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Fixed Platform Crane for Equipment Access

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by

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Undergraduate honors thesis under the direction of

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Project 22: Fixed Platform Crane for Equipment Access

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Abstract

Five senior mechanical engineering students at Louisiana State University collectively known as Team CraneWorks were tasked with finding a solution to Taminco's equipment access problem. Currently Taminco rents a 60–ton crane to raise and lower equipment on the top two levels of their Alkylalkanolamines (AAA) unit. It was desired for Team CraneWorks to design and implement a cheaper, permanent, and reliable alternative. The mechanical design process was followed and summarized in two primary components: engineering specifications and embodiment proposal. Team CraneWorks initially performed relevant background research, identified all potential customers and project constraints, generated concepts to meet the solution, as well as performed a decision matrix for the crane selection. Though many crane types were considered, the 30-foot box boom crane met the design criteria the best. EBI was the optimal manufacturer and from their crane specifications the team performed extensive engineering analysis on the effects of the crane to the AAA structure. It was found that modifications had to be made including the addition of multiple W-beams and a steel plate to distribute the expected loads. On March 25th, the team was notified that they were now responsible solely for a scaled prototype and would no longer be associated with Taminco due to lack of funding and time constraints. Similar to the previous designs, a FEA analysis was conducted and manufacturing drawings created. The prototype underwent static and dynamic testing where the Team measured maximum displacement at four critical locations on the modified structure and compared it to the expected behavior of the full-scale model. Figure 1 shows the proposed full-scale model with supporting components.

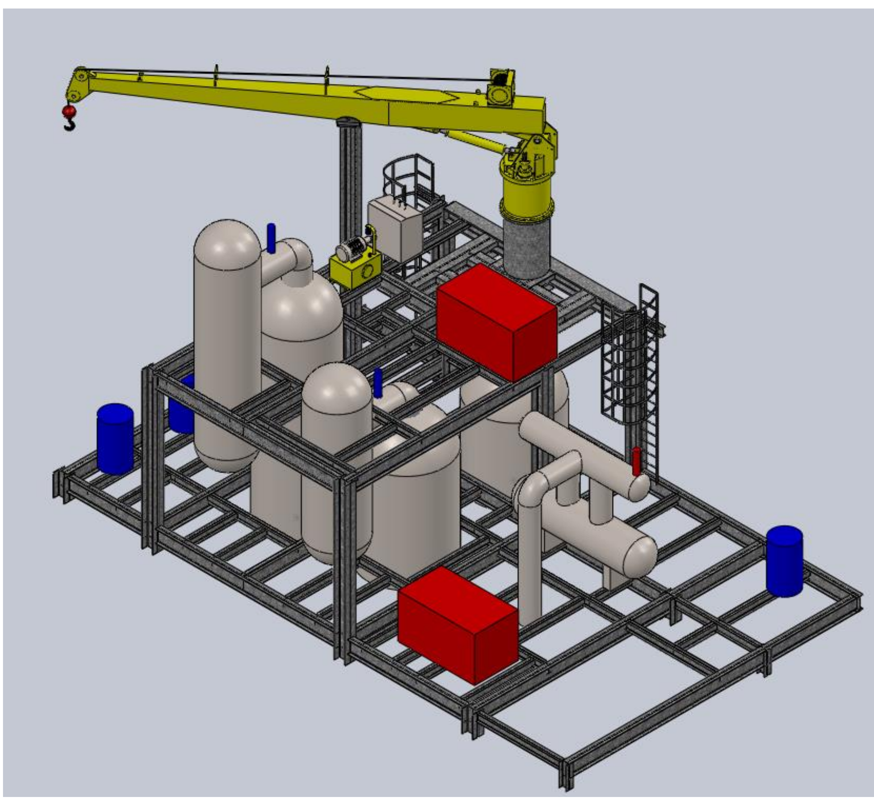

Figure 1: Assembly View of the Proposed System

Executive Summary

Five senior mechanical engineering students from Louisiana State University were tasked with finding a solution to Taminco's equipment access problem as their capstone project. The Alkylalkanolamines (AAA) unit located in Taminco's St. Gabriel plant has a large amount of equipment that must be accessed for routine maintenance. In order to perform maintenance on any equipment on the top two levels, Taminco must rent a 60-ton crane. The project goal is to install a fixed platform crane on the AAA unit that will access all primary and secondary equipment on the top two levels shown in Figure 2 below. The primary equipment includes two pumps and a PSV colored in red. The secondary components include the two heat exchangers and three PSV's. In total, the crane is expected to lift a maximum of 5,000 pounds.

Constraints for the fixed platform crane include safe operation, cost, ease of operation, functionality, and reliability. Team CraneWorks generated nine concepts that could meet Taminco's requirements; however only five were analyzed based on feasibility and cost. A decision matrix was performed on all five concepts where each design was rated against criteria set by the sponsor. Team CraneWorks' final design is to purchase a 30-foot box boom crane from EBI. The box boom design offers a safe and reliable option to private crane ownership. The box boom offers minimum moving parts without sacrificing functionality. Compared to other crane models the box boom is relatively less costly to purchase, maintain, and operate. Figure 2 shows the 30-foot box boom mounted on to the top of the AAA unit.

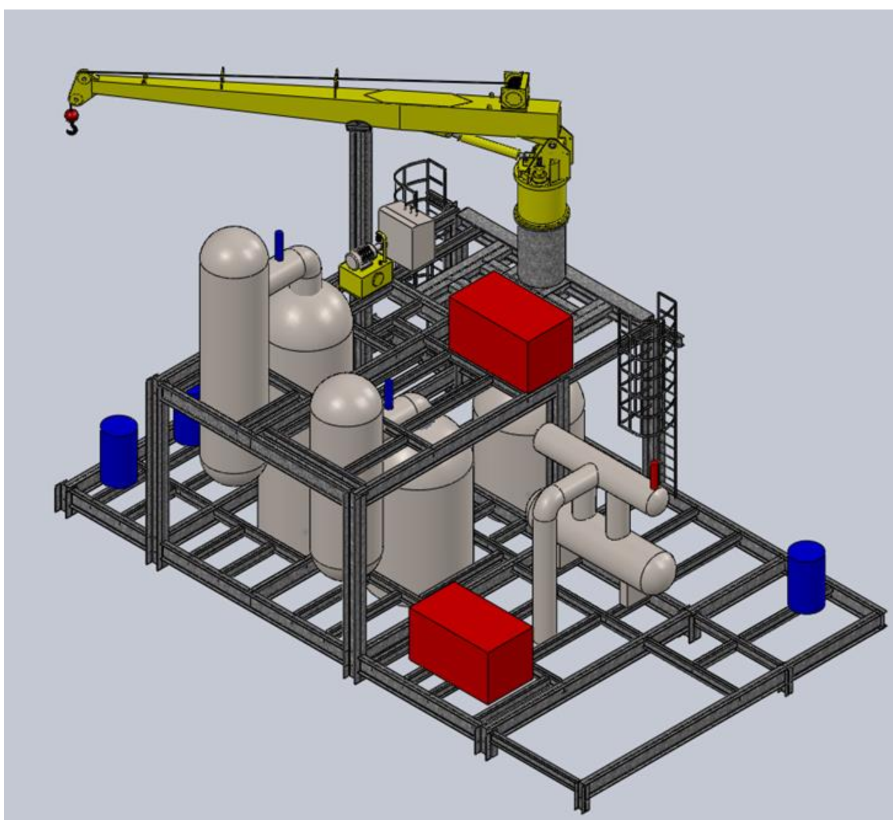

Figure 2: Proposed Crane Design on AAA Unit

API-2C standards were followed for the crane design. The box boom will be mounted to a 36 inch diameter pipe that is 56 inches tall. A flange will be welded to the top of the pipe so the crane head can be bolted to the flange on the pipe. The crane head has a 36 inch diameter pipe that is 34 inches tall, which is welded to the slewing bearing. The steel plate will be welded to the pipe and the AAA unit. After a local engineering analysis on the 7th floor, the current beam arrangement was deemed insufficient to support the expected loads and moments. A total of six beams will have to be replaced with W14x48 and W12x170 beams. Cross beams were also included in the design to distribute the load of the crane on the structure. Once the six beams are changed, non-destructive testing will be done on the welds and the crane can then be attached to the AAA unit. Supporting components to the crane include the hydraulic power unit, the operator pedestal, and the boom rest. The functionality of the boom rest is to secure the boom during inclement weather as well as alleviate unnecessary loads on the crane pedestal. Team CraneWorks developed a manufacturing plan that details all work that needs to be accomplished before and during crane installation. The anticipated monetary savings for this installation would be approximately $175,000 to $225,000 per year. The project was assigned a $200,000 budget where all expenses must be justified to Taminco. A detailed timeline is shown at the end of the document and projects the expected delivery dates of key components as well as the initiation of the different phases of the project.

Due to industry standards it is required for a Professional Engineer (PE) to sign off on all design proposals before any modifications are done on the AAA unit. Audubon Engineering is the selected firm and will be responsible for confirming Team CraneWorks design proposal and final approval of the design. Based on their professional opinion, Team CraneWorks performed only a local analysis on the 7th floor versus a global analysis on the AAA unit.

The Mechanical and Industrial Engineering Department notified the team on March 25th that the scope of the senior design project would be changed based on lack of funding from Taminco and time constraints. The team must deliver a fully operational and tested scaled prototype by the end of the semester in order to prove their final design would be sufficient on the full-scale model. Similar to Design III, a SolidWorks FEA analysis was conducted on the prototype and manufacturing drawings were constructed. The team purchased and obtained the raw materials within two days of placing the order and built the prototype in twenty-four hours at a Team member's house in Houma, Louisiana. The prototype was driven back to LSU for testing. Both static and dynamic tests were conducted on the structure measuring maximum deflection at four critical locations for eight different loadings. The maximum deflection for the static and dynamic test was 0.016 inches and 0.020 inches, respectively. Based off the FEA analysis the maximum deflection should have been around 0.040 inches. Since the deflection was less than the expected value, it can be concluded that the prototype well reflects the loading on the full-scale model and that it is more than sufficient to support all expected loads and moments.

Engineering Specifications

Objective Statement

The goal of this project is to design, construct, and install a fixed platform crane to access equipment on the top two levels of the Alkylalkanolamines (AAA) unit located in Taminco's St. Gabriel plant. The equipment consists of two pumps, two heat exchangers, and four pressure safety valves (PSV's) located on the top two levels of a 7-story platform. One PSV and the two pumps are primary equipment, while the other three PSVs and the two heat exchangers are secondary equipment.

The design must be able to access primary equipment on the top two levels of the AAA unit and raise and lower the equipment to the ground. In order to reach all the primary and secondary equipment, which are spread out between the top two levels. The design must be able to adjust to the elevation and location changes. Lastly, the design implementation, construction, and installation should remain within the budget of $300,000; all expenses at the end of the project must be justified by Team CraneWorks and approved by the sponsor.

Background Information and Existing Technologies

The sponsor for the Capstone Design project is Taminco. The St. Gabriel facility was originally built in 1976 by AirProducts as a grass roots facility. Acquired by Taminco in 2006, the facility is currently the world's largest higher amines plant. The higher amine products are used as raw materials in the production of herbicides and other consumer end products such as engine block molds and various pharmaceutical applications (Matlosz, 2013).

The focus of the project is to create a solution for equipment access on the top two levels of the AAA unit. The AAA unit is operating as a campaign unit, which is a multi-functional unit where Taminco can produce different products from the same unit. There is a significant amount of equipment on the top two levels that require routine maintenance. Since there is no available spare equipment on the unit for replacement, a failure leads to a significant downtime for production.

Currently, a 60-ton crane is used to service the equipment on the top two levels. The current method entails a significant cost for renting the crane and the operator. It also presents safety hazards associated with the relocation and operation of a high capacity mobile crane. The 60-ton crane is considered the competitor to the subsequent design.

Potential Customers

Considering that the project is essentially utilizing preexisting technology and applying it on a custom individual scale, a wide range of potential customers can be considered depending on the scope. For instance, if one has similar needs and requirements as the AAA facility at Taminco then Team CraneWorks' design and prototype may be an ideal fit. On the other hand, if one considers a much broader scope and considers that this design is the foundation for any custom crane application, then many industries and customers can be considered. Below is a list of a select few:

- **Chemical Industry** – Any company producing a chemical that requires tall infrastructure with limited clearance space immediately surrounding the structures. Companies may include: Albemarle, BASF, DOW Chemical, etc.

- **Oil and Gas Industry** – For similar reasons as the chemical industry, these companies typically include large-scale refineries that have tall infrastructure with heavy equipment on various levels that need to be accessed. Companies may include: Shell, ExxonMobil, Chevron, Marathon Oil, etc.

- **Industrial Gas Industry** – Primarily concerned with gas separation by breaking air into its fundamental components. This processes requires extremely tall separation and chiller towers that have heavy equipment routinely in need of service. Companies may include: Air Liquide, Air Products and Chemicals, Praxair, Linde Group, etc.

For most design situations there are more than one customer, in order to design a product that is beneficial to all users, general customers must be determined. All personnel that come in contact with the design will have their own requirements. Determining all user requirements is a necessary part in designing a product that can benefit all consumers. The direct consumers will be the operators, maintenance personal, and management. Furthermore, standards organizations must be considered as customers, because they set requirements for the design. (Ullman, 2010)

Functional Requirements

The requirements stated by the sponsor are as follows: the design must raise and lower all primary equipment from ground level to the top two levels of the AAA unit, the design must be able to adjust to the elevation and location changes in order to access all the targeted equipment, and the design must operate safely and follow all safety organization standards. The design must also use available resources and existing facilities, save the company money, be quick and efficient, use standard parts and methods for production, and perform in inclement weather.

Qualitative Constraints

- **Safety and Ethics** – Without proper safety considerations, Team CraneWorks' design fails. It is Team CraneWorks' number one priority to promote safety and engineering integrity throughout the design process.

- **Cost** – The overall budget of the project must be considered including manufacturing and operating costs.

- **Ease of Operation –** All experienced crane operators must be able to familiarize themselves with the designs controls in a short amount of time. The control panel must be completely accessible and have a simplistic interface.

- **Reliability –** The design must be able to last more than three years. The project must be durable as it is exposed to all ambient weather conditions.

- **Functionality –** The project must be able to access, lift, and lower all primary equipment. It is expected that the project will be able to perform all functions of the rental crane.

Engineering Requirements

To achieve the customer's requirements, the design must accomplish the engineering specifications detailed in **Table 1** below..

Type	
G	Goal
O	Objective
F	Function
P	Performance
C	Constraint

Type	**Number**	**Goal**
G	**0.0**	**To design, construct, and install a fixed platform crane to access equipment on the top two levels of the Alkylalkanolamines (AAA) unit in Taminco's St. Gabriel plant.**

Type	**Number**	**Objective**
O	**1.0**	**Team CraneWorks and the design shall comply with all Capstone Design and Taminco's requirements.**
O	**2.0**	**Team CraneWorks and the design shall comply with all required safety standards.**
O	**3.0**	**The design shall access and move equipment in the top two levels of the AAA Unit.**
O	**4.0**	**The design shall follow standard industry maintenance procedures.**
O	**5.0**	**The design should adhere to standard manufacturing processes.**
O	**6.0**	**The design should follow industry standard operating procedures for crane operation.**

Type	Number	Requirement
O	**1.0**	**Team CraneWorks and the design shall comply with all Capstone Design and Taminco's requirements.**
C	1.1	Team CraneWorks shall provide a complete design with manufacturing drawings, by the end of Fall 2013.
C	1.2	Team CraneWorks shall complete the construction, installation, and testing of the design by the end of Spring 2014.
C	1.3	Team CraneWorks shall complete all the required documentation before the respective deadlines.
C	1.4	Team CraneWorks should remain within the budget allocated by Taminco.
C	1.5	Team CraneWorks shall adhere to Taminco's design approval process.
C	1.6	Team CraneWorks should host regular advisory meetings with Dr. Helms, Ms. Reed, and Taminco.

Type	Number	Requirement
O	**2.0**	**Team CraneWorks and the design shall comply with all required safety standards.**
P	2.1	The design shall comply with American Petroleum Institute (API) 2C.
F	2.2	The design shall have an emergency stop function.
F	2.3	The design shall clearly display operational envelope for which the design is rated.
F	2.4	The design shall have safety protection barriers around all components which constitute a hazard under expected operating conditions.
P	2.5	The design should warn the user when the design is operating outside its functional constrains.

Type	Number	Requirement
O	**3.0**	**The design shall access and move equipment in the top two levels of the AAA Unit.**
F	3.1	Team CraneWorks shall design a crane able to raise, lower, and maneuver the primary and secondary targets listed below.
F	3.1A	Primary: Pump 1, Pump 2, and Pressure Safety Valve 1.
F	3.1B	Secondary: Pressure Safety Valve 2, 3, and 4, Heat Exchanger 1, and Heat Exchanger 2.
F	3.2	The crane shall be able to raise and lower the equipment a minimum of 130 ft.

Type	Number	Requirement
O	**4.0**	**The design shall follow standard industry maintenance procedures.**
F	4.1	Team CraneWorks shall compile a maintenance manual and schedule for proper care and operation of the design.
P	4.2	The design should be easily serviceable by any certified personnel.
P	4.3	The design shall be compatible with industry standard components for maintenance and repair uses.

Type	Number	Requirement
O	**5.0**	**The design should adhere to standard manufacturing processes.**
F	5.1	Any manufacturing in the design shall be performed according to industry standards.
F	5.2	The manufacturing process shall be conducted by certified personnel.
F	5.3	The design should be mostly composed of readily-available parts.
F	5.4	Any custom or non-stock parts should be compatible with the other standard parts in the design.

Type	Number	Requirement
O	**6.0**	**The design should follow industry standard operating procedures for crane operation.**
F	6.1	Team CraneWorks shall provide an operating manual for the installed design.
F	6.2	The design shall use existing power supply on site.
F	6.3	Any certified personnel should be able to operate the design.

Table 1: Engineering Requirements

Measureable Engineering Specifications

In this design, the measureable specifications are governed by where the components to be serviced are located on the structure. Figure 4 and Figure 5 show the dimensions of the unit and the relative locations of the pumps, PSVs, and heat exchangers. The unloading zone, shown in Figure 3, is determined to be on the north side of the AAA unit due to the ease of accessibility.

Figure 3: Drop Zone on the North Face of the AAA Unit

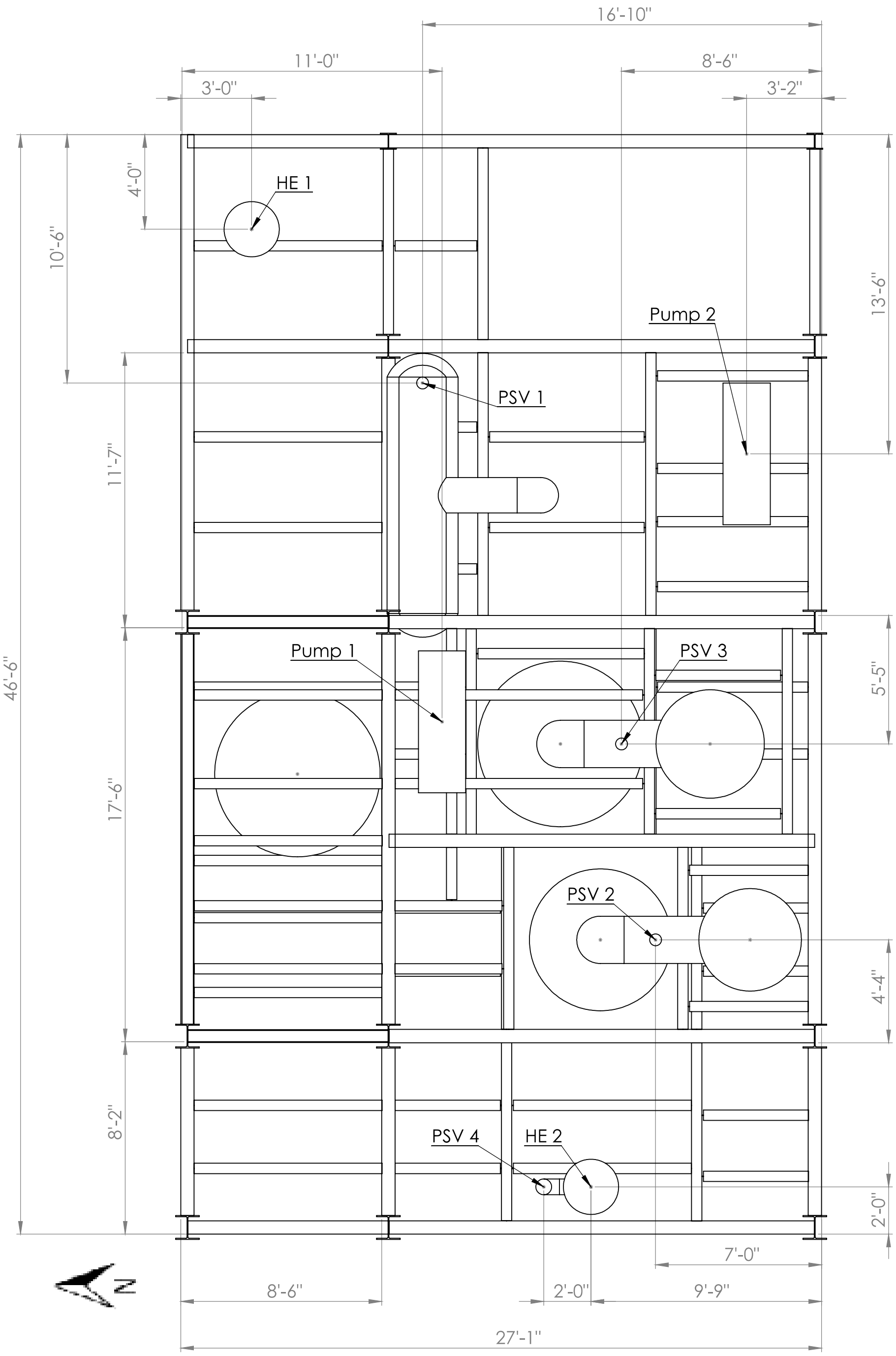

Figure 4: Top View Showing Location of Equipment on the 6th and 7th Floors

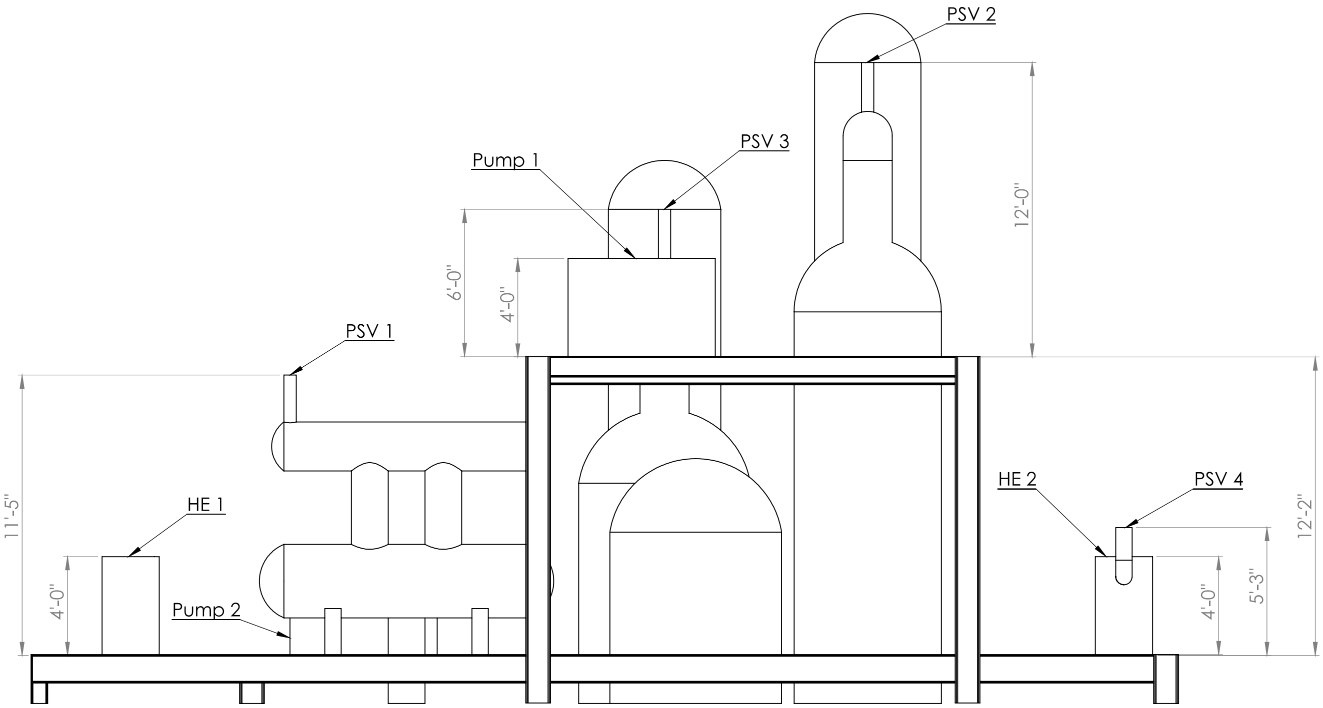

Figure 5: South View Showing Location of Equipment of 6th and 7th Floor

The weights of the objects are listed in Table 2 along with the dimensions of the objects and the heights from ground floor to final placement on the unit.

Component	Label	Weight	Dimensions	Height From Ground Floor
E-2623	HE 1	1720 lbs.	3ft X 3ft X 4ft	89ft 2in
E-2622	HE 2	4115 lbs.	3ft X 3ft X 4ft	89ft 2in
P-2644	Pump 1	1650 lbs.	5ft X 3ft 2in X 4ft	101ft
P-2653/P-2654	Pump 2	2500 lbs.	5ft X 3ft 2in X 4ft	89ft 2in
PSV-26104	PSV 1	60 lbs.	6in X 6in X 3ft	89ft 2in
PSV-26123	PSV 2	190 lbs.	6in X 6in X 3ft	116ft
PSV-26362	PSV 3	200 lbs.	6in X 6in X 3ft	105ft
PSV-26363	PSV 4	50 lbs.	6in X 6in X 3ft	99ft

Table 2: Components

Functional Decomposition

The next step in the design process is to generate the important functions that the design will have to accomplish in order to meet the engineering requirements and constraints. This is done through a technique called functional decomposition explained in *The Mechanical Design Process* (Ullman, 2010).

The team subdivided the project into two main parts the design and the support. The support includes all necessary attachments needed to secure the design. The support has two main sub functions. The support must maintain a secure and stable attachment between the design and the proposed structure, and allow enough degrees of freedom for the design to operate properly.

The design is subdivided into three main functions consisting of movement in the horizontal plane, movement in the vertical plane, and the design must maintain load attachment. The horizontal movement allows the design to adjust for different locations of the equipment as seen in Figure 4. The design shall also reach the drop-off point to the side of the platform. The vertical movement allows the design to adjust for the different elevations of the equipment seen in Figure 5. The design shall also be able to lift and lower equipment to and from the ground. The design must maintain proper attachment to the equipment while in operation. The functional decomposition is shown graphically in Figure 6.

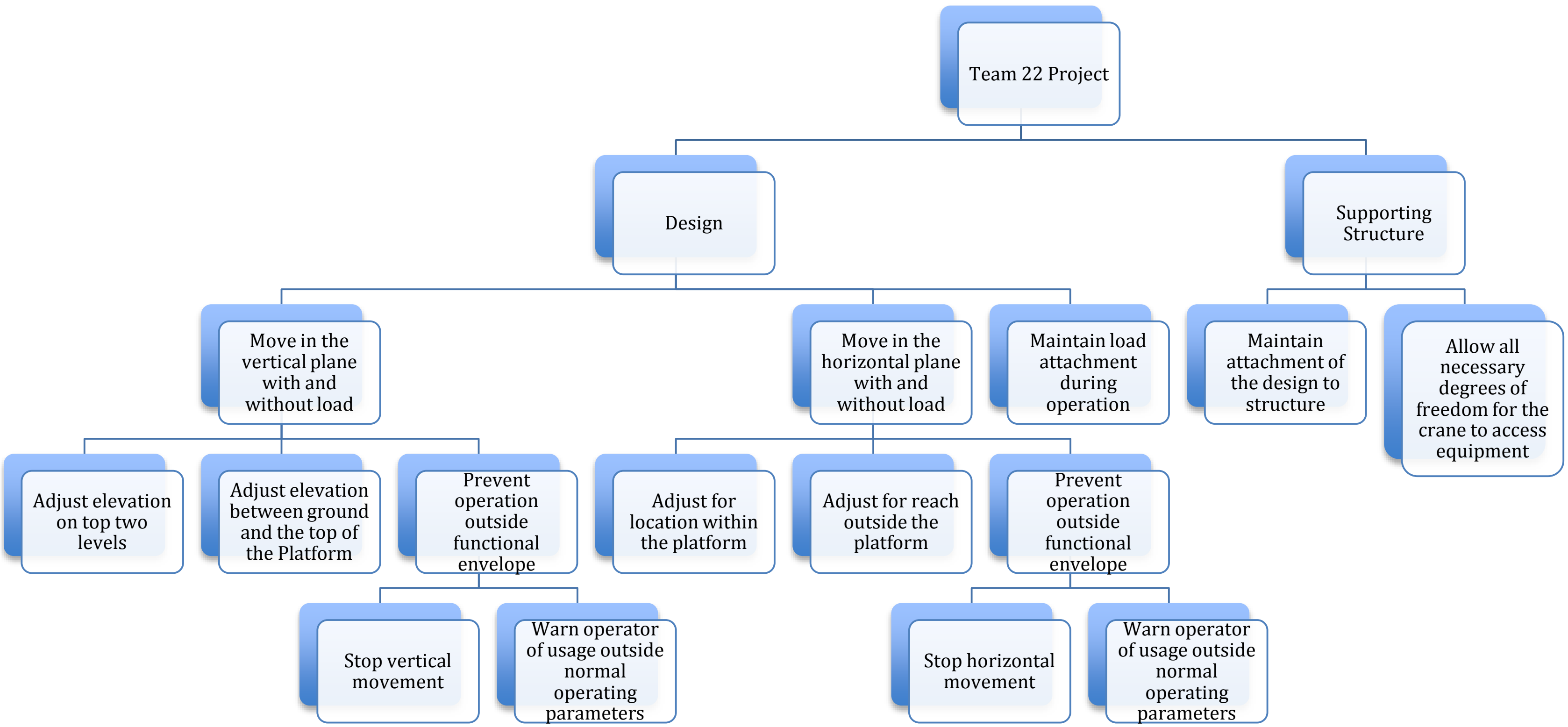

Figure 6: Functional Decomposition

Concept Generation

Concept ideation and generation is one of the most important steps in a successful project. Taking the necessary time to generate viable options and thinking “outside the box” is a critical component in creating project alternatives and finding the best solution to the problem. Team CraneWorks developed nine different options; however, only five were sufficient to evaluate in the decision matrix shown in the following sections.

Preliminary concepts included a truss crane on the top level, elevator shaft along the side of structure, an aerial lift of the components, and a Component Launch System (CLS). The truss crane concept could adequately reach all necessary components as well as lower them to ground level, however, the crane weight and the applied moment about the base structure was enough concern to eliminate the concept from further evaluation. The elevator shaft concept involved a crane placing the components on an external elevator shaft that would lower the components safely to the ground to be transported off via a forklift. This design helped mitigate safety concerns but was disbanded after observing the AAA unit and realizing the lack of space immediately surrounding the unit. Another option was for a helicopter to come and perform an aerial lift of the components. This would eliminate the need for a permanent structure on the AAA unit however would be more costly than the current method and less preferred. The final preliminary concept was the CLS, which involved encasing the components within a rocket payload and launching it to a nearby location. This rocket would have short-range capability and parachutes for a steady landing. Problems with this design involved price, stability, controls, and no adequate launch structure for the rocket.

The following five options were considered “extremely viable” and were further analyzed via a decision matrix shown in a later section. These concepts included a 30-foot jib crane on the 7th floor, a hydraulic crane on the 7th floor, a knuckle crane on the 7th floor, a 40-foot jib crane on the 8th floor, as well as an overhead bridge crane. The 30-foot jib crane would be located towards the north side of the platform. The 30-foot jib crane design would be capable of reaching all necessary equipment and have the flexibility to extend the equipment over the edge of the structure and lower to ground. Consideration must be made for the height differentials of the targeted equipment including the PSV, which is roughly 12-feet above the 7th floor. The second extremely viable consideration is a hydraulic crane on the 7th floor, similar location to the 30-foot jib crane; however, the main difference is the type of crane performing the operation. Likewise, a knuckle crane can be placed in the same location as the 30-foot jib crane and the hydraulic crane. The knuckle crane would be similar to the other cranes however a knuckle crane is more flexible in height differentials. The 40-foot jib crane will require another level to be built on the platform known as the 8th floor. The base of this level would extend from the northwest corner of the structure on the 6th floor upward. The 40-foot jib crane would be mounted on top of the platform and would have complete access to all equipment on the 6th and 7th floors. Unlike the previous concept, height differential would be less of an issue; however, applied moments about the base would be a greater concern. The last consideration is a bridge crane. A bridge crane could be constructed above the AAA unit and would have complete access to all equipment on the 6th and 7th floors. Considerations are an increase in wind loading as well as stability during lowering. Unlike jib and hydraulic cranes, the bridge crane cannot simply rotate to clear the structure to lower the components. Thus, a

modification must be made to extend the track of the crane over the edge of the unit. This extension will allow the crane to lower all components to the ground in a safe manner.

The figures below show the locations of the five viable designs. Note that the figures show the locations of the cranes in the platform, not the specific type of crane used. Figure 7 shows the jib crane, hydraulic crane, and knuckle boom crane location. Figure 8 shows the location of the jib crane on the 8^{th} floor. Figure 9 shows the location of the bridge overhanging the structure.

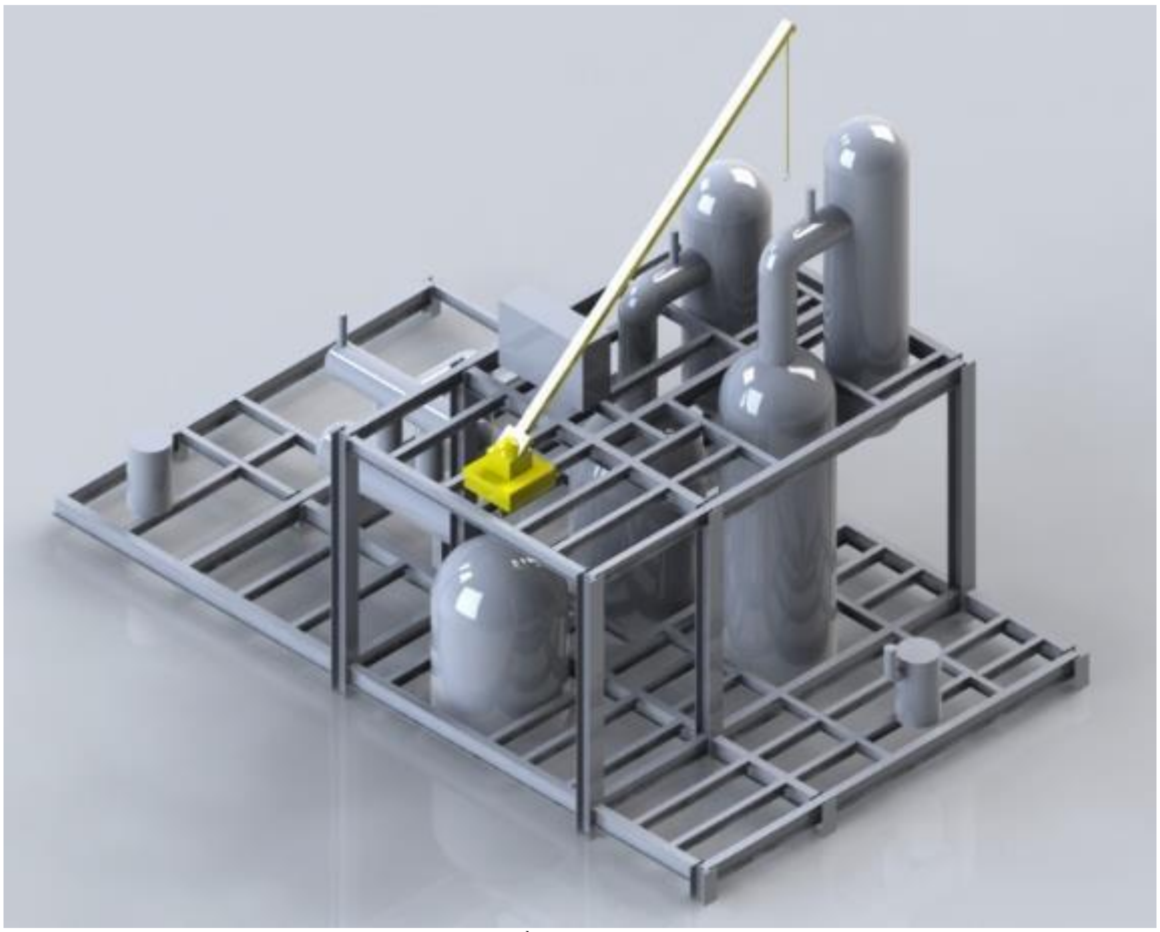

Figure 7: 7^{th} Floor Crane Concept

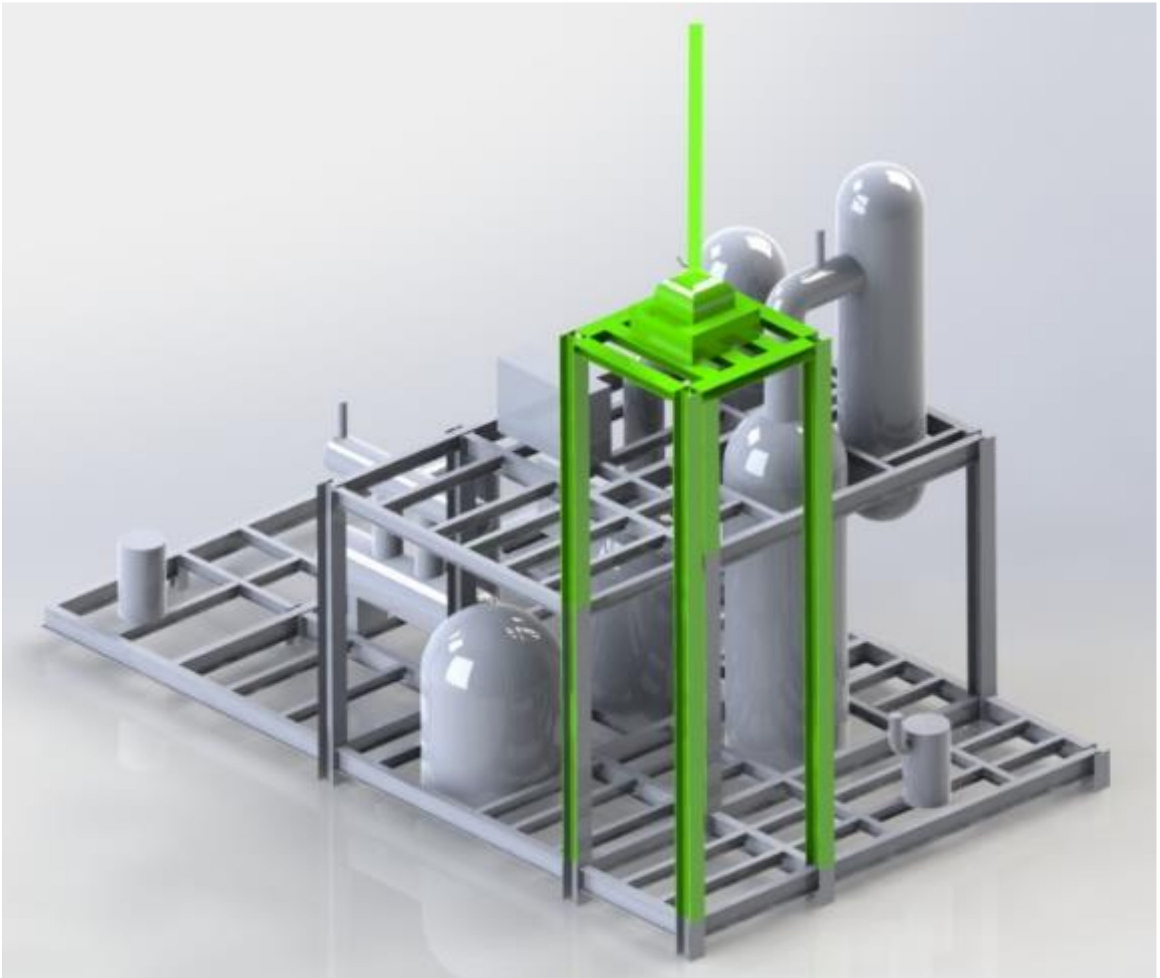

Figure 8: 8th Floor Crane Concept

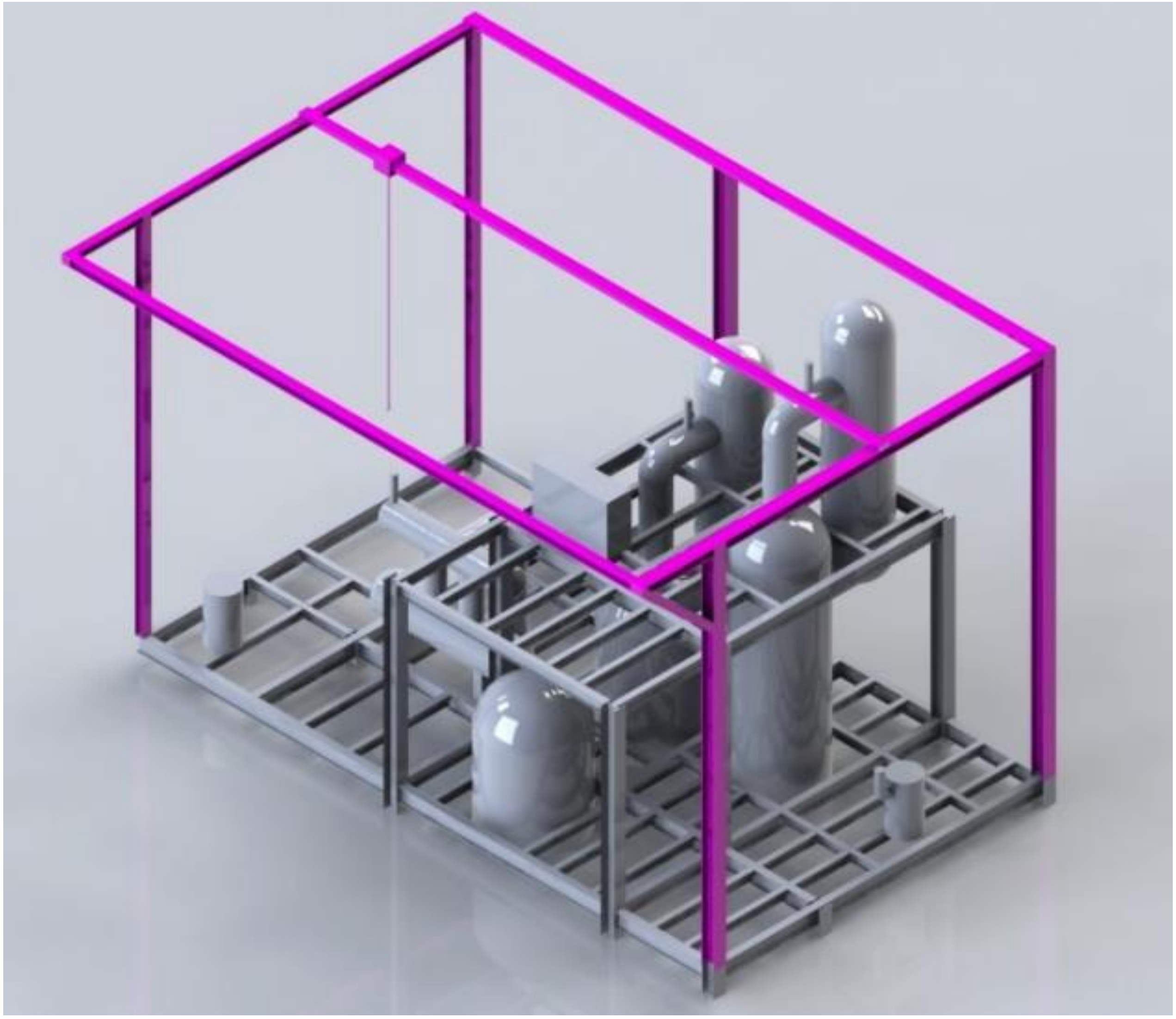

Figure 9: Bridge Crane Concept

Concept Evaluation and Selection

Once the concepts were generated, the next step was to evaluate each concept against the engineering specifications and against the other concepts to determine the best concept that will most closely match the requirements. This process is done using the Quality Function Deployment (QFD) method specified in *The Mechanical Design Process* (Ullman, 2010). The ultimate goal of the QFD is to develop a detailed table, the House of Quality (HOQ), which will compare all concepts against the customer requirements and engineering specifications.

The most important aspect of the HOQ is the Demanded Quality Section shown in Table 3. The Demanded Quality Section is an accumulation of specifications provided to Team CraneWorks by Taminco as well as some important requirements that Team CraneWorks has provided. Team CraneWorks sent out a survey to find the importance of each of the requirements and the relative weights. The survey and results are listed in the Appendix.

1	Lift and lower all primary objective equipment from ground leve to the top two decks.	4.35	8.95
2	Lift and lower all secondary objective equipment from ground level to the top most deck	3.50	7.20
3	Comply with all required safety standards, Taminco's and regulatory standards.	4.93	10.14
4	Use of available resources (Human, and equipment)	3.71	7.63
5	use existing facilities (local structure and surrounding area)	3.43	7.05
6	Cost Effective	3.86	7.94
7	Reliable	4.50	9.25
8	Uses standard parts and methods for production	3.57	7.34
9	Easy to maintain	4.14	8.51
10	Performs in Inclement weather	3.93	8.08
11	Quick and efficient	3.71	7.63
12	Least modification to structure	5.00	10.28

Table 3: Customer Requirements and Importance (Fehlmann, 2010)

By finding the relative weights of each of the requirements, one is able to determine the design characteristics. Each of these characteristics has a target or limit value. After going through the HOQ, Team CraneWorks developed the relative weights for each of the characteristics. The characteristics are compared to how well they meet the customer requirements. The customer requirements are then used to find the relative weights of each of these characteristics. The relative weights will help determine what the critical design components are. By knowing which design component is the limiting factor, one is able to weigh the relative importance when selecting a design. Table 4 shows a small example of select design components along with the relative weights in percentages.

Row Number	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Minimize (▼), Maximize (▲), or Target (x)	Target or Limit Value	Max Relationship Value	Requirement Weight	Relative Weight (Relative Importance)
1	Wind Loads	▲	125 MPH	9	380.18	4.86%
2	Weight	▼	10k lbs	9	298.24	3.82%
3	Moment	▼	150k ft-lbs	9	494.27	6.32%
4	Primary Lifting Load	▲	2.5k lbs	9	197.80	2.53%
5	Secondary Lifting Load	x	4.5k lbs	9	135.68	1.74%
6	Cost of Manufacturing	▼	$150k	9	278.56	3.56%
7	Number of Parts	x	50	9	233.92	2.99%
8	Operators	▼	6	9	68.72	0.88%
9	Crane Cost	▼	$120k	9	312.63	4.00%
10	Number of Structural Modifications	▼	0	9	489.43	6.26%
11	Operational Footprint	▼	Area of Structure	9	469.75	6.01%
12	Power Requirement	▼	480 Volts 3 Phase AC	9	264.17	3.38%
13	Lifting Speed	▲	40 ft/min	9	149.05	1.91%
14	Lifting Height	▲	125ft	9	488.84	6.25%
15	Number of Crane Modifications	x	0	9	444.79	5.69%
16	Storage Area	▼	20 ft by 20 ft	9	158.00	2.02%
17	Wench Capacity	▲	70k lbs	9	246.55	3.15%
18	Cable diameter	x	1/2"	9	395.45	5.06%
19	Boom Length	▼	40 ft	9	431.86	5.53%
20	Loading Area Distance	x	5 ft from Structure	9	328.19	4.20%
21	Maintenance Cost	▼	$10k/Year	9	225.11	2.88%
22	Number of Anchor Points	▼	5	9	362.26	4.63%
23	Expected Life	▲	10 Years	9	337.74	4.32%
24	Rotating Speed	x	1.5 RPM	9	262.11	3.35%
25	Power Pack Location	▼	20 ft. from Crane	9	363.00	4.64%

Table 4: Design Characteristics

After the relative weight of each engineering specification is determined, the next step is to compare each concept design with the other designs and against the desired values for the specifications. A decision matrix is used. In the decision matrix, the specifications and their relative weights are given. All the designs are scored for each specification on a 1 to 10 scale. 10 meaning the design meets the specifications perfectly while a 1 means the design does not meet the specifications at all. Each score is multiplied by the relative weight of the specification. This gives the percentage of how well the design meets that particular specification. The percentages for all specifications are added to obtain the overall performance of the design. This was done for all designs.

As can be seen in Figure 10, all the designs score high and, therefore, are all suitable choices to pursue. This is because before this matrix was constructed, the team filtered the designs that were clearly not going to perform the principal functions specified earlier. These designs were not considered because they failed to perform any one of the critical functions detailed in the Functional Decomposition. If the design could not meet these basic requirements, then they were not pursued any further. The designs presented in the matrix

performed these functions and were therefore considered viable to be compared in detail with the engineering specifications.

The first design considered was the bridge crane. It scored a 70% because it would need extensive modifications to the cable drum. This is because there was no bridge crane with enough cable length to lift to 130 ft. The bridge crane would also require several modifications to the structure. The 8^{th} floor crane scored 74% because it required an addition of an 8^{th} floor and rerouting of several pipes that run under the proposed location. The hydraulic and knuckle booms were too expensive and/or required modifications to the crane itself, therefore they scored below 80%. The design that scored the highest is the 7^{th} floor 30-foot jib crane, which is the design that Team CraneWorks selected as the final design. The location is free of obstacles and the crane performs all the functions for a cheaper price. The next step is extensive analysis and design of the support needed to attach the crane to the structure.

			Concept Alternatives									
			Bridge Crane		Jib 7th Floor 30 ft		Jib 8th Floor 40 ft		Hydraulic 7th Floor		Knuckle 7th Floor	
Criterion	**Target Value**	**Rel. Wts.**	**Score**	**Relative Score**	**Score**	**Relative Score**	**Score**	**Relative Score**	**Score**	**Relative Score**	**Score**	**Relative Score**
Wind Load	125 mph	6.54%	6	0.039	8	0.052	2	0.013	9	0.059	9	0.059
Weight	10k lbs	5.14%	8	0.041	8	0.041	1	0.005	8	0.041	8	0.041
Moment	250k ft-lbs	8.51%	9	0.077	7	0.060	7	0.060	8	0.068	8	0.068
Primary Lifting Load	2.5k lbs	3.41%	10	0.034	10	0.034	10	0.034	8	0.027	8	0.027
Secondary Lifting Load	4.5k lbs	2.34%	10	0.023	10	0.023	10	0.023	7	0.016	7	0.016
Operators	6	1.19%	10	0.012	10	0.012	10	0.012	10	0.012	10	0.012
Crane Cost	$120k	5.39%	10	0.054	9	0.049	8	0.043	10	0.054	3	0.016
Number of Structural Modifications	0	8.43%	5	0.042	5	0.042	1	0.008	5	0.042	5	0.042
Power Requirement	480 Volts 3-Phase AC	4.55%	7	0.032	10	0.046	10	0.046	10	0.046	10	0.046
Lifting Speed	40 ft/min	2.57%	6	0.015	10	0.026	10	0.026	10	0.026	10	0.026
Lifting Heigth	125ft	8.42%	0	0.000	10	0.084	10	0.084	0	0.000	10	0.084
Number of Crane Modifications	0	7.66%	0	0.000	10	0.077	10	0.077	7	0.054	10	0.077
Cable Diameter	1/2"	6.81%	8	0.054	10	0.068	10	0.068	10	0.068	10	0.068
Boom Length	40 ft	7.45%	10	0.075	8	0.060	10	0.075	8	0.060	9	0.067
Loading Area Distance	5 ft from Structure	5.66%	10	0.057	10	0.057	10	0.057	10	0.057	10	0.057
Maintenance Cost	$10k/Year	3.89%	10	0.039	10	0.039	10	0.039	10	0.039	10	0.039
Number of Anchor Points	5	6.23%	8	0.050	2	0.012	2	0.012	2	0.012	2	0.012
Expected Life	10 Years	5.81%	10	0.058	10	0.058	10	0.058	6	0.035	6	0.035
Overall Total		100.00%	29		27		27		23		23	
Weighted Total				**70.21%**		**83.88%**		**73.94%**		**71.50%**		**79.19%**

Figure 10: Decision Matrix for Crane Design

Embodiment Proposal

System Description/Product Architecture

From the concept evaluation, it was decided that a 30-ft jib crane on the 7th floor would be ideal to reach all primary and secondary equipment. A proposed layout is shown in Figure 11. Considering the physical and functional constrains of the crane, it was determined that the crane will be placed on the north side of the 7th floor. The location is selected because there is adequate space for the crane and other components. This placement allows the crane to have the necessary flexibility to reach all equipment on the top two floors of the unit. At the same time, the selected location has minimum interference with other equipment on the structure making it easy for installation and operation.

The system is comprised of five main modular components: the crane, the control unit, the hydraulic power unit, the boom rest and the structural modification. Each of these components are considered to be modular because they are complete systems within themselves however can also be combined as is the case for Team CraneWorks project.

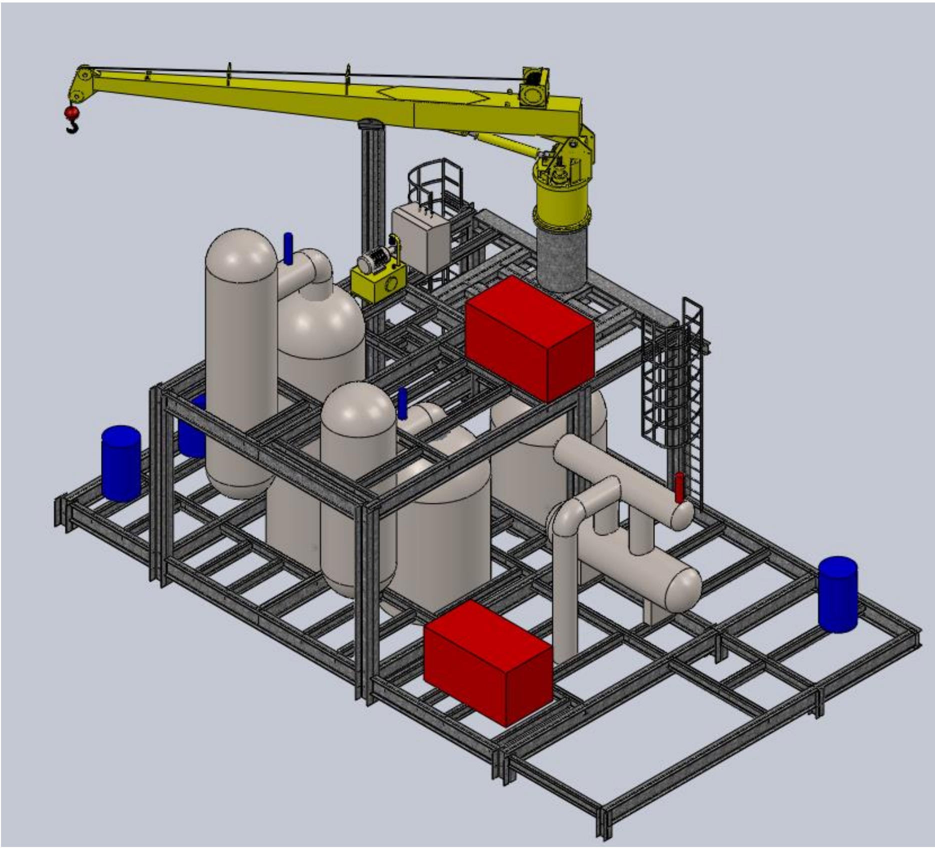

Figure 11: Crane with Plate Mounted on AAA Unit

The primary function of the crane is to raise and lower the equipment from the top two floors to ground level. Additionally, the crane is responsible for accessing the primary and secondary components without interfering with other existing machinery and equipment. The crane selected is a 30-foot box boom crane from EBI. The crane has swing stops at -90 degree and +235 degree (taking north to be 0 degrees and clockwise rotation

to be positive). The swing stops limit the crane's rotation so that the boom never passes over the control unit due to OSHA safety requirements.

The control unit, manually operated by trained personnel, is responsible for the operation and control of the crane. It determines the raising and lowering speed, height at which the boom is over the object, as well as the rotation of the crane. The control unit is placed on the northwest side on the 7th floor as shown in Figure 11. The location is ideal for operators to access the controls with a clear visual on all primary components. Note that according to standard crane operation techniques, there will be multiple operators assisting with the lift so a complete 100% visual is not always required. However the control unit has been placed at the location with the greatest vantage point.

The hydraulic power unit is similarly located on the 7th floor south of the control unit. The hydraulic power unit is responsible for providing 3,000 psi hydraulic oil to the systems. An existing electrical tray is between the Motor Control Center (MCC) and the hydraulic power unit therefore no electrical conduit has to be installed. All the electrical connections will be analyzed by Audubon Engineering who is also responsible the approved drawings.

The functionality of the boom rest is to support the weight of the boom while the crane is not in operation. It is required that the boom be secured during inclement weather. The boom rest will be located on the west side of the 7th floor, shown in Figure 11.

The structure is responsible for adequately distributing the load across the floor into the columns. The current structure is analyzed based off the expected loadings. Team 22 concluded that in order to support the applied loads, structural modifications had to be made to the 7th floor. Through the design process, Team 22 analyzed three various designs. Design I represents the current structure, Design II is the suggested design Team 22 came up with during Fall 2013 semester, and Design III is modified based off Audubon Engineering's recommendation during the Spring 2014 semester. Each design is discussed in the section below in detail.

Engineering Analysis for Design I

Crane and Platform Configuration

Design I represents the current beam configuration on the 7th floor of the AAA unit, shown in Figure 12. There are five main beams that will help directly distribute the loading. Beams 1, 2, and 3 will encounter direct contact with the plate and will transfer the load from the crane to beams 4 and 5. Beams 4 and 5 are connected to four columns. Currently, beams 1, 2, and 3 are sized as W8x18, beam 4 is W10x22, and beam 5 is W14x48. Because there is limited space on the 7th floor, the crane will be raised 10 feet by a pipe for personnel clearance. The pipe will be welded to a plate of steel that will be mounted to the platform.

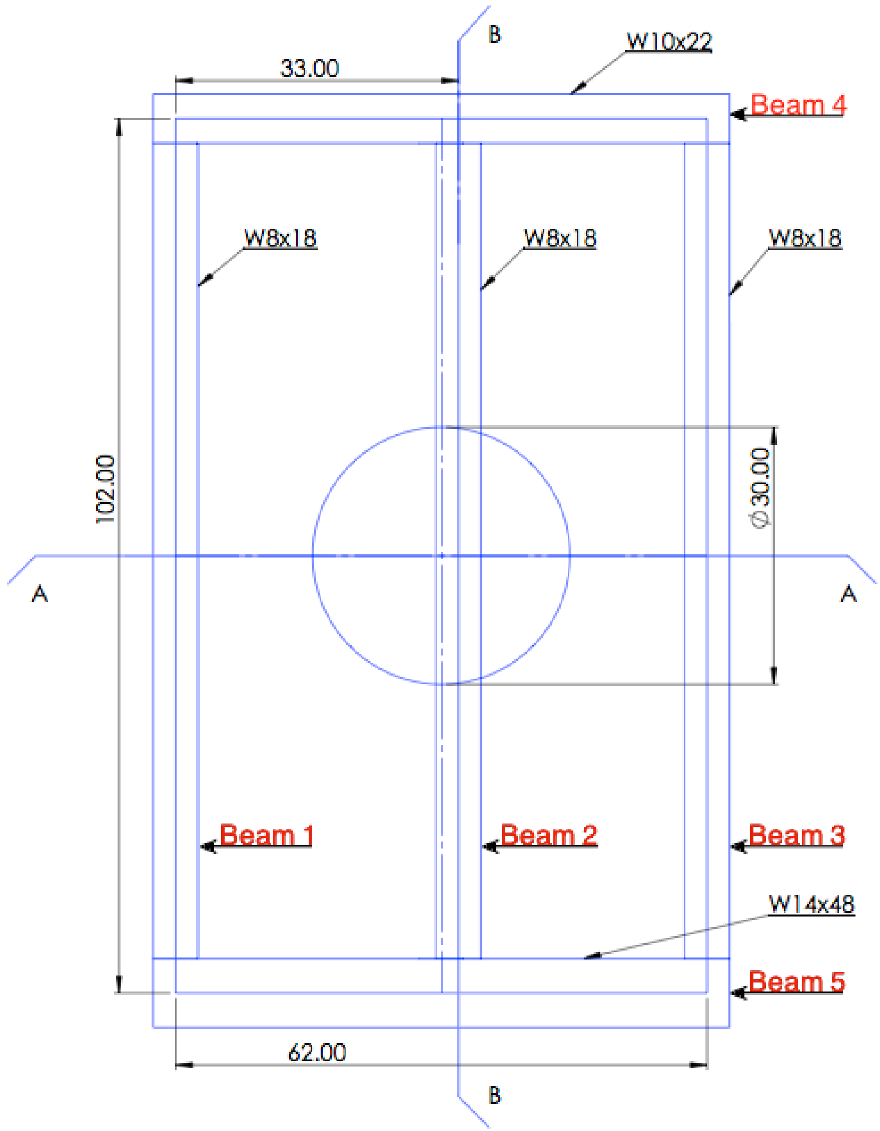

Figure 12: Existing AAA Beam Configuration on the 7th Floor

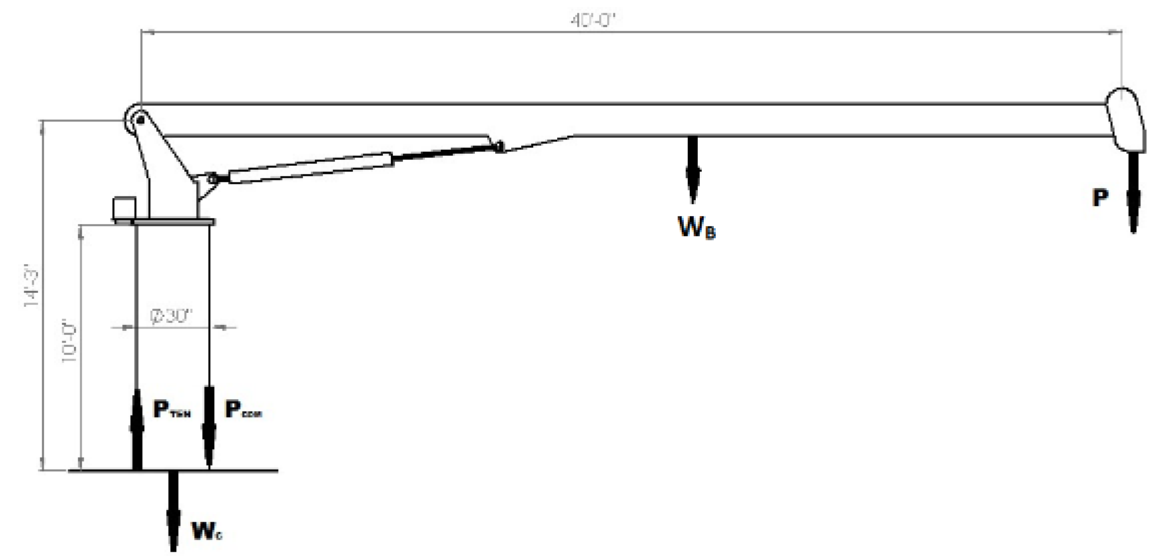

Figure 13: Crane Model

The crane modeled in Figure 13 illustrates the forces exerted on the structure due to the crane and the load. At this point in the project, Team CraneWorks designed for a 40 foot boom because it was the most readily available crane in the market. All crane loading parameters are engineering estimates from a variety of different crane manufacturers. The crane pedestal must be designed to withstand the maximum forces transmitted under all defined loads. Table 5 lists the expected loads for the crane modeled.

Component	Measurement
Weight of Crane	10,000 *lbs.*
Weight of Equipment	5,000 *lbs.*
Weight of Boom*	3,000 *lbs.*
Weight of Plate	$1{,}800 \cdot t_w$ *lbs.*
Moment	3,120,000 *lbs.-in.*
***The weight of the boom is included in the weight of the crane. The thickness of the plate is denoted as t_w.**	

Table 5: Crane Parameters

The forces are transmitted through the crane itself to the plate. The plate distributes the applied load and weight of the crane and plate to the supporting beams. The crane to plate and plate to beam connections are made through appropriately sized welds. Three W8x18 beams run in the north-south direction directly underneath the plate along with two W8x18 beams in the west-east direction. From this point, the forces are transmitted to the existing structure of the AAA unit including the four W12x65 columns running to the 3rd floor. Note that beam-to-beam and beam-to-column connections are made through appropriate bolting and welding.

Team CraneWorks will focus on the local structure analysis and manufacturing drawings. A global analysis of the AAA unit was considered, however was ruled out based on Audubon Engineering's professional opinion. They suggest that based on the size of the crane and the loads imparted in the structure; a local analysis of the 7th floor beams and columns is sufficient.

Force Analysis

Through the force analysis the plate thickness is determined for various loading directions of the crane. In order to determine the plate thickness, the plate must be analyzed where the maximum forces are assumed to occur shown as Section A-A and Section B-B in Figure 12. These two sections are assumed to experience the greatest forces on the plate. For Section A-A, the boom is facing either East or West with a load (into the page) of 5,000 lbs at 40 ft. reach. For Section B-B, the boom is facing either North or South with the same loading conditions as Section A-A. Team CraneWorks' analysis will begin with Section A-A.

Section A-A

Section A-A is modeled as a simply supported beam with three supports as shown in Figure 14. The moment from the crane is modeled as a coupled force due to the diameter of the pipe. The weight of the crane is divided by a factor of 2 and located at the edges of the pipe. The weight of the plate was separated into two parts each located in the center of the supports. The model depicted in Figure 14 does not depict the actual locations of the supporting beams as shown in Figure 12. The center beam (beam 2) is located 2 inches from the center of the plate and pipe location, in order to simplify the calculations the beam 2 was assumed to be located in the center of the plate.

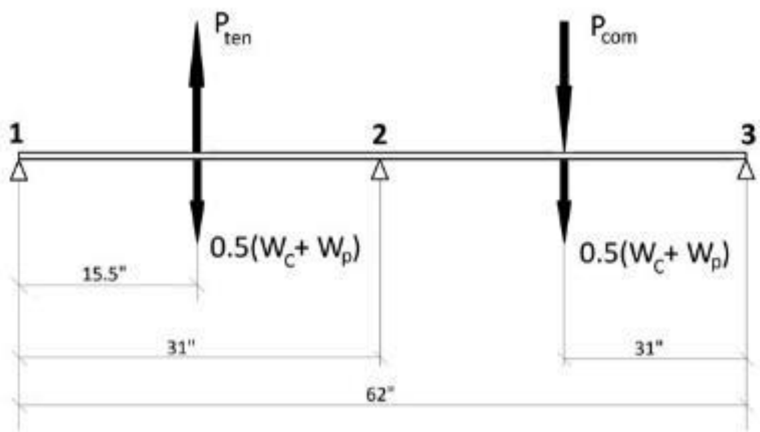

Figure 14: Plate Section A-A

The equations used are from the *Manual of Steel Construction: Load and Resistance Factor Design* from the American Institute of Steel Construction. Equations 1, 2, and 3 determine the reactions on the plate. Equation 4 is used to determine the maximum moment on the plate. The different contributions from the four forces are added by means of superposition.

$$R_1 = \frac{13}{32}P$$

Equation 1

$$R_2 = \frac{11}{16}P$$

Equation 2

$$R_3 = -\frac{3}{32}P$$

Equation 3

$$M_{\max} = \frac{13}{64}Pl$$

Equation 4

The reactions for the A-A section of the plate are recorded in Table 6. Tension forces are denoted as *T* and compression forces as *C*. The crane boom is assumed to be facing east for the A-A section. However, since the boom can rotate 360°, the maximum reaction, R_3, can be assumed to exist at R_1 when the crane boom is facing west. This assumption can be made because the crane is symmetric with respect to the plate.

Reaction	Measurement
R_1	47,478 *lbs* T
R_2	12,512 *lbs* C
R_3	53,162 *lbs* C
M_{max}	824,077 *lbs-in* CW

Table 6: Section A-A Reactions

Equation 5 is used to determine the plate thickness. A572 steel is considered, which has yield strength of 50,000 psi. Additionally a safety factor of 2 was incorporated. Table 7 shows the thickness calculated from the von Mises failure criteria. The maximum von Mises stress is due to the bending moment in the plate. Note that the plate also experiences a maximum transverse shear at the neutral axis but it is negligible compared to the maximum bending stress at the surface of the plate.

$$\frac{6Mt_w}{l{t_w}^3} = \frac{S_y}{n}$$

Equation 5

Plate Thickness	Measurement
t_w	1.72 *in*

Table 7: Section A-A Plate Thickness

Section B-B

Section B-B was modeled as a fixed beam with two supports as shown in Figure 15. The moment from the crane was modeled as a coupled force due to the diameter of the pipe. The weight of the crane was divided by a factor of 2 and located at the edges of the pipe. The weight of the plate was separated into two parts.

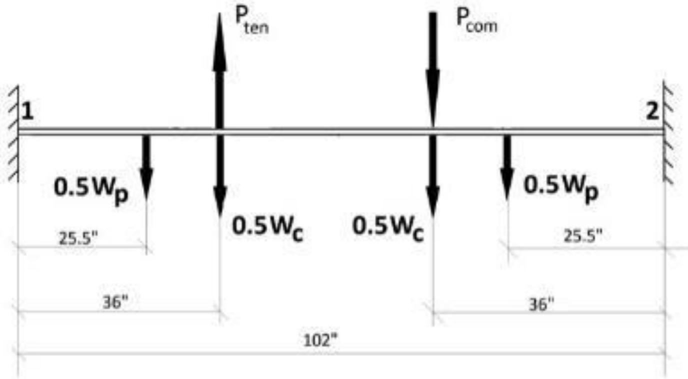

Figure 15: Plate Section B-B

Equations 6, 7, 8, 9, and 10 are from the LRFD and were used to determine the reactions from Figure 15.

$$R_1 = \frac{Pb^2}{l^3}(3a+b)$$

Equation 6

$$R_2 = \frac{Pa^2}{l^3}(a+3b)$$

Equation 7

$$M_1 = \frac{Pab^2}{l^2}$$

Equation 8

$$M_2 = \frac{Pa^2b}{l^2}$$

Equation 9

$$M_P = \frac{Pa^2b^2}{l^3}$$

Equation 10

The reactions for Section B-B of the plate are recorded in Table 8. The crane boom is assumed to be facing south with a load of 5,000 lbs. However, since the boom can rotate 360°, the maximum reaction, R_2, can be assumed to exist at R_1 when the crane boom is facing north. This assumption can be made, because the crane is symmetric with respect to the plate.

