# Pre-Fabrication 1 L/s, Fall 2016

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**Abstract**

Since January 2016, the Pre-Fabrication team has been experimenting with the creation of a 1 L/s water treatment plant. The Spring 2016 team successfully created a small scale version of the sedimentation tank and the Summer 2016 team fabricated a full scale plant. This full-scale plant will be shipped to Honduras in December 2016, and the goal of the Fall 2016 team is to construct an additional 1 L/s plant with a focus on streamlining and improving the production methods and accuracy. The team will focus most heavily on improving the methods of the flocculator and determining the structural integrity of the plant to confirm the validity of its design approach.

## Introduction

Historically, AguaClara has created plants with a volume flow rate of 5 L/s and higher. Fabricating a 1 L/s plant opens many opportunities for global deployment of new water treatment technologies. For communities that depend on smaller bodies of surface water, implementing an AguaClara plant would be too expensive. AguaClara plants have high fixed costs that make them relatively cheap for higher flow rates but very expensive for plants with a volume flow rate less than 5 L/s, hence the need for a differently designed plant. The prefabricated plant provides a method to utilize AguaClara technologies at a much lower cost. A majority of the costs to build a plant in another country are related to technology transfer. The materials in the prefabricated plant cost approximately $2,500. The Pre-Fabrication team seeks to lower the labor costs for fabrication through researching more efficient and accurate fabrication techniques and methods.

## Previous Work

In January 2016, AguaClara started to work on creating water treatment plants for smaller communities. The first team in Spring 2016 (Buhl et al., 2016) based its entire semester on the construction of a sedimentation tank. Fabrication was particularly difficult due to the lack of space for the plastic welder to move around within the tank. Despite the setbacks due the plastic welder puncturing holes in the corrugations, the Spring 2016 team proved that the fabrication

Figure 1: This is the 1/3 scale tank. It is a foot in diameter and stands a little over 3 ft. It is connected to a tube flocculator.

techniques were viable and that the geometry of the sedimentation tank was functional.

In the Summer of 2016, a new team was assembled, which took the data from the spring semester to create a full sized 1 L/s flocculation-sedimentation plant. New fabrication methods were developed such as crimping and using jigs for cutting the sedimentation tank(Guzman et al., 2016). Crimping is used for making flocculators and involves heating PVC pipes until they are malleable and crushing them to create contractions.

The experimental results showed that the flocculator didn't quite preform as calculated. The headloss of 51 cm required was not met because the calculations done did not account for the fact that the contractions were ellipses and not circles. The Fall 2016 team plans to improve upon the designs of their predecessors.

# 1 Fabrication Methods

## 1.1 Sedimentation Tank

The sedimentation tank is where the floc blanket sits and flocs are settled out of water. For the 1L/s plant, the sedimentation tank (”sed tank”) is the centerpiece of the plant, holding the plate settlers, inlet manifold, base plates, floc hopper, and diffusers. To create the sedimentation tank, a 3 foot diameter pipe is cut and welded back together to give the pipe a 30 degree bend from the vertical. The 30 degree bend allows the plate settlers to function properly. (see Figure 2).

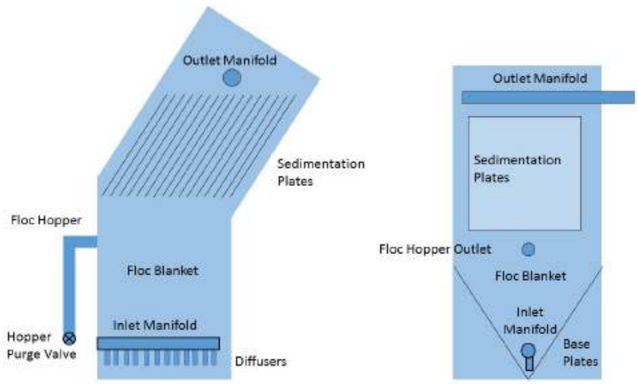



Figure 2: Sedimentation Tank Diagram describing the overall gemometry of the sedimentation tank, including the 30 degree bend in the upper half and the 60 degree difference between the base plates

### 1.1.1 I Beams

In order to elevate the sedimentation tank pipe evenly and sturdily for the cut, it was rested across four steel I-beam supports.

Figure 3: Sedimentation Tank on I Beams. It is necessary to offset them such that one is pulled left and the adjacent one is pulled to the right. This is done so that the sedimentation tank is set firmly in place and won't roll

### 1.1.2 Cutting the Sedimentation Tank

To get the 30 degree angle bend in the pipe needed for the plate settlers, a single cut of 15 degrees was needed. This one cut created two rods that are rotated 180 degrees from each other to create a total bend of 30 degrees. In order to create an accurate 15 degree cut, a wooden jig consisting of a plywood board and frame with an elliptical hole cut in the middle was used. The ellipse was large enough for the 3 foot diameter pipe to be inserted through it. 80/20 is a T-slotted aluminum frame building material that was used in attaching the jig to the sedimentation tank.

The jig was fixed to the sides of the pipe using 80/20 rods and 80/20 joints so that the frame would stay fixed in its center, but free to change its vertical angle. The jig was then inclined from its vertical resting position so that it made a 75 degree angle with the surface of the pipe.This angle chosen so that the total angle of the cut would be 15 degrees.

Figure 4: The plywood board jig supporting the 30 degree angle. There are four 80/20 rods that attach the jig to the tank, each 90 degrees from one another. 2 are circled

The Pre-Fab team used the Milwaukee M12 Cordless HackZALL Reciprocating Saw, but it is referred to as saw in the report.

The cradle (Guzman et al., 2016) is a jig used (Figure 5) for holding the saw parallel to the plywood board. This is needed because the saw is not flat enough to hold against the board. After working a puncture into the side of the wall of the pipe, the saw and cradle were slowly worked around the entirety of the pipe to ensure as consistent and straight a cut as possible.

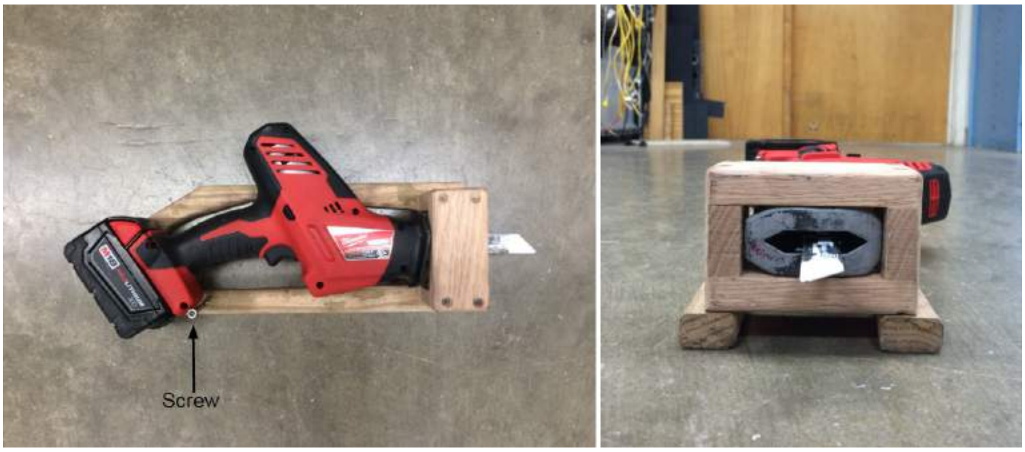



Figure 5: Saw with jig from a top side view (left) and from the front (right)

Despite using the sedimentation tank frame and the cradle, both of which served to prevent the blade from offsetting from the 15 degree angle, there were still complications in cutting. This was due to the person using the saw not being able to see if the frame of the cradle and the plywood were directly parallel to each other while cutting. Thus, spotters are needed in order to establish an objective view of the cutting.

The team used a yellow blade(See Figure 6), that had larger teeth and wider thickness than the standard blades, to create the initial cut. This blade should not be used for the rest of the cut because it cuts away large amounts of material, bending the blade and adding error to the cut. After the initial cut, a finer blade was used to finish the job. Tooth spacing for the yellow blade is 4.5 mm and 1.4 mm for the finer blade.

