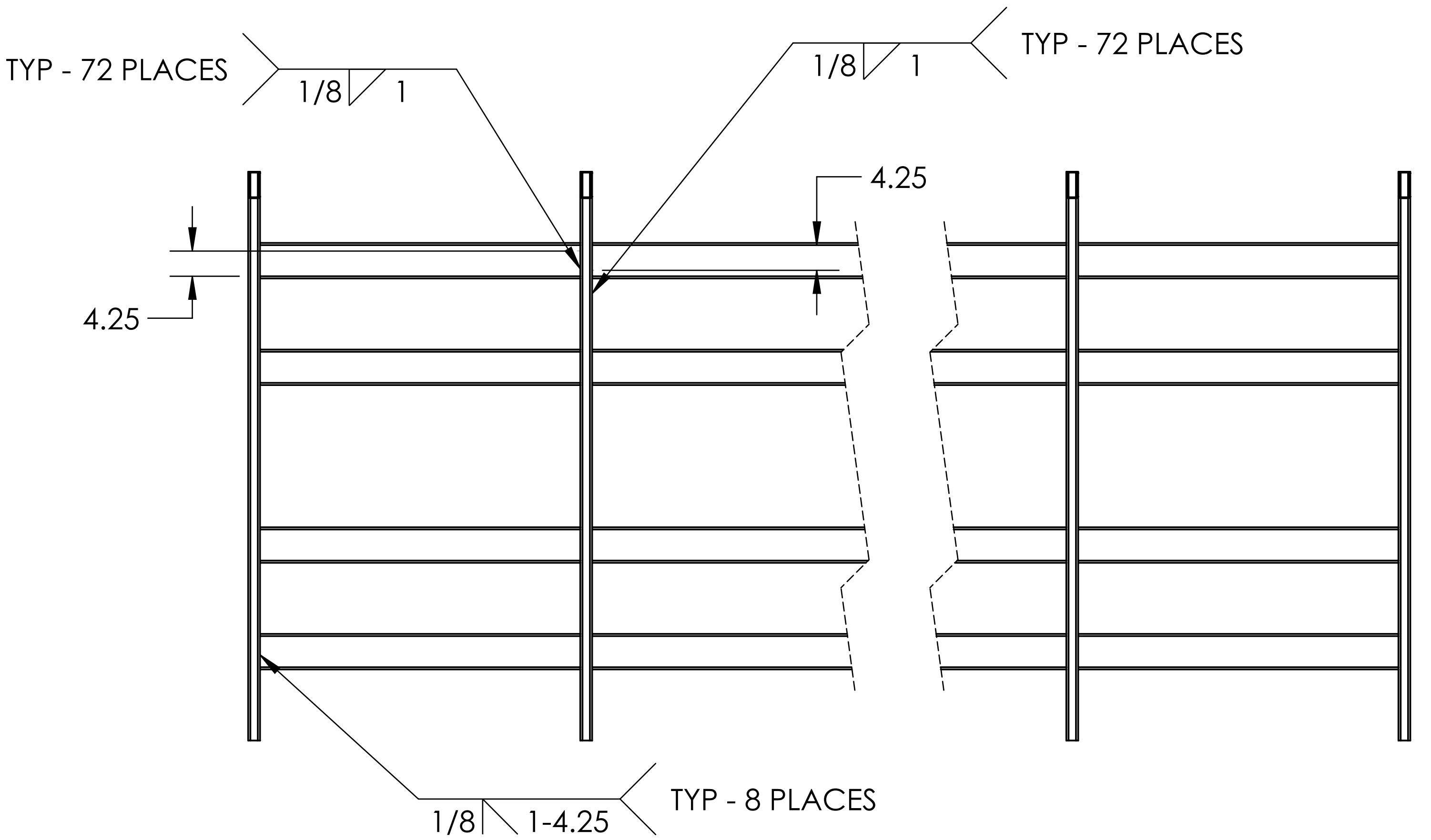

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			MFG APPR.			
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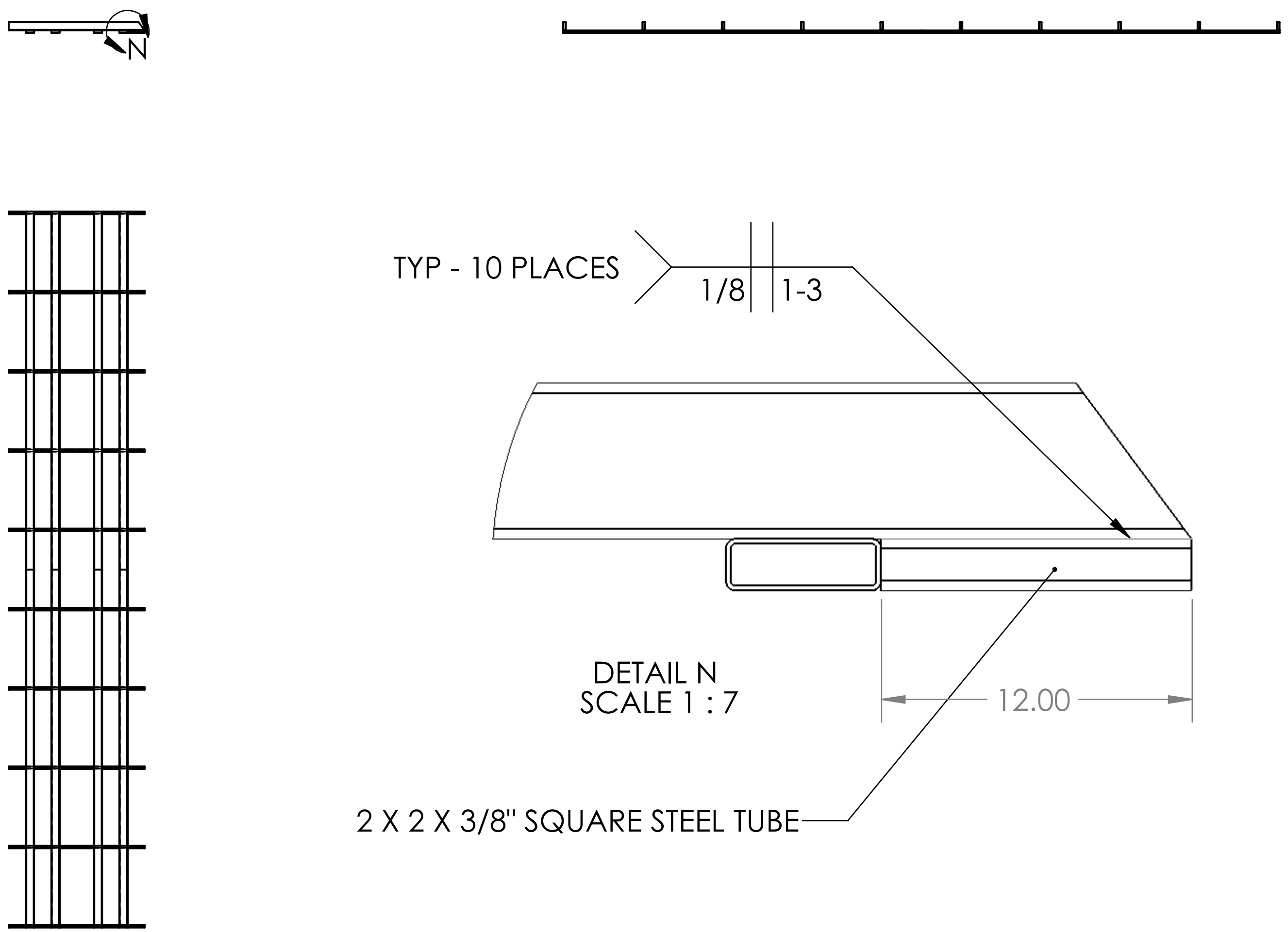

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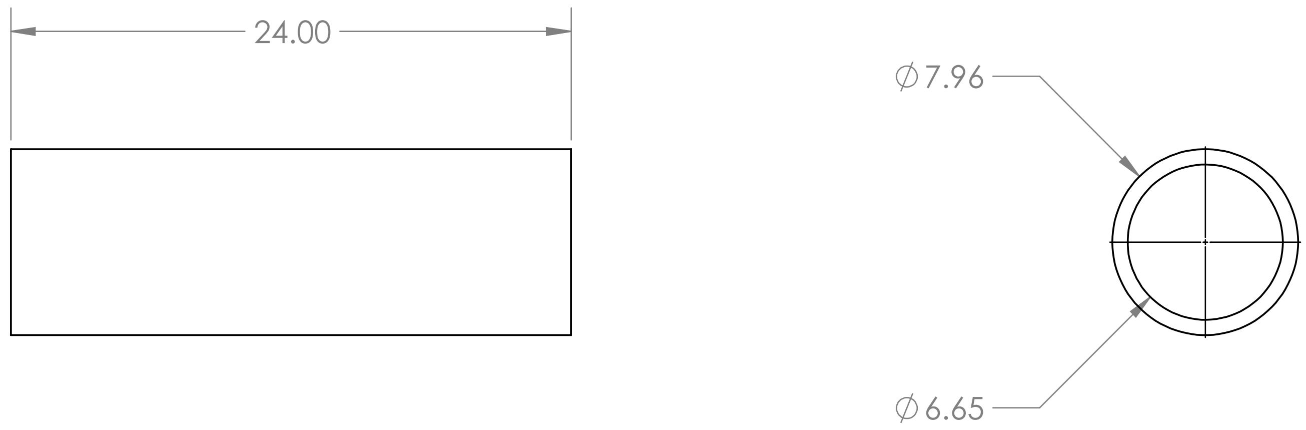

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BUSHING

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A		

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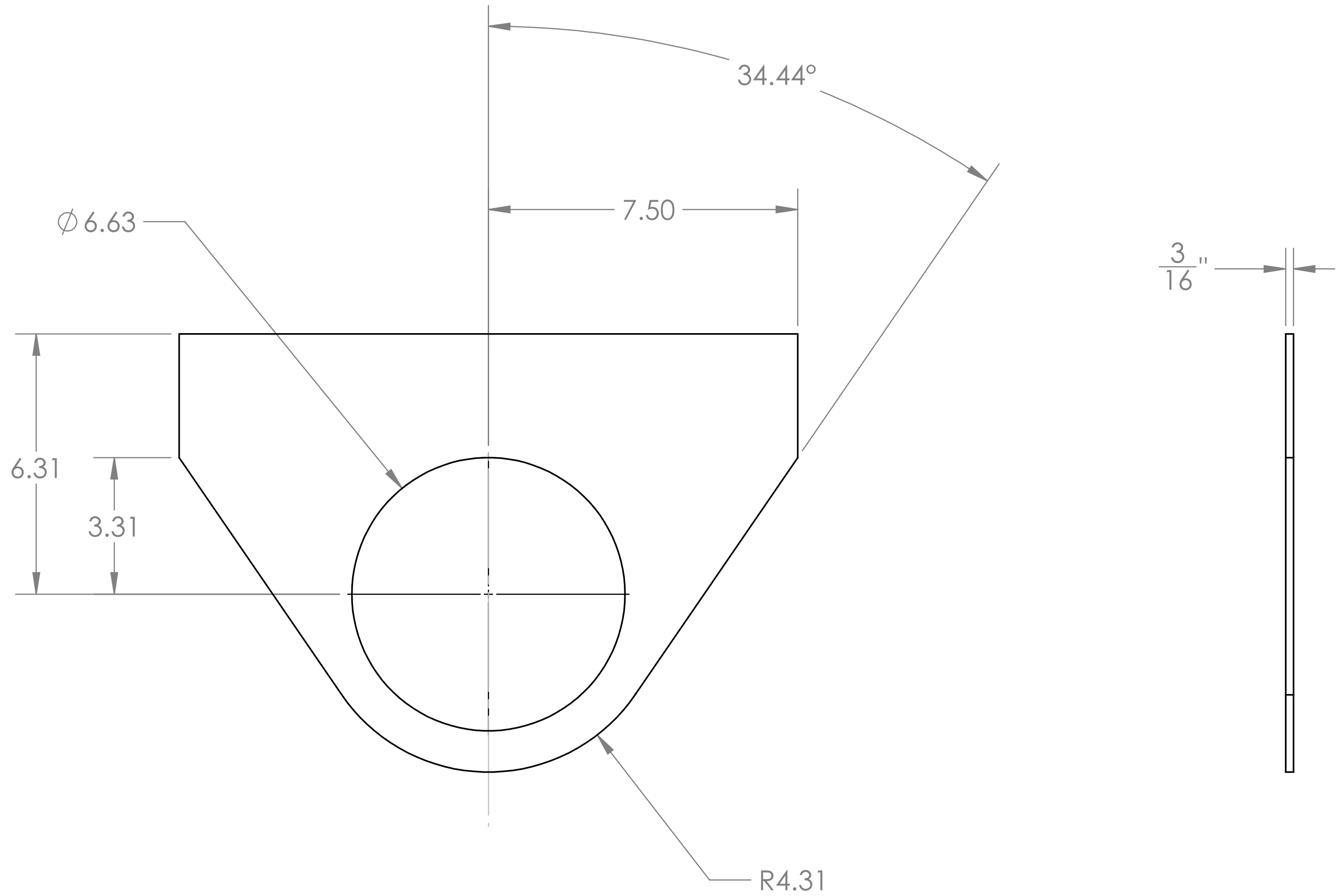

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TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

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MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