Reaction	Measurement
R_1	34,022 *lbs* T
R_2	52,222 *lbs* C
M_1	484,236 *lbs-in* CW
M_2	894,846 *lbs-in* CCW
M_{max}	968,342 *lbs-in* CW

Table 8: Section B-B Reactions

Equation 5 is used to determine the plate thickness. The same parameters for Section A-A were used for Section B-B. Table 9 shows the thickness calculated from the von Mises failure criteria. Because the thickness from Section A-A was larger than Section B-B, a plate thickness of 1.75 inches will be used.

Plate Thickness	Measurement
t_w	1.50 *in*

Table 9: Section B-B Plate Thickness

Analyzing both Section A-A and Section B-B it is determined that a minimum of a 1.5 inch plate will satisfy both loading conditions.

Beams 1 and 3

Since the plate thickness is calculated, the next analysis is to determine if the current W8x18 beams can support the crane during operation. The three beams supporting the plate are shown in Figure 12 and are labeled beams 1, 2, and 3. Beams 1 and 3 will be modeled differently than beam 2. This is because the reactions R_1 and R_3 from Section A-A are assumed to act as a distributed load across the entire beam, while the forces on Section B-B are point forces.

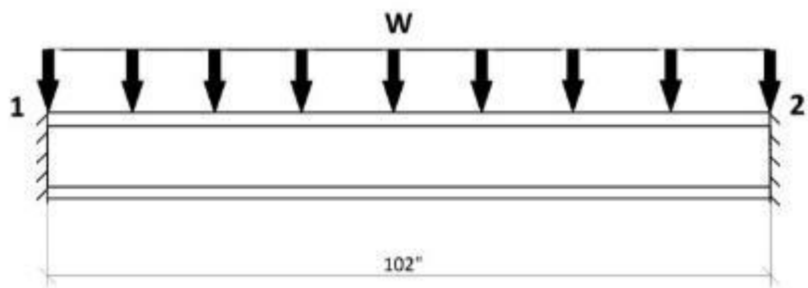

Figure 16: Beams 1 and 3

Figure 16 shows the model for beams 1 and 3. Equations 11, 12, and 13 were used to determine the reactions on beams 1 and 3. A distributed load of 443 lbs/in is calculated. The distributed load is calculated from the maximum reaction in Section A-A. The reactions for beams 1 and 3 are recorded in Table 10.

$$R_{1,2} = \frac{wl}{2}$$

Equation 11

$$M_{1,2} = \frac{wl^2}{24}$$

Equation 12

$$M_{\max} = \frac{wl^2}{12}$$

Equation 13

Reaction	Measurement
w	443 *lbs/in*
$R_{1,2}$	26,581 *lbs* C or T
$M_{1,2}$	265,810 *lbs-in* CW or CCW
M_{max}	531,620 *lbs-in* CW or CCW

Table 10: Beams 1 and 3 Reactions

Beam 2

Figure 17 shows the model for beam 2. Equations 6, 7, 8, 9, and 10 are used to determine the reactions from the crane.

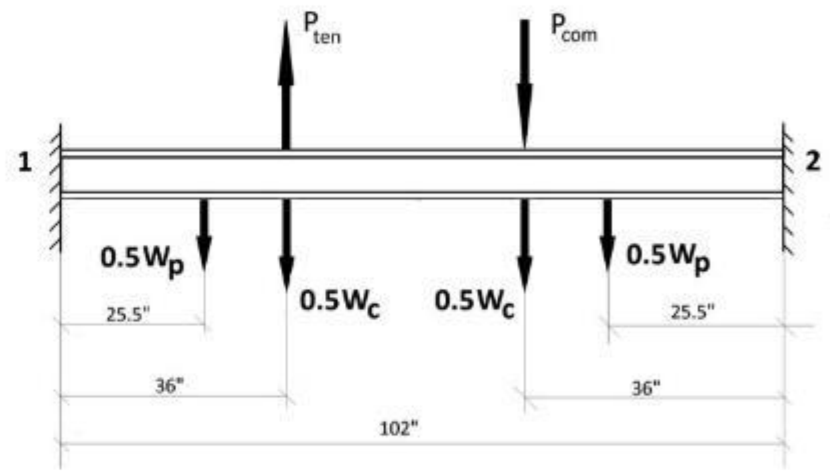

Figure 17: Beam 2

The reactions for beam 2 are recorded in Table 11. The crane boom is assumed to be facing south with a load of 5,000 lbs. However, since the boom can rotate 360°, the maximum reaction, R_2, can be assumed to exist at R_1 when the crane boom is facing the north.

Reaction	Measurement
R_1	34,022 *lbs* T
R_2	52,222 *lbs* C
M_1	484,236 *lbs-in* CCW
M_2	894,846 *lbs-in* CW
M_{max}	968,342 *lbs-in* CCW

Table 11: Beam 2 Reactions

Beams 4 and 5

Since all the reactions for beams 1, 2, and 3 are known, the next step is to find the reactions for beams 4 and 5. There are two scenarios that are of particular interest. The first scenario is when the crane is facing east and the second is when the crane is facing south. In the next section the two scenarios will be evaluated and the worst case will be used.

Figure 18 shows the model for beams 4 and 5 when the crane is facing east. Equations 6, 7, 8, 9, and 10 were used to determine the reactions in Figure 18. The reactions for beams 4 and 5 are recorded in Table 12.

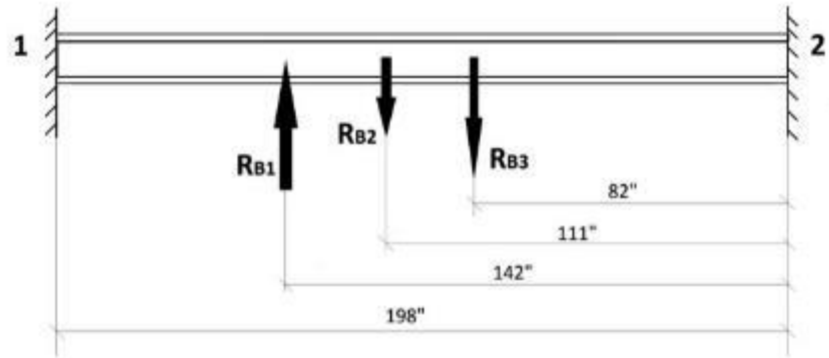

Figure 18: Beams 4 and 5 Model When Crane Moment is East

Reaction	Measurement
R_1	8,176 *lbs* T
R_2	14,676 *lbs* C
M_1	56,270 *lbs-in* CW
M_2	610,020 *lbs-in* CCW
M_{max}	593,388 *lbs-in* CW

Table 12: Beams 4 and 5 Reactions When Crane Moment is East

For the next scenario, Figure 19 shows the model for beams 4 and 5 when the crane is facing south. Equations 6, 7, 8, 9, and 10 were used to determine the reactions in Figure 19. The reactions for beams 4 and 5 are recorded in Table 13.

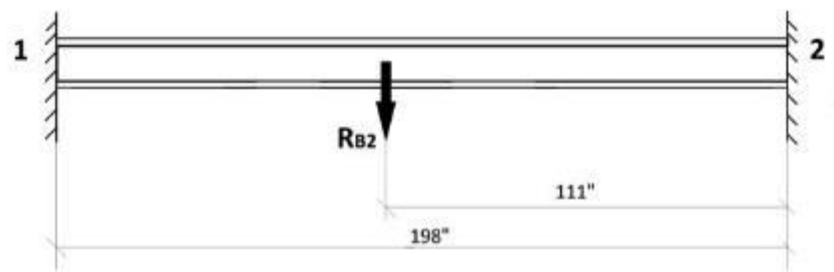

Figure 19: Beams 4 and 5 Model When Crane Moment is North

Reaction	Measurement
R_1	31,885 *lbs* C
R_2	22,115 *lbs* C
M_1	1,476,483 *lbs-in* CCW
M_2	1,157,244 *lbs-in* CCW
M_{max}	1,297,516 *lbs-in* CW

Table 13: Beams 4 and 5 Reactions When Crane Moment is North

Stress Analysis

Beam Stresses

After the plate thickness is calculated, stress analysis will determine if the current structure is sufficient for the applied loading. Equation 14 is used to determine if the stress

exerted on the beams exceeded the yield strength of the material. Based on standard structural steel properties, a yield strength of 36,000 psi was used for the beams.

$$\sigma = \frac{Mc}{I}$$

Equation 14

For different loading scenarios, four beam sizes are considered: W8x18, W10x22, W10x60, and W14x48. The tables below show the calculated stress for each beam. Every beam except the W10x60 is currently used on the structure. The W10x60 is listed here as a reference because it is considered to have the same height as the W10x22 beam but with a greater moment of inertia. In the tables, $\sigma_{At\ Ends}$ means the stress at the supports while $\sigma_{At\ Max}$ means the stress at the point of maximum deflection.

Beam	$\sigma_{At\ Ends}$	$\sigma_{At\ Max}$
W8x18	34,955 *psi*	17,477 *psi*
W10x22	22,909 *psi*	11,454 *psi*
W10x60	7,966 *psi*	3,983 *psi*
W14x48	7,557 *psi*	3,779 *psi*

Table 14: Beams 1 and 3 Stress Analysis

Beam	$\sigma_{At\ Ends}$	$\sigma_{At\ Max}$
W8x18	58,837 *psi*	63,669 *psi*
W10x22	38,448 *psi*	41,605 *psi*
W10x60	13,409 psi	14,510 *psi*
W14x48	12,721 *psi*	13,766 *psi*

Table 15: Beam 2 Stress Analysis

Beam	$\sigma_{At\ Ends}$	$\sigma_{At\ Max}$
W10x22	26,287 *psi*	25,570 *psi*
W10x60	9,016 *psi*	8,770 *psi*
W14x48	8,672 *psi*	8,435 *psi*

Table 16: Beams 4 and 5 Stress When Crane Moment is East/West

Beam	$\sigma_{At\ Ends}$	$\sigma_{At\ Max}$
W10x22	63,626 *psi*	55,914 *psi*
W10x60	21,823 *psi*	19,177 *psi*
W14x48	20,990 *psi*	18,446 *psi*

Table 17: Beams 4 and 5 Stress When Crane Moment is North/South

It can be concluded that the current beams on the AAA unit WILL NOT be able to sustain the crane pedestal. Table 14 and Table 15 show the stresses for beams 1, 2, and 3. The number calculated show that beams W10x60 and W14x48 are possible beam replacements for beams 1, 2, and 3.

For beams 4 and 5 the same process applies and the results are shown in Table 16 and Table 17. From the analysis, the current W10x22, beam 4, is not strong enough and should be replaced by either a W10x60 or W14x48 beam.

Plate Stress

Using the von Mises failure criteria with the maximum moment of all the loading conditions, the stress in the plate is found to have a maximum value of 30,600 psi. The moment created a normal stress and a transverse stress on the cross-section of the plate. However a transverse shear stress is negligible (< 1,000 psi) compared to the normal stress. To obtain a factor of safety of 2.0, the minimum yield strength of the plate material must be 61,000 psi.

Weld Analysis

Two main welding geometries are analyzed: welding of the crane pipe pedestal to the plate and welding of the plate to the beams. Fillet welds are used in the analysis. The analysis is based on that presented by Budynas and Nisbett.

Crane to Plate Welding

The first step in the welding analysis is to determine the reactions at the base of the pipe with maximum crane loading conditions. The bending moment, *M*, is 3,120 kip-in and the compressive force, *P*, is 15 kips. At this location the base of the pipe is pure bending, there is no transverse shear and the primary shear stress in the welds is zero. The secondary shear stress in the welds is equal to the sum of the normal stress from bending and the compressive stress. This sum is a function of the weld leg size, *h*. The total shear stress in the welds is given in Equation 15. The radius of the pipe (15 in) is denoted as *r*.

$$\tau = \frac{Mc}{I} + \frac{P}{A} = \frac{Mr}{0.707h\pi r^3} + \frac{P}{1.414\pi hr}$$

Equation 15

There are two criteria for fillet weld failure due to shear stress at the weld throat. The first criterion is that the shear stress must not exceed 3/10 of the ultimate tensile stress of the material in the weld electrode. The other criterion is that shear stress must not exceed 4/10 of the yield strength of the base metal. Using the lowest strength weld electrode (E60xx with S_{UT} of 62,000 psi) and the carbon steel with the lowest yield strength (SAE 1006 with S_y of 24,000 psi), the criteria indicates a maximum shear stress of 9,600 psi. This yields a minimum weld size of 0.67 in. Note that the failure criterion already includes a 1.4 factor of safety. Additional safety can be included if a better base metal and/or better weld electrode is used. The weld will be specified as an E70xx electrode with a leg size of ¾” to increase the factor of safety 2.0.

The stresses in the welds due to the maximum wind load are also checked. In this case, the crane will not be in use, so there is no load on the crane. The wind loads cause a transverse shear, a bending moment, and torsion at the base of the pipe. In this instance, the primary shear in the welds is not zero. An equivalent von Mises stress was used to calculate secondary shear due to the bending moment and the torsion. The necessary weld size was calculated to be 0.19 inches. It is smaller than the one calculated for a fully-loaded crane. This is because the wind loads are more than an order of magnitude smaller than those of the crane in operation.

Plate to Beams Welding

The total weld length must be calculated first and is found to be 312 inches for an all-around weld. A worst case scenario when the loads from the crane are supported by only two legs of the weld is assumed. In such a case, following the same procedure used for the pipe welding, with a different moment of inertia value, the weld size is found to be 0.61 inches for a weld length of 51 inches. This length is half the length of the worst case scenario. If a full length weld is used, the required weld size is reduced to 0.3 inches. An all-around weld size of 3/8 of an inch is specified to obtain a factor of safety of 2.0.

Engineering Analysis for Design II

Crane and Platform Configuration

Based off the results from Design I, Team CraneWorks proposed Design II to improve the structure capacity. An engineering analysis for the proposed new beam layout must be conducted to prove that the layout can support the loads from the crane. The new beam layout, shown in Figure 20, helps alleviate the stresses on the plate by replacing W10x18 with W14x48 beams. The pipe will be welded to the plate and the plate will be welded to the beams. In this configuration, all the beams will be changed to larger sizes which increase the endurance of the structure on large moments. At the same time, two cross beams are added at the edge of the pipe to distribute the concentrated loading from the pipe to the plate. An exploded view of the 7th floor layout is given in Figure 21.

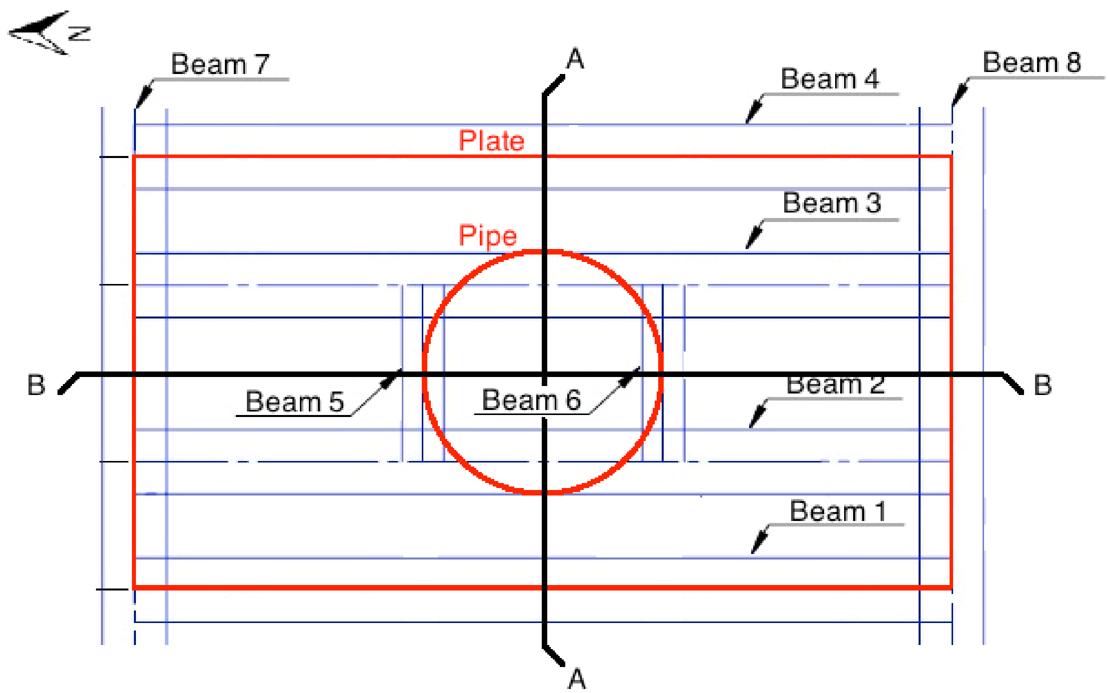

Figure 20: Fall Proposed Beam Layout

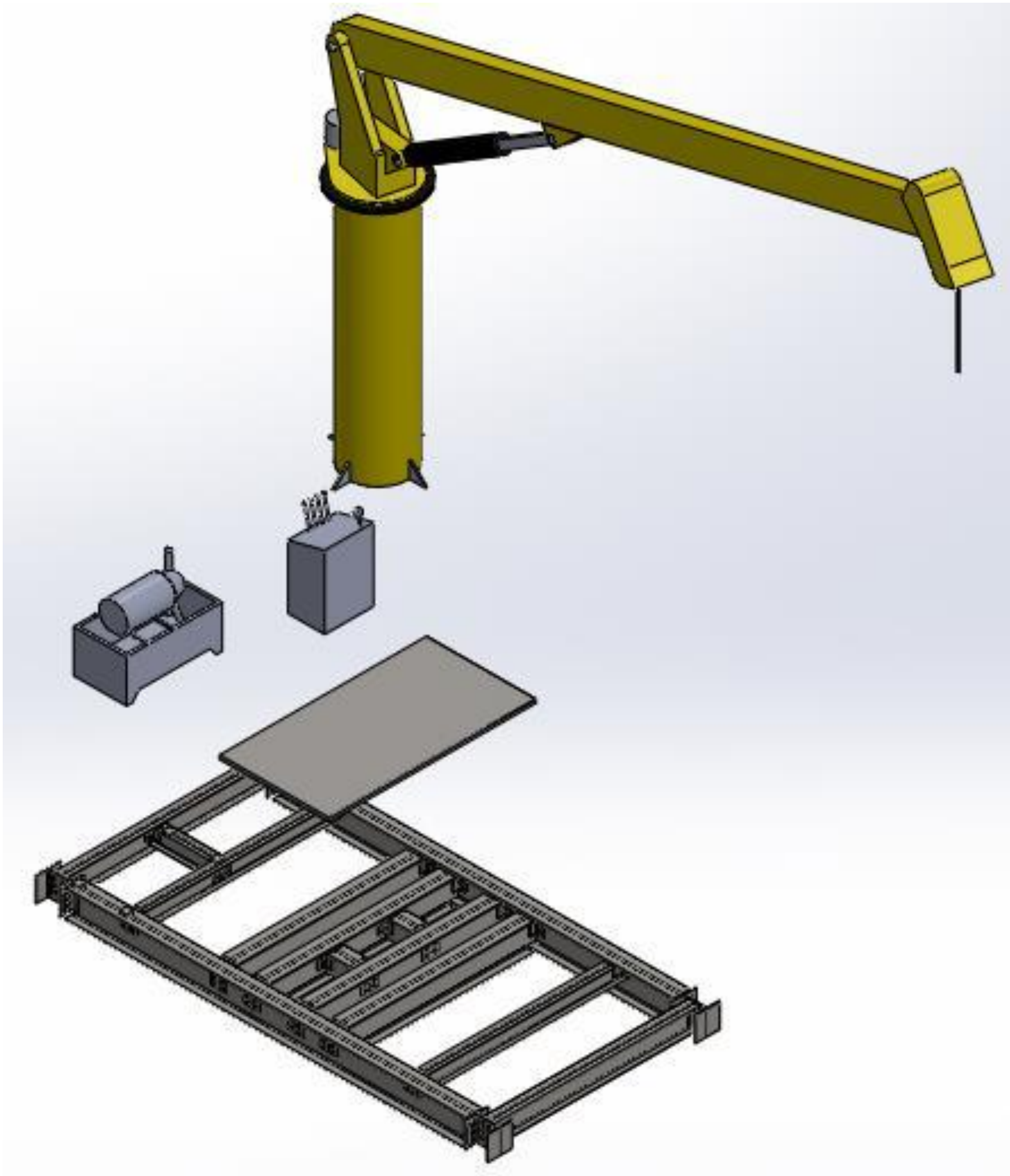

Figure 21: Exploded Assembly View of the 7th Floor

All crane loading parameters are engineering estimates from a variety of different crane manufacturers. The crane pedestal must be designed to withstand the maximum forces transmitted under all defined loads. Table 18 lists the expected loads for the crane modeled.

Component	Measurement
Weight of Crane	8,000 *lbs*
Weight of Equipment	5,000 *lbs*
Weight of Boom*	3,000 *lbs*
Weight of Plate	$1{,}800 \cdot t_w$ *lbs*
Moment	3,120,000 *lbs-in*
***The weight of the boom is included in the weight of the crane. The thickness of the plate is denoted as t_w.**	

Table 18: Crane Parameters

Force Analysis

Section A-A

SolidWorks beam calculator was used to determine the reactions for each structural steel cross section. The beam calculator does not use a mesh like normal FEA programs, thus a convergence check is not necessary. Section A-A of the plate is modeled as a simply supported beam with four supports as shown in Figure 22. Figure 22 shows the forces exerted on the plate as well as the reaction forces. The moment from the crane is modeled as a coupled force due to the diameter of the pipe and the weight of the crane is divided by a factor of 2. The coupled moment and the weight of the crane are located at the edges of the pipe. The crane boom is assumed to be facing east for the A-A section with the load (into the paper) of 5,000 lbs at a distance of 40 ft.

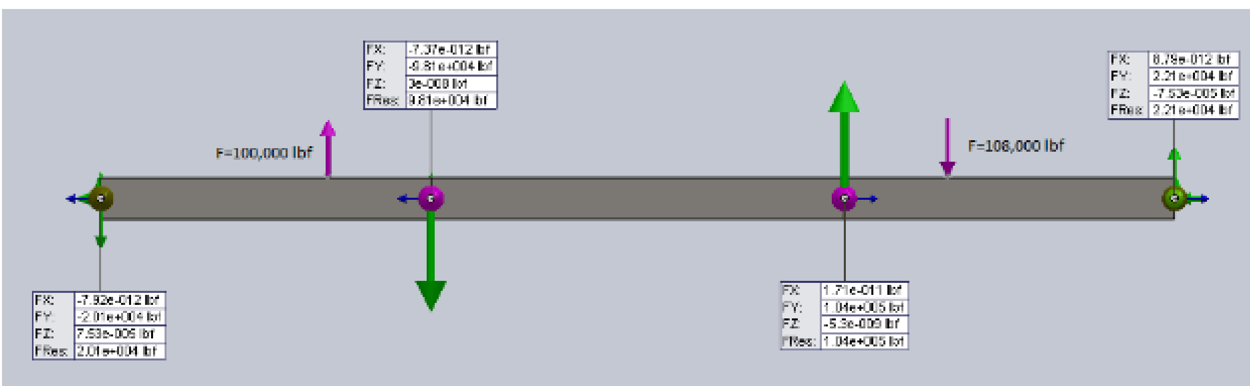

Figure 22: Section A-A Cross Section

The reactions for Section A-A of the plate are given in Table 19. Since the boom can rotate 360°, the maximum reaction, R_3, can be assumed to exist at R_2 when the crane boom is facing west. The reactions for the new beam layout are larger than the old beam layout. This is because the supporting beams are closer to the edge of the pipe, which helps alleviate the stress in plate.

Reaction	Measurement
R_1	20,100 *lbs* T
R_2	98,100 *lbs* T
R_3	104,000 *lbs* C
R_4	22,100 *lbs* C

Table 19: Reactions for Section A-A

The four beams supporting the plate shown in Figure 20 are labeled beams 1, 2, 3, and 4. The reactions from Section A-A are assumed to act as distributed loads across each beam. Figure 23 shows the distributed load that acts on beam 3, which is the beam with the largest reaction.

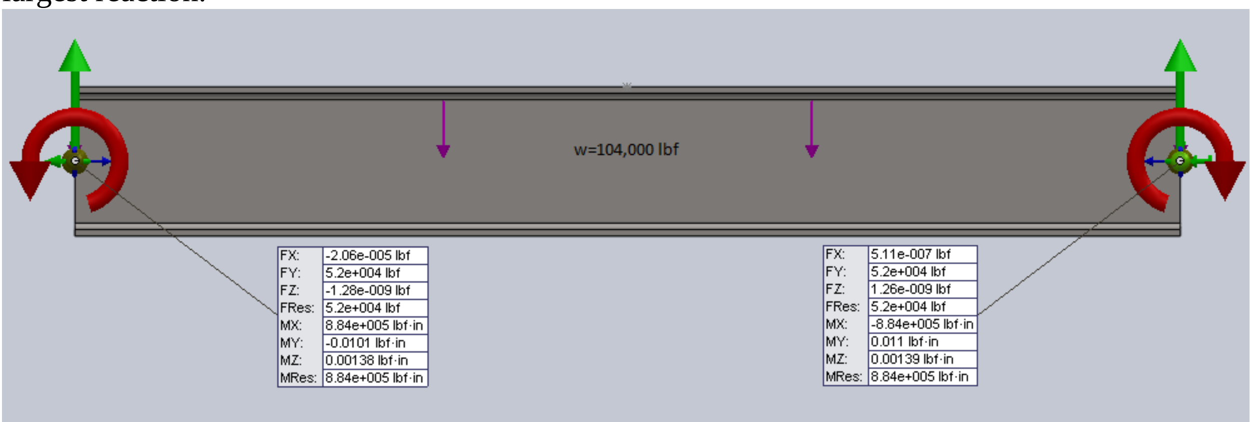

Figure 23: Reactions for Beam 3

The reactions for beam 3 are shown in Table 20. Since the reactions are half of the applied load the assumption can be made for all four beams that support the plate. Beams 1, 2, and 4 are modeled as distributed loads and the reaction are half of the applied load.

Reaction	Measurement
R_1	52,000 *lbs* C
R_2	52,000 *lbs* C

Table 20: Reactions for Beam 3

Since all the reactions for beams 1, 2, 3, and 4 are known, the next step is to find the reactions for beams 7 and 8. Beams 7 and 8, shown in Figure 20, connect to the supporting columns. Figure 24 shows the loads from beams 1, 2, 3, and 4 acting on beams 7 and 8.

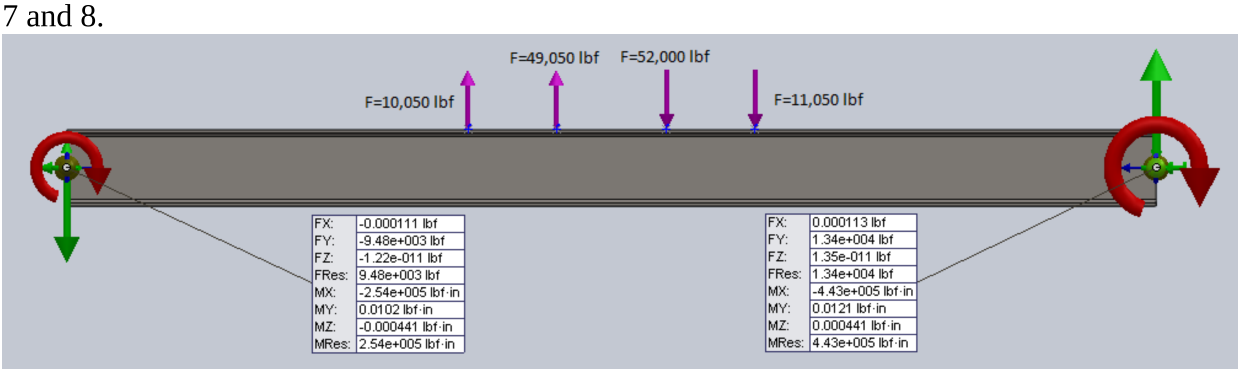

Figure 24: Reactions for Beams 7 and 8 for Section A-A

The reactions for beams 7 and 8 are shown in Table 21.

Reaction	Measurement
R_1	9,480 *lbs* T
R_2	13,400 *lbs* C

Table 21: Reactions for Beams 7 and 8 for Section A-A

Section B-B

Section B-B is modeled as a simply supported beam with four supports as shown in Figure 25. Figure 25 shows the forces exerted on the plate as well as the reaction forces. The moment from the crane is modeled as a coupled force due to the diameter of the pipe and the weight of the crane is divided by a factor of 2. The coupled moment and the weight of the crane are located at the edges of the pipe. The crane boom is assumed to be facing north for the B-B section.

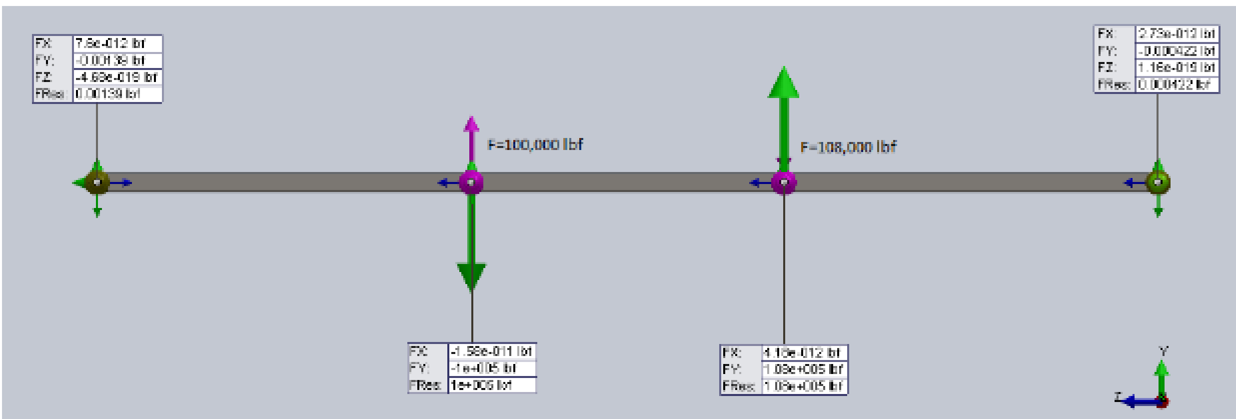

Figure 25: Section B-B Cross Section

The reactions for Section B-B of the plate are given in Table 22. Since the boom can rotate 360°, the maximum reaction, R_3, can be assumed to exist at R_2 when the crane boom is facing south. Beams 5 and 6 shown in Figure 20 are small beams that are located beneath the edge of the pipe to ensure the load of the crane is transferred into the structure instead of the plate.

Reaction	Measurement
R_1	0 *lbs*
R_2	100,000 *lbs* T
R_3	108,000 *lbs* C
R_4	0 *lbs*

Table 22: Reactions for Section B-B

Reactions R_2 and R_3 form Section B-B are assumed to act as a distributed load on beams 5 and 6. Figure 26 shows the distributed load modeled on beam 5.

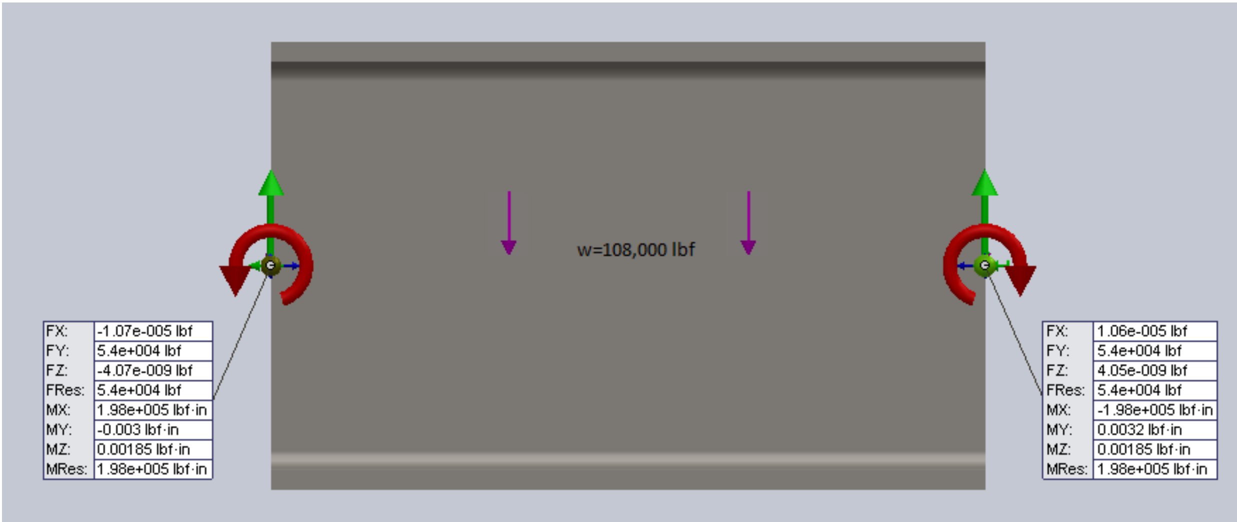

Figure 26: Reactions for Beam 5

The reactions for beam 3 are shown in Table 23. Since the reactions are half of the applied load the same can be assumed for beam 6.

Reaction	Measurement
R_1	54,000 *lbs* C
R_2	54,000 *lbs* C

Table 23: Reactions for Beam 5

Since the reactions for beams 5 and 6 are known the next step is to determine the loads that act on beams 2 and 3. Figure 27 shows the point loads from beams 5 and 6.

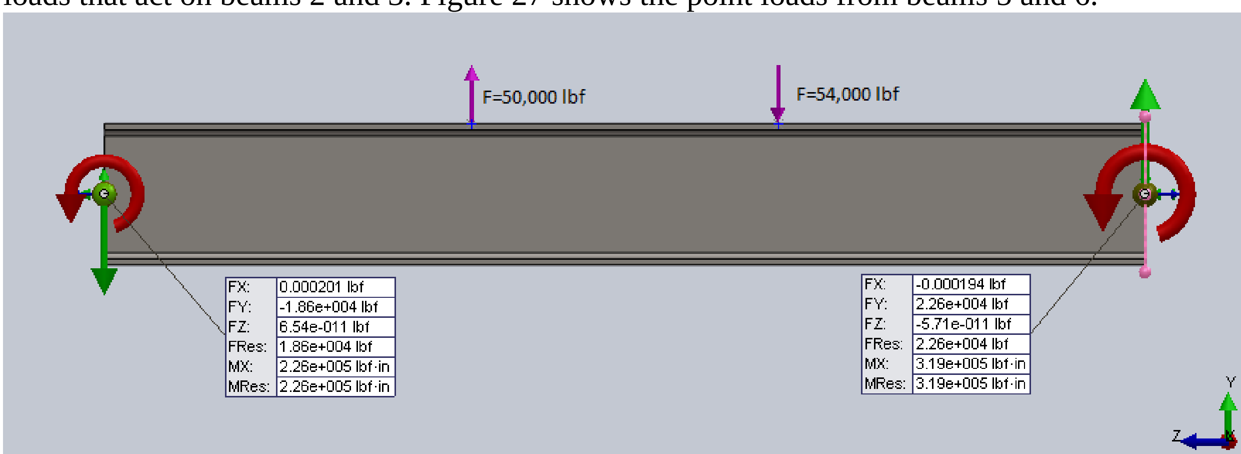

Figure 27: Beams 2 and 3 FBD

The reactions for beams 2 and 3 are shown in Table 24. Since the boom can rotate 360°, the maximum reaction, R_2, can be assumed to exist at R_1 when the crane boom is facing south.

Reaction	Measurement
R_1	18,600 *lbs* C
R_2	22,600 *lbs* C

Table 24: Reactions for Beam 2 and 3

Since the reactions for beams 2 and 3 are known, the next step is to find the reactions for beams 7 and 8. Beams 7 and 8 are shown in Figure 20 and connect to the supporting columns. Figure 28 shows the loads from beams 2 and 3 acting on beams 7 and 8.

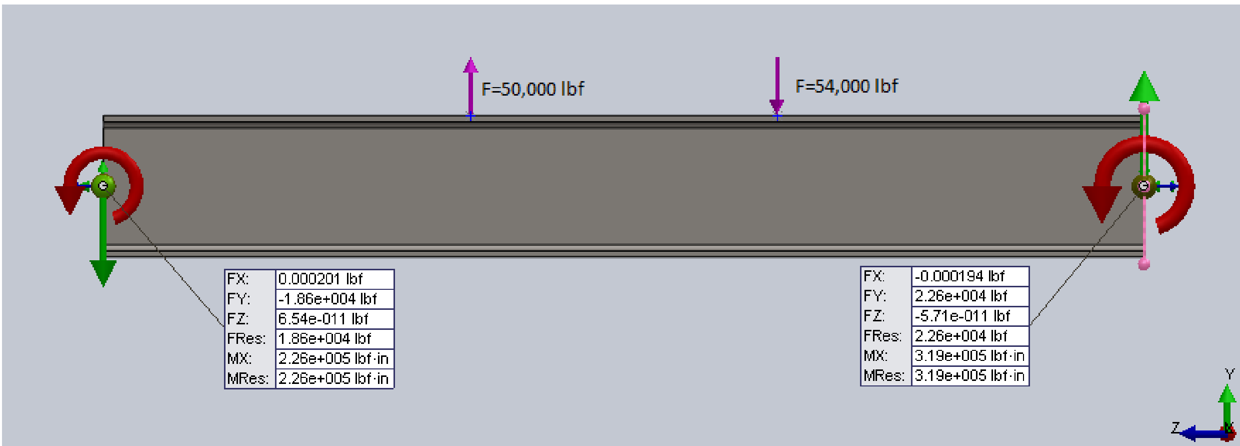

Figure 28: Reactions for Beams 7 and 8 for Section B-B

The reactions for beams 7 and 8 are shown in Table 25.

Reaction	Measurement
R_1	18,600 *lbs* C
R_2	22,600 *lbs* C

Table 25: Reactions for Beams 7 and 8 for Section B-B

Stress and Weld Analysis

The maximum bending moment of all loading cases were found to be 235,370 lbs-in for the plate and 884,000 lbs-in for the beams. These moments correspond to a stress of 8,540 psi for the plate and 12,575 psi for the beams. These stresses give a factor of safety greater than 2.0 for the plate and the beams. Therefore, the new beam layout experiences less stresses than the old layout, as predicted. Also, the weld analysis from Design I is valid for Design II.

Engineering Analysis for Design III

Crane and Platform Configuration

After Audubon viewed Design II they proposed modifications which make up the foundation of Team CraneWorks Design III. This design also incorporates the team's best judgment anticipating Audubon's final design by including a plate with gussets at the base of the pedestal. An engineering analysis for the proposed beam layout must be done to

prove that the structure can support the loads from the crane. The new beam layout, shown in Figure 29, adds considerable support to the existing structure.

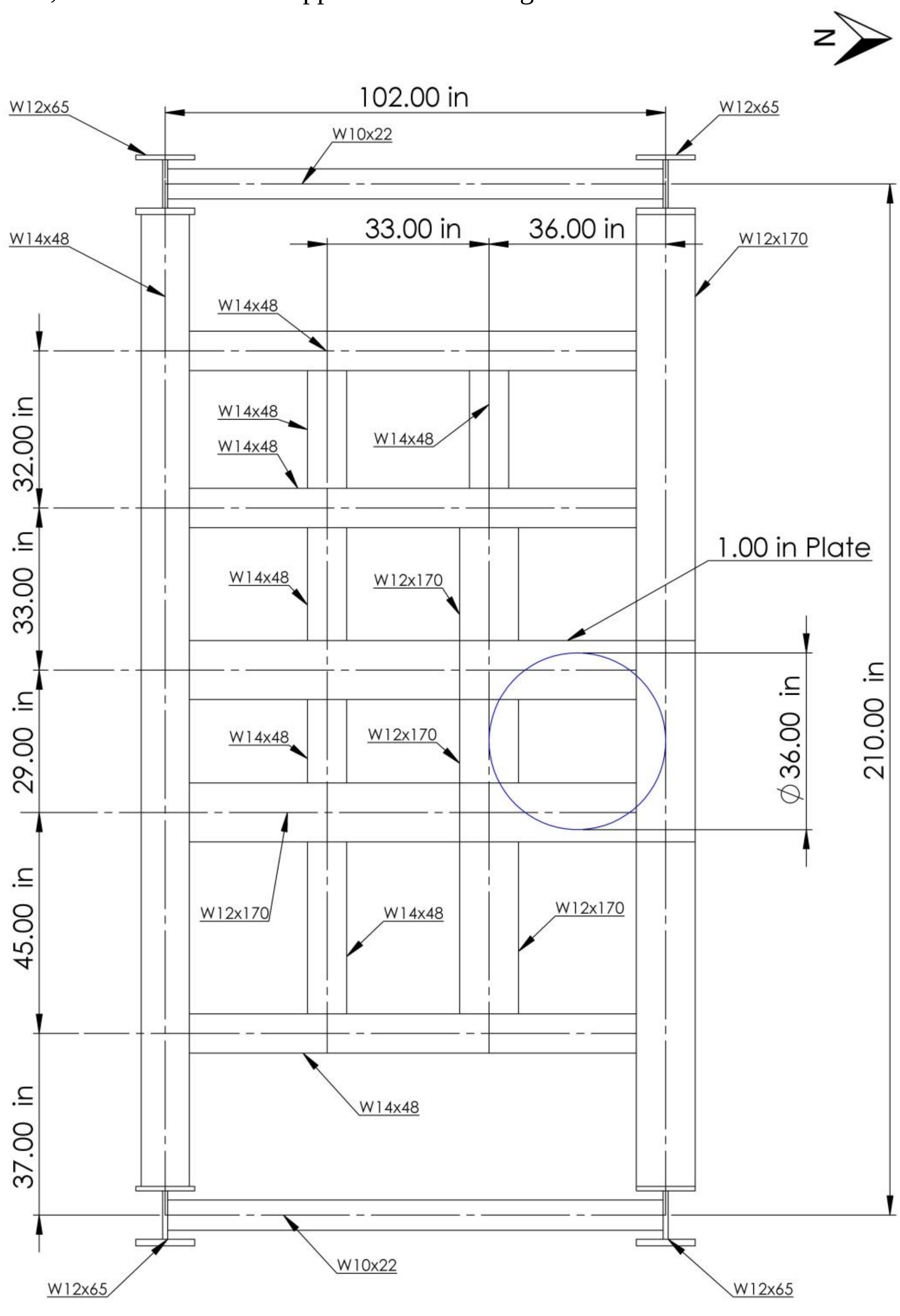

Figure 29: Design III Structural Beam Layout

Considerable beam changes were done in design III compared to design II, because the actual crane selected had higher design loads than expected. Beams further away from the reactions are reinforced to provide a better distribution for the loads. Also, the plate connecting the pipe and the beam is included in Design III to avoid possible stress

concentrations. At this point in the project EBI provided the loading and reactions for the crane, which are used in the following analysis. A safety factor of 3 is incorporated into the maximum overturning moment and the maximum axial force based on API standards. The crane pedestal must be designed to withstand the maximum forces transmitted under all defined loads. Table 26 lists the expected loads for the crane modeled.

Component	Measurement
Weight of Crane	6,285 *lbs*
Weight of Boom*	3,915 *lbs @ CG* 118.2 in
Max Axial Force	36,165 *lbs*
Max Overturning Moment	6,259,752 *lbs-in*
***The weight of the boom is included in the weight of the crane.**	

Table 26: Crane Parameters

The crane is bolted to a pipe extension, which is a 36 in OD pipe with a height of 56 in and a thickness of 1/2 in. Figure 29 shows the location for the crane pipe extension. Considerable supports are used to ensure that the forces from the crane are distributed into the supporting structure. These pipe extension supports consist of four large gussets and a 1 in thick plate. The pipe will be welded to the gussets and to the plate. And the plate will be welded to the structural members.

The new beam layout, shown in Figure 29, helps distribute the load from the crane by increasing the size of the beams and adding crossbeams. All the beams immediately surrounding the plate are sized as W12x170. W12x170 beams are considerably larger than the W14x48 beams and are able to sustain 4 times larger the moment; Due to this reason, W12x170 beams are expected to incur most of the load from the crane. The W14x48 beams are used to transfer and distribute the loads from the W12x170 beams into the structure.

FEA Analysis

In order to analyze Design III, SolidWorks (SW) FEA Static Simulation was used. Team CraneWorks decided to use SW due to its small learning curve yet accurate results. The first stage of the FEA analysis was to construct the plate as a solid model. SW Toolbox was used to model the structural beams. The LRFD was used to determine the correct coping and connecting method for the structural beams. Detailed drawings for the structural beams can be seen in the Final Assembly Drawings section of the report.

The crane pipe was modeled as an FEA beam model. The beam model was chosen so the maximum overturning moment from the crane and the maximum axial force can be applied to the center of the crane pedestal. The rest of the structure, except for the plate, was modeled as a beam members. All beam to beam contacts were modeled as joints. The pipe joint is bonded to the plate surface. The beam surfaces are bonded to the plate surface. The decision to make the plate contacts as bonded by contact was an assumption made by Team CraneWorks, however bonded by contact was not the only contact method considered. The use of welds was also considered, but the linear problem required iterative solutions that took a long time to run and sometimes failed to converge.

Fixtures were modeled as fixed due to recommendations from Audubon Engineering. The crane manufacturer provided Team CraneWorks with the maximum

overturning moment and the maximum axial force. These forces were applied to the crane pipe extension. Figure 30 shows where the fixtures and loads are located.

A curvature based mesh was used for the plate. The curvature based mesh creates more elements in higher-curvature areas of stress concentration automatically (without the need to apply mesh controls). Typically curvature based meshes do not need additional user applied mesh controls, and take less steps to achieve convergence. A standard mesh was also used but the von Mises stresses were less than the curvature based mesh, and the curvature based mesh had a small delta in stress convergence. However both the standard mesh and curvature based mesh results were very close to one another. A maximum mesh size of 2-inches and a minimum mesh size of 0.44-inches. Refinement at the plate edges was also applied. Also an element growth size ratio of 1.6 was used and the minimum number of elements in a circle is 8. The beams were modeled with 10 elements per beam. The mesh is shown in Figure 30. The mesh parameters are shown in Figure 31.

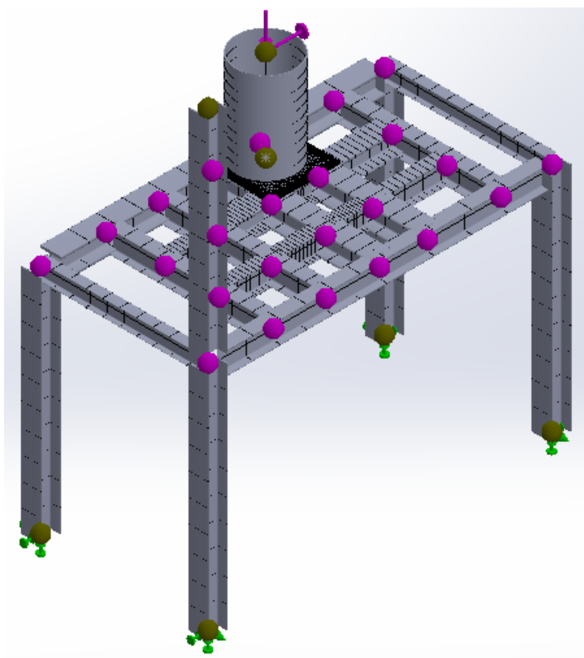

Figure 30: Structural Platform Mesh

Study name	Load+Wind (-Default-)
Mesh type	Mixed Mesh
Mesher Used	Curvature based mesh
Jacobian points	29 points
Jacobian check for shell	On
Mesh Control	Defined
Max Element Size	2.2 in
Min Element Size	0.44 in
Mesh quality	High
Total nodes	42362
Total elements	23934
Remesh failed parts with incompatible mesh	Off
Time to complete mesh(hh:mm:ss)	00:00:08
Computer name	

Figure 31: Mesh Parameters for all Cases

Team CraneWorks assumed there to be eight main cases that the structural members will encounter. These eight cases will be determined by the direction of the maximum overturning moment. The eight cases are for boom orientations of N, NE, E, SE, S, SW, W, and NW. The convergence characteristics can be observed for the case with maximum stress, SW. Only the results for this case are presented as this is the limiting case.

Figure 32 show the maximum von Mises stress for the solid mesh. Table 27 shows the maximum von Mises stress for varied element sizes. As the size decreases the stress increases and is shown to converge to a stress of about 50,742 psi. The maximum stress is below the yield strength of 54,000 psi.

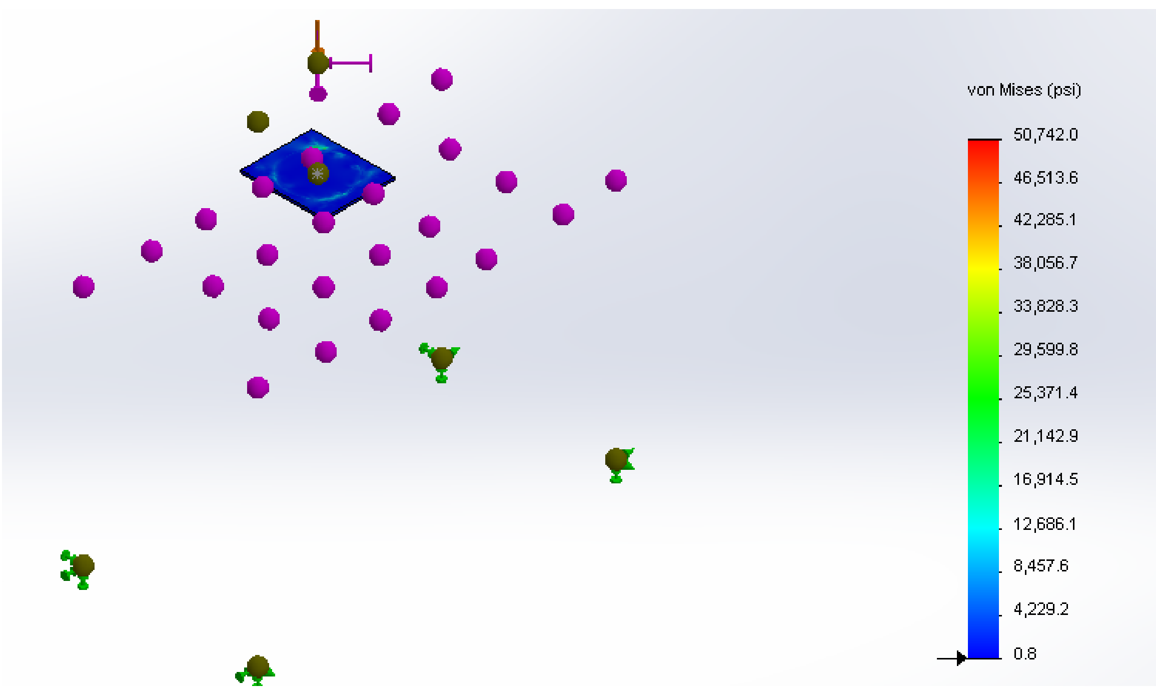

Figure 32: von Mises Stress Plot for Case with Max Stress

Max Element Size (in)	Min Element Size (in)	Max von Mises Stress (psi)
2.5	**0.50**	45,878.7
2.4	**0.48**	35,315.6
2.3	**0.46**	44,839.5
2.2	**0.44**	50,472.0

Table 27: Solid Mesh Convergence Proof for Case with Maximum Stress

Figure 33 shows the axial and bending stress plot for the beam mesh. Table 28 shows the convergence criteria. As the number of beam elements increases the stress decreases and is shown to converge to a stress of about 14,891.5 psi.

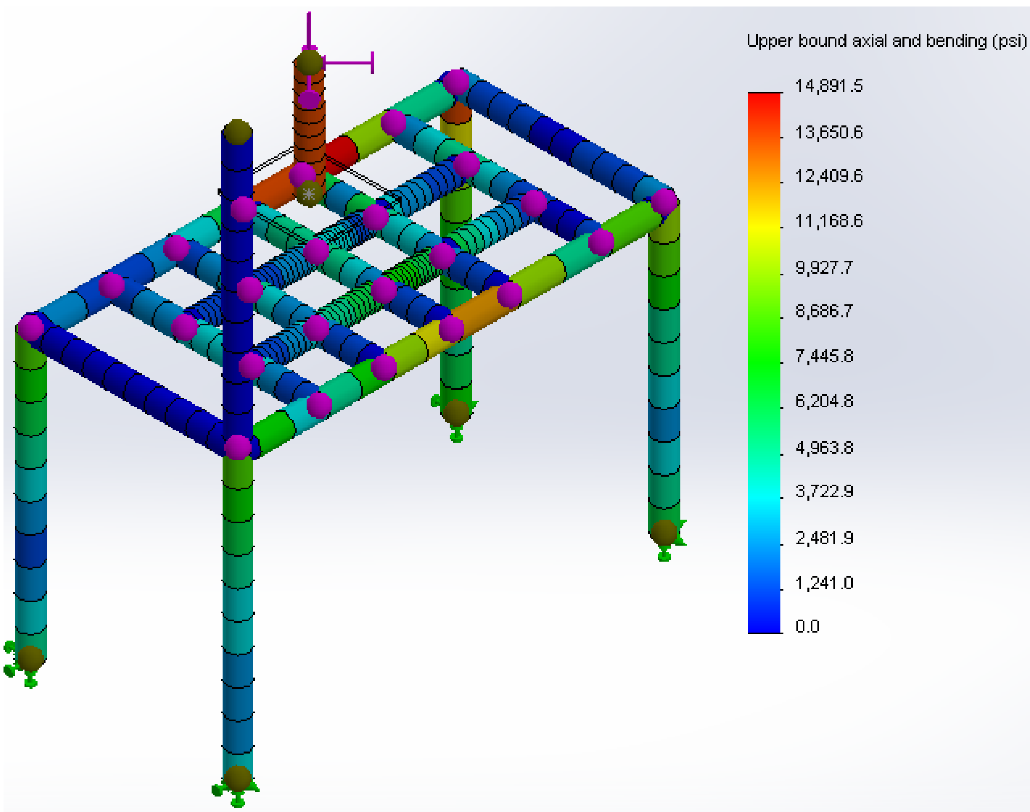

Figure 33: Max Stress Case – Beam Mesh

N	Max von Mises Stress (psi)
7	15,096.7
8	14,922.0
9	14,920.8
10	14,891.5

Table 28: Beam Mesh Convergence Proof for Case with Maximum Stress

The displacement plot is shown in Figure 34. This happens with the boom oriented south. Note that the maximum displacement occurs in the pipe, not in the structure. The maximum deflection in the structure is approximately 0.28 inches in the south beam. This is below the allowable deflection of 0.36 inches (span/540). The stresses and displacements for other boom orientations were also checked. The results show smaller stresses and displacements than the cases presented here.

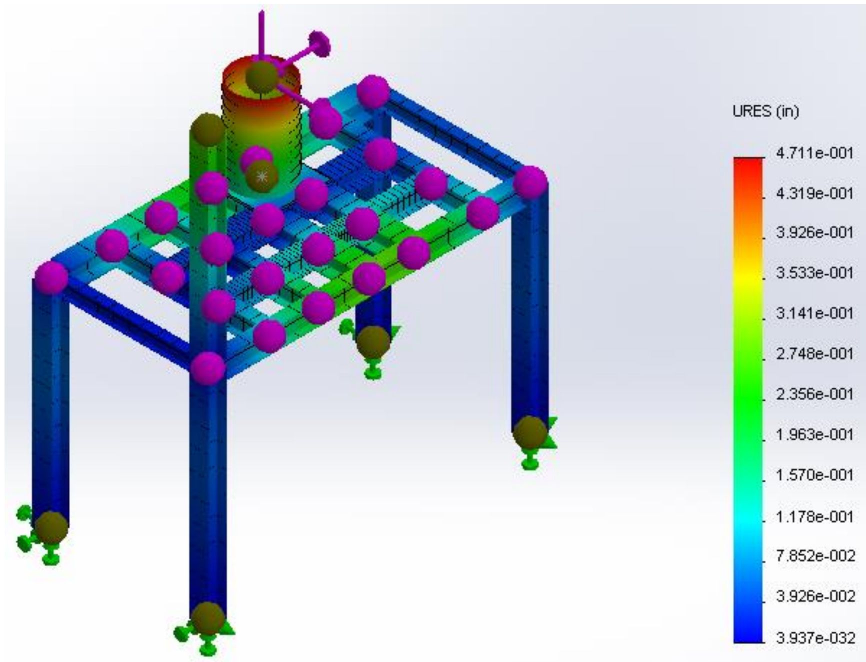

Figure 34: Max Displacement Plot

Pipe Buckling

The Crane will be mounted to a structural pipe that must withstand the forces from the crane. The crane boom and pedestal will be mounted to a 36-inch diameter steel pipe with a wall thickness of 0.50 inches, and a height of 8 feet. Equation 16 is used to determine the critical force that will buckle the pipe, and Equation 17 is the moment of inertia for the hollow pipe.

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

Equation 16

$$I = \frac{5}{4}\pi({R_o}^4 - {R_I}^4)$$

Equation 17

The top of the pipe is assumed to be free whereas the bottom of the pipe is assumed to be fixed. From the parameters listed, it was found that a force of 1,364,000,000 pounds would have to be applied for the pipe to buckle. The maximum axial load for the crane is 36,165 pounds, which is not close to the critical buckling force.

Weld and Connection Analysis

Plate Stress

The stress in the plate is found to have a maximum of 50,742 psi. This is calculated using the von Mises failure criteria using the maximum moment of all the loading conditions studied. The moment created a normal stress on the cross-section of the plate. There is also a transverse shear stress, but it is negligible (< 1,000 psi) compared to the normal stress. The minimum yield strength of the plate material must be 54,000 psi, which is greater than the 50,742 psi expected.

Crane to Plate Welding

Two main welding geometries are analyzed: welding of the crane pipe pedestal to the plate and welding of the plate to the beams. Fillet welds are used in the analysis. The analysis is based on that presented by Budynas and Nisbett.

The first step in the welding analysis is to determine the reactions at the base of the pipe with maximum crane loading conditions. The bending moment, *M*, is 6,259 kip-in and the compressive force, *P*, is 36 kips. At this location the base of the pipe is pure bending, there is no transverse shear and the primary shear stress in the welds is zero. The secondary shear stress in the welds is equal to the sum of the normal stress from bending and the compressive stress. This sum is a function of the weld leg size, *h*. The total shear stress in the welds is given in Equation 18. The radius of the pipe is denoted as *r*.

$$\tau = \frac{Mc}{I} + \frac{P}{A} = \frac{Mr}{0.707h\pi r^3} + \frac{P}{1.414\pi hr}$$

Equation 18

There are two criteria for fillet weld failure due to shear stress at the weld throat. The first criterion is that the shear stress must not exceed 3/10 of the ultimate tensile stress of the material in the weld electrode. The other criterion is that shear stress must not exceed 4/10 of the yield strength of the base metal. Using the lowest strength weld electrode (E60xx with S_{UT} of 62,000 psi) and the carbon steel with the lowest yield strength (SAE 1006 with S_y of 24,000 psi), the criteria indicates a maximum shear stress of 19,200 psi. This yields a minimum weld size of 0.67 in. Note that the failure criterion already includes a 1.4 factor of safety. Additional safety can be included if a better base metal and/or better weld electrode is used. The weld will be specified as an E70xx electrode with a leg size of ¾” to increase the factor of safety to 2.0.

Plate to Beams Welding

The total weld length must be calculated first and is found to be 130 inches for an all-around weld. A worst case scenario when the loads from the crane are supported by only two legs of the weld is assumed. In such a case, following the same procedure used for the pipe welding, with a different moment of inertia value, the weld size is found to be 1 inch for a weld length of 60 inches. This length is half the length of the worst case scenario. If a full length weld is used, the required weld size is reduced to 0.5 inches. An all-around weld size of 0.5 inch is specified to obtain a factor of safety of 2.0.

Beam Connection

The structural platform features two types of connections, welded frame beam connections and bolted frame beam connections. A detail for the platform connections is shown in Figure 35.

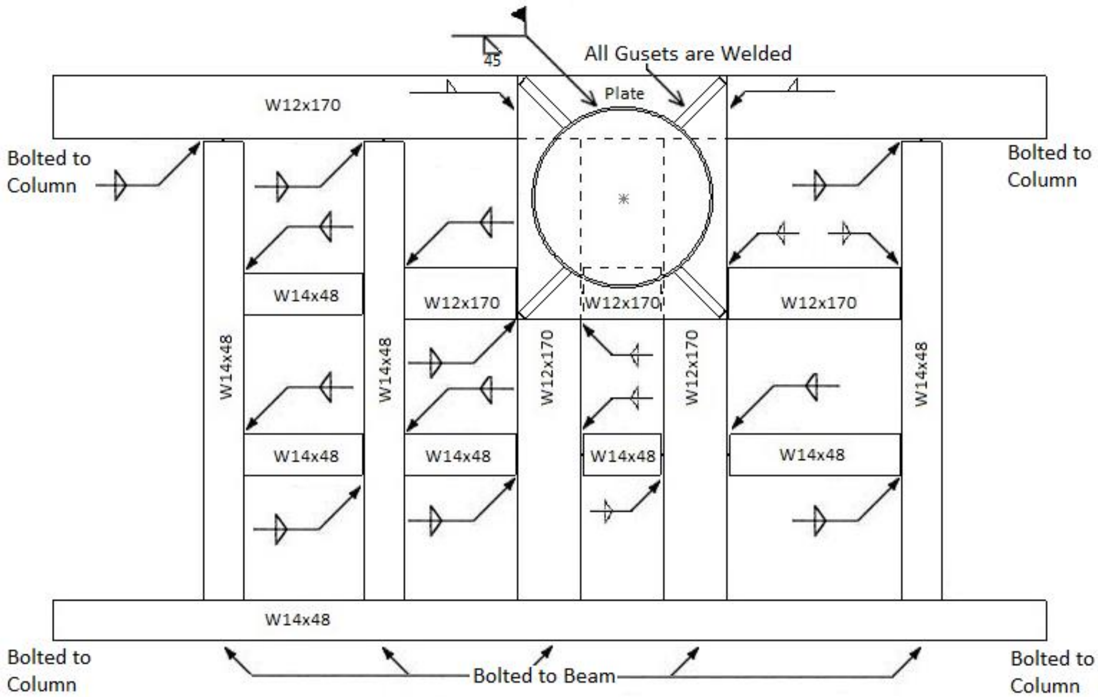

Figure 35: Map of Platform Connections

Beam Weld Analysis

As shown in Figure 35 There are multiple weld connections. There are three main framed beam connections; the W12x170 to W12x170, the W14x48 to W12x170, and the W14x48 to W14x48. Lindeburg lists the capacities and details for angle connections welded to both the beam web and the supporting member. Table 29 shows the framed beam connection for the three cases.

Frammed Beam Connection	Weld A		Weld B		Angle Length	Angle Size F_y=36ksi	Minimum Web Thickness for Weld A F_y=50 ksi
W Beam	Capacity Kips	Size in	Capacity Kips	Size in	in	in	in
W12x170 to W12x170	154	0.3125	96.5	0.375	9	3x3x0.5	0.5
W14x48 to W12x170	92	0.1875	64.4	0.25	9	3x3x0.3125	0.3
W14x48 to W14x48	102	0.1875	75.8	0.25	10	3x3x0.3125	0.3

Table 29: Framed Beam Connections

The L-angle has two weld connections, weld A and weld B. Weld A is welded to the beam web and weld B is welded to the supporting member. Figure 36 shows where weld A and B is located with respect to the structural member.

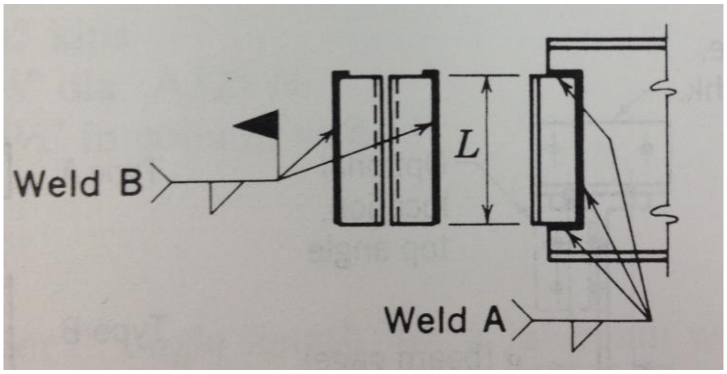

Figure 36: Framed Beam Connection for Weld A and B

Beam Bolt Analysis

The beam connections are all Type 2 according to the criteria presented by Lindeburg. These connections consist of two beams intersecting at a right angle and connect with an L-angle on each side that is bolted or welded to both the beams. Specifically, the current connections have the bigger beam bolted to the L-angles while the smaller beam is welded to the L-angles. On the AAA Unit the south W14x48 beam will not be changed, because of this the bolt locations from the previous W8x18 beam will be used.

Lindeburg refers the reader to the LRFD for the analysis of these connections. The analysis procedure can be found in Case I of Framed Beam Connections: Welded – E70xx Electrodes for Combination Connections (5-31). The required inputs are the dimensions of the smaller beam, the reaction force, the bolt diameter, bolt standard, and welding electrode. The outputs of the procedure are the angle length, angle thickness, number of bolts, and connection capacity.

The procedure yield the following results: The angles are specified as two L4 x 3½ x5/16 x 0'-8½." The bolts are specified as four ¾" diameter ASTM A325-N grade bolts and the welds are specified as ¼" fillet E70xx welds. The connection capacity is 72,000 pounds. All bolts are tightened to a pre-stressed level, which precludes relief of preload in the most heavily loaded fastener under any design load. All bolts shall be permanently marked with their fastener manufacturer's identification mark and ASTM material grade. From the FEA analysis the largest force on any bolted connection is 32,100 pounds, which less than the rated 72,000 pounds. The same procedure is repeated for all connections with the required angle sizes.

Column Analysis

The AAA Structure is supported by multiple W12x65 columns. Four structural columns connect directly to the crane platform. These connections are located at R1, R2, R3, and R4 as seen in Figure 37

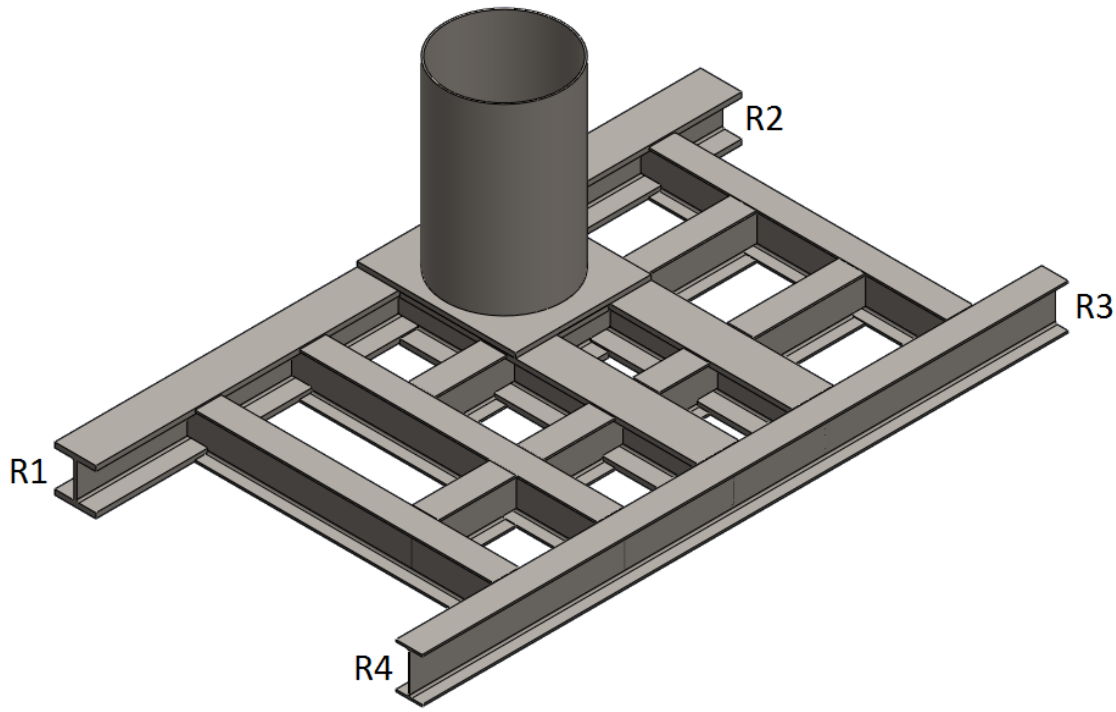

Figure 37: Crane Platform Connections to the Structural Columns

The reactions for each case is shown below. The maximum compressive reaction is 57, 300 pounds and the maximum tensile reaction is 33,100 pounds.

	R1 (lbs)	R2 (lbs)	R3 (lbs)	R4 (lbs)
Z axis CW	-11200	-19100	40600	25800
Z axis CCW	35200	54700	-33100	-20600
X axis CW	-27300	57300	7520	-1330
X axis CCW	51300	-21700	-1700	6520

Table 30: Reaction Values for each Case

Compression Columns

The basis of any column analysis is Euler's Column Formula, Equation 19, (Budynas & Nisbett, 2011). P_{cr} is the critical load that, when exceeded, will buckle the column. *A* is the cross sectional area of the column. *C* is the end constant, which is dependent on how the column is supported at the ends. *E* is Young's modulus and l/k is the slenderness ratio. To determine whether the column can be modeled using Equation 19, the critical slenderness ration $(l/k)_1$ needs to be determined. Using a criteria of P_{cr}/A equal to half the yield strength, $(l/k)_1$ is found using Equation 20.

$$\frac{P_{cr}}{A} = \frac{C\pi^2 E}{(l/\mathrm{k})^2}$$

Equation 19

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

Equation 20

Using a C of 0.25, a S_y of 24,000 psi, and an E of 29,000,000 psi, the critical slenderness ratio is found to be 77.22. This number is compared to the slenderness ratio of the columns in the structure. From the geometry of the columns, their slenderness ratios are calculated to be fewer than 77.22 for both cross-sectional axes. Therefore, these columns do not fall under the envelope of Equation 19.