Figure 6: Yellow blade and finer blade side by side. Both blades are six inches in length. Yellow blade and finer blade has a tooth spacing of 4.5 mm and 1.4 mm, respectively.

As a contingency plan, the team had to redo the cuts on both sections of pipe. This was accomplished in the same fashion as the initial cut, but with the jig set up so that the reciprocating saw only took about a quarter of an inch off of the end on each pipe.

This length was chosen to correct the errors of the original cut and also so that the dimensions of the entire plant are not offset. If the team attempted to cut more of the pipe off, it would require the flocculator to be shorter or the sedimentation tank to be elevated.

An additional precaution taken for the second round of cutting was the augmentation of the reciprocating saw cradle using a clamp(Figure 1.1.2) in order to draw a reference line on the inside of the pipe to make sure the cuts were consistent. The markerjig is made by using a clamp on the cradle. On the skinny side of the clamp duct tape a piece of marker onto the clamp. A piece of metal was used to separate the clamp and the marker to adjust the distance between the marker and the cut, a thicker piece of a metal making the distance larger.

Figure 7: The markerjig in use. It is held against the plywood board to ensure that it's perpendicular.It consists of a clamp, the cradle jig, a piece of 80/20, a marker. Duct tape is used to connect the clamp to the marker and clamp.

## 1.2 Base Plates

The base plates are structures that serve as the bottom of the sedimentation tank. They are based off of traditional AguaClara sedimentation tank design, with the plates set at 60 degree angles from the ground and each other in order to prevent floc settling. These plates need to be made as identical half ellipses to fit correctly against the inner wall of the sedimentation tank pipe. The structure consists of a 3 inch PVC pipe cut in half–called the jet reverser–and two ellipses welded onto this half-pipe. The jet reverser is used to redirect the water flow upwards from the inlet manifold as well as a joint for the ellipse halves. The length of the 3 inch diameter jet reverser equals the diameter of the sedimentation tank pipe. The dimensions of the base plates ellipses are calculated based on the equations shown below.

$$MinorAxis = Diameter = 35.5in \tag{1}$$

$$\theta = 60\deg \tag{2}$$

$$MajorAxis = \frac{Diameter}{cos(\theta)} = 71in \tag{3}$$

$$Focus_{Distance} = \sqrt{\frac{Major^2}{4} - \frac{Minor^2}{4}} = 30.744in \tag{4}$$

$$String_{Length} = MajorAxis + 2 \times Focus_{Distance} = 132.488in \tag{5}$$

In order to create the ellipses, a method using a string loop wrapped around the ellipse foci was used. At first the team duct taped the two square plates of PVC plates together and drew the ellipse on them.

Figure 8: The taped two square PVC plates with the ellipse drawn on them. This is actually the incorrect way to set up the ellipses because, there is no 6 inch gap between the two halves

Then the major axis was drawn, which was 71 inches. The minor axis doesn't have to be drawn directly. The more important measurement is where the flat end of the ellipse halves sit on the edge of the jet reverser as shown in the picture of the experimental apparatus. Specifically measuring the correct width of each ellipse to match the length of the jet reverser is critical to ensure that they fit in the tank correctly.

The positions of the foci were marked 30.75 inches from the center of the ellipse lengthwise along the major axis. On the foci, a thin plastic tube (welding rod) was welded to the surface of the PVC. A string loop with a circumference of 132.5 inches was then strung around both the foci. A marker was guided around the string loop to mark the ellipse halves. Finally the PVC was clamped onto a surface and cut along the mark.

The first version of base plates did not correctly sit on the edges of the jet reverser because the jet reverser length was not taken into account. A second geometry was then drawn and it was established that base plates should be measured from the edges of the jet reverser, which has a diameter of 3 in. This meant that the each base plate ellipse needed to be cut 3 inches shorter, which was accomplished with the use of a spacer.

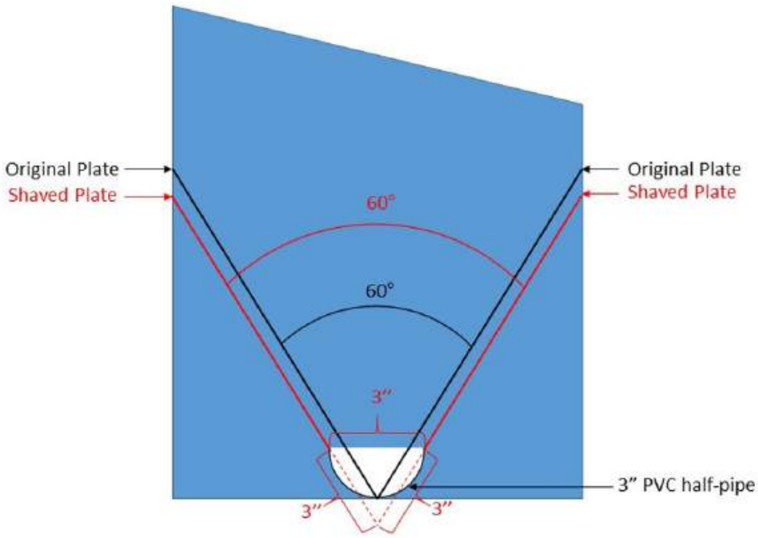



Figure 9: Base plate diagram showing the original geometry and the second geometry accounting for the jet reverser

The team set up the initially cut plates together with a 6 inch spacer in the middle to account for the 3 inches needed to be taken off each of the previous ellipses. Then, using the original measurement for the major axis and measuring specifically to ensure the plate width was equal to the jet reverser length, a new ellipse was drawn on the previous plates using the method from the first trace.

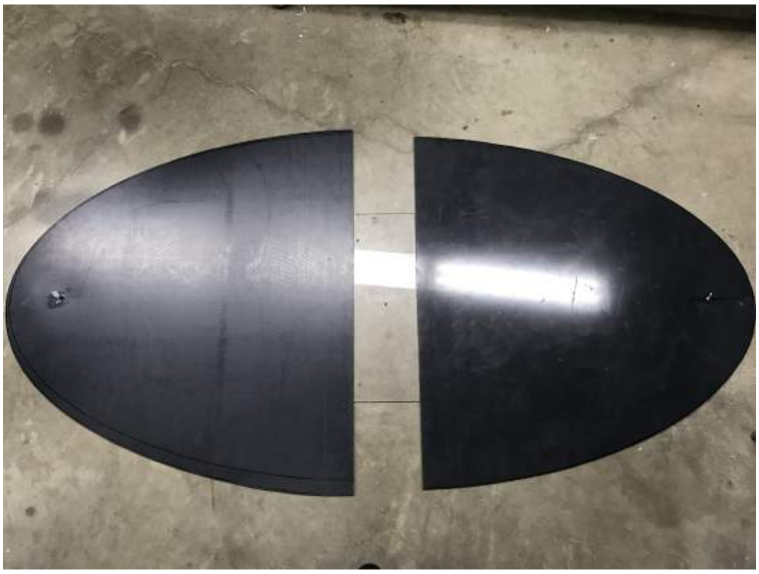


Figure 10: Base Plates Cutting - second time, showing the proper use of the 6 inch spacer to account for the gap needed by the jet reverser

### Experimental Apparatus

After one ellipse half was cut to the proper geometry, it was used as a template to trace subsequent ellipse halves. Using a template speeds up the process by avoiding measuring and drawing ellipses altogether.

Figure 11: Base Plates Sitting on the edge of the half pipe, shown in this picture from the Summer 2016 team. This picture also shows where the jet reverser sits (white pipe) in relation to the ellipse halves

### Welding

In order to weld the ellipses to the jet reverser, a plastic welder was used. The plastic welder was set to 600 F and the fastest airflow setting yielded the best results. To actually perform the weld, the ellipses and jet reverser were mounted on a jig consisting of two equilateral triangles made of 80/20 rods and wood held together by two cross bars. This jig holds the plates at the necessary 60 degree angle and the plates were held in place on the jet reverser using duct tape.