GUSSET

SIZE A | DWG. NO. | REV

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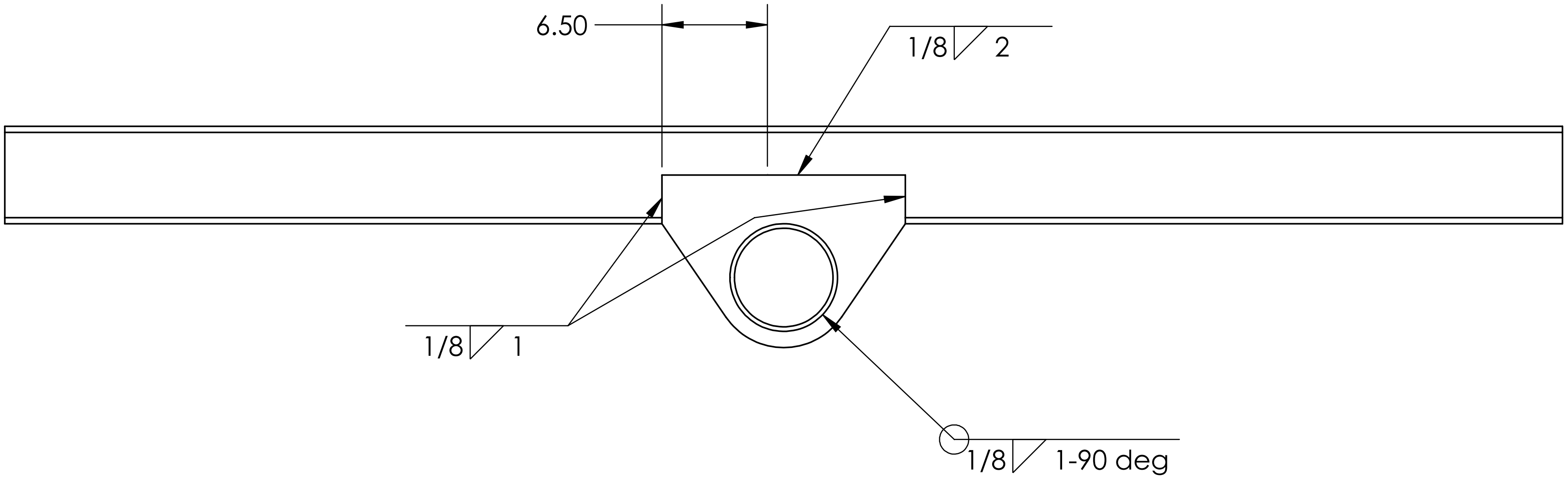
5 4 3 2 1

NOTE:
THIS WELD PATTERN IS FOR ALL 4 GUSSETS



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GUSSET WELDS

SIZE	DWG. NO.	REV
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5 4 3 2 1

Sooner/Exiss Trailer: Redesign of Sidewall Jig

Engineering
Solutions

KTK Engineering

Kevin Roehm Tanisha Hamm Kaden Wanger

Sooner/Exiss Trailers

- Located in El Reno, OK
- Sooner and Exiss are brands under Universal Trailers Corporation
- 8 total Brands
- 9 Manufacturing locations
- Custom Aluminum Trailers

Problem Assessment

Welding Trailer Side Walls

Problem

- Sooner/Exiss Trailer needs increased production
- Trailer side-wall production is current limiting factor
- Current jigs are too small
- Custom sides lead to long set up time

Current Production Jig

Patent Research

- Sellers, L. 1979. Wall component fabricating jig. U.S. Patent No. 4154436
- Bingham, G. A. and V. C. Stone. 1997. Adjustable framing jig. U.S. Patent No. 5628119.
- Shipley, T. G. 1951. Welding Jig for rail car under frames. U.S. Patent No. 2553947

Solution

- Design a new jig
- Increase Production
- Accommodate all trailer sizes
  - 16’ to 42’ long
  - 5’6” to 8’ tall

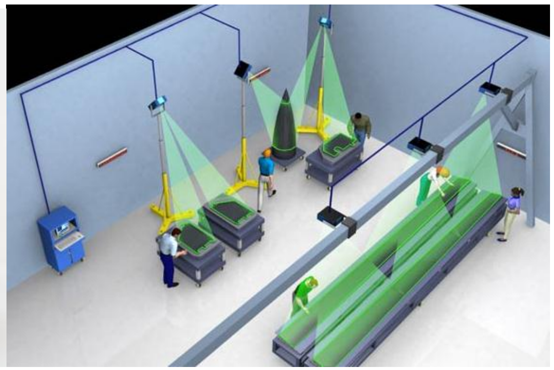
Solution

- Ergonomic
  - No climbing required
  - Minimize worker injuries
  - Reduce overhead welding

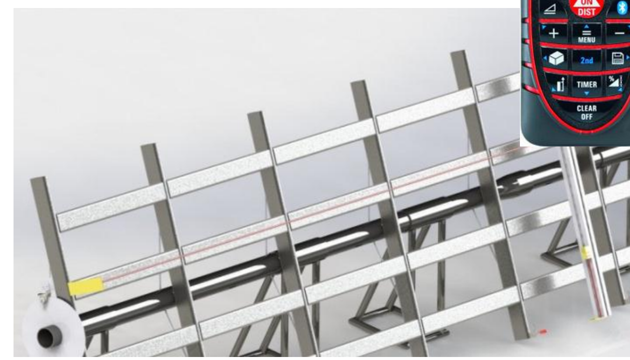
- Rotational
  - Must not deflect or cause deformities in trailer sides
  - Adequate supporting stands

Jig Options- Fall Semester 2012

3 Measurement Options



Assembly Guide

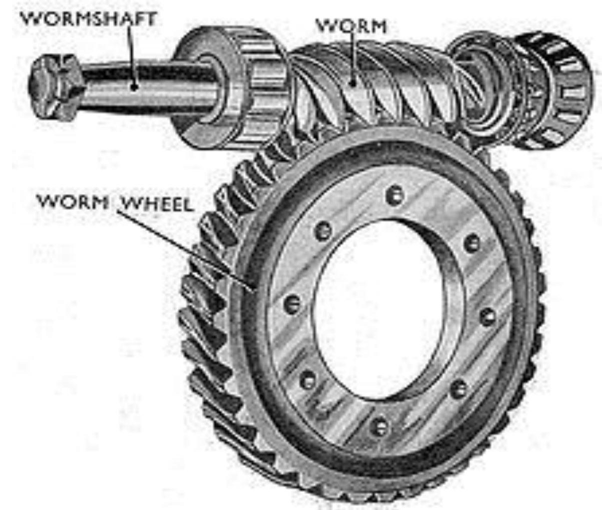


Laser Projection Track System

Adhesive Backed Rule

Jig Options- Fall Semester 2012

- Movement Options
  - Crank
  - Motorized



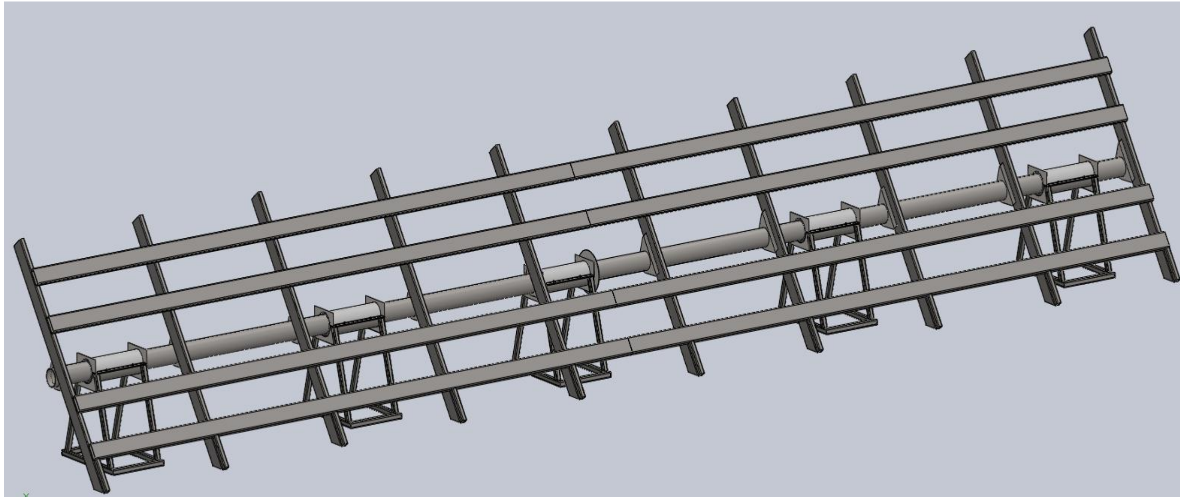
- Crank Movement used worm gear and hand crank

- Motorized option used worm gear and electric motor

Basic information

- Assumed material will be a typical hot rolled carbon steel (SAE 1020)

Weight Full Jig
Table – 2,387 lbs
Stands – 690 lbs
Center Shaft – 797 lbs
Total – **3,874** lbs

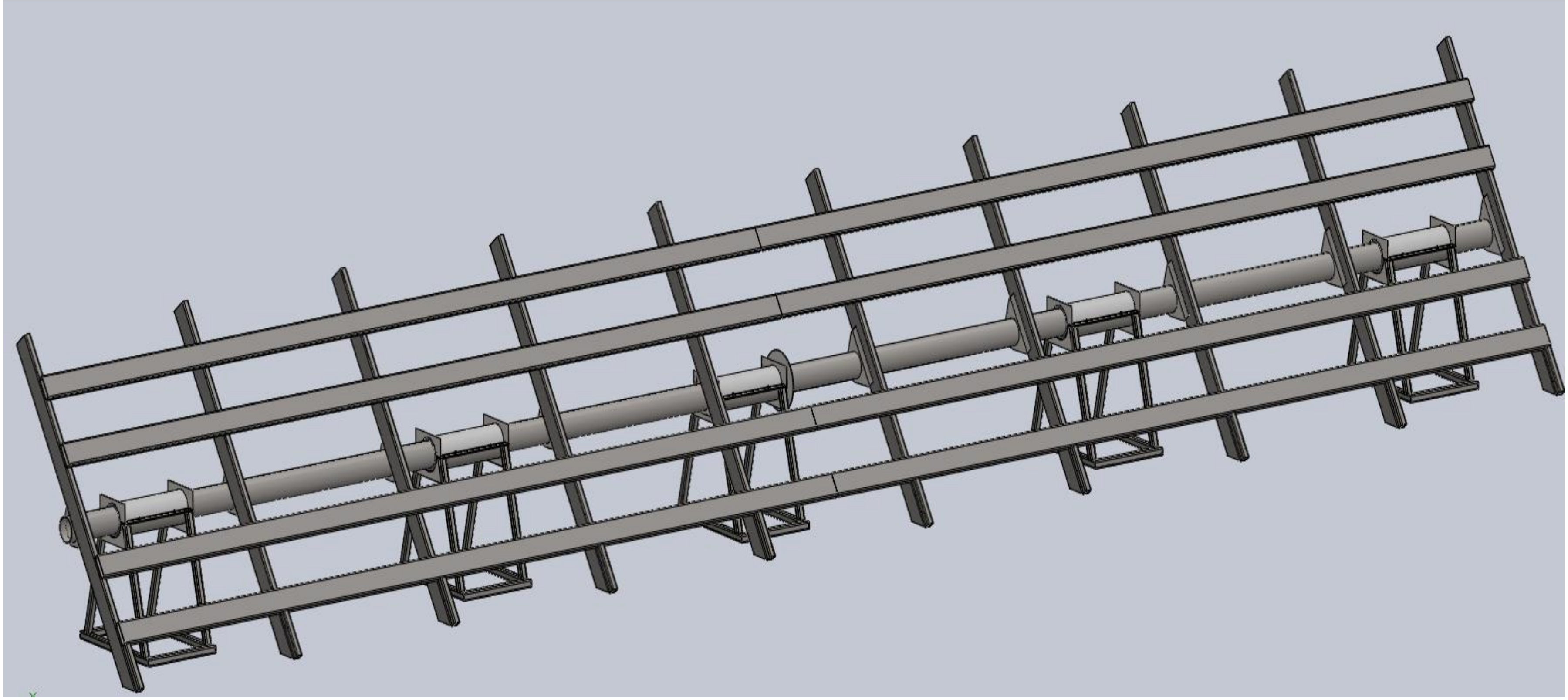


- Table Frame is 2” x 6” x 3/8” Rectangular Steel tubing

Basic information

- Rotating Shaft- 6 in Sch 40 pipe
- Outer Shaft on stands- 8 inch Sch 40 pipe
- Stands- 2x2 inch square tubing
- Bushings are UHMW Polyethylene
- Gussets 3/16” Sheet metal

Full Jig Design



Engineering Calculations

Deflection, Torsion, Tipping

Buckling and FEA

Engineering Calculations

- Deflection of 6” Schedule 40 Center Pipe

$$y = \frac{Wx}{24EI} * (2lx^2 - x^3 - l^3)$$

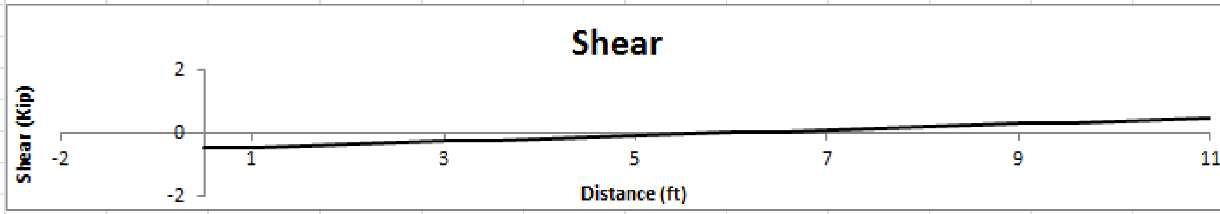
y = deflection W = distributed load E = modulus of elasticity	I = Moment of inertia x = location along beam l = total length

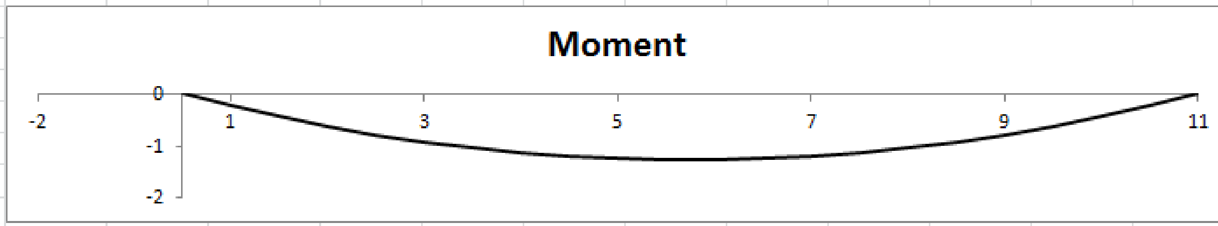
Engineering Calculations

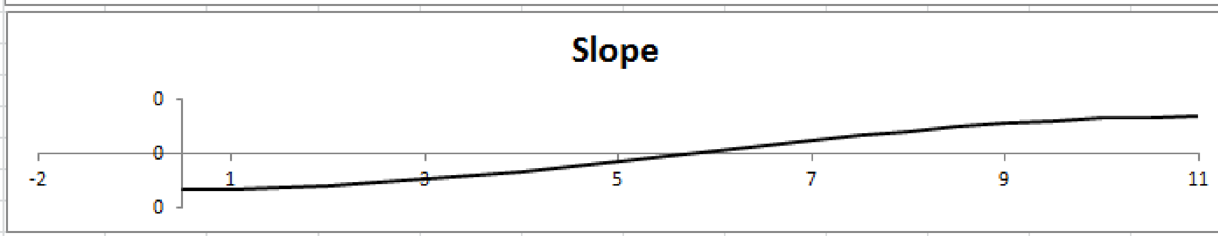
Values		
Fixed		
E =	4176000	Kip/ft^2
ρ =	490.752	lb/ft^3
Variable		
L =	42	ft
A =	0.04532	ft^2
num sec =	4	
W =	**0.09213**	kip/ft
I =	**0.00156**	ft^4
L act =	**10.5**	ft