The appropriate analytical model is Johnson's Formula. For the same criteria used in Equation 20, Johnson's Formula is shown in Equation 21.

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

Equation 21

The critical load was found to be 429,000 lbs. The highest compression load was found to be 57,300 lbs. distributed in two columns. Therefore, in any single column the load applied is about 13.4% of the critical load of the column. Therefore the columns are deemed to be safe for placing the crane in the 7^{th} floor.

Tension Columns

The maximum tensile force in the columns is 33,100 lbs. The columns are all W12x65 with a cross-sectional of 19.1 in^2. This gives a stress of 790 psi for the highest tension column. The minimum yield strength of structural steel under industry standards is 50,000 psi. Therefore the columns are safe.

Wind Analysis

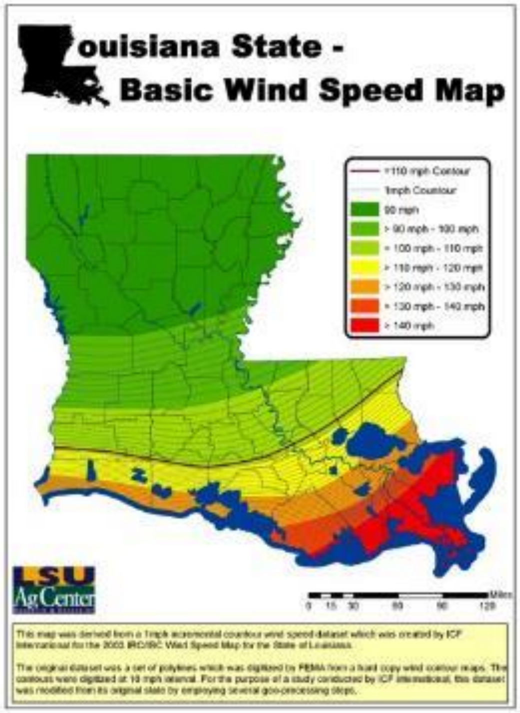

Figure 38: Louisiana State-Basic Wind Speed Map (Wind Speed and Elevation Map)

Being on the Gulf Coast, Taminco is subject to hurricane force winds that have to be accounted for in the crane design. Taminco requires all buildings to be designed for 120 mph at their facility, which is within API 2C standards. The wind speed that is common to the area is displayed in Figure 38 with a wind speed of 120 mph. For the design criteria a wind speed of 125 mph is counted for the 10mph intervals.

The basic design can be broken down into two cross sectional areas, which are known as the boom and pedestal. The exact surface area was determined by the use of the solid modeling. The area seen by the wind is shown in Figure 39, the shape coefficient is also noted.

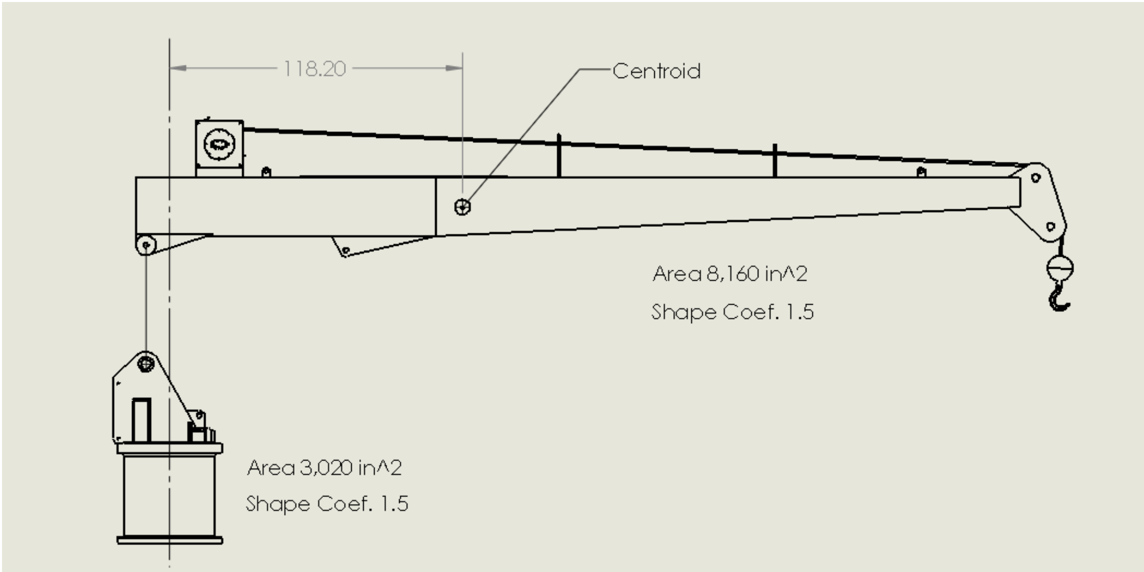

Figure 39: Crane Surface Area and Shape Coefficients

The basic equation comes from the Bernoulli Principle of incompressible viscous flow and neglects the end effects of the models shown as Equation 22 with F_D as Force of Drag, C_D as the coefficient of drag, ρ as air density, A as the area normal to the wind velocity and V as the wind velocity (Pritchard & Leylegian, 2011).

$$F_D = C_D A \rho \frac{1}{2} V^2$$

Equation 22

Other assumptions that are used include atmospheric conditions during a Category 3 hurricane including temperature and atmospheric pressure as well as assuming ideal gas properties of air. Referencing the sample calculations in the Appendix and subsequent assumptions, the force calculations are for minimum and maximum forces for maximum area normal to flow. These are shown in Table 31. Note that the maximum force is calculated assuming a flat plate for the components.

Geometry	Force	Total Maximum Force
Boom	2875 lbs	3947 lbs
Cylinder	1072 lbs	

Table 31: Wind Loads

From the results one can see that the boom is responsible for most of the forces on the crane due to the wind pressure. These wind pressures would create a moment on the crane itself however these moments that would be created by the wind are much lower than the moments the crane would be putting on the structure when lifting the design load so the wind will have a negligible effect on the structure from the crane. This was checked by applying the wind loads to the FEA model presented earlier. The stresses and displacements on the boom rest and the structure were indeed found to be negligible. For wind forces during operation, API 2C calls for 60 mph winds. These forces were already applied to the FEA model presented earlier and thus their effect has already been quantified in the operating loads that the crane imposes on the structure.

One concern with the wind during a hurricane is to make sure the crane is properly secured. Taminco will need to provide a hurricane plan to secure the crane in place for a storm. If the crane isn't properly secured to the boom rest, the hook and wench system could sway and damage other equipment on the structure. To prevent the boom from swaying with the wind, a tie down point on the boom rest will be provided.

Dynamic and Fatigue Analysis

According to API 2C, the dynamic loading effects of raising, lowering, and swiveling the load is included with a 1.33 factor of safety for cranes on fixed platforms. This same factor of safety can be included in the supporting structure. The calculations shown include a minimum factor of safety of 2.0 for all components in the structure. The calculations, therefore, fully account for the dynamic loading effects on the structure.

Another important aspect covered in the API 2C and API RP 2A codes is the fatigue safety factor for the supporting structure. API 2C states that an additional 1.5 factor of safety must be added to the supporting structure, giving a total factor of safety of 2.0. API RP 2A states that a factor of safety of 2.0 can be used for the supporting structure as well. In any case, Taminco will only use the crane approximately five to six times a year. Therefore fatigue is not considered to play a factor over the operational lifespan of the crane.

Crane Boom Rest Engineering Analysis

Location and Functionality

A critical part of the crane is the boom rest. The boom rest is needed to support the weight of the boom while the crane is not in operation and secure the boom in inclement weather. The boom rest will be located on the west side of the 7th floor, shown in Figure 40.

The west side of the 7th floor is ideal based on the fact that the boom will not interfere with any of the surrounding equipment and it will allow Taminco personnel easy access to the boom tip for maintenance. Note that the tip is overhanding the far west side of the AAA unit however during periods of service scaffolding will be installed to reach the tip. The east side of the 7th floor was considered which would allow the boom tip to be within the confines of the AAA unit however there was not a clear location for the rest to easily support the boom.

In addition to supporting the boom in inclement weather, the rest allows the crane's hydraulics to relax and releases the loading on the hydraulic cylinder. The boom rest is also designed to withstand wind loadings during hurricanes.

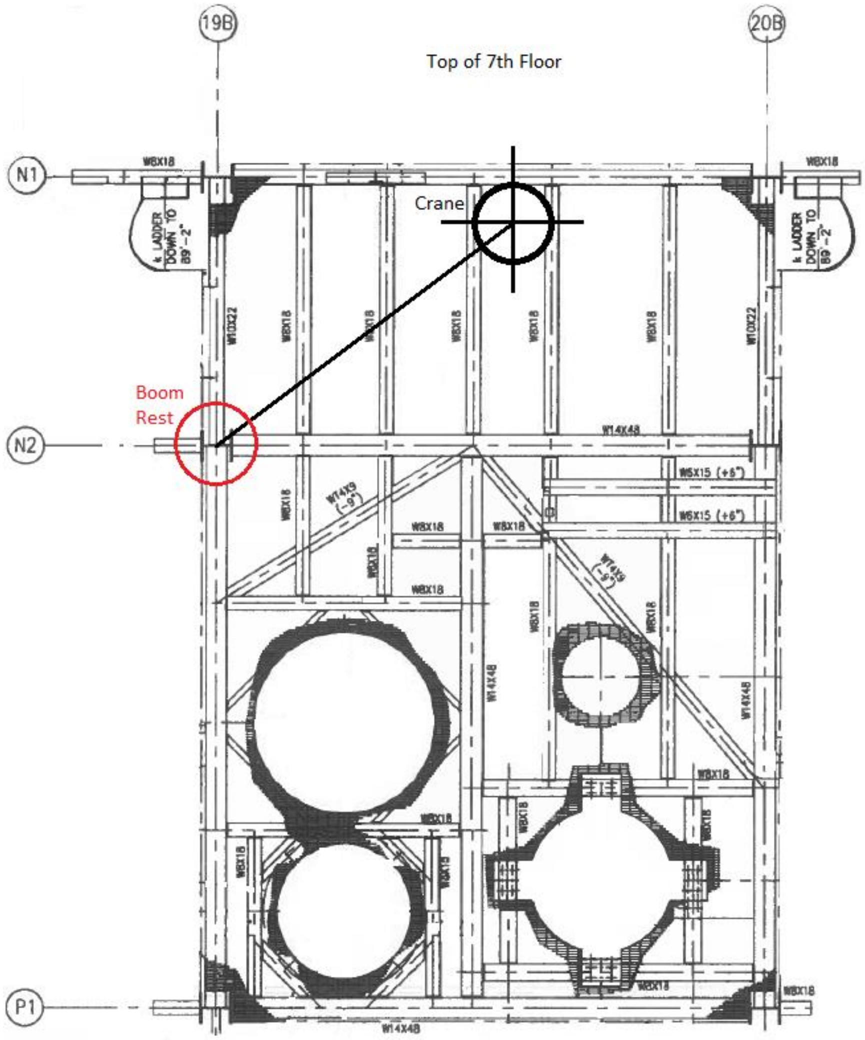

Figure 40: Location of Boom Rest With Respect to the 7th Floor

Boom Rest Engineering Analysis

The location of the boom rest with respect to the crane is shown in Figure 41 as well as the centroid of the crane. The weight of the boom and the wind force occur at the centroid. The values for the weight of the boom and the wind force are shown in Figure 41 as well as the respective distances. Note that the design force is the resulting reactions to the boom rest from the 125 mph wind on the crane boom and pedestal.

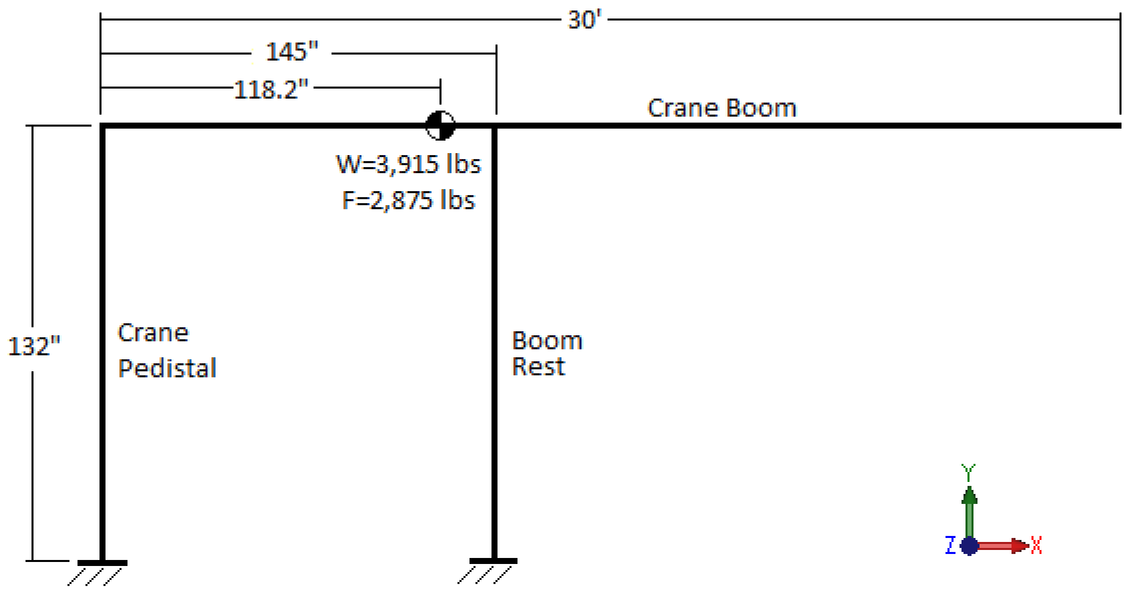

Figure 41: Crane and Boom Rest Model

Using summation of moments the forces acting on the boom can be determined. The forces acting on the boom rest are shown in Figure 42. The boom rest consist of a W12x65 beam, a boom rest, and two connecting plates. The boom rest extends from the existing W12x65 columns on the AAA unit. The steel plates are used to bolt boom rest to the existing W12x65 columns. A compression analysis was done to ensure the column will not buckle under the weight of the boom, however the applied load is less than 1% of the critical load of the column. Next the steel plates need to be analyzed, where SW static FEA analysis was used. The boom rest was modeled as a FEA solid model. The boom rest was modeled as bonded by contact and bolt connections were used on the plates. A standard 3/4 in steel bolt was used and was set to a torque of 80 ft-lbs. Also a W12x65 column stub was used to bolt the boom rest to the structure. An infinitely fixed geometry was used for the W12x65 column stub.

A curvature based mesh was used for the boom rest analysis. A maximum mesh size of 2 in and a minimum mesh size of 0.4 in was used on the structural members as well as the plate and gussets. Also an element growth size ratio of 1.1 was used. The parameters for the curvature-based mesh are shown in Figure 43.

Figure 42: Force on Boom Rest

Study name	Study 1 (-Default-)
Mesh type	Solid Mesh
Mesher Used	Curvature based mesh
Jacobian points	4 points
Max Element Size	2 in
Min Element Size	0.4 in
Mesh quality	High
Total nodes	303309
Total elements	166375
Maximum Aspect Ratio	8.8785
Percentage of elements with Aspect Ratio < 3	95.4
Percentage of elements with Aspect Ratio > 10	0
% of distorted elements (Jacobian)	0
Remesh failed parts with incompatible mesh	Off
Time to complete mesh(hh:mm:ss)	00:00:15
Computer name	

Figure 43: Mesh Parameters for Boom Rest

Figure 44 show the von Mises stress plot for the boom rest. Table 32 shows the maximum von Mises stress for varied minimum number of elements in a circle, N. As N increases the stress increases and is shown to converge to a stress of about 14,960 psi. The maximum stress is seen to occur in the W12x65 column. The bolt holes and the plate are proved to work.

N	Max von Mises Stress (psi)
4	13,908.8
8	14,633.3
16	14,957.0

Table 32: Convergence Proof for Boom Rest Design

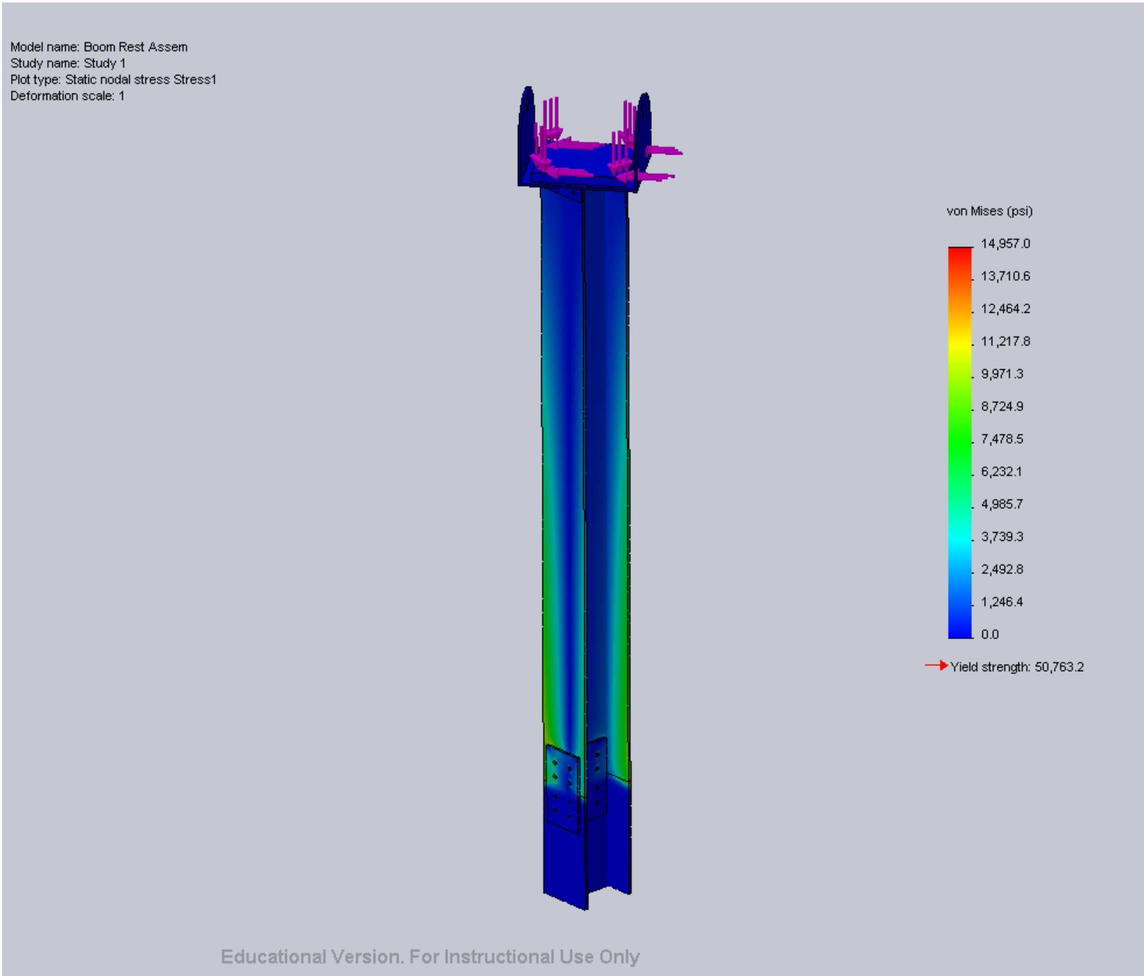

Figure 44: Boom Rest von Mises Stress Plot

Material Selection

Team CraneWorks' primary responsibility is the selection of the plate and beam materials as well as the welding electrode. The crane itself is certified based on API 2C standard and is designed to withstand outdoor marine conditions. It is the crane manufacturer's responsibility to comply with the standards set in the API 2C code.

Based on the result of stress analysis, the material selected for the plate is ASTM A572, which has a yield strength of 54,000 psi. The beam material requirement, by standards, is the ASTM A36 grade. Replacing the beams in the unit to the larger sized means that the new beams will need to comply with current standards, which specify a grade of ASTM A992. Since there will be extensive welding on the new beams, all the processing will be done in the machine shop. After welding, the partially completed structure (including the beams, the plate and the lower pipe) will be sent to a 3rd party for galvanization.

All the welding calculations performed in the previous section assumed an E60xx electrode, and it has been proven that E60xx can provide enough strength at the connection. However, based on AISC, E70xx electrode is required for the beam connections on

structures. Therefore, the stronger E70xx weld electrode to be used in all welding operations.

Final Assembly Drawings

The final manufacturing drawings and assembly drawings are attached in the Design III Manufacturing Drawings section.

General Manufacturing and Assembly

Taminco reached a definite decision on a crane vendor on February 25th based on the crane requirements, price, and lead-time of the crane. EBI is the crane vendor of choice and an official purchase order wasn't processed until March 12th. EBI requires an eight-week lead time for the crane to arrive at Taminco's facility. Meanwhile, structural modifications to the structure can be made.

From Team CraneWorks' engineering analysis, the current structure's beams will not be able to support the crane loading. Though Design III is based off of Audubon's recommendation, the final design that is implemented will ultimately be the design Audubon creates and stamps. Team CraneWorks and Audubon are in the process of creating a scope of work for the contractors. Once the scope of work proposal is completed, Team CraneWorks and Taminco will hold a meeting with various contractors and discuss the scope of the project and ask the contractors for their bids. Taminco will then select the contractor that will complete the work discussed.

The scope of work proposal will explain, in detail, all the work expected as well as what supplies the contractor must provide. Taminco will supply the installation crane, the EBI crane, steel plate, beams, nuts, and bolts. The contractor will be expected to supply anything extra in order to complete the job; this may include paint, tools, some metal, and welding supplies. Since time is of the upmost importance, the contractor with the shortest lead-time will be heavily considered compared to any others.

Team CraneWorks will have the opportunity to go onsite to EBI's facility and witness nondestructive weld testing and their Factory Acceptance Test. Here the team will gather a first hand experience on crane manufacturing and see the machinery involved with the process.

Team CraneWorks will have to be in constant communication with the contractor as well as Taminco's maintenance and operations personnel during the planning and installation period. Before any modifications can be made to the structure, a lift plan will have to be set by Taminco in place to be able to bring all of the pieces of equipment to the top most deck so proper safety procedures can be followed. The first thing that will have to be done will be to remove all grating from the specific beams. Also any pipe racks that hang from any beam being removed will have to be braced and supported from the floor below. Once all the beams are clear of these attachments, they will be unbolted from their supports and lowered to the ground.

In order to mount the EBI crane all structural modifications must be finished. This includes the welding and bolting of the all the replacement beams along with the plate welded to the W12x170's. An installation crane will lift the EBI crane and place it on top of the plate. From here, onsite contractors will weld the pedestal extension to the flat steel plate.

The next item that needs to be lifted is the control unit along with the hydraulic power unit. Prior to this lift, all of the hydraulic lines will be piped along the deck to where the reservoir, crane, and remote station will be positioned. The electrical wiring will all have to be Class I Division II with a certified electrician to wire crane into the onsite electrical power grid. Note that Taminco will install the necessary 480VAC power line before the assembly is installed. Once the hydraulic equipment is in place the boom rest will be lifted and bolted to the AAA unit. Once the entire grating is in place the boom will be lifted and pinned to the crane pedestal.

Safety Considerations

Safety is the priority of the design; it plays a vital role in the assembly and the testing phases of the project. For the design, API 2C standards are followed for physical apparatus and OSHA standards are adopted for both personnel and operation safety. API 2C details the requirements for design, construction, and testing of pedestal-mounted cranes. Contractors will complete the crane manufacturing and will therefore take on the responsibility of adhering to all relevant safety standards. Team CraneWorks will be overseeing the manufacturing process to ensure all standards are being followed. Team CraneWorks will have to rely on Taminco or the contractor to supply all required Personal Protective Equipment (PPE) when onsite. All design elements in the supporting structure of the crane have a safety factor of at least 3 built in to comply with API standards. Personnel must be trained through the crane manufacture and have at least two people (one operator and one spotter) to operate the crane at all times. Safety must also be considered when transporting the raw materials to the St. Gabriel plant; all road safety standards must be followed at all times during transportation.

Testing Plan

During the testing phase, 3 major testing phases will be conducted: Factory Acceptance Testing (FAT), structural testing, and operation testing. The crane manufacturer is responsible for the FAT, but Team CraneWorks will be on site during the testing to record all the testing results and processes. After the construction of the structure, non-destructive testing will be conducted on connections and weld surfaces. The first step will be a visual inspection to see if there are any obvious cracks and surface breaches. Then both ultrasonic testing and magnetic particle testing will be applied for further intrinsic analysis. The operation testing of the design will occur after the final installation of the crane and all supporting members. Following is an outline for the operation testing:

1. Pre-test Procedures

- Check that an operators manual is available for the crane and review for operational limitations.
- Check that all lifting attachments are clearly marked with their safe working load.
- Review previous test and inspection certificates, wire rope inspections, and deficiency reports and determine that any necessary corrections have been made.
- Inspect the crane in its entirety according to the checklist normally used for that type of crane.

- Conduct a visual examination of the crane, power unit, and operator's station prior to commencing the test.
- The crane should be operated without a load through its full range of operation and all safety devices and limit switches should be checked.

2. Load Test

- Lift the rated load to a height of 4-8 inches above the ground. Check crane visually.
- Raise the rated load approximately five feet above the ground. With the hoist controller in the neutral position, release the holding brake. The load controlling device should control the load. With the holding brake in the released position, start the load down slowly and then return the controller to the off position as the test load is lowering. The load controlling device should prevent the load from accelerating.
- In order to test the reaction of the hoist unit in the event of power failure during a lift, hoist the rated load to a convenient distance above the surface. Lower the load at high speed and, with the controller in the lowering position, disconnect the main power source. The test load should stop lowering when the power is disconnected.
- Increase the test load to 125% of rated load to achieve the proof load. While handling the proof load, operate the crane at speeds appropriate to the safe operation and control of the load.

3. Post-test Inspection

- After the tests are completed, conduct a thorough examination to ensure that the crane has satisfactorily withstood the tests. Park the crane at the proper location for service access and relax all rigging and reeving to allow for inspection of the wire rope and reeving components.
- Check all components of the crane for structural damage including cracks, weld separation, permanent deformation, paint flaking and loose fasteners.
- Check the crane and runway electrical components for deterioration and proper condition. Verify the integrity of wiring, connections and enclosures, checking for neatness, security and conformance to appropriate electrical codes.

Once all tests are completed the crane can be certified commissioned and Team CraneWorks would have completed all of Taminco's deliverables.

Budget, Project Schedule, and Timeline

The proposed budget is detailed in Table 33. The crane cost is the largest component of the budget. This is the cost specified in the quote from EBI. The price of the beams, steel plate, bolts, and boom rest materials come from personal contact with steel vendors. The labor costs are estimates that will be finalized in the contractor bids. The allocated budget for this project was $300,000. The installation crane rental is not included because Taminco has two of these cranes on-site.

Item	Quantity	Cost/Unit	Total Cost
EBI Crane	1	$88,806.00	$88,806.00
Audubon Engineering	1	$65,000	$65,000
W14X90 18’	1	$645.00	$645.00
W12X170 9’	4	$322.00	$1,288.00
Steel Plate	1	$2,800.00	$2,800.00
Bolts	1	$250.00	$250.00
Boom Rest Materials	1	$10,000.00	$10,000.00
Hydraulic lines (ft)	15	$10.00	$150.00
Welders (hrs)	30	$70.00	$2,100.00
Welding Supplies	1	$500.00	$500.00
Electricians (hrs)	30	$70.00	$2,100.00
Fabricators (hrs)	20	$70.00	$1,400.00
Total Cost			**$175,039.00**

Table 33: Budget

The following timeline is a schedule of the major tasks and milestones. This timeline is divided between the Fall and Spring semester, Figure 45 and Figure 46 respectively. One can deduce that for the Fall semester the project focus is on the mechanical design process and analysis on the proposed design. The Spring semester involves construction, implementation, testing, and ultimately commissioning the crane.

The major milestones completed include a final list of engineering specifications, selection of a crane design, engineering analysis, development of a manufacturing plan, and full assembly drawings.

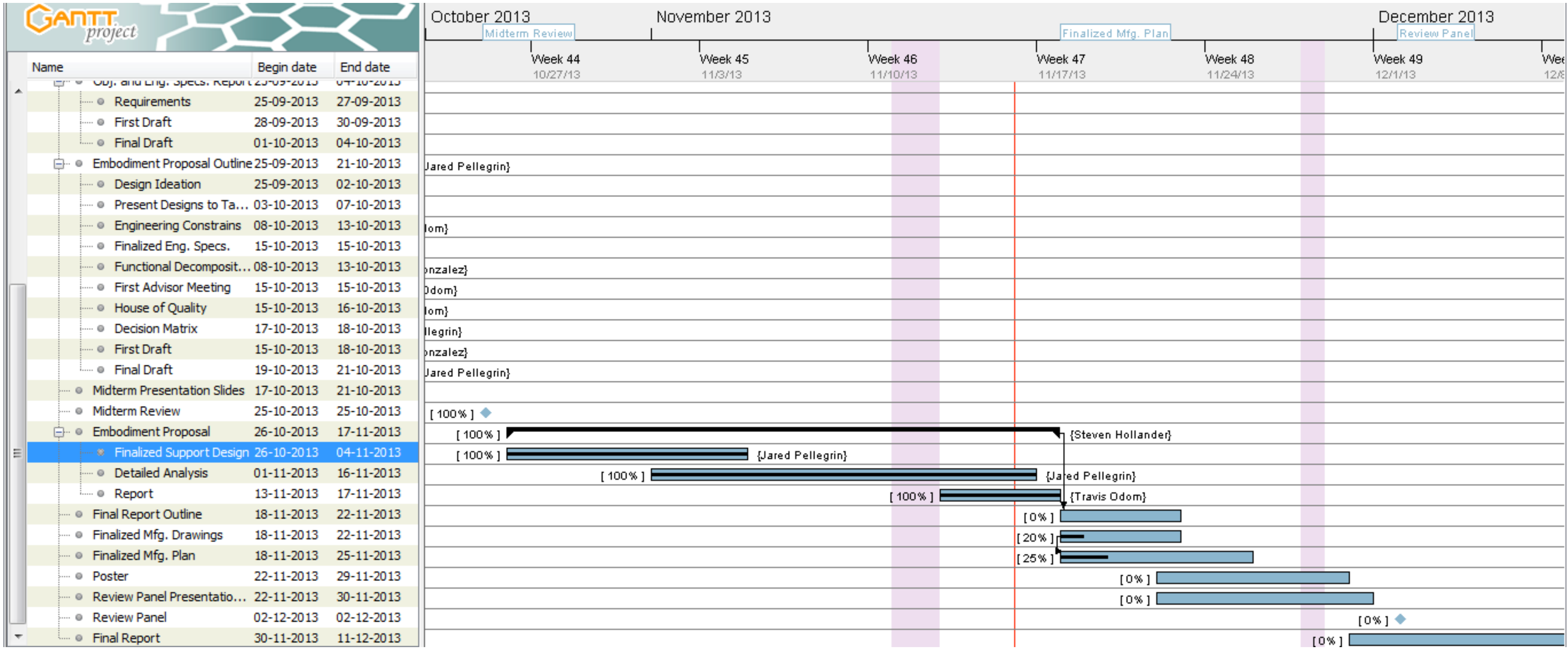

Figure 45: Timeline for Fall Semester

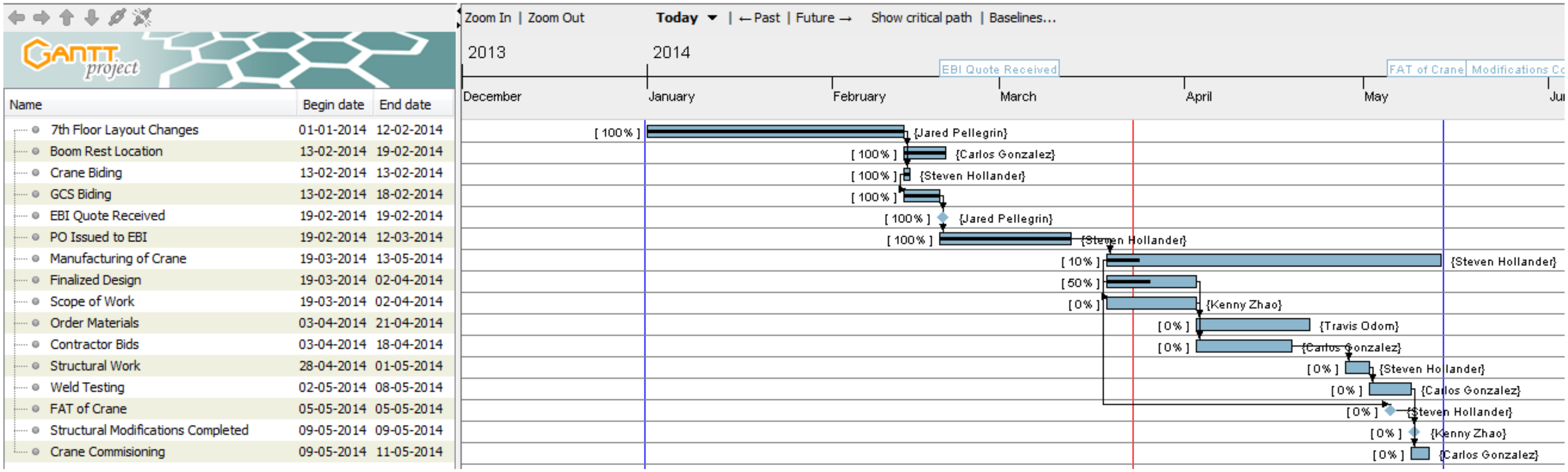

Figure 46: Timeline for Spring Semester

Prototype Design

Due to the lack of funding necessary for timely completion of the project, it was decided on March 25th to design, build, and test a proof of concept prototype at LSU. The report up to this point details the design and future manufacturing plans for the installation of the crane on Taminco's AAA Unit. From this point forward, the report specifies the design, manufacture, and testing of the prototype whose responsibility is solely Team 22's.

The purpose of the prototype is to adequately scale down the full size model and simulate the expected loads and moments on the scaled structure. The modified structure is the focus of the design; the crane being modeled as only a device to transfer loads.

Crane and Platform Scale Model

In order to meet realistic geometric and monetary constraints, a scale of 20% of the modified section of the 7th floor is proposed. At 20%, a geometric footprint of 20.4"x42" is required for the structure. Due to the geometric constraint, only Team 22's structural modifications will be modeled versus a global perspective of the AAA unit. Through research, no structural beams are available based on the scaled geometrical and second moment of area requirements. Therefore, steel bar stock will be considered and used to replace all wide flange beam modifications. Note that this geometric change of steel members will change the magnitude and location of the stress concentrations. The scaled model will have the same steel member layout as the full-scale design. With the second moment of area in both cross sectional axes being properly scaled down, the structural integrity of the full-scale design will be maintained. At 20% scale, all the connections will be welds due to size limitations of the bar stock. Consequently, this will not adequately represent the connections on the full-scale model, which includes both weld and bolt connections. The base will be made of concrete, designed to counteract the overturning moment of the crane, and will have rebar attachments for a forklift to maneuver the structure. The prototype is shown in Figure 47. The crane will not be scaled to strictly to 20% since it only serves to transfer the static and dynamic loads to the structure.

The 20% scale was chosen because of several reasons. The material is readily available at a price within the allocated budget. The bar stock is large enough to handle comfortably but not large enough to require an overhead crane for lifting the bar stock. The size of the bar stock is large enough so that the necessary welds can be easily welded in-house without the need of specialized equipment or personnel. The larger bar stock at 20% scale will also suffer a smaller heat affected zone relative to the size of the stock than a smaller scale. Furthermore, the price for the material for a 10% and a 15% scale did not change appreciably compared to the price for the materials for a 20% model.

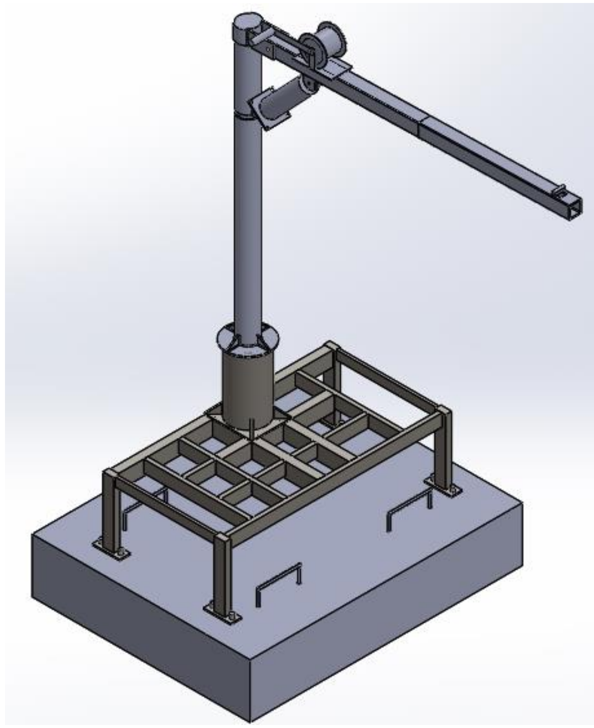

Figure 47: Prototype Design

FEA Analysis

In order to analyze the prototype design, SolidWorks (SW) FEA Static Simulation was used. The first stage of the FEA analysis was to construct the parts as solid models. Note that static simulation is used with the required API safety factor of 3.0 times the Safe Working Load (SWL) therefore no dynamic analysis is required as it is already covered in this safety factor. Square bar stock was modeled and used as the structural members for the prototype. Detailed drawings for the scaled square bar stock can be seen in the Prototype Design Manufacturing Drawings section of the report.

The crane pipe was modeled as an FEA beam model. The beam model was chosen so the maximum overturning moment from the crane and the maximum axial force can be applied to the center of the crane pedestal. The rest of the structure, except for the plate, was modeled as a beam members. All beam to beam contacts were modeled as joints. The pipe joint is bonded to the plate surface. The beam surfaces are bonded to the plate surface. The decision to make the plate contacts as bonded by contact was an assumption made by Team CraneWorks, however bonded by contact was not the only contact method considered. The use of welds was also considered, but the linear problem required iterative solutions that took a long time to run and sometimes failed to converge.

Fixtures were modeled as fixed, as in Design III. The maximum overturning moment and the maximum axial force for the full scale model were appropriately scaled. These forces were applied to the crane pipe extension.

A curvature based mesh was used for the plate. The curvature based mesh creates more elements in higher-curvature areas of stress concentration automatically (without the need to apply mesh controls). Typically curvature based meshes do not need additional user applied mesh controls, and take less steps to achieve convergence. A standard mesh

was also used but the von Mises stresses were less than the curvature based mesh, and the curvature based mesh had a small delta in stress convergence. However both the standard mesh and curvature based mesh results were very close to one another. A maximum mesh size of 0.44-inches and a minimum mesh size of 0.-inches. Refinement at the plate edges was also applied. Also an element growth size ratio of 1.6 was used and the minimum number of elements in a circle is 8. The beams were modeled with 10 elements per beam. The mesh is shown in Figure 48. The mesh parameters are shown in Figure 49.

The scale factor, *s*, is equal to 0.2. Concentrated forces are scaled by a factor of s^2, moments are scaled by a factor of s^3, and second moments of area are scaled by a factor of s^4, according to (Harris, 1980) and (Ghosh, 2011). The loads are shown in Table 34.

Scaling Factor	Original API Max Overturning Moment (in-lbs)	Scaled API Max Overturning Moment (in-lbs)	Original Maximum Axial Load (lbs)	Scaled Maximum Axial Load (lbs)
0.2	6,259,752	50,078	36,165	1,447

Table 34: Load Scaling

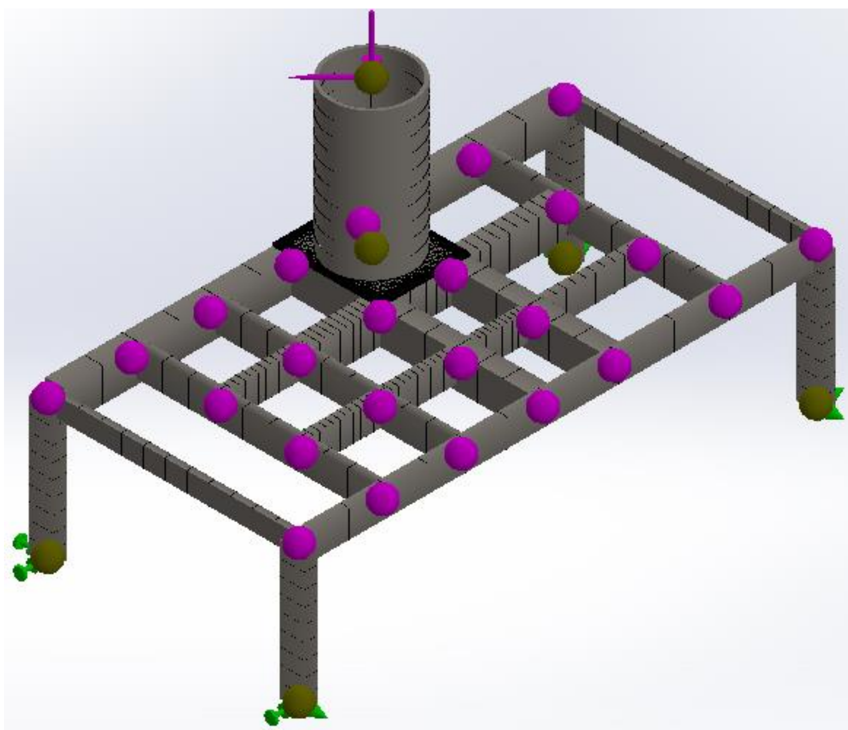

Figure 48: Mesh for the Prototype

Study name	Load (-Default-)
Mesh type	Mixed Mesh
Mesher Used	Curvature based mesh
Jacobian points	29 points
Jacobian check for shell	On
Mesh Control	Defined
Max Element Size	0.44 in
Min Element Size	0.088 in
Mesh quality	High
Total nodes	44501
Total elements	25089
Remesh failed parts with incompatible mesh	Off
Time to complete mesh(hh:mm:ss)	00:00:05
Computer name	[illegible]

Figure 49: Mesh Parameters for Prototype

Team CraneWorks assumed there to be eight main cases that the structural members will encounter. These eight cases will be determined by the direction of the maximum overturning moment. The eight cases are for boom orientations of N, NE, E, SE, S, SW, W, and NW. The convergence characteristics can be observed for the case with maximum stress, SW. Only the results for this case are presented as this is the limiting case.

Figure 50 shows the maximum von Mises stress for the solid mesh. Table 35 shows the maximum von Mises stress for varied element sizes. As the size decreases the stress changes and is shown to converge to a stress of about 31,570.9 psi. The maximum stress is below the yield strength of 54,000 psi.

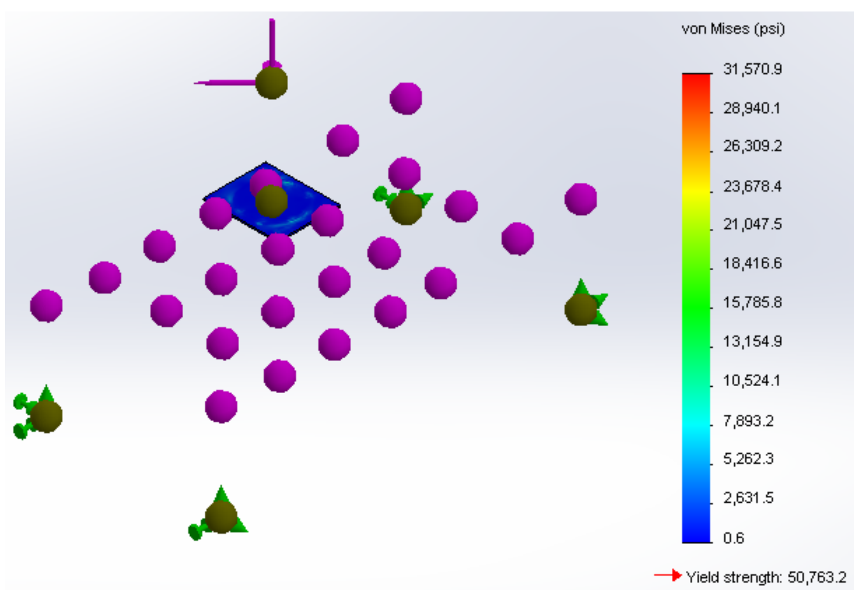

Figure 50: Prototype von Mises Stress Plot for Case with Max Stress

Max Element Size (in)	Min Element Size (in)	Max von Mises Stress (psi)
0.5	0.1	25,608.7
0.48	0.096	32,812.7
0.46	0.092	31,937.7
0.44	0.088	31,570.9

Table 35: Prototype Solid Mesh Convergence Proof for Case with Maximum Stress

Figure 51 shows the axial and bending stress plot for the beam mesh. Table 36 shows the convergence criteria. As the number of beam elements increases the stress decreases and is shown to converge to a stress of about 4,218.8 psi.

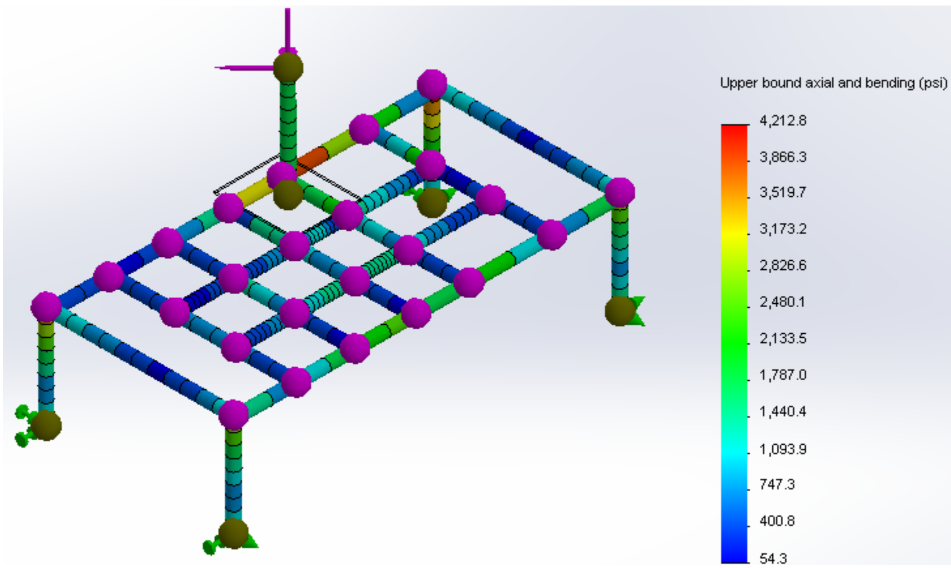

Figure 51: Prototype Max Stress Case – Beam Mesh

N	Max von Mises Stress (psi)
7	4,157.6
8	4,195.2
9	4,210.5
10	4,218.8

Table 36: Beam Mesh Convergence Proof for Case with Maximum Stress

The displacement plot is shown in Figure 52. This happens with the boom oriented south. Note that the maximum displacement occurs in the pipe, not in the structure. The maximum deflection in the structure is approximately 0.013 inches in the south beam. This is below the allowable deflection of 0.075 inches (span/540). The stresses and displacements for other boom orientations were also checked. The results show smaller stresses and displacements than the cases presented here.

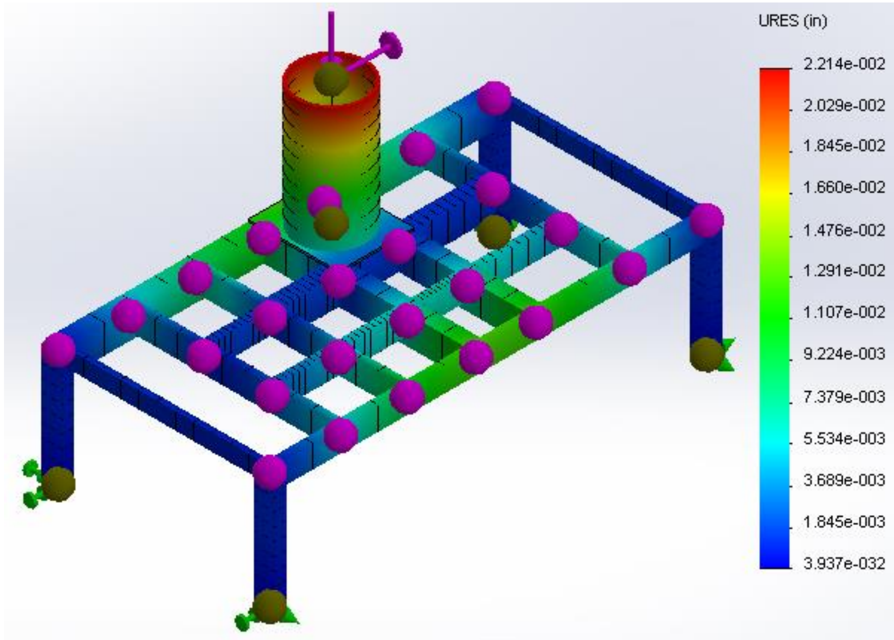

Figure 52: Prototype Max Displacement Plot

Crane Analysis

Team 22 performed hand calculations to confirm that the two principal crane components, boom and pedestal, can support the 290-lbs load at the boom tip. Static analysis for bending of the boom and pedestal were performed. The results show that the pedestal and boom are more than sufficient for the expected loads. The factors of safety (2.38 for boom and 5.26 for pipe) are larger than 1.33, which is the required API factor of safety against failure due to dynamic loading. Furthermore, the full functionality of the crane was tested with a 300-lbs weight.

Manufacturing

Due to the short timeline and shop space availability, all manufacturing will be done at our team member Jared Pellegrin's house in Houma, LA. The materials were purchased on April 2nd, 2014 and expected to arrive on-site by April 4th, 2014. Team CraneWorks will arrive at Jared's house the afternoon of the 4th to begin constructing the prototype.

First the workspace must be prepared for the construction that will take place. Preparation includes moving all hazardous materials from the area, checking all tool's availability, laying down proper protection for the house and shop, aligning and accounting for all raw materials, and making sure that all safety concerns are addressed including wearing personal protective equipment.

Once the workspace is properly prepared, the team is ready to begin construction. First Jared's trailer will be wheeled into the workspace to start building the concrete slab. Liner is laid out across the trailer and wood is cut and assembled to create the frame for the concrete. An industrial concrete mixer is rented to assist in mixing the concrete and water. Within the wooden frame, rebar will be placed in a mesh formation to reinforce the foundation and will also extend from the surface providing a handle for the forklift. Once

the rebar is set, the concrete will be poured to the desired height within the wooden frame. While the concrete is still wet, anchor bolts will be installed to provide the necessary connection for the steel structure. Allow a day for the concrete foundation to harden and set.

The steel structure is next to be built and will be assembled off the trailer. Note that once the structure is fully welded together, a shop crane hoist will be used to raise the structure and place it on the concrete foundation. First, the plates must be cut to the appropriate sizes for the supporting based and the gussets. All manufacturing drawings must be followed with precision, as that will be the basis for comparing the testing to the analysis. Team CraneWorks must cut all steel members with a steel-rated chop saw to the proper dimensions before connecting. After all components are cut to the correct sizes, welding takes place. Begin welding with the top of the structure starting with the center cross-hatchings. Work inside-out to where the last member that is welded should be the columns. Allow for four hours for the structure to rest and cool down after the welding process.

Crane components were found in the scrap metal pile behind the MIE shop such as a pipe and a winch. The boom will be replaced with one manufactured by Team 22. The crane shall be lifted onto the steel structure and welded to the plate. Next the gussets need to be installed in order to provide the appropriate support for the various loading locations. The crane will have all dynamic degrees of freedom as that of an actual crane. It will be able to raise and lower a load, rotate 360 degrees, as well as boom up and down.

At this point the prototype is complete but the testing weights must still be manufactured. Team CraneWorks will construct weights of approximately 100, 200, 300 pounds out of scrap metal in the back of the MIE shop to act as the dead load lifted by the crane. Note that for the 20% scaling factor, a 283 lbs weight is appropriate to model the Safe Working Load.

Once all manufacturing is complete, the prototype will be driven to LSU’s campus for testing and commissioning to be displayed in the College of Engineering courtyard. Manufacturing drawings are attached in the Prototype Design Manufacturing Drawings section. The following figures outline the manufacturing process including creating the cement base, welding and milling the steel bar stock, and final assembly on the trailer.

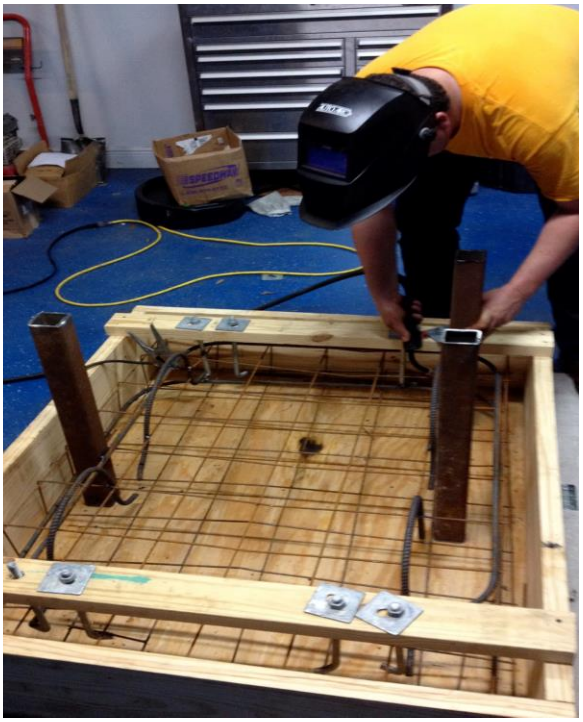

Figure 53: Construction of the Cement Base

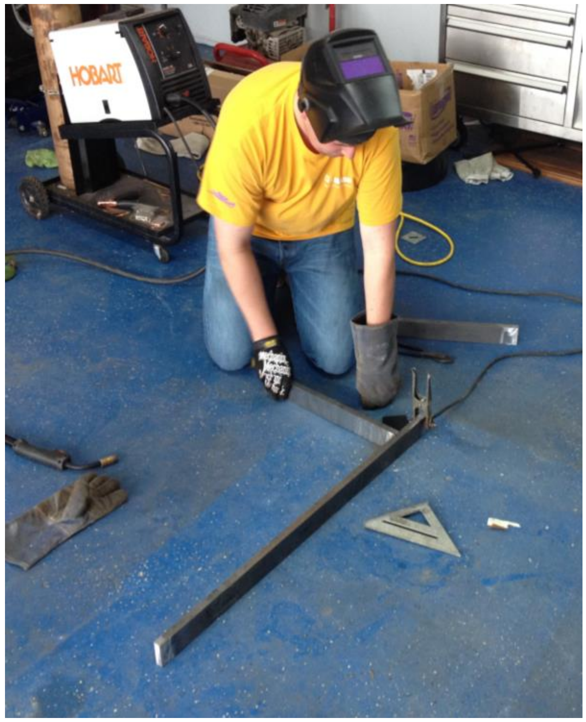

Figure 55: Welding of the Bar Stock

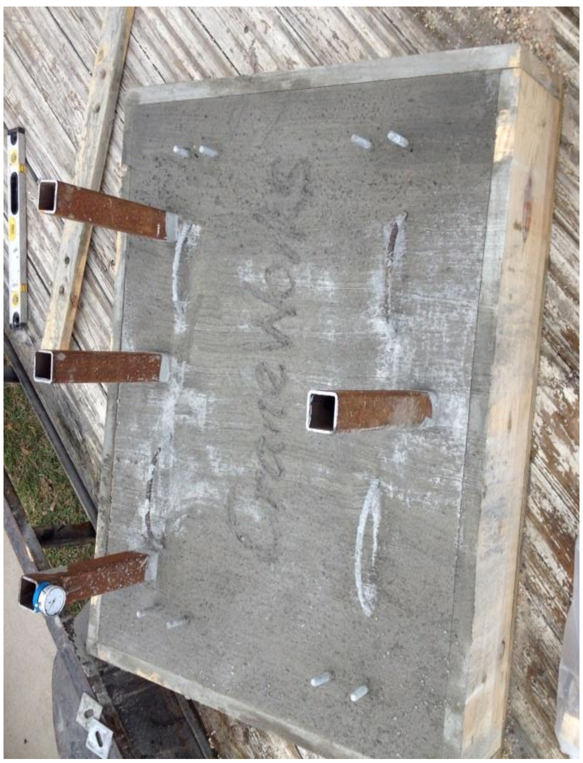

Figure 54: Finished Cement Base

Figure 56: Bar Stock Platform Mounted to Base

Figure 57: Finalized Prototype

Materials

The materials for the prototype were chosen to closely approximate the material properties of the planned structural modifications and based on the availability of stock parts. The bar stock was chosen as AISI 1018 low-carbon steel with a yield strength of 54,000 psi because of its availability and close match to the yield strength of the beam material. The plates and gussets are made of AISI 1026 carbon steel with a yield strength of 60,000 psi. The pipe is a standard-wall Schedule 40 pipe made of ASTM A53 with a yield strength of 30,000 psi. The concrete is a ready-mix with a compressive strength of 3,000 psi. The anchor bolts are made of ASTM A36 with a yield strength of 36,000 psi.

The rebar in the concrete base is made of ASTM A615 Grade 40 has a minimum yield strength of 40,000 psi. For the welding wire, an all-purpose ER70S-6 wire will be used with a CO_2/Ar mixture shielding gas. The crane boom is made of standard steel square tubing. The material is assumed to be ASTM A500 Grade B with a yield strength of 46,000 psi. The crane pedestal is assumed to comply with ASTM A53 standards which specifies a yield strength of 30,000 psi.

Bill of Materials

The bills of materials is shown in the Prototype Design Quotes section as quotes. Tools and expendable supplies are not shown.

Testing and Validation

Testing Objectives

In order to justify that the full-size structural modifications, both static and dynamic load testing will be performed on the 20% scale model. The static testing will evaluate the structure with various boom orientations; the dynamic testing will consider full rotation, load swinging and load bouncing situations. Since the Safe Working Load (SWL) of the full-size crane is 1,980,000 in-lbs, the scaled SWL for our model would be 15,840 in-lbs. Having the boom 56 inches long requires a maximum load of 283 pounds to stimulate the SWL.

Instrumentation

Beam vertical deflections are measured as the parameter to evaluate the structure. Based on the result of the FEA analysis, the four critical locations on the structure are identified and shown in Figure 58- Location 1 on the south beam and Location 2, 3 and 4 on the north beam. A dial Indicator is used during all the testing to measure the deflections of the critical beams. The dial indicator will be reset to zero and placed at the predetermined critical location before applying the load for each test.

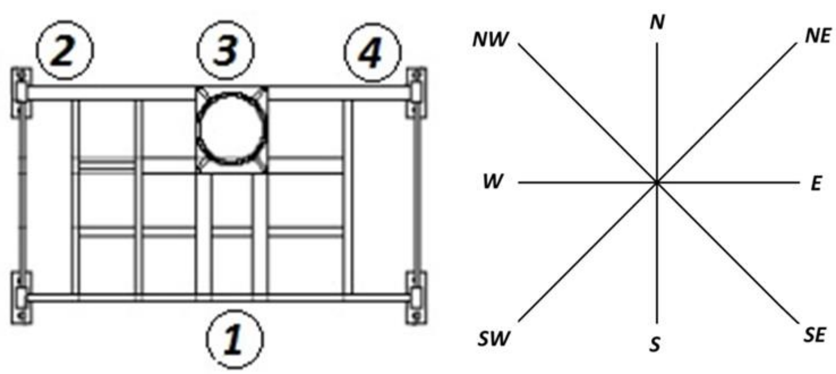

Figure 58: Structure Critical Locations along with Orientations

Testing Protocols

Static Load Testing

As shown in Figure 58, eight different boom orientations will be considered in the static load testing. During each run, test loads will be applied and the deflection at critical positions will be recorded using the dial indicator.

For accuracy of the results, the deflection of each configuration is measured four times. A total number of 128 data points will be collected for the static analysis. (8 boom orientations at 4 locations and 4 runs at each configuration)

Dynamic Load Testing

In order to accurately reflect the dynamic effects on the structure, there will be four components for the dynamic load testing: full rotation testing, load swinging testing both perpendicular and parallel to the boom, and load bounce testing.

Full Rotation Testing

Attach the load to the end of the wire rope and lift the load to 6 inches above the ground level. With the boom placed horizontally, manually push on the boom to complete a full rotation at a constant rotating speed (estimated by the operator for each run). Record the maximum deflection of the critical beam and the boom orientation during the process.

Load Swing Testing

In order to simulate the possible swinging situation of the load, Team 22 assumes the maximum load swing would be 3 feet from the vertical in the full-scale structure, under the assumption that only certified crane operator is operating the crane. The swinging will exert a rotating moment on the boom determined by the deviation from the vertical and the weight of the load. The 20% scale model has a wire rope length of 3 feet, which results in a scaled down deviation of 4 inches from the vertical to simulate the same moment effect on the boom.

To test the structure on load swinging, attach and lift the testing load to 3 feet below the boom tip. Manually displace the load approximately 4 inches away from the vertical centerline and then release the testing load. Visually observe the effect of swinging on the structure and look for obvious sign of failure. The static deflection at each configuration was used as a reference point and the fluctuations of deflections were recorded when applying the dynamic loadings. This process was performed with the load swinging both along the boom direction and perpendicular to the boom direction.

Load Bounce Testing

Based on information provided by the crane manufacturer, in case of the hydraulic failure, the load would drop a maximum of one foot in the vertical direction. Therefore, the load bounce test is to simulate the dynamic effect of hydraulic failure. With the 20% scale, the load needs to be displaced about 2.5 inches in the vertical direction to exert the same load onto the structure. The static deflection at each configuration was used as a reference point and the fluctuations of deflections were recorded when applying the dynamic loadings.

Data Acquisition/Processing

The prototype testing was completed in two phases. The first phase was conducted on April 19th 2014, which includes the static testing and the full rotation testing; the second phase was performed on April 25th 2014, which includes the swing testing and the bounce testing. During both phases, one of our team members was designated for measurement readout. The team also used the Go-Pro camera to record the entire testing process for future data validation.

Data Analysis

Static Testing Data Analysis

The average defection at each location is plotted against the boom orientation as shown in Figure 59. Location 1 represents the deflection on the south beam and shows the maximum deflection fluctuation from approximately -0.0016in when the boom is facing north to +0.0016in when the boom is facing south (Note: A positive number indicates the beam deflections downwards, and a negative number indicates the beam deflects upwards). Location 2, 3 and 4 are all on the south side of the pedestal and shows very similar trends.

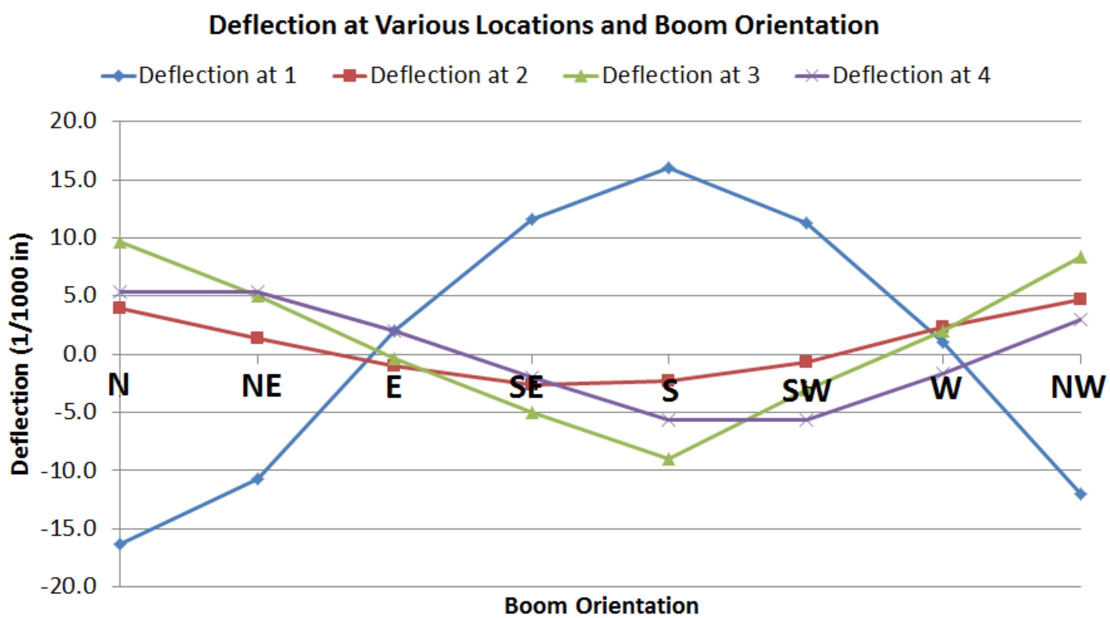

Figure 59: Static Testing Results

Complete Rotation Testing Analysis

During the rotation testing, the absolute maximum deflections was +0.017in, occurs when the boom is facing southwest at location 1. Compare to the static result with the same configuration, we found a 0.006 in increase due to the dynamic factors.

Load Swing and Bounce Testing Analysis

Based on the reference deflection and the recorded fluctuation, the absolute defections for swing and bounce testing were obtained. For swinging both parallel and perpendicular to the boom, the maximum deflections occur when the boom is facing northwest at location 1. The absolute deflection fluctuates between -0.0115 inches to -0.015 inches for swinging parallel to the boom, and -0.011 inches to -0.014 inches for swinging perpendicular to the boom. For the load bounce testing, the maximum deflection occurs when the boom is facing south at location 1. The deflection fluctuates between +0.02 inches to +0.009 inches.

Testing Results

In conclusion, the maximum deflection during static testing was +0.0163 inches when the boom is facing south at location 1. This result matches with our FEA analysis which yields a 0.0153 inch deflection with the same configuration. For other configurations, the averaged difference between the testing results and FEA analysis is 36.1%. For the dynamic testing, the absolute maximum fluctuation ranges from +0.02 inches to -0.015 inches, which we can conclude to have minimal effect on the structure.

Safety

Team 22 will observe all common safety consideration for machine shop operations. Safety glasses and steel toe shoes will be worn at all times. Earplugs will be worn when doing any machining. Since welding will be the most important manufacturing process used, MIG welding helmets and heat-resistant gloves will be worn at all times by the welder. During testing, Team 22 will wear steel toes shoes and safety glasses and will clear area before the test.

Even though the crane is not built to API 2C standards, the factors of safety on the structure and the crane are 3.0 or higher.

Budget, Project Schedule, and Timeline

The allocated budget is $5,000. The majority of the expenditures are the bar stock, plates, and pipe. The cement foundation is the second most expensive component in the prototype. Other expenditures include miscellaneous hardware, welding supplies, and other tools. The budget is shown in Table 37.

Component	Quantity	Unit Price ($)	Subtotal ($)
Pipe	1	313.36	313.36
Pipe Plate	2	41.61	83.22
Flanges Plate	1	29.47	29.47
Bar Stock	-	-	1,027.05
Concrete	-	-	266.47
Mixer Rental	1	75.00	75.00
Hardware, Supplies, and Tools	-	-	500.00
Total			2,294.57

Table 37: Prototype Budget

The prototype schedule (Figure 60) is as follows:

- March 25: Notice of prototype decision received.
- March 26: Team 22 met with Capt. Giurintano to discuss the deliverables and scope of project.
- March 27: Prototype proposal submitted.
- March 27-April 1: Design phase.
- April 2: Purchase order issued for bar stock and concrete.
- April 3: Prototype design submitted.
- April 4: Materials arrive at Jared's house.
- April 4 - April 6: Manufacturing of prototype.
- April 11 - April 13: Contingency manufacturing time if the materials do not arrive on time or manufacturing is not finished in the previous weekend.
- April 14 – April 20: Testing phase
- April 22: Project poster due.
- April 27: Final presentation slides due.
- May 7: Final report due.

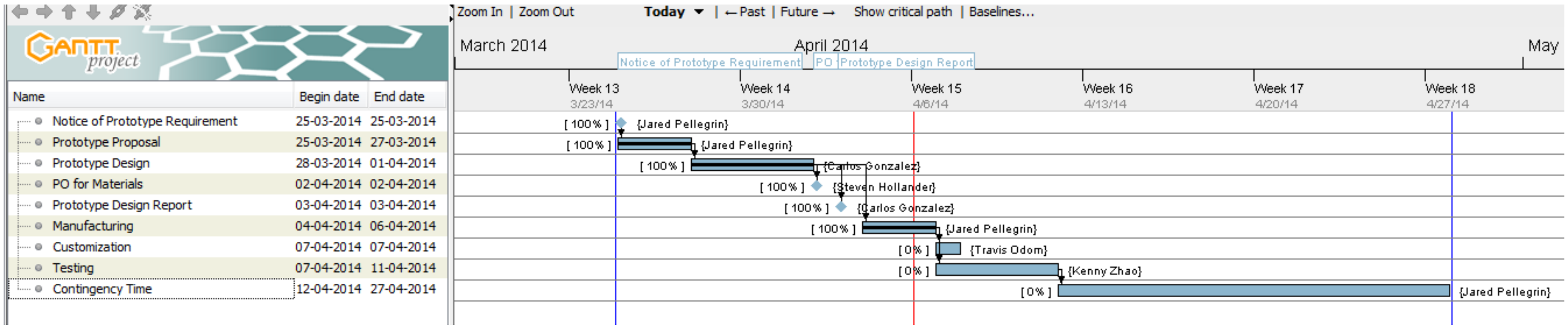

Figure 60: Prototype Design Timeline

Conclusions

Team CraneWorks was tasked with designing and constructing a fixed platform crane to access equipment on the top two levels of Taminco's AAA unit at their St. Gabriel facility. A 30-foot jib crane was selected based off of price and its ability to reach all the necessary equipment. The crane will be placed on the north side of the seventh floor because this is most optimal location to access all primary and secondary equipment while also maintaining a high vantage point. The original beam layout (Design I) was analyzed using hand calculations and was found not to be sufficient in supporting the expected loading of a crane. Thus, the team proposed Design II, which involved slight geometric changes with the substitution of stiffer W-beams. Audubon Engineering, a professional engineering firm, assisted in overseeing the project and made suggestions, which were taken into account for Design III. EBI was the decided crane manufacturer and was responsible for the construction, testing, and delivery of the crane itself.

