Final Report

Weld Quality Test Tank

Team Members

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Abstract

Our group has worked with Triton Metals Products who specializes in manufacturing projects for the automotive, aerospace, and construction industries. Our group worked with the welding department as they make automotive pressure tanks. Triton Metal Products contacted IPFW and were seeking help with testing the welds of their pressure tanks. Their current process of testing these tanks is not ideal for the amount of product they need to produce. Their goal with contacting our group was to replace their water test tank and develop potential machine design, so the amount of manual labor can be reduced.

The owners of Triton Metal Products had an idea of how they wanted this new water tank to look. Our group determined the size of the new water tank based on the size of their pressure tanks that need to be tested. From there our group had to calculate the weight of the tank that we designed with the water that would be put into it. From this we gathered more information as to how thick the acrylic needed to be due to the water pressure on the sides of the tank. Our group then came up with a more appropriate design for the acrylic by giving it additional structural support with a metal frame around all sides. This increased the strength of the new water tank significantly. Triton Metals Products also required our group to come up with a filtration system for this tank, so that the water remains clear enough to see leaks in the products if a defect is found which is indicated by air bubbles.

This project taught our group how to best stay on a timeline with changing project goals, communication, teamwork, and experience working with a company. With this experience came situations in which our group could not control. Dealing with the situations while still finishing the project on time big learning outcome for our group.

Throughout the project our group did run into problems. There was a lack of communication between Triton Metal Products and our group on some decisions which delayed purchasing and fabrication. Our group was unable to complete every part of the project that Triton Metal Products wanted, but again that was due to a lack of time. Our group provided them with many designs for a swing arm for the machine they wanted which could no longer be done in our timeline. Even though that part of the project was discontinued, we continued to work on the new water tank and filtration system.

Introduction

Located in Hamilton, IN, Triton Metals contacted the IPFW engineering department in search of help to improve their current weld inspection procedure for a variety of pressure tanks they build for customers. This project was the first time Triton Metals reached out to a local engineering school with hopes of moving toward a more effective system of catching fabrication errors in their products. Our team has explored several components acting as building blocks to improve the inspection system. Being as this was the first time Triton Metals actively pursued an improvement, it was an eye-opening experience for all persons involved as far as design ideas, budgetary decisions, and building a water tank that would not limit the type of work Triton Metals could receive in the future.

Background

Triton Metals has employees who are experts in welding, but the reality is that mistakes do happen. This is why each pressure tank is tested by an employee in the welding department before the product is shipped to a customer. The employee must plug all the holes in a pressure tank when inspecting so that the water solution does not leak into their product. Then the employee attaches an air hose to the pressure tank which is used to gradually increase the air pressure inside of the pressure tank until the pressure reaches 20psi. This simulates what the product will be faced with when installed as well as testing the quality of the welds. Once everything is attached and plug, the operator puts the product into the water container under the water. The employee then must adjust the air pressure and continue to check the product by constantly turning it under water while looking for air bubbles coming from the part. If there are air bubbles then there is a leak, and the defected area on the product must be corrected. Once that is done the product will go through the same testing process as before.

Objectives

These objectives are what the owner of Triton Metals have emphasized are ideal outcomes of the project.

- Increase visibility for the inspector
- New water tank is largest enough the fit all pressure tanks needing to be tested
- New water tank is elevated to where the inspector views the product at eye level
- Filtration system removes impurities from the water

Problem Statement

The plan our group proposed to Triton Metals was to completely restructure their whole testing operation. The first problem is the physical struggle for the inspector to hold the pressure tanks under water during the inspection is not ergonomically friendly. The walls of the current water container are too high and pose a difficult problem for the employee preforming the inspection to get their arms over the top of the container.

The second problem is the air pressure leading into the tank is manually adjusted by the employee while at the same time the employee is holding the pressure tank under water. This leaves the employee holding onto the pressure tank with one hand, and the other hand is reaching for the valve to adjust the air pressure.

The third problem is that the water container that the weld department is using to submerge their product during inspection is not made for this application. The walls are not transparent at all so the only line of sight the employee has is by looking over the top of the container.

The fourth problem is the green water solution in the container does not get filtered. The result is filthy water which takes away from the inspector's visibility when trying to locate leaks in the pressure tank. Figures 1-3 shows the current setup used by the welding department for their inspections.

Figure 1

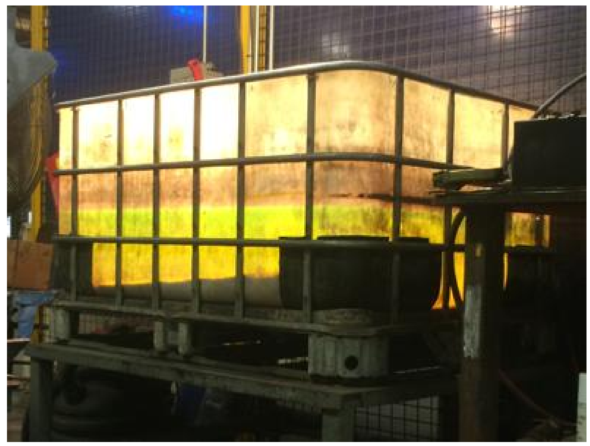


Figure 2

Figure 3

Research Process

The research started with brainstorming possible ways of mechanically submerging the pressure tank under water which again is currently done manually by an employee. The owners and employees of Triton Metals have emphasized how difficult it is to physically hold and rotate the pressure tanks under water while adjusting the air pressure.

Our group knew there would be more than one way to approach mechanically submerging the pressure tank, thus we brainstormed multiple ways of accomplishing this. The first bit of research was to obtain quotes on a hydraulically powered lift table and bolt the new water tank onto the top of the table. Our team pursued a quote from Solution Dynamics Inc. for the best possible lift table for our project. The quote from Solution Dynamics Inc. was $4,830. Our team and the owners of Triton Metals agreed to forget about the hydraulic lift table and return to the drawing board for another idea.

Our group did many hours of searching through online catalogues and on the internet for existing machines that made the movements we would need our machine to do. The only problem is that the pressure tank would have to travel a vertical distance of nearly 55 inches. There are several possible ways to make an object travel 55 inches, but unfortunately the weight of the pressure tank created structural problems through which our team could not find any solutions given the allowable time frame. The idea our team was working on when the decision was made to stop progress on the machine was to use a pneumatically operated linear slider which we found from a supplier by the name of Direct Industry. The linear slider was fully capable of traveling a distance of 55 inches. We determined after reviewing the product manual for the linear slider that some of the weights of the pressure tanks were over the designed limit of the linear slider, and thus that idea was not working out.

The focus of the project was then moved toward constructing roughly a 420 gallon water tank to replace the existing water container. Our team determined the necessary dimensions of the new water tank given the size of the largest pressure tank that would need to be tested. Volume and calculation work resulted in the weight of the water tank plus the additional weight of 420 gallons of water equaling out to nearly 4,500 pounds. Material strengths were obtained through online sources containing lab tested data.

The filtration system for the new water tank needed a filter and a water pump to return the water. The Home Depot website was the main source for determining what filter to purchase. The water pump was purchased online from a company by the name of Northern Tool. The main specifications that absolutely needed to match up between the water filter and the water pump is the water flow rate in gallons per minute. The filter needed to have a higher allowable flow rate than what the pump could flow.

Solutions

Water Tank

Final drawings of the new water tank can be found in Appendix I. The interior dimensions of the tank are designed to be 48 inches long by 48 inches wide and 48 inches tall. The largest pressure tank that Triton Metals would currently need to submerge is roughly 35 inches long. The machine that Triton will use in the future will rotate the pressure tanks in all directions once under water. The new water tank needed to be able to fit not only the largest pressure tank, but also the water tank needed to be able to accommodate the testing of a potentially larger pressure tank in the future.

The walls of the new water tank are extruded acrylic with a thickness of ½ inch. The acrylic is bolted inside of a fully bounded metal frame. The entire frame was fabricated out of 304 stainless steel which is necessary to prevent corrosion. The bolts are also stainless steel so they do not rust as well. The bolts are all 3/8 in diameter and a variety of lengths depending on what part of the tank the bolt is used for. Rubber washers were sandwiched between a metal bolt and the inside of the tank to prevent water from leading out from the bolt holes.

Tank Stand

Final drawings of the tank stand can be found in Appendix I. The metal stand to elevate the new water tank has a height of 34 ½ inches from the floor to the top of the metal tubbing. This height was determined after doing an ergonomic calculation for how high an object should be placed so that an employee in the welding area can view the submerged pressure tank at eye level. The cross bars are designed to add structural integrity so that the stand is firm and unable to bend or wobble especially when the weight of the water-filled tank equals out to around 4,550 pounds.

The tubbing used for the stand needed to be 2 ½ inch square tubbing with a wall thickness of 0.188 inches. This was selected after solving a section modulus strength calculation when the weight of 4,550 pounds was divided and applied directly to the main frame tubes that are actually connected to the legs of the stand. The smallest sized of tubing that could have been used was 2.00 inch square tubing with a wall thickness of 0.25 inches. Triton Metals already uses 2 ½ inch square tubing with a wall thickness of 0.188 inches, and therefore it was easier and quicker for the company to use what they already had in their inventory.