Figure 12: The jig used to hold the half ellipses to the jet reverser at the correct angle. This image shows just one ellipse half mounted so that it is possible to see more of the jig itself

The plates were then welded to the jet reverser by running the welder over the joint and depositing the plastic weld material in single lines down the entire length of the joint. This process was repeated three times on each spot that needed a weld, once on the initial joint and then additional times on either side of the first weld. This was done on both the inner and outer parts of the joint with the jet reverser. To accurately perform the weld on the inner surface of the ellipses a "gooseneck" attachment that changed the angle of the head of the welder was necessary. This attachment allowed accurate welding even in more confined situations.

## 1.3 Plate Settlers

At the top of the sedimentation tank are the plate settlers. Located in the upper half of the tank, plate settlers serve as the final step in the sedimentation process, their purpose being to trap flocs that did not collide with and join the floc blanket and reintroduce them into the floc blanket, increasing their chance of collision and subsequent removal through the sludge drain. The plate settlers were created in the proper dimensions to trap small flocs rising upwards with the water. By being set at a particular angle and length, the plate settlers were optimized to trap many of the flocs that rise above the floc blanket.

### 1.3.1 Fabrication

The plate settlers were made of clear, 1/16 inch acrylic polycarbonate sheets. and cut to the dimensions of the sedimentation tank. In total, there are 34 plate settlers and each of them are 2 feet long and varying widths, depending on how close they are to the sides of the tank. Plate settlers' width depend on the position they are in with respect to the sedimentation tank, sheets directly in the middle of the circular tank will be larger than those near the sides. The plate settlers are to be held in place by 8 stainless steel threaded rods. The rods will be parallel to the ground, while the plate settlers are at a 60 degree angle to the rods.

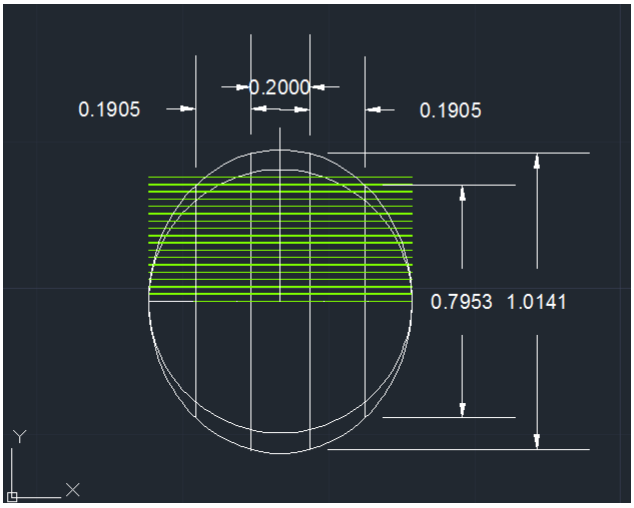



Figure 13: Dimensions of the plate settlers and how they will sit in the sedimentation tank. The plate settlers are angled 60 degrees from the horizontal and are 2 feet in length. The frame of reference is from the top and show how the plate settlers need to decrease in width closer to the sides to fit the circular tank.

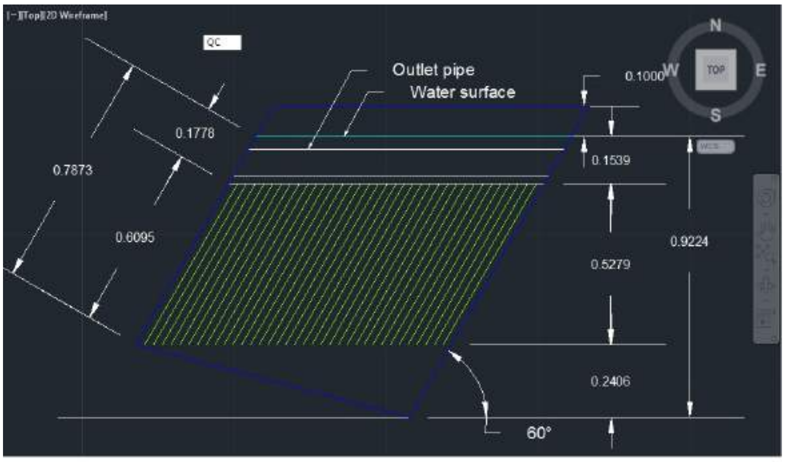



Figure 14: Dimensions of the plate settlers, and how they will sit in the sedimentation tank. The plate settlers are angled 60 degrees from the horizontal and are 0.6095 meters in length. The figure shows a side perspective of the plant.

#### 1.3.2 Jig

Before the team began to fabricate the plate settlers, a new jig was proposed due to the introduction of the shear cutter (see Figure 20). This shear cutter was specifically ordered for cutting plate settlers, but required a jig to be able to cut the sheets in a straight line.

The jig was created with 6 square rods of 3 feet 80/20 pieces. It is assembled by creating a square frame that has two rods running down the middle of the square. These two rods are braced with a plate joint that allows for the plate settlers of 1/16 inch to slide in between (see Figure **??**. The jig also had two 80/20 corner bracket pieces that were used to clamp onto the sheets to keep the sheets in place while cutting in order to account for the spacing between the shear and the blade (see Figure 20), the Pre-Fab team added an extra inch to the measurements.

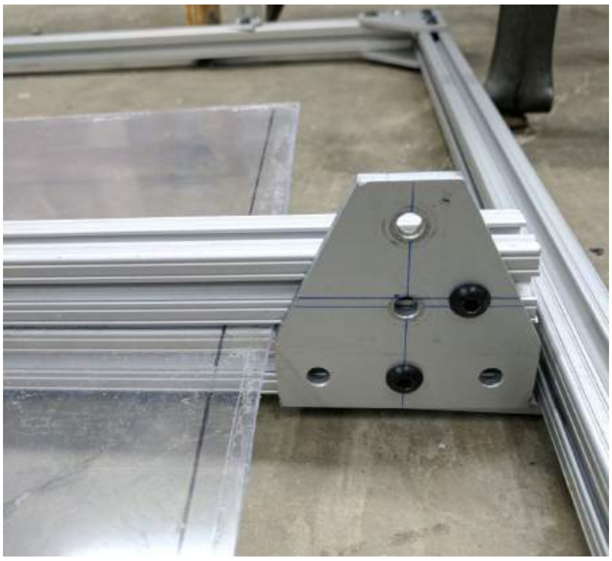


Figure 15: Plate joint. 1/16 inch above the center hole of the piece, another hole was drilled to hold the 80/20 piece 1/16 inch above the bottom to create the gap for sheets to slide into.

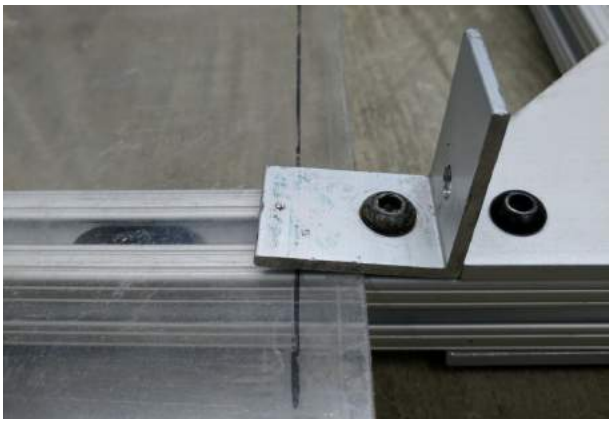


Figure 16: Closeup of the clamp. The 80/20 corner bracket piece was used to clamp down onto the sheet to prevent the sheet from moving while cutting.