On March 25th, the Mechanical and Industrial Engineering Department at LSU officially changed the scope of Team CraneWorks project to only involve the production and testing of a scaled prototype of the full-scale structure. The project change was based on the fact that funding was not readily available from Taminco and the crane would not be installed by graduation. With less than a month, the team designed a 20% scale model of the structure, ran FEA analysis, ordered and expedited the raw materials, and constructed and tested the prototype. Due to minimal shop space at LSU, the structure was manufactured at a team member's house in Houma, Louisiana. The prototype underwent both static and dynamic testing. Deflections of the beams were indicated at four critical locations for eight different loadings. Additionally, the dynamic testing included a complete 360-degree rotation test, parallel and perpendicular weight swing test, and a weight bounce test. For all of these, only the maximum deflection was recorded. A maximum deflection of 0.016 and 0.02 inches were recorded for the static and dynamic tests respectively. Based off the FEA analysis, the maximum deflection should have been around 0.040 inches. Since the deflection was less than the expected value, it can be concluded that the prototype well reflects the loading on the full-scale model and that it is more than sufficient to support all expected loads and moments.

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Appendix

Customer Survey

This tool is used to determine the importance of customer demands and to document the weighted importance of each requirement to be given back to the design group. Please list any customer requirements not listed in the table and fill in the relative importance of each requirement.

Demanded Quality		Importance Scale 5 = Extremely Important 4 = Very Important 3 = Important 2 = Relatively Important 1 = Somewhat Important
#	Design Requirements	Customer Evaluation
1	Lift and Lower all primary* objective equipment from ground level to the top two decks.	
2	Lift and Lower all Secondary** objective equipment from ground level to the top most deck	
3	Comply with all required safety standards, Taminco's and regulatory standards.	
4	Use of available resources (human, and equipment)	
5	Use existing facilities (local structure and surrounding area)	
6	Cost effective	
7	Reliable	
8	Uses standard parts and methods for production.	
9	Easy to maintain	
10	Perform in inclement weather	
11	Quick and efficient	

* 2 vacuum pumps and 1 PSV
** Second PSV and 2 heat exchanger

Table 38: Customer Survey Results

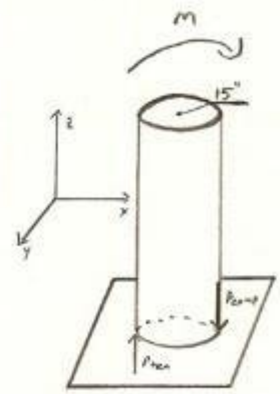
Customer Survey Results															
Importance scale															
5	Extremely Important														
4	Very Important														
3	Important														
2	Relatively Important														
1	Somewhat Important														
Customer Evaluation															
Design Requirements	Demanded Quality														Average Value
Lift and lower all primary objective equipment from ground level to the top two decks	4	5	5	4	5	5	5	3	3	4	3	5	5	5	4.36
Lift and lower all secondary objective equipment from ground level to the top most deck	2	3	5	4	3	5	3	3	3	4	3	5	2	4	3.50
comply with all required safety standards, Taminco's and regulatory standards	5	5	5	5	5	4	5	5	5	5	5	5	5	5	4.93
Use of available resources (human, and equipment)	4	3	3	3	4	4	3	3	3	5	5	4	3	5	3.71
Use existing facilities (local structure and surrounding area)	4	2	4	3	4	3	4	3	3	5	3	4	2	4	3.43
Cost effective	3	4	5	4	4	3	5	3	3	5	3	4	3	5	3.86
Reliable	5	5	4	5	5	4	4	4	3	5	5	5	5	4	4.50
Uses standard parts and methods for production.	3	3	3	3	4	3	3	3	3	5	4	5	4	4	3.57
Easy to maintain	5	3	4	4	4	3	4	5	5	5	3	5	4	4	4.14
Perform in inclement weather	5	3	5	2	3	4	1	5	5	5	3	5	5	4	3.93
Quick and efficient	4	4	3	3	3	3	2	5	4	5	3	5	3	5	3.71

Design I

Force Analysis

Pipe Buckling

Buckling Pipe



$$P_{crit} = \frac{\pi^2 E I}{l^2}$$

$$I = \frac{\pi}{4}\pi\left(R_o^4 - R_i^4\right)$$

$$= \frac{\pi}{4}\pi\left(15^4 - 14.25^4\right)$$

$$= 36{,}876.9 \text{ in}^4$$

$$E = 29e^6 \text{ psi}$$

$$l = 10 \text{ ft} = 120 \text{ in}$$

$$P_{crit_{3/4"}} = 732{,}475{,}493 \text{ lb} = 732 \text{ M lb}$$

$$\sigma_z = \frac{P_{weight\ crane}}{\pi\left(R_o^2 - R_i^2\right)} \pm \frac{M R_o}{I}$$

$$= \frac{15{,}000}{\pi\left(15^2 - 14.25^2\right)} \pm \frac{3{,}120{,}000 \cdot 15}{36{,}876.9}$$

$$= 1486.7,\ -1051.4 \text{ psi}$$

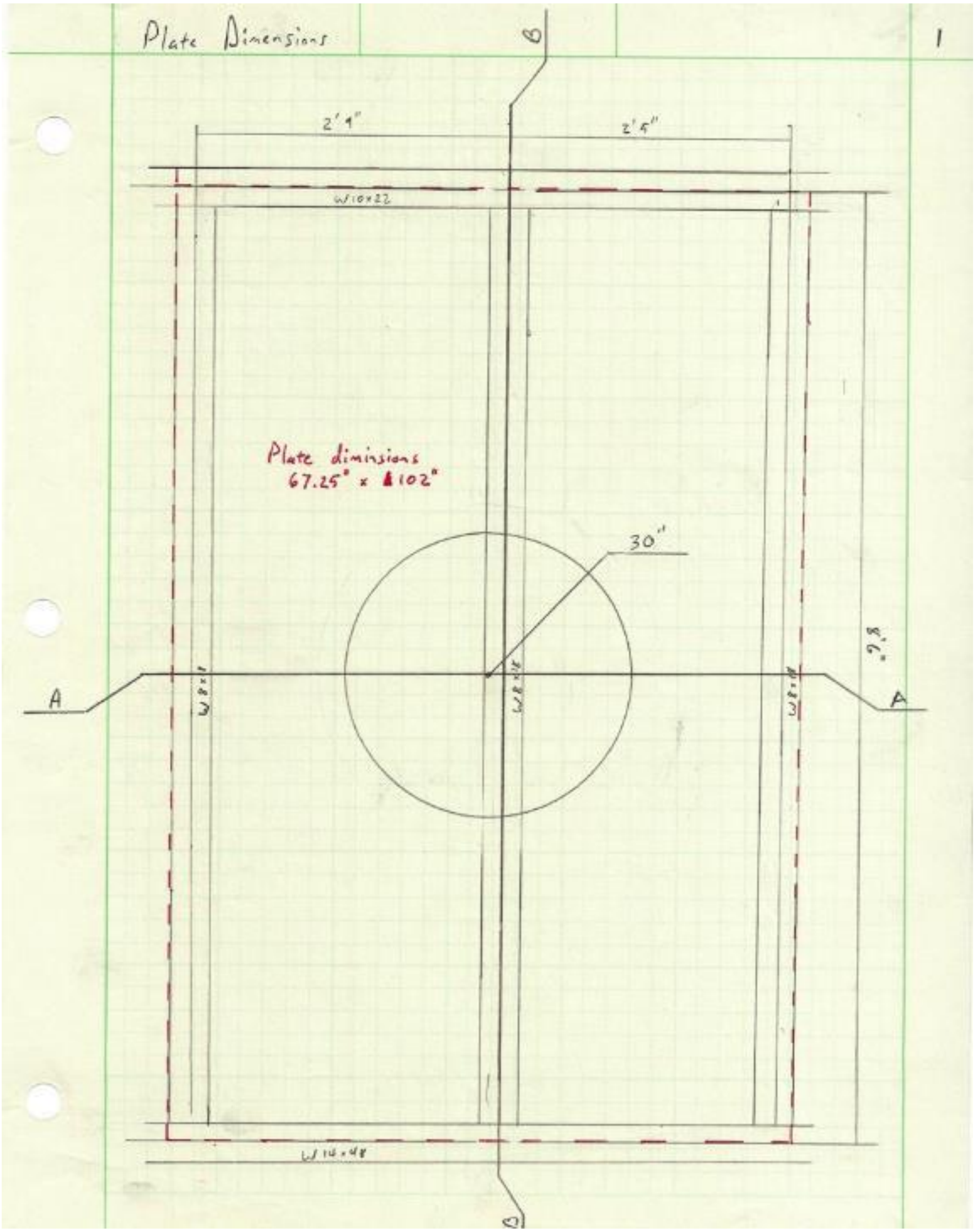
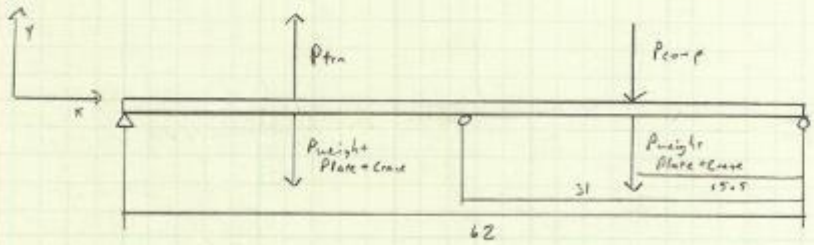


Plate Dimensions
1
2'4"
2'5"
W10x22
Plate dimensions
67.25" x 102"
30"
A
A
B
B
W14x48

Section A-A

Beam Forces | Section A-A | 2

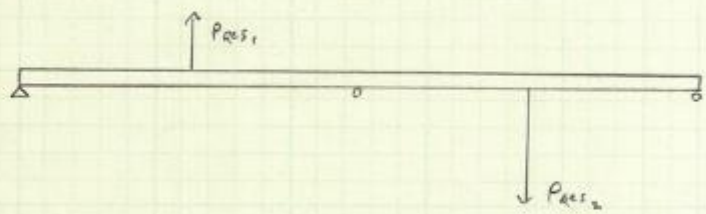


$$P_{weight_{crane}} = \frac{10{,}000 \text{ lb} + 5{,}000 \text{ lb}}{2} = 7{,}500 \text{ lb}$$

$$P_{weight_{plate}} = 0.2837 \left(\frac{lb}{in^3}\right) \cdot 31 \text{ (in)} \cdot 102 \text{ (in)} \cdot 1.75 \text{ (in)} \simeq 1600 \text{ lb}$$

$$M = 5{,}000 \text{ (lb)} \cdot 480 \text{ (in)} + 3000 \text{ (lb)} \cdot 240 \text{ (in)} = 3{,}120{,}000 \text{ lb} \cdot \text{in}$$

$$P_{comp} = P_{ten} = \frac{M}{31 \text{ (in)}} = 100{,}645.16 \text{ lb}$$

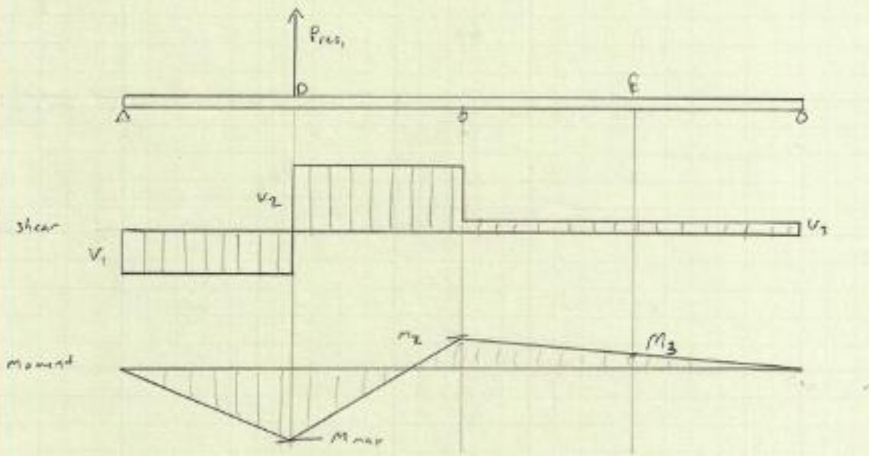


$$P_{Res_1} = P_{ten} - P_{weight_{crane}} - P_{weight_{plate}} = 91{,}545 \text{ lb}$$

$$P_{Res_2} = P_{comp} + P_{weight_{crane}} + P_{weight_{plate}} = 109{,}745 \text{ lb}$$

✭ All beam Diagram formulas are from:

Manual of Steel Construction
First Edition
p 3-140



$R_1 = V_1 = -\frac{13}{32} P = -\frac{13}{32} \cdot 91{,}545 = -37{,}190$ lb

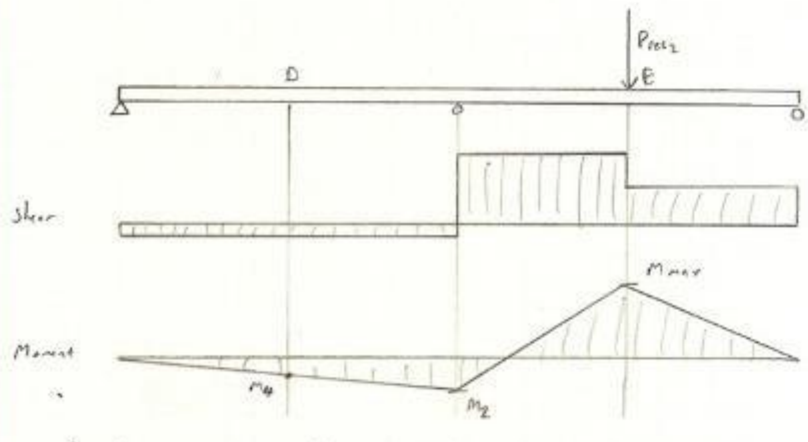
$R_2 = V_2 + V_3 = -\frac{11}{16} P = \frac{-11}{16} \cdot 91{,}545 = -62{,}937$ lb

$R_3 = V_3 = \frac{3}{32} P = \frac{3}{32} \cdot 91{,}545 = 8{,}582$ lb

$M_{max} = \frac{13}{64} P\ell = \frac{13}{64} \cdot 91{,}549 \quad 31 = 576{,}448$ lb-in

$M_2 = \frac{3}{32} P\ell = \frac{3}{32} \cdot 91{,}545 \quad 31 = 266{,}053$ lb-in

$M_3 = -8582\ (31+15.5) + 532{,}105 = 137{,}026$ lb-in



$R_1 = V_1 = \frac{13}{32} P = \frac{-3}{32} \cdot 109{,}745 = -10288$ lb

$R_2 = V_2 + V_3 = \frac{11}{16} P = \frac{11}{16} \cdot 109{,}745 = 75{,}449$ lb

$R_3 = V_3 = -\frac{3}{32} P = \frac{13}{32} \cdot 109{,}745 = 44{,}583$ lb

$M_{max} = \frac{13}{64} P\ell = \frac{13}{64} \cdot 109{,}745 \cdot 31 = 691{,}091$ lb·in

$M_2 = \frac{3}{32} P\ell = \frac{3}{32} \cdot 109{,}745 \cdot 31 = 318{,}946$ lb·in

$M_4 = 159473.$ lb·in

total $R_1 = -37{,}190 - 10288 = -47{,}478$ lb

$R_2 = -62{,}937 + 75{,}449 = 12{,}512$ lb

$R_3 = 8{,}582 + 44{,}583 = 53{,}162$ lb

$M_D = 576{,}448 + 159{,}473 = 735{,}921$ lb·in CCW

$M_E = 691{,}051 + 133{,}026 = 824{,}077$ lb·in CW

$M_2 = 266{,}053 - 318{,}946 = 52{,}893$ lb·in CC

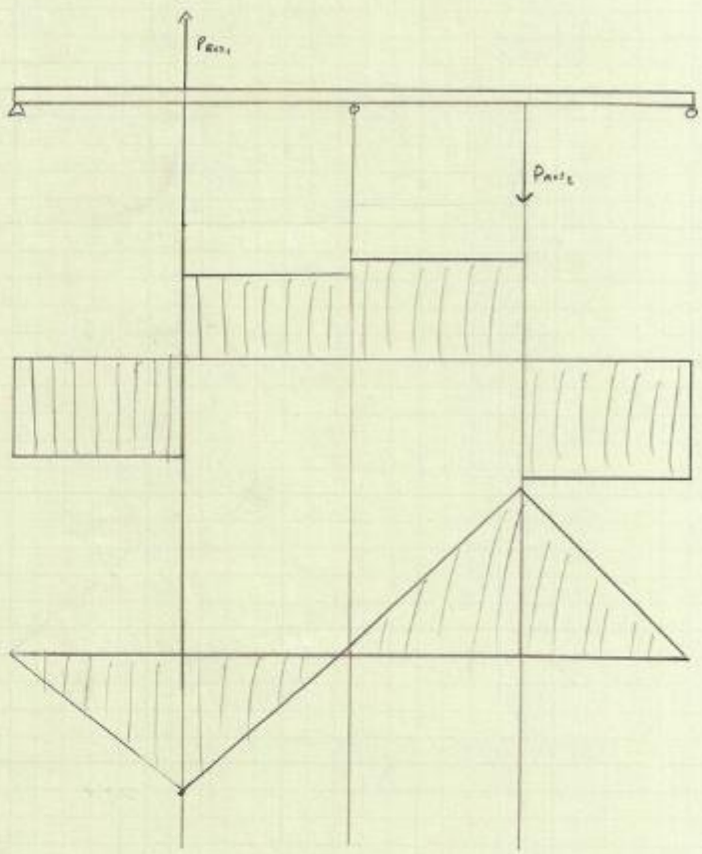


Plate Thickness

6

$V_{max} = 53,162$ lb $\qquad S_y = 50,000$ psi – A572 Grade

$M_{max} = 824,077$ lb·in $\qquad \xi = 2$

$$\left[\frac{M \frac{1}{2} t}{\frac{1}{12} l t^3}\right]^2 + 3\left[\frac{3V}{2 l t}\right]^2 = \left[\frac{S_y}{\xi}\right]^2$$

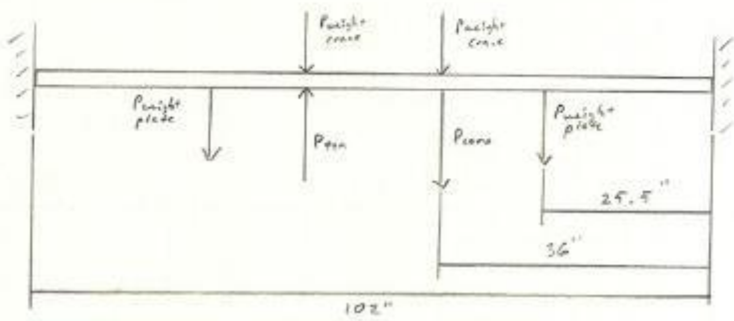
$$\Rightarrow \left[\frac{824,077 \cdot \frac{1}{2} t}{\frac{1}{12}(67.25) \cdot t^3}\right]^2 + 3\left[\frac{3 \cdot 53,162}{2(67.25) \cdot t}\right]^2 = \left[\frac{50,000}{2}\right]^2$$

$$\Rightarrow t = \underline{1.72 \text{ in}}$$

thus a thickness of 1.75" plate steel can be used

Section B-B

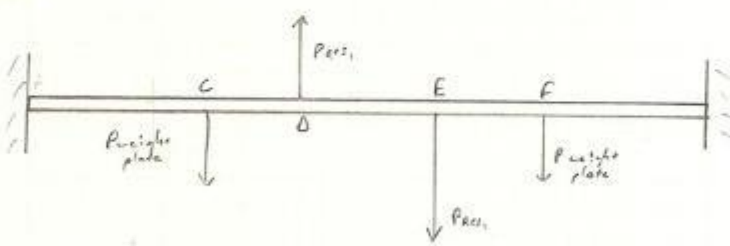
Beam Forces Section B-B 7



$P_{weight\ crane} = 7{,}500$ lb

$P_{weight\ plate} = 1600$ lb

$P_{comp} = P_{ten} = 100{,}645$ lb

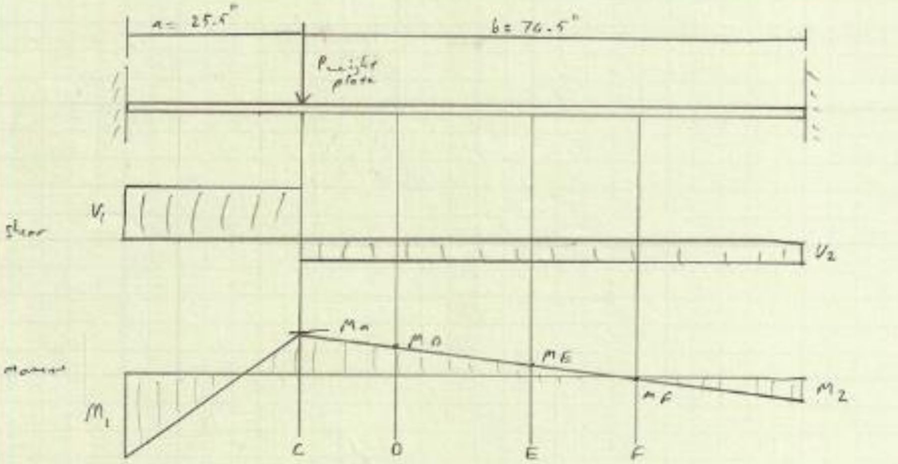


$P_{Res_1} = P_{ten} - P_{weight\ crane} = 93{,}145$

$P_{Res_2} = P_{comp} + P_{weight\ crane} = 108{,}145$

* All beam diagram formulas are from:

Manual of steel Construction
first edition
p 3-315



$$R_1 = V_1 = \frac{Pb^2}{l^3}(3a+b) = \frac{1600 \cdot 76.5^2}{102^3}(3(25.5)+76.5) = -1350 \text{ lb}$$

$$R_2 = V_2 = \frac{Pa^2}{l^3}(a+3b) = \frac{1600 \cdot 25.5^2}{102^3}(25.5+3(76.5)) = -250 \text{ lb}$$

$$M_1 = \frac{Pab^2}{l^2} = \frac{1600 \cdot 25.5 \cdot 76.5^2}{102^2} = -22{,}950 \text{ lb}\cdot\text{in}$$

$$M_2 = \frac{Pa^2b}{l^2} = \frac{1600 \cdot 25.5^2 \cdot 76.5}{102^2} = -7{,}650 \text{ lb}\cdot\text{in}$$

$$M_a = \frac{2Pa^2b^2}{l^3} = \frac{2(1600)\,25.5^2 \cdot 76.5^2}{102^3} = 11{,}475 \text{ lb}\cdot\text{in}$$

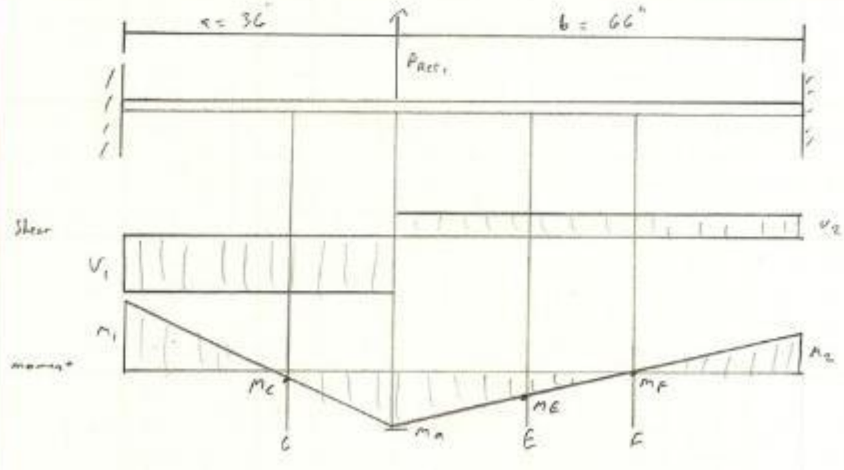
$$M_C = M_a$$

$$M_? = -250x + 17850$$

$$M_D = -250(36) + 17850 = 8{,}850 \text{ lb}\cdot\text{in}$$

$$M_E = -250(66) + 17850 = 1{,}350 \text{ lb}\cdot\text{in}$$

$$M_F = -250(76.5) + 17850 = -1{,}275 \text{ lb}\cdot\text{in}$$



$$R_1 = V_1 = \frac{Pb^2}{l^3} = \frac{93,145 \cdot 66^2}{102^3}(3(36) + 66) = 66,527 \text{ lb}$$

$$R_2 = V_2 = \frac{Pa^2}{l^3} = \frac{93,145 \cdot 36^2}{102^3}(36 + 3(66)) = 26,618 \text{ lb}$$

$$M_1 = \frac{Pab^2}{l^2} = \frac{93,145 \cdot 66^2 \cdot 36}{102^2} = 1,403,446 \text{ lb} \cdot \text{in}$$

$$M_2 = \frac{Pa^2 b}{l^2} = \frac{93,145 \cdot 36^2 \cdot 66}{102^2} = 765,789 \text{ lb} \cdot \text{in}$$

$$M_a = \frac{2Pa^2b^2}{l^3} = \frac{2 \cdot 93,145 \cdot 36^2 \cdot 66^2}{102^3} = -491,021 \text{ lb} \cdot \text{in}$$

$$M_b = M_a$$

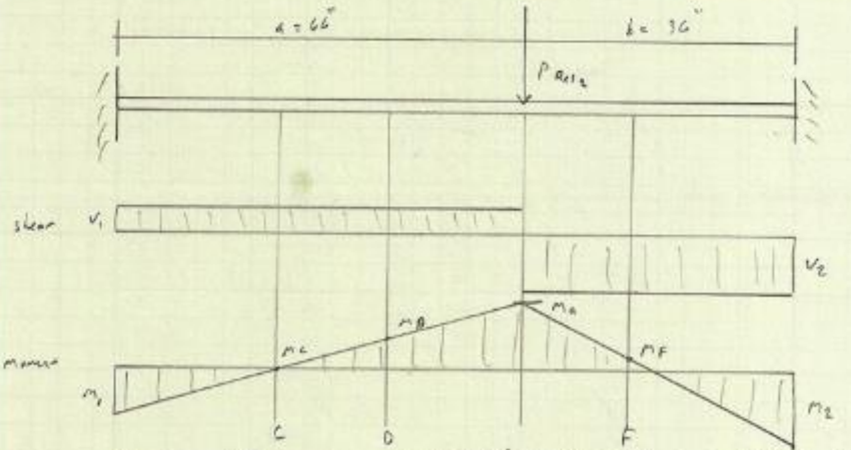
$$M_{x_1} = -66,526x + 1403946$$

$$M_C = -66,526(25.5) + 1403946 = -292,489 \text{ lb} \cdot \text{in}$$

$$M_{x_2} = 26,618x - 1944281$$

$$M_E = 26,618(66) - 1944281 = -192,471 \text{ lb} \cdot \text{in}$$

$$M_F = 26,618(76.5) - 1944281 = 87,021 \text{ lb} \cdot \text{in}$$



$$R_1 = V_1 = \frac{Pb^2}{l^3}(3a+b) = \frac{108{,}145 \cdot 36^2}{102^3}(3(66)+36) = -30{,}905 \text{ lb}$$

$$R_2 = V_2 = \frac{P_a^2}{l^3}(a+3b) = \frac{108146 \cdot 66^2 (66+3(36))}{102^3} = -77{,}240 \text{ lb}$$

$$M_1 = \frac{P_a b^2}{l^2} = \frac{108145 \cdot 36^2 \cdot 66}{102^2} = -889{,}110 \text{ lb}\cdot\text{in}$$

$$M_2 = \frac{P_a^2 b}{l^2} = \frac{108145 \cdot 66^2 \cdot 36}{102^2} = -1{,}630{,}035 \text{ lb}\cdot\text{in}$$

$$M_a = \frac{2P_a^2 b^2}{l^3} = \frac{2 \cdot 108145 \cdot 36^2 \cdot 66^2}{102^3} = 1{,}150{,}613 \text{ lb}\cdot\text{in}$$

$$M_E = M_a$$

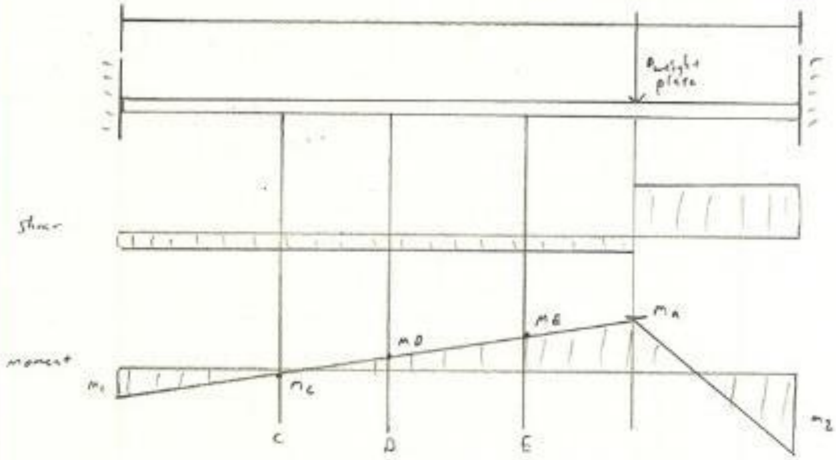
$$M_{?_1} = 30904x - 889110$$

$$M_C = 30904(25.5) - 889110 = 558{,}964 \text{ lb}\cdot\text{in}$$

$$M_D = 30904(36) - 889110 = 883{,}466 \text{ lb}\cdot\text{in}$$

$$M_{?_2} = -77240x + 6{,}248{,}467$$

$$M_F = -77240(76.5) + 6248967 = 339{,}607 \text{ lb}\cdot\text{in}$$



$R_1 = -250$ lb

$R_2 = -1350$ lb

$M_1 = -7{,}650$ lb·in

$M_2 = -22{,}950$ lb·in

$M_a = 11{,}475$ lb·in

$M_F = M_a$

$M_c = -1{,}275$ lb·in

$M_D = 1{,}350$ lb·in

$M_E = 8{,}850$ lb·in

total

$R_1 = -1350 + 66527 - 30905 - 250 = 34,022$ lb

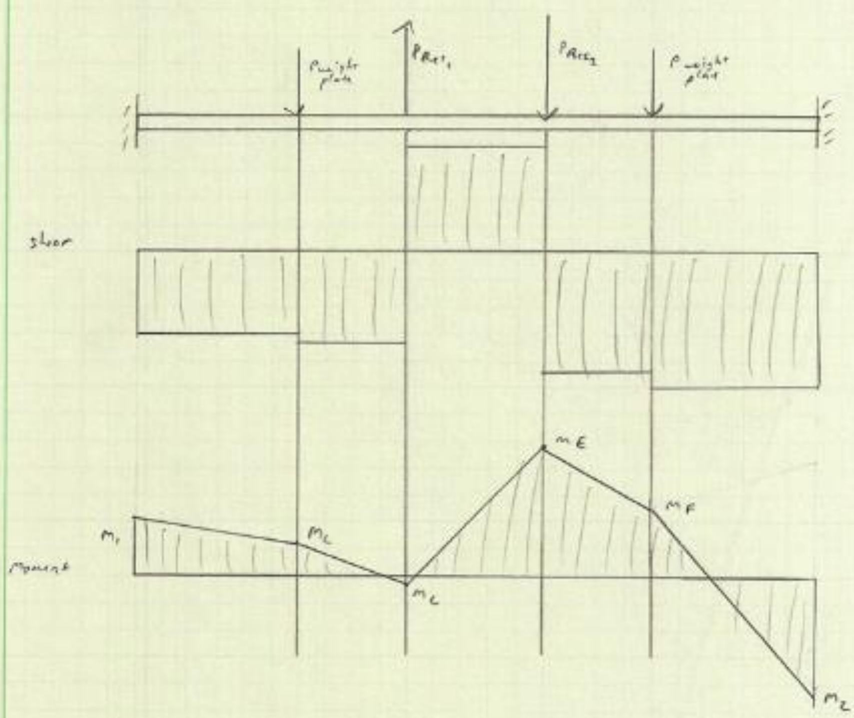
$R_2 = -250 + 26618 - 77240 - 1305 = -52222$ lb

$M_C = 11475 - 292494 + 558964 - 1275 = 276,675$ lb·in

$M_D = 8850 - 991021 + 883466 + 1350 = -97,355$ lb·in

$M_E = 1350 - 192471 + 1150613 + 8850 = 968,342$ lb·in

$M_F = -1275 + 87021 + 339607 + 11475 = 436,828$ lb·in



$M_1 = -22950 + 1403946 - 889110 - 7650 = 484,236$ lb·in

$M_2 = -7650 + 765789 - 1630035 - 22950 = -894,846$ lb·in

Plate Thickness 13

$V_{max} = 52222$ lb $\qquad S_y$ 50,000 psi – A572 Grade

$M_{max} = 968{,}342$ lb·in $\qquad \xi = 2$

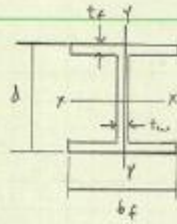
$$\left[\frac{M \frac{1}{2}t}{\frac{1}{12} l t^3}\right]^2 + 3\left[\frac{3V}{2lt}\right]^2 = \left[\frac{S_y}{\xi}\right]^2$$

$$\Rightarrow \left[\frac{968{,}342 \cdot \frac{1}{2} t}{\frac{1}{12}(102)\cdot t^3}\right]^2 + 3\left[\frac{3\cdot 52222}{2(102)t}\right]^2 = \left[\frac{50000}{2}\right]^2$$

$\Rightarrow t = 1.50$ in

– thus we will use 1.75 in because that was thickness for the A-A section

Beams	A (in^2)	d (in)	t_w (in)	b_f (in)	t_f (in)	I_{xx} (in^4)	I_{yy} (in^4)
W 14 × 48	14.1	13.79	0.340	8.030	0.595	485	51.4
W 14 × 34	10.00	13.98	0.285	6.745	0.455	340	23.3
W 12 × 96	28.2	12.71	0.550	12.160	0.900	833	270
W 12 × 30	8.79	12.34	0.260	6.520	0.440	238	20.3
W 10 × 22	6.49	10.17	0.240	5.750	0.360	118	11.4
W 8 × 18	5.26	8.14	0.230	5.250	0.330	61.9	7.97



From: American Institute of Steel Construction AISC

Beams 1 and 3

Beam Analysis A

15

$R = \frac{wl}{2} = 23739$ lb

(at ends) $M_{max} = \frac{w l^2}{12} = 474{,}780$ lb·in

(at center) $M_1 = \frac{w l^2}{24} = 237{,}390$ lb·in

W8x18 Beam

$E = 29{,}000$ ksi

$I = 61.9$ in^4

$\sigma_{at\,ends} = \frac{M_{max} c}{I} = \frac{474780\left(\frac{8.14}{2}\right)}{61.9} = 31{,}217.36$ psi

$\sigma_{center} = \frac{M_1 c}{I} = \frac{237{,}390\left(\frac{8.14}{2}\right)}{61.9} = 15{,}608$ psi

W14x48

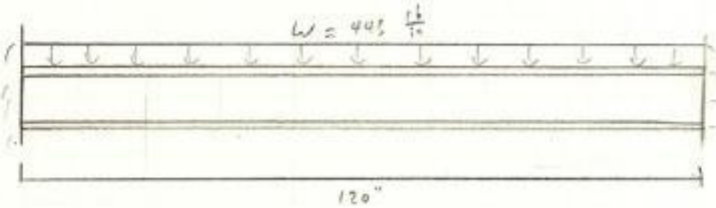
$\sigma_{at\,ends} = \frac{M_{max} c}{I} = \frac{474780\left(\frac{13.79}{2}\right)}{485} = 6{,}749.7$ psi

$\sigma_{center} = \frac{M_1 c}{I} = \frac{237390\left(\frac{13.79}{2}\right)}{485} = 3{,}374.9$ psi

W10x22

$\sigma_{at\,ends} = \frac{M_{max} c}{I} = \frac{474780\left(\frac{10.17}{2}\right)}{118} = 20{,}399.4$ psi

$\sigma_{center} = \frac{M_1 c}{I} = \frac{237390\left(\frac{10.17}{2}\right)}{118} = 10{,}199.7$ psi



$R = \frac{wl}{2} = 26{,}581 \text{ lb}$

$M_{max} = \frac{wl^2}{12} = 531620 \text{ lb·in}$

$M_1 = \frac{wl^2}{24} = 265{,}810 \text{ lb·in}$

W 8×18

$\sigma_{at\ ends} = \frac{M_{max}\, c}{I} = \frac{531620\left(\frac{8.14}{2}\right)}{61.9} = 34{,}954.7 \text{ psi}$

$\sigma_{center} = \frac{M_1\, c}{I} = \frac{265810\left(\frac{8.14}{2}\right)}{61.9} = 17{,}477.3 \text{ psi}$

W 14×48

$\sigma_{at\ ends} = \frac{531620\left(\frac{13.79}{2}\right)}{485} = 7557.8 \text{ psi}$

$\sigma_{center} = \frac{265810\left(\frac{13.79}{2}\right)}{485} = 3778.9 \text{ psi}$

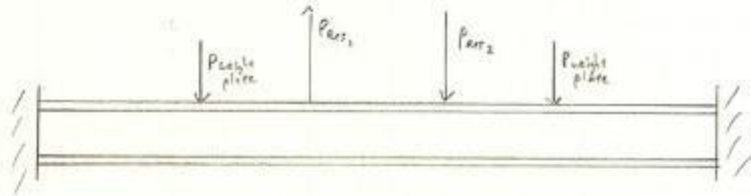
W 10×22

$\sigma_{at\ ends} = \frac{531620\left(\frac{10.17}{2}\right)}{118} = 22{,}909.2 \text{ psi}$

$\sigma_{center} = \frac{265810\left(\frac{10.17}{2}\right)}{118} = 11{,}454.6 \text{ psi}$

Beam 2

Beam Analysis B 17



$R_1 = 34{,}022$ lb

$R_2 = -52{,}122$ lb

$M_1 = 484{,}236$ lb·in

$M_2 = -894{,}846$ lb·in

$M_{max} = 968{,}342$ lb·in

<u>W8x18</u>

$$\sigma_{at\ ends} = \frac{M_1 c}{I} = \frac{484{,}236\left(\frac{8.10}{2}\right)}{61.9} = 31{,}839 \text{ psi}$$

$$= \frac{M_2 c}{I} = \frac{894846\left(\frac{8.10}{2}\right)}{61.9} = 58837 \text{ psi}$$

$$\sigma_{center} = \frac{M_{max} c}{I} = \frac{968{,}342\left(\frac{8.10}{2}\right)}{61.9} = 63669 \text{ psi}$$

<u>W14x48</u>

$$\sigma_{at\ ends} = \frac{48236\left(\frac{13.79}{2}\right)}{485} = 6884 \text{ psi}$$

$$= \frac{894846\left(\frac{13.79}{2}\right)}{485} = 12721 \text{ psi}$$

$$\sigma_{center} = \frac{968342\left(\frac{13.79}{2}\right)}{485} = 13766 \text{ psi}$$

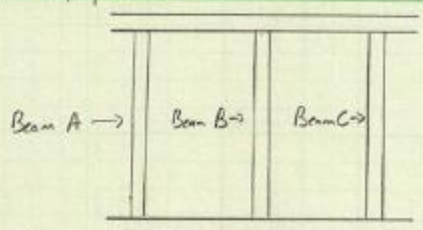
<u>W10x22</u>

$$\sigma_{at\ ends} = \frac{484236\left(\frac{10.14}{2}\right)}{118} = 20805 \text{ psi}$$

$$= \frac{894846\left(\frac{10.14}{2}\right)}{118} = 38448$$

$$\sigma_{center} = \frac{968342\left(\frac{10.14}{2}\right)}{118} = 41605$$

Beam Analysis A, B, and C



	A (in^2)	d (in)	tw (in)	bf (in)	tf (in)	I_{xx} (in^4)	I_{yy} (in^4)
W10×60	17.6	10.22	0.420	10.080	0.680	341	116

Beam A

$$\sigma_{at\ ends} = \frac{474,780\left(\frac{10.22}{2}\right)}{341} = 7,114 \text{ psi}$$

$$\sigma_{center} = \frac{237,390\left(\frac{10.22}{2}\right)}{341} = 3,557 \text{ psi}$$

Beam B

$$\sigma_{at\ ends} = \frac{489,236\left(\frac{10.22}{2}\right)}{341} = 7,331 \text{ psi}$$

$$= \frac{894,846\left(\frac{10.22}{2}\right)}{341} = 13,409 \text{ psi}$$

$$\sigma_{center} = \frac{968342\left(\frac{10.22}{2}\right)}{341} = 14,510 \text{ psi}$$

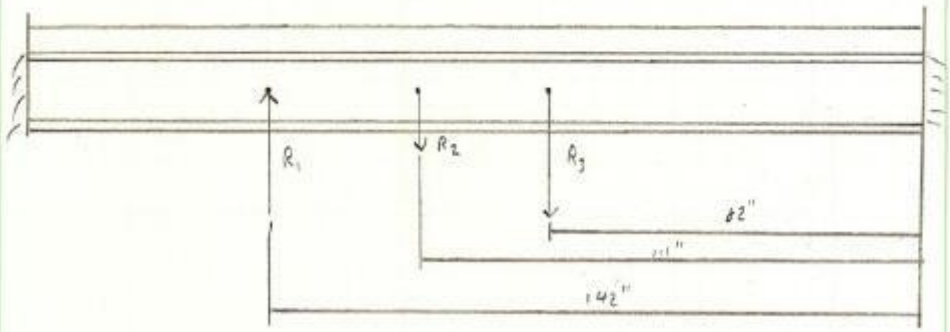
Beam C

$$\sigma_{at\ ends} = \frac{531,620\left(\frac{10.22}{2}\right)}{341} = 7,966 \text{ psi}$$

$$\sigma_{center} = \frac{265,810\left(\frac{10.22}{2}\right)}{341} = 3,983 \text{ psi}$$

Beams 4 and 5

Beam D and E | Moment to East



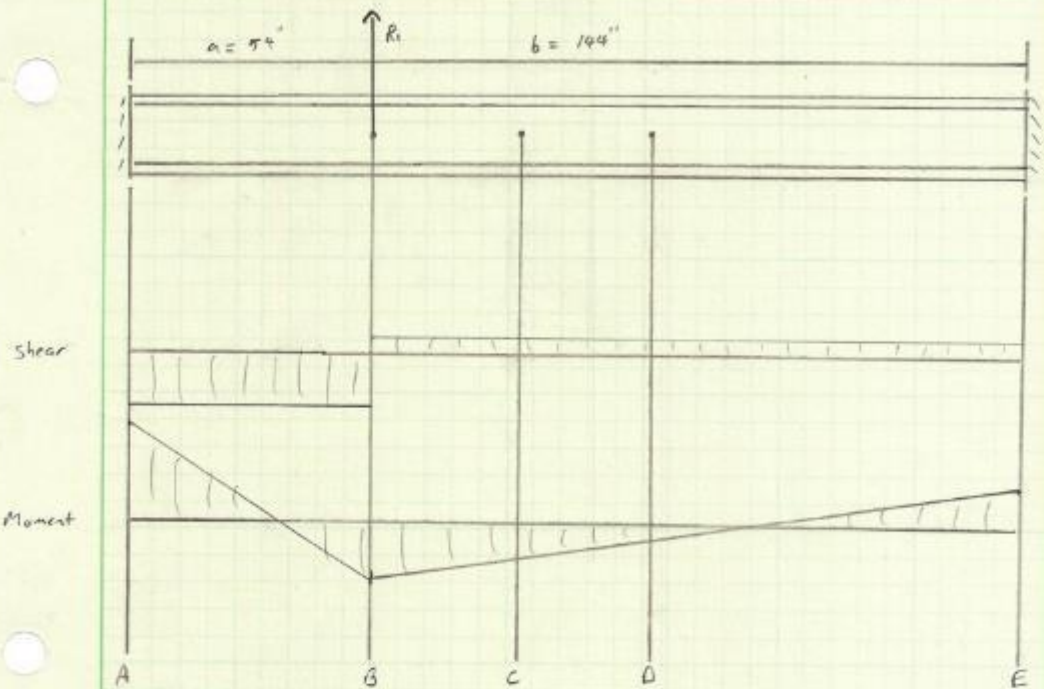
$R_1 = R_3 \simeq 27{,}000$ lb $\quad R_2 \simeq 6{,}500$ lb

The Reactions come from Beams A, B, and C

* All Diagram formulas are from:

Manual of steel construction
first Edition
p 3-135

Beam D and E | moment to East | 1



$$R_A = \frac{P b^2}{l^3}(3a+b) = \frac{27{,}000 \cdot 144^2}{198^3}(3(54)+144) = 22{,}071 \text{ lb T}$$

$$R_E = \frac{P a^2}{l^3}(a+3b) = \frac{27{,}000 \cdot 54^2}{198^3}(54+3(144)) = 4{,}929 \text{ lb T}$$

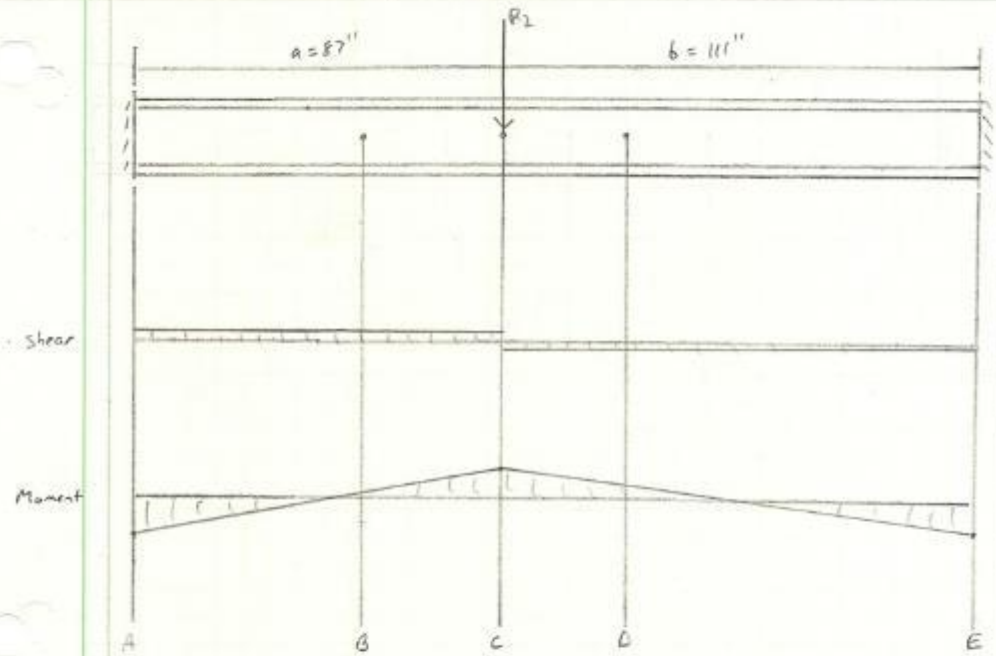
$$M_A = \frac{P a b^2}{l^2} = \frac{27{,}000 \cdot 54 \cdot 144^2}{198^2} = 771{,}174 \text{ lb}\cdot\text{in CW}$$

$$M_E = \frac{P a^2 b}{l^2} = \frac{27{,}000 \cdot 54^2 \cdot 144}{198^2} = 289{,}190 \text{ lb}\cdot\text{in CW}$$

$$M_B = \frac{2 P a^2 b^2}{l^3} = \frac{2 \cdot 27{,}000 \cdot 54^2 \cdot 144^2}{198^3} = -420{,}640 \text{ lb}\cdot\text{in CCW}$$

$$M_C = 4929(87) - 686826 = -257{,}970 \text{ lb}\cdot\text{in CCW}$$

$$M_D = 4929(116) - 686826 = -115{,}018 \text{ lb}\cdot\text{in CCW}$$



$R_A = \frac{Pb^2}{\ell^3}(3a+b) = -3{,}838$ lb C

$R_E = \frac{Pa^2}{\ell^3}(a+3b) = -2{,}662$ lb C

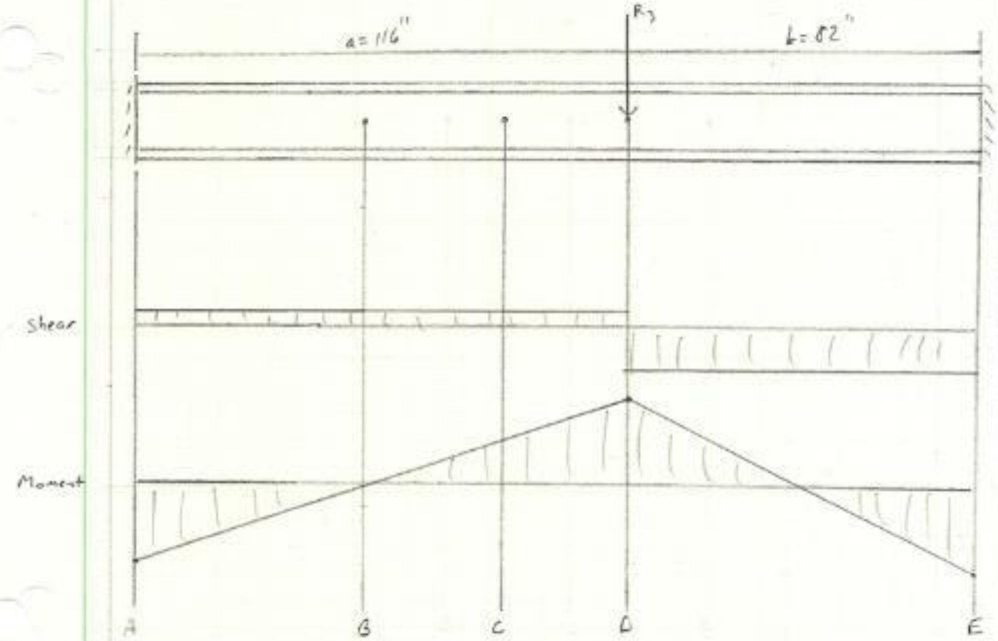
$M_A = \frac{Pab^2}{\ell^2} = -177{,}725$ lb·in ccw

$M_E = \frac{Pa^2b}{\ell^2} = -139{,}298$ lb·in ccw

$M_C = \frac{2Pa^2b^2}{\ell^3} = 156{,}182$ lb·in cw

$M_B = 3838(54) - \frac{6{,}500(87)(111)^2}{198^2} = 129{,}527$ lb·in cw

$M_D = -2661(116) + 387774 = 78{,}484$ lb·in cw



$$R_A = \frac{P b^2}{l^3}(3a + b) = -10,057 \text{ lb C}$$

$$R_E = \frac{P a^2}{l^3}(a + 3b) = -16,943 \text{ lb C}$$

$$M_A = \frac{P a b^2}{l^2} = -537,579 \text{ lb·in CCW}$$

$$M_E = \frac{P a^2 b}{l^2} = -759,412 \text{ lb·in CCW}$$

$$M_D = \frac{2 P a^2 b^2}{l^3} = 629,422 \text{ lb·in CW}$$

$$M_B = 10057(54) - \frac{27,000 \cdot 116 \cdot 82^2}{198^2} = 5,898 \text{ lb·in CW}$$

$$M_C = 10057(87) - \frac{27,000 \cdot 116 \cdot 82^2}{198^2} = 337,779 \text{ lb·in CW}$$

$R_A = 22071 - 3838 - 10057 = 8176$ T

$R_E = 4929 - 2662 - 16943 = -14676$ C

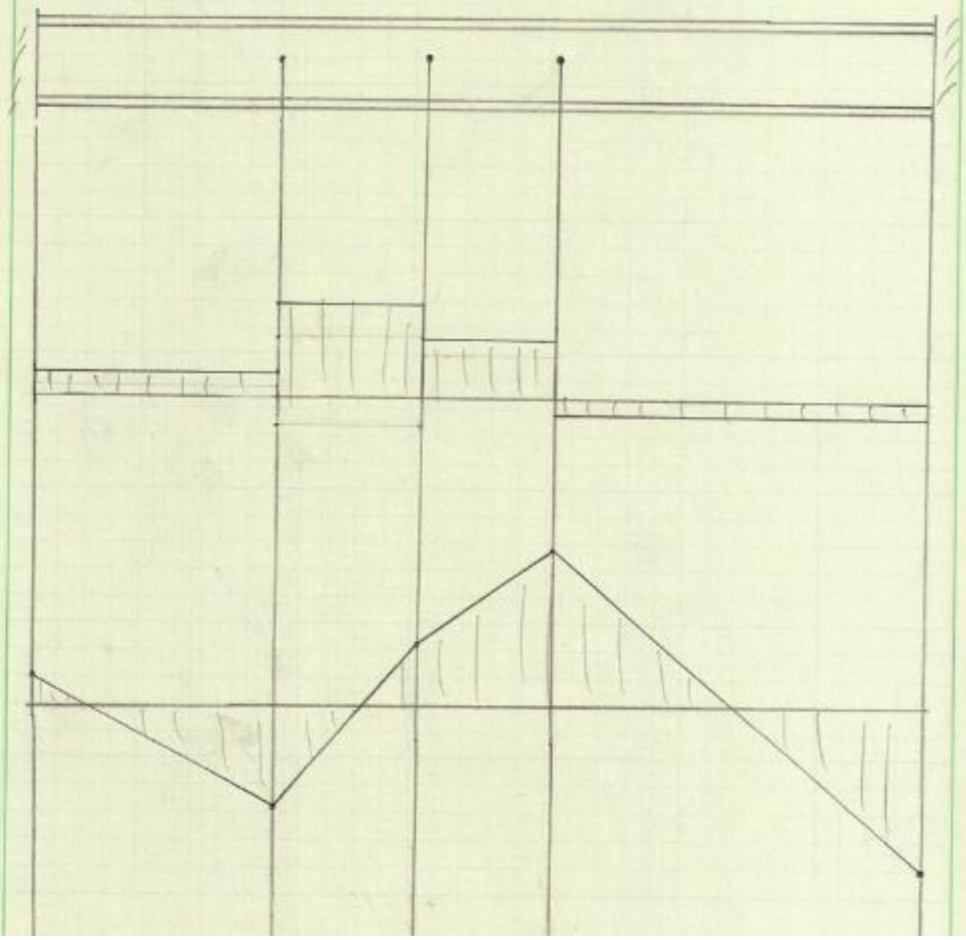
$M_A = 778174 - 177725 - 53179 = 547{,}270$ CW

$M_E = 289190 - 139298 - 759912 = -610020$ CCW

$M_B = -420640 + 29527 + 5898 = -385{,}215$ CCW

$M_C = -257970 + 156182 + 337779 = 235{,}991$ CW

$M_D = -115018 + 78984 + 629422 = 593{,}388$ CW



Stress Analysis

Beam Stresses

Stress D and E | moment to East

W 14x48

$$\sigma_{at\ ends} = \frac{M_{max}\,c}{I} = \frac{610020\left(\frac{13.79}{2}\right)}{485} = 8{,}672 \text{ psi}$$

$$\sigma_{at\ center} = \frac{M_{max}\,c}{I} = \frac{593388\left(\frac{13.79}{2}\right)}{485} = 8{,}435 \text{ psi}$$

W10x22

$$\sigma_{at\ ends} = \frac{M_{max}\,c}{I} = \frac{610020\left(\frac{10.17}{2}\right)}{118} = 26{,}287 \text{ psi}$$

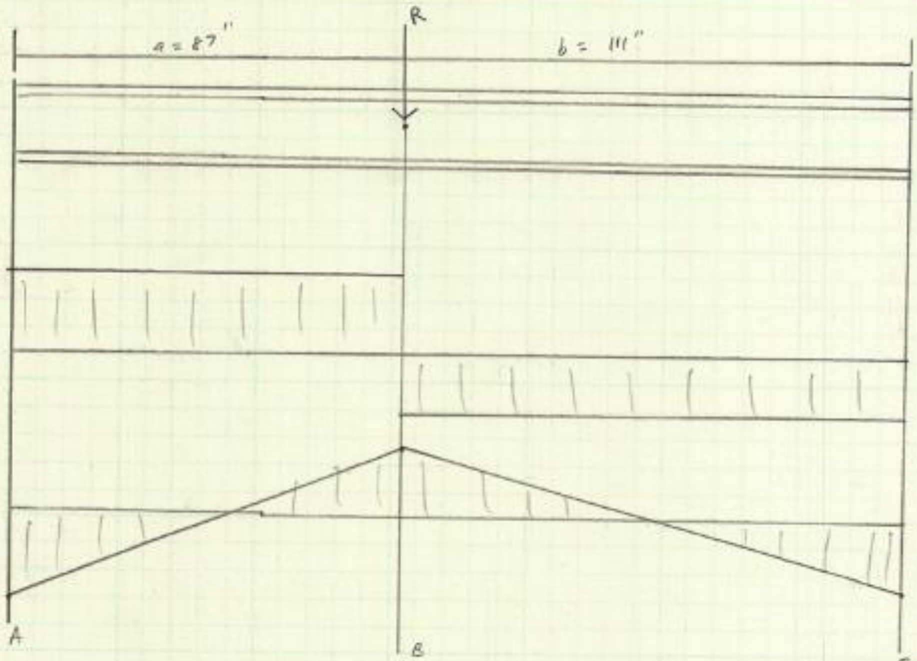
$$\sigma_{at\ center} = \frac{M_{max}\,c}{I} = \frac{593388\left(\frac{10.17}{2}\right)}{118} = 25{,}570 \text{ psi}$$

W10x60

$$\sigma_{at\ ends} = \frac{M_{max}\,c}{I} = \frac{610020\left(\frac{10.08}{2}\right)}{341} = 9{,}016 \text{ psi}$$

$$\sigma_{at\ center} = \frac{M_{max}\,c}{I} = \frac{593388\left(\frac{10.08}{2}\right)}{341} = 8770 \text{ psi}$$

Beams D and E | Moment to North | 1



$$R_A = \frac{Pb^2}{\ell^3}(3a+b) = \frac{54{,}000 \cdot 111^2}{198^3}(3(111)+87) = -31{,}885 \text{ lb C}$$

$$R_C = \frac{Pa^2}{\ell^3}(a+3b) = \frac{54{,}000 \cdot 87^2}{198^3}(3(87)+111) = -22{,}115 \text{ lb C}$$

$$M_A = \frac{Pab^2}{\ell^2} = \frac{54{,}000 \cdot 87 \cdot 111^2}{198^2} = 1{,}476{,}483 \text{ lb} \cdot \text{in}$$

$$M_C = \frac{Pa^2b}{\ell^2} = \frac{54{,}000 \cdot 87^2 \cdot 111}{198^2} = 1{,}157{,}244 \text{ lb} \cdot \text{in}$$

$$M_B = \frac{2Pa^2b^2}{\ell^3} = \frac{2 \cdot 54{,}000 \cdot 87^2 \cdot 111^2}{198^3} = 1{,}297{,}516 \text{ lb} \cdot \text{in}$$

Stress P and E | Moment to North

W 14x48

$$\sigma_{\text{at ends}} = \frac{M_{max}\,c}{I} = \frac{1476483\left(\frac{13.79}{2}\right)}{485} = 20990 \text{ psi}$$

$$\sigma_{\text{at center}} = \frac{M_{max}\,c}{I} = \frac{1297516\left(\frac{13.79}{2}\right)}{485} = 18446 \text{ psi}$$

W10x22

$$\sigma_{\text{at ends}} = \frac{M_{max}\,c}{I} = \frac{1476483\left(\frac{10.17}{2}\right)}{118} = 63626 \text{ psi}$$

$$\sigma_{\text{at center}} = \frac{M_{max}\,c}{I} = \frac{1297516\left(\frac{10.17}{2}\right)}{118} = 55914 \text{ psi}$$

W 10x60

$$\sigma_{\text{at ends}} = \frac{M_{max}\,c}{I} = \frac{1476483\left(\frac{10.08}{2}\right)}{341} = 21823 \text{ psi}$$

$$\sigma_{\text{at center}} = \frac{M_{max}\,c}{I} = \frac{1297516\left(\frac{10.08}{2}\right)}{341} = 19177 \text{ psi}$$

Plate Stress

Plate Stress Analysis

From Section A-A and Section B-B and a plate thickness of $t = 1.75$ in

$M_{max} = 824{,}077$ lb·in $\qquad M_{max} = 968{,}342$ lb·in

$V_{max} = 53{,}162$ lb $\qquad V_{max} = 52{,}222$ lb

Simply supported plate is in bending and transverse shear

A-A

$$\sigma_{max} = \frac{M_{max}\, c}{I} = \frac{824{,}077\left(\frac{1.75}{2}\right)}{\frac{1}{12}(102)(1.75)^3} = 15{,}828 \text{ psi}$$

B-B

$$\sigma_{max} = \frac{M_{max}\, c}{I} = \frac{968{,}342\left(\frac{1.75}{2}\right)}{\frac{1}{12}(67.25)(1.75)^3} = 28{,}210 \text{ psi}$$

when $\sigma = \sigma_{max}$ $\quad \tau = 0$

Applying a safety factor of 1.5

$S_{y\,min} = 42{,}315$ psi

The steel selected for the plate is A572, $S_y = 50{,}000$ psi

Wind Load Calculations

Wind Loading | Drag Force

Modeling 3 cases for normal to surface:
- Flate Plate
- Vertical Cylinder
- Horizontal square box

For all 3 cases Assuming:
- Incompressible viscous flow and neglecting end effects
- Uniform flow
- Atmospheric conditions in a hurricane (Katrina)
- Ideal Gas

Constants:

$V = 125\ mph \left| \frac{1}{15/22\ mph} \right| 0.3048\ m/s = 55.88\ m/s$

$P_{atm} = 920\ mbar = 27.17\ inHg \left| \frac{3.386\ kPa}{inHg} \right. = 91.977\ kPa\ (abs)$

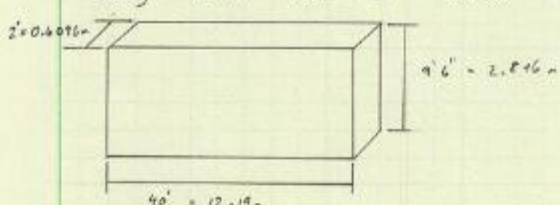
$T_{atm} = 93°F = 34°C$

$\rho_{atm} = \frac{P_{atm}}{R\ T_{atm}} \Rightarrow \frac{91,977\ Pa}{286.9\left(\frac{J}{kg\,k}\right)(34+273)(k)} = 1.044\ \frac{kg}{m^3}$

$\mu = 1.88 \times 10^{-5}\ \frac{N \cdot s}{m^2}$

Flat Plate

using entire area of crane as a square box



$F_D = C_D A \frac{1}{2} \rho V^2$

$Re = \frac{\rho V D}{\mu} = \frac{1.044(55.88)(0.6096)}{1.88 e^{-5}} = 1.89 e^5 >> 10^3$

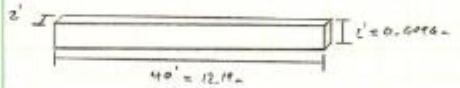
$F_D = (2.05)(12.19 \cdot 2.89)\frac{1}{2}(1.044)(55.88)^2 = 1.1796 e^5\ N$

$F_D = 26.52\ kip$

Although this number is high the system can be modeled better. However this number is a reference

Wind Load

Horizontal square boom



$\frac{b}{h} = \frac{40}{2} = 20 \Rightarrow 1.06\ C_D$

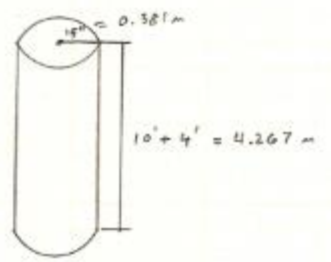
$F_D = (1.06)(0.6096 \cdot 12.19)\frac{1}{2}(1.044)(55.88)^2 = 12{,}839\ N$

$F_D = 2878.57\ lb$

using a higher $C_D = 2.05$

$F_D = 5567.06\ lb$

Vertical Pipe



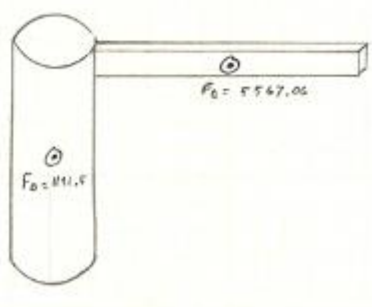
$A = 4.267 \cdot .381 \cdot 2 = 3.25\ m^2$

$Re_D = \frac{\rho V D}{\mu} = \frac{1.044(55.88)(0.762)}{1.88e^{-5}} = 2.36e^6$

$C_D \simeq 1.0$

$F_D = (1.0)(3.25)\frac{1}{2}(1.044)(55.68)^2 = 5300\ N$

$F_D = 1191.5\ lb$



Column Analysis

Compression Columns

Column Analysis | Compression Columns   1

Judging from the AAA unit, all beams are fixed - fixed

$C = 4$ but we use $C = \frac{1}{4}$

$E = 29{,}000{,}000$ psi

$S_y = 24{,}000$ psi

$$\left(\frac{L}{k}\right) = \left(\frac{2\pi^2 CE}{S_y}\right)^{1/2} = \left(\frac{2\pi^2 (1/4)(29000000)}{24000}\right)^{1/2} = 77.22$$

The Columns are a total length of 546 in; however, for this model the column will be measured from the 6th floor => $L = 146$ in

The Column is W 12x65

$I_x = 533 \text{ in}^4$ $I_y = 174 \text{ in}^4$ $A = 19.1 \text{ in}^2$

$I = Ak^2 \Rightarrow k_x = 5.28 \text{ in}$ $k_y = 3.018 \text{ in}$

$$\left(\frac{L}{k}\right)_x = \left(\frac{146}{5.28}\right) = 27.69$$

$$\left(\frac{L}{k}\right)_y = \left(\frac{146}{3.018}\right) = 48.38$$

Since both $\left(\frac{L}{k}\right)$ are less than the worse case Euler's formula is not applicable; We must use Johnson's formula

$$\frac{P_{cr}}{A} = S_y - \left(\frac{S_y}{2\pi}\frac{L}{k}\right)^2 \frac{1}{CE} = 24{,}000 - \left(\frac{24{,}000}{2\pi}\frac{146}{5.28}\right)^2 \frac{1}{1/4 \; 29000000}$$

$$\frac{P_{cr}}{A} = 22{,}463 \text{ psi} \Rightarrow P_{cr} = 429{,}043 \text{ lb}$$

With a safety factor of 1.5

$P_{cr} = 286{,}029$ lb

From beam D and E analysis

$R_{max} = 22{,}115$ lb

This is the maximum reaction at any of the 4 columns, which is insignificant to the P_{cr} value

Tension Columns

Column Analysis | Tension Columns | 2

From Beam D and E analysis

$$R_{max} = 8,176 \text{ lb}$$

This is the maximum tension reaction at any of the 4 columns

$$\sigma = \frac{R_{max}}{A} = \frac{8,176}{19.1} = 428 \text{ psi}$$

$$\sigma_y = 24,000 \text{ psi}$$

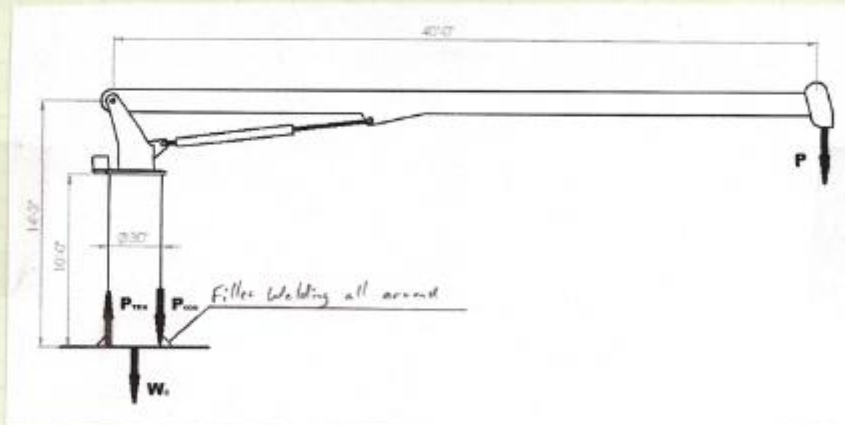
$$n = \frac{\sigma_y}{\sigma} = \frac{24000}{428} = 56.07$$

Which is incredidibly large

Weld Analysis

Crane to Plate Welding

Weld Analysis | Crane to Plate



$P = 15{,}000$ lb

$M = 3{,}120{,}000$ lb · in

$\tau' = 0$ since pipe is in pure bending and compression

$$\tau'' = \frac{Mc}{I} + \frac{P}{A} = \frac{Mr}{0.707 h \pi r^3} + \frac{P}{1.414 \pi h r}$$

$$= \frac{3{,}120{,}000\,(15)}{0.707 (h) \pi (15)^3} + \frac{15{,}000}{1.414 (\pi)(h)(15)}$$

$\tau_{allowable} = 0.30 \cdot S_{ut}$ for weld metal or $0.40 \cdot S_{ut}$ for base metal

lowest strength electrode E60xx => $S_{ut} = 62{,}000$ psi

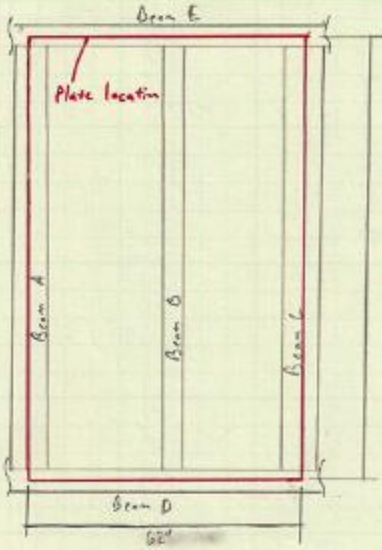
Minimum strength carbon steel => $S_{ut} = 24{,}000$ psi

$\tau_{allowable} = 9600$ psi

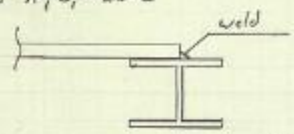
$9600 = \tau''$

solve for $h = 0.6733$ in

Weld Analysis | Plate to Beam

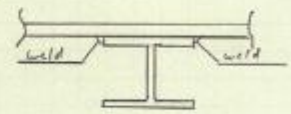


Beams A, C, D and E



The plate goes to the middle of the beam so the grating can rest on the rest of the beam

Beam B



Welding on Beams A, C, D, and E

All beams W 14x48 $b_f = 8.030$

Welds are in pure bending and pure tension $\Rightarrow \tau' = 0$

We assume that only two welds will hold the plate and that these two welds will be the smallest length which would be welds on beams D and E

$$\tau = \frac{Mc}{I} + \frac{R}{A} = \frac{Mc}{0.707hL\frac{c^2}{2}} + \frac{R}{1.414hL}$$