Filtration System

A ½ inch drain was installed to the bottom of the tank. The drain is connected directly to a 2-way flow valve. One side of the valve can be connected to a hose and then drained in the event of all the water needing to be removed from the tank. The other side of the valve leads into the rest of the filtration system. The first stage is the water filter which was purchased from General Electric. After the filter the water is forced back up to the top of the water tank with the help of a water pump purchased from Northern Tool. The entire system is linked together with a hose having an internal diameter of ½ inch. Figure 4 is the water filter from General Electric. Figure 5 is the water pump from Northern Tool.

Figure 4: GE Water Filter

Model #GXWH04F

Figure 5: Norther Tool Water Pump

Item #52067

Calculations

The first set of calculation are determining some general information.

Volume = LWH

Volume = (48in) (48in) (48in)

Volume =110,592in^3

Weight$_{water}$ = (Volume)(Density)

Weight$_{water}$ = (110,592in^3)(0.361 lbs/in^3)

Weight$_{water}$ = 3,993 lbs

Weight$_{Tank}$ = 550 lbs *obtained from solid model

Weight$_{Total}$ = Weight$_{Water}$ + Weight$_{Tank}$

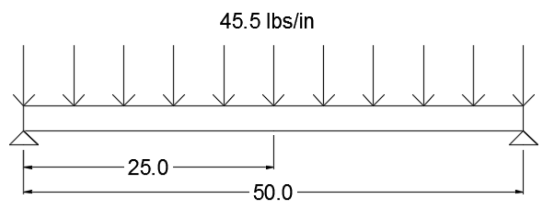
Weight$_{Total}$ = 4,543 lbs

The total weight will be evenly supported on the two main pieces of square tubing, therefore each piece is supporting 2,272 lbs. This weight is acting as a uniform load across the piece of square tubing. The following calculation to use the weight information to determine what is the appropriate size of square tubing to build the stand with.

To find exactly what the uniformly distributed load is equal to we must take the weight acting on the piece of tubing and divide it by the length of the tubing.

Weight per inch of tubing = Weight / Length

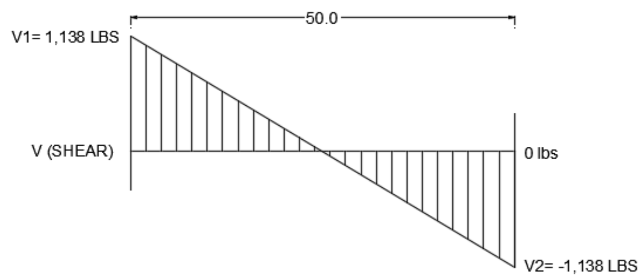
2,272 lbs / 50in = 45.5 lbs/in



Since the weight is uniformly distributed, we know the reactions at Ra and Rb will be equal to each other while each is supporting half of the total load.

Ra = Rb = 2,272 lbs / 2 = 1,136 lbs

From there we can analyze the shear diagram.

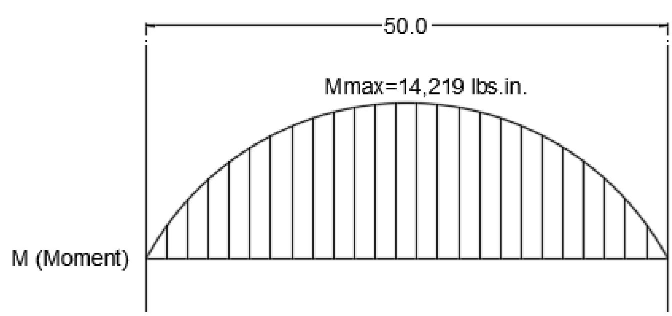


$M_{max} = [WL^2] / 8$ [2]

$M_{max} = [(45.5)(50in)^2] / 8$

$M_{max} = 14{,}219$ lbs.in.

From there we can draw the moment diagram.



The following calculation is to find the required section modulus for the square tubing.

$Z_{req} = [(1.67)(M_{max})] / \sigma_{y.s.}$ [2]

$Z_{req} = [(1.67)(14{,}219 \text{ lbs.in.})] / 36{,}000 \text{ psi}$

$Z_{req} = 0.660 \text{ in}^3$

An engineering data sheet shows that the section modulus for 2.00 inch square tubing with a wall thickness of 0.25 inches is 0.747 in^3. This size of square tubing weighs 0.45lbs/in. The calculation must be redone to analyze if the added weight of the tube effects the required section modulus. The results of the recalculation are shown below.

$Weight_{New\ Total} = Weight_{water} + Weight_{Tank} + Weight_{Tubing}$

$Weight_{New\ Total}$ = 2,300 lbs

Total weight per length = 2,300 lbs / 50 in = 46.0 lbs/in

Ra = Rb = 2,300 lbs / 2 = 1,150 lbs

$M_{max} = [(46.0)(50in)^2] / 8 = 14,375$ lbs.in.

$Z_{req} = [(1.67)(14,375 \text{ lbs.in.})] / 36,000 \text{ psi} = 0.667$ in

Since the required section modulus is still less than the section modulus of the square tubing, it can be confirmed that 2.00 square tubing with a wall thickness is 0.25 inches will be strong enough. It just so happens that the company already uses 2.50 inch square tubing with a wall thickness of 0.188. The section modulus of that square tubing is 1.080 in^3 which is much more than required; however, it does make it easier to use since that size of tubing is already sitting on a shelf at Triton Metals.

Since weight is a force we can use a similar equation to find the force at the bottom of the water container. The weight will be that of a single column of water with an area of 1in^2 and a height of 48 inches.

$W = p_{water} * V$

$W = 0.036 \frac{lbs}{in^3} * (1in*1in*48in)$

W = 1.7 pounds

F = W = 1.7 pounds

Knowing the force at the bottom of the container is important when determining the thickness of the acrylic panel used as the walls of the water container. The force is dependent on the depth of the water as shown below in Figure 6.

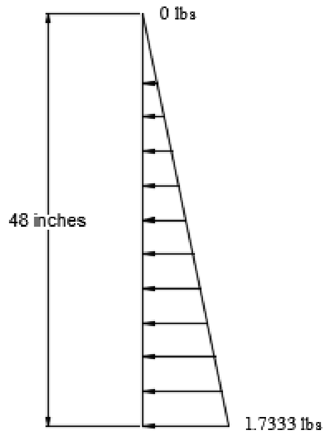


Figure 6: Force of water on the side wall of the container.

The equation shown below will be used to determine an appropriate allowable bending stress based on the flexural rupture strength of acrylic which is 13,000 psi. [2]

$\sigma_{Allowable} = 0.4 * \sigma_{Maximum}$ [2]

$\sigma_{Allowable} = 0.4 * 13{,}000 \frac{lbs}{in^2}$ [3]

$\sigma_{Allowable} = 5{,}200 \frac{lbs}{in^2}$

Below is the calculation for the necessary thickness of the acrylic panels. The calculation done is in confidence that the acrylic panels are fully braced on all sides.

Table 1: Values for determining variables in stress calculation. [1]

a/b	1	1.5	2	2.5	3	3.5	4
β	0.16	0.26	0.32	0.35	0.37	0.38	0.38
α	0.022	0.042	0.056	0.063	0.067	0.069	0.070

$\sigma_{allowable} = \frac{\beta q b^2}{t^2}$ [1]

$t = \sqrt{\frac{\beta q b^2}{\sigma_{all}}}$

$t = \sqrt{\frac{0.16*1.7*48^2}{5{,}200}}$

$t = 0.35$ inches

where: q = force at the bottom of the container (lbs)

b = length of container (in)

t = thickness (in)

This thickness will be rounded up to 0.5 inches which is the closest standard acrylic sheet thickness. 0.5 inches is only the nominal thickness. The actual thickness will be 0.472 inches. The price of a 48 inch by 48 inch sheet of acrylic at that thickness is about $169.23. Purchasing 4 sheets equates to a price of around $724 after tax.

Now that we know the thickness of the acrylic sheet we can find the actual stress that will be present when the tank is full of water.

$Ơ_{allowable} = \frac{\beta q b^2}{t^2}$ [1]

$Ơ_{Maximum} = \frac{0.16(1.7)(48^2)}{0.5^\wedge 2}$

$Ơ_{Maximum}$ = 2,507 psi

The following calculation is to find the deflection of the acrylic panels when under pressure from the water.

$Max_y = \frac{-\alpha q b^4}{E t^3}$ [1]

$Max_y = \frac{-(0.22)(1.7)48^4}{(480{,}000)(0.5)^3}$ [3]

Max_y = 0.83in

This means there should be a noticeable deflection when the tank is full of water, but the stress on the acrylic sheet will not be enough to cause any damage.

Ergonomic Calculation

In ergonomics we have to accommodate for 95% of the work force, to do this you have to take the 95th percentile male and 5th percentile female. Obtaining the standard standing eye height level from Professor Narang, these values come out to be 174.29 cm and 141.52 cm respectively. Convert it to inches by using the conversion 1 in = 2.54 cm. 95pM = 174.29 cm * $\frac{1in}{2.54cm}$ = 68.62 in 5pF = 141.52 cm * $\frac{1in}{2.54cm}$ = 55.72 in. This means the overall height of the final product should be 55.72 in to 68.62 in. Since the tank is 42 in tall and we plan on having the parts lowered 21 inches in the tank, we have to subtract that from the overall height of the table that needs to be built should be 34.72 in - 47.62 in tall.

Findings and Results

Some of the major results from our calculations were in finding the required thickness of the acrylic to ensure it was strong enough when the tank is full of water. The calculation surprisingly enough resulted in a less thick of acrylic than we were planning on using. The minimum required thickness was 0.322 inches meaning we were able to purchase a sheet that was ½ inch thick from ACME Plastics.