Figure 17: The jig before the last piece was installed (left) and the jig when it was finished (right)

Figure 18: Top view of the jig

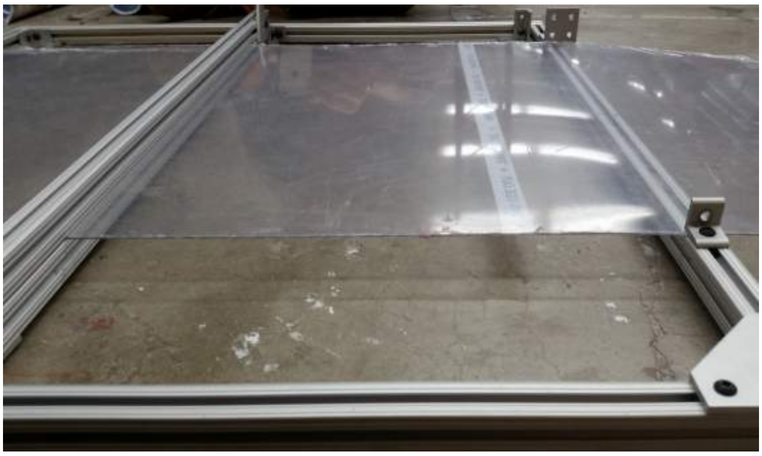


Figure 19: Closeup on how the sheet fits into the jig for cutting

The plate settler dimensions are listed in the table below. Each plate has to be produced twice, as there will be 34 plates in total.

| Plate Settler Number | Width(cm) | Width(ft) |
|---|---|---|
| 1 | 90.776 | 2.9782 |
| 2 | 90.515 | 2.9696 |
| 3 | 89.981 | 2.9521 |
| 4 | 89.171 | 2.9255 |
| 5 | 88.075 | 2.8896 |
| 6 | 86.683 | 2.8439 |
| 7 | 84.981 | 2.7881 |
| 8 | 82.949 | 2.7214 |
| 9 | 80.562 | 2.6431 |
| 10 | 77.787 | 2.5521 |
| 11 | 74.580 | 2.4469 |
| 12 | 70.883 | 2.3255 |
| 13 | 66.612 | 2.1854 |
| 14 | 61.649 | 2.0226 |
| 15 | 55.805 | 1.8309 |
| 16 | 48.761 | 1.5998 |
| 17 | 39.877 | 1.3083 |
| | | |

Figure 20: Shear in action. An inch has to be accounted for between the end of the shear and the blade to obtain precise cuts.

#### 1.3.3 Shear Cutter

To use the shear, the correctly measured (Add an inch to Figure1.3.2) plate settler is placed between the middle two 80/20 rods. Then it was braced with L-brackets on each of the four corners. Before cutting the plates, a spotter stood on the jig to make sure it didn't move and to make sure the cut was going straight.

During the actual cut, both hands were used used. One that has the hand on the trigger, and the free hand holding the cutter against the guide. Without the additional force holding the cutter against the guide, the cut can easily go off course.

## 1.4 Problems with Cutting the Plate Settlers

Unfortunately, the team mistakenly added more to the measurements.The calculations for the plate settlers' width already accounted for an extra 1/4 inch, causing each sheet fabricated to be longer. The sheets' measurements had an extra 1/4 inch added in order to make sure that the sheets are flushed against the sides of the tank so flocs are not able to go up through the sides where there aren't any plates (in order to prevent short-circuiting). As the team started using the jig, the team realized that midway through the cut, the sheets used the clamps as a pivotal point that shifted the sheets while cutting (see Figure **??**). The shift made the sheets have a curve, not straight, edge along the cut. In order to recut the sheets, the team tried three different ways of cutting the sheets.

### 1.4.1 Bandsaw

The team first attempted to cut the sheets with the bandsaw but saw that there was no way to properly clamp one side to make sure the other was straight. While the team used a square to draw a straight line, the cut was not straight.

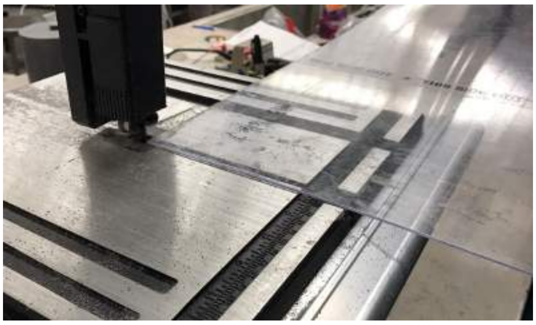


Figure 21: Cutting the sheets with the band saw. Because there isn't a way to clamp the sheet, the cut cannot be straight.

### 1.4.2 Table Saw

The majority of the sheets had one straight edge (manufactured edge) and one imperfect edge. In order to recut the edges to be straight, the team needed a way to use the given straight edge to make the other edge straight. A square was used to draw guide lines for cutting. The team used the table saw to hold the straight edge and cut the sheets to their exact measurement. However because the sheets are 1/16 inch thin, the team had to have something pressed down onto the sheet while cutting since the blade was strong enough to destroy it. Because the blade's jaws grabbed the material, the team reversed the blade to make the cut easier. The team also grabbed an inch thick plywood and adjusted the blade to be at a height just enough to cut through the sheets (1/16 inch). The team ran the plywood through the blade first to create a small cut that would allow it to hold the blade while cutting the sheets. With the plywood on the blade, the team was able to cut the sheets to their exact measurements without destroying them.

Figure 22: Cutting the sheets on the table saw with plywood. This plywood is clamped so that the sheet will not be destroyed while cutting.

#### 1.4.3 Foot Shear Machine

In addition to the use of the table saw, band saw, and the shear cutter, the foot shear machine (See Figure**??**) was also employed.The machine was originally used in the summer of 2016, but the fall team wanted to explore more accurate and efficient methods to fabricate plate settlers.

After finding that many of the plates had to be squared again because of manufacturing issues, the machine was brought into use again to aid in the process. It required a person to place the square edge of the plate on the right side of the machine and secure it by pushing the black bar away from oneself. Then the plate settler is cut by a guillotine blade by jumping on the foot bar or by pressing it with sufficient pressure.

The cuts on the plate settlers were fairly accurate, but it requires a person to carefully line up the blade with the desired cut. It is also not very portable, as the machine is very immobile. This method of fabrication is not encouraged for those above reasons.

Figure 23: Use of the foot shear machine to cut the sheets. The sheet is cut by a guillotine blade by jumping on the foot bar or by pressing it with sufficient pressure. The team member's left hand is on the bar used to secure the plate, and his left foot is on the foot bar.

## 1.5 Spacers

Between every sheet, there is a spacer that separates them from each other. The spacers between the plate settlers were originally calculated to be 2.5 cm. During the initial fabrication of the full scale plant, the spacers were cut inaccurately to approximately 2.8 cm. The Summer 2016 team was unable to fit all 34 plate settlers into the rod due to the collective error from cutting. When cutting the spacers, they have to be angled to fit correctly onto the plate settlers. The placement of the plate settlers and spacers onto the eight rods is a three-person job. Because it is difficult to place even pressure onto the plate settlers when pushing them onto the rods, it is critical to be aware of the orientation of the spacers so they do not rotate.

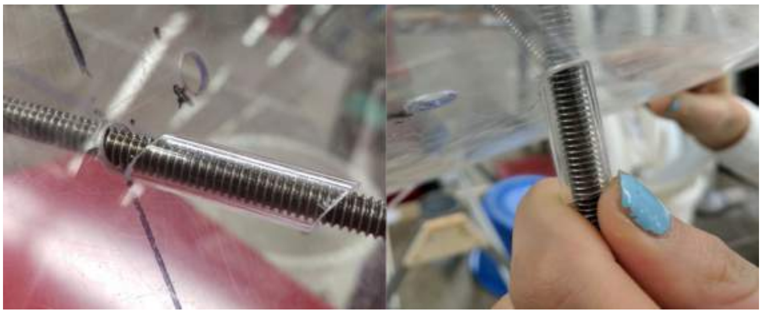


Figure 24: Example of a spacer with the wrong orientation (left) and the right orientation (right)

The spacers were cut to 2.3 cm. To see the fitting of the plate settlers, the team cut small plates and spacers to assemble onto a rod to see if it would successfully fit in the sedimentation tank. When the team created a small scale stimulation of the plate settlers, the team was unable to fit all 34 sheets with the spacers at 2.5 cm into the length of the tank. The team calculated the space between the sheets and found that 2.3 cm was an appropriate length to cut the spacers to. The spacing was not a perfect fit to the entire diameter of the tank but a spacers with a length in between 2.3 and 2.4 cm would have been difficult to machine.