τ allowable $= 0.30 \cdot S_{ut}$ for electrode or $0.40 \cdot S_{ut}$ for base metal

$$\tau \text{ allowable} = 9600 \text{ psi} = \frac{3{,}120{,}000(31)}{0.707(h)(62)\left(\frac{31^2}{2}\right)} + \frac{15{,}000}{1.414(h)(62)}$$

$h = 0.496$ in

Because this is a worse case a h of 0.5 in can be chosen

Bolt Analysis

Bolt Analysis

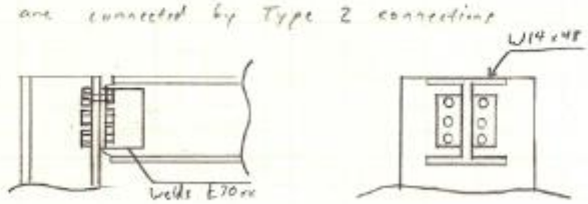
The current bolts on the AAA unit are:

A 325 3/4"

And the gusset plates are:

3/8" plate

Beams are connected by Type 2 connections



$t_w = 0.340$ in

Type 2 connections don't transfer any moment

They are combonation (bolt and weld) formed beam conections

The max shear at any connect is:

$V_{max} \approx 54{,}000$ lb

From LRFD section 5

Table III p 5-34

Load Capacity: 120 kips   size: $\frac{1}{4}$"   Angle Length: $8\frac{1}{2}$

Minimum Web Thickness: 0.55"   Max Number of Bolts: 3

Table II-C p 5-30

Bolt Diameter: 3/4   load capacity of 98.9 kips

L-Angle: 5/16"   # of Bolts: 3

Spec J2.2 p 6-62

Maximum Weld size = Thickness of critical part = 1/16"

$h_{max} = 5/16" - \frac{1}{16}" = 1/4"$ $h = h_{max}$

$h_{min} = 3/16"$

Thus weld has to be $3/16" \leq h \leq 1/4"$

Bolt Analysis

Table II-A p 5-28

Bolts : A 325-N 3/4" Angle thickness of 5/16"

3 Bolts with 93 kips Angle length of 8 1/2"

Weld connection capacity

$\left(\frac{t_w}{t_{w,min}}\right)$ 120 kips = 74.2 kips

Final

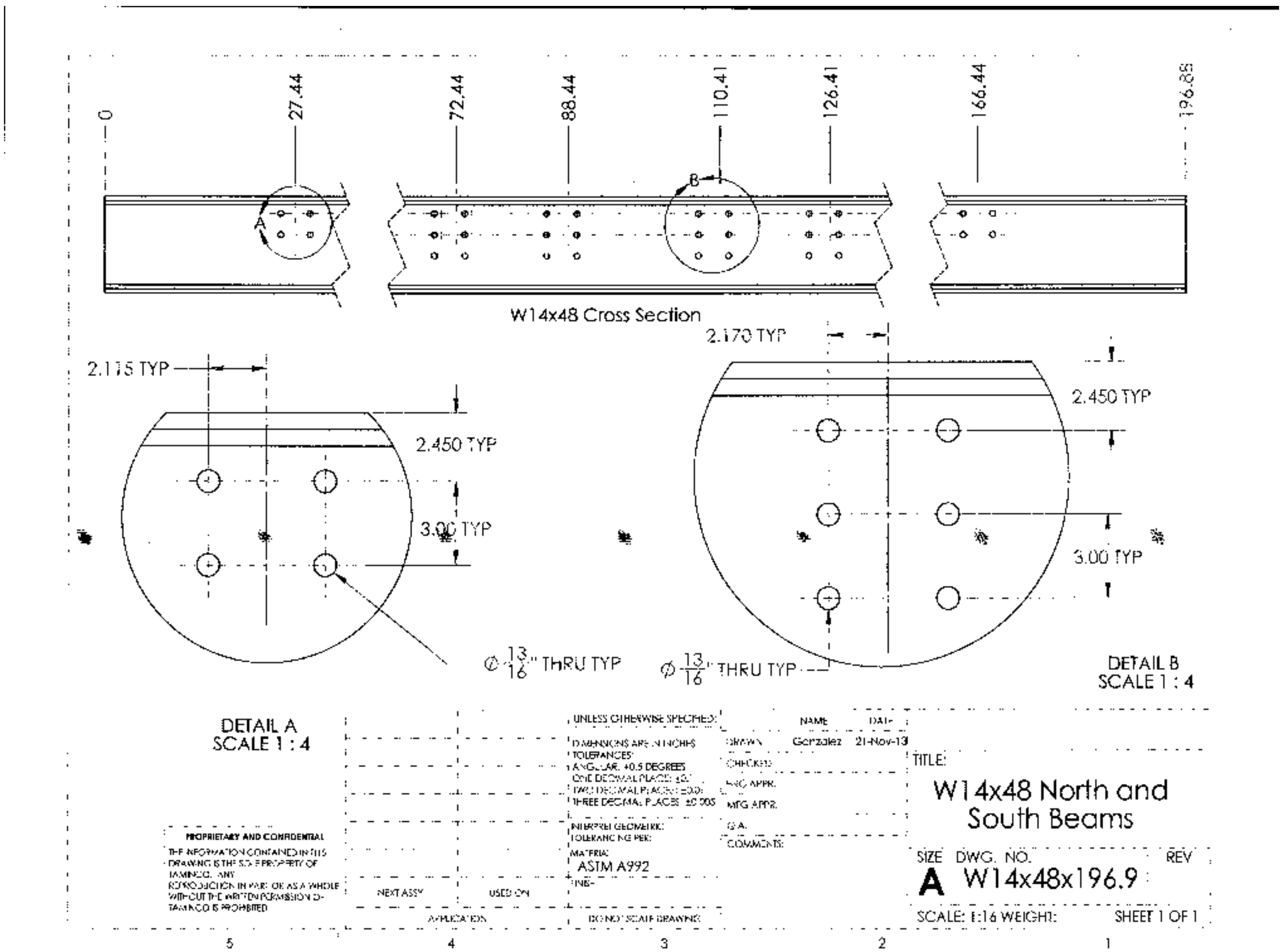
Two L4 x 3 1/2 x 5/16 x 8 1/2

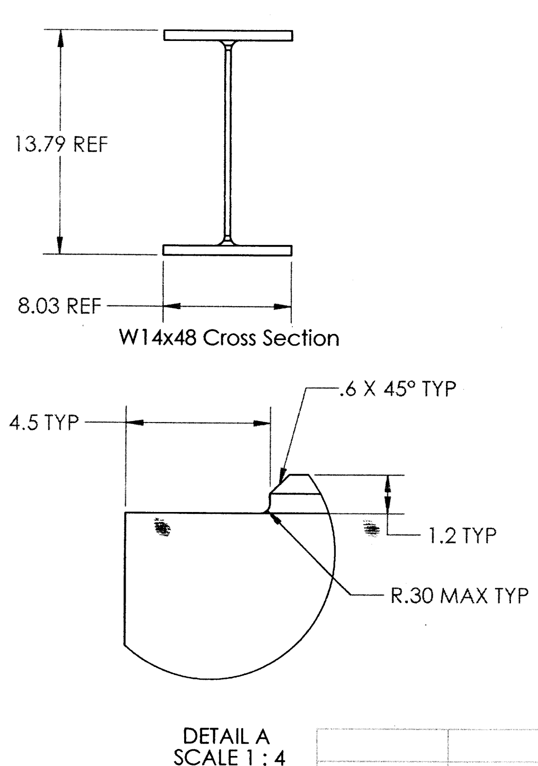
Six 3/4" dia ASTM A 325-N Bolts

1/4 fillet weld E 70 xx

Design II Manufacturing Drawings

Beams





UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±0.5 DEGREES ONE DECIMAL PLACE: ±0.1 TWO DECIMAL PLACES: ±0.01 THREE DECIMAL PLACES: ±0.005	DRAWN	Gonzalez	21-Nov-13
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL ASTM A992	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

TITLE: W14x48 Cross Beams

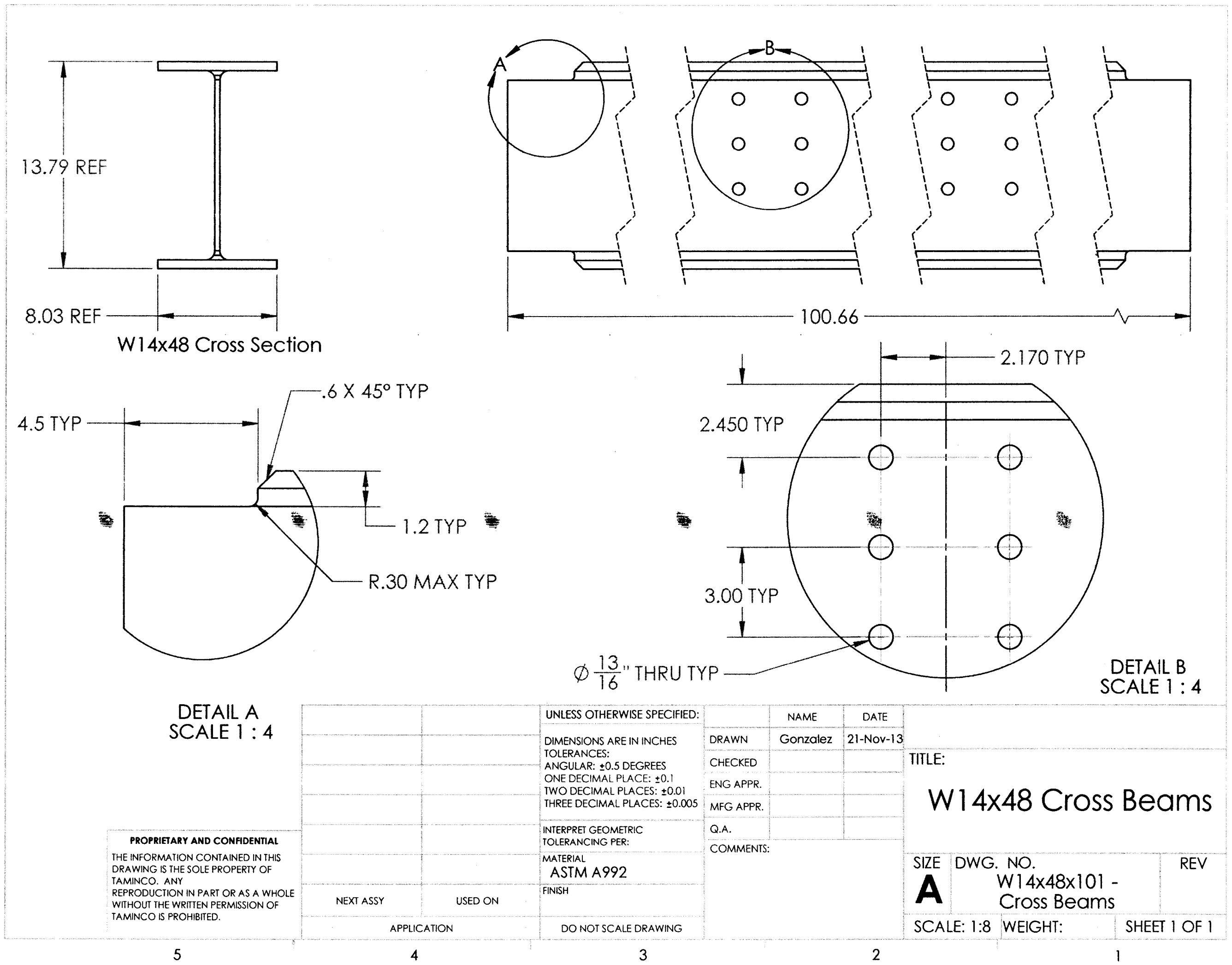
SIZE A | DWG. NO. W14x48x101 | REV

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

NEXT ASSY | USED ON

APPLICATION

5 4 3 2 1


13.79 REF
8.03 REF
W14x48 Cross Section
A
B
100.66
2.170 TYP
2.450 TYP
3.00 TYP
Ø 13/16" THRU TYP
DETAIL B
SCALE 1 : 4
4.5 TYP
.6 X 45° TYP
1.2 TYP
R.30 MAX TYP
DETAIL A
SCALE 1 : 4
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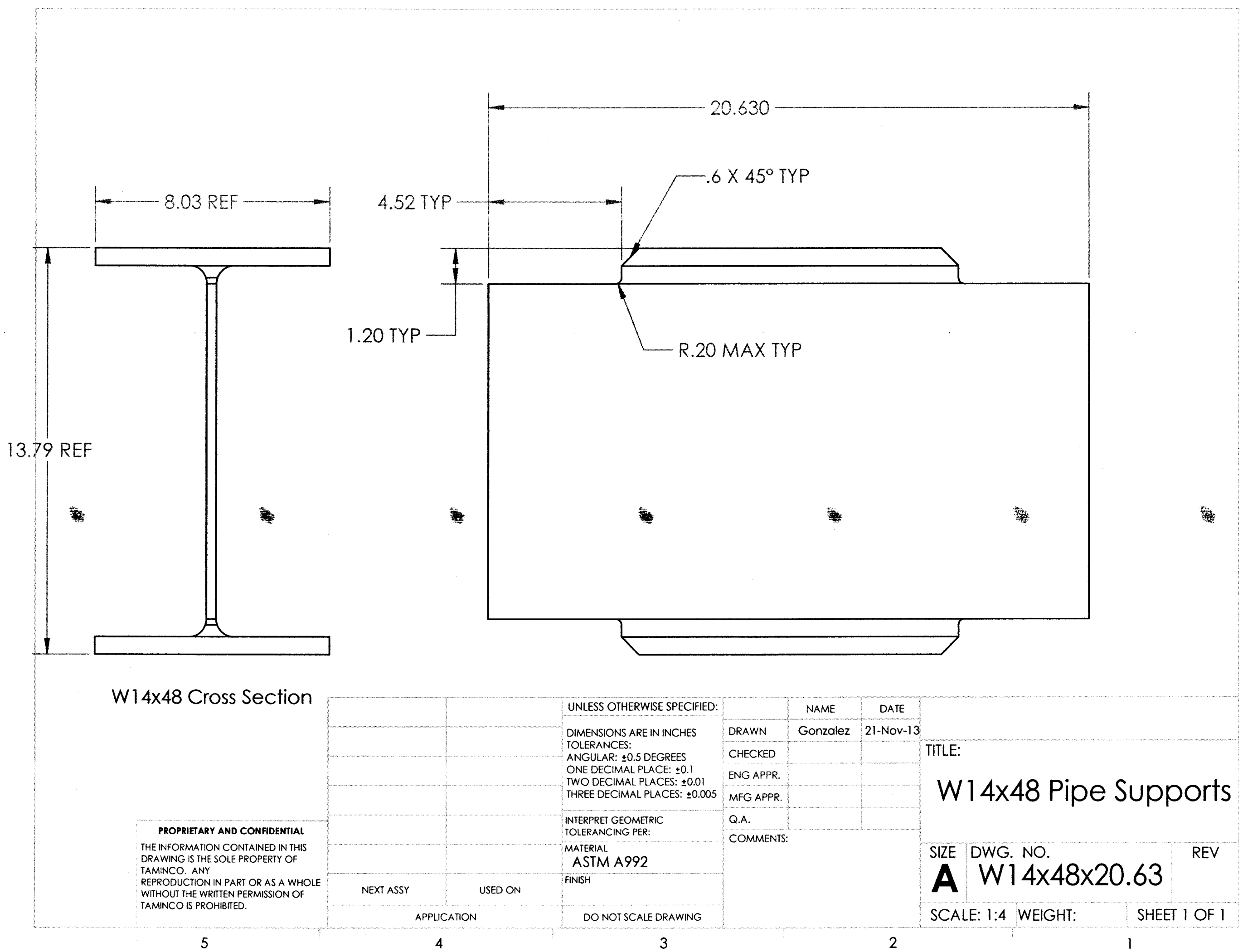
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A992
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W14x48 Cross Beams
SIZE
A
DWG. NO.
W14x48x101 -
Cross Beams
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



20.630
.6 X 45° TYP
8.03 REF
4.52 TYP
1.20 TYP
R.20 MAX TYP
13.79 REF
W14x48 Cross Section
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A992
FINISH
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W14x48 Pipe Supports
SIZE
A
DWG. NO.
W14x48x20.63
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
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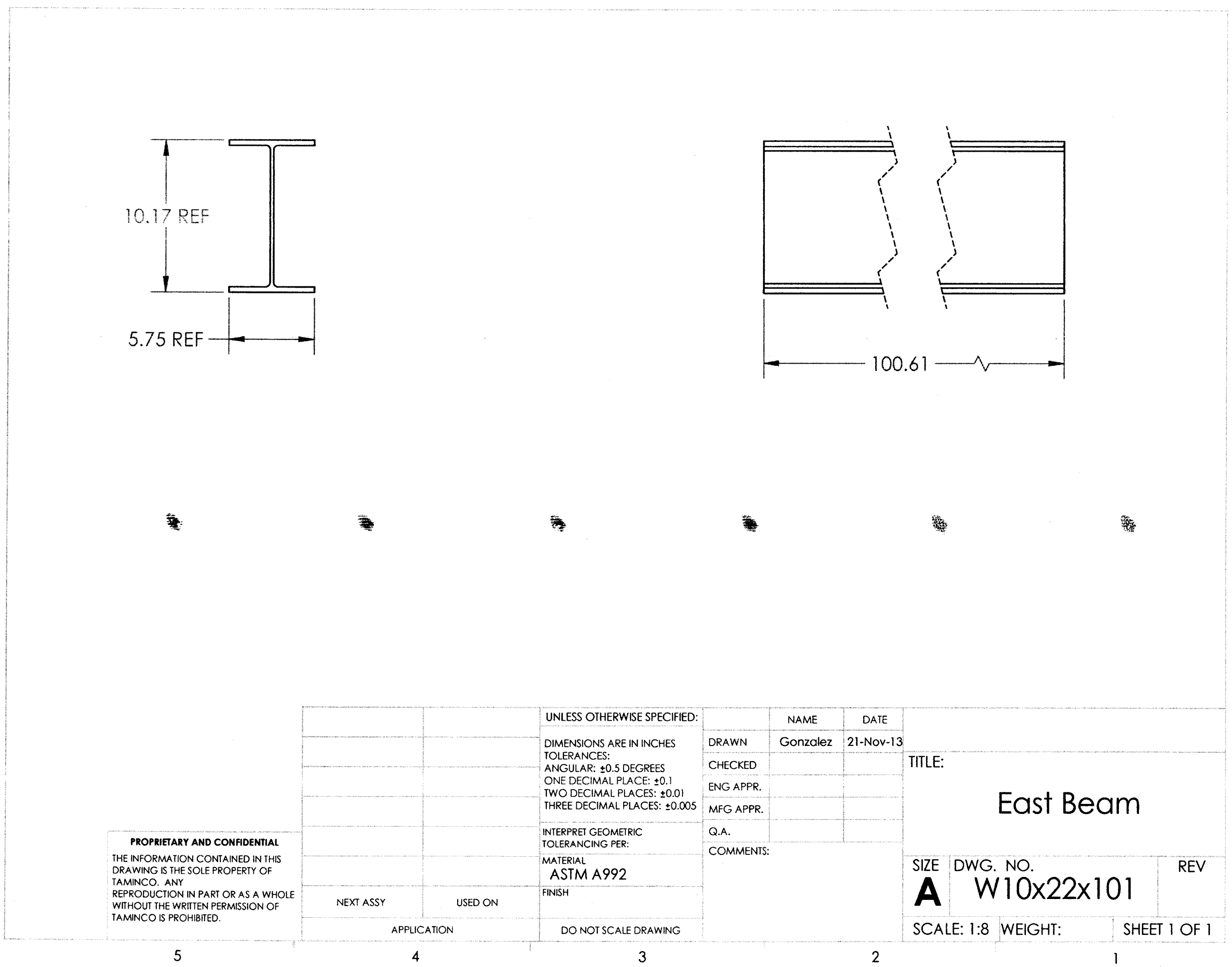
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
5
4
3
2
1


10.17 REF
5.75 REF
100.61
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A992
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
East Beam
SIZE
A
DWG. NO.
W10x22x101
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
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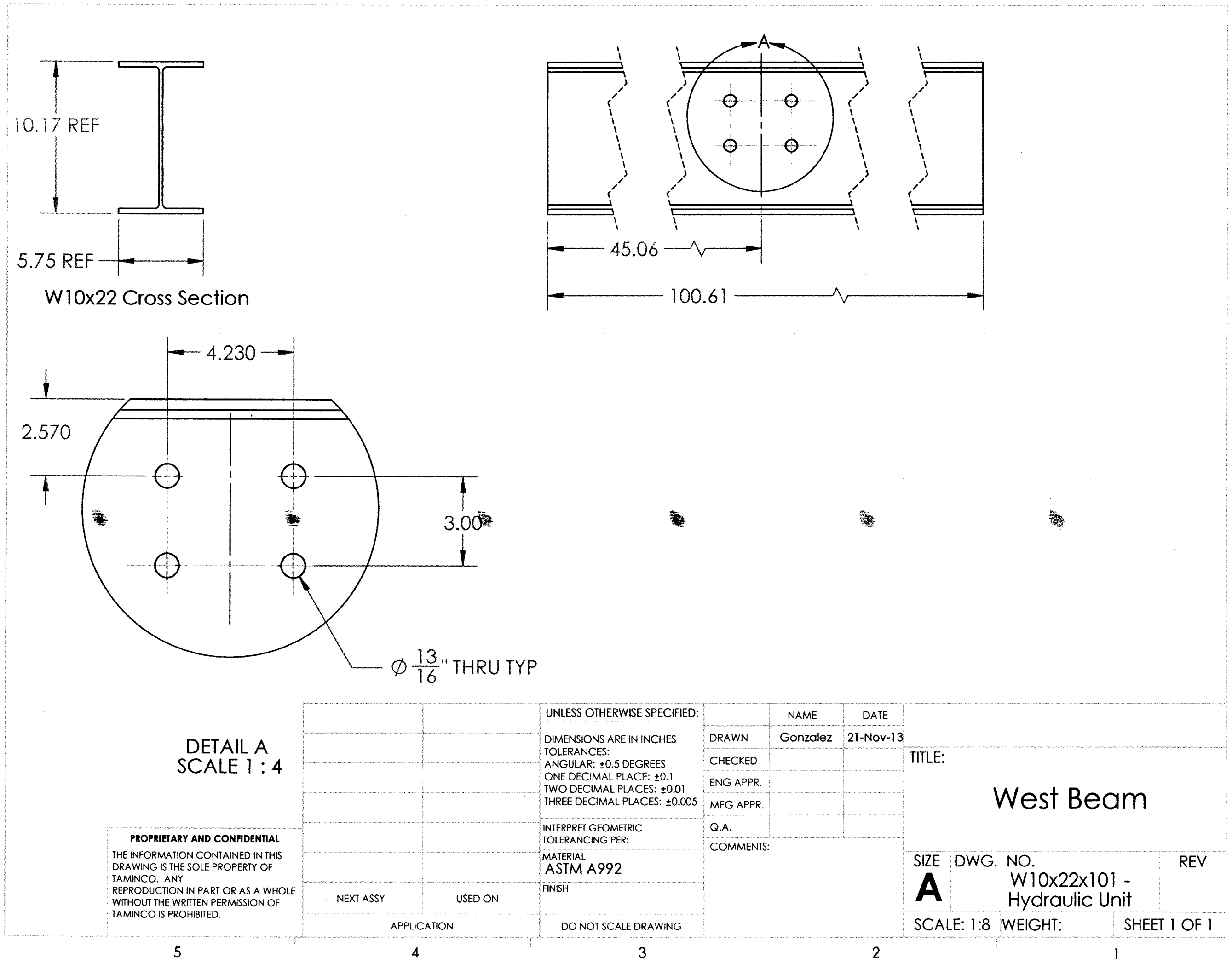
USED ON
APPLICATION
5
4
3
2
1


10.17 REF
5.75 REF
W10x22 Cross Section
A
45.06
100.61
4.230
2.570
3.00
Ø 13/16" THRU TYP
DETAIL A
SCALE 1 : 4
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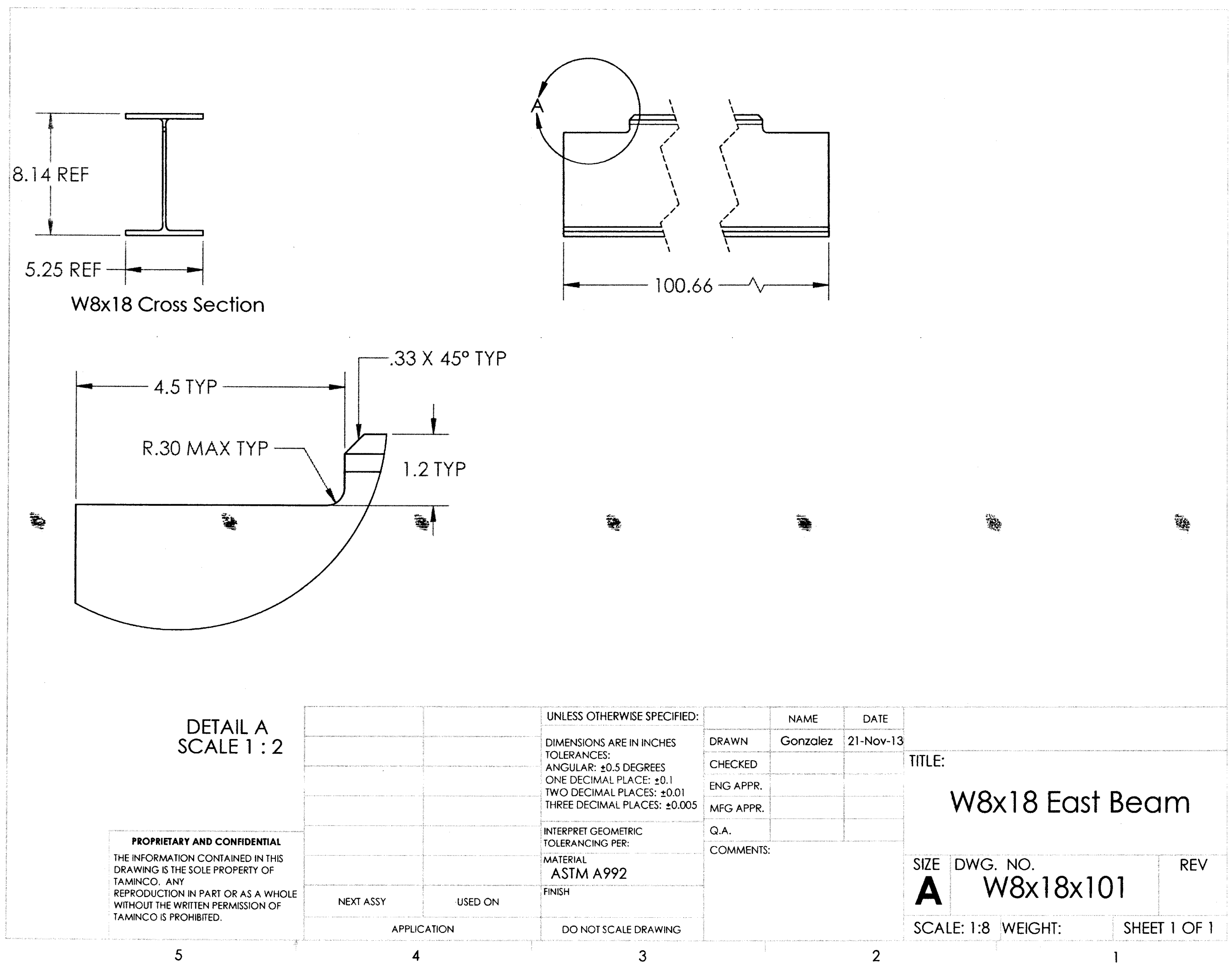
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A992
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
West Beam
SIZE
A
DWG. NO.
W10x22x101 - Hydraulic Unit
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


8.14 REF
5.25 REF
W8x18 Cross Section
A
100.66
4.5 TYP
.33 X 45° TYP
R.30 MAX TYP
1.2 TYP
DETAIL A
SCALE 1 : 2
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TOLERANCES:
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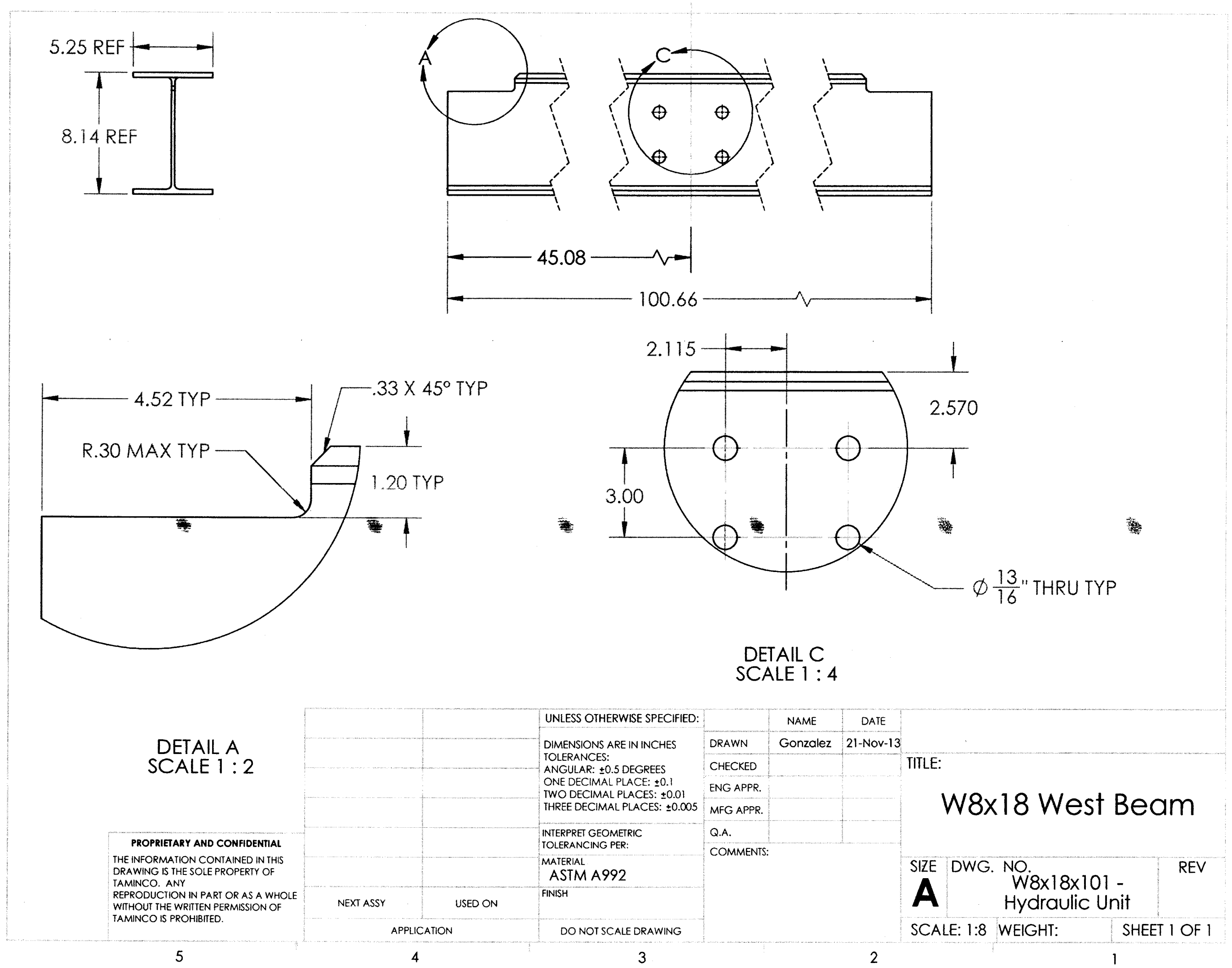
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A992
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W8x18 East Beam
SIZE
A
DWG. NO.
W8x18x101
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



5.25 REF
8.14 REF
A
C
45.08
100.66
4.52 TYP
.33 X 45° TYP
R.30 MAX TYP
1.20 TYP
2.115
2.570
3.00
Ø 13/16" THRU TYP
DETAIL C
SCALE 1 : 4
DETAIL A
SCALE 1 : 2
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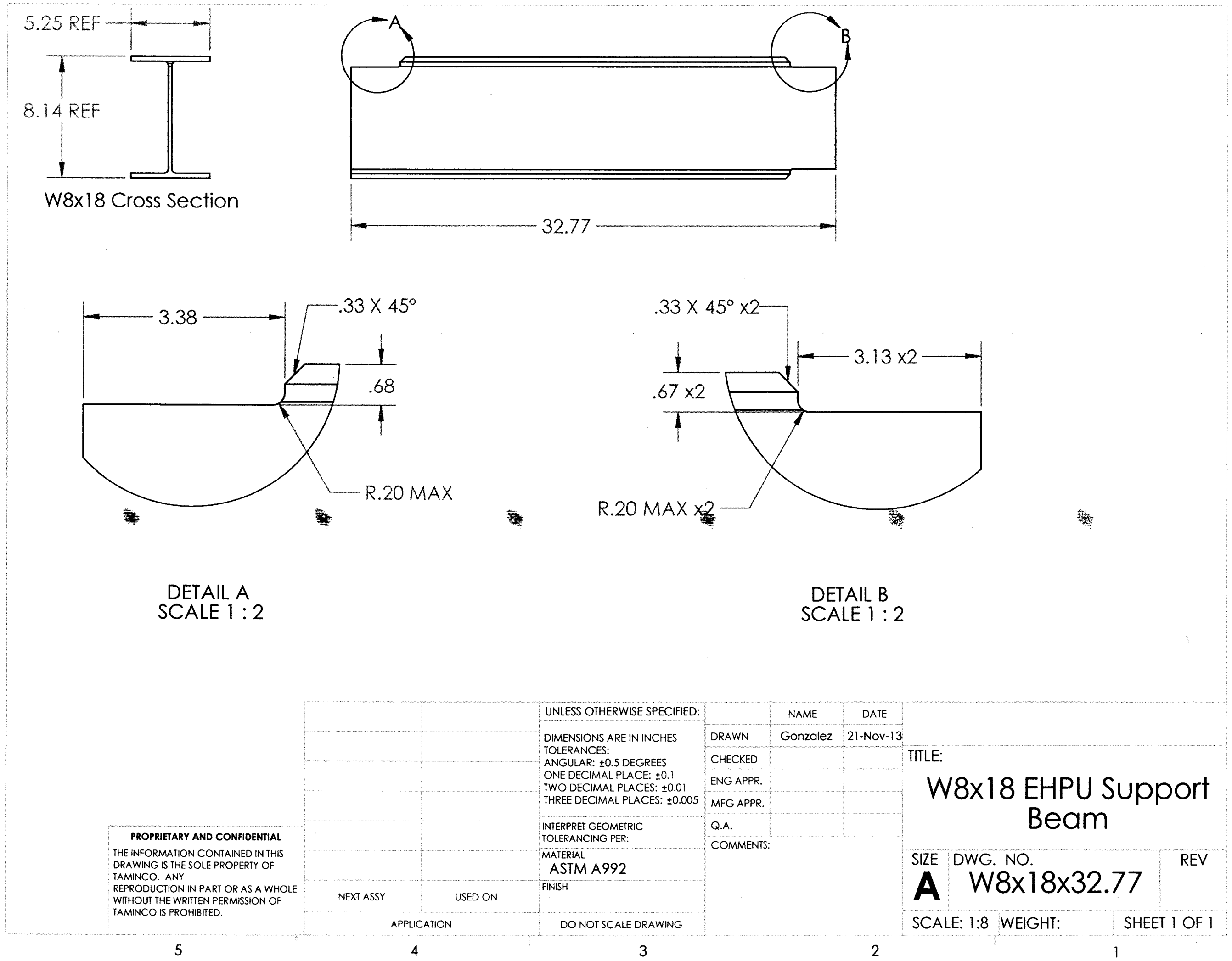
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A992
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W8x18 West Beam
SIZE
A
DWG. NO.
W8x18x101 - Hydraulic Unit
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


5.25 REF
8.14 REF
W8x18 Cross Section
A
B
32.77
3.38
.33 X 45°
.68
R.20 MAX
.33 X 45° x2
3.13 x2
.67 x2
R.20 MAX x2
DETAIL A
SCALE 1 : 2
DETAIL B
SCALE 1 : 2
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APPLICATION
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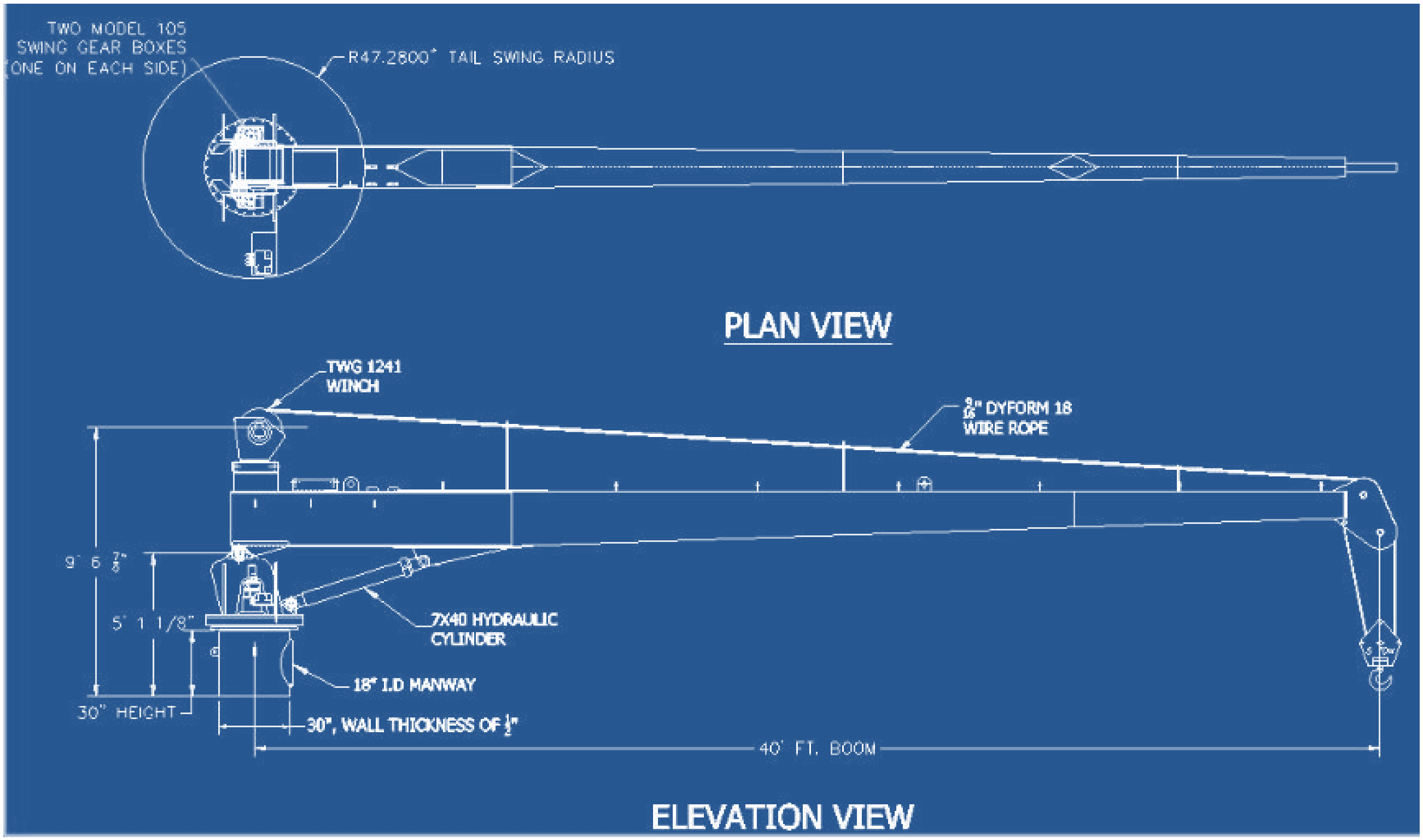
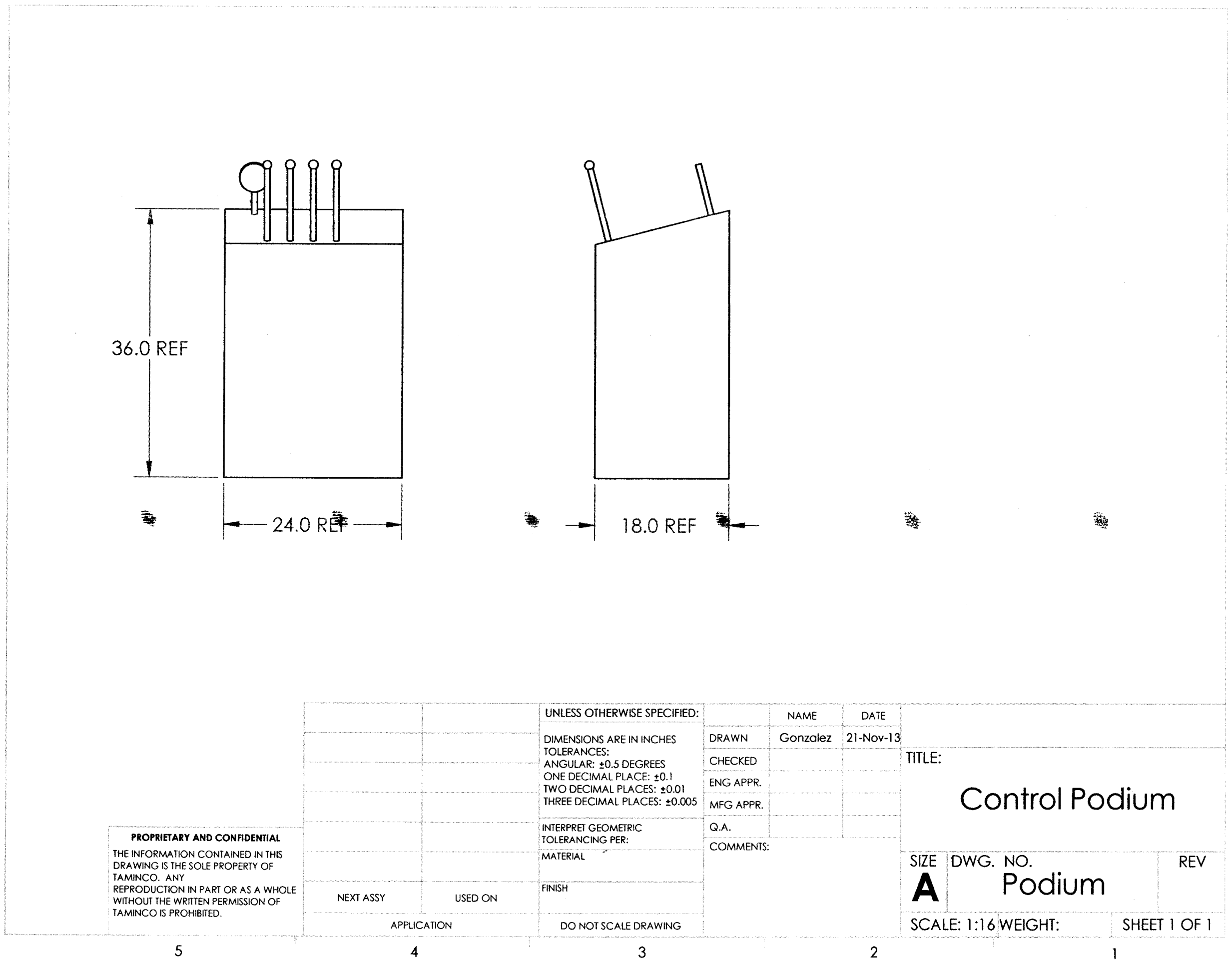
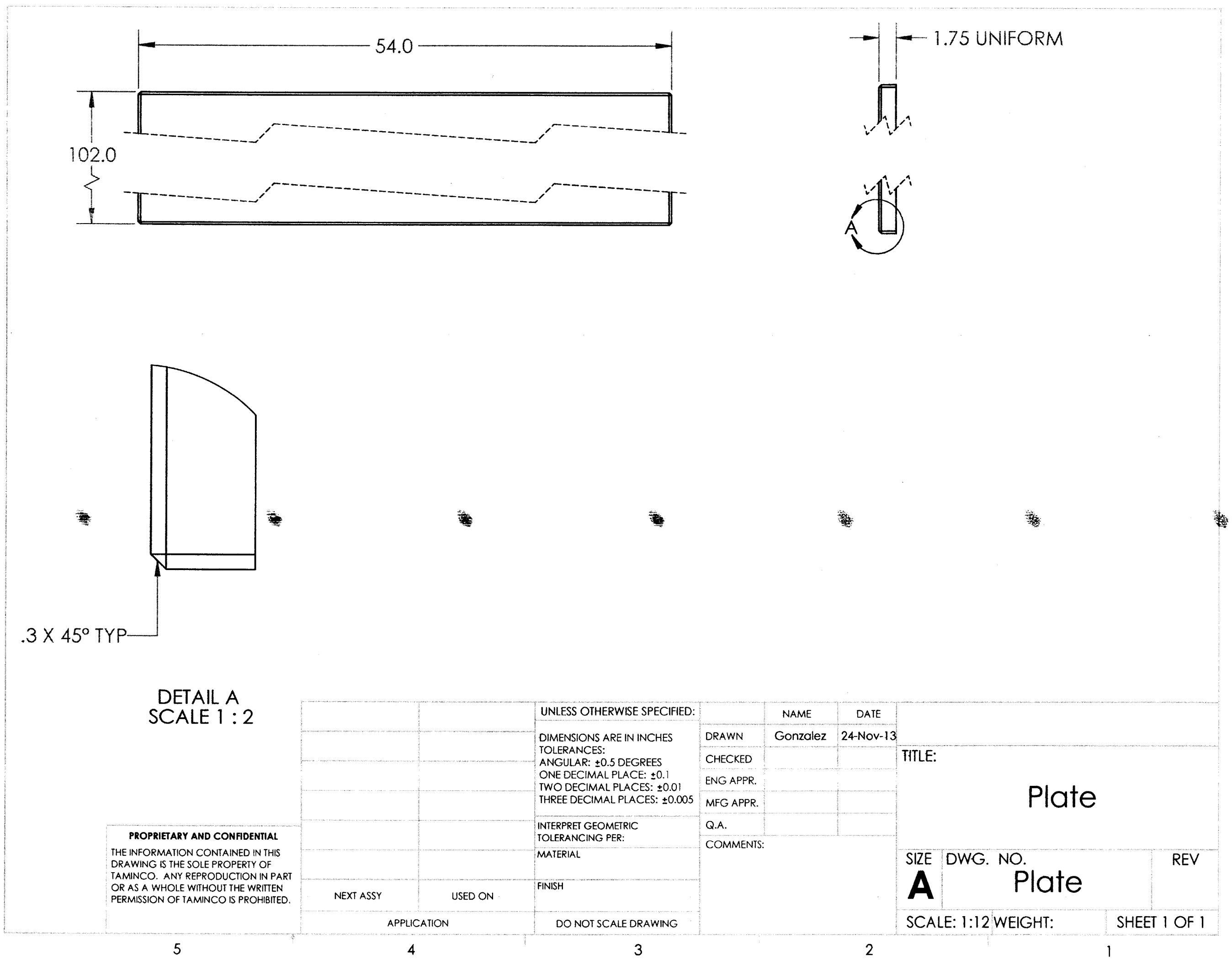
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A992
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W8x18 EHPU Support Beam
SIZE
A
DWG. NO.
W8x18x32.77
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

Crane


TWO MODEL 105
SWING GEAR BOXES
(ONE ON EACH SIDE)
R47.2800" TAIL SWING RADIUS
PLAN VIEW
TWG 1241
WINCH
DYFORM 18
WIRE ROPE
7X40 HYDRAULIC
CYLINDER
18" I.D MANWAY
30", WALL THICKNESS OF ½"
5' 1 1/8"
30" HEIGHT
40' FT. BOOM
ELEVATION VIEW

Other Components




54.0
102.0
1.75 UNIFORM
A
.3 X 45° TYP
DETAIL A
SCALE 1 : 2
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
24-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Plate
SIZE
A
DWG. NO.
Plate
REV
SCALE: 1:12
WEIGHT:
SHEET 1 OF 1
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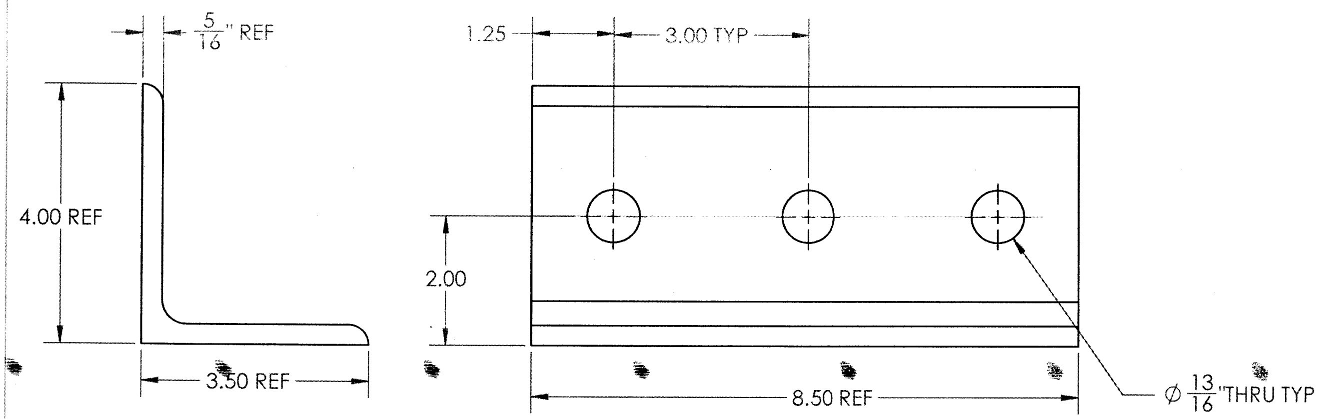
5
4
3
2
1



Standard L4x3.5x5/16x8.5 Angle

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
ASTM A36

FINISH

	NAME	DATE
DRAWN	Gonzalez	21-Nov-13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

Large L-Angle

SIZE A DWG. NO. L4x3.5x0.3125x8.5 REV

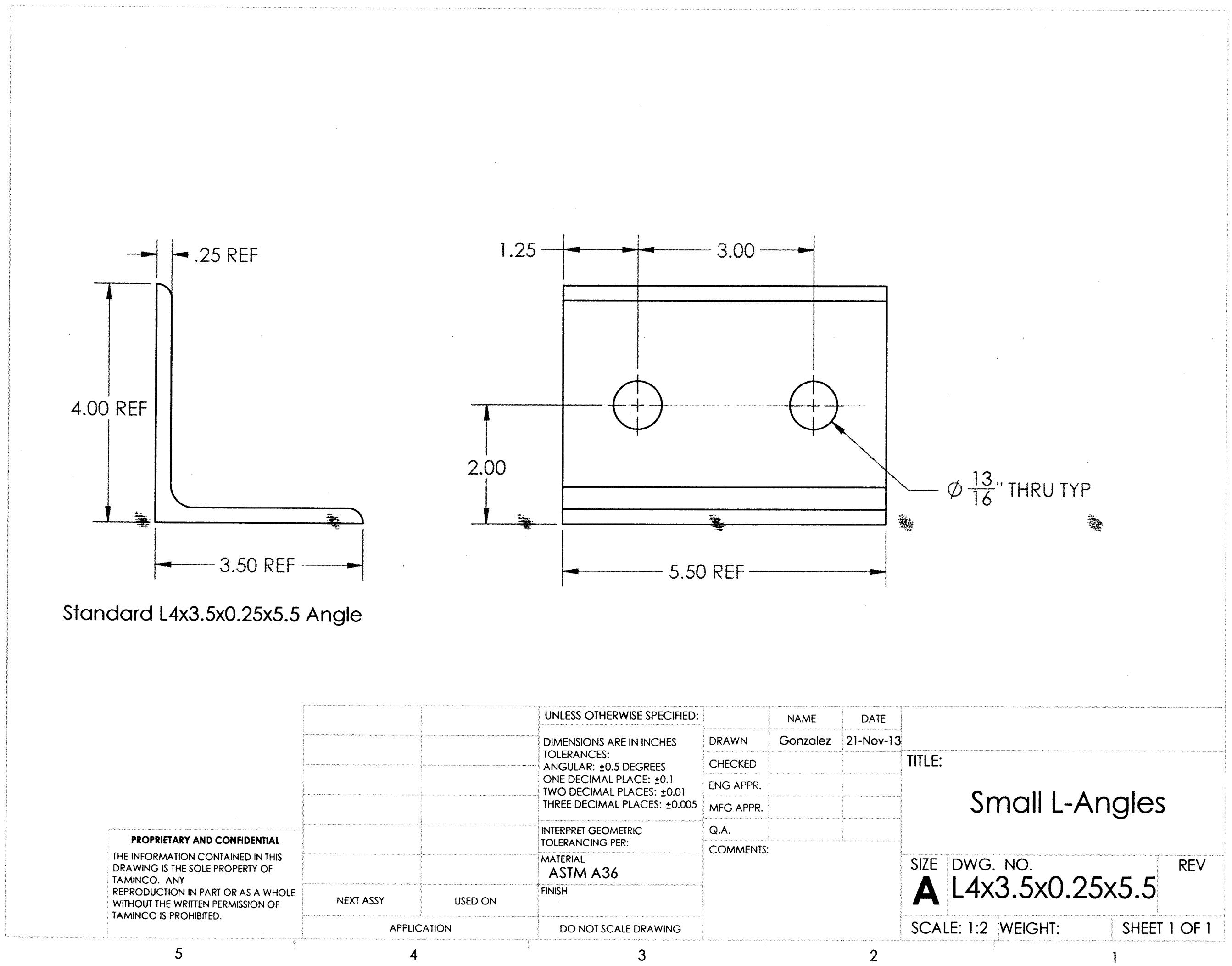
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

NEXT ASSY | USED ON

APPLICATION

DO NOT SCALE DRAWING

5 4 3 2 1



.25 REF
4.00 REF
3.50 REF
Standard L4x3.5x0.25x5.5 Angle
1.25
3.00
2.00
5.50 REF
Ø 13/16" THRU TYP
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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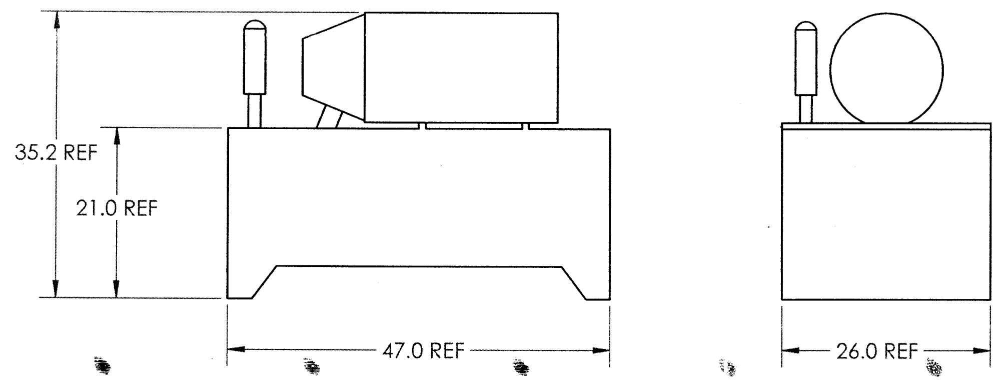
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Small L-Angles
SIZE
A
DWG. NO.
L4x3.5x0.25x5.5
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

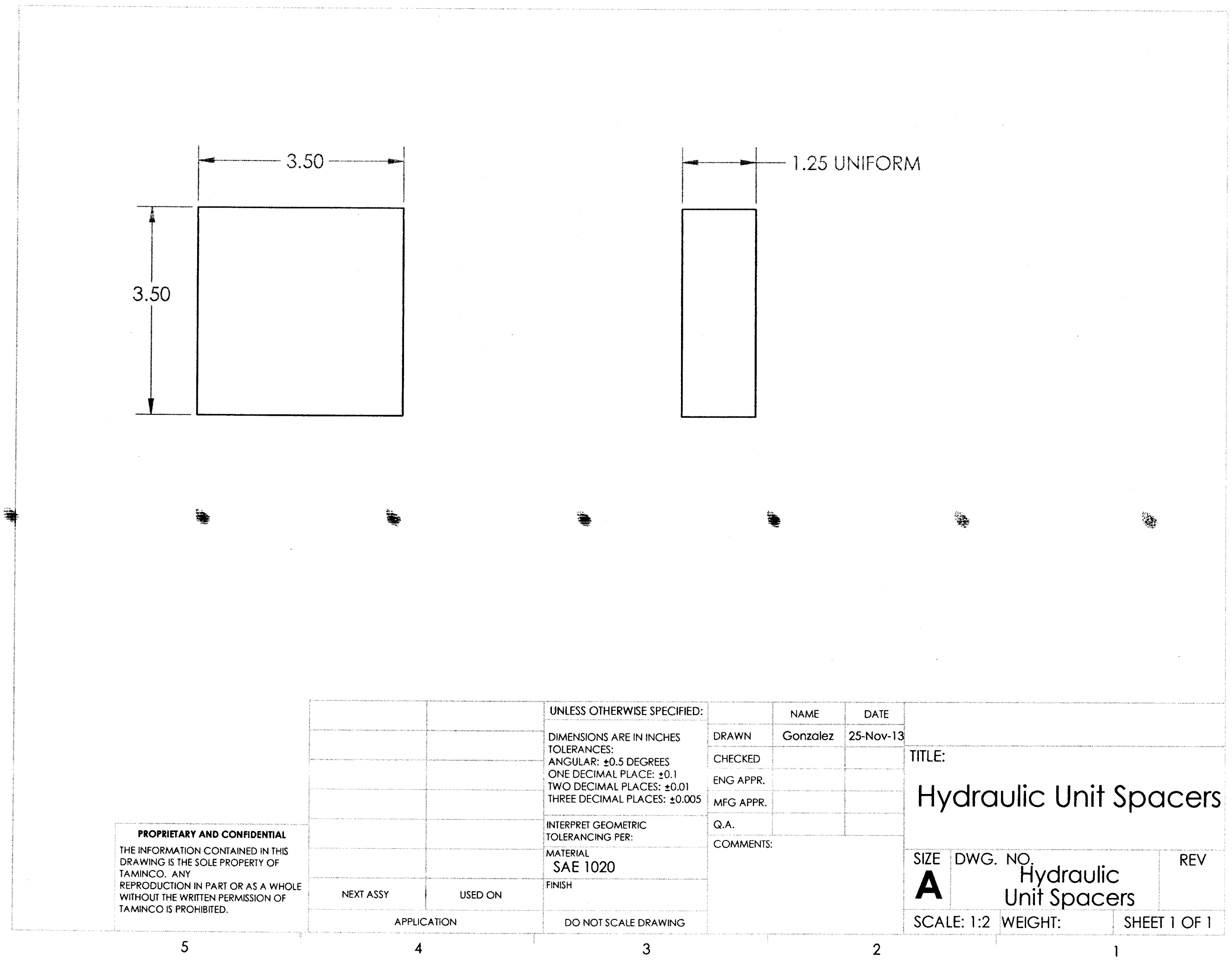


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±0.5 DEGREES ONE DECIMAL PLACE: ±0.1 TWO DECIMAL PLACES: ±0.01 THREE DECIMAL PLACES: ±0.005	DRAWN	Gonzalez	21-Nov-13	TITLE: Electrohydraulic Power Unit
	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL	COMMENTS:			SIZE A DWG. NO. Hydraulic Unit REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:16 WEIGHT: SHEET 1 OF 1

NEXT ASSY | USED ON

APPLICATION

5 4 3 2 1


3.50
3.50
1.25 UNIFORM
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
SAE 1020
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
25-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Hydraulic Unit Spacers
SIZE
A
DWG. NO.
Hydraulic Unit Spacers
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
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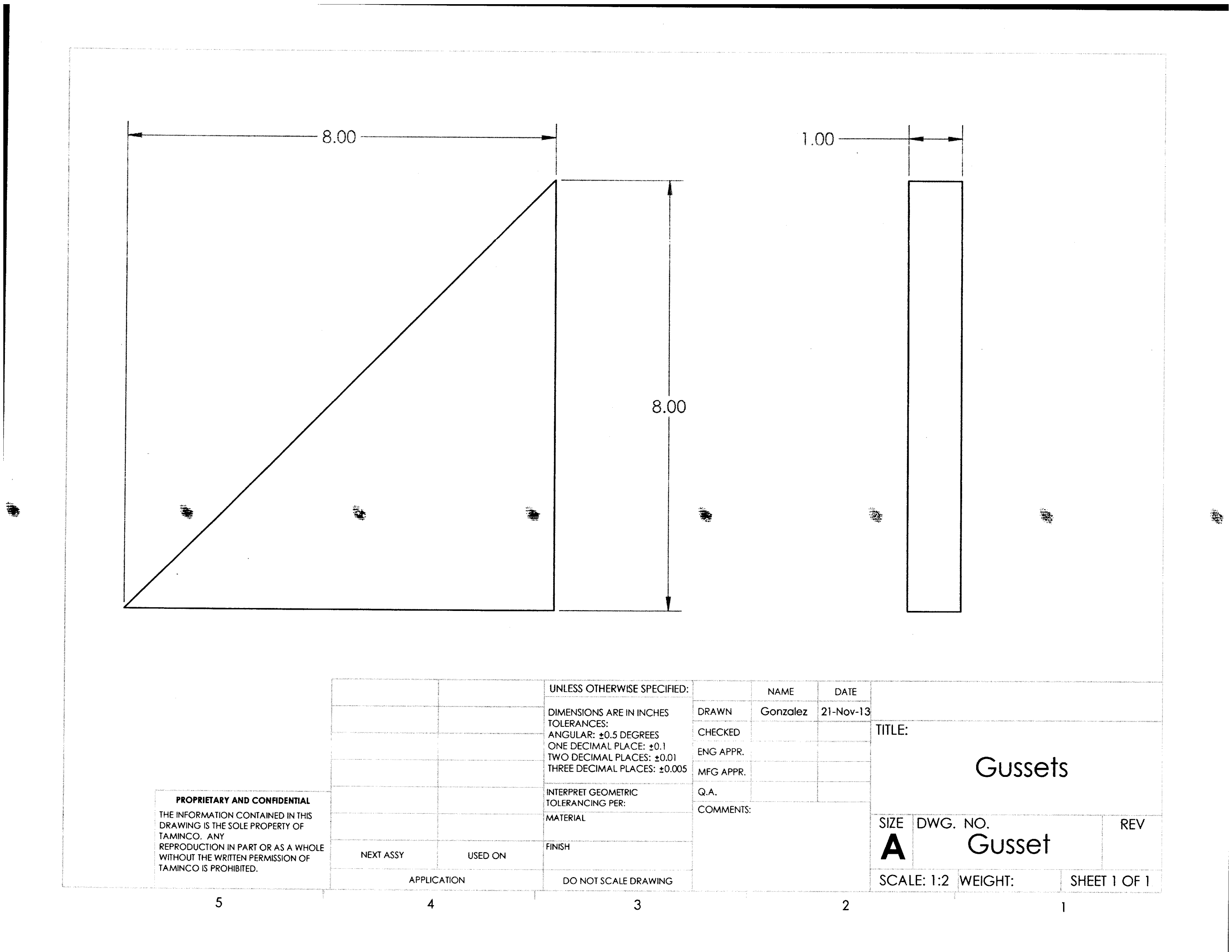
8.00
1.00
8.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Gonzalez
21-Nov-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Gussets
SIZE
A
DWG. NO.
Gusset
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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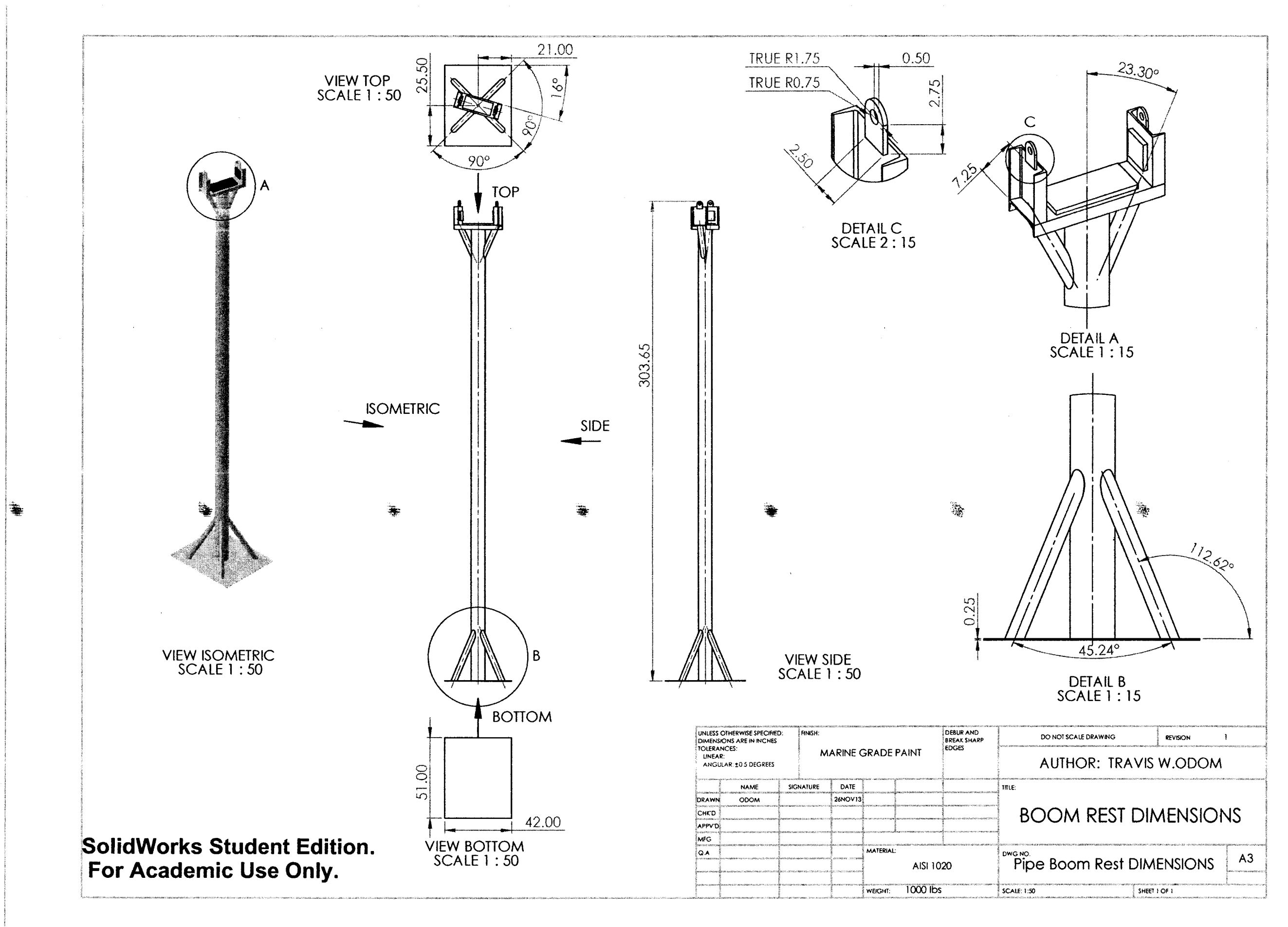
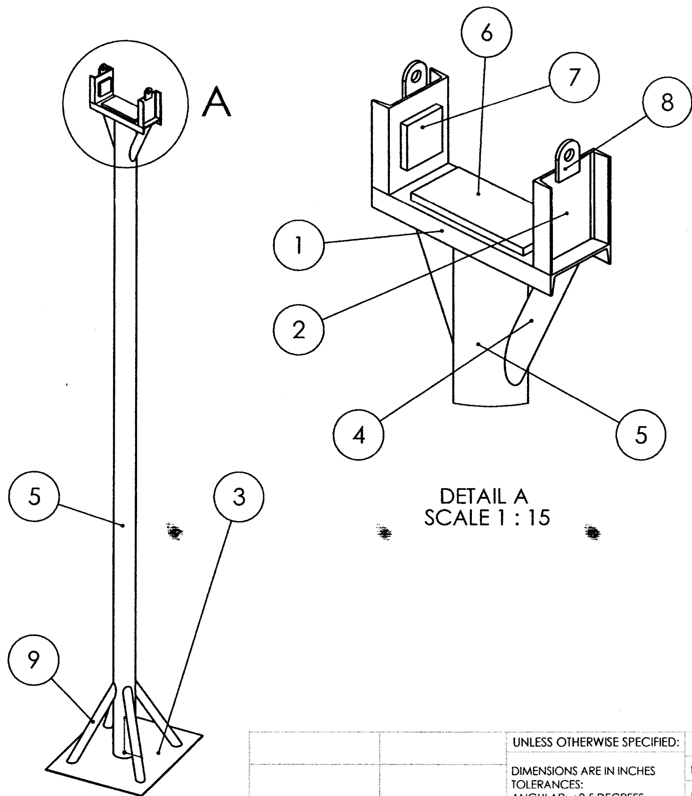
NEXT ASSY
USED ON
APPLICATION
5
4
3
2
1

Boom Rest


VIEW TOP
SCALE 1 : 50
21.00
25.50
16°
90°
90°
TOP
A
ISOMETRIC
SIDE
303.65
B
VIEW ISOMETRIC
SCALE 1 : 50
BOTTOM
51.00
42.00
VIEW BOTTOM
SCALE 1 : 50
VIEW SIDE
SCALE 1 : 50
TRUE R1.75
TRUE R0.75
0.50
2.75
2.50
DETAIL C
SCALE 2 : 15
23.30°
C
7.25
DETAIL A
SCALE 1 : 15
112.62°
0.25
45.24°
DETAIL B
SCALE 1 : 15
MARINE GRADE PAINT
AUTHOR: TRAVIS W.ODOM
BOOM REST DIMENSIONS
AISI 1020
Pipe Boom Rest DIMENSIONS
A3
1000 lbs
SolidWorks Student Edition.
For Academic Use Only.