Overall the design for the new water tank is exactly what the owner of Triton Metals asked for. The dimension of the new water tank, the ergonomically optimal elevation, and the filtration system were all what the welding department at Triton Metals needed in order to improve their testing operations.

The filtration system is designed to be able to clean about 300 gallons per hour which when compared to the water tank holding about 420 gallons means that most of the volume of the water tank can be cleaned if the system is ran for just over an hour each day.

Testing Procedure and Results

There is not much our groups was able to do as far as testing in preparation. We did intend to do at least two test. One is upon completion of building the tank, we would fill it to a water level of 46 inches which submerges all bolts. As stated before we only intend for the tank to be filled with 42 inches of water, but it was necessary to make sure all bolts were tightened enough to not allow for leaks. Another purpose for this test is to ensure the tank can withstand the pressure of 4 more inches of water even though all of our design calculations accounted for 48 inches of water just as a worst case scenario approach for safety.

Another test we performed is running the water filtration system to ensure all of the components work as planned. We ensuring the water pump was able to circulate the water back to the top of the tank. We also ensured the drain system works correctly in case the water tank would ever need to be drained for any reason.

The results of the tests preformed on April 20th were a bit concerning. The water tank and stand did not show any signs of stress when the tank was full of water. The acrylic sheets did show minor bowing. According to the calculation the ½ inch acrylic should not have deflected much. The filtration system worked as planned. The water pump was powerful enough to create a large enough suction to draw the water through the filter and pump it back to the top as planned for.

The only unsuccessful result from the test is the Sikaflex 211 caulking material used around the edges of the acrylic and metal on the inside of the tank did not fully seal. Several areas were found to be leaking upon the first test. Another minor problem is water was slowly escaping from the bolt holes. Nearly 10 bolts were found to be slowly leaking water. Figure 10 below shows the fill test with the leaks.

Figure 7: Testing conducted on April 20th

The result from this newly acquired information was enough to drain the tank completely. The next step taken to fixing the leaks was to fully weld around the underside of the water tank where the base plate comes in contact with the corner support brackets. All bolts around the bottom of the tank were retightened even if they were not leaking water during the test to ensure they were not going to leak on the second test.

The second fill test was then conducted and the results were not as desired. Four areas were found to still be leaking water, but none of the bolt holes were leaking anymore. The only other option for sealing the bottom of the water tank was to use Sikaflex 252 on the bottom of the water tank where the acrylic was bolted to the metal. Visible signs showed that some of the acrylic may have been melted during one of the welding processes, and the only fix for this was to use Sikaflex 252 to fully seal the connection edge where the acrylic meets the metal plates and supports.

Cost Analysis

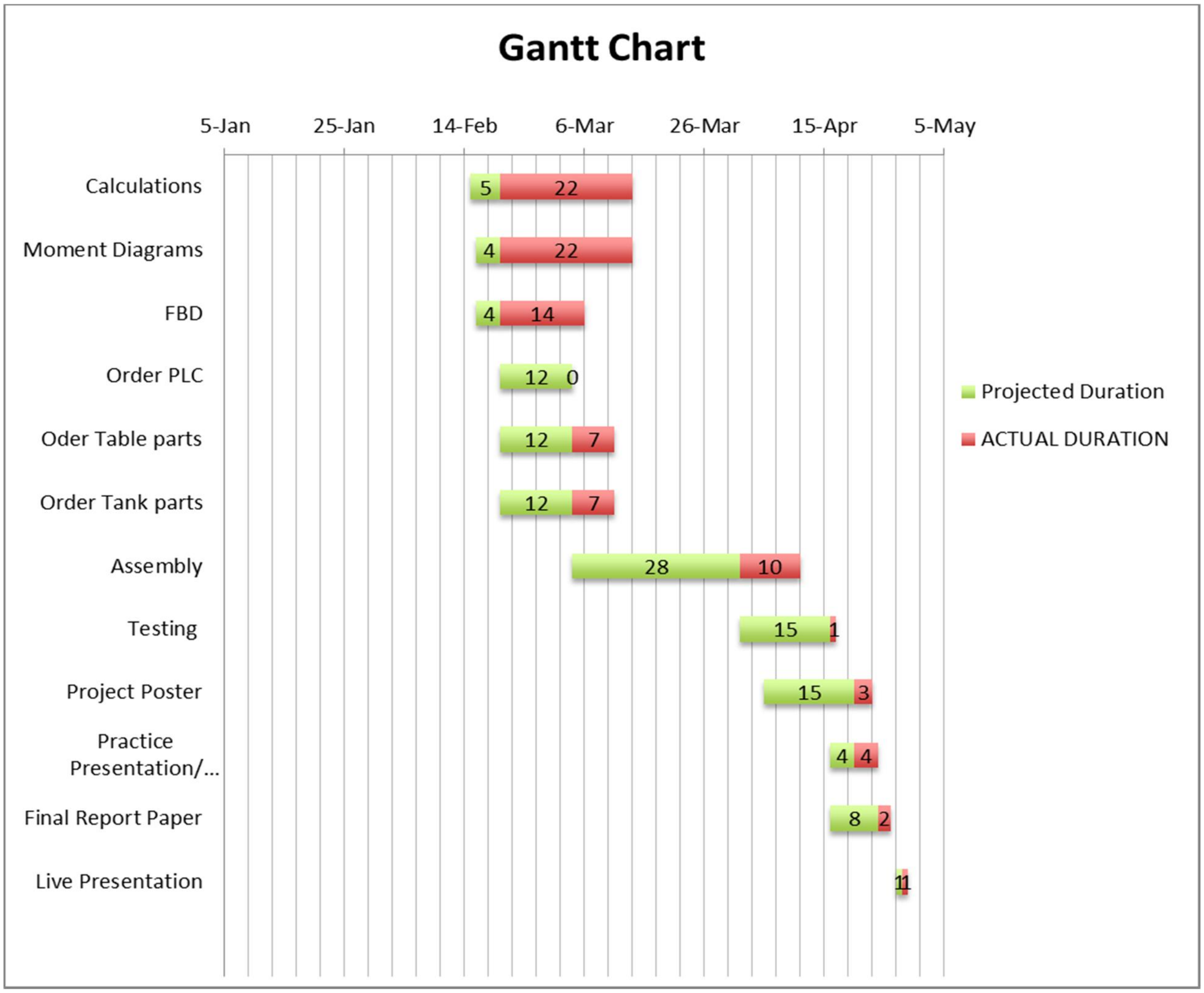
Cost Analysis			
Item	Number Purchased	Cost Per Item	Total Cost
Water Filter Case	1	$20	$20
Water Filter	1	$9	$9
Water Pump	1	$95	$95
120-in x 60-in Stainless Steel	1	$469	$469
20 foot length of 2 1/2-in Square Tubbing	4	$69	$277
Samar 3/4-in x 10-ft Reinforced PVC Reinforced Water Hose	10 feet	$19	$19
Apollo 3/4-in x 1/2 in dia Brass PEX Male Adapter Crimp Fitting	2	$4	$8
BrassCraft 1/2-in x 3/4-in Barbed Bard x Garden Hose Adapter Fitting	1	$8	$8
BrassCraft 1/2-in x 1/2-in Barbed Bard x FIT Adapter Fitting	2	$4	$8
BrassCraft 1/2-in x 1/2-in Barbed Bard x MIP Adapter Fitting	2	$4	$8
Yardsmith brass 2-Way Restricted-Flow Water Shut-Off	1	9..98	$10
Acrylic Extruded Clear Sheet 48-in x 48-in, 1/2-in thick	4	$169	$677
3/8-in Rubber Washer	144	$0	$23
3/8-in x 3-in Zinc Plated Standard (SAE) Hex Bolt	8	$1	$10
3/8-in x 1-in Zinc Plated Standard (SAE) Hex Bolt	136	$1	$92
Project Pak 25-Count 3/8-in Zinc-Plated Standard (SAE) Hex Nut	144	$3	$16
Strand of Lights	1	$70	$70
		Total	**$1,820**

The owners of Triton Metals did not give a budget for the project being they did not know where the project would end up. The final price of our project is $1,820. The labor cost for fabricating the metal sheet and other parts is not included in the cost analysis since all work was done by

Triton Metals at their shop. Our initial cost estimate was around $2,200, but that included some components for the machine which did not end up getting built, therefore the final price of the project is roughly where we thought it would be.

Gantt Chart

As mentioned, there were many time delays and critical decisions that redirected the project. That is the reason for most of the project being behind schedule. The most important thing is that Triton Metal Products was still pleased with the project our group is leaving with them.