Figure 25: New spacers that can correctly fit 34 plate settlers

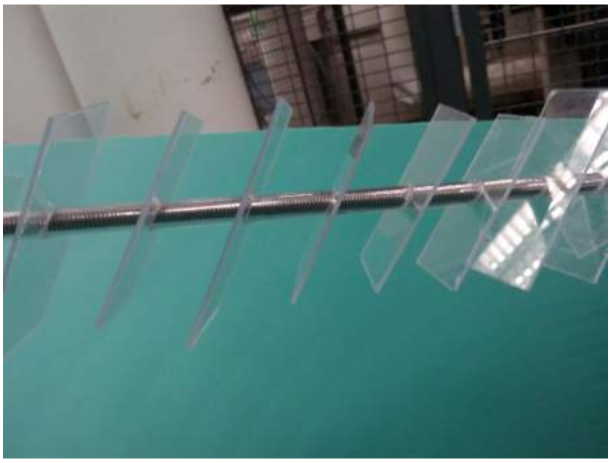


Figure 26: Closeup of plate settlers small scale stimulation.

To cut the spacers, longer PVC pipes are cut into lengths that could be easily handled. Using the element shown below, the pipes are placed on 60° angle to optimize the amount of spacers per rod and the spacers were cut to 2.3 cm.

Figure 27: Spacers before cutting at the band saw (left) and the set-up before cutting (right).

Figure 28: Spacers after they were cut to 2.3 cm

# Conclusions

This semester's goal of reproducing a fully functional tank was not met; however, many valuable lessons were learned in the process of trying to meet that goal. Our biggest error was the botched cut on the sedimentation tank, which took many hours to correct.

We learned that when cutting the sedimentation tank, there must be a minimum of two team members. One person makes the actual cut and the other watches to make sure that the sawzall jig does not deviate away from the frame.

To make accurate cuts, the team had to assemble a jig for the plate settlers. The jig has two stopping ends and two clamps. When cutting the sheets, the sheer causes the sheets to vibrate. After midcut, the clamps act as a pivoting point for the sheet and causes a slight curve in the cut. In order to have the sheets not move during the cut, the team recommends one member to either hold stand on the side of the sheet. The team further recommends that when using the jig again to insert another 80/20 piece approximately 3/4 inch away from the middle bar to lock the sheer while cutting. Restricting the shear from moving sideways while cutting will push for a straight cut.

The Prefabrication team also learned that the ellipse calculations were correct; however the team did not take into the account of the jet reverser. The first cut only fit in the sedimentation tank without the jet reverser. The second time around, accounting for the miscalculation, the ellipses were cut correctly. It is important to note that the better the ellipses fit within the pipe the less it will have to bend when welding it onto the inside of the pipe.

Accuracy should always be priority over time, because material costs are the central factor that goes into making these plants affordable to smaller communities. Of all the mistakes that the team has made so far, the botched cut on the sedimentation tank was the most troubling. Messing up the cut costed a lot of time and if it were any worse, it could have made the entire pipe unusable. With a worse botched cut, the team might not have been able to recut and use the same pipe. It would have forced the team to order another pipe, costing us a large amount of time and money. Thus careful consideration and care should be taken to ensure that everything is made accurately, especially the sedimentation tank.

## Future Work

The next step is to assemble the sheets and spacers together with the 8 stainless steel threaded rods. The team has already cut all 34 sheets into their respective sizes and cut all spacers. In order to finish assembling the plate settlers, holes for the rods need to be drilled into all of the sheets. To make the process easier and quicker, the team will clamp all the plate settlers together, the smallest one on the top and the largest sheet on the bottom. The top sheet will have a center-line drawn so when machining, the team can correctly drill the holes onto all the sheets.

Afterwards, the team will be able to fully assemble the plate settlers onto the eight rods and test with the upper half of the sed tank to make sure that the plate settlers are arranged properly. Then the base plates will be welded onto the walls of the bottom half of the sedimentation tank. Once it is confirmed that the plate settlers and the base plates were correctly orientated, the upper half and bottom half of the sedimentation tank is welded to become one again.

The flocculator is to be built last. The team is collaborating with a group from class CEE 4540. Originally, the Summer 2016 team used crimping as a way to create turbulence; however, instead of using a crimping design, an orifice design is suggested. The team plans to test a design where the turbulence is created from the placement of semi-circles secured with a rod in the center and touching the surface of the inner diameter. The design and calculations will be done by the collaborating subteam.

## References

Buhl, K., DeVoe, C., Kruskopf, M., and Yang, F. (2016). Prefab 1 l/s, spring 2016.

Guzman, J., Hinterberger, J., Quintero, J. M., Marroquin, E., Mendhekar, D., Sabha, I., Rodríguez, C. V., Zhang, V., and Weber-Shirk, M. (2016). Aguaclara mini-plant.

# Semester Schedule

## Task Map

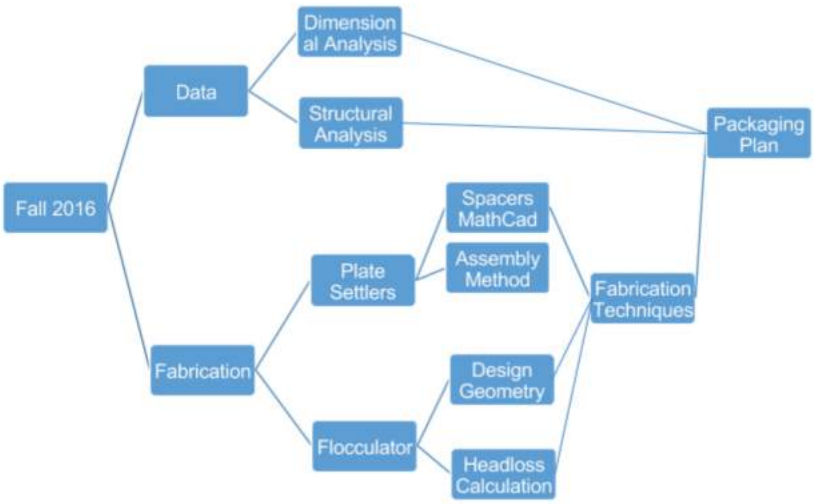



Figure 29: Fall 2016 Task Map

## Task List

You should keep and update your detailed task list from the first assignment in each of your reports. Denote completed tasks and modify your deadlines to reflect your most recently completed progress and any delays.

1. Dimensional Analysis (Sept 7) - Estimate the volume and weight of the plant itself with the sedimentation tank and flocculator. Send details to the Agua para el Pueblo Engineers. - Completed

   Structural Analysis (October)- Development of a structural analysis to check stability and efficiency of the current design and calculate other alternatives.

2. Compute and determine the structural integrity of the sedimentation tank. The goal is to create a stable structure while discarding of extra materials.

3. Plate Settlers (October 15)- Create a more accurate fabrication method for plate settlers. The current fabrication method is very imprecise- we want to keep the error to 1/8” maximum. The design of the rods and the spacing of the sheets will be rearranged and the machining will entail copious markings and orientation labels.

4. Flocculator (November)- The current flocculator is hard to assemble because of the crimping involved. Crimping requires heating up the plastic

and reshaping it. The team wants to create a new fabrication technique that involves the use of orifices.

5. Structural Fabrication (December) - Have the complete plant done to replace the current plant that is going to Honduras.

6. Packaging Plan (December) - Develop a plan to send each component of the 1 L/s plant in a way that would be appropriate to send via shipping container to Honduras. Having the components of the plant being shippable will need to be taken into account during fabrication of Plate Settlers/Flocculator.

**Report Proofreader:** Sung Min Kim

# Annex 1: Structural analysis (stability and efficiency)

This analysis considered the capacity and effectiveness of the previous design. The team's findings indicate that the current design, using three vertical PVC sheets 6 mm wide on each side, has an acceptable deflection with a very conservative safety factor.