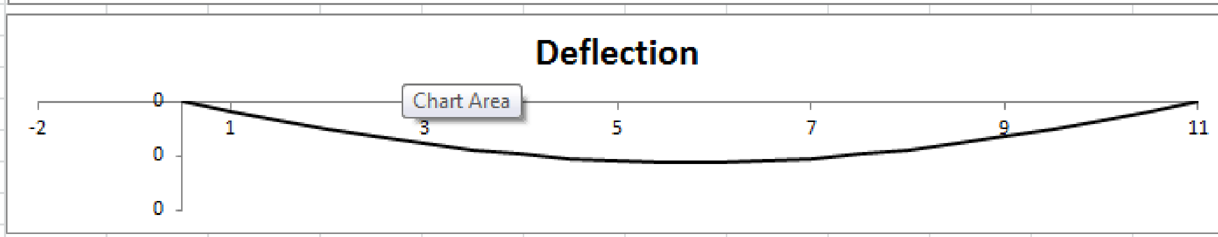
OD =	6.625	in
t =	0.33	in
A =	6.52619	in^2
I =	32.4155	in^4
w =	15.7	lb/ft

Refresh Graphs





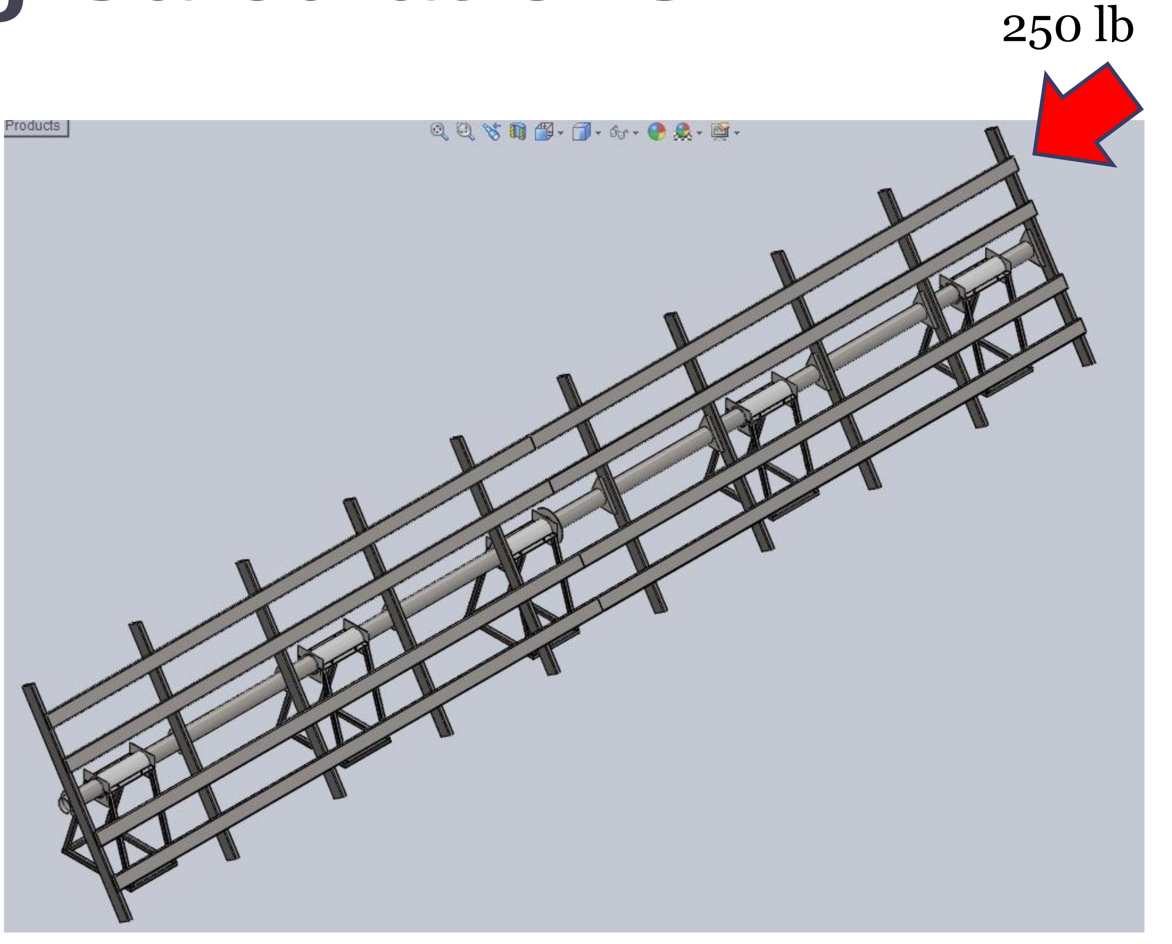




Allowable Deflection =	0.0026	ft	0.03125	
Maximum Deflection =	**0.0022**	**ft**	0.0268	in

Engineering Calculations

- Torsion
- $\theta = \frac{Tl}{JG}$
- T=load
- L=length of jig
- J= Polar Moment of Inertia
- G=Modulus of Rigidity



Engineering Calculations

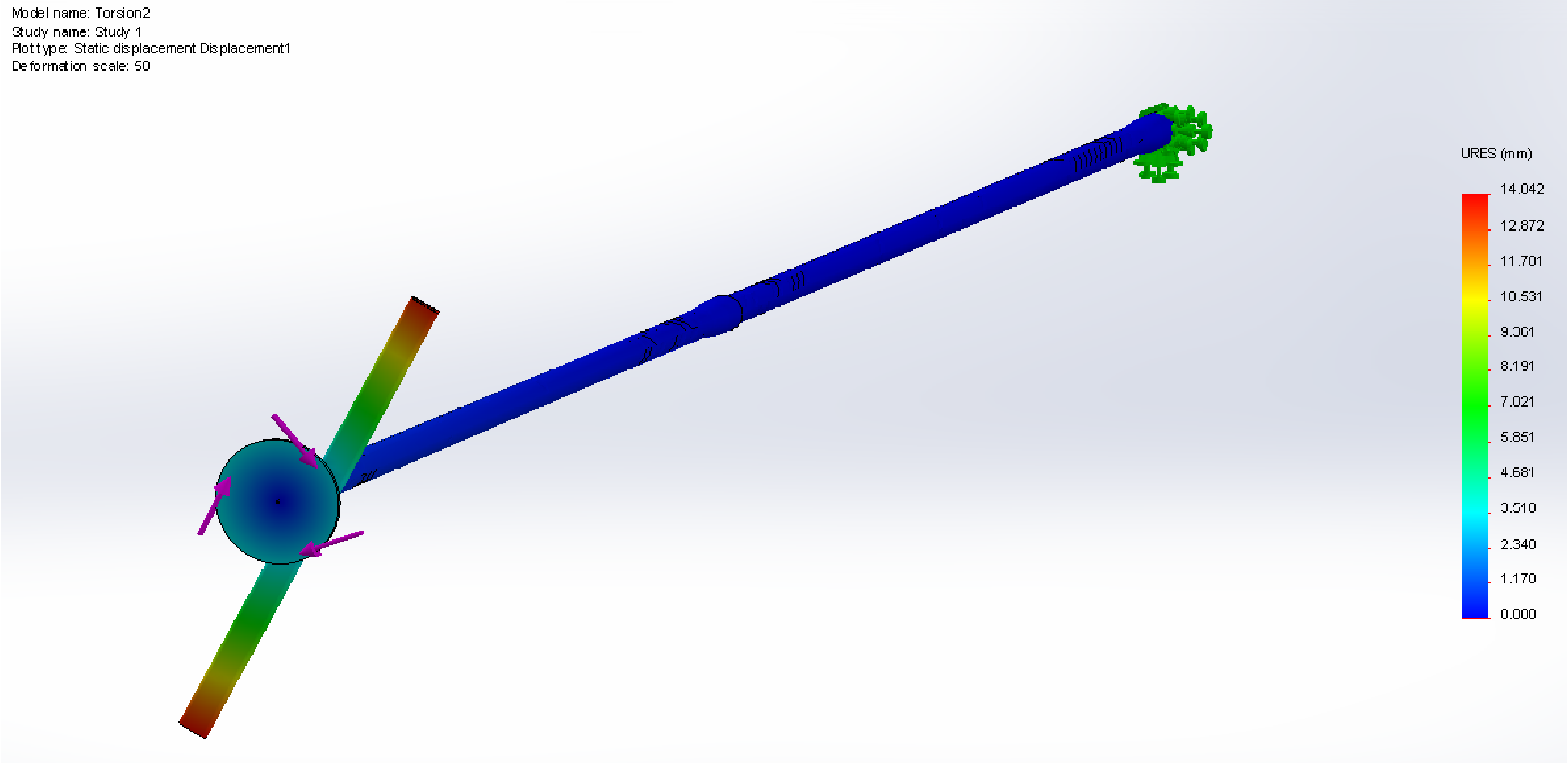
- 250 lb man on far corner
- One side fixed
- 1.65 inch deflection from vertical

$$\theta = \frac{Tl}{GJ}$$

Worst Case T =	24	kip-in
L=	504.0	in
OD =	6.625	
t =	0.660	
ID =	5.965	
J =	61.02	
G =	11500	ksi
theta max =	0.017	rad
=	0.988	deg
	1.655024	inches Deflection for entire table

Engineering Calculations

- CAD FEA
- 1.1 inch deflection from vertical



Engineering Calculations

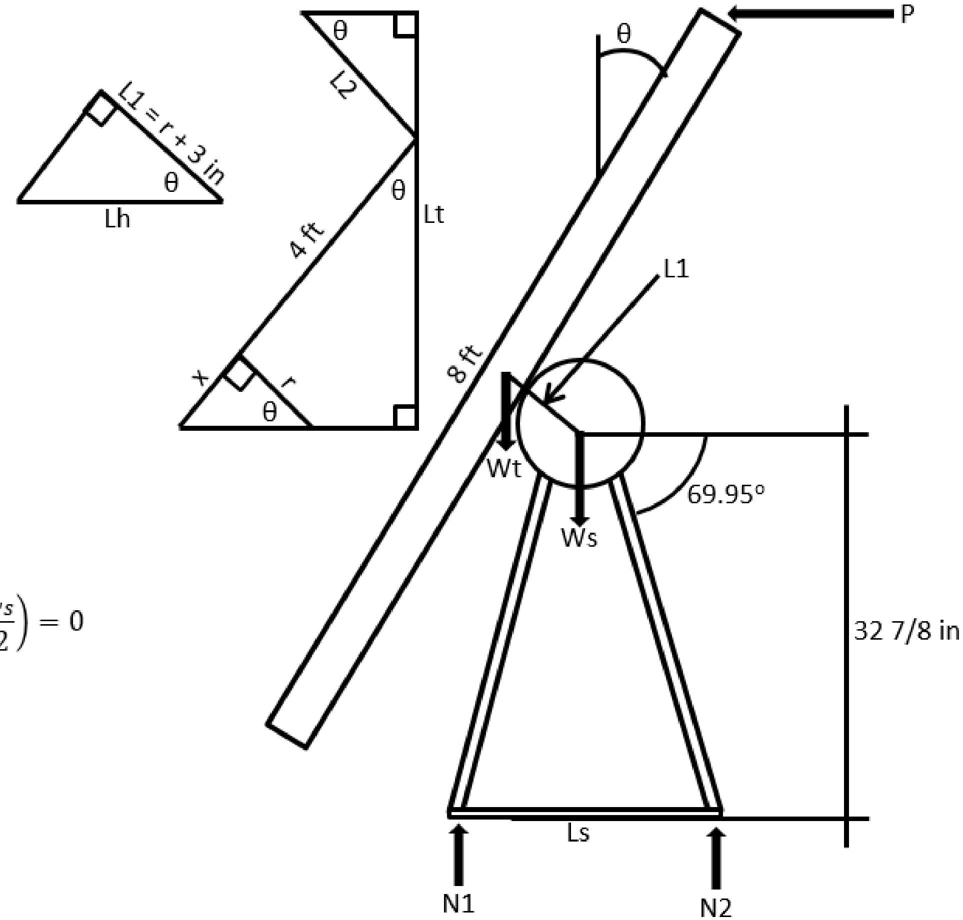
TIPPING CALCULATION

Ws =	1620	lb (includes the weight of the stands)
Wt =	2384	lb
N1 =	4003	lb
N2 =	0	lb
L1 =	6.313	in
L2 =	6	in
Ls =	3	ft
r =	3.313	in
hj =	32.88	in
theta =	30	degrees
x =	1.912	in
Lt =	46.23	in
Lh =	7.289	in

$$\sum M_{center} = -P\left(L_t + h_j\right) - W_t(L_h) + N_1\left(\frac{L_s}{2}\right) = 0$$

$$\boldsymbol{P = \frac{N_1\left(\frac{L_s}{2}\right) - W_t(L_h)}{L_t}}$$

P =	**1,182.94**	**lb**



Engineering Calculations

Buckling Calculation

Material Properties

E =	3.00E+07	psi
Sy =	3.00E+04	psi (Assuming 1020 HR Steel)

Pipe Information

D =	2	in
OD =	2.375	in
ID =	2.07	in
t =	0.15	in
k =	2.474	in
A =	1.065	in^2
I =	0.661	in^4
F =	249.474	lb
theta =	20.05	degrees
L =	41.44	in
P =	234.3539	lb
C =	1.2	(fixed/fixed)
l/k =	16.7476209	

Euler Column Check

$$\left(\frac{l}{k}\right)_1 = \left(\frac{2\pi^2 CE}{S_y}\right)^{\frac{1}{2}}$$