Conclusion

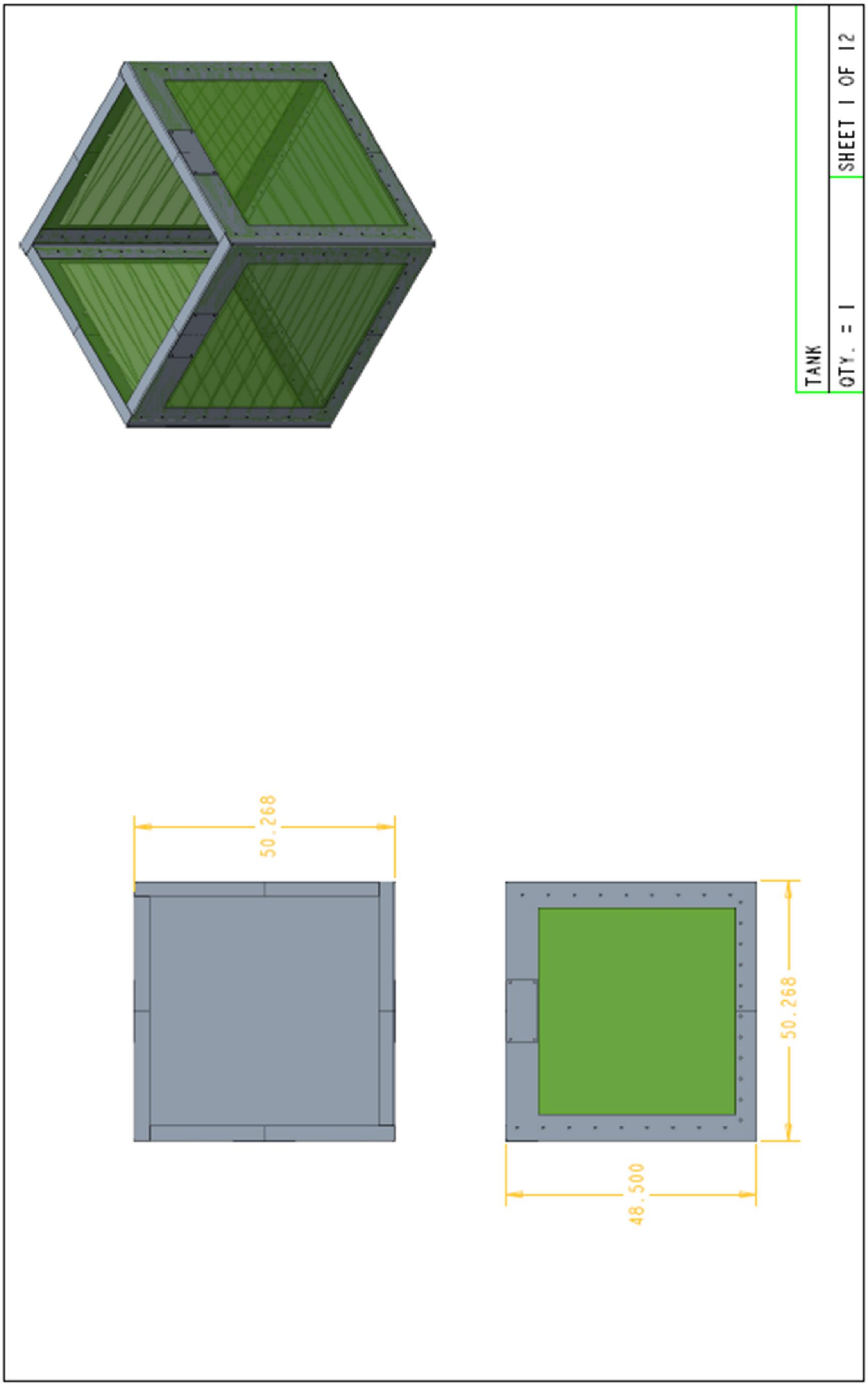
The new water tank and filtration system project is only the first step for Triton Metals. The owners would like to continue the research our group started, and have their engineers design a fully automated machine to submerge the pressure tanks. The end goal is to completely remove the employee handling portion of the testing procedure. The plant manager made it very clear how lacking this area of their company is and acknowledges improvements can and should be made.

The other major component toward the end goal is to have a computer program set to increase the pressure of the air supply into the pressure tank. Our group pursued quotes on how much this type of air pressure controlling system would cost, but all who have been involved in this project agreed that an automated system was not a necessary step at this point in time.

The team of Skyler Hayes, Lucas Kaiser, Taylor Lantz, and Riley Schuette are proud to have worked with Triton Metals and wish the company the best of luck as they continue to improve their welding department. More time would have allowed for additional building blocks of this project to be completed such as the machine and the air pressure controller. The most important outcome of this project is that the owners of Triton Metals now know that what they want for the future of the weld testing department is possible.