Several assumptions have been considered to perform the analysis, indicated in the following pages. These have always been selected to fall on the worst case scenario.

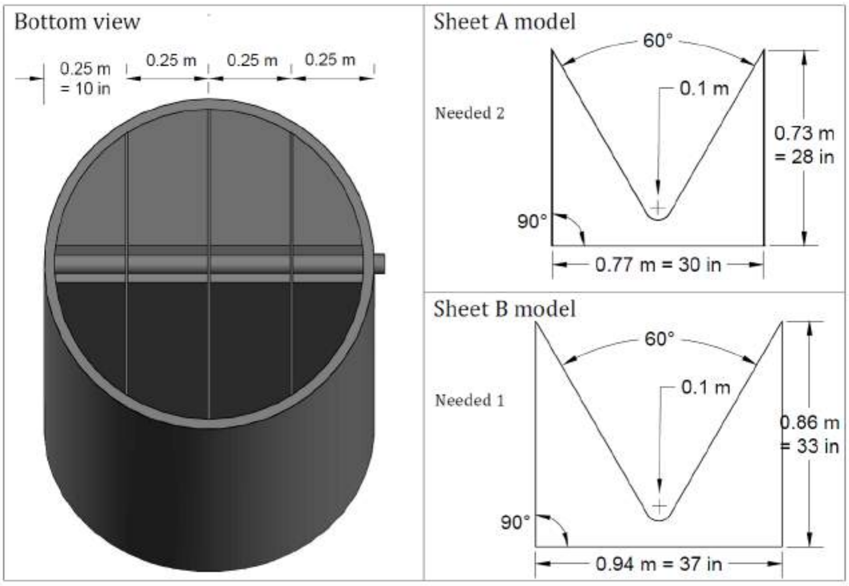
The main consideration that governs all structural analysis has been the relative price of all the necessary material to construct it, way lower than the total cost of the water treatment plant. Also, the building conditions and transportation of the element have been considered. Because of these two reasons, the design hasn't been optimized for economical cost, being very conservative on every step of the design process.

## Calculations and methodology

This design uses cut PVC sheets that are welded to the base plates of the sedimentation tank.

The design PVC sheets are 1/4" wide (6 mm) thick.

Dimensions and location of each piece are clarified in the following figure, also included is the cutting parameter for the two kinds of sheets:




Sheet B being the center one, and Sheet A the two at the sides. THis sheet is prepared to be printed and handled by all workers and assemblers of the base of this structure, containing all necessary dimensions to build he base of the water treatment plant.

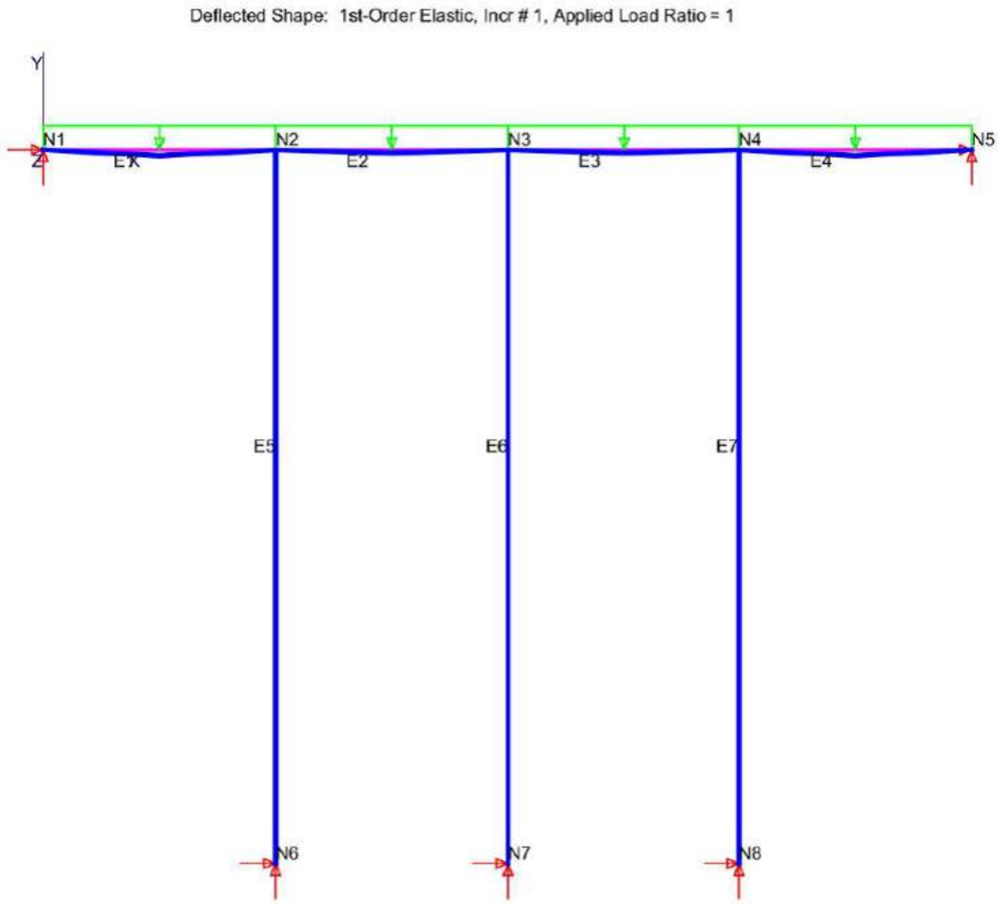
This analysis uses Young's modulus of PVC plates as 3 GPa, this being a safety side consideration. Also, as shown in the structural analysis the PVC is considered to remain in the elastic behavior zone as the strain is much smaller than 0.001.

The structural analysis introduces a very conservative scenario, by these two conditions. Geometry has been considered as a constant height top plate with three 33 in x 37 in (0.86 m x 0.94 m) vertical sheets. Pressure has been considered as uniform taking the value of the bottom pressure of the tank (maximum pressure) equal to 1730 kg/m2 that corresponds to a depth of 1.73 m (68 in).

The structural analysis has been performed using the open software MASTAN®. This software is able to make two dimensional structural analysis of both, frames and trusses, introducing material properties (Young's modulus) and dimension properties (length, cross section area and inertia). State that all dimensions must be consistent as MASTAN® doesn't have the ability of converting between units.

(Document .mat used in this analysis is going to be uploaded to Google Drive folder AguaClara/Prefab1Ls/Fall2016)

The introduced dimensions and characteristics of the design plot the following deflection diagram (no scale applied). This shows the real proportions of the cross section




The biggest deflection takes place in middle span of the left and right intervals between the exterior pipes and the support sheets. The value of that deflection is negative 6.5 mm (1/4 in).

Provided here is the bending moment diagram (data in N per m):

