Chemical Dose Controller Modifications

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May 16, 2014

Problem Definition

Introduction

As the AguaClara Chemical Dose Controller (CDC) team progressed towards a more robust linear chemical dose controller for AguaClara plants in Honduras as well as chlorine dosers for India, modifications will need to be accounted for in the Automated Design Tool (ADT). Over the past semesters, efforts have been made to incorporate the changes into the current ADT, and our tasks this semester are to continue updating CDC code and complete the drawings.

There are four main tasks in CDC modifications. Our main goal of this semester is to complete AutoCAD drawing to allow for a more accurate and integral representation of CDC. It will also facilitate better understanding of the operation of the system. The Spring 2013 team had created a Sketchup drawing of the dosing system with the new manifold system, as shown in Figure **1.**

The first task is to fix and finalize the current flexible tubing function and use it to draw the tubing which connects the various pieces of CDC. Meanwhile, we will also explore other functions or approaches to the problem per recommendation of a past member of the team. The second is to complete the placement of both manifold systems so that the wall length can be properly integrated into the dosing tube calculations. Additionally, it is necessary to revise the sizing and concentration of the chemical stock tanks in order to simplify the mixing process of the stock solution. We will also finalize the updates to the calibration column and constant head tank drawing code, as well as incorporate in the AutoCAD drawing the most recent changes in CDC design such as the half size doser. Lastly if time permits, we will cooperate with the CDC team to improve the chlorine doser packaging process by providing a spreadsheet that automatically calculate for the number of each component that needs to be packed.

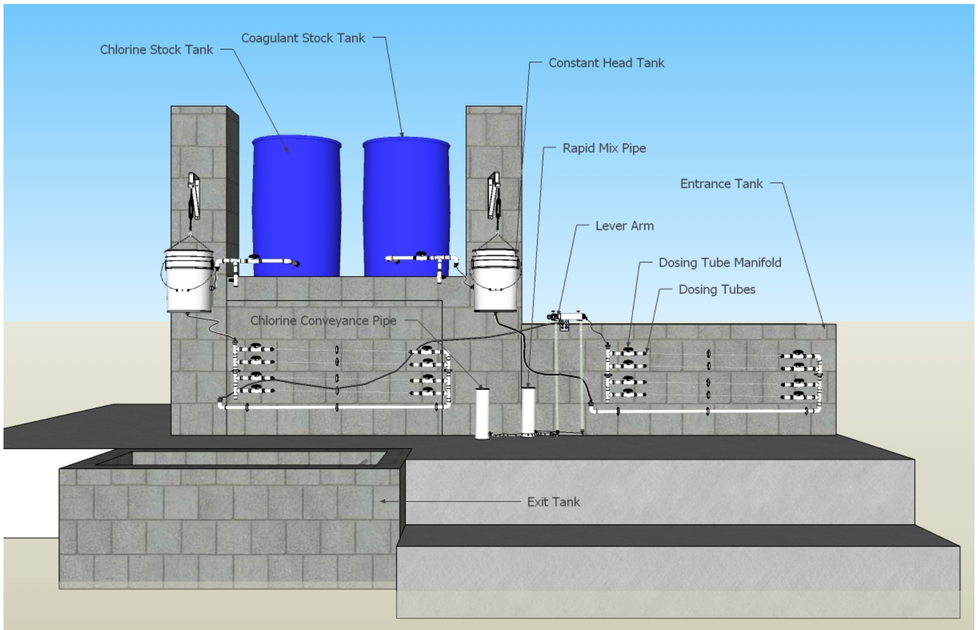


Figure 1: CDC SketchUp Drawing

Design Details

Updating the drawing code and completing the CDC AutoCAD drawing

The current CDC AutoCAD drawing produced by ADT is incomplete, a snapshot of the drawing for a 20 L/s plant is shown in Figure2. Although components such as the stock tanks and doser are in place, the drawing does not reflect the most recent CDC system. We still need to add flexible tubing connecting the various pieces of the system, a sediment trap to the supply PVC pipe, a vent

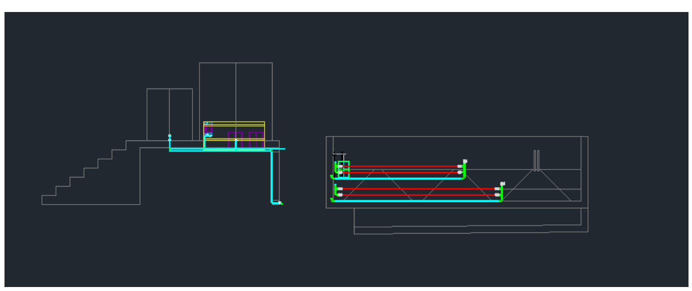


Figure 2: Drawing of the CDC system

waste valve at a high point and plumbing connecting the dosers to the dosing points.