Appendix I

Sheet Number	Page Description
1 of 12	Tank Isometric View
2 of 12	Tank Component View
3 of 12	Bottom Plate
4 of 12	Tank Support Inside
5 of 12	Tank Support Outside
6 of 12	Tank Side Plexiglass
7 of 12	Triton Metals Name Plate
8 of 12	Tank Stand
9 of 12	Tank Stand Isometric Component View
10 of 12	Leg of Stand
11 of 12	Top Cross Support of Stand
12 of 12	Top Cross Support of Stand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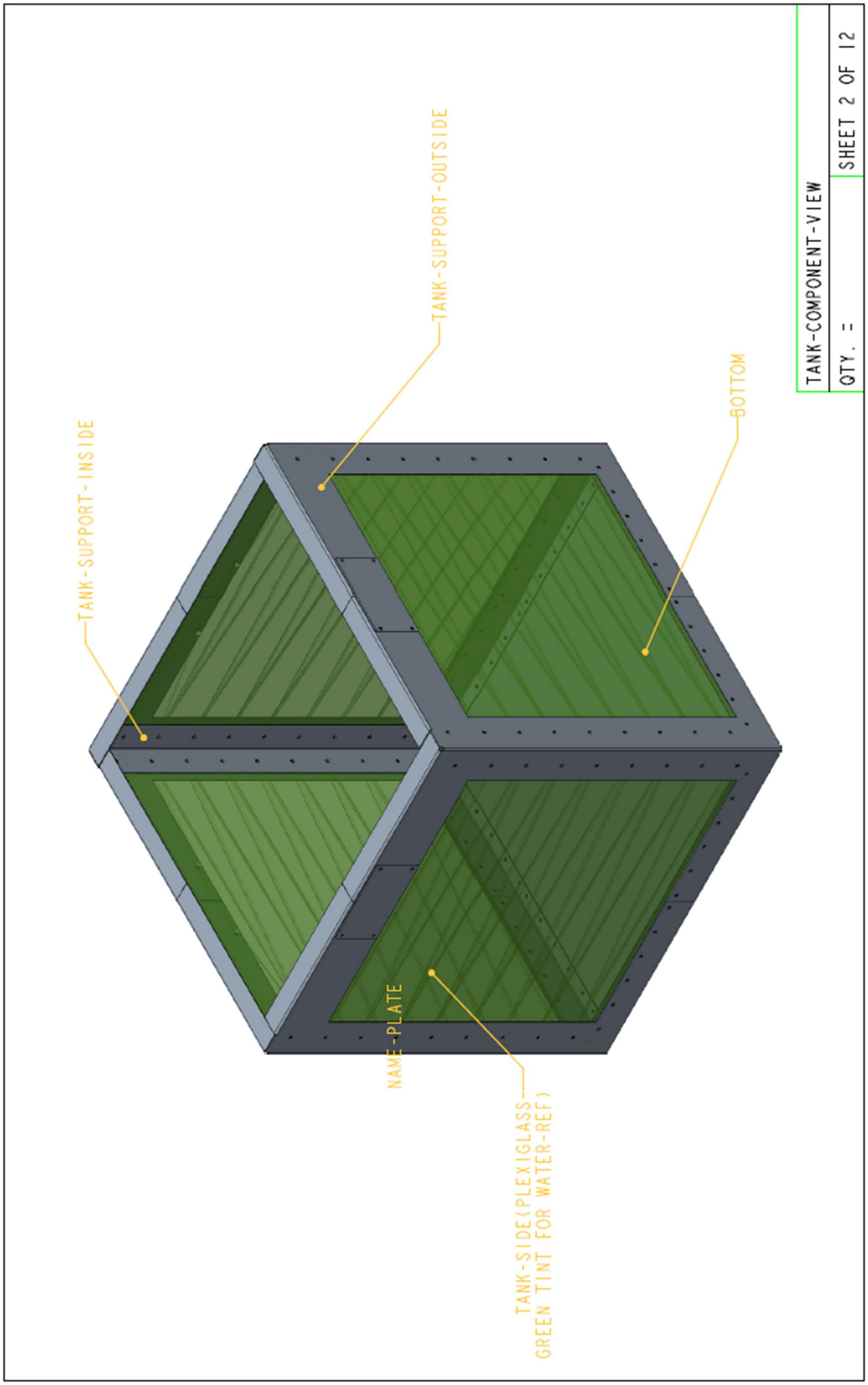