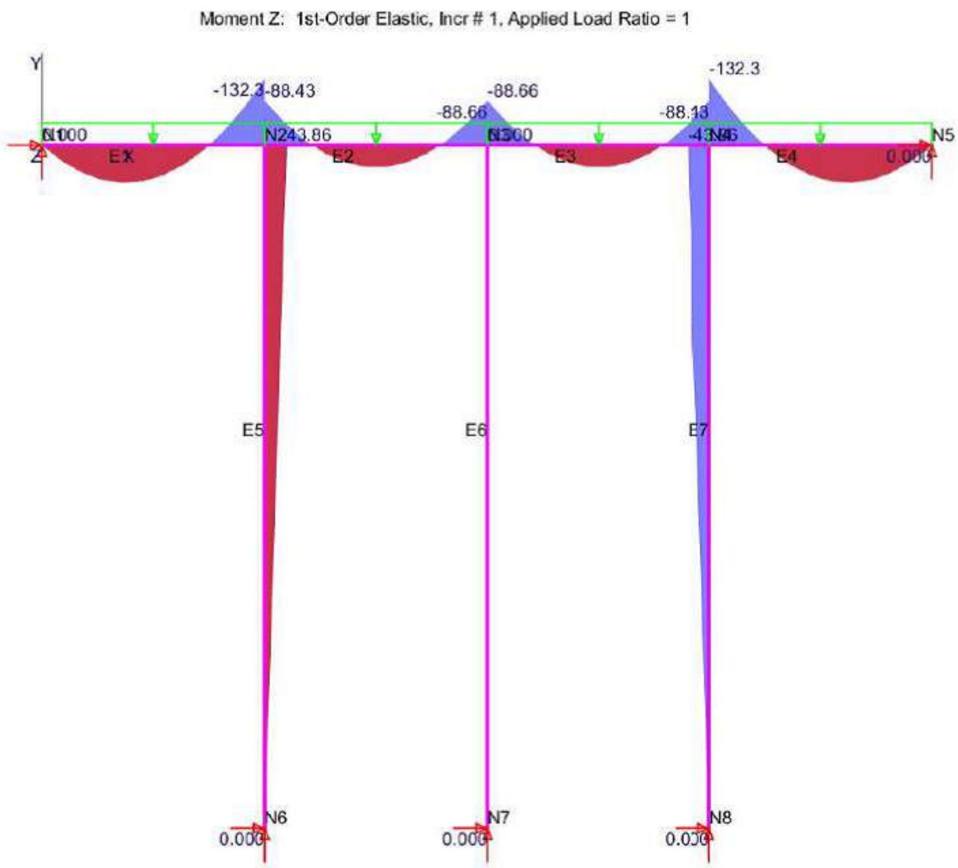



Figure 30: Bending moments in N m

The maximum positive bending moment is given at 10 cm (3.9 in) from the contact with the exterior pipe being 75 N per m.

The maximum negative bending moment is given in the exterior support sheets being 133 N per m.

Provided here are the shear and axial force diagrams (data in N):

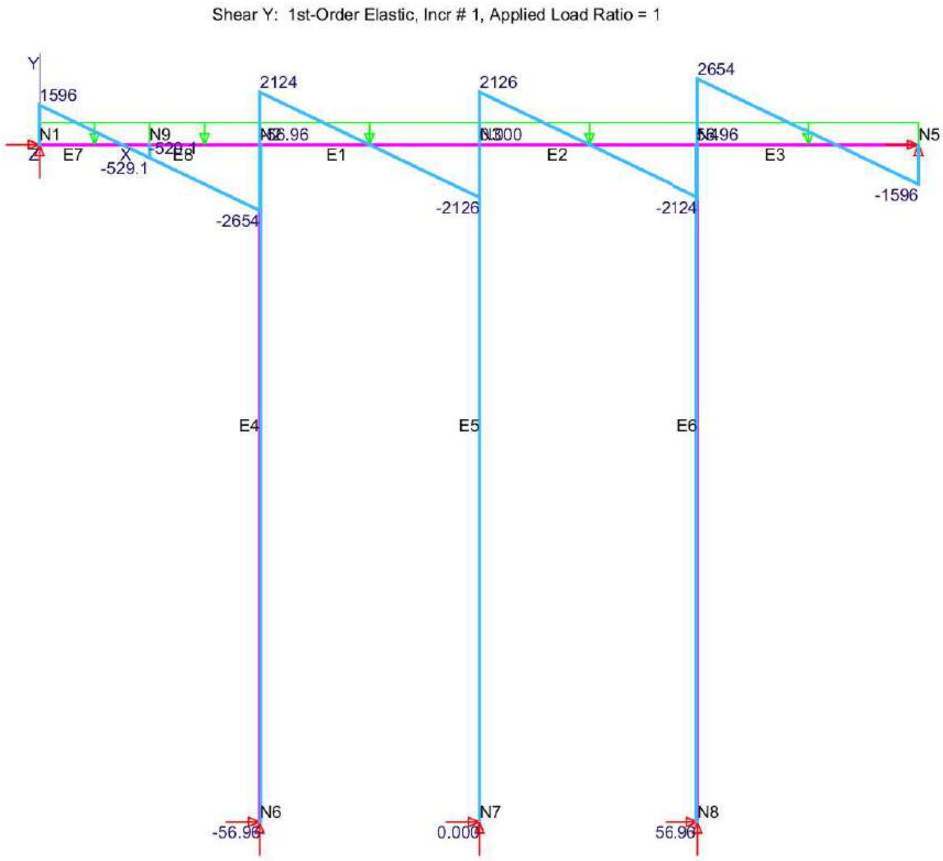



Figure 31: Shear Forces in N

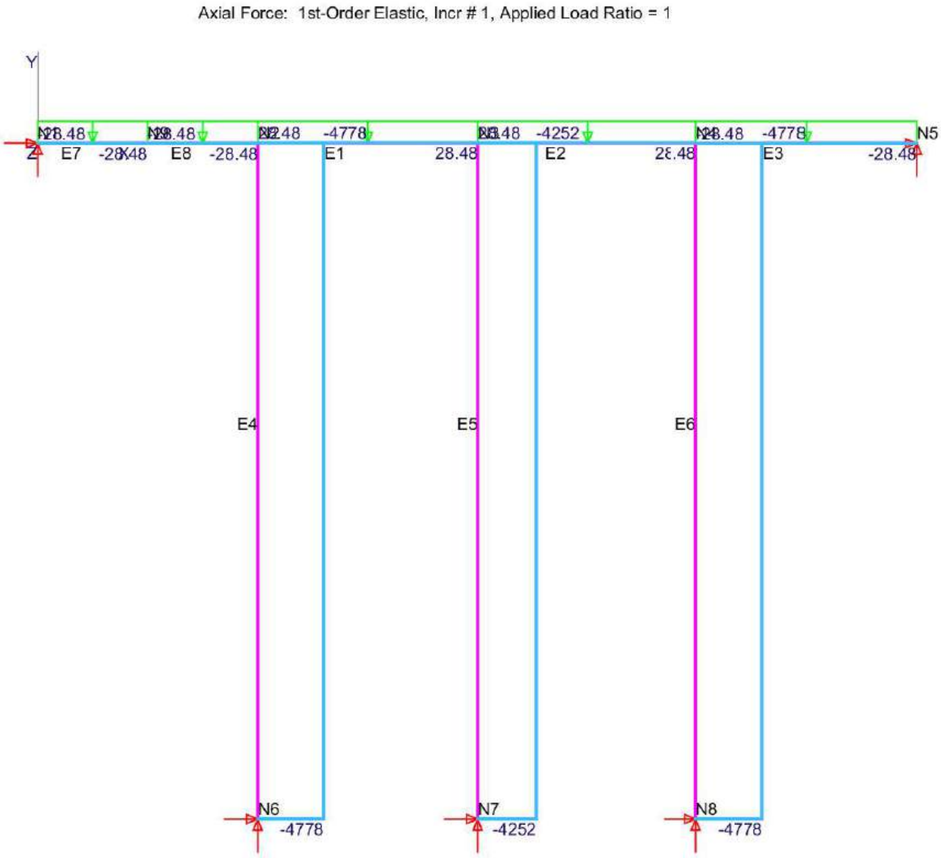



Figure 32: Axial Forces in N

The maximum shear force, 2100 N is in the middle support sheet

The maximum axial force, 4800 N, is at the bottom of the support sheets

The resultant force against the sides of the exterior pipe is 30 N perpendicularly and 1600 N of shear force.

A comparison of all data is provided in the following table which shows results using one, two adn three support sheets. introducing also results using two and one support sheet.

| | Three supports | Two supports | One support |
|---|---|---|---|
| **Maximum deflection (mm)** | **6.5 (1/4 in)** | 50 (2 in) | 100 (4 in) |
| **Maximum positive bending moment (Nm)** | 75 | 180 | 270 |
| **Maximum negative bending moment (Nm)** | 130 | 350 | 530 |
| **Maximum shear force (N)** | 2100 | 4300 | 5300 |
| **Maximum axial force (N)** | 4800 | 7000 | 10000 |
| **Resultant forces** | | | |
| **Perpendicular (N)** | 30 | 150 | 0 |
| **Parallel (N)** | 1600 | 1600 | 3200 |

Figure 33: Results table

Deflection is not admissible with this configuration for two or one supports being respectively 50 and 100 mm (2 and 4 in).