$(L/k)_1$= 153.90598

Use Euler Column equation when $l/k > (L/k)_1$

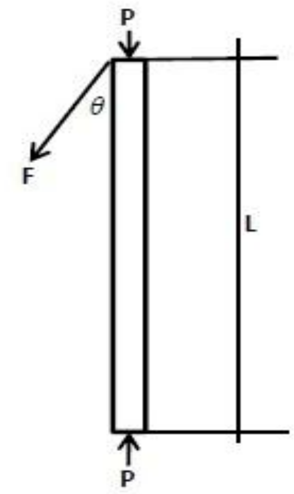
Strut Check

$$\left(\frac{l}{k}\right)_2 = 0.282\left(\frac{AE}{P}\right)^{\frac{1}{2}}$$

$(l/k)_2$ = 104.11

Consider column a strut if $l/k < (l/k)_2$

If $(l/k)_2 < (l/k) < (l/k)_1$ consider column as intermediate



Euler Calculation

$$P_{cr} = \frac{(\pi^2 EI)}{l^2}$$

Pcr = 113,888 **lb**

Intermediate Calculation

$$\frac{P_{cr}}{A} = S_y - \left(\frac{S_y}{2\pi}\frac{1}{k}\right)^2 \frac{1}{CE}$$

Pcr = 31,943 **lb**

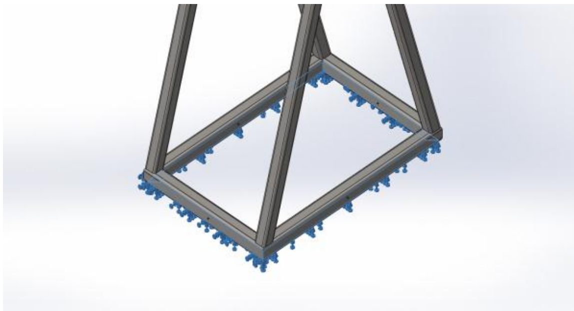
Strut Calculation

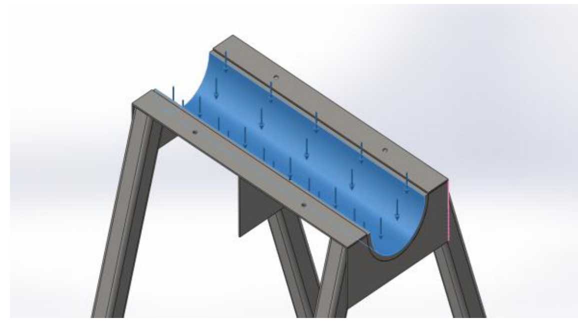
$$\sigma_c = \frac{P}{A} + \frac{My}{I}$$

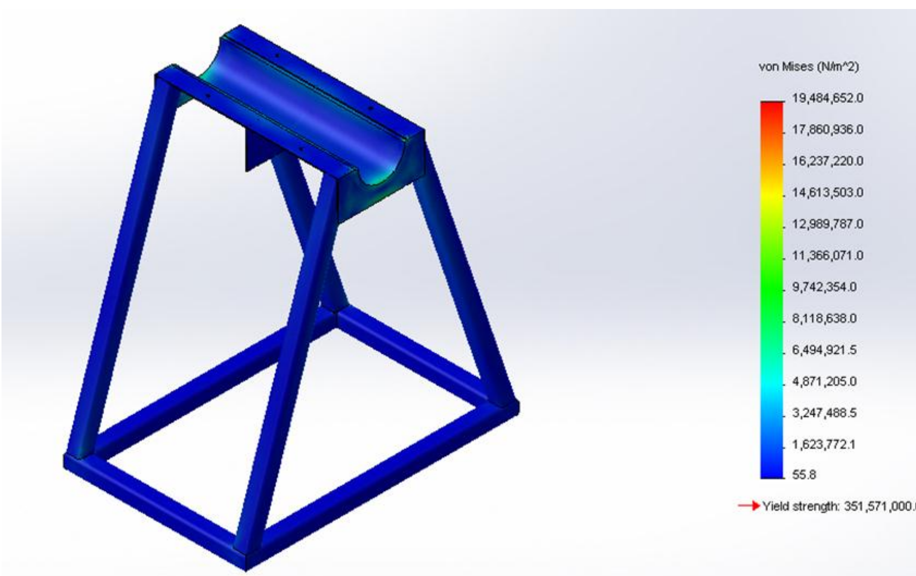
sigma c = 6,592 **psi**

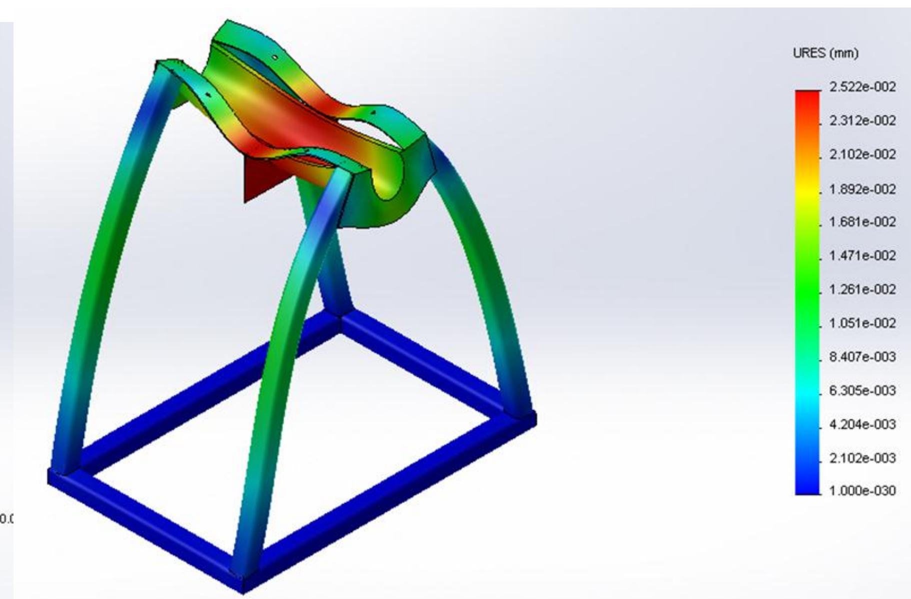
factor of saftey = 4.55

Engineering Calculations









Current Design

15’ Prototype

Base and Table Design

- Rotational
- 8’ X 15’
- Custom Side Friendly
- Adhesive backed rules
- Toggle Clamps

Attachments

- Adhesive Backed Ruler
  - Attached to jig
  - Improved manual measurement
  - Decrease time spent using hand held tape measures

- Drive System
  - Electric Motor
  - Worm Gear
  - Idler Sprocket
  - Chain Sprocket

- Toggle Clamps

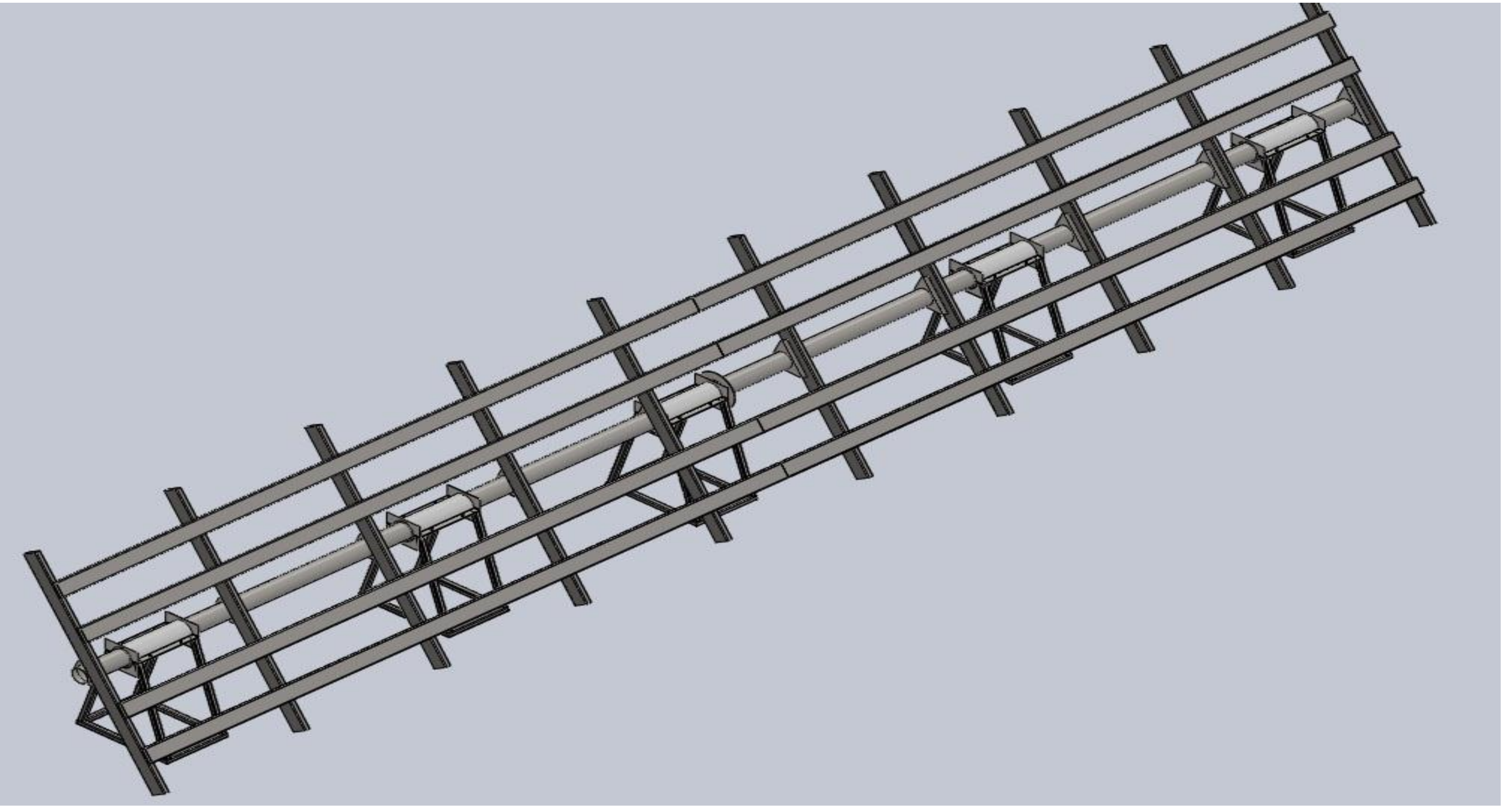
Prototype

Cost Analysis

Full Jig

Cost Analysis

- $2341 for Bases and Table



Cost Analysis

- Jig Redesign Total **$3850**
- Steel $2341
- Drive System $700
- Adhesive Ruler $79.63 / unit
- Toggle Clamps $25.00 / unit
- Bushings UHMW Polyethylene $9.68 / foot

KTK's Recommendations

Recommendation

- KTK Engineering Solutions recommends that Sooner/Exiss Trailer purchase 2 jigs for production
- Each jig be motorized
- Utilize adhesive backed rules
- Toggle clamps

Acknowledgements

- Sooner/Exiss Trailer
- Scott Fultz
- Larry Zahasky
- Dr. Paul Weckler
- Don Lake
- Mike Raymond
- Wayne Kiner
- BAE Shop

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Questions?

Fall Report: Sooner/Exiss Trailers Jig Design

December 5, 2012

Engineering:
Tanisha Hamm
Kevin Roehm
Kaden Wanger

Economics:
Garrett Haskins
Gina Jackson

Prepared for: Sooner/Exiss Trailer

Contents

Customer Requirements & Quantitative Specifications

KTK Engineering Solutions compiled a list of customer requirements for Sooner/Exiss Trailer's new welding jigs. The most important jig requirement is that it increases the quantity of trailers manufactured per day from 7 trailers to 10 trailers. Another important requirement is that the welders using it like it, and that the ergonomics are pleasing. Sooner/Exiss needs the jig to be longer to accommodate their longer trailers, which are up to 42', but it must also be capable of manufacturing trailer sides as short as 16'. The jig must also accommodate different heights, ranging from 5'6" to 8'2". In addition, the jig must accommodate all 72 different trailer sides which Sooner/Exiss has in production.

After speaking with the welders at Sooner/Exiss, their requirements were that the jig be shorter than it is now, but be able to accommodate the tall trailers. Currently, the welders have to climb on the jig, and after the redesign, they should not need to climb on it. However, the welders want dedicated footholds to prevent slipping and easily accessible clamps. More cross members on the jig were another specification, purely for the welders to easily clamp aluminum tubing to during placement.

KTK thinks that the requirements from both management and wage workers at Sooner/Exiss can be accommodated with the exception of climbing which is clearly undesirable. The budget for the redesign can be up to $20,000. KTK also has ideas for a jig that has powered or manual rotation designs which can accommodate Sooner/Exiss funding requirements

KTK plans on using rectangular steel tubing to build the jig, with it being adequately supported to prevent the jig from sagging and therefore building sag into the sides of the trailer. The jig will be built to last, using quality materials and engineering design.

Statement of Work

Background

KTK Engineering Solutions was tasked to redesign a welding jig at Sooner/Exiss Trailer. Sooner/Exiss needed to increase trailer production by 30% per day. The jig needed to be ergonomic for workers as well as improve their safety. The jig needs to limit the number of handheld measurements, which leads to inconsistencies in trailer manufacturing, resulting in reworks.

Current Setup

Sooner/Exiss Trailer currently uses four fixed jigs to manufacture side walls. KTK Engineering made two visits to observe workers and daily work. Figure 1 shows Sooner/Exiss Trailer's current jig setup. The figure also demonstrates the unsafe climbing which welders commonly do in order to reach higher welds. The danger of this action is increased by the welder's helmets which are opaque and prevent the workers from seeing to catch themselves in the event of a fall. The elimination of climbing is one of the requirements the new jig will meet.

Figure 1- Sooner/Exiss Current Jig Setup

Scope of Work

The scope of work only included the redesign and possible fabrication of a new jig which will be used in trailer side production. The engineers of KTK researched relevant patents, and spoke to experienced engineers whom had also worked on the project. The general manager at Sooner/Exiss wanted a jig that would not require workers to climb on the jig. KTK needed to make sure the jig did not deflect when a trailer side was being constructed. The jig needed to increase accuracy of framing posts and window and door placement so fewer trailers would need to be reworked.