TANK-COMPONENT-VIEW
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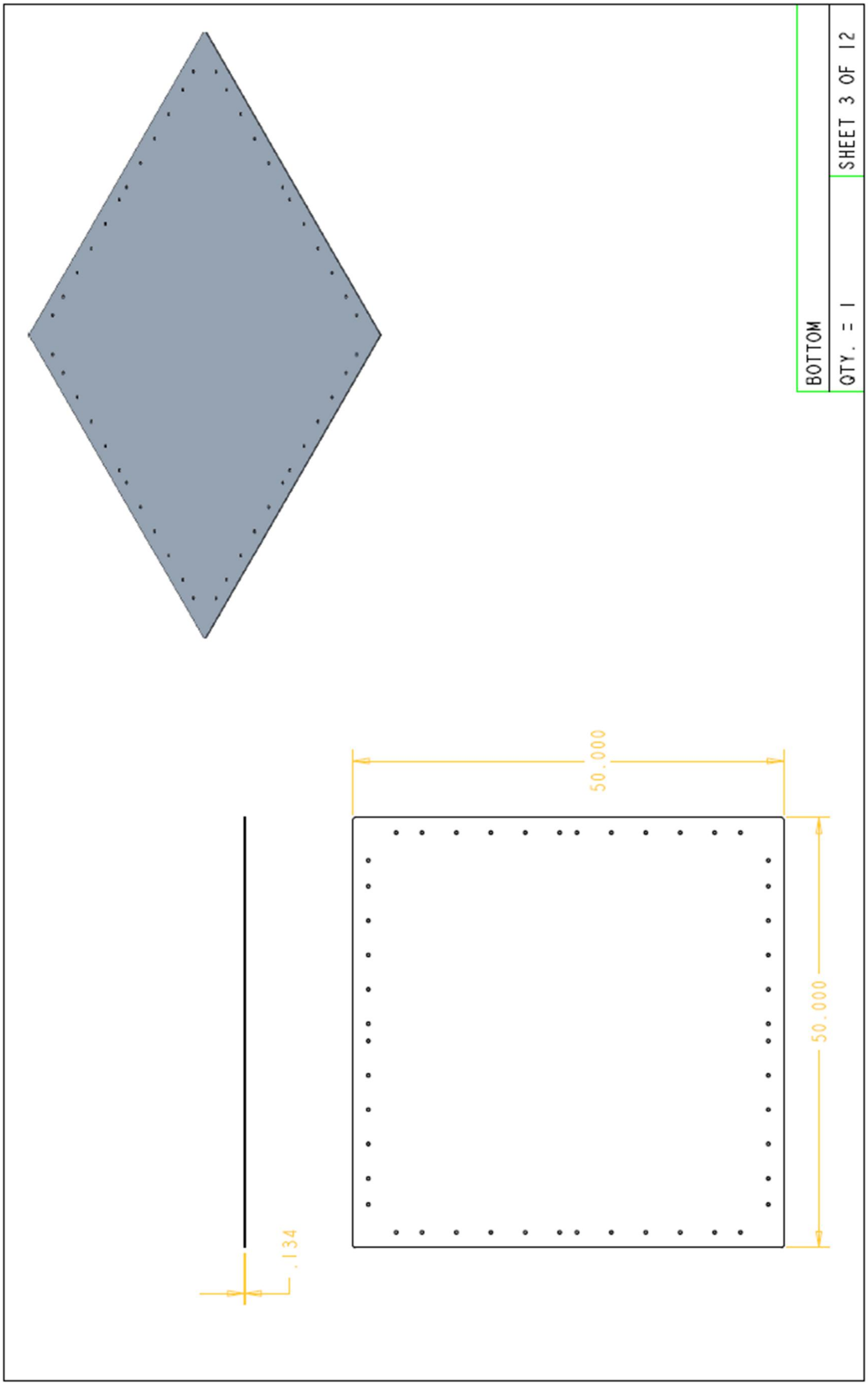
TANK-SUPPORT-INSIDE
BOTTOM
NAME-PLATE
TANK-SIDE(PLEXIGLASS-
GREEN TINT FOR WATER-REF)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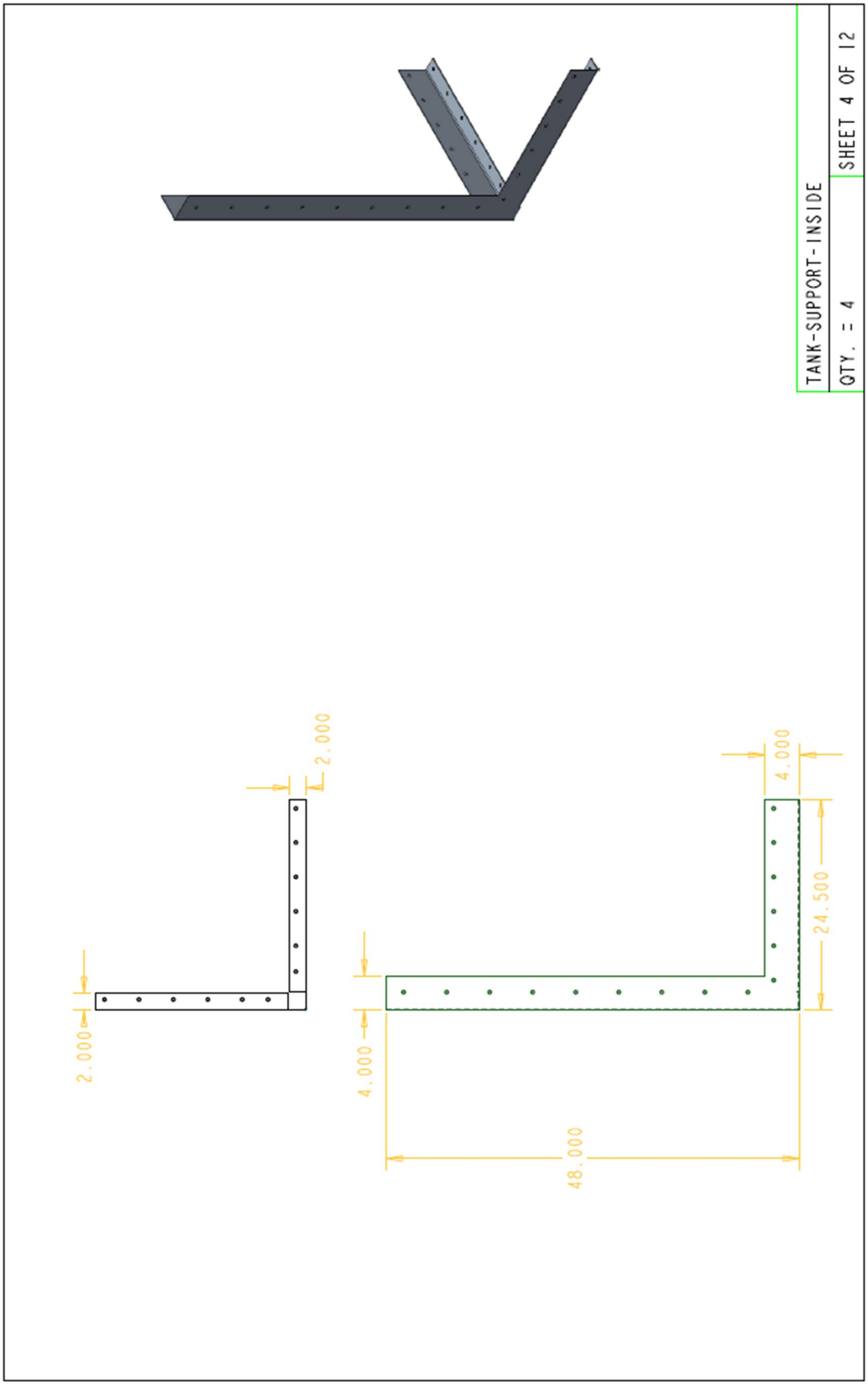
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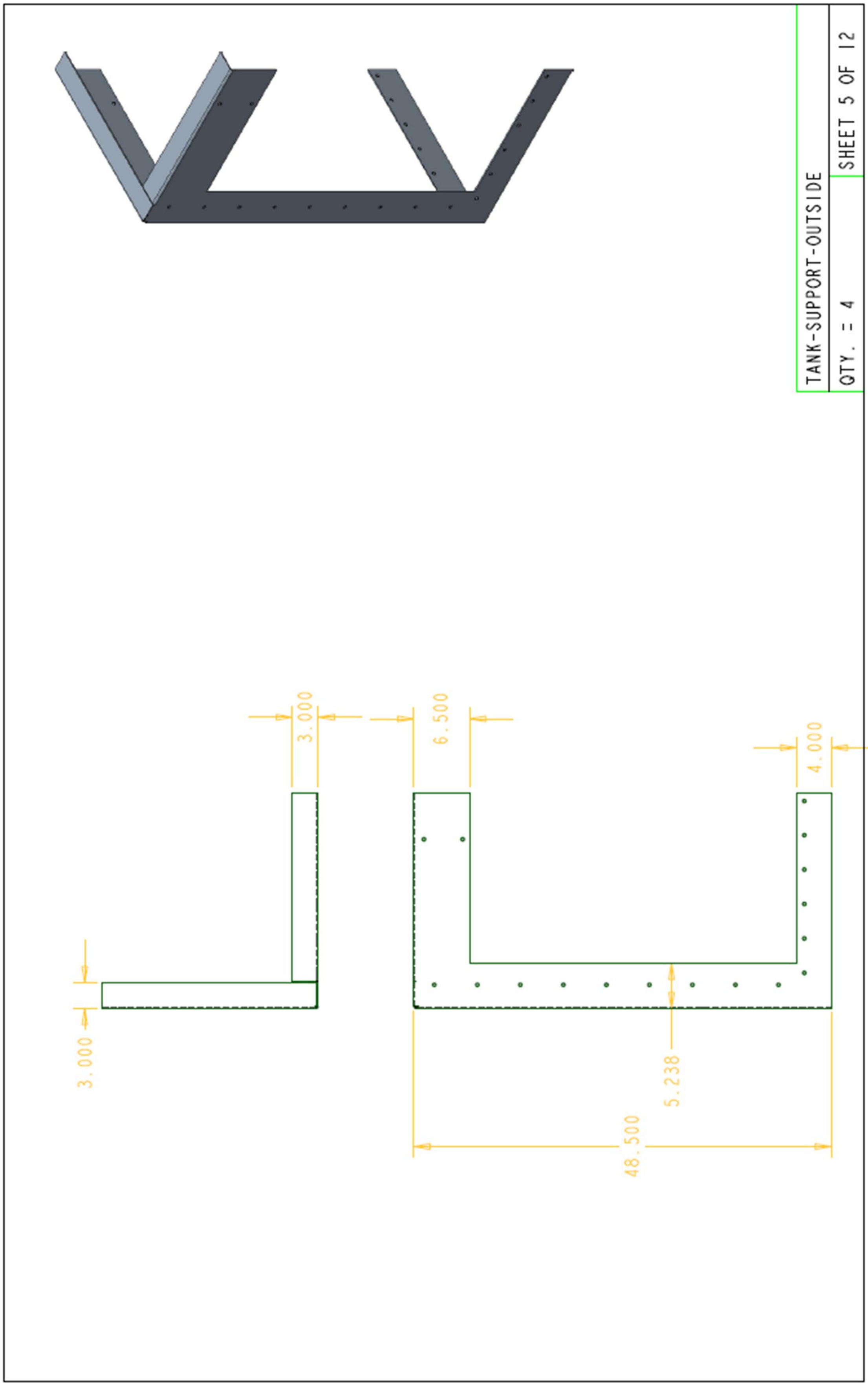