ITEM NO.	QTY.	MATERIAL	DESCRIPTION	LENGTH
1	1	AISI 1020	C10X20	2' - 4.72"
2	2	AISI 1020	C10X20	11.62"
3	1	AISI 1020	1/4" PLATE	42" X 51"
4	2	AISI 1020	P3	1' - 10.75"
5	1	AISI 1020	8 S20	24' - 0.00"
6	1	RUBBER	REST PAD	1" X 6" X 1'
7	2	RUBBER	OUTER PAD	1" X 6" X 6"
8	1	AISI 1020	TIE DOWN	0.25" THICK
9	4	AISI 1020	P3	3'-1.29"

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	ODOM	25-Nov-13
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:
BOOM REST CUTOUT

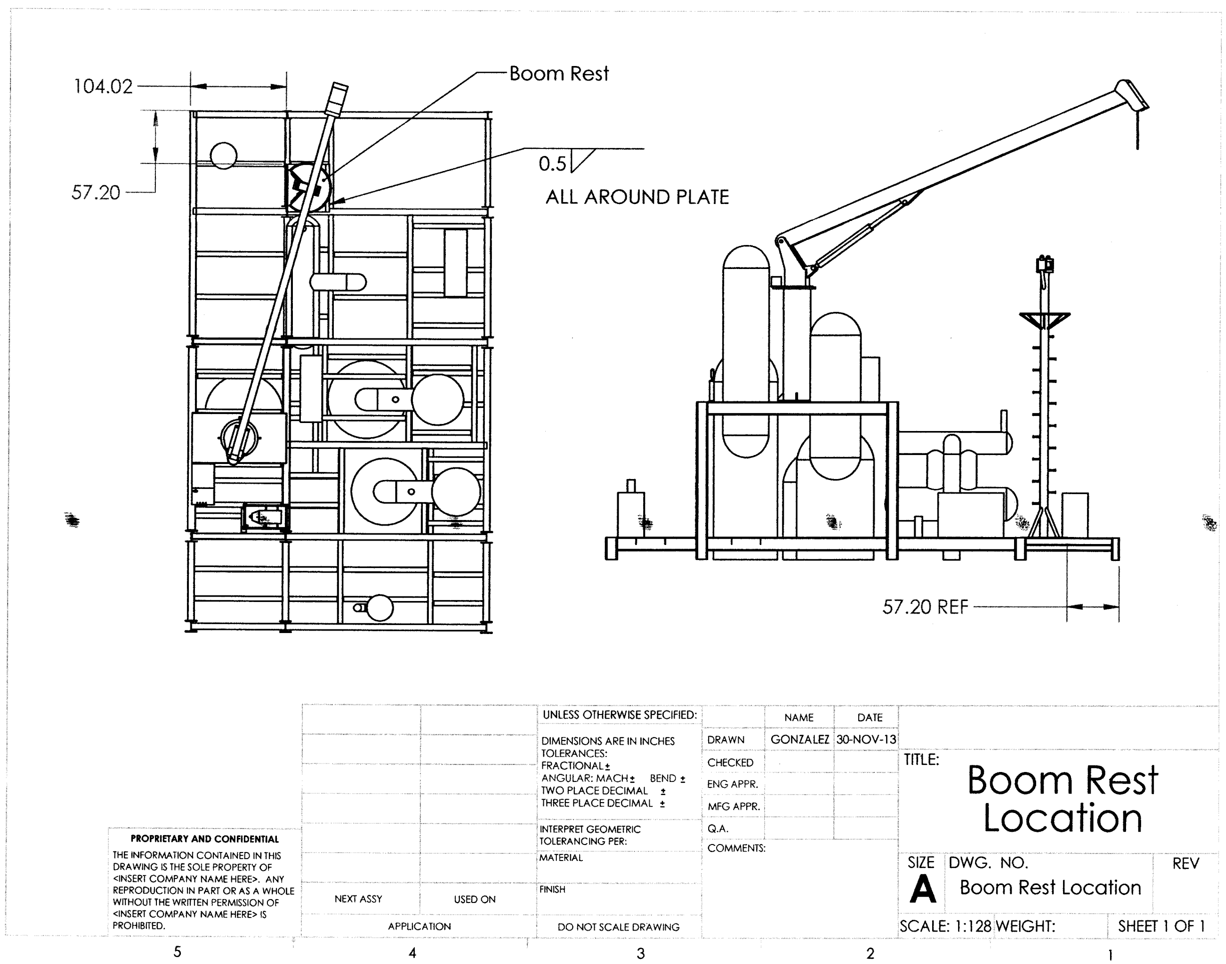
SIZE A | DWG. NO. Pipe Boom Rest Cut List | REV 1

SCALE 1:50 | WEIGHT: | SHEET 1 OF 1

NEXT ASSY | USED ON
APPLICATION

5 4 3 2 1

Assembly


104.02
57.20
Boom Rest
0.5
ALL AROUND PLATE
57.20 REF
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
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
GONZALEZ
30-NOV-13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Boom Rest Location
SIZE
A
DWG. NO.
Boom Rest Location
REV
SCALE: 1:128
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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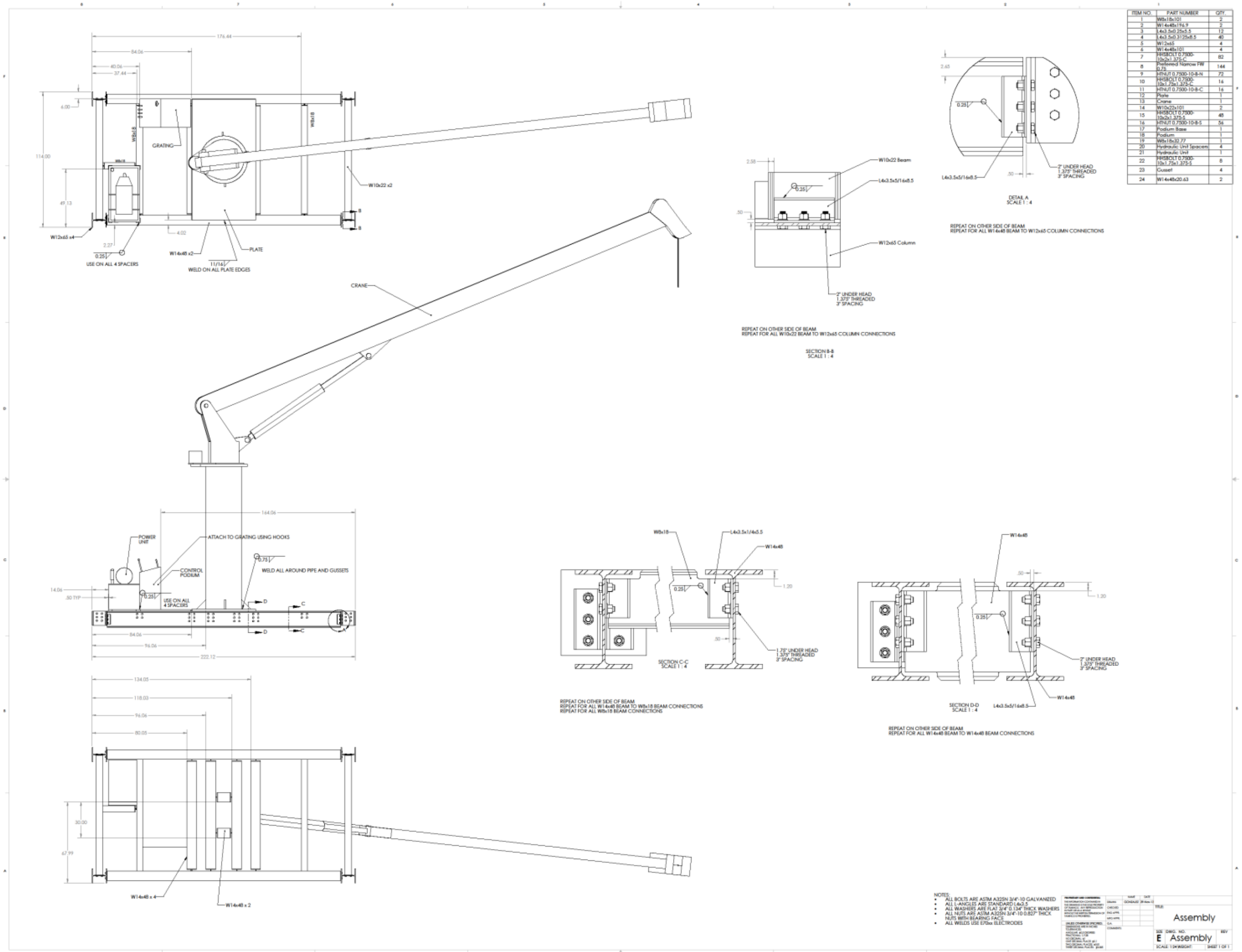
5
4
3
2
1

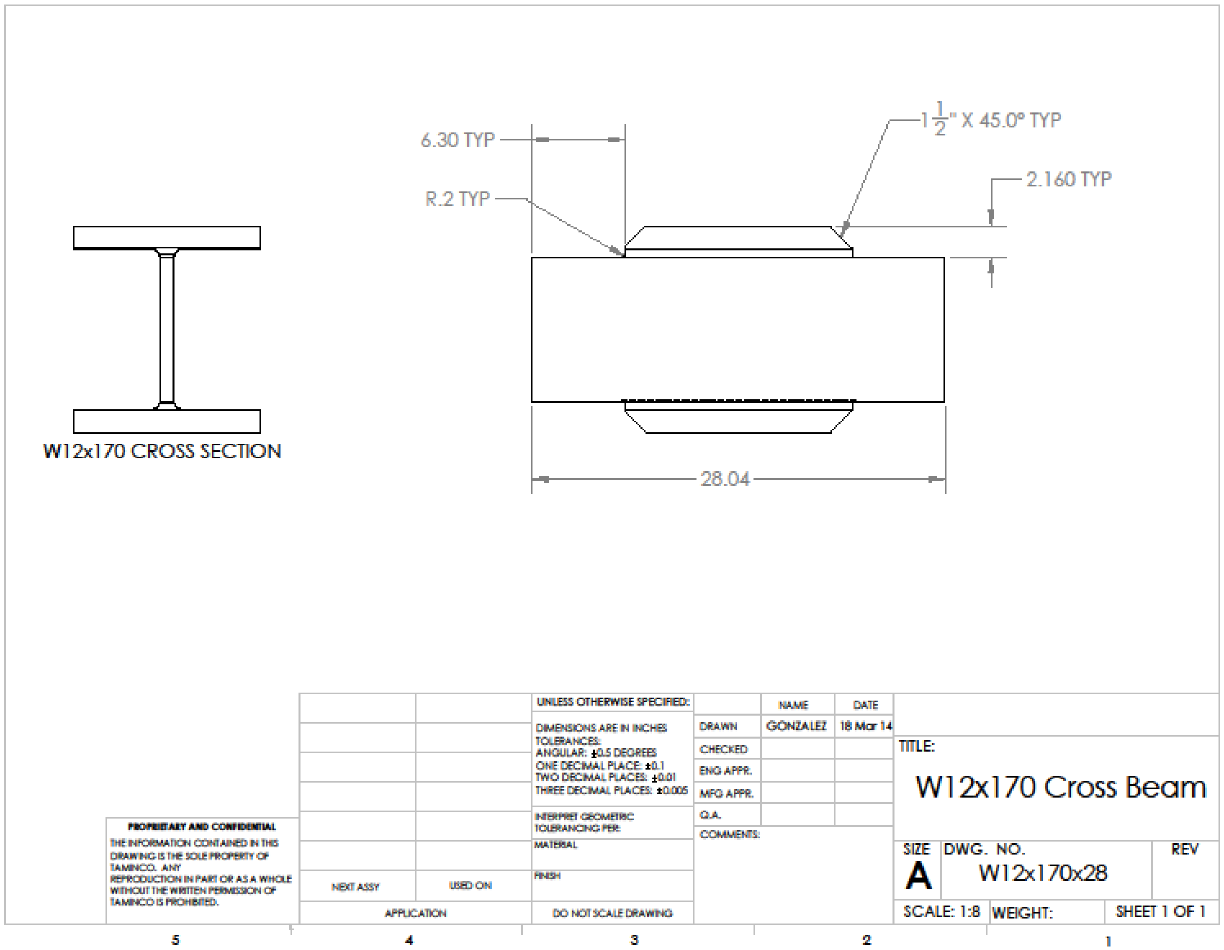


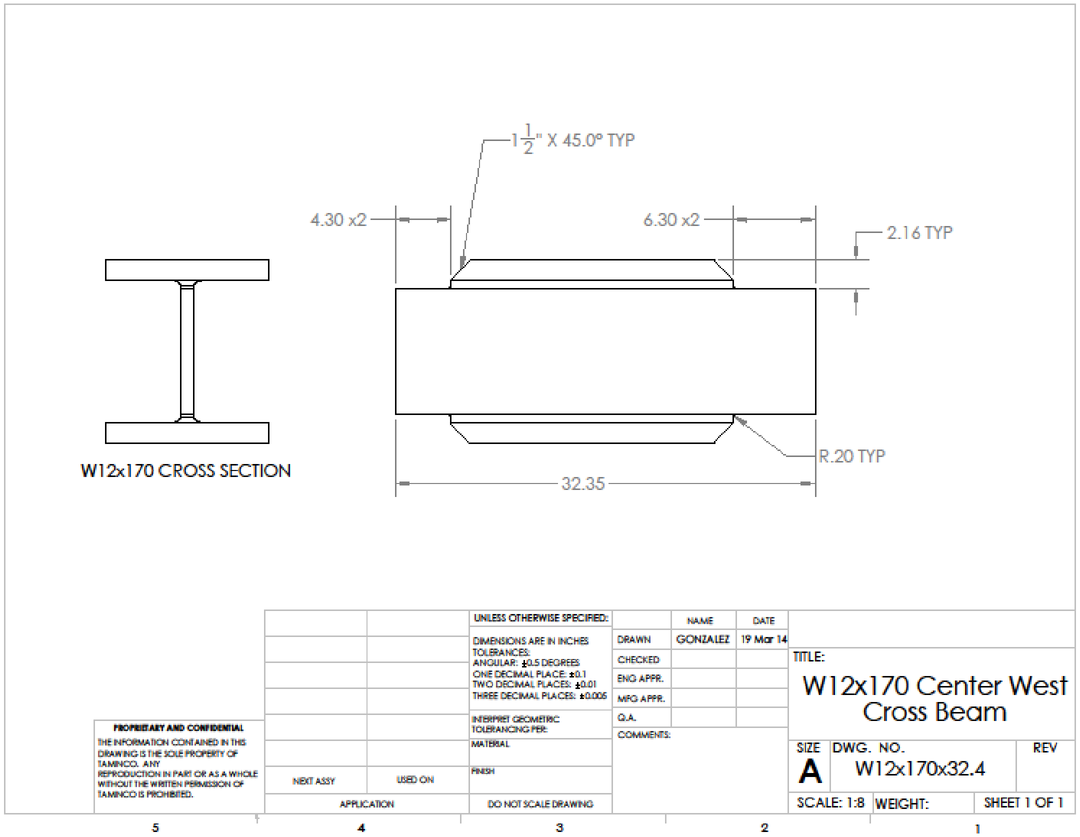
ITEM NO.	PART NUMBER	QTY.
1	W8x18x101	2
2	W14x48x196.9	2
3	L4x3.5x0.25x5.5	12
4	L4x3.5x0.3125x8.5	40
5	W12x65	4
6	W14x48x101	4
7	HHSBOLT 0.7500-10x2x1.375-C	82
8	Preferred Narrow FW 0.75	144
9	HTNUT 0.7500-10-B-N	72
10	HHSBOLT 0.7500-10x1.75x1.375-C	16
11	HTNUT 0.7500-10-B-C	16
12	Plate	1
13	Crane	1
14	W10x22x101	2
15	HHSBOLT 0.7500-10x2x1.375-S	48
16	HTNUT 0.7500-10-B-S	56
17	Podium Base	1
18	Podium	1
19	W8x18x32.77	1
20	Hydraulic Unit Spacers	4
21	Hydraulic Unit	1
22	HHSBOLT 0.7500-10x1.75x1.375-S	8
23	Gusset	4
24	W14x48x20.63	2

This is a size E sheet. It is recommended to open the attached pdf file to view more clearly.

Design III Manufacturing Drawings

Beams





1 1/2" X 45.0° TYP
4.30 x2
6.30 x2
2.16 TYP
R.20 TYP
32.35
W12x170 CROSS SECTION
PROPRIETARY AND CONFIDENTIAL
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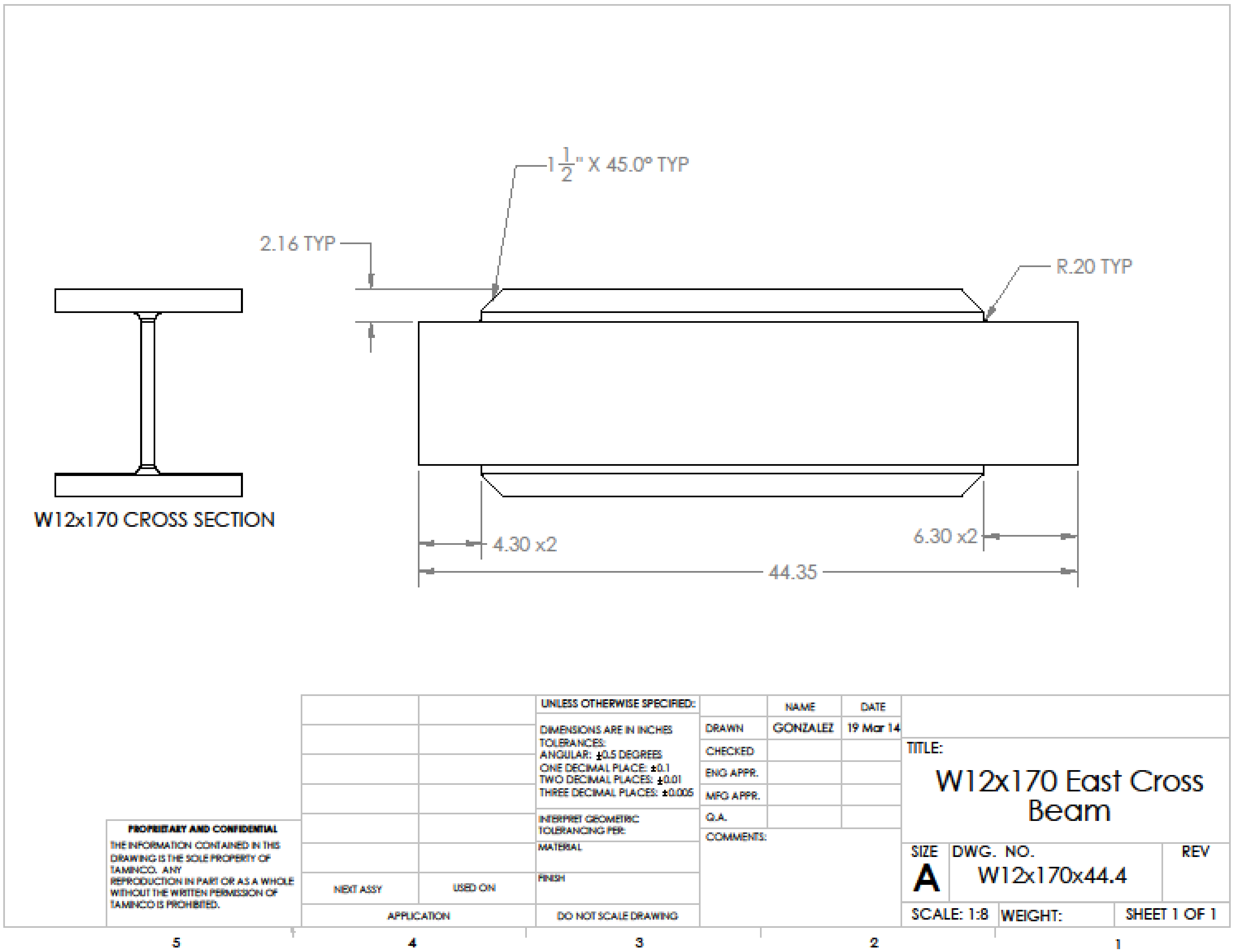
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
19 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W12x170 Center West Cross Beam
SIZE
A
DWG. NO.
W12x170x32.4
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



1 1/2" X 45.0° TYP
2.16 TYP
R.20 TYP
W12x170 CROSS SECTION
4.30 x2
6.30 x2
44.35
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
19 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W12x170 East Cross Beam
SIZE
A
DWG. NO.
W12x170x44.4
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
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4
3
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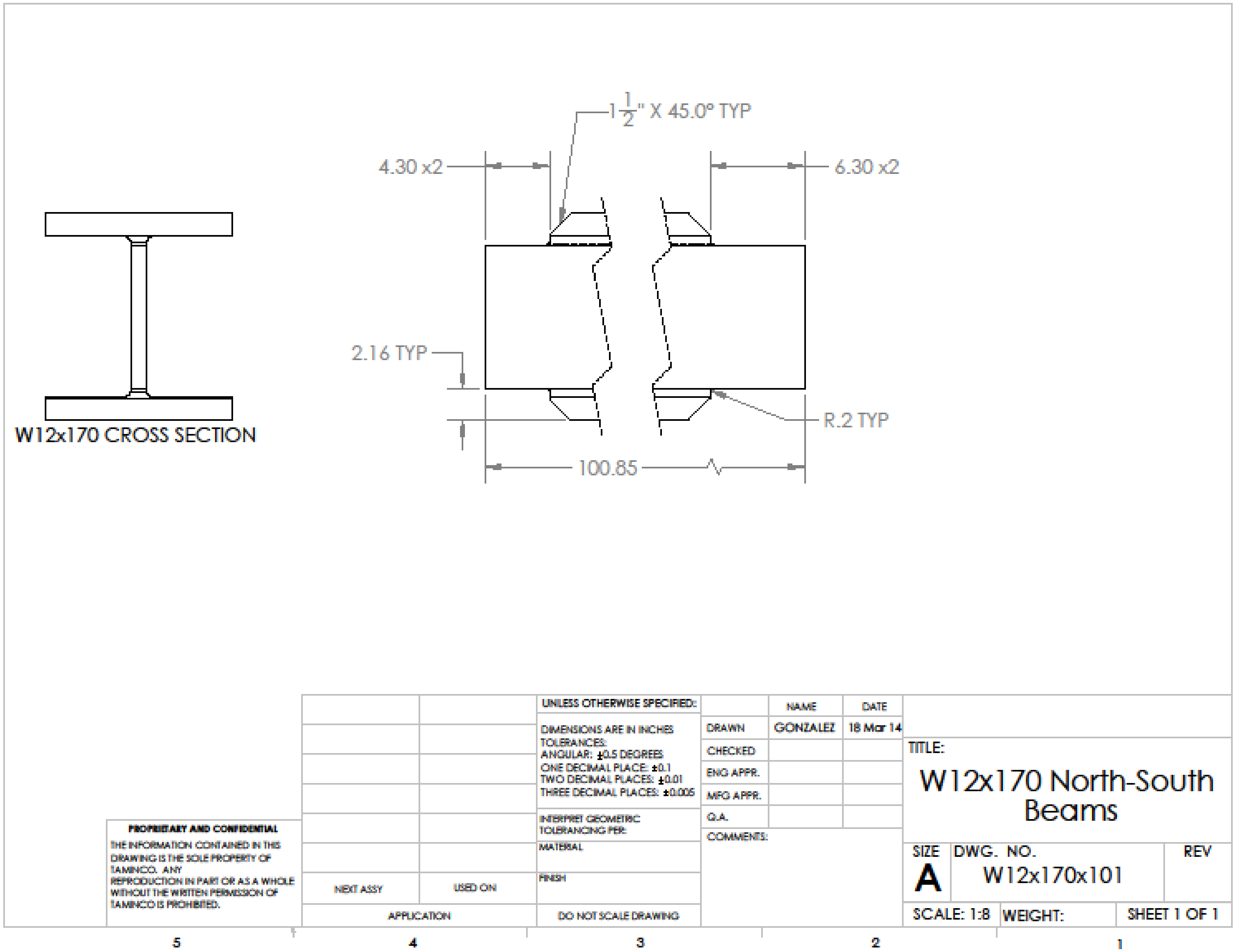
W12x170 CROSS SECTION
1 1/2" X 45.0° TYP
4.30 x2
6.30 x2
2.16 TYP
R.2 TYP
100.85
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
18 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W12x170 North-South Beams
SIZE
A
DWG. NO.
W12x170x101
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
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3
2
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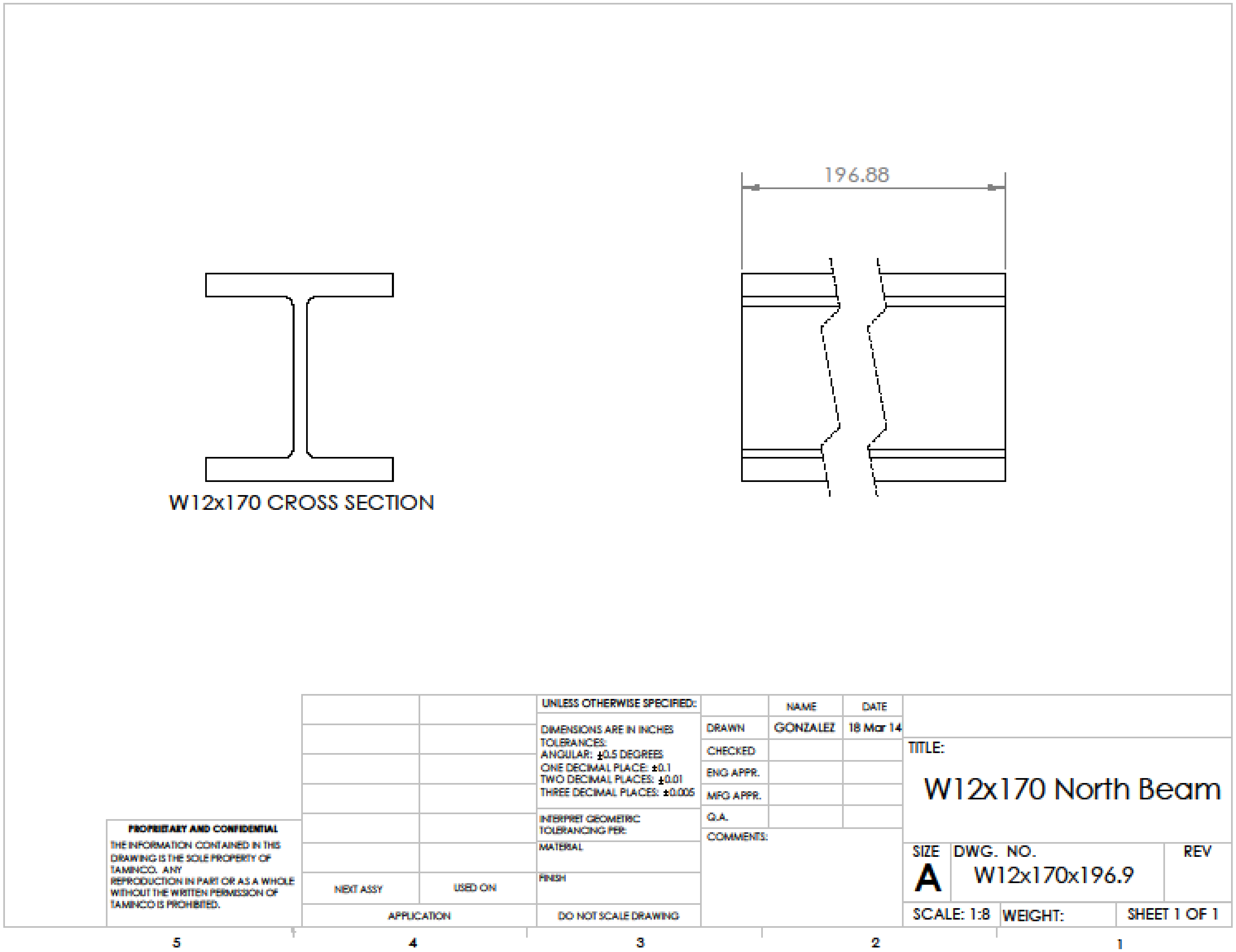
196.88
W12x170 CROSS SECTION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
18 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W12x170 North Beam
SIZE
A
DWG. NO.
W12x170x196.9
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
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4
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2
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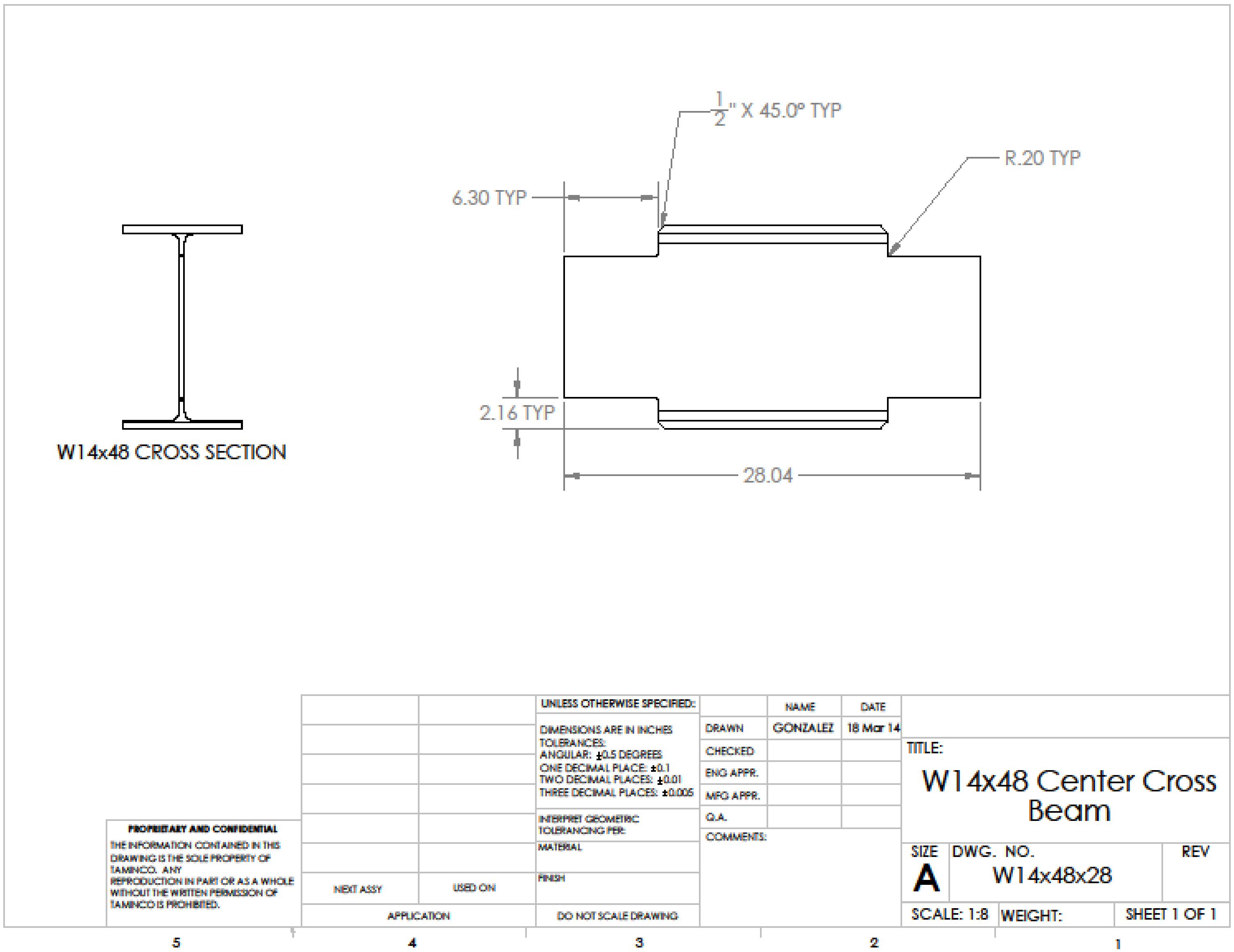

1/2" X 45.0° TYP
R.20 TYP
6.30 TYP
2.16 TYP
28.04
W14x48 CROSS SECTION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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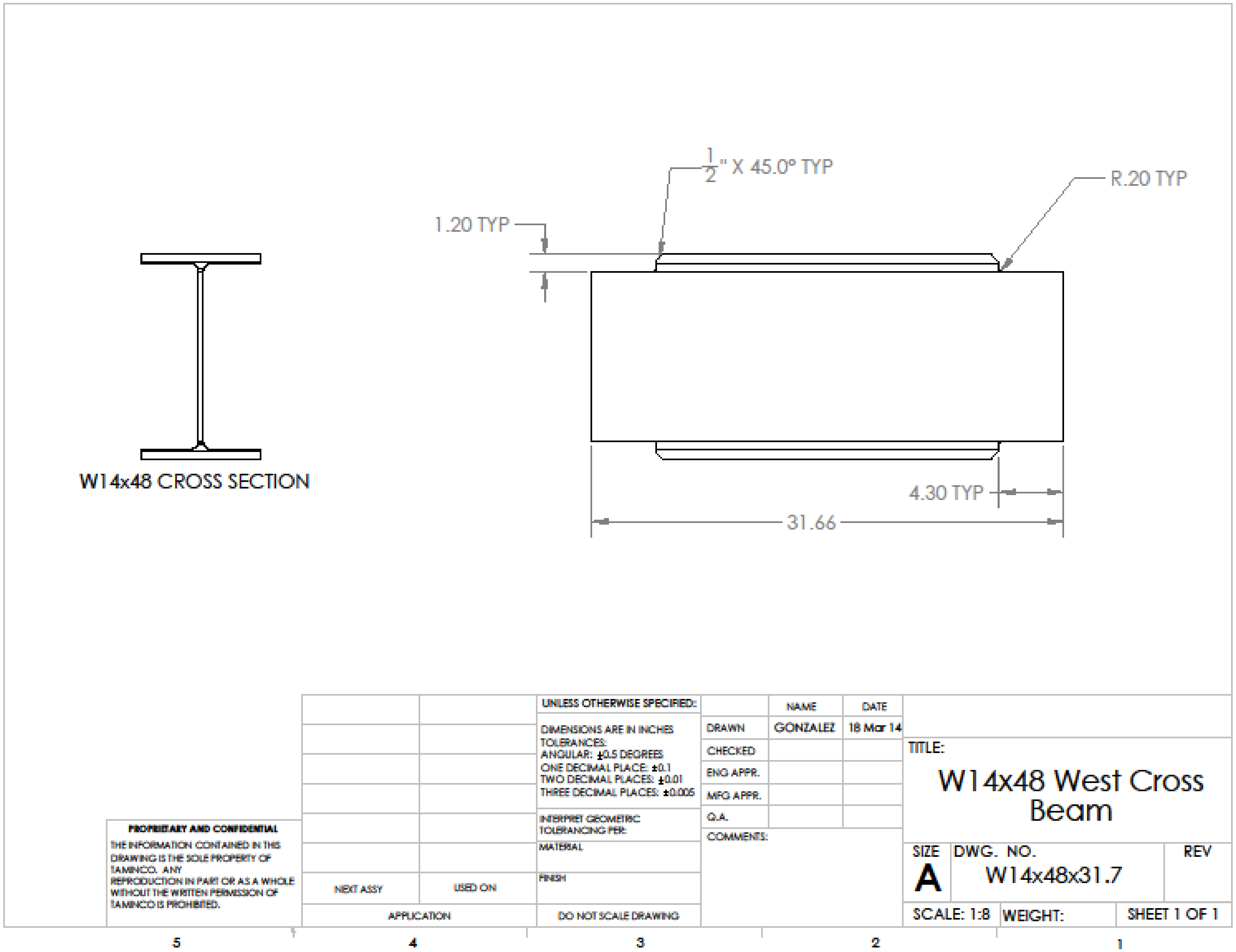
NAME
DATE
DRAWN
GONZALEZ
18 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W14x48 Center Cross Beam
SIZE
A
DWG. NO.
W14x48x28
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


W14x48 CROSS SECTION
1/2" X 45.0° TYP
R.20 TYP
1.20 TYP
4.30 TYP
31.66
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
18 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W14x48 West Cross Beam
SIZE
A
DWG. NO.
W14x48x31.7
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
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4
3
2
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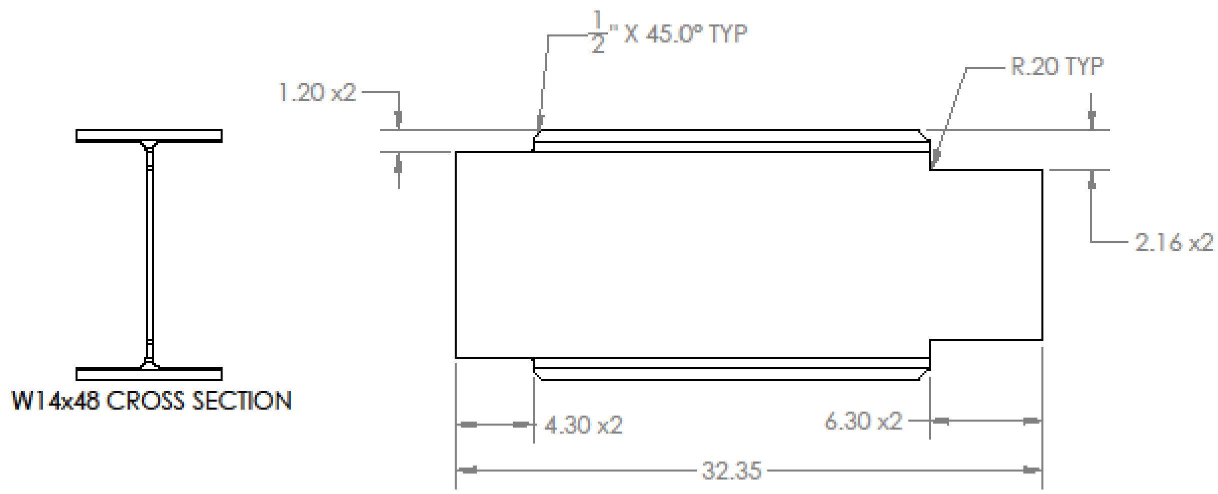

PROPRIETARY AND CONFIDENTIAL

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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	GONZALEZ	18 Mar 14
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

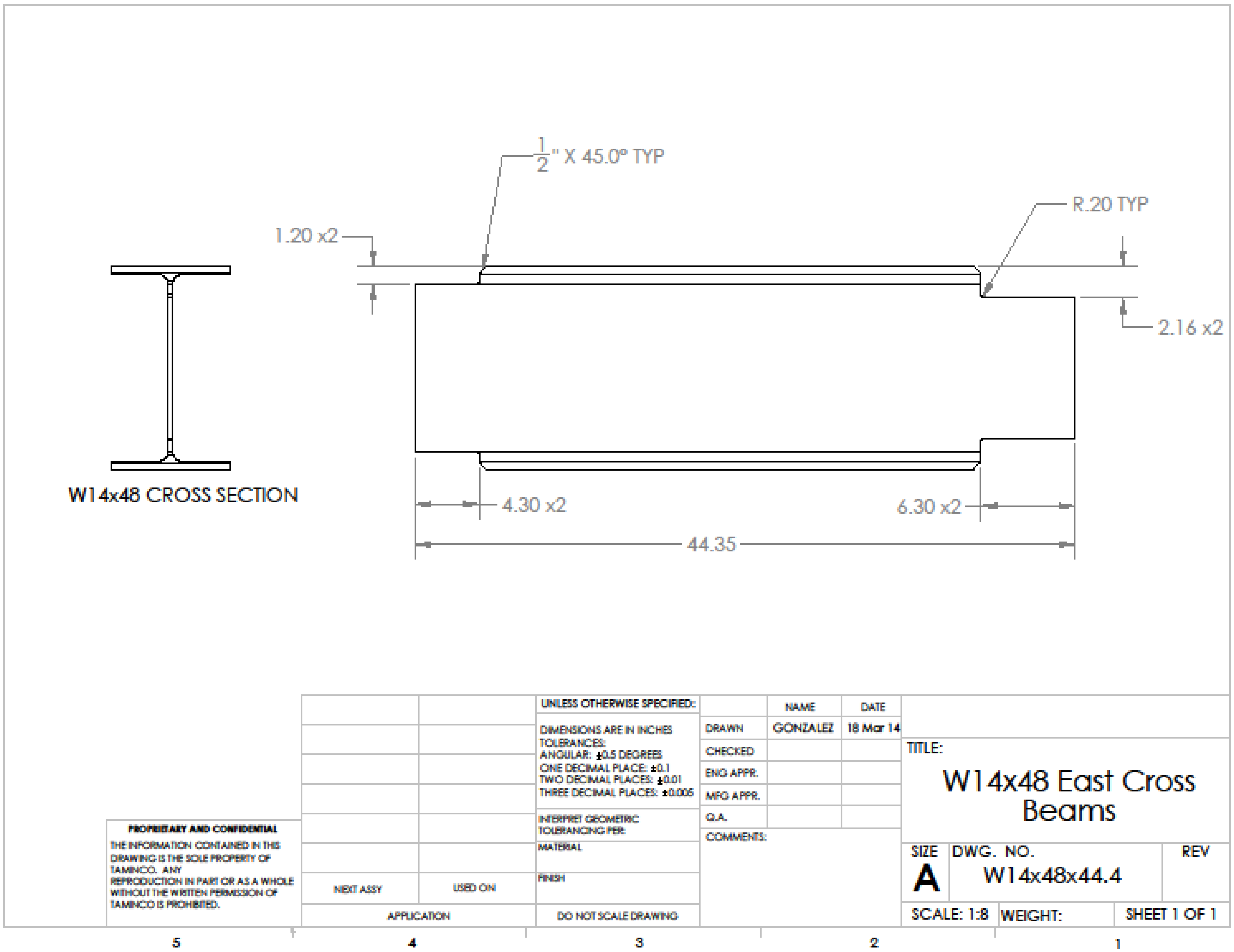
TITLE:

W14x48 Center West Cross Beams

SIZE	DWG. NO.	REV
A	W14x48x32.4	

SCALE: 1:8 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



1/2" X 45.0° TYP
R.20 TYP
1.20 x2
2.16 x2
W14x48 CROSS SECTION
4.30 x2
6.30 x2
44.35
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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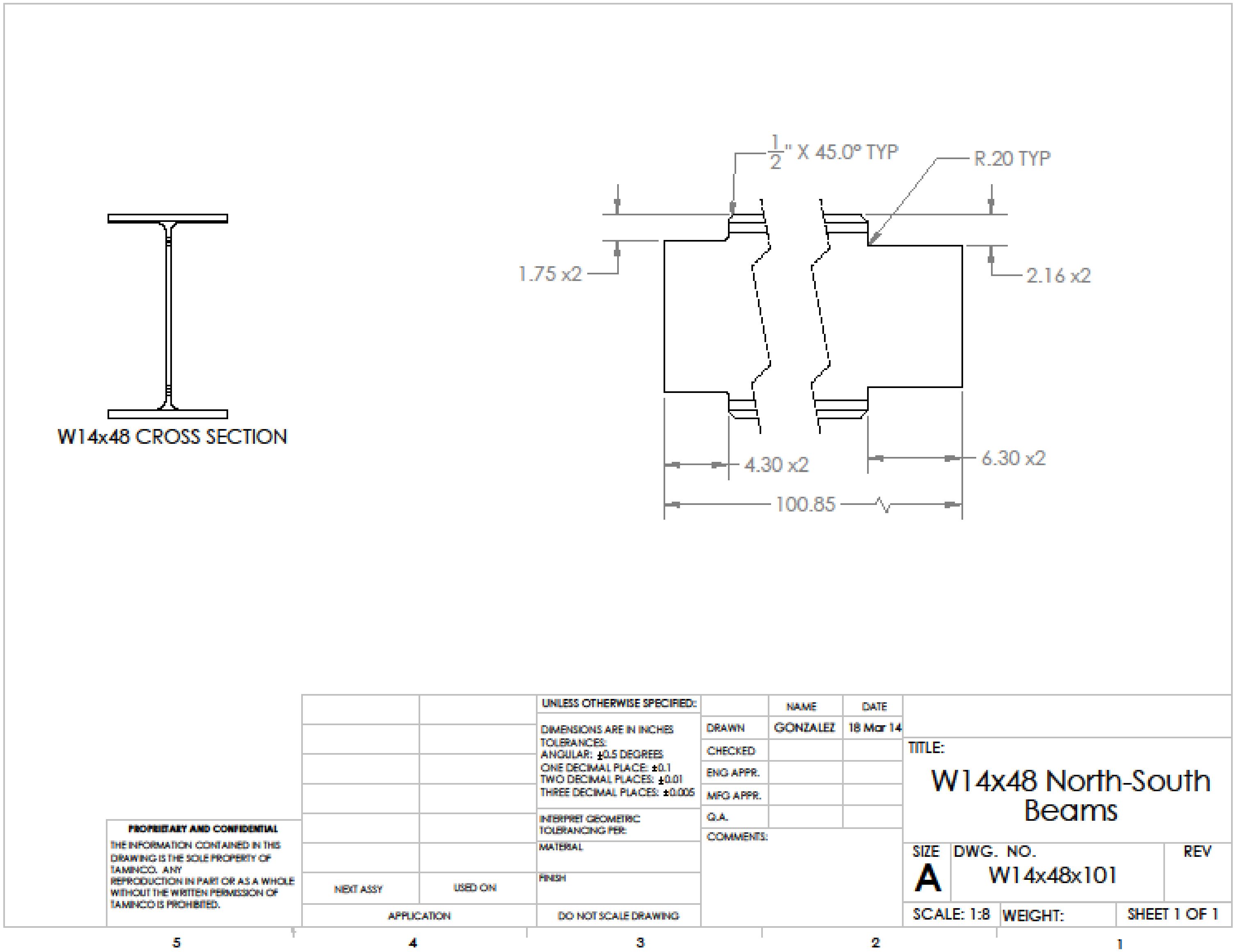
NAME
DATE
DRAWN
GONZALEZ
18 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W14x48 East Cross Beams
SIZE
A
DWG. NO.
W14x48x44.4
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


W14x48 CROSS SECTION
1/2" X 45.0° TYP
R.20 TYP
1.75 x2
2.16 x2
4.30 x2
6.30 x2
100.85
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
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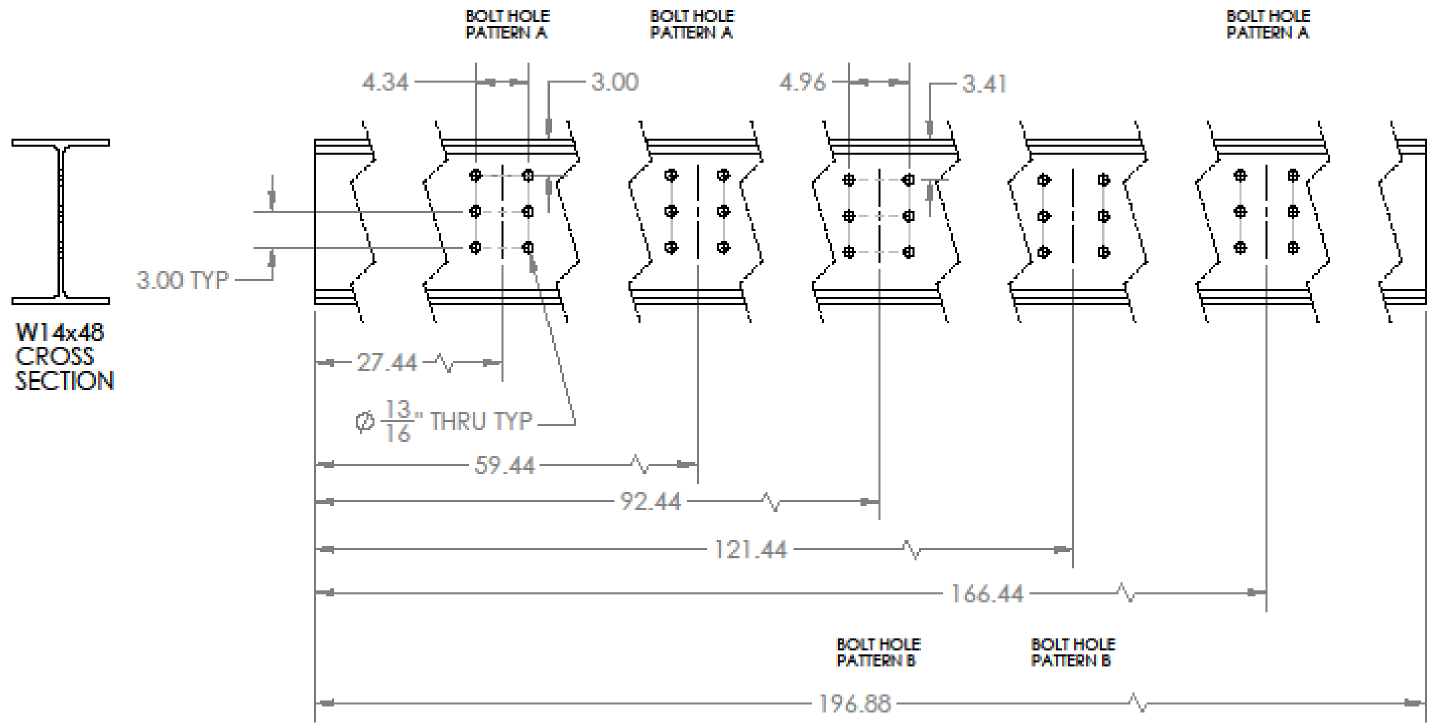
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
18 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
W14x48 North-South Beams
SIZE
A
DWG. NO.
W14x48x101
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



NOTE: THIS BEAM IS AN ORIGINAL BEAM IN THE 7TH FLOOR OF THE AAA UNIT. USE ONLY TO SPECIFY BOLT HOLES.

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±0.5 DEGREES ONE DECIMAL PLACE: ±0.1 TWO DECIMAL PLACES: ±0.01 THREE DECIMAL PLACES: ±0.005	DRAWN	GONZALEZ	18 Mar 14
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

NEXT ASSY	USED ON
APPLICATION	

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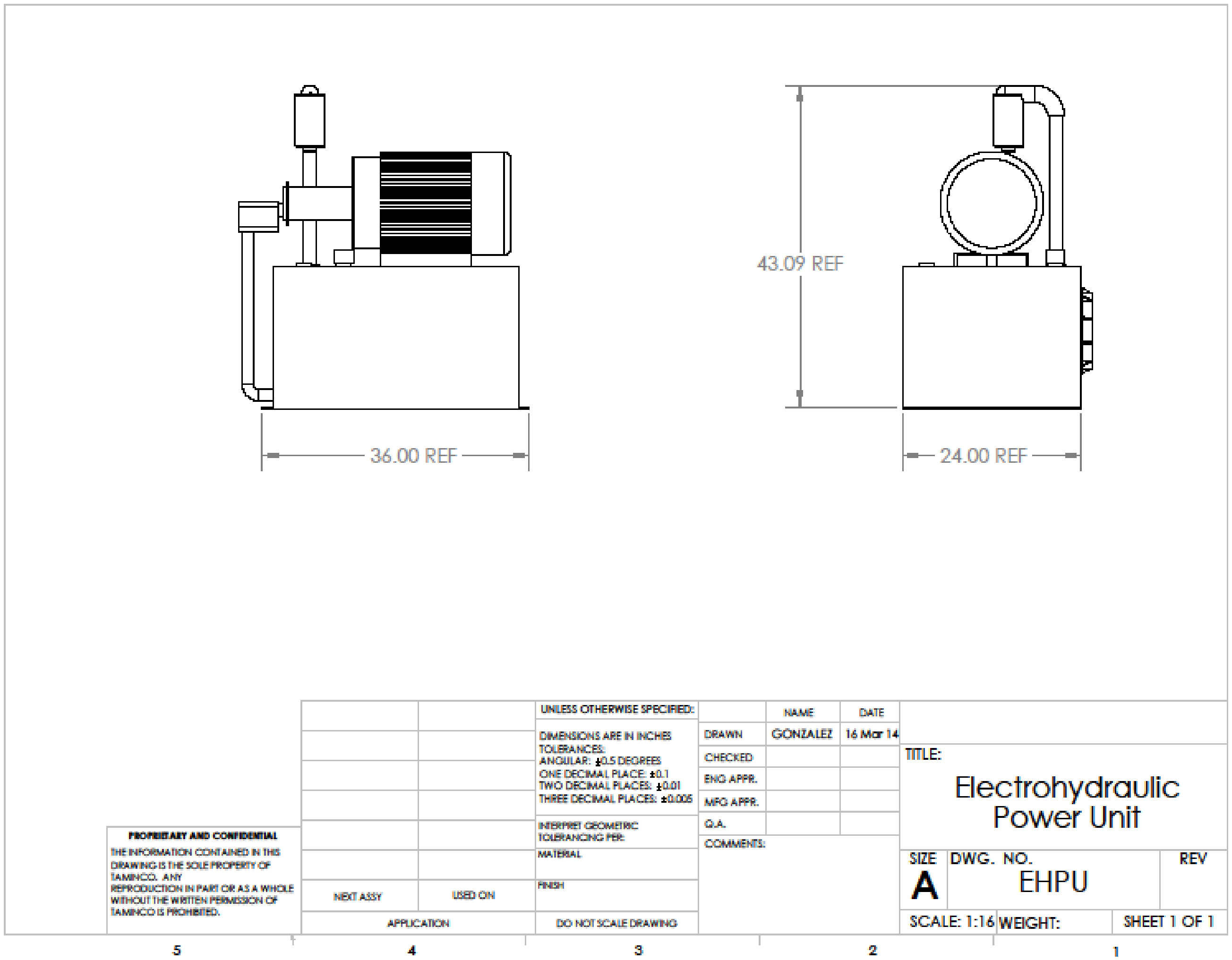
TITLE:

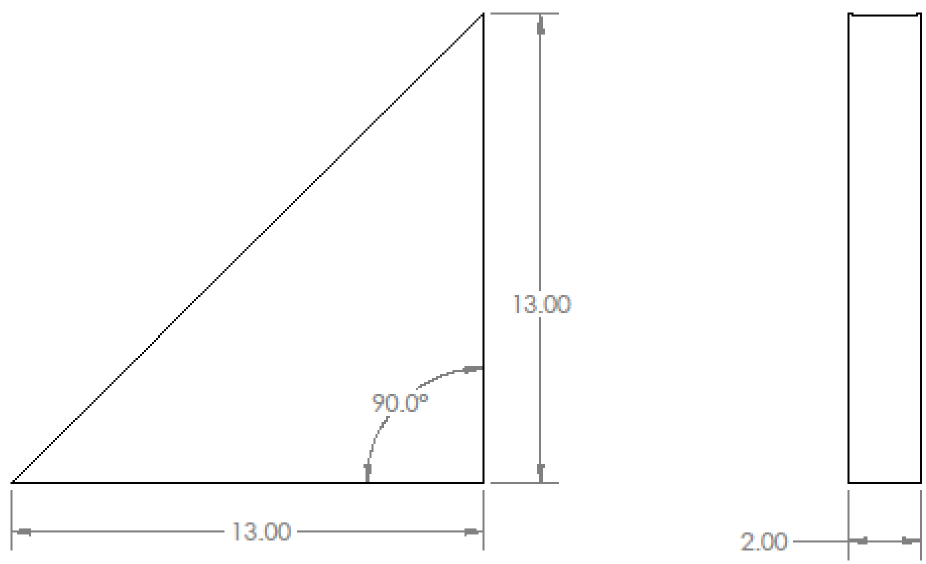
W14x48 South Beam

SIZE	DWG. NO.	REV
A	W14x48x196.9	
SCALE: 1:12	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

Other Components





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NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	GONZALEZ	19 Mar 14
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

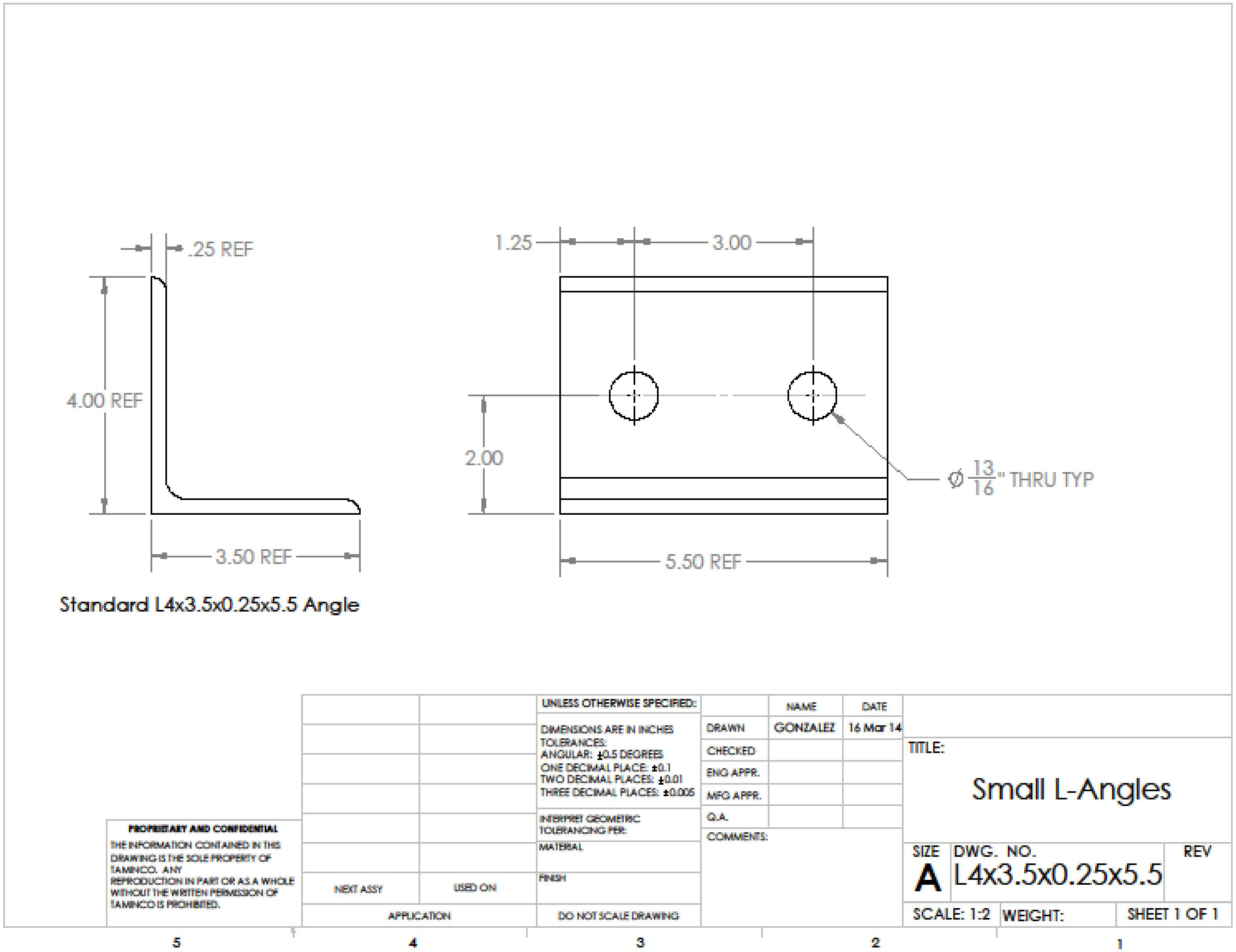
TITLE:

Gusset

SIZE A | DWG. NO. Gusset | REV

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

5 4 3 2 1


.25 REF
4.00 REF
3.50 REF
Standard L4x3.5x0.25x5.5 Angle
1.25
3.00
2.00
5.50 REF
Ø 13/16" THRU TYP
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
16 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Small L-Angles
SIZE
A
DWG. NO.
L4x3.5x0.25x5.5
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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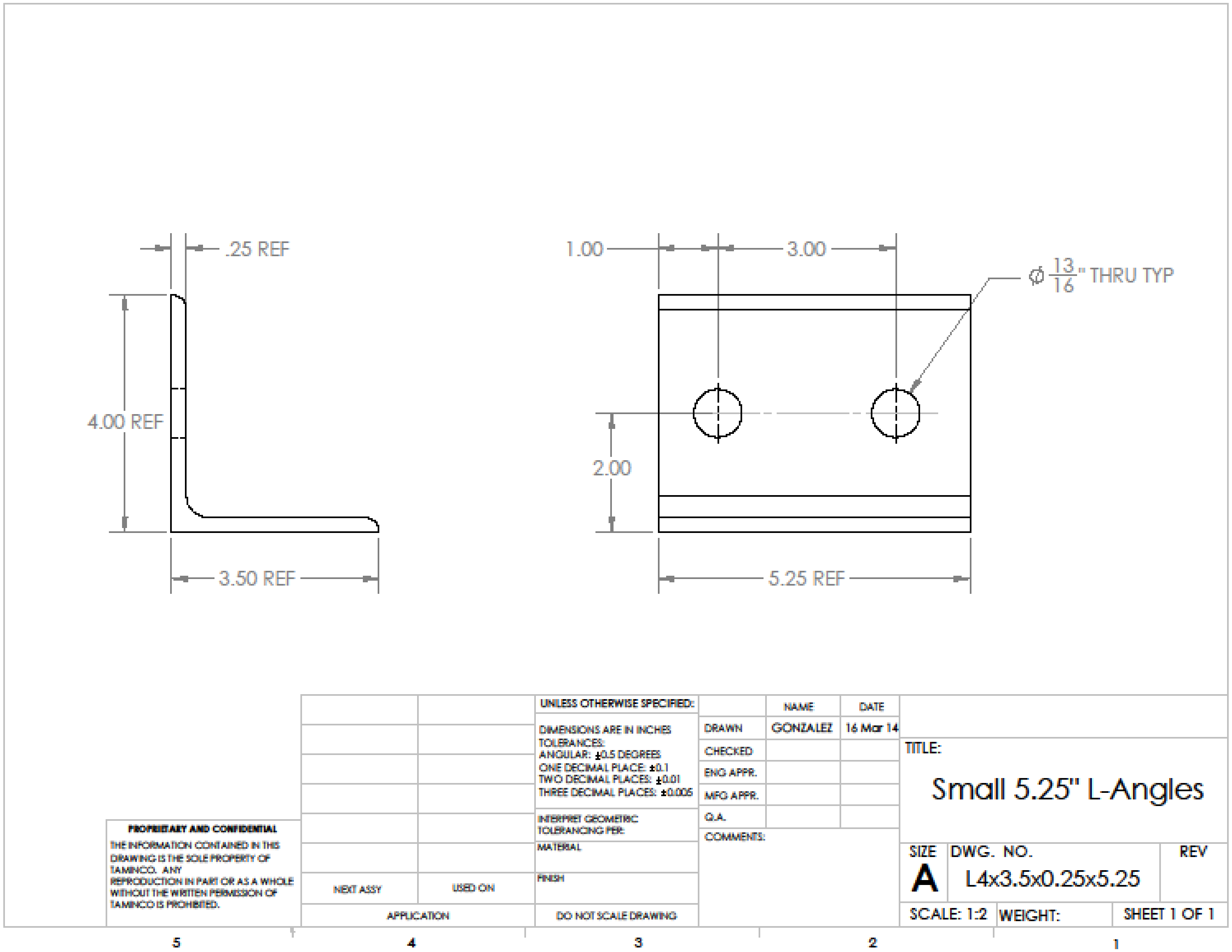
NEXT ASSY
USED ON
APPLICATION
5
4
3
2
1



.25 REF
4.00 REF
3.50 REF
1.00
3.00
Ø 13/16" THRU TYP
2.00
5.25 REF
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
16 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Small 5.25" L-Angles
SIZE
A
DWG. NO.
L4x3.5x0.25x5.25
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
5
4
3
2
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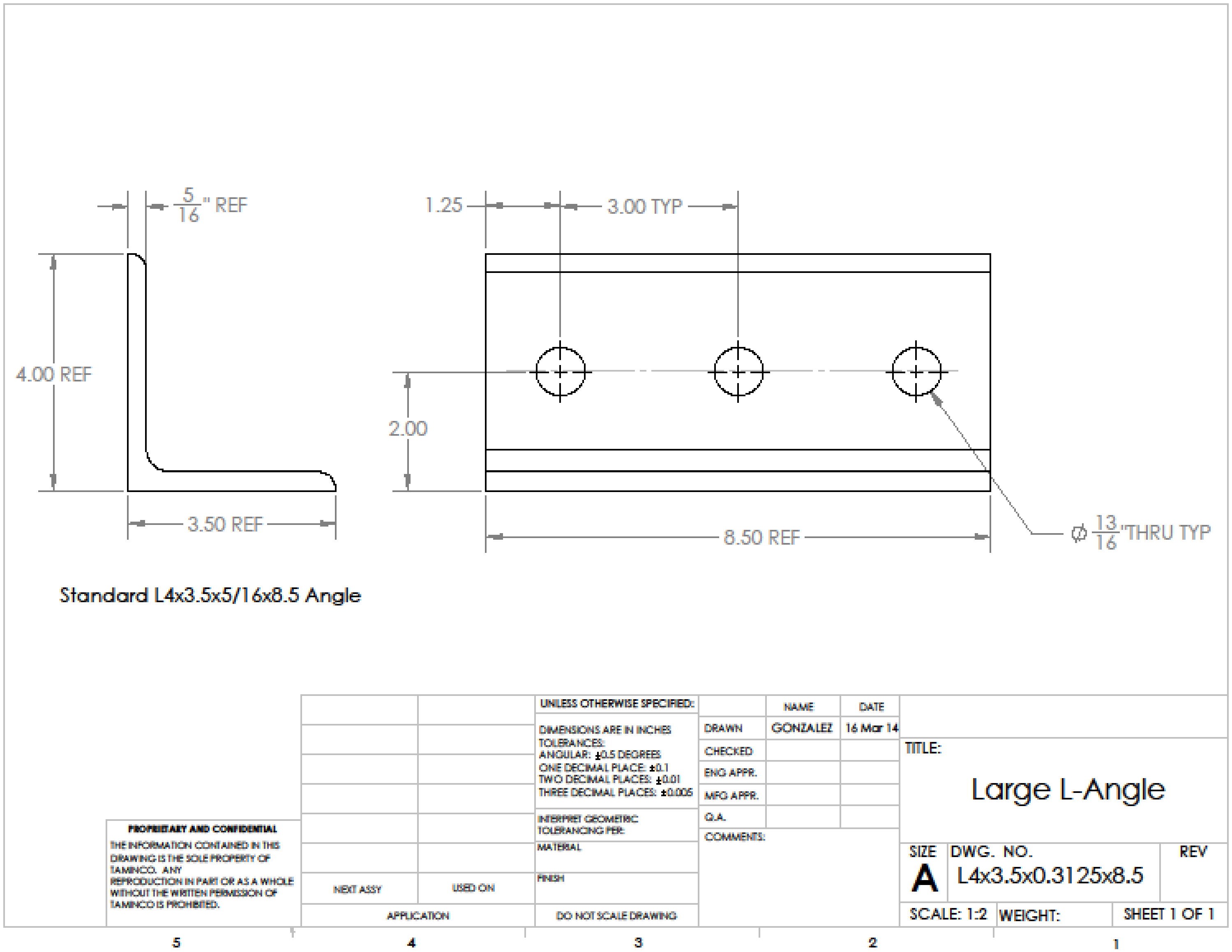
5/16" REF
1.25
3.00 TYP
4.00 REF
2.00
3.50 REF
8.50 REF
⌀ 13/16"THRU TYP
Standard L4x3.5x5/16x8.5 Angle
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
16 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Large L-Angle
SIZE
A
DWG. NO.
L4x3.5x0.3125x8.5
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
5
4
3
2
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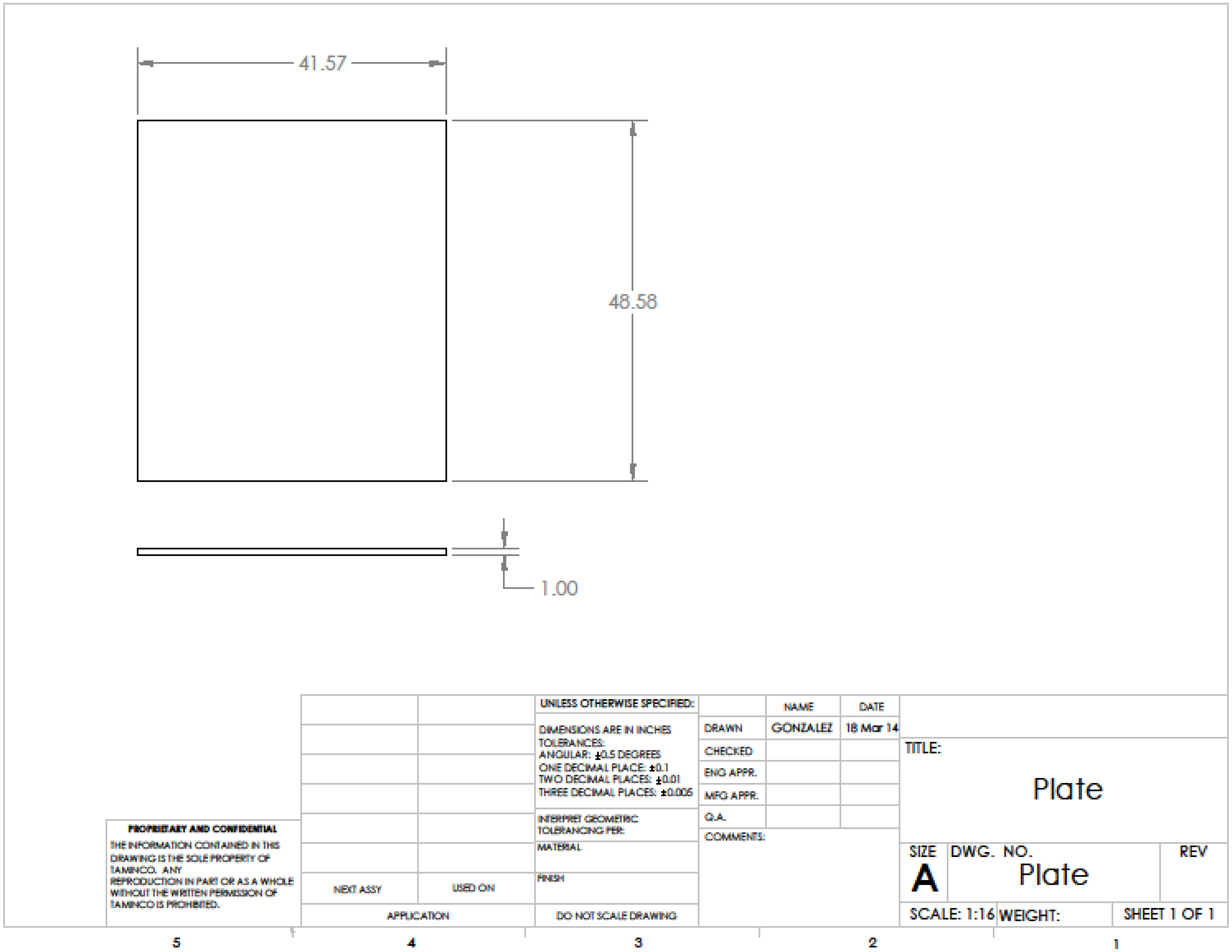
41.57
48.58
1.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
18 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Plate
SIZE
A
DWG. NO.
Plate
REV
SCALE: 1:16
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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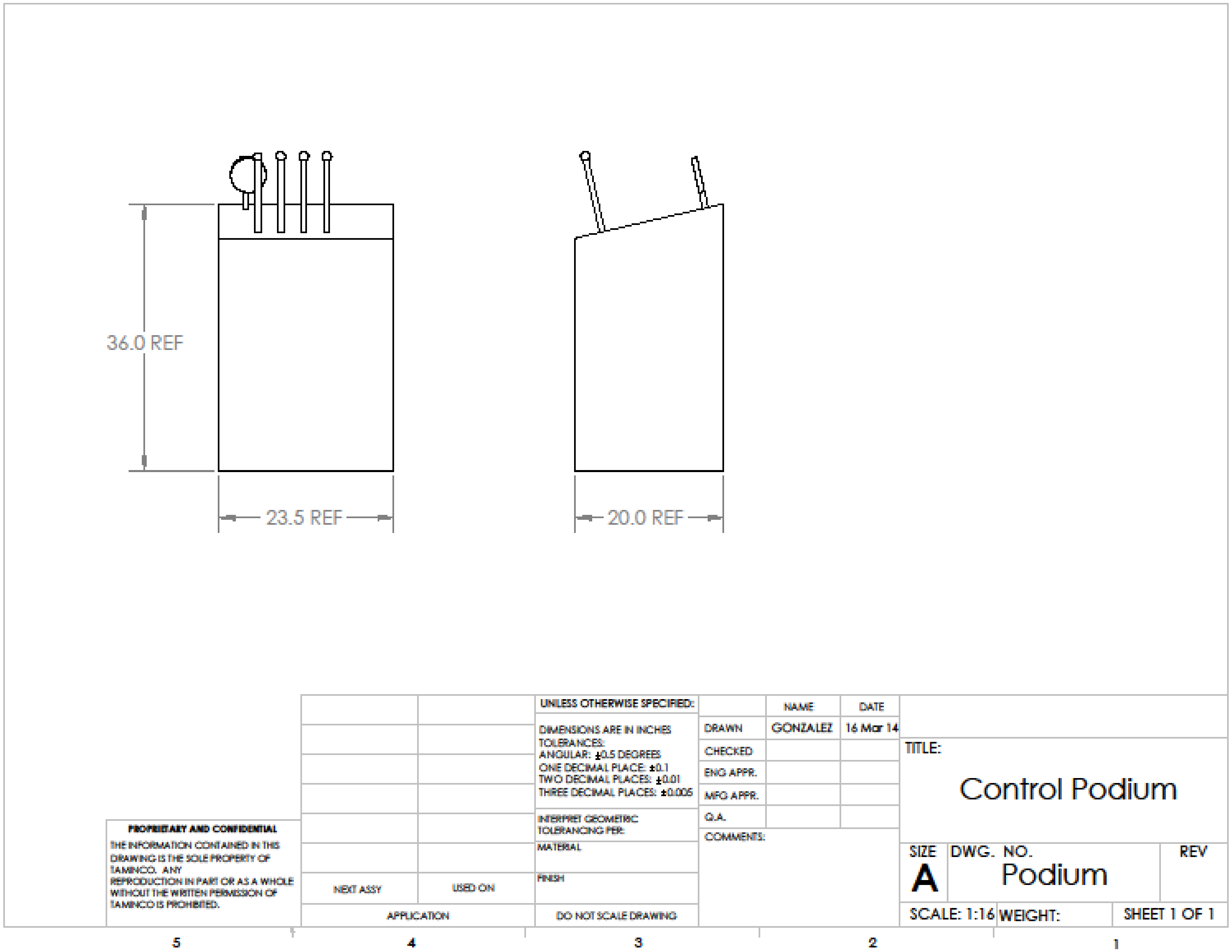
5
4
3
2
1