In order to complete the drawing, it is important to be able to incorporate the flexible tubing. However, the FlexTubeF function cannot properly draw the flexible tubing, despite that many efforts have been made to fix it. Nevertheless, previous team member Tori Klug was able to make changes to the function inputs so that they were more intuitive to the users. Instead of taking an input of inner and outer diameter, only nominal diameter is required now. And the layer name and color were elimnated as inputs. In the past semester, the flexible tubing was modelled with a catenary function and parabola function. However since the current function cannot work properly and many efforts trying to improve it have been fruitless, we will look for another approach to the model in addition to fixing the current one.

In addition, updates to the calibration column and constant head tank drawing code are required. The constant head tanks need to be in a location that can be easily connected with the stock tanks and the manifold systems.

Revising sizing and concentration of chemical stock tanks

Currently stock solution mixing requires weighing out the amount of chemical to be mixed into the solution, which is inconvenient to the plant operators. AguaClara Engineer Drew Hart proposed to simplify the mixing process by mixing an integer number of 25 kg sacks of PACl into the stock tank, and this will allow for more accurate stock tank concentrations. Our goal is to modify the code to report integer number of chemical bags to be mixed into the stock solution and the depth of the water in stock tanks to reach the required stock concentration. As Drew Hart suggested, several parameters will need to be changed as well. The stock tank concentration will be capped at approximately 120 mg/L to reduce corrosive effects on fittings. Furthermore, the coagulant stock could be refilled once every 24 hours and chlorine should not last longer than 48 hours. We realize that the stock tank concentration and volume are interdependent, so it is necesary to create a function that solves for the stock tank volume and the water depth iteratively. The function should be created in a way that the dose selected by the CDC algorithms can continue to be used.

Determining equation for chlorine viscosity

In current calculations, the viscosity of chlorine is assumed to be the same as water, and Monroe also indicates that the calcium hypochlorite solutions that we use are quite dilute and thus the difference between water and the chlorine solutions is likely not very significant. Although the discrepancy is small given the low concentration we use in the plant, we would still like to determine an equation that calculates chlorine viscosity as a function of concentration. We will evaluate existing studies on the correlation between CaCl2 viscosity and concentration, and find the best model to use in our design. Monroe suggests that we can use the article "Modeling Viscosity of Multicomponent Electrolyte Solutions" written by M.M. Lencka, A. Anderko, S. J. Sanders, and R. D. Young. This article modifies viscosity as a function of ionic strength, and it calculates concentration dependence of viscosity based on the Jone-Dole Equation.

Documented Progress

Stock tank function

Since stock tank concentration and volume are interdependent, the volume and water depth or "fill line" will need to be solved iteratively. We created a function that takes the coagulant stock tank flow rate, the time between refills, and the supplier chemical tank volume as inputs, and outputs the volume of the stock tank and the number of coagulant bags needed. The stock tank volume calculated by multiplying the stock tank flow rate and residence time is set as the minimum stock tank volume, because it can only be increased to achieve the desired dose concentration when additional bags of coagulant are mixed in the water. The loop starts with one bag of PaCl, if the calculated volume based on this concentration is less than the minimum volume, another bag will be added until the calculated stock tank volume is greater than or equal to the minimum volume. Once the volume of coagulant tank is calculated, the dimensions of the tank can be calculcated using the existing functions.