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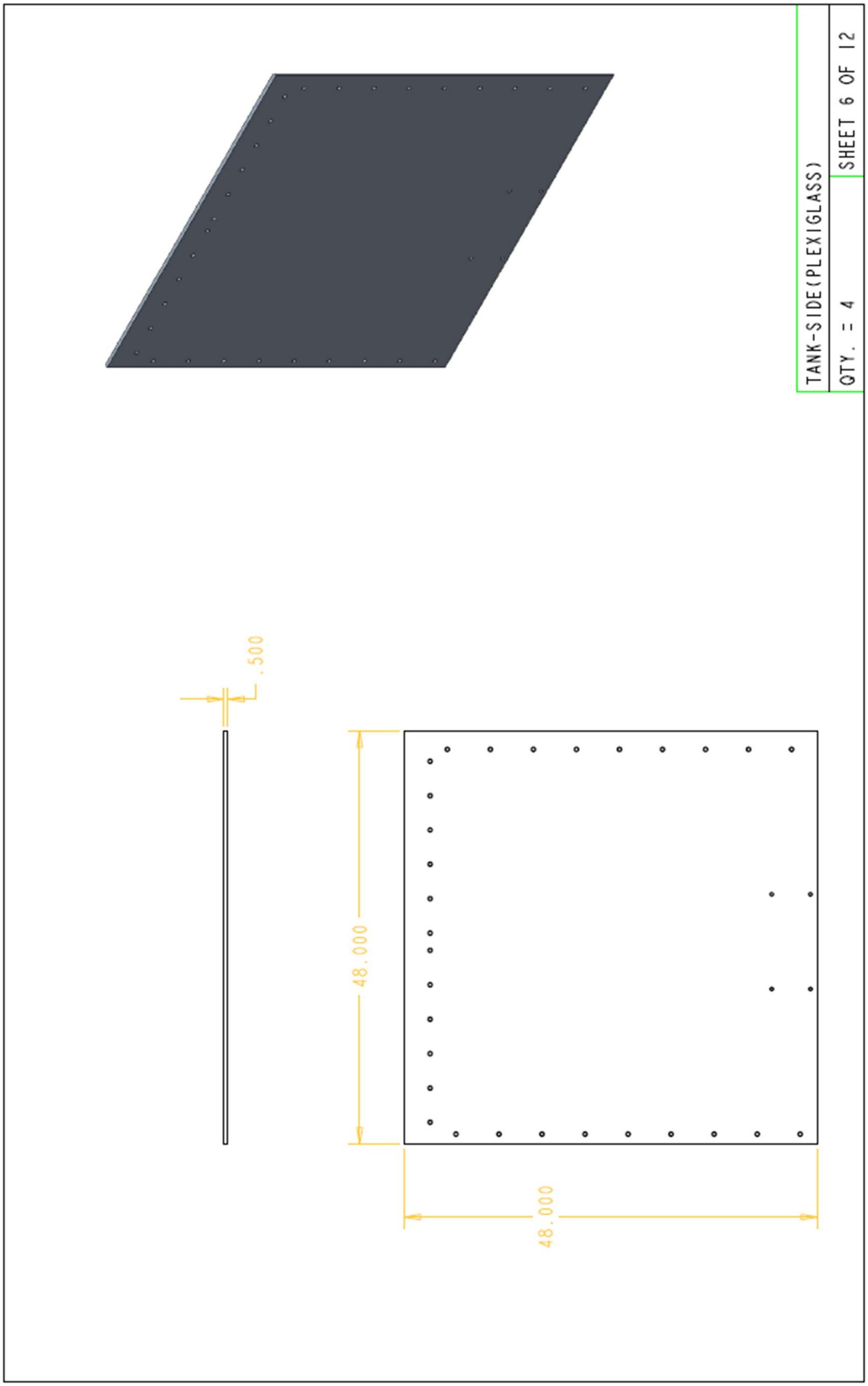
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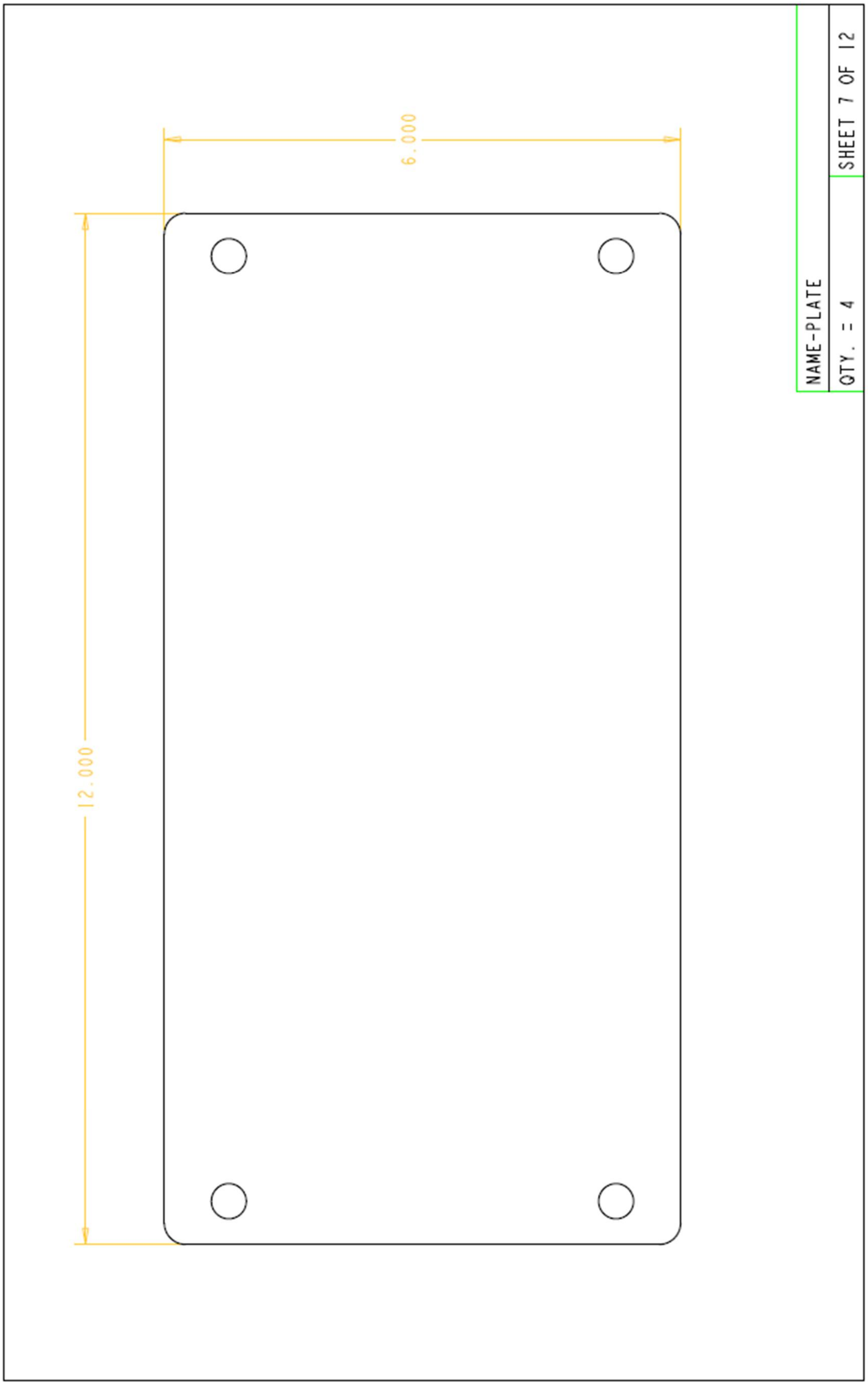
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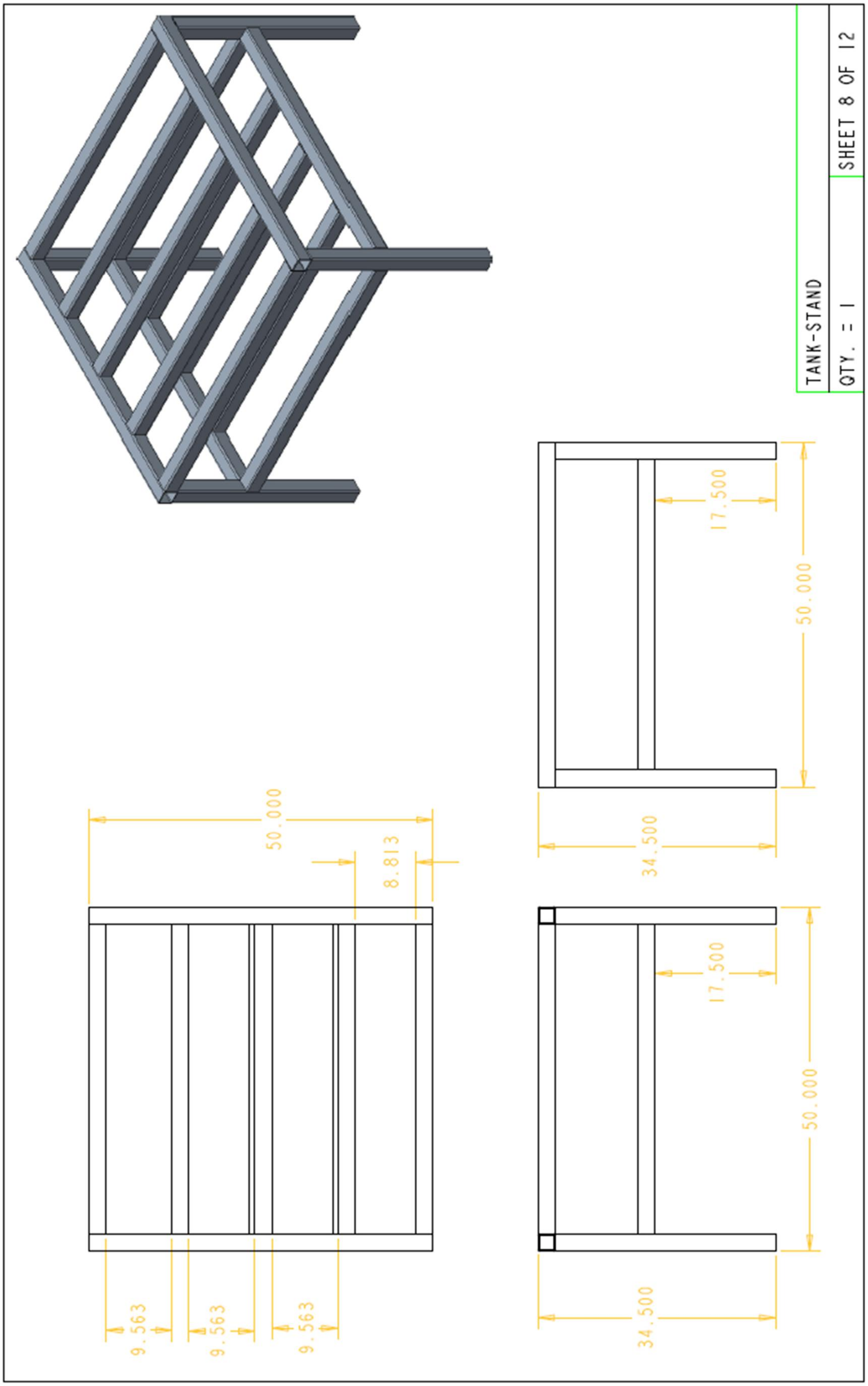
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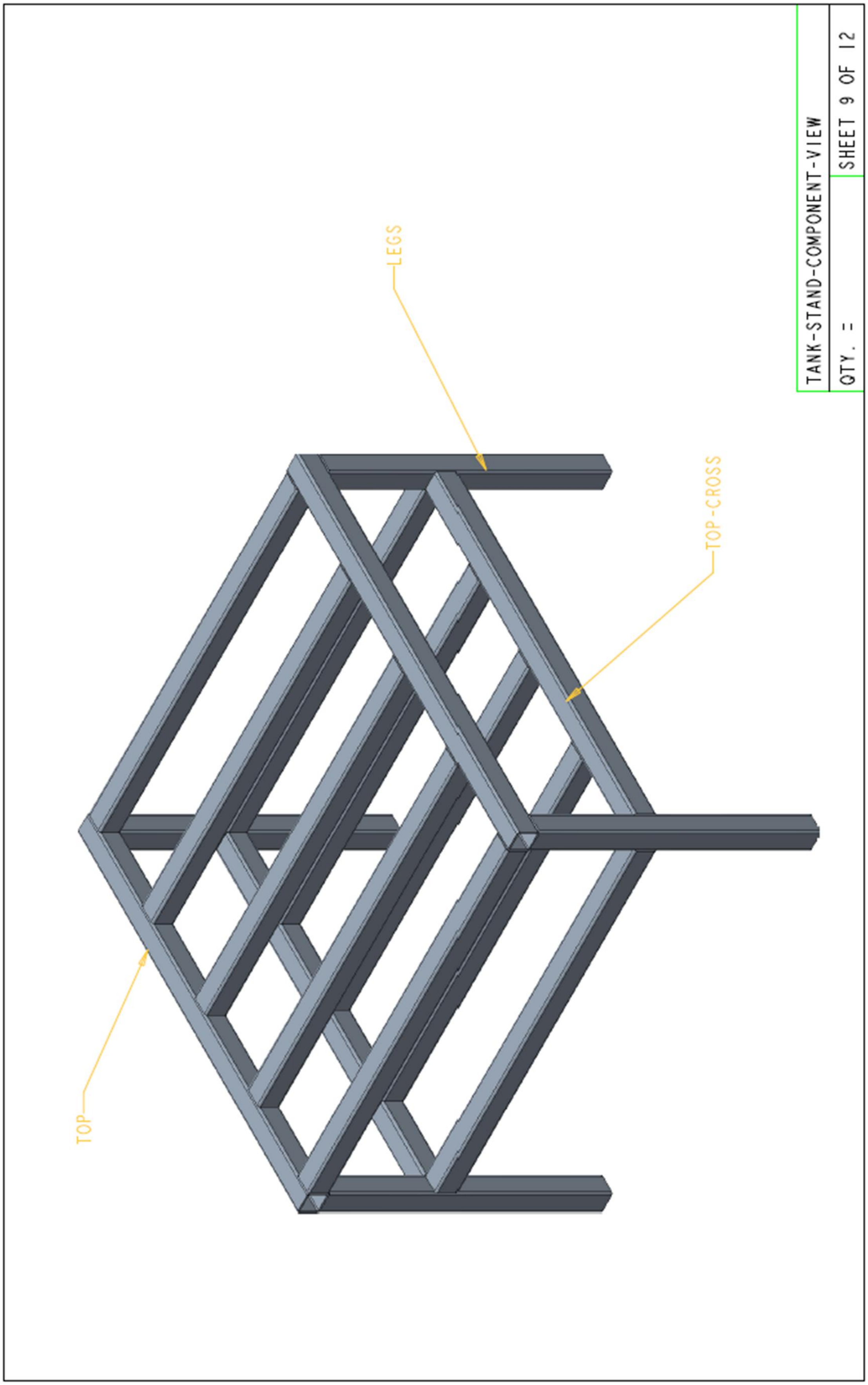
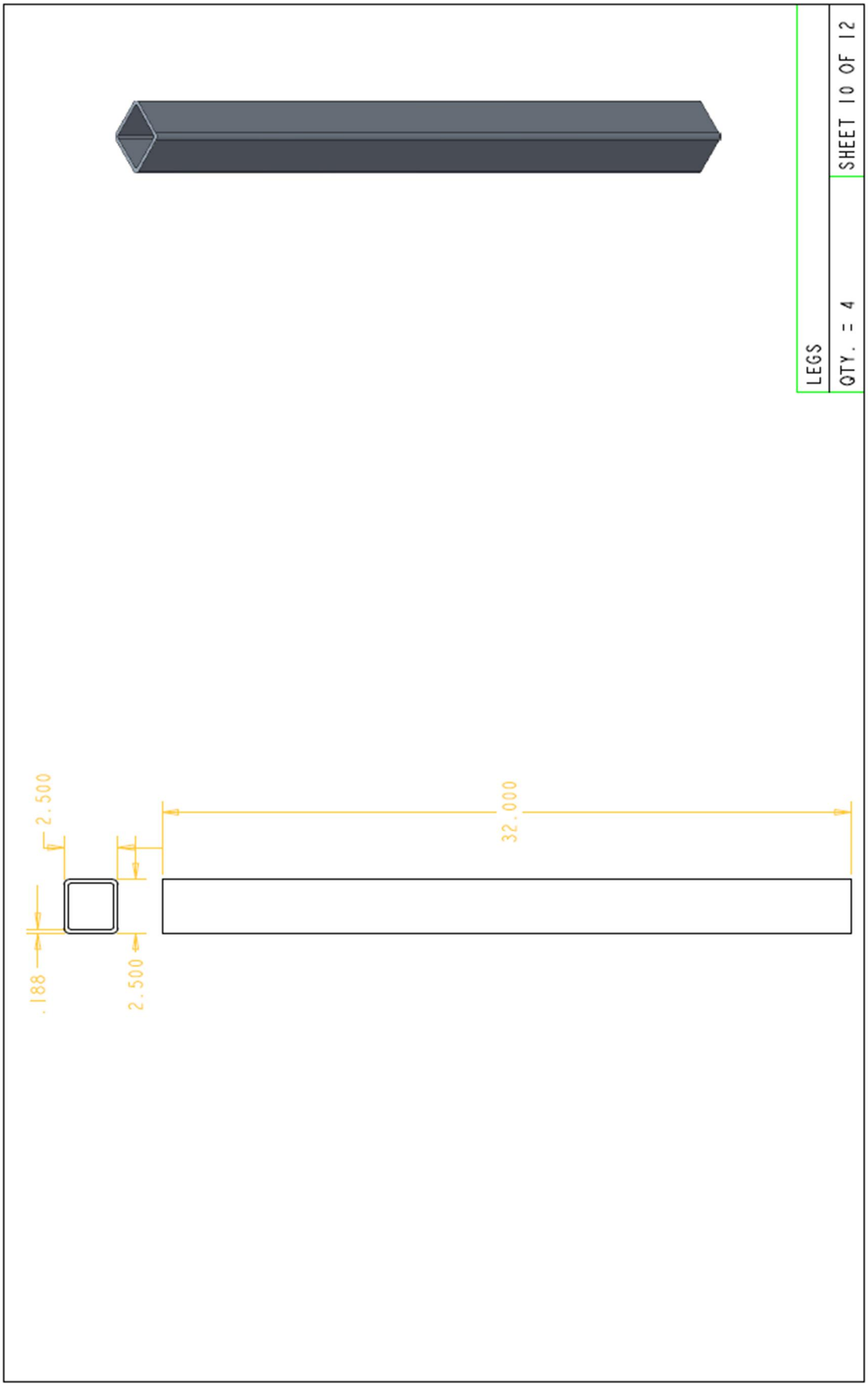
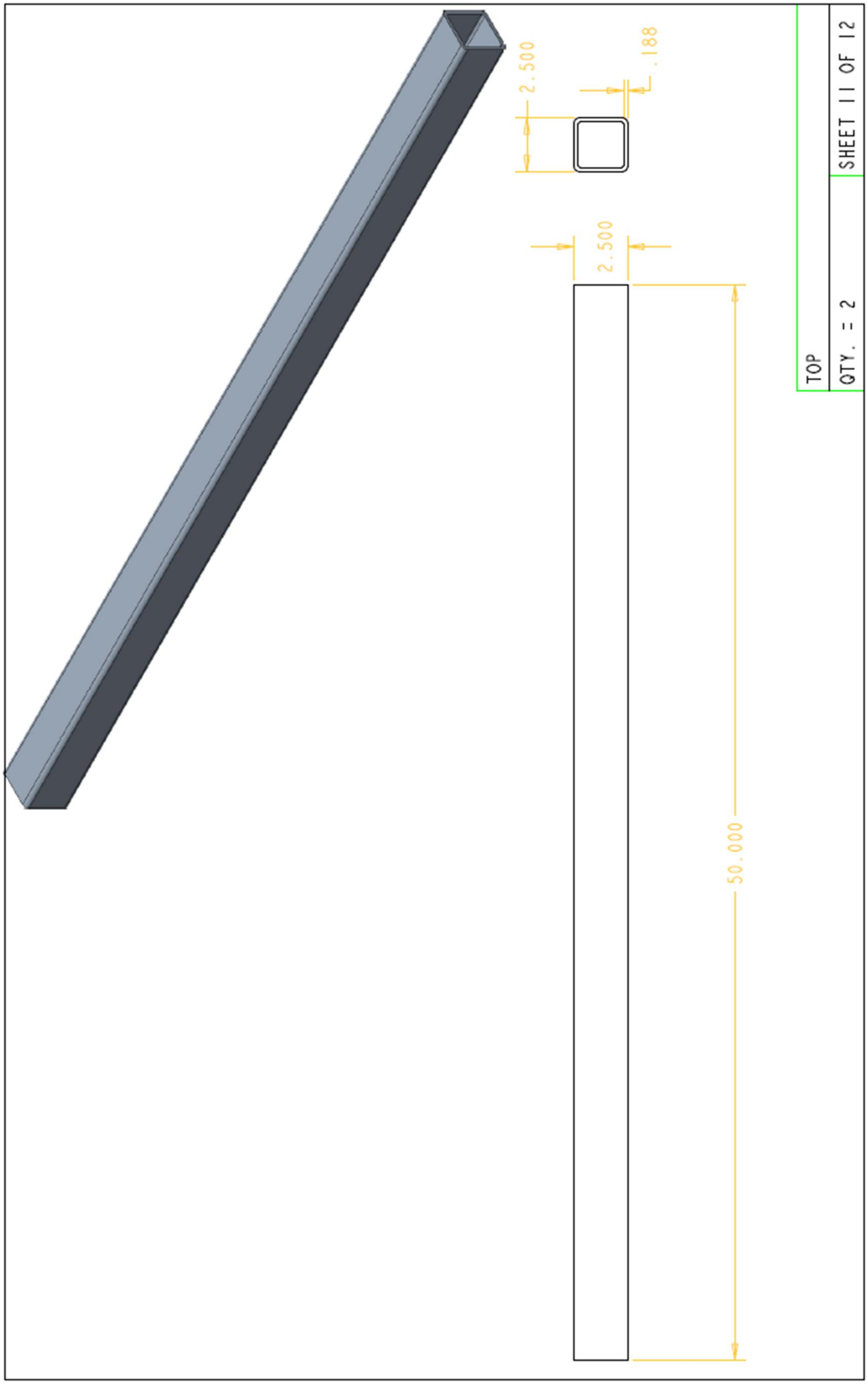
17.500
50.000