Physical Location

The construction of the project occurred in the Oklahoma State University Biosystems and Agricultural Engineering (BAE) laboratory and at the factory in El Reno at Sooner/Exiss. Solidworks models were used to communicate ideas between Sooner/Exiss Trailer and KTK Engineering. Design work was performed at Oklahoma State University

Period of Performance

KTK Engineering Solutions' engineers began the redesign of the jig in the Fall Semester of 2012. Design work was to be completed by December of 2012, and the final design review was completed in the weeks of December 3rd-14th. The project will be completed in April of 2013.

Delivery Requirements

Table 1 – Delivery requirements by date and day of week

Monday	10/29/12	SOW Due
Friday	11/2/12	WBS Due
Monday	11/5/12	Task List Due
Monday	11/12/12	Engr Design Concepts Due
Monday	11/19/12	1st Draft Report Due
Monday-Friday	12/3-12/14/12	Technical Presentation
Friday	12/7/12	Report due to Sooner/Exiss
Monday	4/22/2013	Project Complete

Detailed Work

KTK began the redesign in the fall semester of 2012.

The jig needs to accommodate trailers between 5'6" and 8'6" tall and between 16' and 42' long. The jig needs to be structurally sound as to not deflect when in a horizontal position. The jig also needs to accommodate the available floor space in the factory in El Reno.

The design selected is a table type jig with vertical and horizontal square tube for workers to clamp to. The jig will rotate manually, manually assisted, or powered. The jig will be balanced to aid ease of movement. The jig will have a braking system for workers to be able to stop the jig in a desired position. The jig will rotate past horizontal to the backside for welders to weld the top rail in place without having to climb on the jig. The jig will allow workers to place components and weld without needing tape measures, due to the measurement system attached to the jig. The welders will be able to weld in an ergonomic position, without having to weld over their heads. The jig will accommodate moving welding hoses up off the floor, eliminating trip hazards. The jig will have a set square in the front, eliminating the time to square up the first post. The jig will also have a bottom rail or fixed toggle clamps for welders to place the bottom rail of the trailer.

KTK spent time on this list of actions for the redesign.

- Brainstorming for ideas for the redesign
- Developing a scope of work
- Drawing ideas in Solidworks
- Calculating deflection in main drill stem pipe
- Calculating torsional deflection in drill stem pipe
- Selecting appropriate materials based on calculations
- Developing different ideas for measurement system
- Analyzing cost differential between different systems

Incorporating manager and wage workers wants and needs resulted in several design options. Appendix 3 contains a chart of design options. This chart assisted KTK throughout the design process.

Task List

KTK developed this task list to help organize thoughts and find the direction to pursue for the redesign.

1) Jig Prototype
    a. Redesign
        i. Determination of Rotation Mechanism
            1. Hydraulic
            2. Counterweight
        ii. Create Alternative Measurement Solutions
            1. Laser measurement
            2. Laser projection
            3. Attached ‘tape measure’
        iii. Engineering Calculations
            1. Material Determination
            2. Deflection
            3. # of pinions
        iv. Determine clamping locations
            1. Type of clamp

        2. Number of clamps
    v. Solidworks Drawings
        1. Create 3D model
        2. Stress analysis
        3. Deflection analysis
        4. Create Standard Engineering Drawings
    vi. Scale Model
        1. Deflection Testing
        2. Material Validation
        3. Determine Number of Supports needed
  b. Purchasing
    i. Price Lasers/Measurement Systems
        1. Design System suitable
    ii. Pipe Material
    iii. Table Materials
    iv. Clamps
    v. Measurement System

Work Breakdown

1) Jig Prototype
  a. Redesign
    i. Scale Model
        1. Deflection Testing
        2. Material Validation
        3. Number of Supports needed
    ii. Solidworks Drawings
        1. Stress analysis
        2. Deflection analysis
    iii. Engineering Calculations
        1. Material Determination
        2. Deflection
        3. # of pinions
    iv. Determine clamping locations
        1. Type of clamp
        2. Number of clamps
  b. Rotation Jig
    i. Rotation Mechanism
        1. Hydraulic
        2. Counterweight

c. Price Lasers/Measurement Systems
    i. Design System suitable
d. Alternative Solutions
    i. Everything that may not be financially feasible or practical

Payment Schedule

KTK did not receive compensation for the design work or the manufacturing of the jig. All materials were purchased by Sooner/Exiss. Sooner/Exiss set a ceiling of $20,000 for all expenses.

Acceptance Criteria

Sooner/Exiss required a jig that can produce at least 10 trailers per day, a 30% increase in manufacturing, while being ergonomic and pleasing for workers. The jig must also improve worker's safety; the workers must not be required to climb on the jig, reducing injuries from stepping down off the older version of the jig. In addition, welding cords need to be moved off the ground, reducing trip hazards.

Special Requirements

Due to the nature of the project, KTK was required to travel to Sooner/Exiss when a site visit was necessary. Don Lake, Applications Engineering Extension Agent for Oklahoma State University was accommodated by meeting half way, and meeting at times convenient to him when he was in Stillwater, OK, KTK's base location. In addition, KTK collaborated with Mike Raymond with the Oklahoma Manufacturing Alliance, and Aaron Cain with the New Product Development Center at Oklahoma State University.

Technical Analysis

Existing jigs for trailer side framing consist of steel square and round tube welded into a table-like apparatus. For example, Featherlite trailers has a set of jigs very similar to those found at Sooner/Exiss Trailer's manufacturing plant. However, Featherlite has positioning jigs (Figure 2). It is worth mentioning that Featherlite does make use of a robotic welding system, which precision welds the frame for the gooseneck. The pieces are placed upon a rotating jig with clamps before the robot welds them (Featherlite, 2009)

Figure 2 - Featherlight trailer side frame jig (Featherlite, 2009)

The jigs are made of heavy steel tube which is welded together. Considering this, there should not be any maintenance costs associated with the jig, unless a cutting operation or other activity performed by a welder was to damage it by melting or annealing the metal. Considering the melting point of steel is greater than that of aluminum, (2600-2800 ^{o}F for steel, vs. 660 ^{o}F for aluminum) it is unlikely that any welding or cutting operations should involve high enough temperature to damage the jig. In addition, steel does not transform into austenite below 738 ^{o}C (1360.4 ^{o}F), which provides evidence that the steel jig should not be in danger of annealing (assuming cold rolled steel is used to build the jig).

It would be possible to create a framing jig which can rotate and translate, but only found one working example of a jig which takes advantage of this ability. The example can be found in Figure 3.It should be noted that any jig which incorporates moving components will require more maintenance. At the very least, grease will need to be pumped into the collars holding the rotating shaft.

Figure 3 – Hydraulic, movable trailer framing jig (http://www.mrtrailer.com/t_pic/titan157.jpg)

Sooner/Exiss Trailers did have a rotating jig that was in use at one point in the past. However, the jig had unacceptable deformation when in the horizontal position. Additionally, the jig was unpowered and had to be rotated by hand. The cost of production and the space required to accommodate full jig rotation is also an issue.

Several safety concerns have been associated with the current jigs in use. First, the welders are often required to weld over their heads leading to rotator cuff injuries. Secondly, it creates the potential for sparks to fall into the face of the welder. In addition, the welders must climb onto the frame itself to reach some weld points, creating a hazard when stepping off the jig, as seen on a site visit when KTK was told about a broken foot.

Any powered jig design will have to incorporate a solution to the trip hazard created by any hoses or cords which provide power to the jig, unless it uses manual rotation. Along the same lines, any pinch points and moving components of the jig will require shielding to prevent injury to the welders and a failsafe will be required to prevent accidental operation of the jig (for example, a cover over the operation switch might add protection against accidental contact).

Patent Searches

KTK found several relevant patents. The first is a patent for rail box car under frames which uses clamps attached to the jig table to secure the side sills to the center sill. One of the most relevant points made is that the non-fixed clamps used in design of the jig allow the rail car frame to be removed despite expansion in the metal caused by the welding operations. This will need to be a consideration which is examined, should any fixed dimension jigs be designed by KTK (Shipley, 1951).

The second patent, by Sellers, L. (1979), filed for a jig to fabricate side walls for houses. Included in the patent are designs for movable, U-shaped guides which can be used to place studs at the desired center distances. This could help KTK to design a system by which the trailer side ribs can be placed at the desired center to center intervals quickly and precisely. This would help KTK to meet one of the clients most fervently expressed design goals: reduction in the use of measuring tapes and hand measurement.

The third patent found describes a hand-held jig which can be adjusted using a bolt and wing-nut assembly to place framing studs at the proper center distances. This offers KTK a possible alternative method for placing the trailer ribs which may or may not appeal more to the manufacturing personnel at Sooner/Exiss Trailers. However, it is possible that any design produced by KTK which was similar could violate the patent as it was issued in 1997 and is therefore still in effect (Bingham and Stone, 1997).

Engineering Calculations

Deflection

Deflection within the main beam was calculated to ensure that the jig would not sag more than 1/32" which satisfied the requirement that sidewalls built in a lay-flat configuration would not exhibit unacceptable deformation from the welding jig. Equation 1, found in Appendix 1, was used to simulate deflection in any free span of the jig as a simply supported beam with a distributed load.

Microsoft Excel was then used to create an optimization sheet which would allow the user to determine the maximum span of material which would not result in more than the maximum allowed deflection (Figure 4).

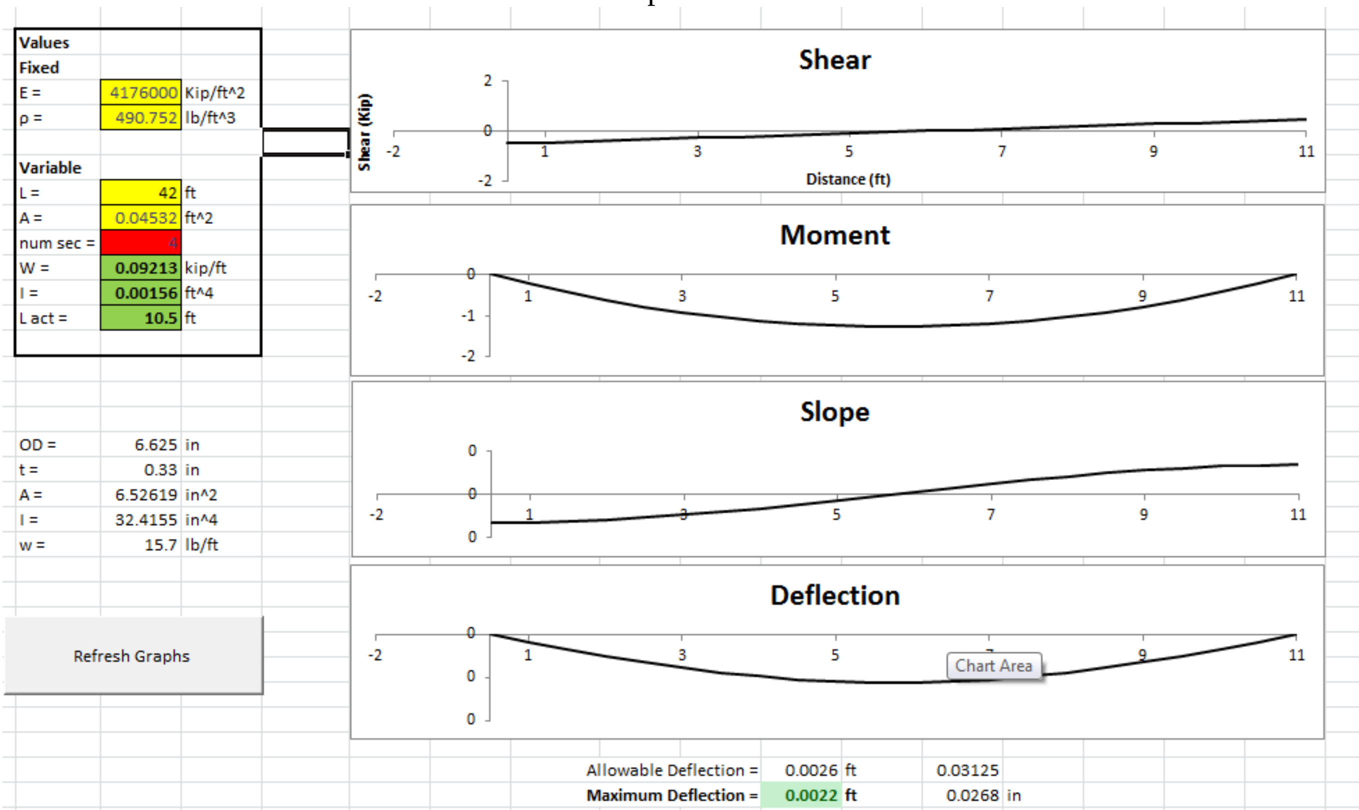

Figure 4 – Output of deflection optimization calculation

As can be seen above, the run resulted in a 10 ft span meeting the 0.0026 ft (1/32 in) maximum deflection allowance with a calculated deflection of 0.0022 ft within each 10 ft span.

Torsion

The torsion of the drill stem was calculated by hand and using computer software. Hand calculations showed that the torsional deflection of the drill stem would be .988 degrees with a 250 pound point load on the top outer corner of the table, assuming one side fixed with a brake. This torsional deflection relates into a 1.655 inch deflection total at the outmost post of the table. Half of that deflection is the top of the table rotating down due to the point load, and the other half is the bottom of the table rotating up. This torsional deflection is considered worst case scenario, with a 42’ trailer being put on the table and a worker climbing on the jig. Equations to find the torsional deflection can be found in Appendix 1. Solidworks was utilized to do a secondary analysis on the torsional deflection. A simplified model was used, shown in Figure 5. The results from Solidworks are 1.1 inch total deflection, half from the top, half from the bottom, as it was in hand calculations.