## 1.6 Instructions for cutting

First element, Sheet A, has to be repeated twice, while Sheet B only once.

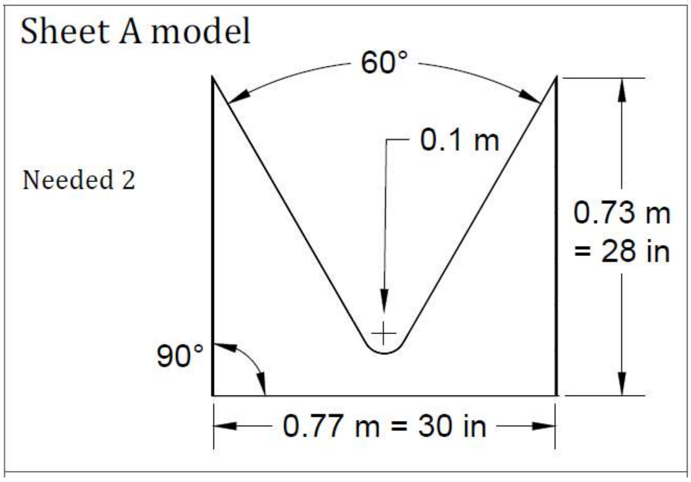



Figure 34: Sheet A

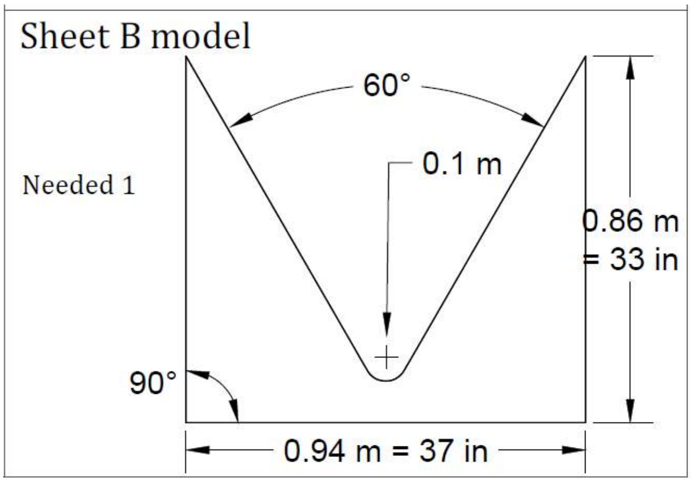



Figure 35: Sheet B

Slope of triangular and vertical side cuts need to make contact with bottom sheets of the deposit to ensure an effective welding.

Radius of curvature of the jet reverser doesn't have to be precise as long as the sheet doesn't make contact with the tube at the bottom of the deposit. The term fillet refers to a concave strip of material roughly triangular in cross section that rounds off an interior angle between two surfaces.

## 1.7 Instructions for assembling

Assembling has to be done as shown in the following figure. Welding contacts with the bottom plates and the exterior pipe.

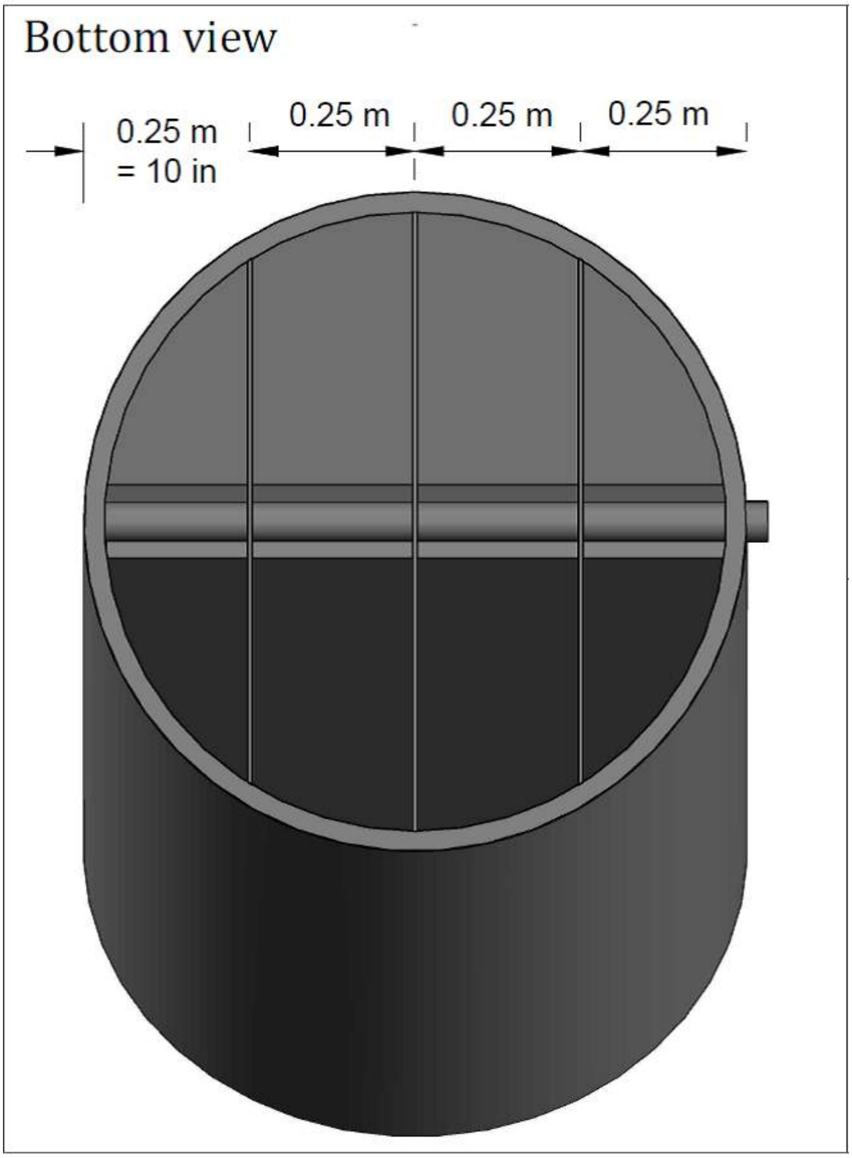



Figure 36: Bottom view

Other extra views from Auto CAD® file “structureDesign.dwg” are included:

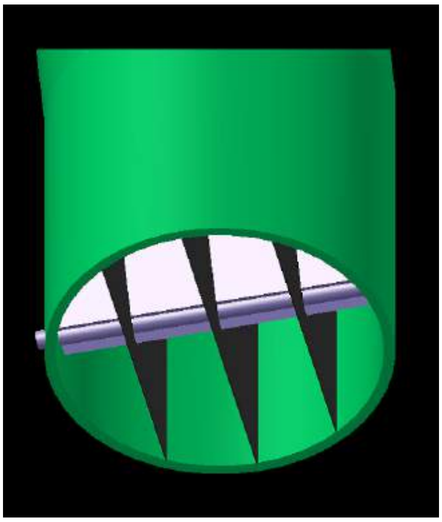


Figure 37: Extra View 1

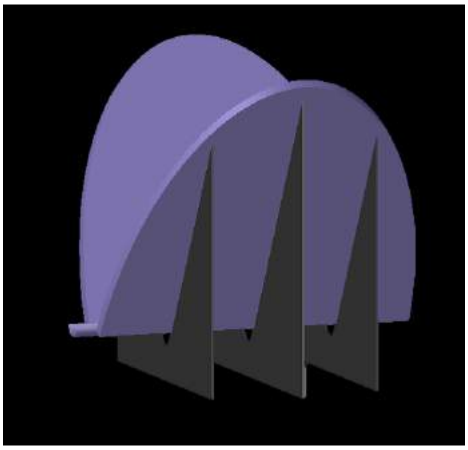


Figure 38: Extra View 2

## 1.8 Recommendations

The whole structure is going to suffer deformations due to the cutting and manipulating process. Also there can be assembling imprecision. Because of that is recommended to measure dimensions of the already assembled elements and adjust, if necessary, dimensions of the supporting sheets.

**Report Proofreader:** David Herrera