36.0 REF
23.5 REF
20.0 REF
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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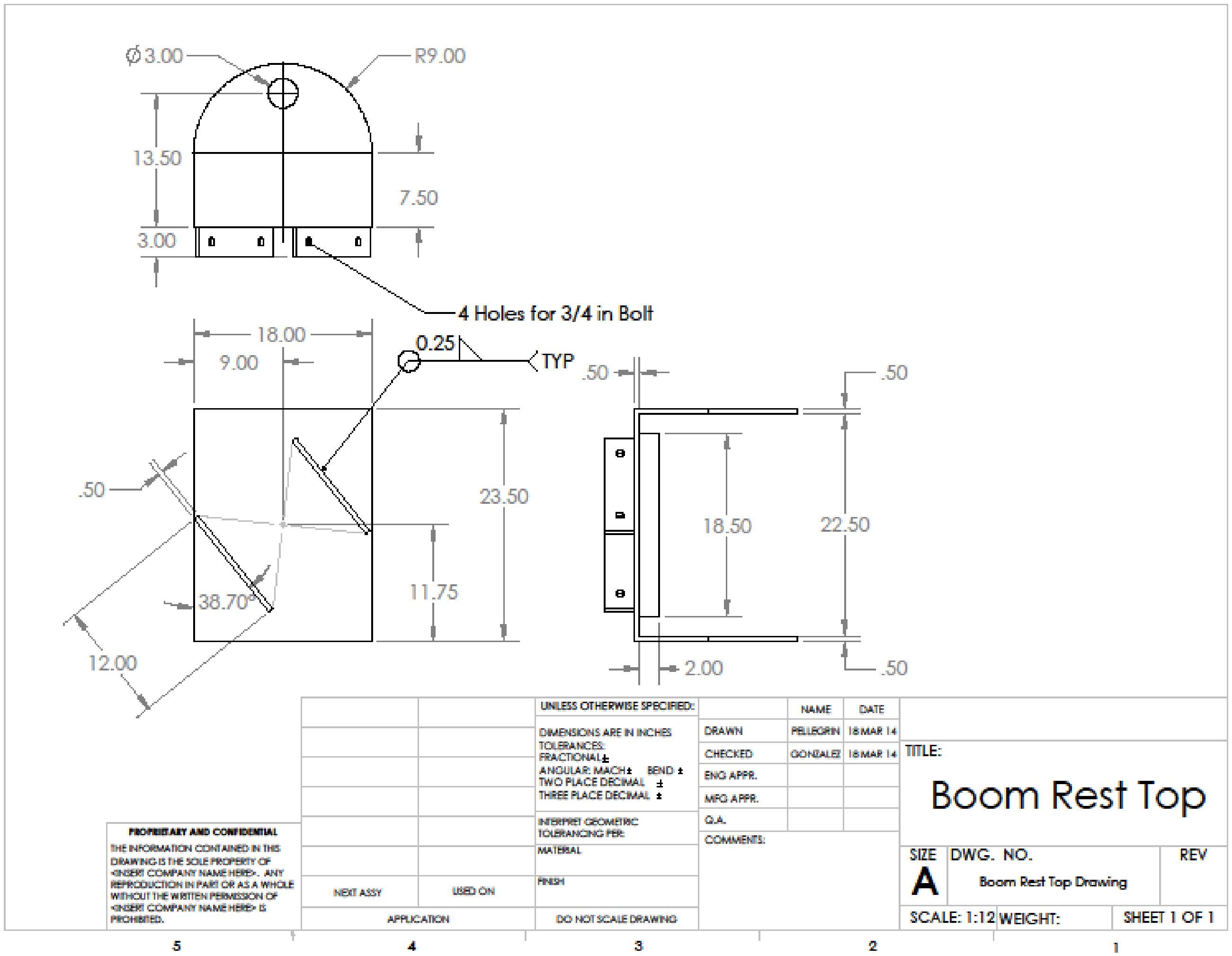
NAME
DATE
DRAWN
GONZALEZ
16 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Control Podium
SIZE
A
DWG. NO.
Podium
REV
SCALE: 1:16
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

Boom Rest



Ø3.00
R9.00
13.50
7.50
3.00
4 Holes for 3/4 in Bolt
18.00
9.00
0.25
TYP
.50
23.50
11.75
38.70°
12.00
18.50
22.50
2.00
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 PELLEGRIN 18 MAR 14
CHECKED GONZALEZ 18 MAR 14
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Boom Rest Top
SIZE
A
DWG. NO.
Boom Rest Top Drawing
REV
SCALE: 1:12
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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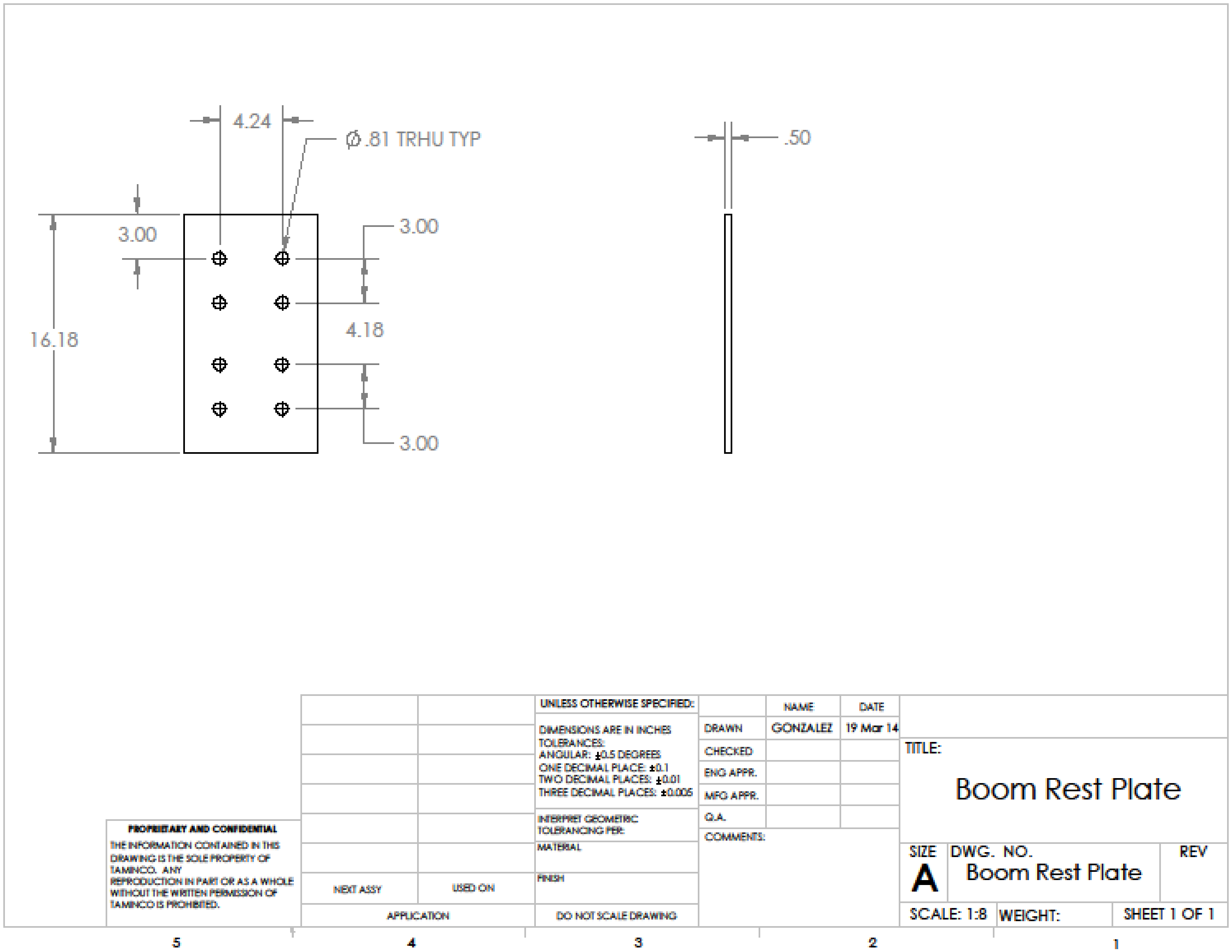
NEXT ASSY
USED ON
APPLICATION
5
4
3
2
1


4.24
Ø.81 TRHU TYP
.50
3.00
3.00
16.18
4.18
3.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
19 Mar 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Boom Rest Plate
SIZE
A
DWG. NO.
Boom Rest Plate
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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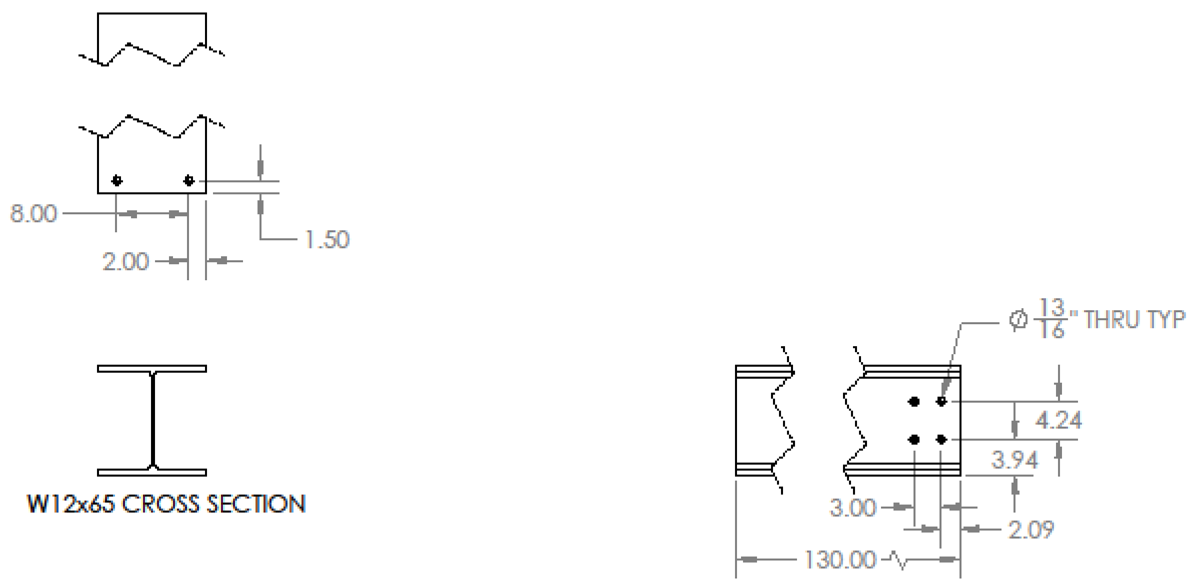
NEXT ASSY
USED ON
APPLICATION
5
4
3
2
1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±0.5 DEGREES ONE DECIMAL PLACE: ±0.1 TWO DECIMAL PLACES: ±0.01 THREE DECIMAL PLACES: ±0.005	DRAWN	GONZALEZ	19 Mar 14
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL
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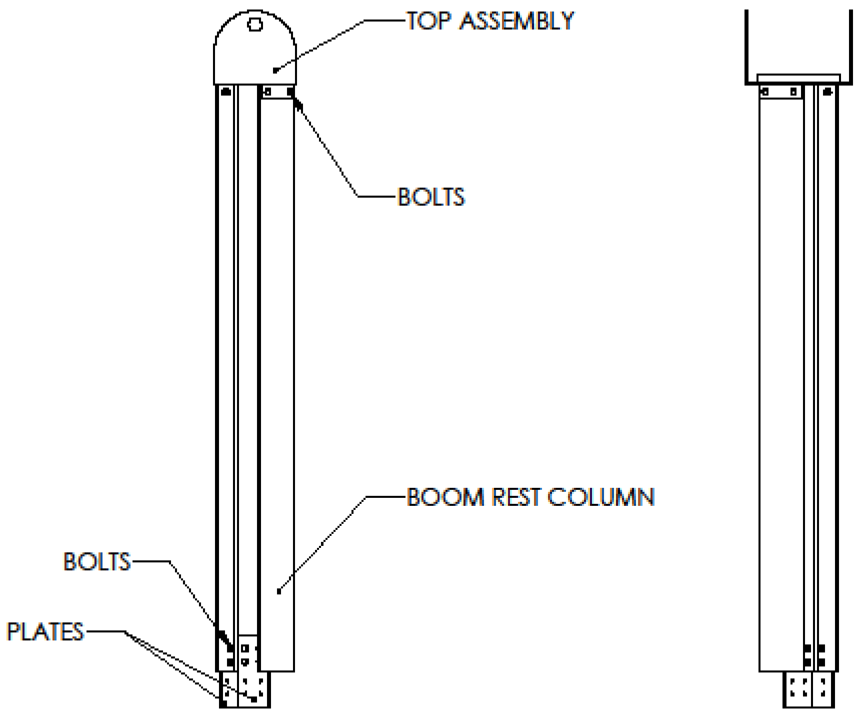
TITLE:
Boom Rest Column

SIZE	DWG. NO.	REV
A	Boom Rest Column	

SCALE: 1:16 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



NOTES:
- ALL BOLTS ARE ASTM A325N 3/4"-10 GALVANIZED 2" LONG SHOULDEREDWITH 1.375" THREADED LENGTH
- ALL WASHERS ARE FLAT 3/4" 0.134" THICK WASHERS
- ALL NUTS ARE ASTM A325N 3/4"-10 0.827" THICK NUTS WITH BEARING FACE
- ALL WELDS USE E70xx ELECTRODES

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

NEXT ASSY | USED ON
APPLICATION

	NAME	DATE
DRAWN	GONZALEZ	19 Mar 14
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

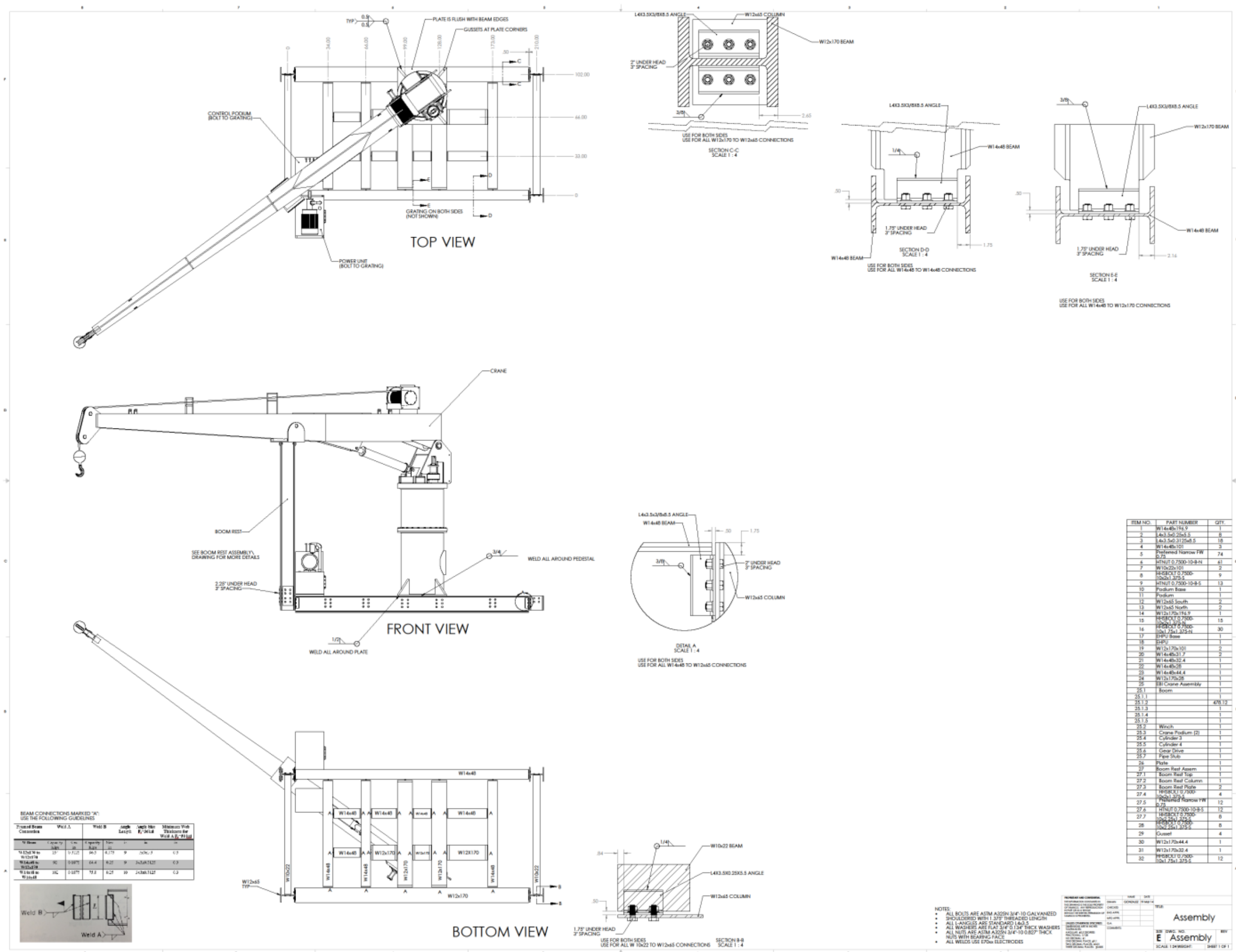
Boom Rest Assembly

SIZE A | DWG. NO. Boom Rest Assem | REV

SCALE: 1:32 | WEIGHT: | SHEET 1 OF 1

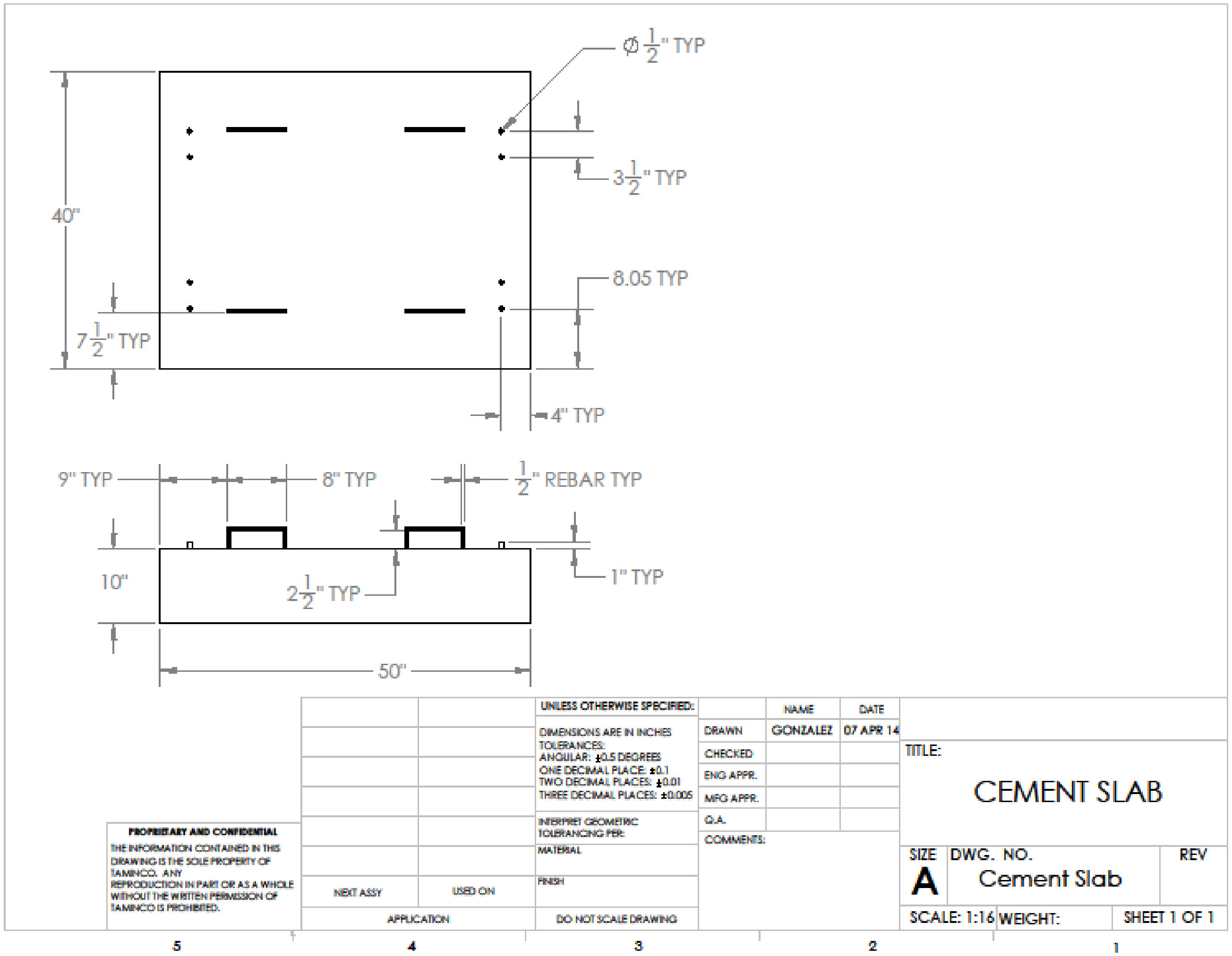
5 4 3 2 1

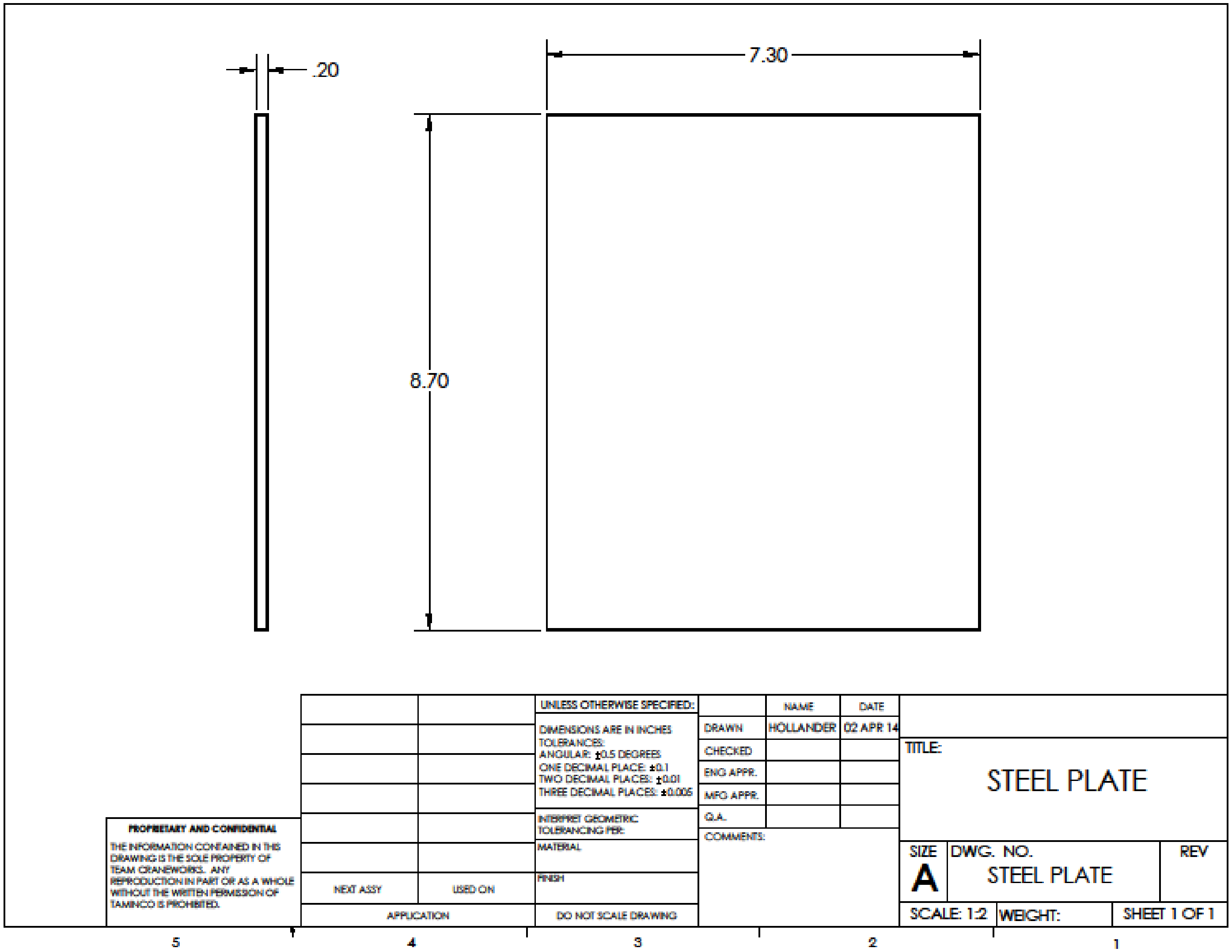
Assembly



This is a size E drawing. It is recommended to view the pdf by clicking on the drawing.

Prototype Design Manufacturing Drawings




.20
7.30
8.70
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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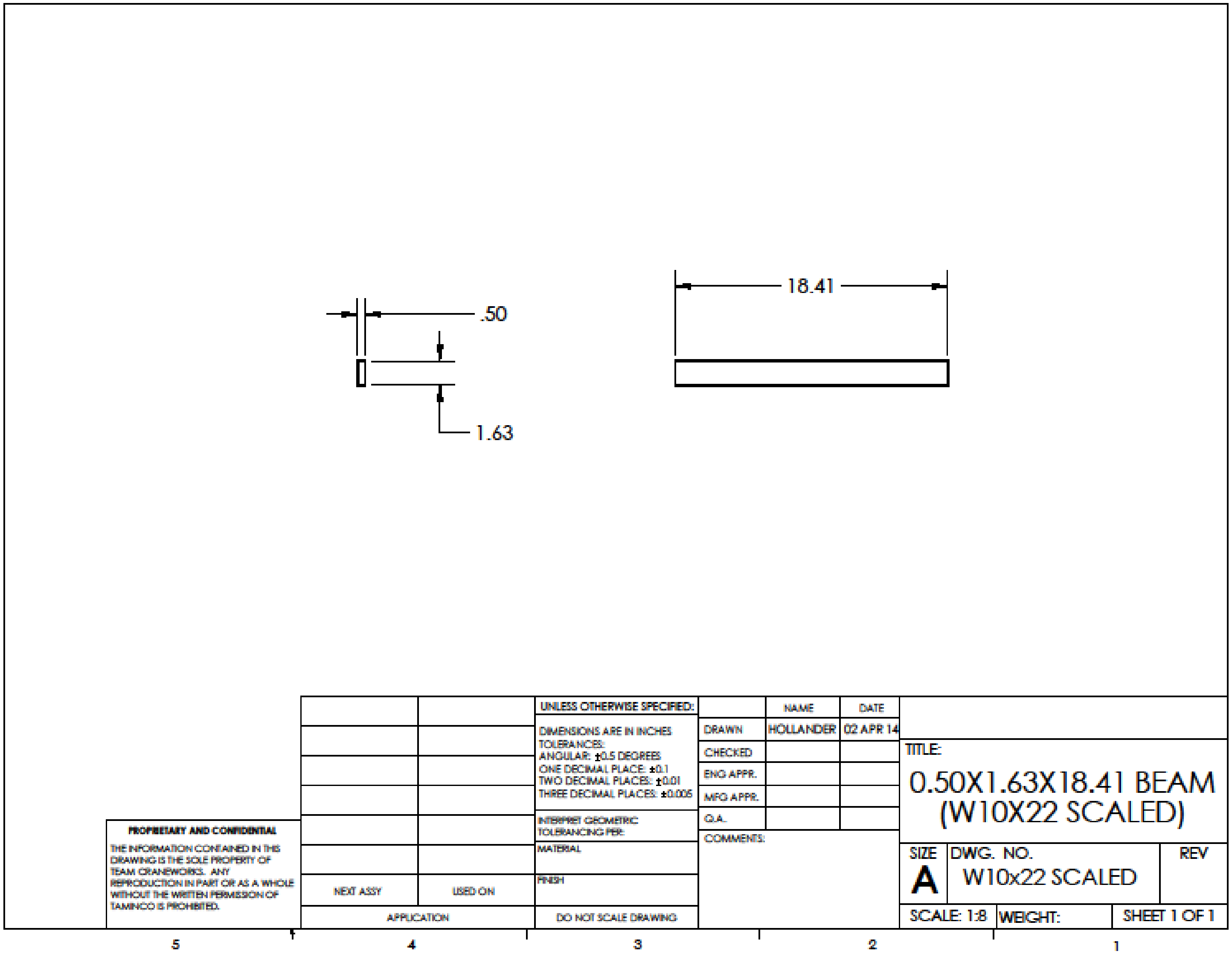
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
STEEL PLATE
SIZE
A
DWG. NO.
STEEL PLATE
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


.50
1.63
18.41
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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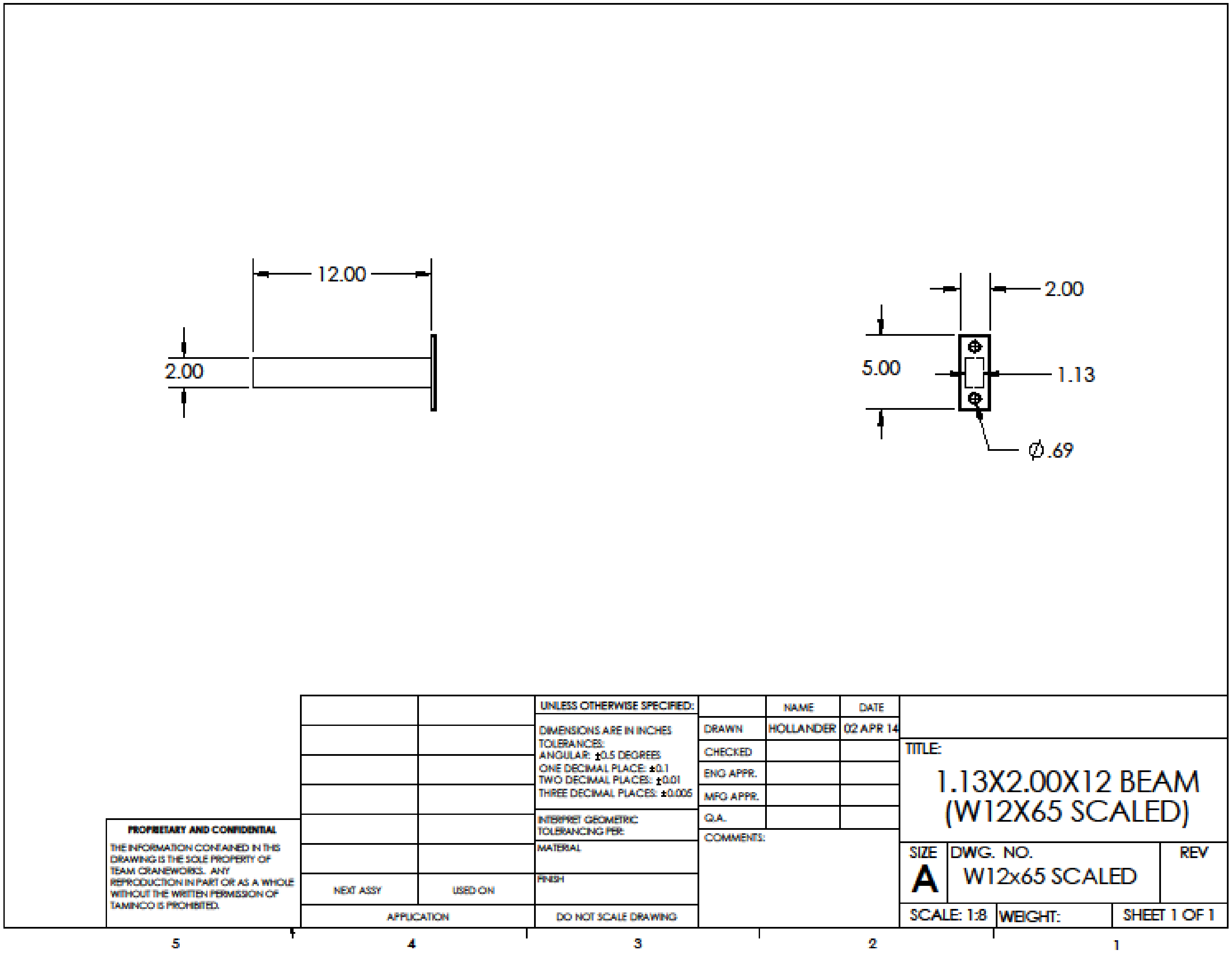
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
0.50X1.63X18.41 BEAM
(W10X22 SCALED)
SIZE
A
DWG. NO.
W10x22 SCALED
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


12.00
2.00
2.00
5.00
1.13
∅.69
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
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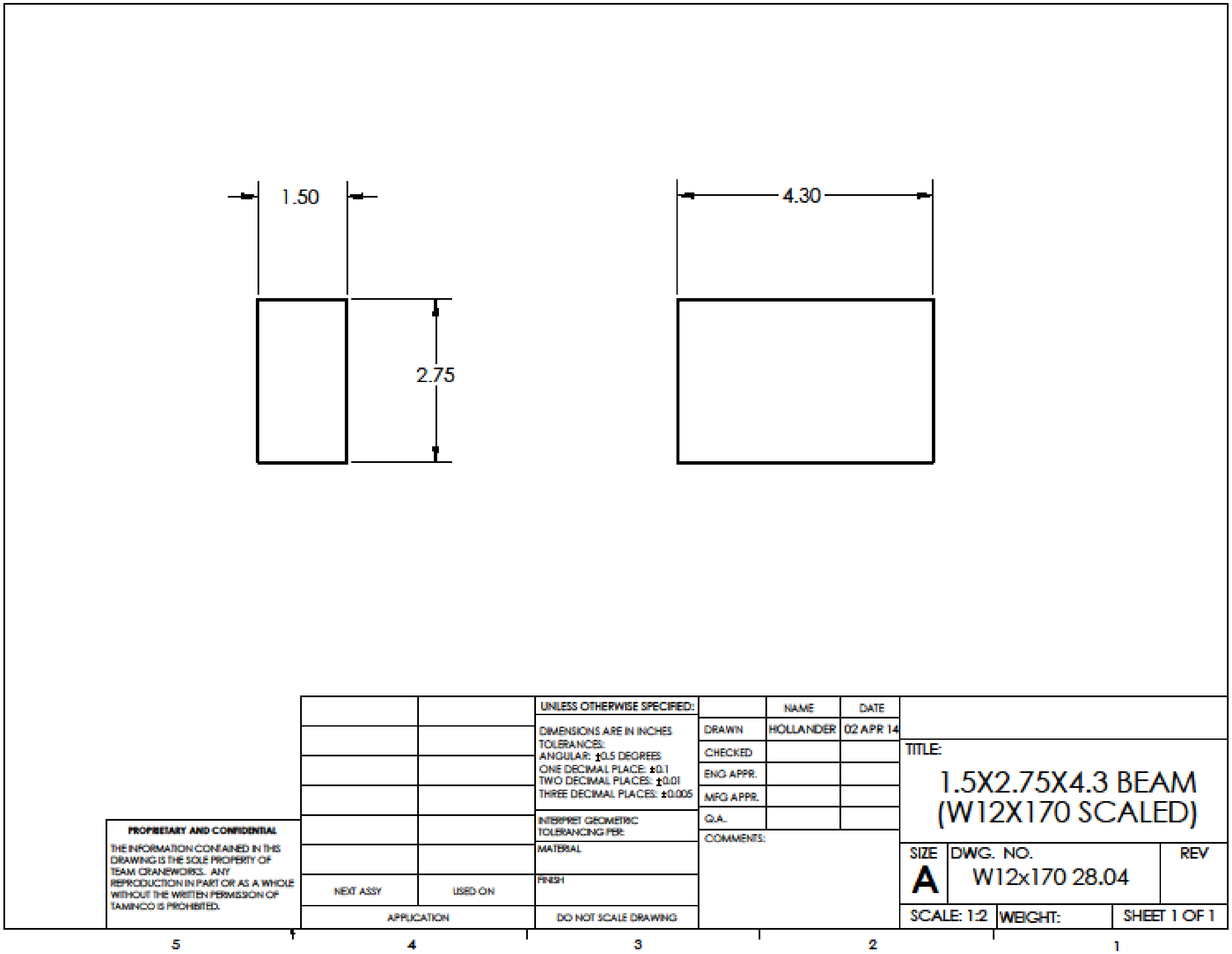
TITLE:
1.13X2.00X12 BEAM
(W12X65 SCALED)
SIZE
A
DWG. NO.
W12x65 SCALED
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


1.50
2.75
4.30
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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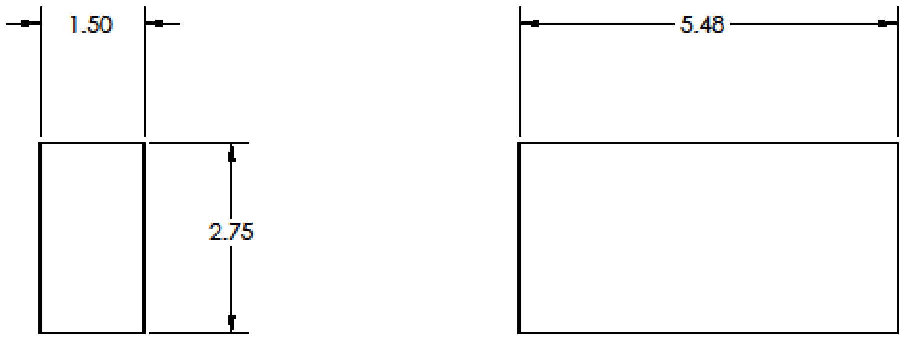
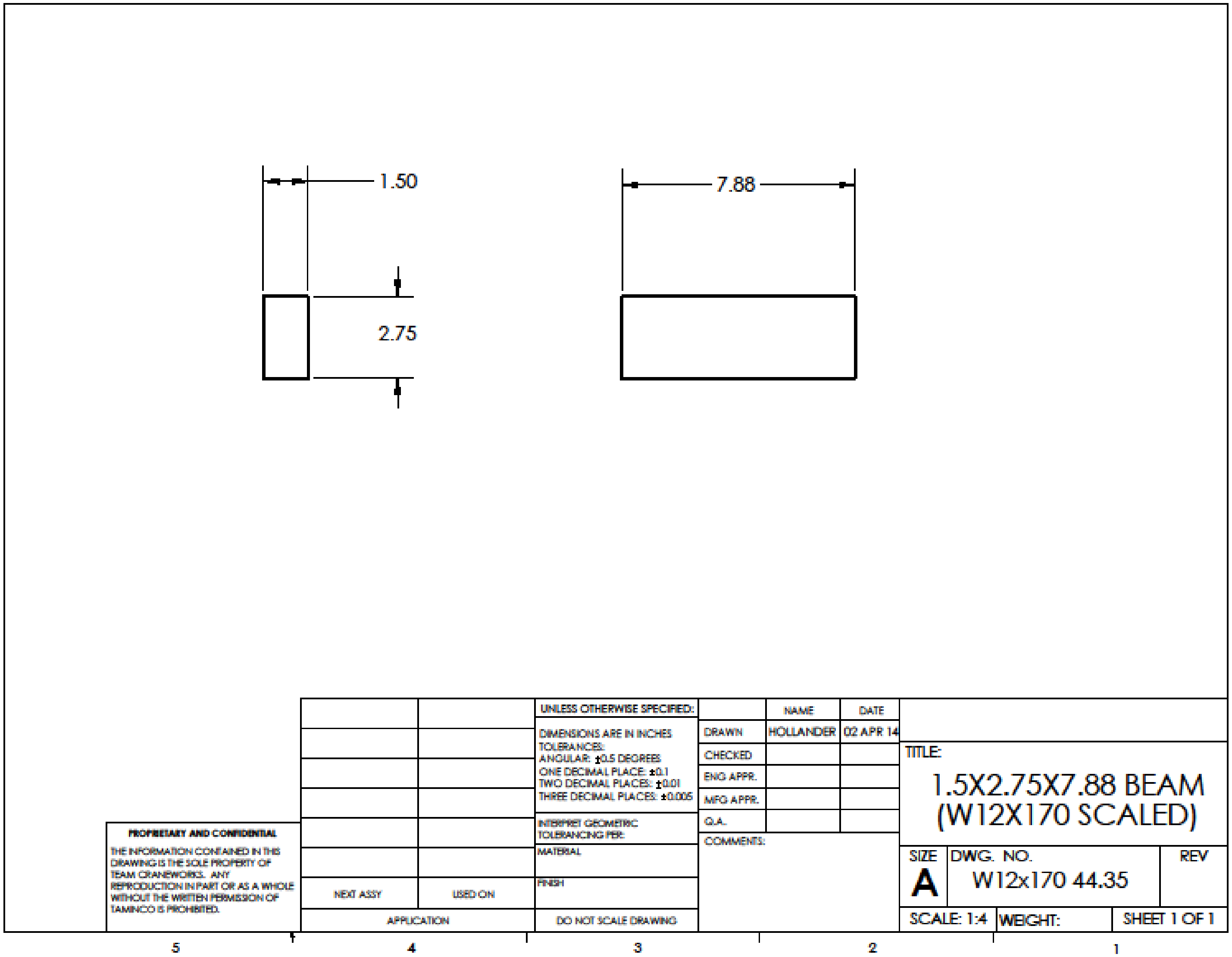
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
1.5X2.75X4.3 BEAM (W12X170 SCALED)
SIZE
A
DWG. NO.
W12x170 28.04
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE		
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±0.5 DEGREES ONE DECIMAL PLACE: ±0.1 TWO DECIMAL PLACES: ±0.01 THREE DECIMAL PLACES: ±0.005	DRAWN	HOLLANDER	02 APR 14	TITLE:	
	CHECKED			1.5X2.75X5.48 BEAM (W12X170 SCALED)	
	ENG APPR.				
	MFG APPR.				
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.				
MATERIAL	COMMENTS:			SIZE A	DWG. NO. W12x170 32.35	REV
FINISH					
DO NOT SCALE DRAWING				SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	

5 4 3 2 1



1.50
7.88
2.75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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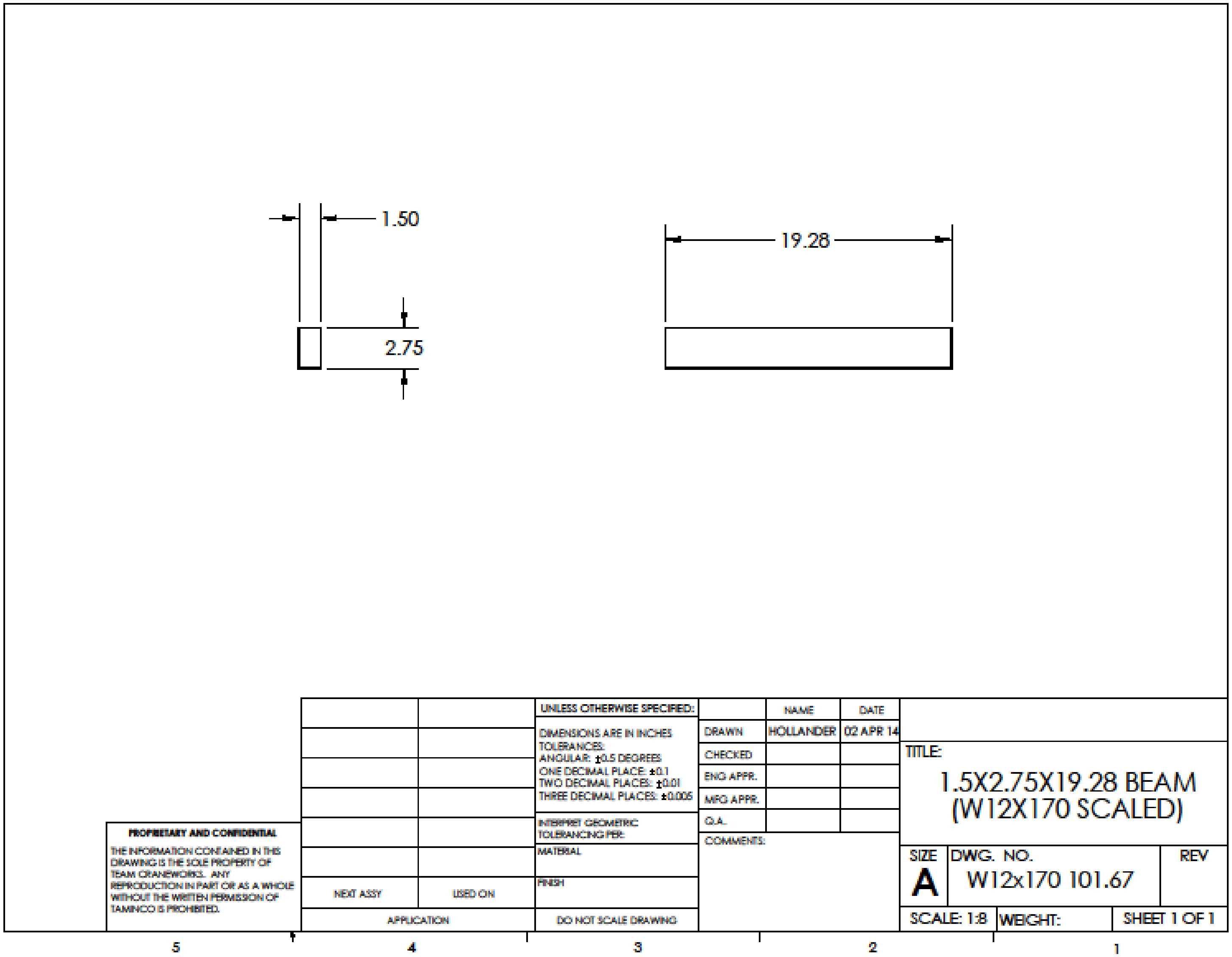
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
1.5X2.75X7.88 BEAM
(W12X170 SCALED)
SIZE
A
DWG. NO.
W12x170 44.35
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


1.50
2.75
19.28
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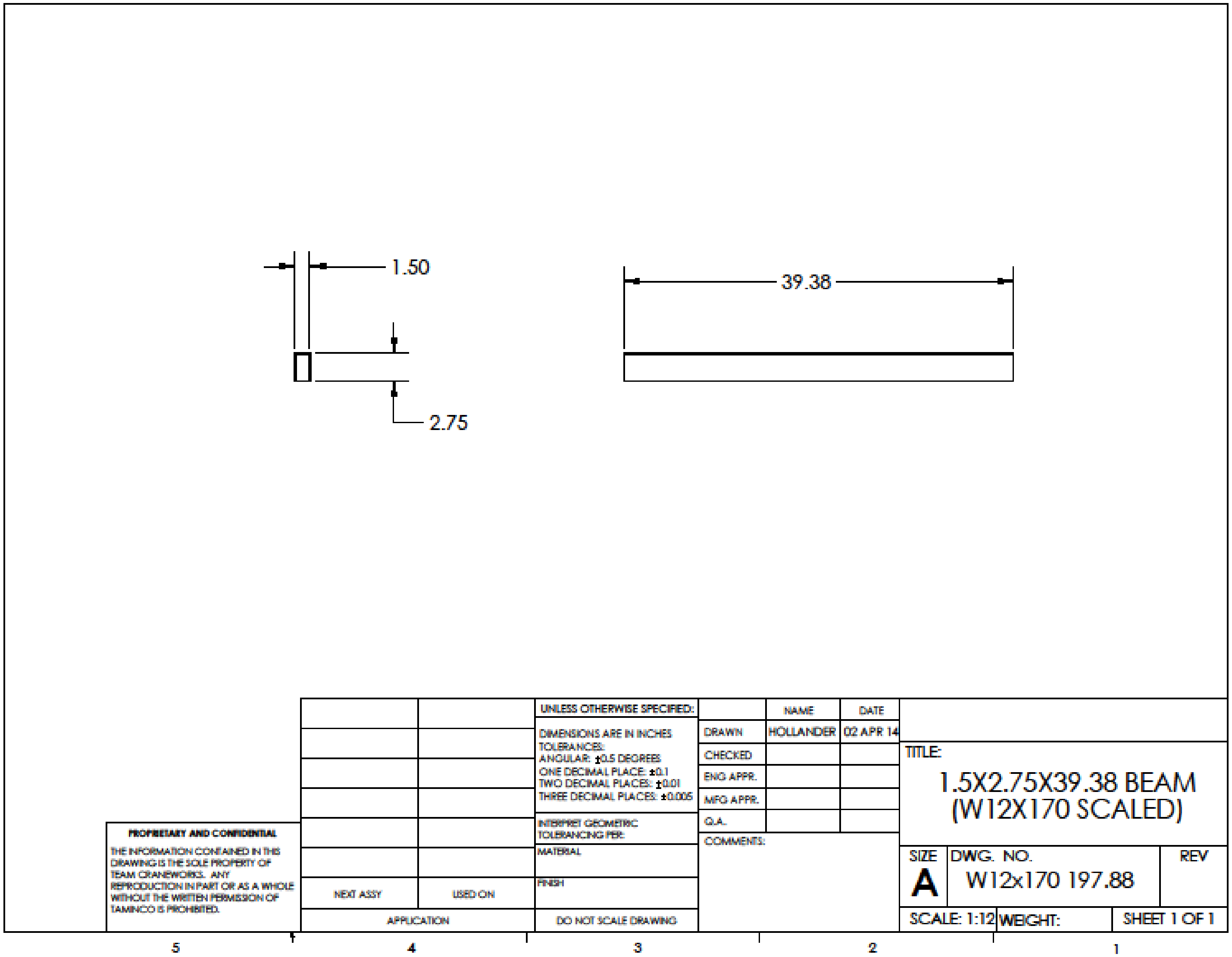
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
1.5X2.75X19.28 BEAM
(W12X170 SCALED)
SIZE
A
DWG. NO.
W12x170 101.67
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


1.50
2.75
39.38
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
1.5X2.75X39.38 BEAM
(W12X170 SCALED)
SIZE
A
DWG. NO.
W12x170 197.88
REV
SCALE: 1:12
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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5
4
3
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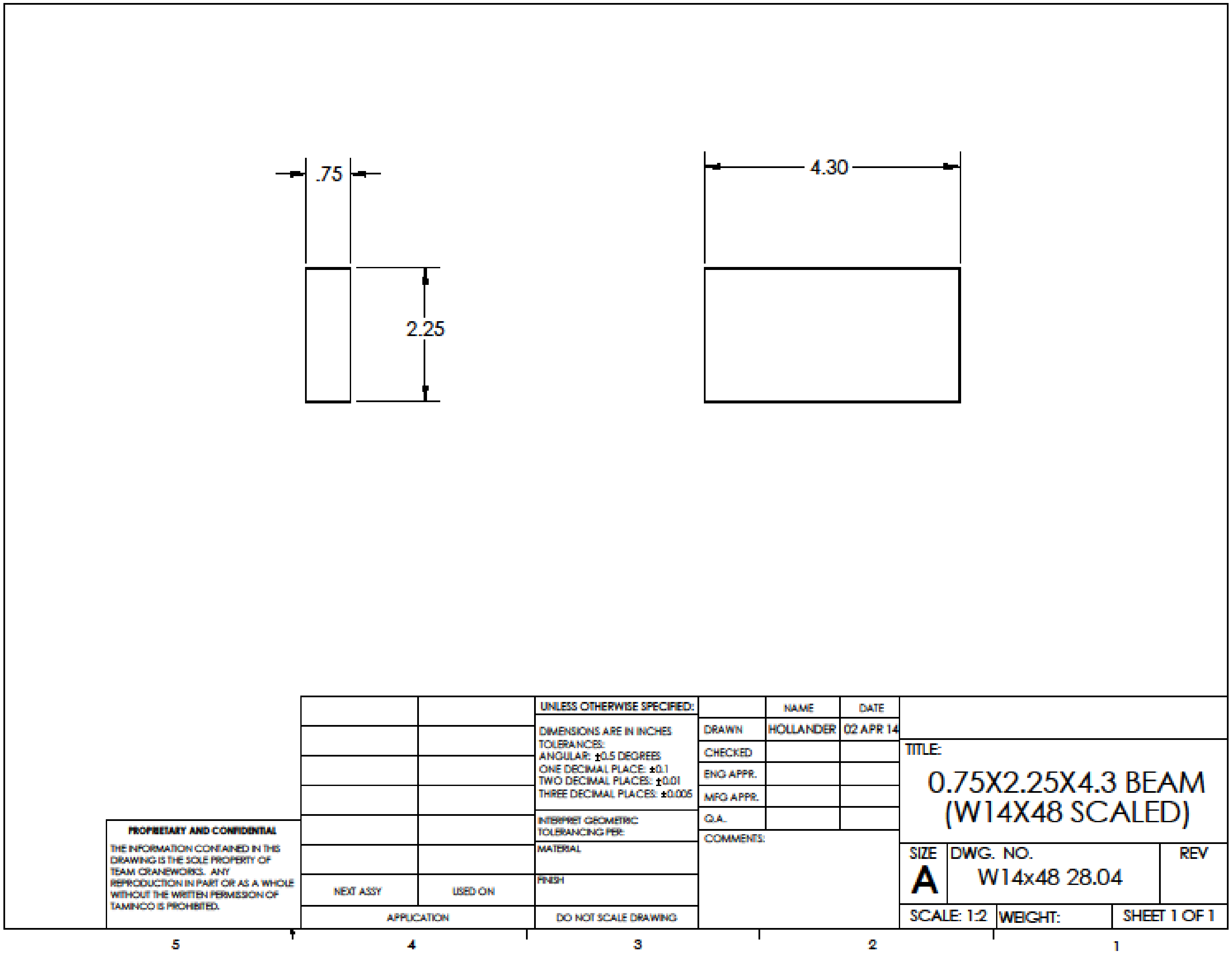
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2.25
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TOLERANCES:
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ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
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NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
0.75X2.25X4.3 BEAM (W14X48 SCALED)
SIZE
A
DWG. NO.
W14x48 28.04
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
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2
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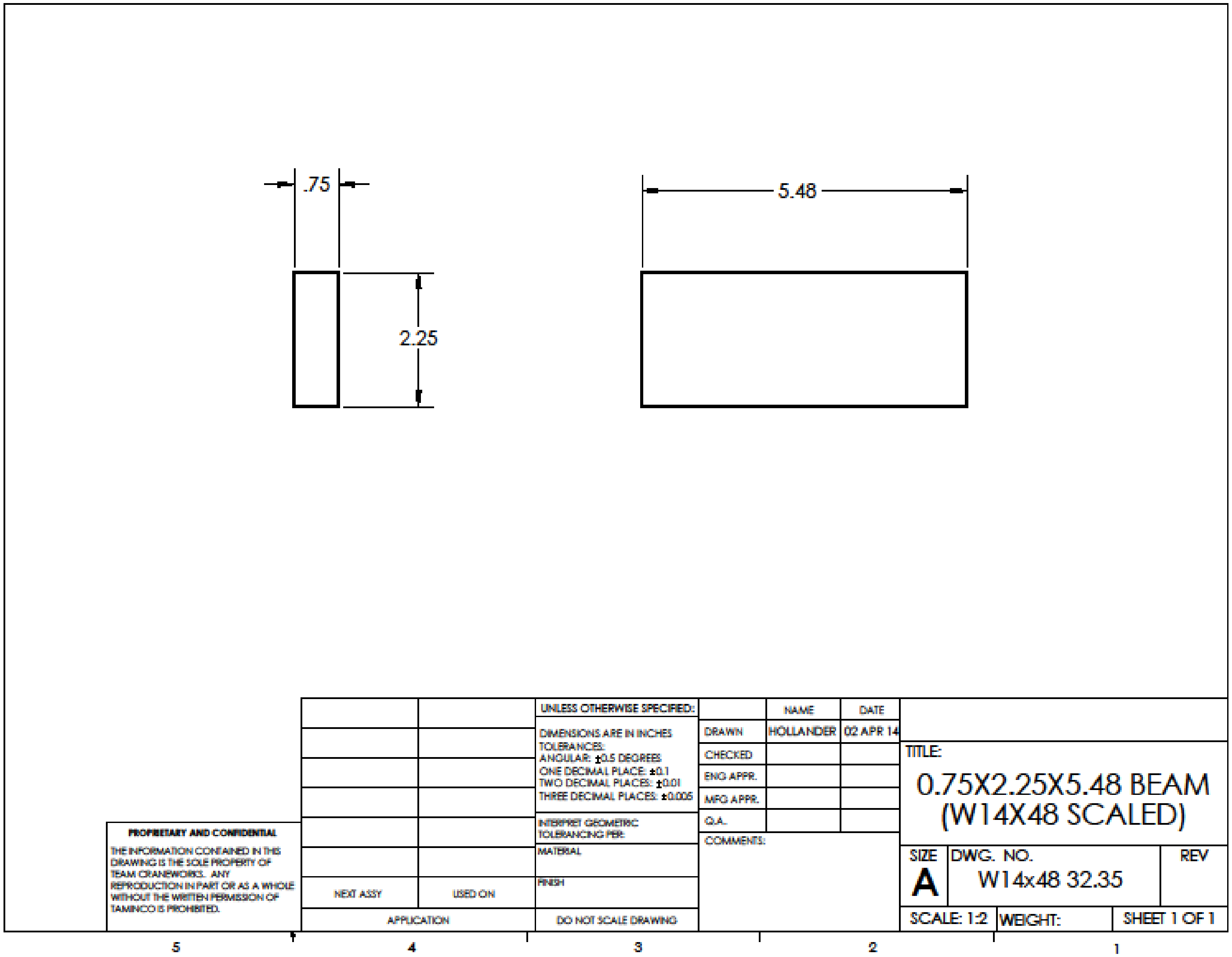
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5.48
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TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
0.75X2.25X5.48 BEAM (W14X48 SCALED)
SIZE
A
DWG. NO.
W14x48 32.35
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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5
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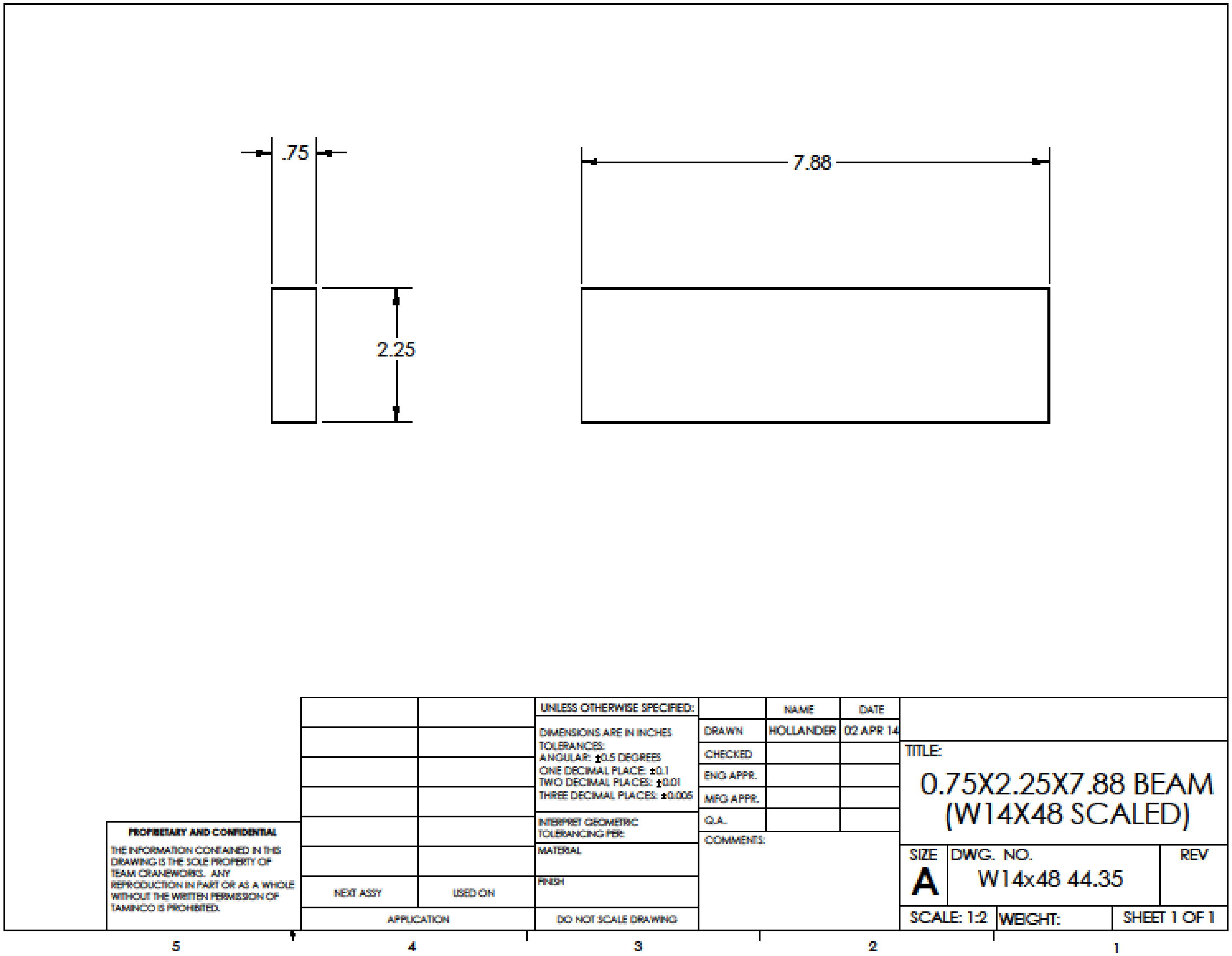