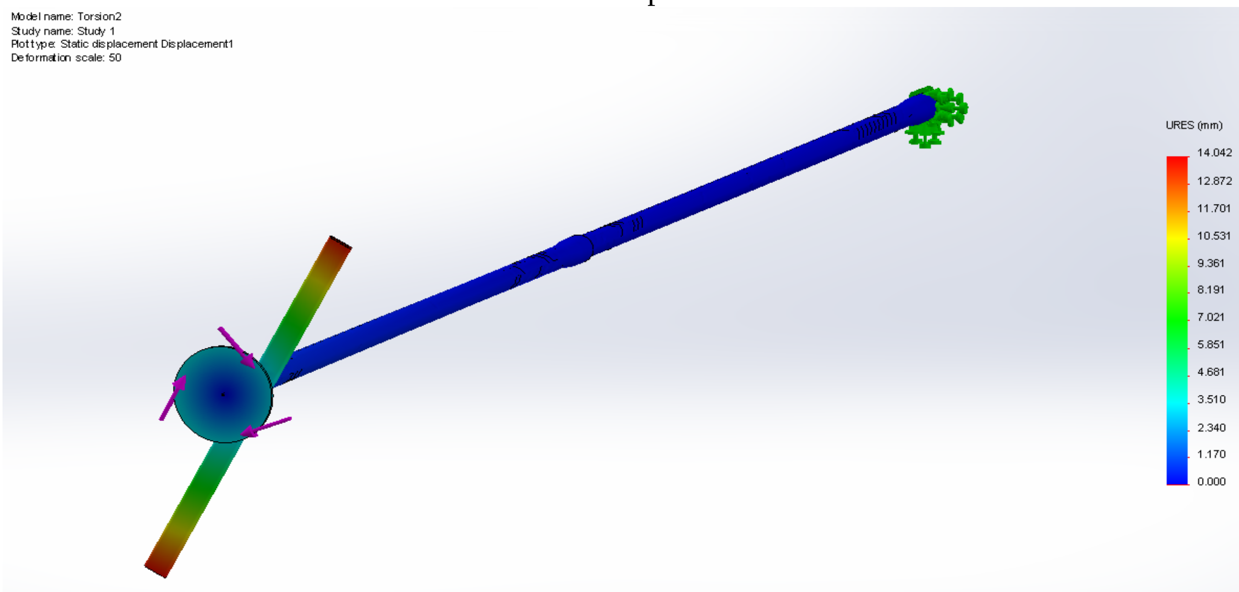

Figure 5-FEA of Torsional Deflection

Current Design

Figure 6 displays the design that KTK Engineering has created for the base model jig. Dimensions are 42’ long by 8’ wide. The table is made out of 2”x 6” rectangular steel tubing. The stands are made out of 2 3/8” Schedule 40 steel pipe, welded together. The table will be welded to the main rotating shaft, which will be 6 5/8” drill stem pipe. There will be fixed toggle clamps on the bottom of each vertical support. The table will rotate to the ground in the front, and approximately 20 degrees past horizontal in the back. The back of the jig will have a 2 3/8” Schedule 40 steel pipe that will prohibit further rotation. Movement options will determine the method of holding the table in a fixed position, but a braking system or a worm gear are both options available.

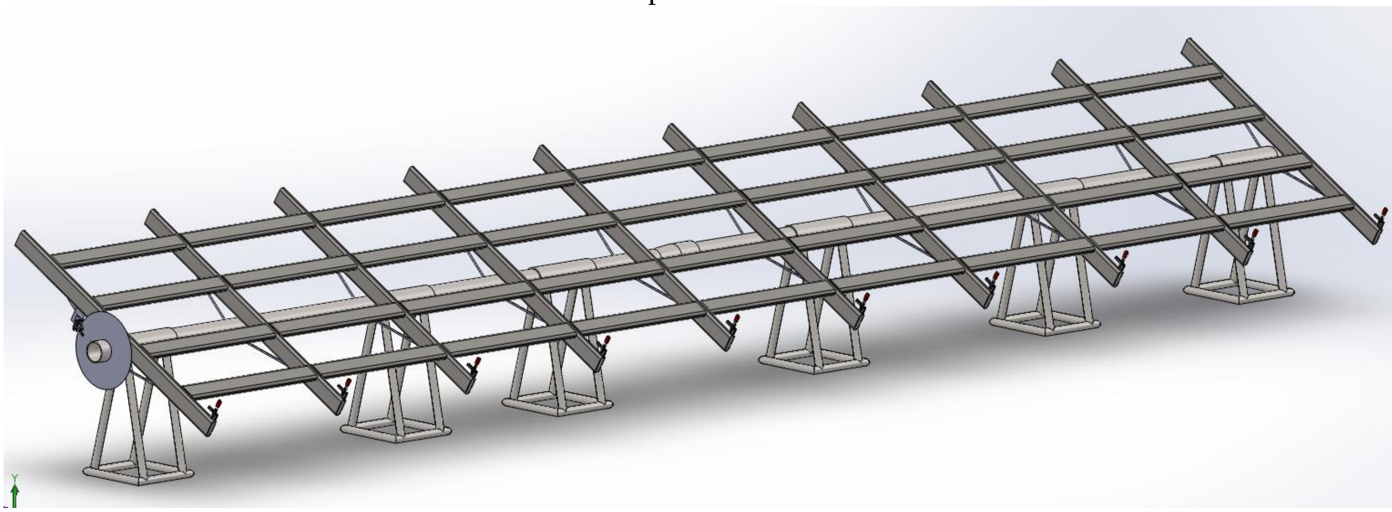

Figure 6- View of Rotating Jig Design

Cost Analysis

Base and Table

Parts List	Quantity (ft)	Price/ft	Total
2x6in Square Tubing	250	$7.00	$1,750.00
6-5/8in Drill Stem Pipe	45	$40.00	$1,800.00
Drawn over mandrel Pipe	12	$48.90	$586.80
2-3/8in Pipe	175	$1.90	$332.50
1/2in Steel Rod	215	$0.78	$167.70
HH-225D Toggle Clamp	10	$4.70	$47.00
			$4,684.00

Option 1- Adhesive Tape

Options	Quantity	Price	Total
Adhesive Tape Measure	2	$94.44	$188.88

Option2- Fixed Lasers

Options	Quantity	Price	Total
Leica Disto D330i	2	$379.00	$758.00
Tracking 1.5"x1.5"x97" Extruded Aluminum	11	$66.10	$727.10
.25in Diameter Track Roller	4	$26.50	$106.00
			$1591.1

Option3- Laser Projection

Options	Quantity	Price	Total
Laser Projector, Computer, Setup, Software	1	$40,000.00	$ 40,000.00

Powered Movement Option	Quantity	Price	Total
Electric Motor	1	$ 485.95	$485.95
Worm Gear	1	$ 200.00	$200.00
			$685.95

Manual Assist Movement Option	Quantity	Price	Total
Worm Gear	1	$200.00	$200.00
Crank Wheel	1	$100.00	$100.00
			$300.00

Total Pricing for One New Welding Jig

Base Jig	**$**	**4,684.00**
Measurement Option 1 + Jig + Powered Movement	**$**	**5,558.83**
Measurement Option 2 + Jig + Powered Movement	**$**	**6,961.05**
Measurement Option 3 + Jig + Powered Movement	**$**	**45,369.95**

Recommendations

KTK recommends that Sooner/Exiss Trailer purchase basic jigs with adhesive rules attached to evaluate the increase in manufacturing. After the purchased jigs have been used, and manufacturing times have been determined, KTK Engineering Solutions recommends that Sooner/Exiss Trailer purchase a laser projection system for the new jig setup and purchase another pair of basic jigs.

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Sellers, L. 1979. Wall component fabricating jig. U.S. Patent No. 4154436

Shipley, T. G. 1951. Welding Jig for car underframes. U.S. Patent No. 2553947

http://www.universaltrailer.com/

http://www.soonertrailers.com/

http://www.exiss.com/

Appendix 1

Equations Used:

$y = \frac{Wx}{24EI}(2lx^2 - x^3 - l^3)$ Horizontal Deflection

y = deflection
W = distributed load
E = modulus of elasticity

I = Moment of inertia
x = location along beam
l = total length

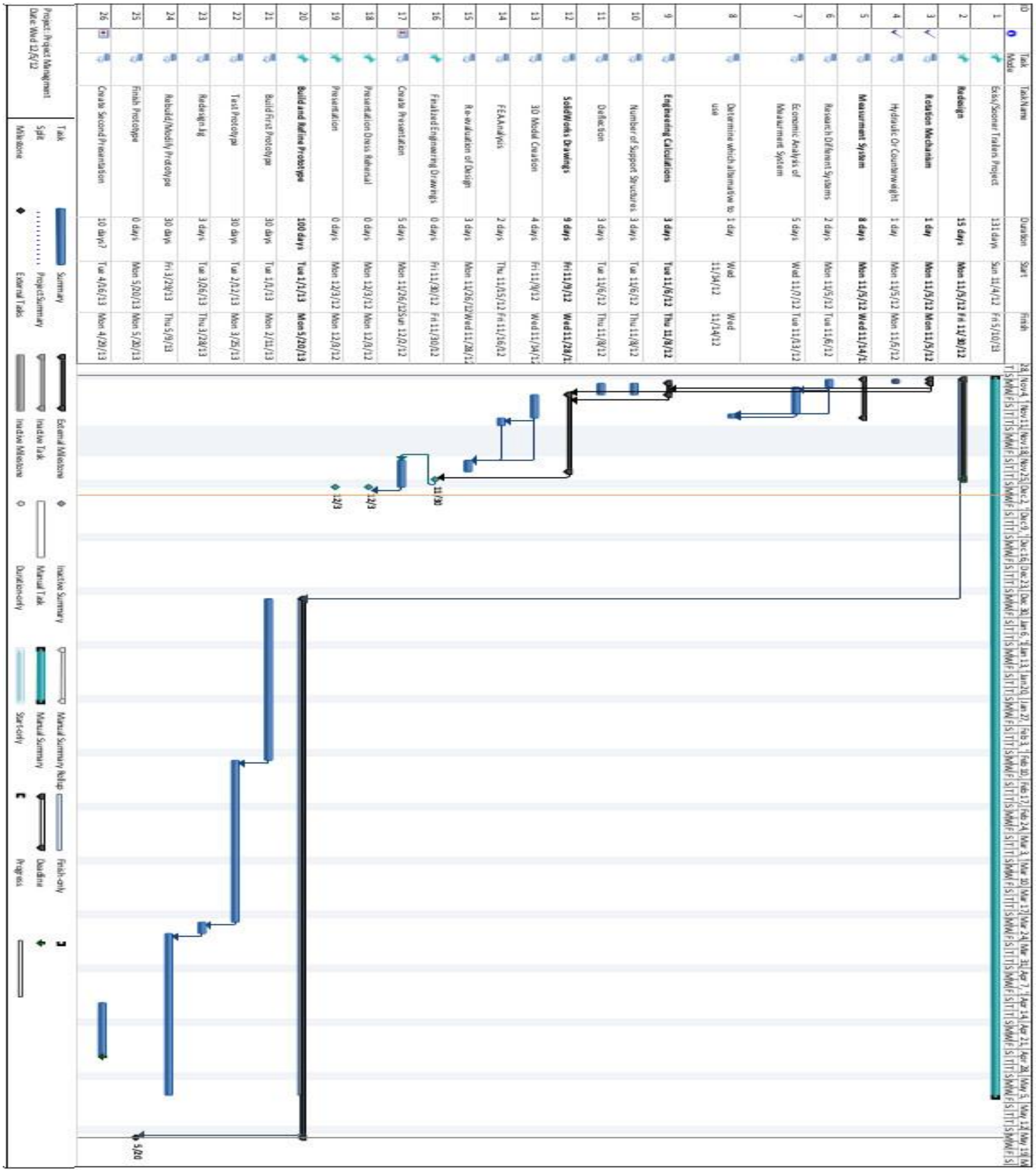
$\theta = \frac{Tl}{JG}$ Torsional Deflection

θ= Torsional Deflection
l=length
G=Modulus of Rigidity

T=Torque
J=Polar moment of Inertia

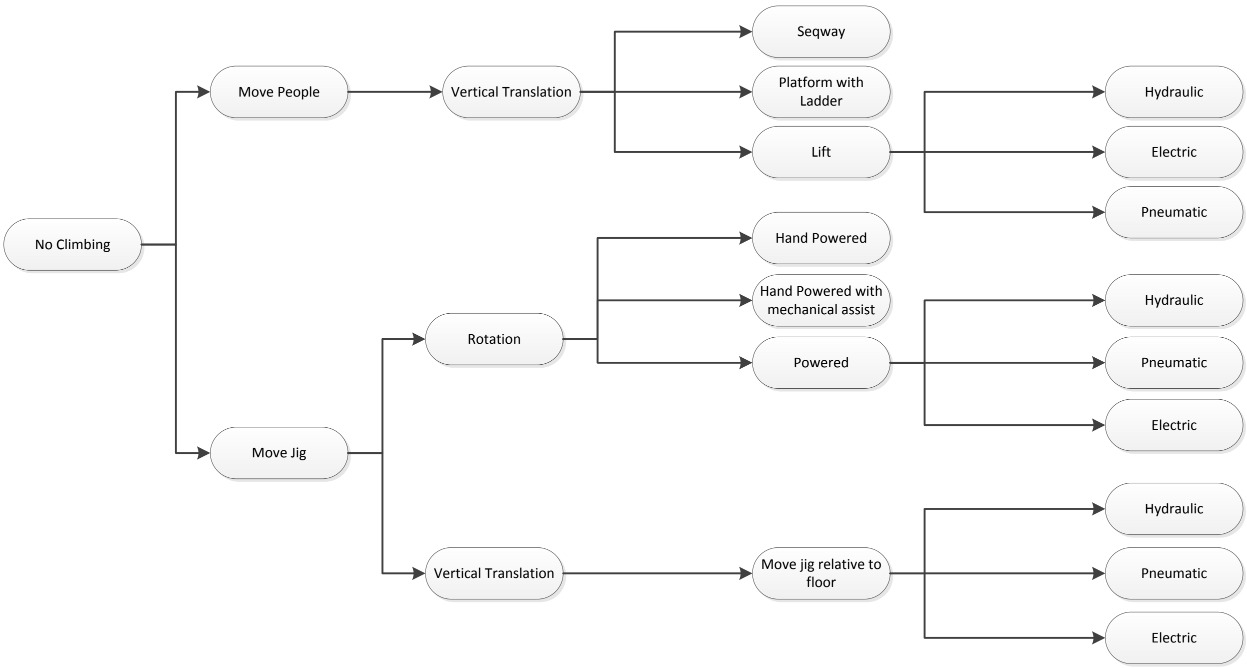
Appendix 2

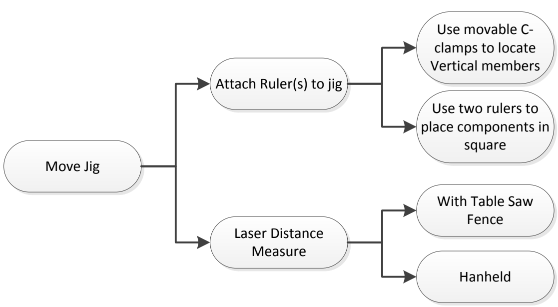
Gantt Chart- Microsoft Project



Appendix 3

Flow Chart of Generated Design Options





Senior Design Presentation
Fall 2012

Engineering
Solutions

KTK Engineering

Kevin Roehm   Tanisha Hamm   Kaden Wanger

Mission Statement

It is KTK Engineering Solutions’ mission to provide high quality, innovative engineering designs. KTK strives to provide customers with cost effective, efficient design focused on making their company stronger. In addition, KTK Engineering Solutions is committed to integrity in all dealings and leaving customers completely satisfied with the outcome of the solution created.