TANK-STAND-COMPONENT-VIEW
QTY. =
SHEET 9 OF 12
LEGS
TOP-CROSS
TOP


LEGS
QTY. = 4
SHEET 10 OF 12
32.000
2.500
2.500
.188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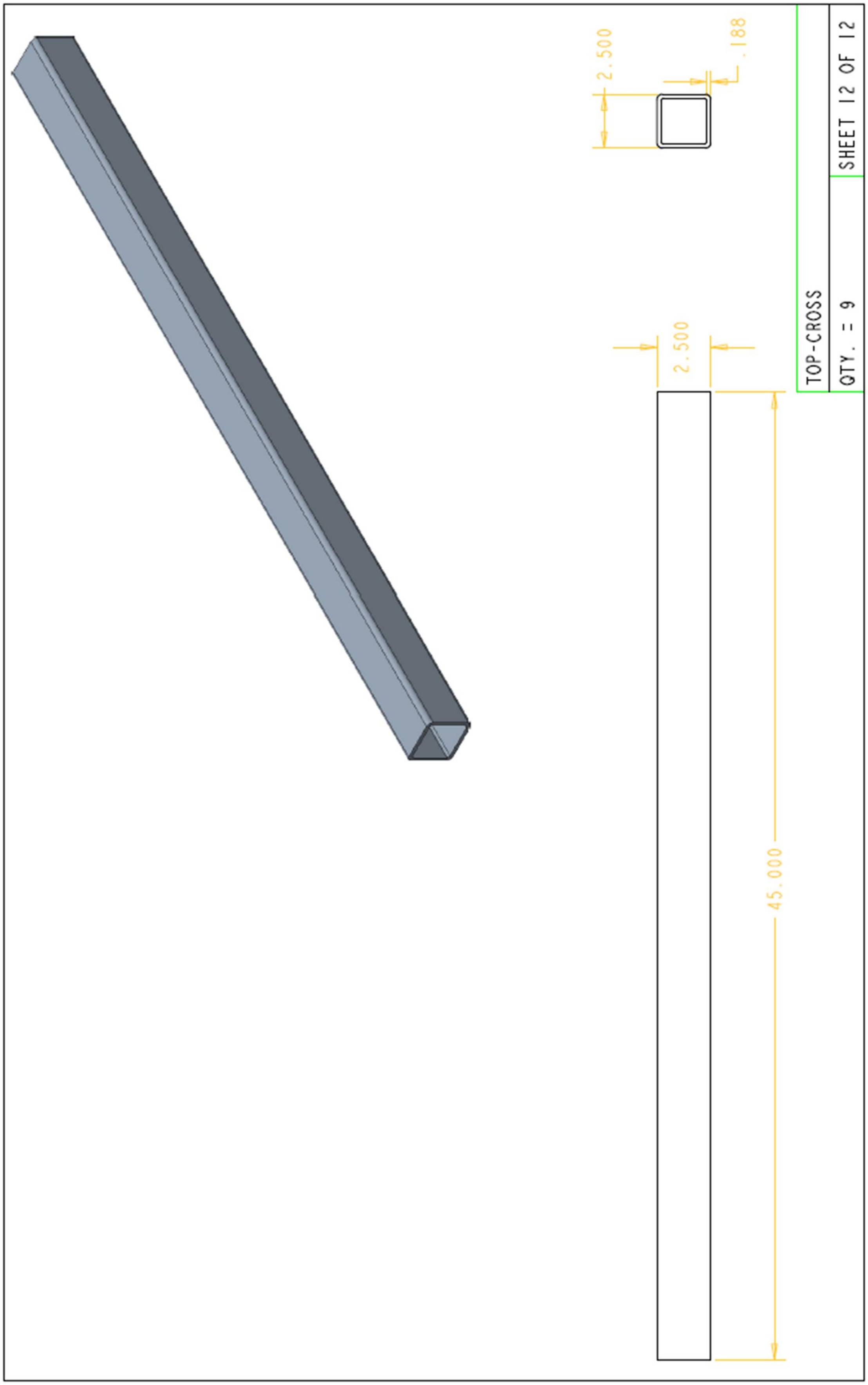
.188
2.500
50.000
TOP
QTY. = 2
SHEET 11 OF 12


2.500
.188
2.500
45.000
TOP-CROSS
QTY. = 9
SHEET 12 OF 12

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