.75
2.25
7.88
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ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
0.75X2.25X7.88 BEAM (W14X48 SCALED)
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DWG. NO.
W14x48 44.35
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
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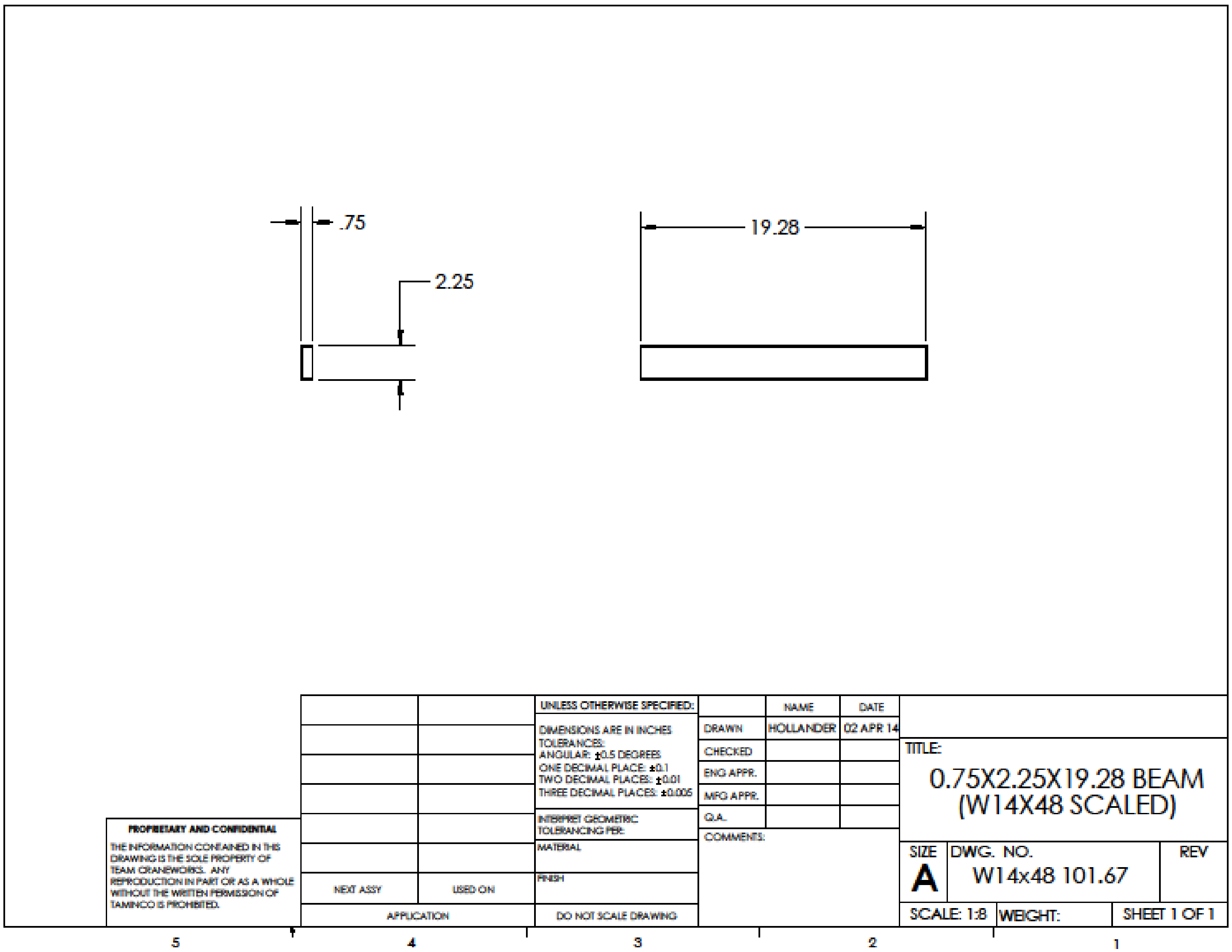
.75
2.25
19.28
PROPRIETARY AND CONFIDENTIAL
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ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
0.75X2.25X19.28 BEAM
(W14X48 SCALED)
SIZE
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DWG. NO.
W14x48 101.67
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
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2
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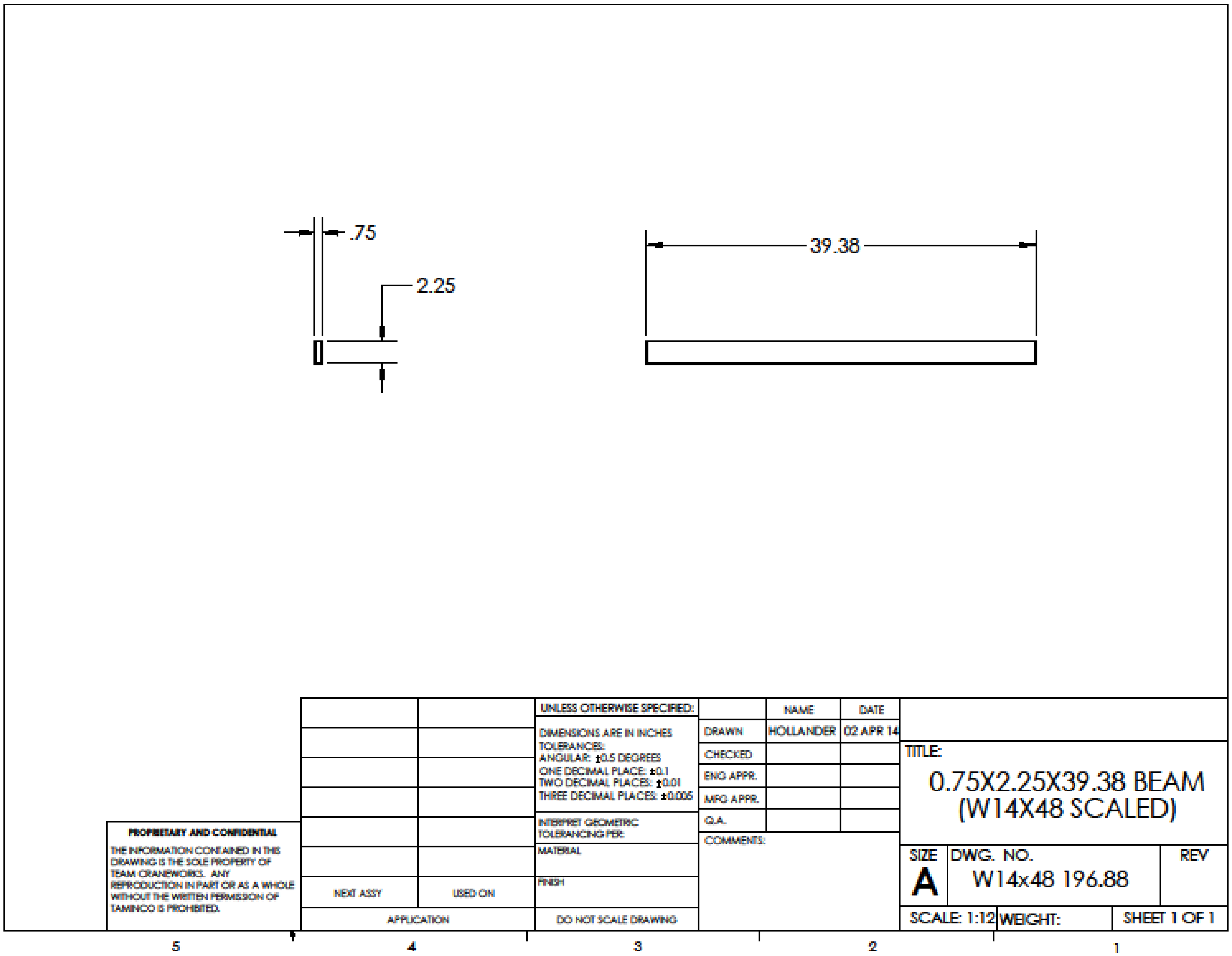
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2.25
39.38
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
0.75X2.25X39.38 BEAM
(W14X48 SCALED)
SIZE
A
DWG. NO.
W14x48 196.88
REV
SCALE: 1:12
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
5
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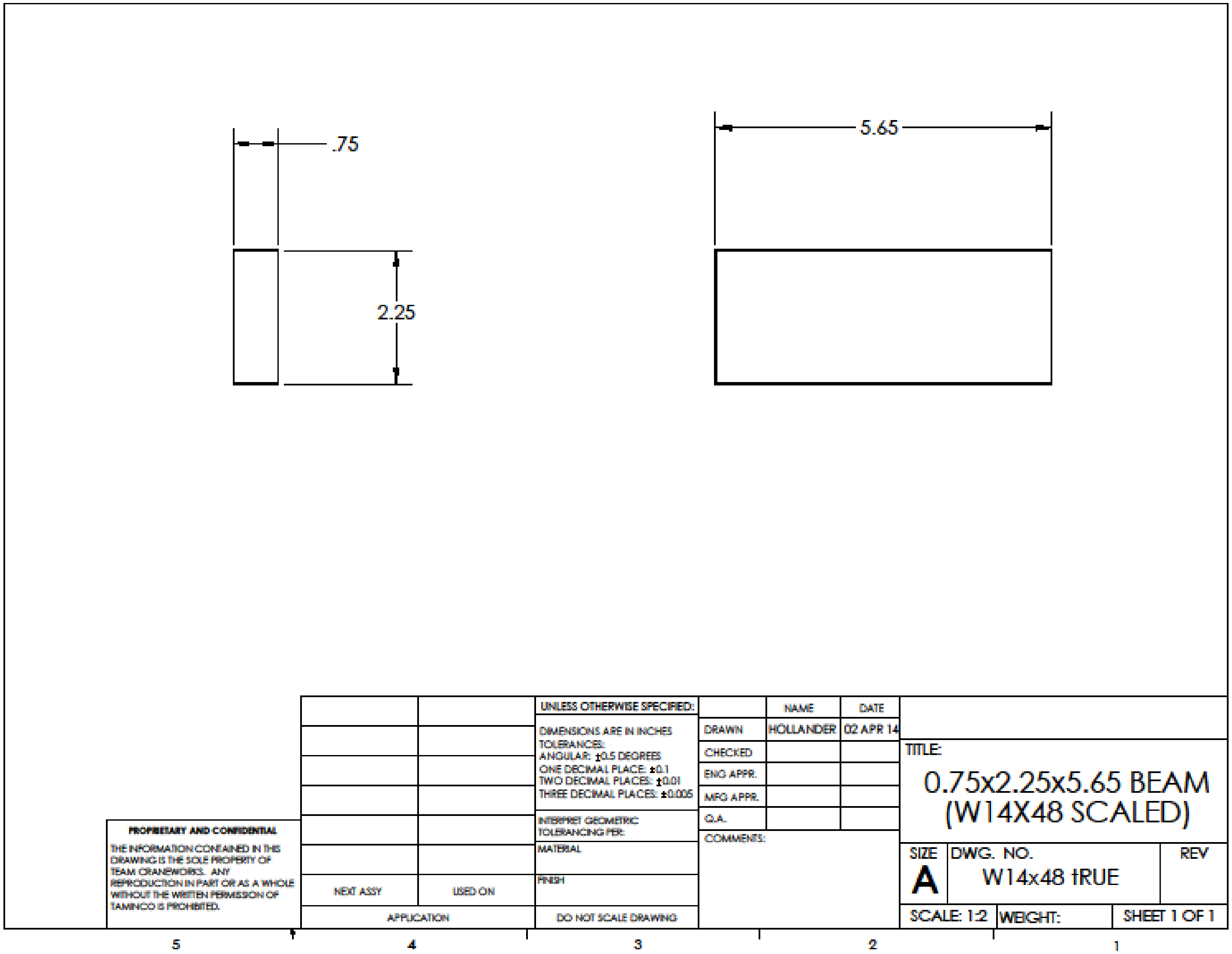
.75
2.25
5.65
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
HOLLANDER
02 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
0.75x2.25x5.65 BEAM
(W14X48 SCALED)
SIZE
A
DWG. NO.
W14x48 tRUE
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
5
4
3
2
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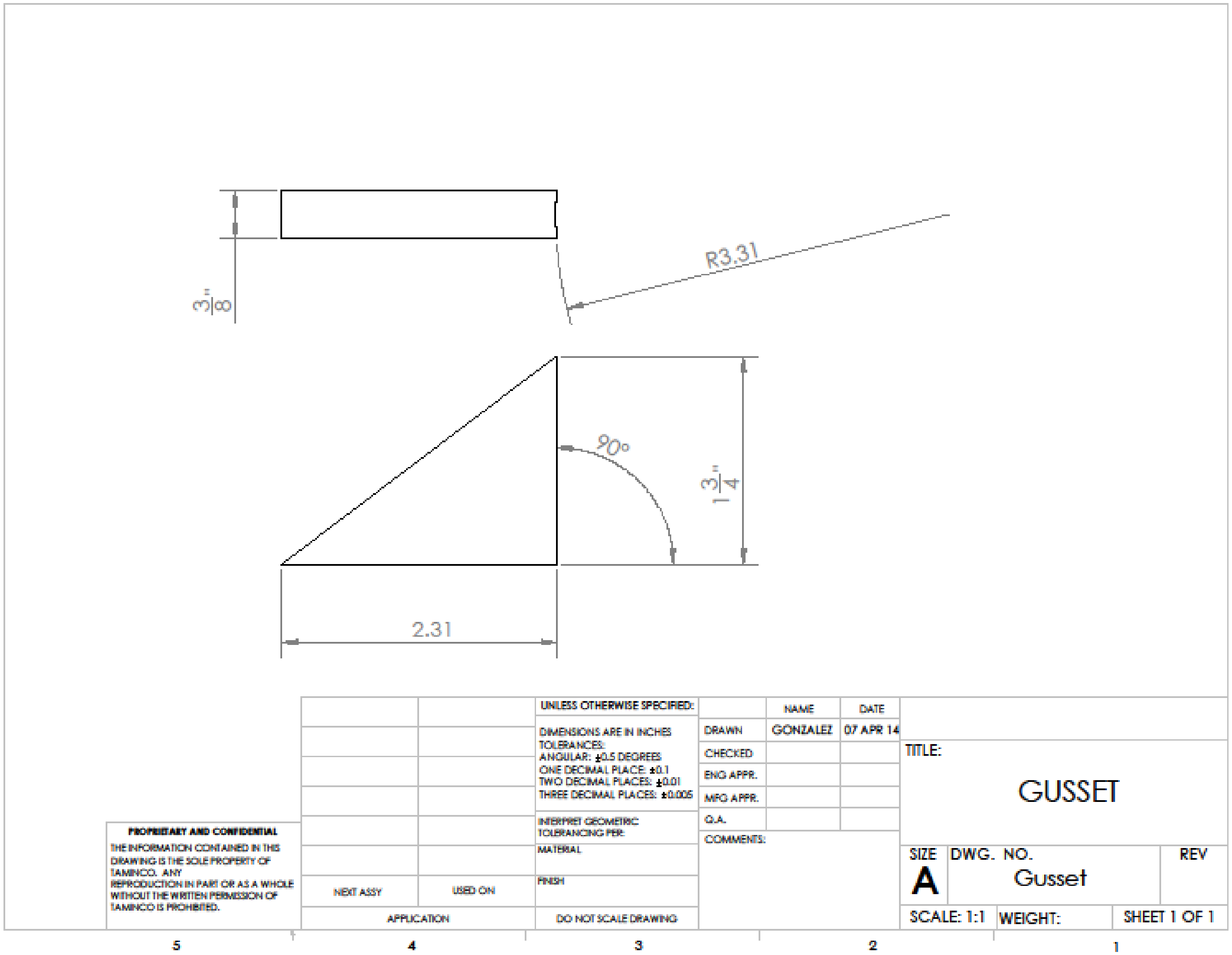

3/8"
R3.31
90°
1 3/4"
2.31
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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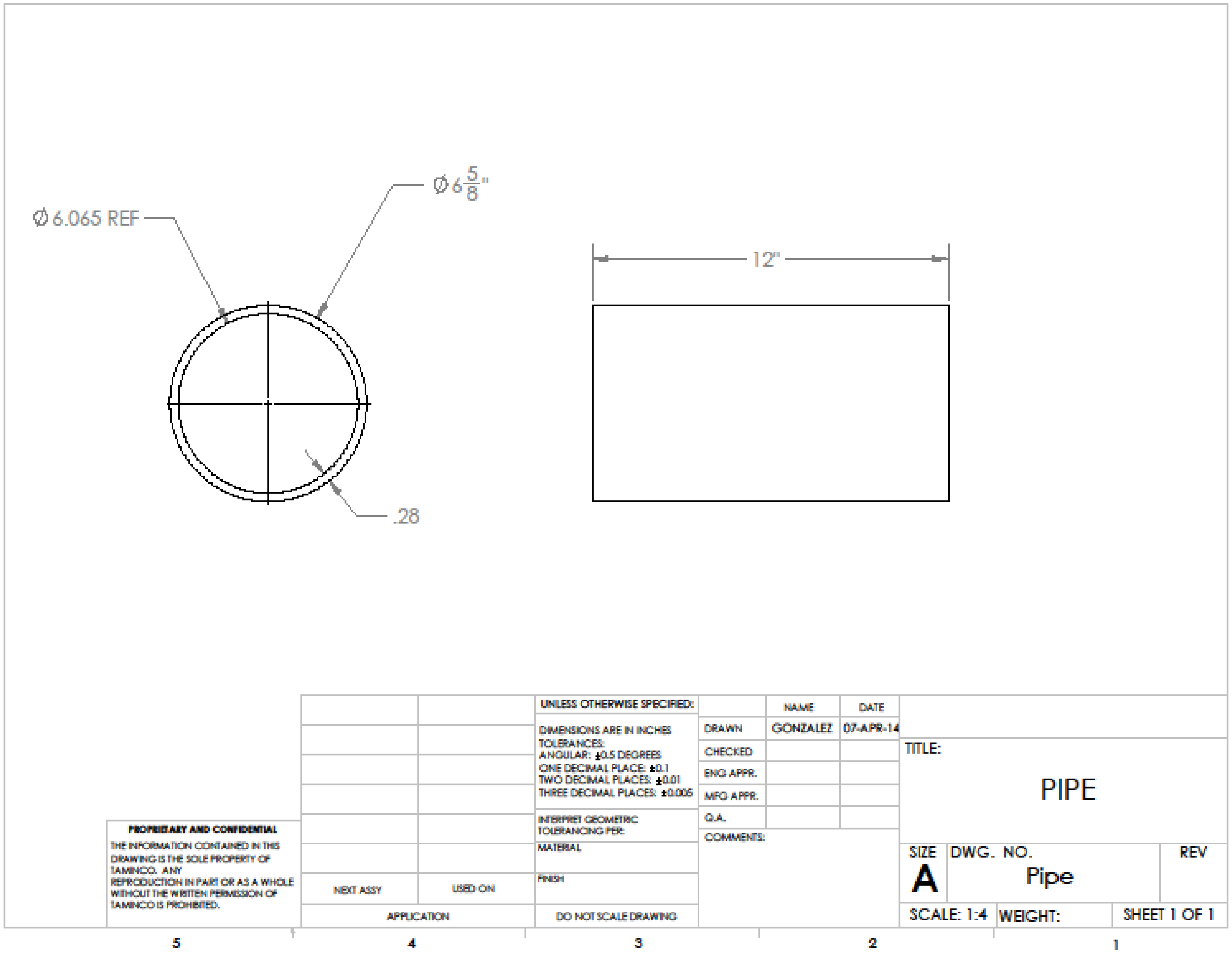
NAME
DATE
DRAWN
GONZALEZ
07 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
GUSSET
SIZE
A
DWG. NO.
Gusset
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1



Ø 6.065 REF
Ø 6 5/8"
.28
12"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
GONZALEZ
07-APR-14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
PIPE
SIZE
A
DWG. NO.
Pipe
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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NEXT ASSY
USED ON
APPLICATION
5
4
3
2
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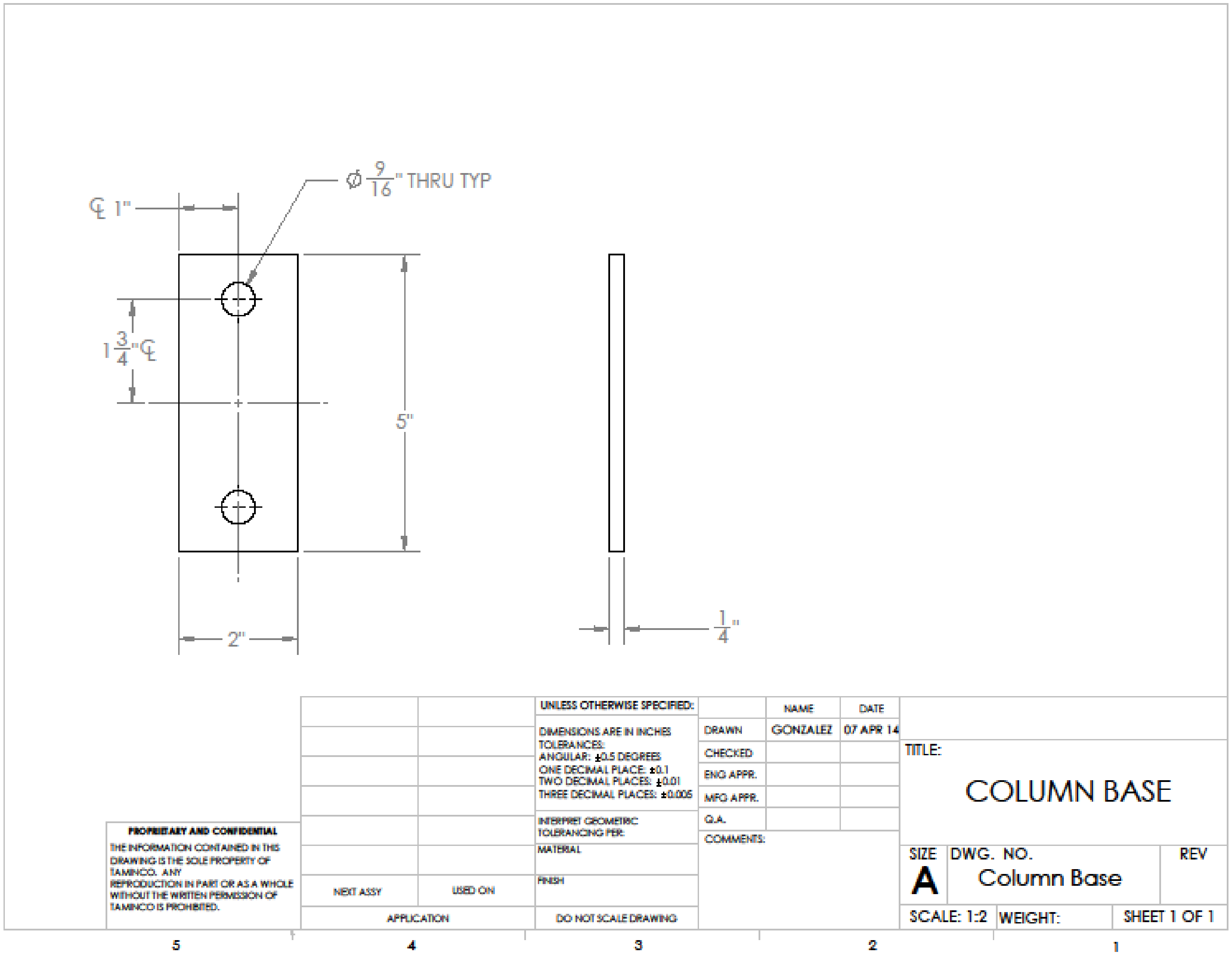

⌀ 9/16" THRU TYP
℄ 1"
1 3/4" ℄
5"
2"
1/4"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
GONZALEZ
07 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
COLUMN BASE
SIZE
A
DWG. NO.
Column Base
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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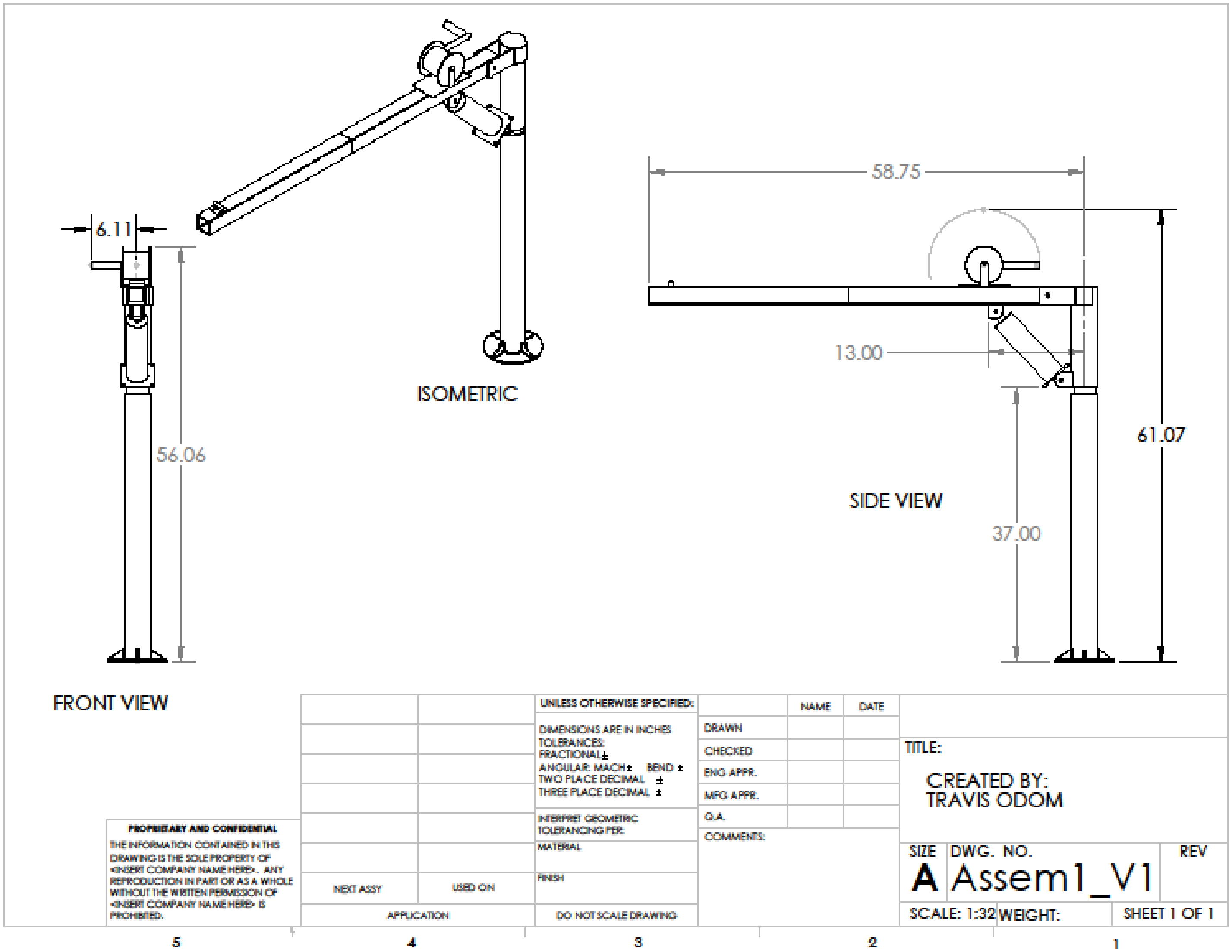
5
4
3
2
1



6.11
56.06
ISOMETRIC
58.75
13.00
61.07
SIDE VIEW
37.00
FRONT VIEW
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
CREATED BY:
TRAVIS ODOM
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
PROPRIETARY AND CONFIDENTIAL
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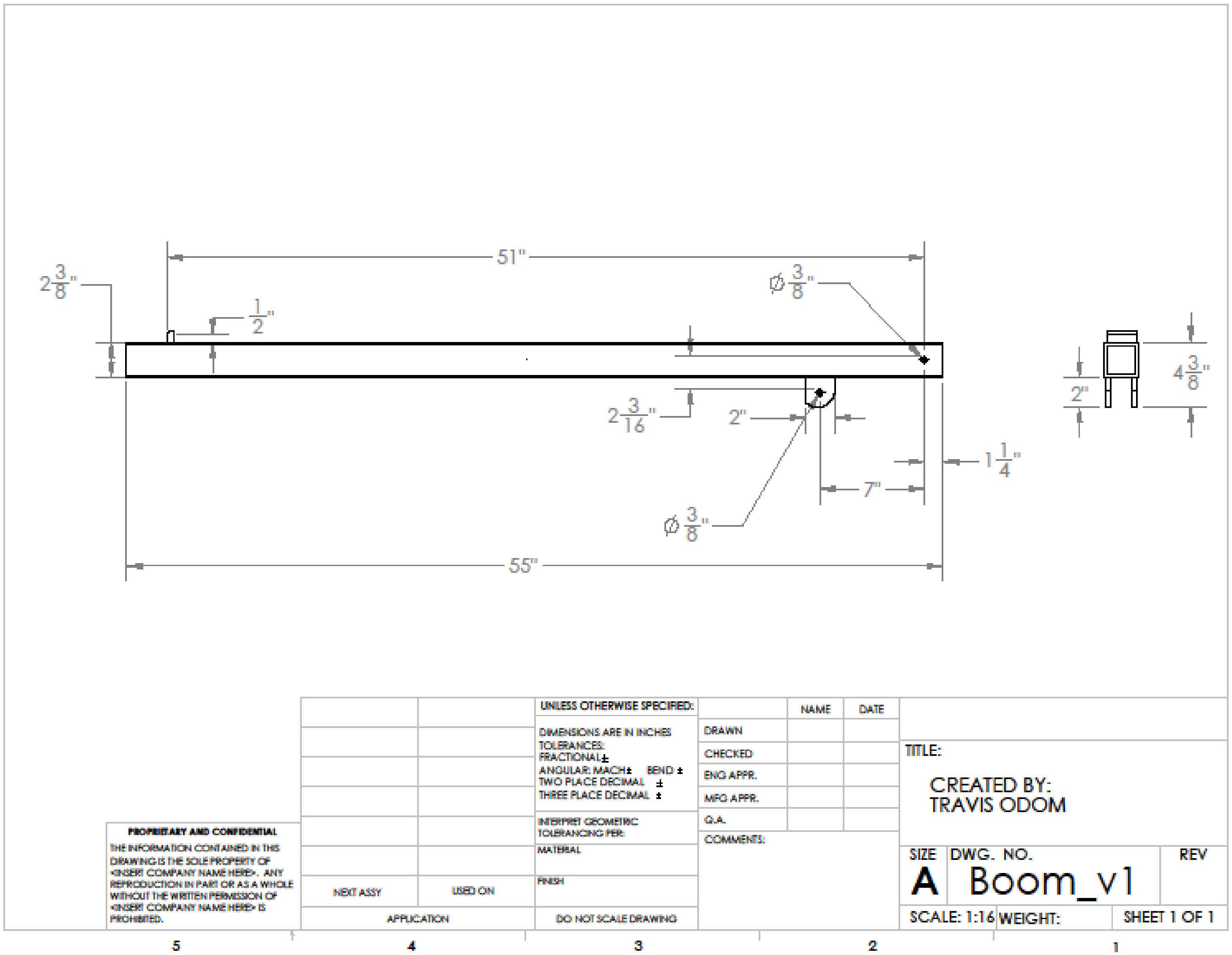
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
SIZE
DWG. NO.
REV
A
Assem1_V1
SCALE: 1:32
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


51"
2 3/8"
1/2"
Ø 3/8"
2 3/16"
2"
1 1/4"
7"
Ø 3/8"
55"
2"
4 3/8"
PROPRIETARY AND CONFIDENTIAL
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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
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
CREATED BY:
TRAVIS ODOM
SIZE
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DWG. NO.
Boom_v1
REV
SCALE: 1:16
WEIGHT:
SHEET 1 OF 1
5
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3
2
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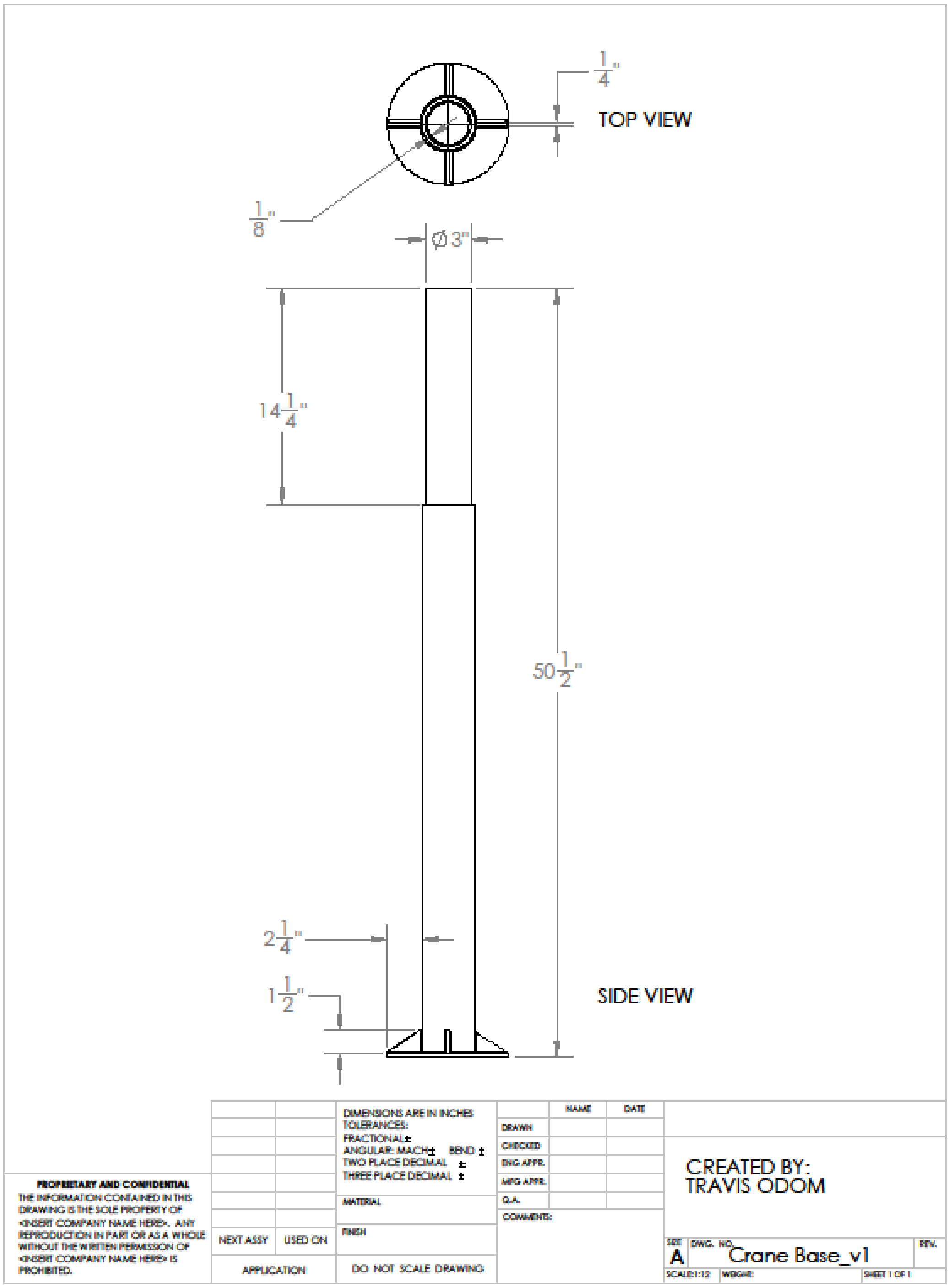
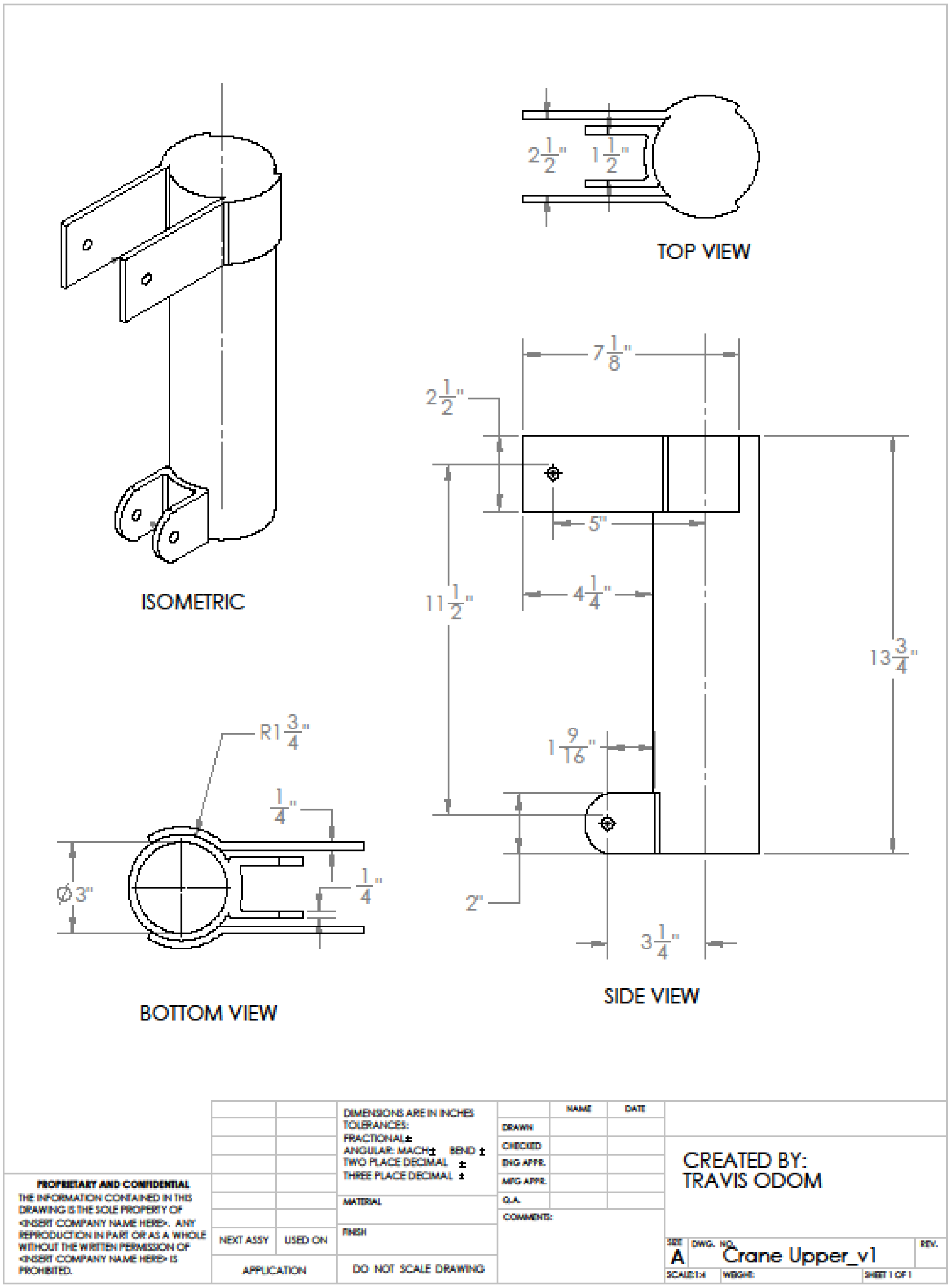


1/4"
TOP VIEW
1/8"
Ø3"
14 1/4"
50 1/2"
2 1/4"
1 1/2"
SIDE VIEW
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
CREATED BY:
TRAVIS ODOM
SIZE
A
DWG. NO.
Crane Base_v1
REV.
SCALE:1:12
WEIGHT:
SHEET 1 OF 1


ISOMETRIC
TOP VIEW
2 1/2"
1 1/2"
7 1/8"
2 1/2"
5"
4 1/4"
11 1/2"
13 3/4"
1 9/16"
2"
3 1/4"
SIDE VIEW
R1 3/4"
1/4"
1/4"
Ø3"
BOTTOM VIEW
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
MATERIAL
FINISH
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
CREATED BY:
TRAVIS ODOM
PROPRIETARY AND CONFIDENTIAL
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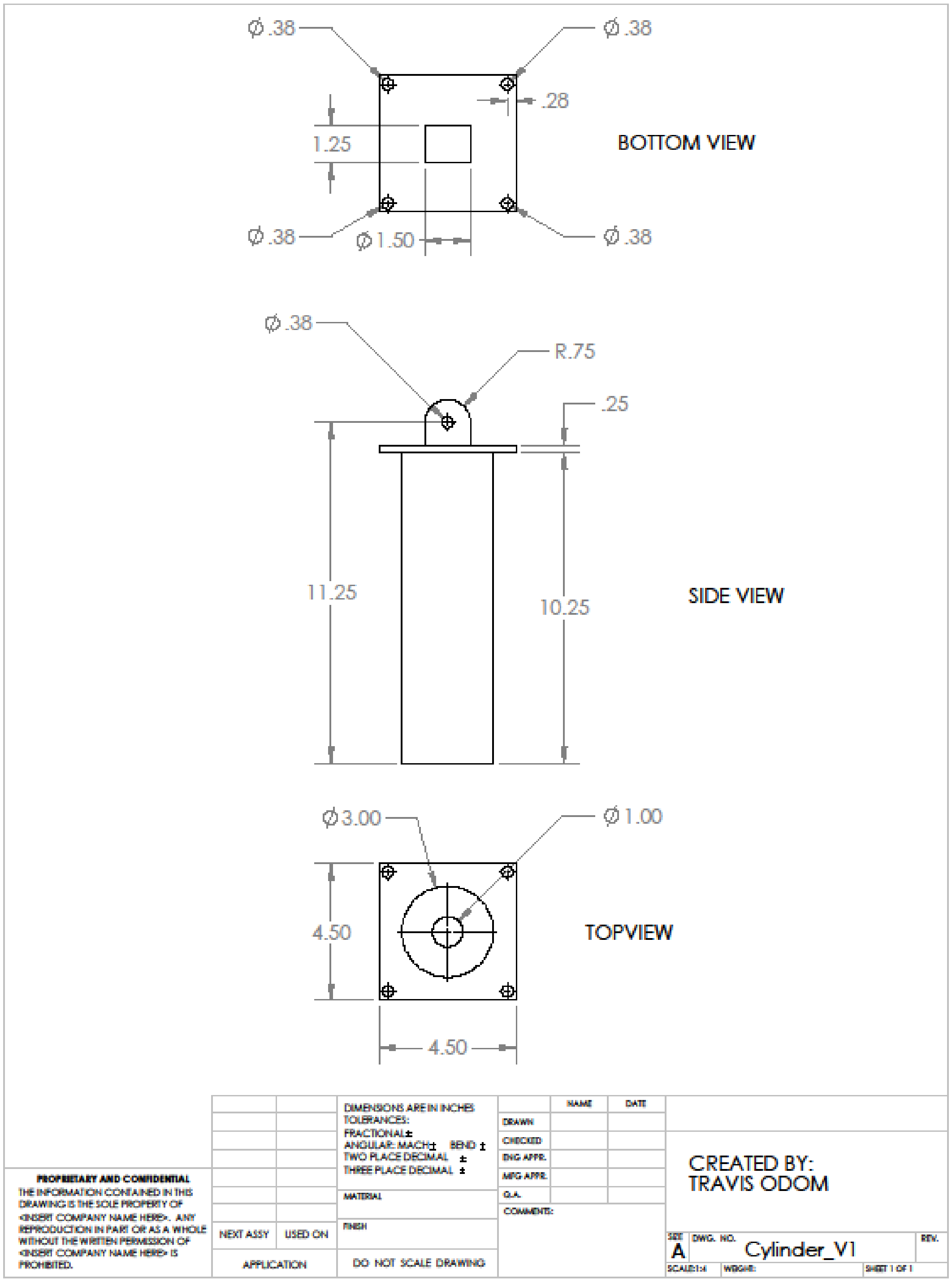
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
SIZE
A
DWG. NO.
Crane Upper_v1
REV.
SCALE:1:4
WEIGHT:
SHEET 1 OF 1


Ø.38
Ø.38
.28
1.25
BOTTOM VIEW
Ø.38
Ø1.50
Ø.38
Ø.38
R.75
.25
11.25
10.25
SIDE VIEW
Ø3.00
Ø1.00
4.50
TOPVIEW
4.50
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
CREATED BY:
TRAVIS ODOM
PROPRIETARY AND CONFIDENTIAL
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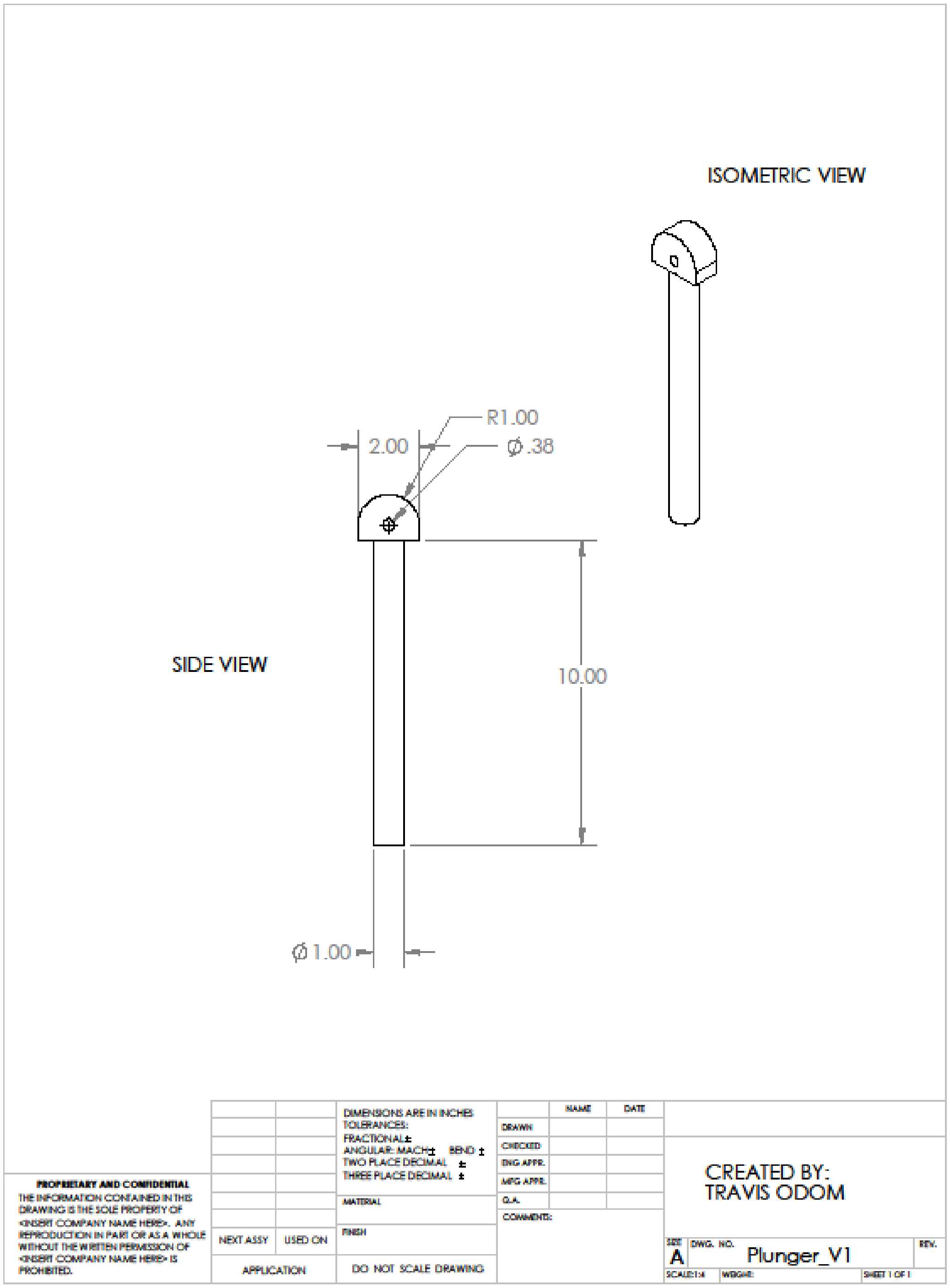
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
SIZE
A
DWG. NO.
Cylinder_V1
REV.
SCALE:1:4
WEIGHT:
SHEET 1 OF 1


ISOMETRIC VIEW
SIDE VIEW
2.00
R1.00
Ø .38
10.00
Ø 1.00
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
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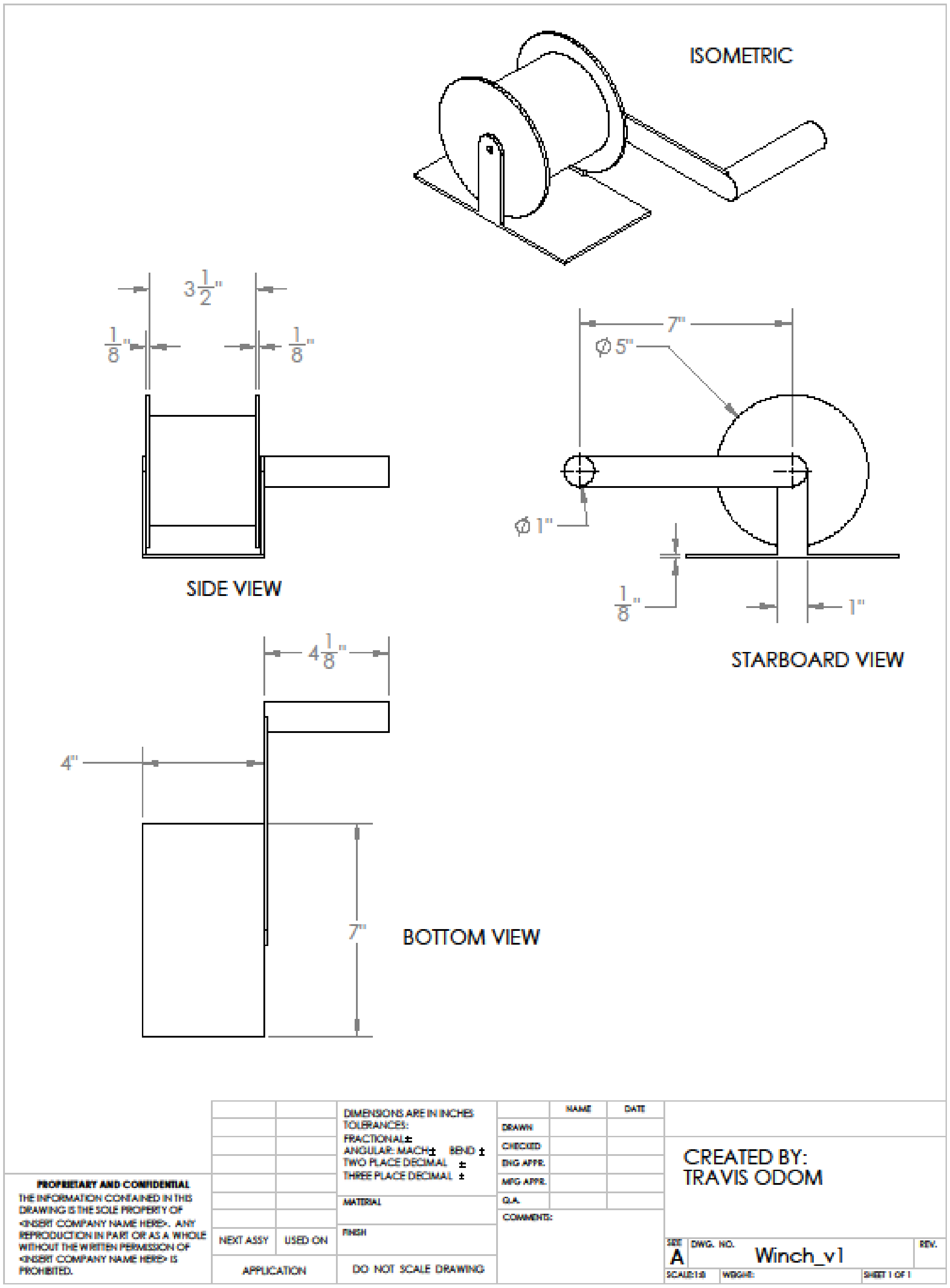
CREATED BY:
TRAVIS ODOM
SIZE
A
DWG. NO.
Plunger_V1
REV.
SCALE:1:4
WEIGHT:
SHEET 1 OF 1


ISOMETRIC
3 1/2"
1/8"
1/8"
SIDE VIEW
7"
Ø 5"
Ø 1"
1/8"
1"
STARBOARD VIEW
4 1/8"
4"
7"
BOTTOM VIEW
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
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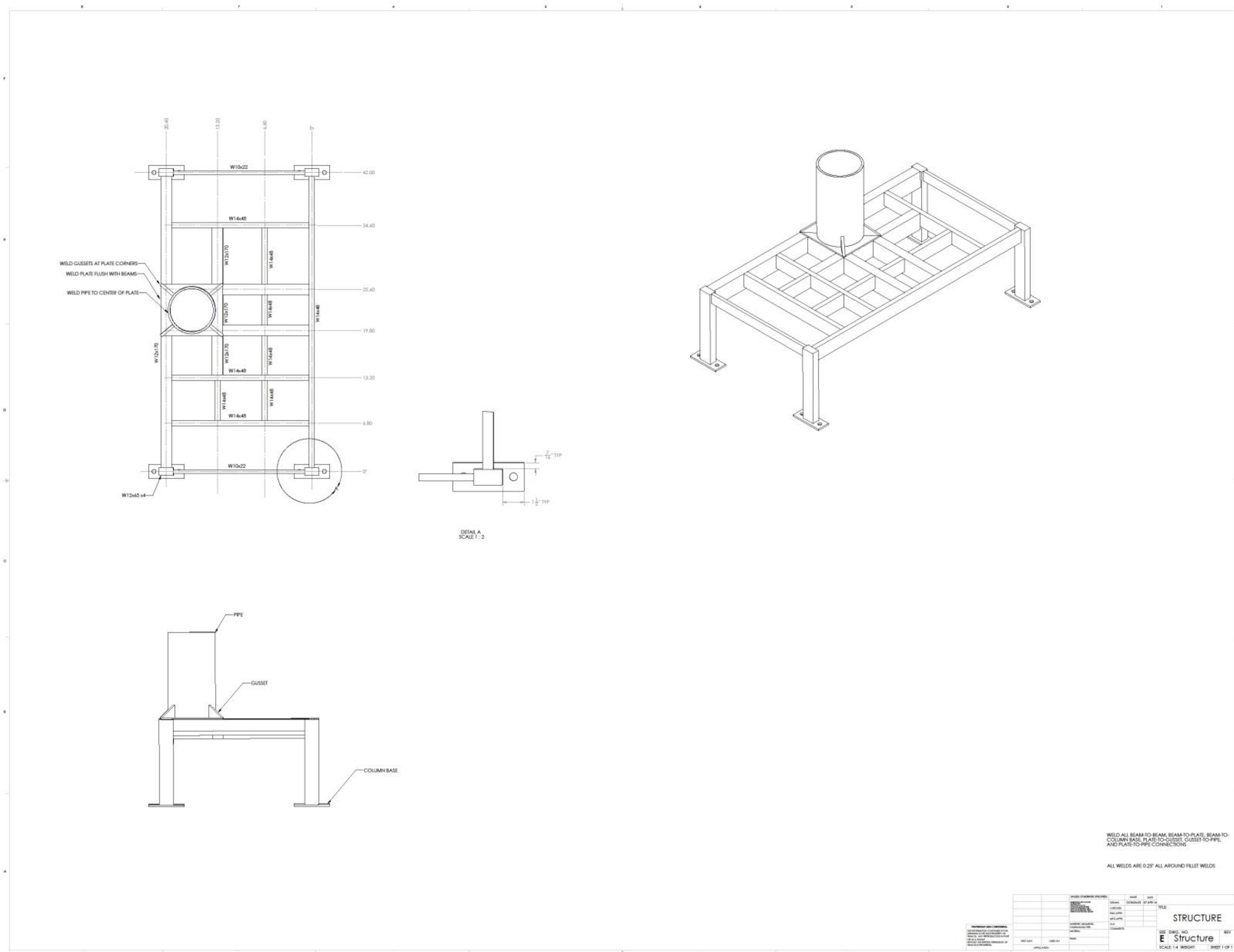
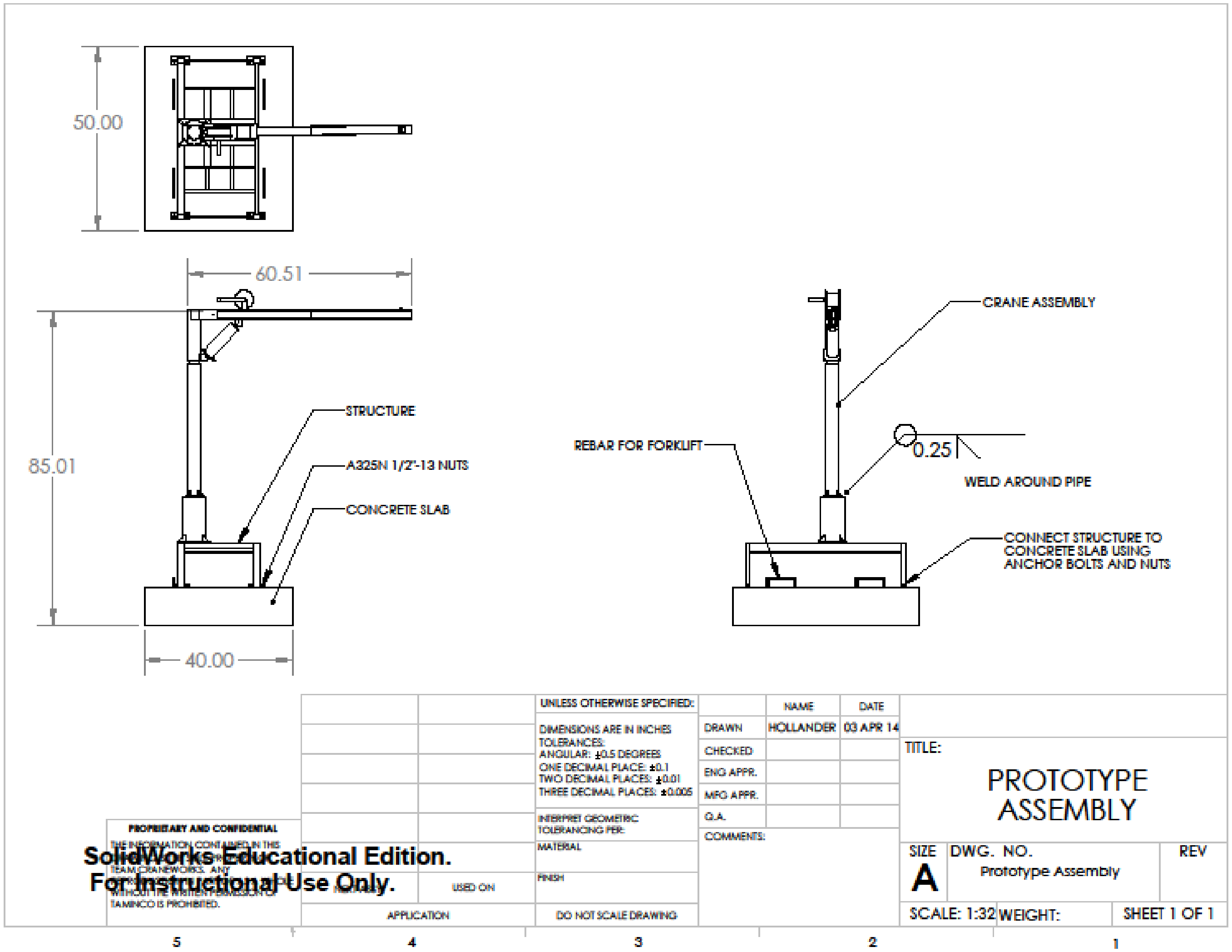
CREATED BY:
TRAVIS ODOM
SIZE
A
DWG. NO.
Winch_v1
REV.
SCALE:1:8
WEIGHT:
SHEET 1 OF 1


W10x22
W14x48
WELD GUSSETS AT PLATE CORNERS
WELD PLATE FLUSH WITH BEAMS
WELD PIPE TO CENTER OF PLATE
W12x65 x4
DETAIL A
SCALE 1 : 2
PIPE
GUSSET
COLUMN BASE
WELD ALL BEAM-TO-BEAM, BEAM-TO-PLATE, BEAM-TO-COLUMN BASE, PLATE-TO-GUSSET, GUSSET-TO-PIPE, AND PLATE-TO-PIPE CONNECTIONS
ALL WELDS ARE 0.25" ALL AROUND FILLET WELDS
STRUCTURE
E Structure


50.00
60.51
85.01
40.00
STRUCTURE
A325N 1/2"-13 NUTS
CONCRETE SLAB
CRANE ASSEMBLY
REBAR FOR FORKLIFT
0.25
WELD AROUND PIPE
CONNECT STRUCTURE TO CONCRETE SLAB USING ANCHOR BOLTS AND NUTS
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±0.5 DEGREES
ONE DECIMAL PLACE: ±0.1
TWO DECIMAL PLACES: ±0.01
THREE DECIMAL PLACES: ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
USED ON
APPLICATION
NAME
DATE
DRAWN
HOLLANDER
03 APR 14
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
PROTOTYPE ASSEMBLY
SIZE
A
DWG. NO.
Prototype Assembly
REV
SCALE: 1:32
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
SolidWorks Educational Edition.
For Instructional Use Only.
5
4
3
2
1

Prototype Design Quotes

McMASTER-CARR.

Date April 2, 2014
Purchase order
Order created by 0

Ship to

Send invoice to

Shipping method
Ground

Payment method

Line	Quantity	Product		Ships	Unit price	Total
1	2 each	6544K24	General Purpose Low-Carbon Steel, Sheet, 1/4" Thick, 10" x 10"	today	$41.61 each	83.22
2	1 each	6544K28	General Purpose Low-Carbon Steel, Sheet, 3/8" Thick, 6" x 6"	today	$29.47 each	29.47
3	4 each	8910K65	Low-Carbon Steel Rectangular Bar, 1-1/8" Thick, 2" Width, 1' Length	today (2 from our Chicago warehouse)	$32.91 each	131.64
4	1 each	7750K123	Standard-Wall Steel Unthreaded Pipe, 8 Pipe Size, 1' Length	today	$313.36 each	313.36
5	2 each	8910K943	Low-Carbon Steel Bar, 1/2" Thick, 1-5/8" Width, 2' Length	today	$22.70 each	45.40
6	1 each	8910K88	Low-Carbon Steel Rectangular Bar, 1-1/2" Thick, 2-3/4" Width, 6' Length	today (from our Chicago warehouse)	$225.65 each	225.65
7	3 each	8910K88	Low-Carbon Steel Rectangular Bar, 1-1/2" Thick, 2-3/4" Width, 3' Length	today	$125.36 each	376.08
8	1 each	8910K785	Low-Carbon Steel Rectangular Bar, 3/4" Thick, 2-1/4" Width, 6' Length	today	$89.52 each	89.52
9	3 each	8910K785	Low-Carbon Steel Rectangular Bar, 3/4" Thick, 2-1/4" Width, 3' Length	today	$51.92 each	155.76

Merchandise total $1453.10

Applicable shipping charges and tax will be added.

Phone (562) 692-5911 Fax (562) 695-2323 Internet www.mcmaster.com Email la.sales@mcmaster.com

http://www.mcmaster.com/OrdPad/OrdPadPr.aspx?ordid=2282746078541&time 1396467... 4/2/2014

MORRISON TERREBONNE LUMBER CENTER,
DEL: 605 BARATARIA AVE HOUMA, LA
P.O. BOX 715633
COLUMBUS, OH 43271-5633
(985) 879-1597

DOCUMENT NUMBER	PAGE NO
380813	1

CUST NO: 16524 **JOB NO:** 100
CUSTOMER: BT-INTEGRITY HOME BUILDERS,

134 HOUMAS DR.
HOUMA LA 70360

CREATED BY	SALESPERSON	DATE / TIME
MP	MELISSA LEBOEUF	3/31/14 2:17
TERMINAL		**REFERENCE**
566		

ESTIMATE

-- **DELIVERY** MISC. ACCT.
ADDRESS: INTEGRITY HOME BUILDERS, LLC

EXPIRATION DATE
4/30/14
TAX
205 4% LA 5% TERR

LN#	ITEM	UM	DESCRIPTION	QUANTITY	SUGG	PRICE PER	EXTENSION
1	X9450001	EA	80LB READY MIX CONCRETE MIX	40		3.49 /EA	139.60 S
2	X9150001	EA	1/2X20 RE-BAR	2	6.99	6.64 /EA	13.28 *
3	X9150036	EA	6X6X6GA. (8'X20-MAT) WIRE	1	35.99	34.19 /EA	34.19
4	10121212	EA	2X12X12 #2 PINE	2	19.99	18.39 /EA	36.78 S
5	X1012408	EA	2X4X8 #2 PINE	2	2.99	2.75 /EA	5.50
6	X9150019	EA	PS 5/8X10 GAL.ANC.BOLT W/WASHER	8	1.99	1.89 /EA	15.12

Created For: JARED

TAXABLE	244.47
NON-TAXABLE	0.00
SUBTOTAL	244.47
TAX AMOUNT	22.00
TOTAL AMOUNT	266.47

Testing Data

Static Testing Data

#	Boom Orientation	Deflection at 1 (*1/1000 in)				Deflection at 2 (*1/1000 in)				Deflection at 3 (*1/1000 in)				Deflection at 4 (*1/1000 in)			
		Run A	Run B	Run C	Average	Run A	Run B	Run C	Average	Run A	Run B	Run C	Average	Run A	Run B	Run C	Average
1	**N**	-21	-14	-14	-16.3	5	2	5	4.0	9	10	10	9.7	5	6	5	5.3
2	**NE**	-16	-7	-9	-10.7	2	0	2	1.3	5	5	5	5.0	5	6	5	5.3
3	**E**	2	2	2	2.0	-1	-1	-1	-1.0	0	0	-1	-0.3	2	3	1	2.0
4	**SE**	11	12	12	11.7	-3	-2	-3	-2.7	-5	-5	-5	-5.0	-1	-2	-3	-2.0
5	**S**	16	15	17	16.0	-2	-2	-3	-2.3	-13	-7	-7	-9.0	-6	-5	-6	-5.7
6	**SW**	12	10	12	11.3	0	-2	0	-0.7	-3	-3	-3	-3.0	-7	-5	-5	-5.7
7	**W**	1	1	1	1.0	3	1	3	2.3	2	2	2	2.0	-2	-1	-2	-1.7
8	**NW**	-17	-10	-9	-12.0	5	4	5	4.7	9	8	8	8.3	3	3	3	3.0

Dynamic Testing Data

Boom Orientation	Swing Direction	#	Deflection at 1 (*1/1000 in)			Deflection at 2 (*1/1000 in)			Deflection at 3 (*1/1000 in)			Deflection at 4 (*1/1000 in)		
			Reference	Max	Min	Reference	Max	Min	Reference	Max	Min	Reference	Max	Min
		Run 1		1.0	-1.0		0.0	-1.0		1.0	-1.0		1.0	-1.0
	Parallel to Boom	Run 2		1.0	-1.0		0.0	-1.0		1.0	-1.0		1.0	-1.0
		Run 3		1.0	-1.0		0.0	-1.0		1.0	-1.0		1.0	-1.0
		Run 1		0.5	-0.5		0.0	-1.0		0.0	-1.0		2.0	-0.5
N	**Perpendicular to Boom**	Run 2	-15.0	0.5	-0.5	4.0	0.0	-1.0	9.0	0.0	-1.0	4.0	2.0	-0.5
		Run 3		0.5	-0.5		0.0	-1.0		0.5	-1.0		2.0	0.0
		Run 1		5.0	-5.0		2.0	-3.0		6.0	-4.0		4.0	-3.0
	Bouncing	Run 2		4.0	-4.0		2.0	-3.0		6.0	-4.0		4.0	-3.0
		Run 3		5.0	-5.0		2.0	-3.0		6.0	-4.0		2.5	-3.0
		Run 1		0.5	-0.5		0.5	0.0		0.0	-1.0		0.0	-1.0
	Parallel to Boom	Run 2		0.5	0.0		0.5	0.0		0.0	-1.0		0.0	-1.5
NE		Run 3	-10.0	0.5	0.0	1.0	0.5	0.0	6.0	0.0	-1.0	4.0	0.0	-1.5
		Run 1		0.5	0.0		1.0	0.0		0.5	-1.0		0.0	-1.0
	Perpendicular to Boom	Run 2		0.5	0.0		1.5	0.0		0.5	-1.0		0.0	-1.0
		Run 3		0.5	0.0		1.5	0.0		0.5	-1.0		0.5	-1.0

	Bouncing	Run 1		1.5	-1.5		2.0	-1.0		4.0	-3.0		2.0	-3.0
		Run 2		1.5	-1.5		2.0	-1.0		4.0	-3.0		2.5	-3.0
		Run 3		1.5	-1.5		2.0	-1.0		4.0	-3.5		2.5	-3.0
E	**Parallel to Boom**	Run 1	1.0	0.0	0.0	-2.0	0.0	-1.0	-0.5	0.5	-0.5	0.0	1.0	0.0
		Run 2		0.0	0.0		0.0	-0.5		0.0	0.0		1.0	0.0
		Run 3		0.0	0.0		0.0	-1.0		0.5	-0.5		1.0	-0.5
	Perpendicular to Boom	Run 1		1.0	-2.0		0.5	-0.5		1.5	-0.5		1.0	0.0
		Run 2		1.0	-2.0		0.5	-0.5		1.5	-0.5		1.0	0.0
		Run 3		0.5	-2.0		0.5	-0.5		2.0	-0.5		1.0	0.0
	Bouncing	Run 1		0.0	0.0		0.0	-0.5		0.5	-0.5		2.0	-1.0
		Run 2		0.0	0.0		0.0	-0.5		0.5	-0.5		2.0	-1.0
		Run 3		0.0	0.0		0.0	-0.5		0.5	-0.5		2.0	-1.0
SE	**Parallel to Boom**	Run 1	13.0	1.0	0.0	-4.0	1.0	-0.5	-7.0	1.0	-1.0	-5.0	0.5	-0.5
		Run 2		1.0	0.0		1.0	-0.5		1.0	-1.0		0.5	-0.5
		Run 3		1.0	0.0		1.0	-0.5		1.0	-1.5		0.5	-0.5
	Perpendicular to Boom	Run 1		0.0	-2.0		1.0	0.0		1.0	-0.5		0.0	-1.5
		Run 2		0.0	-2.0		0.5	0.0		1.0	-0.5		0.0	-1.0
		Run 3		0.0	-2.5		0.5	0.0		1.0	0.0		0.0	-1.5
	Bouncing	Run 1		4.0	-4.0		2.0	-0.5		2.0	-3.0		0.5	-1.0
		Run 2		4.0	-4.0		2.0	-1.0		2.0	-3.0		0.5	-1.0
		Run 3		4.0	-4.0		2.0	-0.5		2.0	-2.5		0.5	-1.0
S	**Parallel to Boom**	Run 1	14.0	1.0	-2.0	-3.5	0.5	-0.5	-8.0	2.0	-1.0	-7.0	1.0	-1.0
		Run 2		1.0	-2.0		0.5	-0.5		2.0	-1.0		1.0	-1.0
		Run 3		1.5	-2.5		0.5	-0.5		2.0	-1.0		1.0	-1.0
	Perpendicular to Boom	Run 1		1.0	-1.0		0.5	-0.5		1.0	-0.5		0.0	0.0
		Run 2		1.0	-1.0		0.5	-0.5		1.0	-0.5		0.0	0.0
		Run 3		1.0	-1.0		0.5	-0.5		1.0	-0.5		0.0	0.0
	Bouncing	Run 1		6.0	-5.0		1.0	-0.5		3.0	-3.0		2.0	-3.0
		Run 2		5.0	-5.0		0.5	-0.5		2.5	-3.0		2.0	-3.0
		Run 3		5.0	-5.0		0.5	-0.5		2.5	-3.0		2.0	-3.0
SW	**Parallel to Boom**	Run 1	9.0	1.0	-1.5	-0.5	0.0	0.0	-4.0	1.0	0.0	-6.0	0.5	-1.0
		Run 2		1.0	-1.5		0.0	0.0		1.0	0.0		0.5	-1.0
		Run 3		1.0	-2.0		0.5	-0.5		1.0	0.0		1.0	-1.0

		Run 1		2.0	-0.5		1.0	0.0		0.5	-2.0		0.0	-1.0
	Perpendicular to Boom	Run 2		2.0	-0.5		1.0	0.0		0.5	-1.5		0.0	-1.0
		Run 3		2.0	-0.5		1.5	0.0		0.5	-2.0		0.0	-1.0
		Run 1		5.0	-4.0		0.0	0.0		0.5	-0.5		2.0	-1.0
	Bouncing	Run 2		5.0	-4.0		0.0	0.0		0.5	-0.5		1.0	-1.0
		Run 3		5.0	-4.0		0.0	0.0		0.5	-0.5		1.0	-1.0
		Run 1		0.0	-1.0		0.5	0.0		0.0	0.0		0.5	-0.5
	Parallel to Boom	Run 2		0.0	-1.0		0.5	0.0		0.0	0.0		0.5	-0.5
		Run 3		0.0	-1.0		0.0	0.0		0.0	0.0		0.5	-0.5
		Run 1		2.0	0.0		0.0	-1.0		0.0	-2.0		2.0	0.0
W	**Perpendicular to Boom**	Run 2	0.0	2.0	0.0	2.0	0.0	-1.0	2.0	0.0	-2.0	-3.0	2.0	0.0
		Run 3		2.0	-0.5		0.0	-1.0		0.0	-2.5		1.5	0.0
		Run 1		1.5	-1.5		2.0	-1.0		3.0	-2.0		0.0	0.0
	Bouncing	Run 2		1.5	-1.5		2.0	-1.0		3.0	-2.0		0.0	0.0
		Run 3		1.5	-1.5		3.0	-1.0		2.5	-2.0		0.0	0.0
		Run 1		2.0	-1.0		1.0	0.0		0.5	-1.5		0.0	-0.5
	Parallel to Boom	Run 2		2.0	-1.0		1.0	0.0		0.5	-0.5		0.0	-1.0
		Run 3		2.5	-1.0		1.0	-0.5		0.5	-1.0		0.0	-1.0
		Run 1		3.0	0.0		0.5	0.0		0.5	-1.5		0.0	-2.0
NW	**Perpendicular to Boom**	Run 2	-14.0	3.0	0.0	4.0	0.5	0.0	7.5	0.5	-1.5	2.0	0.0	-2.0
		Run 3		3.0	0.0		0.5	0.0		0.5	-1.5		0.0	-2.0
		Run 1		5.0	-2.0		2.5	-1.5		2.5	-3.0		2.0	-2.0
	Bouncing	Run 2		5.0	-2.0		2.5	-1.5		3.0	-3.0		2.0	-2.0
		Run 3		5.0	-2.0		2.5	-2.0		3.0	-3.0		1.5	-2.0

Codes and Standards Used

The principal standard used is API 2C for the crane design. The crane manufacturer specified the structural design loads to Team CraneWorks and Audubon in accordance with API 2C. A copy of the API 2C standard can be purchased from the American Petroleum Institute (http://www.api.org).

Off-the-Shelf Component Specifications

- The properties for AISI 1018 Steel Cold Drawn used in the bar stock can be found at:

http://amet-me.mnsu.edu/userfilesshared/DATA_ACQUISITION/mts/MaterialData/MaterialData_6809-1018ColdDrawn.pdf

- The properties for AISI 1026 Steel Cold Drawn used in the plate and gussets can be found at:

http://www.matweb.com/search/datasheet.aspx?matguid=f3c08781eced413ebd167d9a9d1211f2&ckck=1

- The properties of ASTM A53 Type F Grade A used in the pipe can be found at:

http://www.exltube.com/Documents/Insert-A53.pdf

- The properties of concrete can be found at:
http://www.engineeringtoolbox.com/concrete-properties-d_1223.html

- The properties of ASTM A36 used in the anchor bolts can be found at:

https://law.resource.org/pub/us/cfr/ibr/003/astm.a36.1997.pdf

- The properties of ASTM A615 used in the rebar can be found at:

http://www.webcivil.com/usrcrebar.aspx

- The properties of ERS70S-6 welding wire can be found at:
http://www.unibraze.com/DataSheets/Data70S-6.pdf