Sooner/Exiss Trailer

Quality Custom Aluminum Trailers

Sooner/Exiss Trailers

- Sooner and Exiss are brands under Universal Trailers Corporation
- 8 total Brands
- 9 Manufacturing locations
- Custom Aluminum Trailer Manufacturer

Engineering Problem

Task Assigned

Problem

- Sooner/Exiss Trailer needs increased production
- Trailer side-wall production is limiting manufacturing time
- Current jigs are too small
- Custom sides lead to long set up time

Solution

- Design a new jig
- Increase Production by 30% per day
- Accommodate all trailer sizes
- Improve worker ergonomics

Patent Research

- Sellers, L. 1979. Wall component fabricating jig. U.S. Patent No. 4154436
- Bingham, G. A. and V. C. Stone. 1997. Adjustable framing jig. U.S. Patent No. 5628119.
- Shipley, T. G. 1951. Welding Jig for rail car under frames. U.S. Patent No. 2553947

Engineering Calculations

Deflection, Torsion, and FEA

Design Specifications

- Controlled Deflection

- Ergonomic
  - No climbing required
  - Minimize worker injuries

- Rotational
  - Braking system

Design Specifications

- User Friendly
- Accommodate all Trailer sizes

Basic information

- Assumed material will be a typical hot rolled carbon steel (SAE 1020)
- Weight
  - Table – 4,200 lbs
  - Stands – 900 lbs
  - Total – 5,100 lbs
- Table Frame is 2" x 6" x 3/8" Rectangular Steel tube

Basic information

- Rotating Shaft- Drill Stem 6 5/8 inch
- Outer Shaft on stands- Drawn Over Mandrel 7.5 inch OD
- .42 inch wall thickness DOM

Engineering Calculations

- Deflection of Drill Stem

$$y = \frac{Wx}{24EI} * (2lx^2 - x^3 - l^3)$$

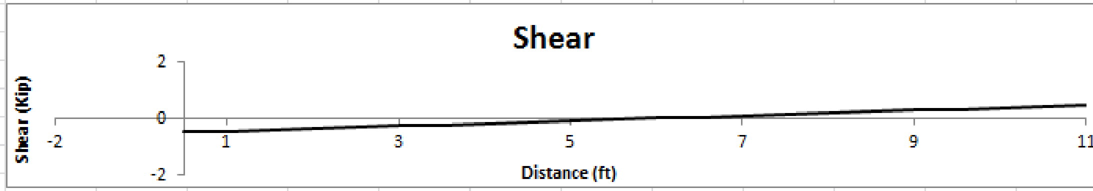
y = deflection **W = distributed load** **E = modulus of elasticity**	**I = Moment of inertia** **x = location along beam** **l = total length**

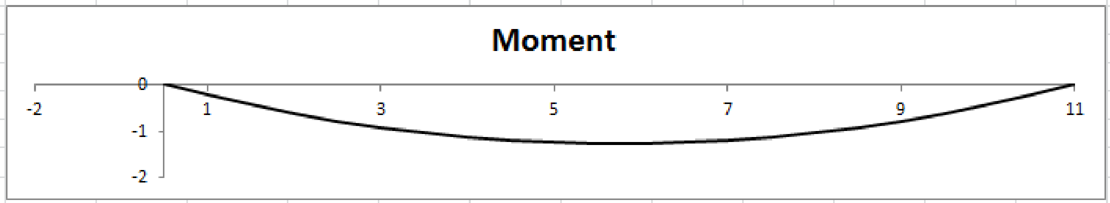
Engineering Calculations

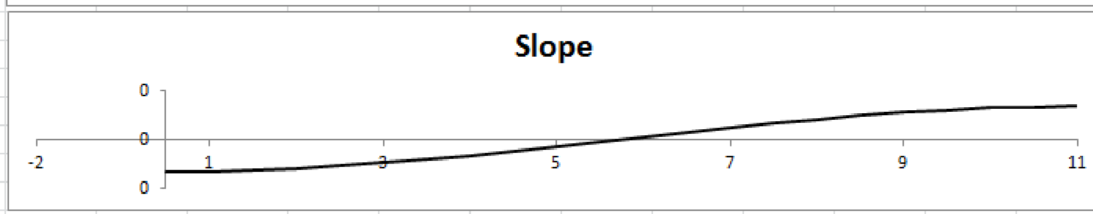
Values		
Fixed		
E =	4176000	Kip/ft^2
ρ =	490.752	lb/ft^3
Variable		
L =	42	ft
A =	0.04532	ft^2
num sec =	4	
W =	**0.09213**	kip/ft
I =	**0.00156**	ft^4
L act =	**10.5**	ft

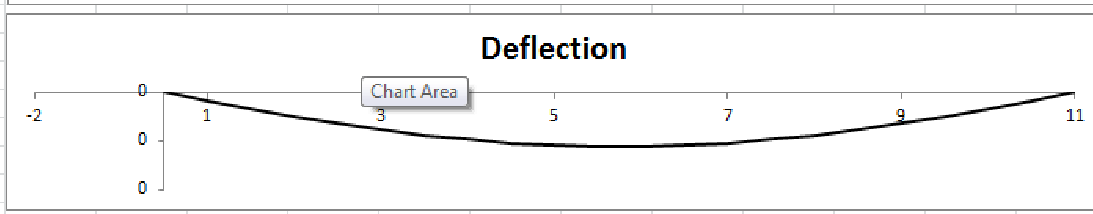
OD =	6.625	in
t =	0.33	in
A =	6.52619	in^2
I =	32.4155	in^4
w =	15.7	lb/ft

Refresh Graphs





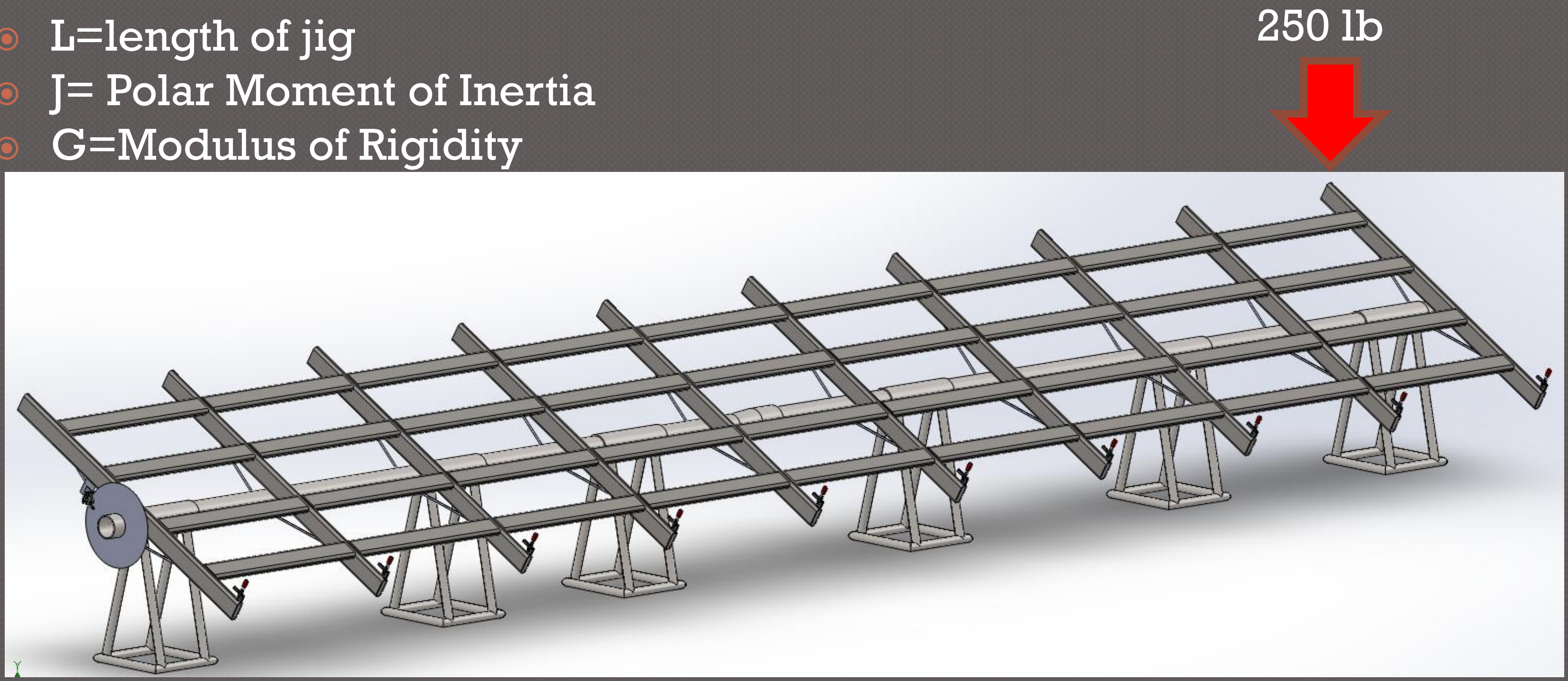




Allowable Deflection =	0.0026	ft	0.03125	
Maximum Deflection =	**0.0022**	**ft**	0.0268	in

Engineering Calculations

- Torsion
- $\theta = \frac{Tl}{JG}$
- T=load
- L=length of jig
- J= Polar Moment of Inertia
- G=Modulus of Rigidity



Engineering Calculations

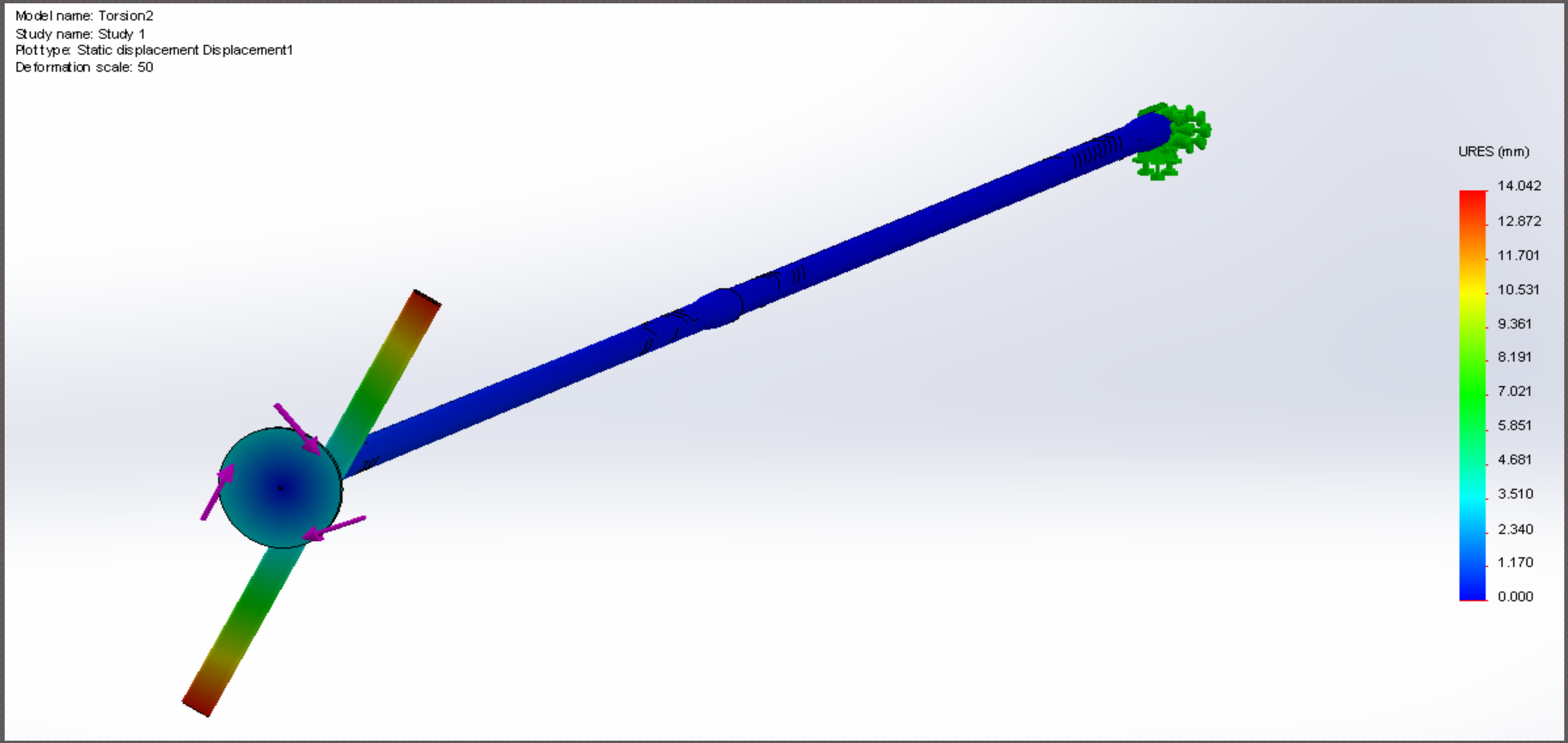
- 250 lb man on far corner
- One side fixed
- 1.65 inch deflection from vertical

$$\theta = \frac{Tl}{GJ}$$

Worst Case T =	24	kip-in
L=	504.0	in
OD =	6.625	
t =	0.660	
ID =	5.965	
J =	61.02	
G =	11500	ksi
theta max =	0.017	rad
=	0.988	deg
	1.655024	inches Deflection for entire table

Engineering Calculations

- CAD FEA
- 1.1 inch deflection from vertical

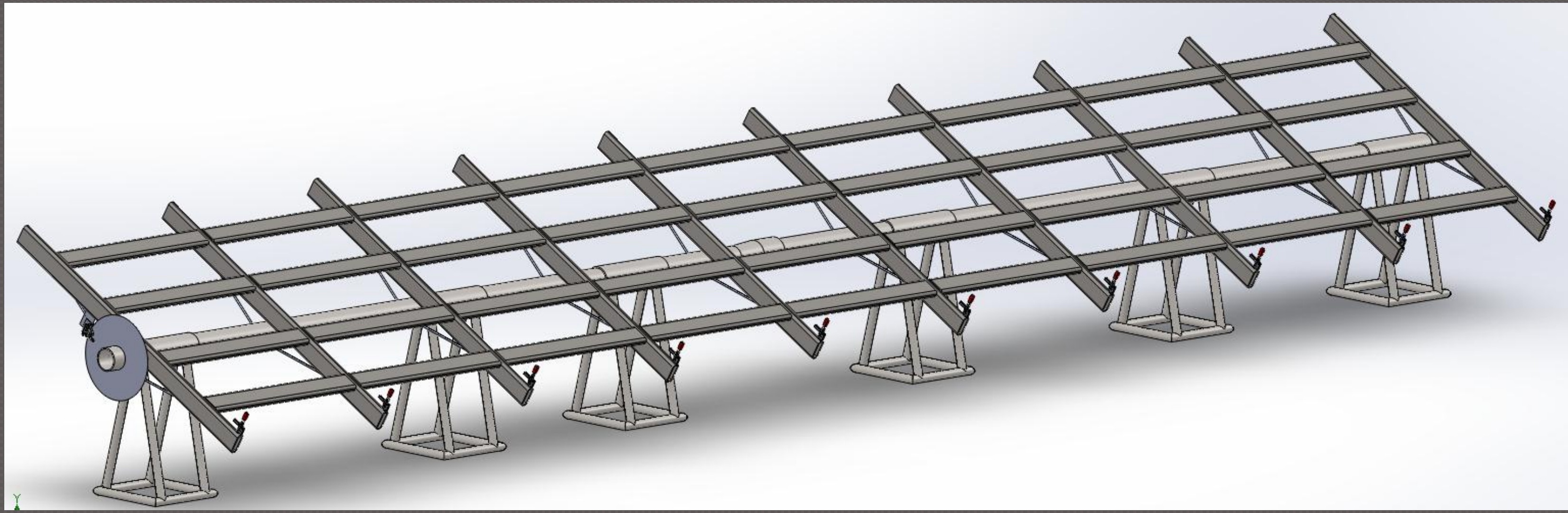


Design Alternatives

3 Major Options

Base and Table Design

- Rotational
- 8’ X 42’
- Custom Side Friendly
- Fixed Lower Toggle Clamps



Design Alternatives-Base Model

- Minimal Cost-$94.44 per Adhesive Backed Ruler
- Attached to jig
- Improved manual measurement
- Decrease time spent using hand held tape measures
- Increase placement accuracy
- Could be damaged by slag

Design Alternatives-Fixed Lasers

- Cost Efficient $300-$600 per laser
- Increase Productivity
- Improve accuracy
- Decrease measurement time
- One Vertical measurement
- One Horizontal measurement
- User friendly

Design Alternatives-Fixed Lasers

- $379/ Laser
- 2 lasers per jig
- Dust and Water resistant
- Fixed Target
- Vertical and Horizontal Measurements

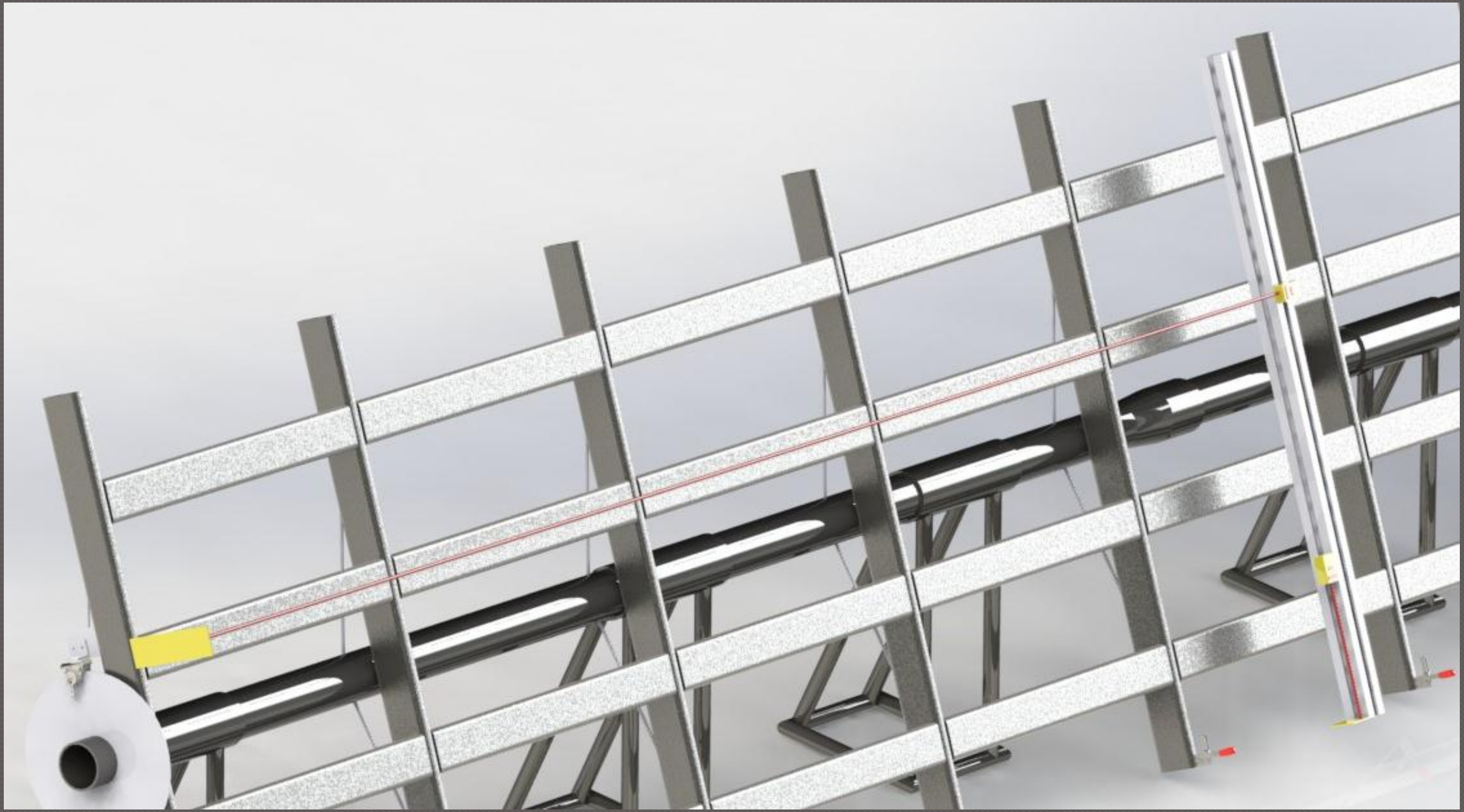
- http://www.engineersupply.com/Leica-Disto-D330i-Laser-Distance-Meter.aspx

Design Alternatives-Fixed Lasers

- $700 Track System
- Raised above Jig
- Lasers attached

- http://www.grainger.com/Grainger/aluminum-extrusions/structural-framing-systems/material-handling/ecatalog/N-c3qZ1z0qh5v
- http://www.grainger.com/Grainger/DYNAROLL-Miniature-Track-Roller-1ZGP9?Pid=search

Design Alternatives-Fixed Lasers

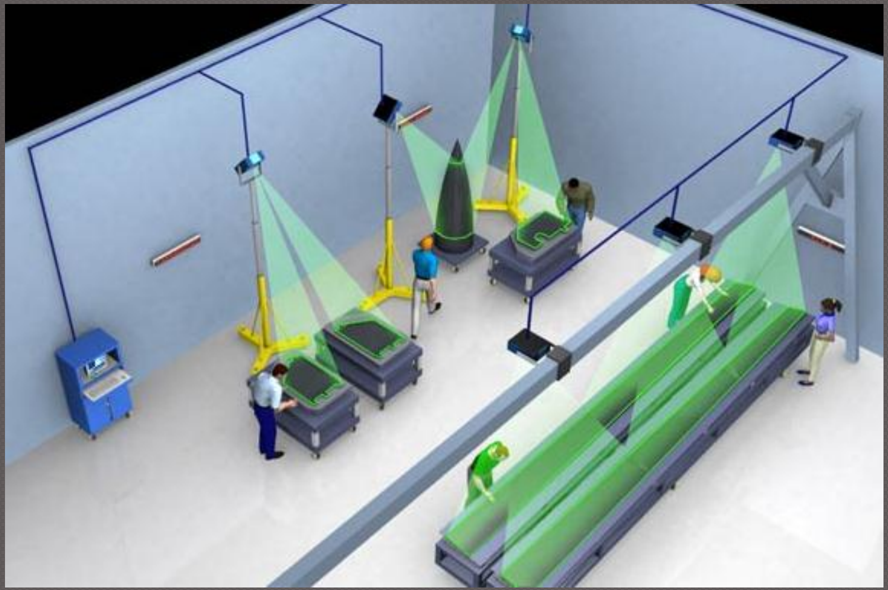


Design Alternatives-Laser Projection

- Most Expensive option $40,000
- Industry first
- No measurement required
- Time savings
- Maximize production
- Jig background needed

Design Alternatives-Laser Projection

- Assembly Guide



http://www.assemblyguide.com/laserguide_systems.php

Movement Options

Manual vs. Powered

Design Alternative- Manual

- No added assistance in rotation
- Heavy
- 2 People needed
- Brake Needed

Design Alternatives-Manual Assist

- Can be added to any option
- Gear Box $200
- Crank Wheel $50-$100
- Cost Efficient

Design Alternatives-Motorized Jig

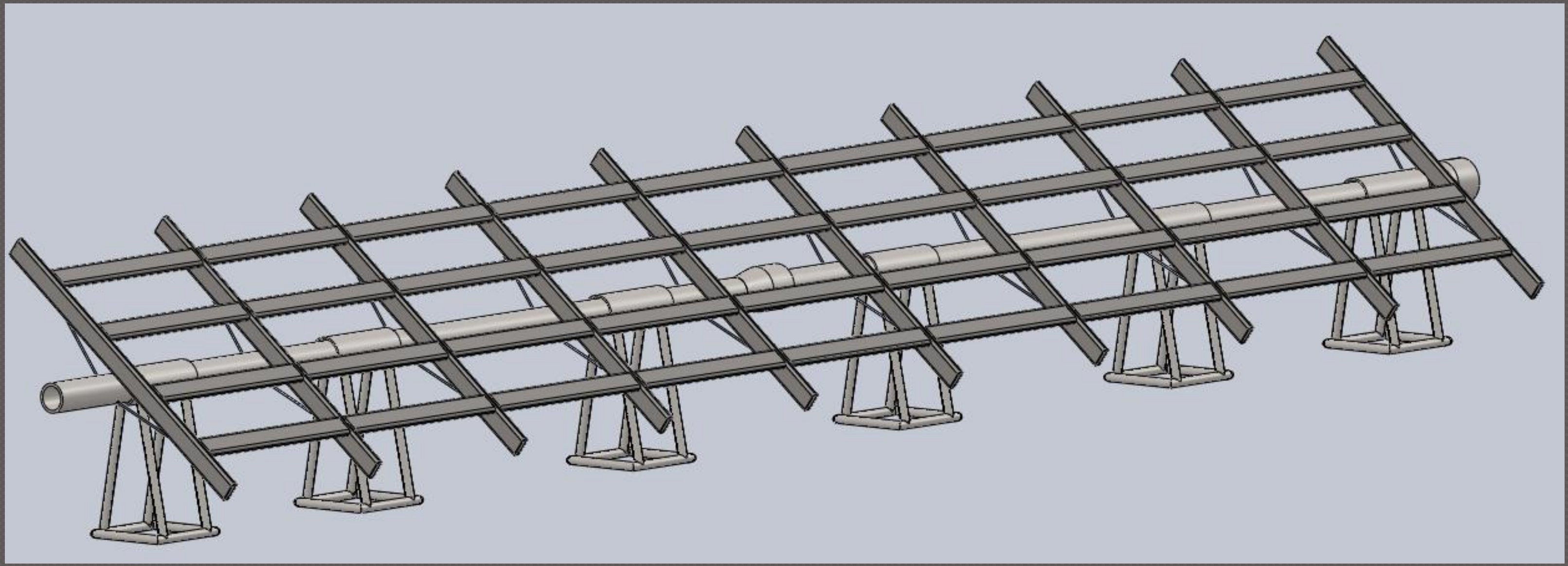
- Can be added to any option
- Electric Motor $500
- Worm gearbox $200
- Convenient

Cost Analysis

3 Different Options

Cost Analysis

- $4700 for Bases and Table



Cost Analysis

- Jig Redesign
- $4,700 per jig
- Brake $500-$2000
- Motor $500
- Worm Gearbox $150

Cost Analysis Base Model

- Adhesive ruler attached to jig
- $94.44 per ruler
- Replace lower Ruler Once per Month
- Replace Upper Ruler every 2 Months

Cost Analysis Fixed Laser

- $379 per laser – 2 lasers per jig
- $758 per jig
- Tracking System $700
- Total Cost $1500
- Recalibrate every 2 months
- Replace every 6 months

Cost Analysis Laser Projection

- $40,000 per Projector setup
- Price includes Projector, Computer, Software, and Setup
- Assume 1 projector per jig $160,000
- Assume 1 projector per pair jigs $80,000
- Maintenance required

Return of Investment

- 30% increase in Production per Day
- Welders spend more time welding
- Welder Ergonomics improved
- Employee turnover rate decreased

KTK's Recommendations

Project Time Frame

Recommendation

- KTK Engineering Solutions recommends that Sooner/Exiss Trailer purchase 2 jigs for Production
- KTK recommends purchasing one laser projector for the pair of jigs
- KTK finally recommends purchasing 4 fixed lasers for the remaining 2 jigs

Final Price Based on Recommendation

- 4 Jig setups -$18,800
- 1 Laser Projector- $40,000
- 4 Fixed Lasers -$1,500

- Final Cost
- $61,000

Project Schedule

- Project complete by May 2013
- Final project specifications by Year End 2012
- Material ordered by end of January 2013
- Shop work, Prototype, and testing finished by April 2013

Acknowledgements

- Sooner/Exiss Trailer
- Larry Zahasky
- Dr. Paul Weckler
- Don Lake
- Mike Raymond
- Aaron Cain
- Dr. Robert Taylor

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Questions?