Chlorine viscosity equation

We are going to use the Jones-Dole Equation to find out how chlorine viscosity changes with the increase of its concentration. The advantage of using the Jones-Dole Equation is "the recognition of a clear distinction among the long-range electronstatic term, contributions of individual ions, and contribustions of interactions between ions or neutral species".

$$\eta_r = 1 + \eta_r^{LR} + \eta_r^{s} + \eta_r^{s-S} \tag{1}$$

And here, $\eta_r^{LR}$is the contributions of long-range electrostatic effects, $\eta_r^{s}$is for the individual species, and $\eta_r^{s-S}$is for the species-species interactions. The factor η_r^{LR}can be found out directly by using Anderko and Lencka's method, which is introduced in the article "Ind. Engineering Chemical Research 1932". The factor η_r^{s} can be developed by the equation below:

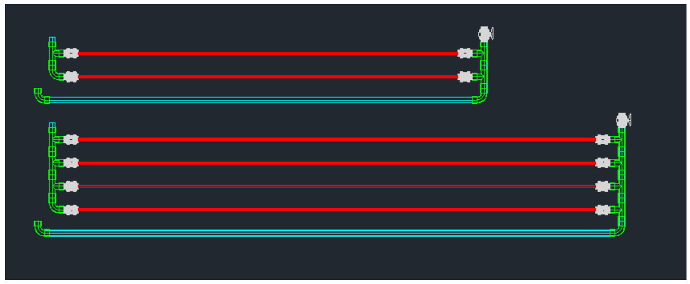


Figure 3: Coagulant and chlorine dosing components with redundancy for 40 L/s plant

$$\eta_r^s = \sum cB \tag{2}$$

Adding chlorine to water will create several different species, and they will interact with each other. After consulting with Prof. Leonard W. Lion, we both think that we cannot model the viscosity equation based on the article. Prof. Lion suggests that we need to use lab method to get the viscosity. And after mixing chlorine with water, we can just assume the viscosity for chlorine is the same as the viscosity of water. As Prof. Lion says, the lab method is easy and not expensive, so using experimental method is feasible and reasonable. However, we do not have enough time to order the materials we need and to set up the experiement. So we suggest that the Stock Tank Mixing team can look into this next semester.

AutoCAD drawing code updates

Dosing components redundancy and entrance tank height adjustment

In the previous semester, the code was modified to generate an extra dosing tube when there is only one dosing tube designed. However, we would want to add an extra tube in all cases. In order to accomplish this, we would need to change the code for both the dosing tube and the manifold. Changing the dosing tube code was fairly easy, because only the array function needs a minor modification. The original function chose the larger number between the number of dosing tube calculated and 2, as the number of rows for the array. Instead of setting 2 as the minimum number of rows, I changed the function to$ArrayLast[(N_{CdcCoagTubes} + 1), 1, B_{DosingTubes}]$, which would draw an extra tube at all times. Similar changes were applied to the manifold code, and the updated manifold systems with dosing tube is shown in **Figure ??**. Since the length of the chlorine manifold would exceed the entrance tank length for low flow rate plants, the origin points of the chlorine manifold were adjusted to be aligned with the coagulant manifold.

While the added redundancy to the dosing components would allow for easier maintenance and operation, it would also increase the size of the manifold systems - they could potentially exceed the height of the designed entrance tank height. The first thing I did was to change the origin points of the delivery pipe so that the entrance tank wall area could be used maximally. After that I tried to draw the manifold systems mounted on the entrace tank wall for different plant flow rates ranging from 40 L/s to 20 L/s , to check at what flow rate will the manifold not be able to fit on the wall.

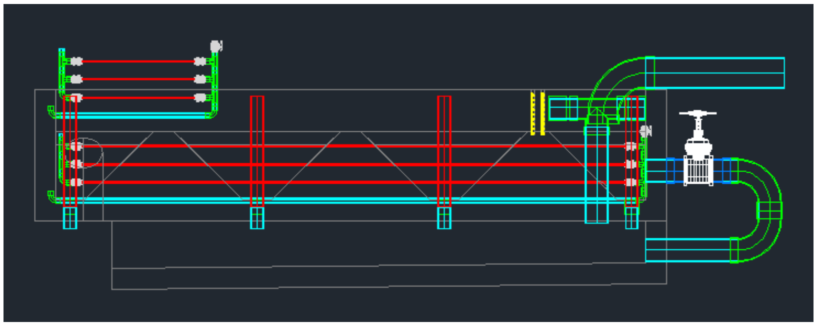
The drawings above showed that adding an extra dosing tube to both manifolds would become a problem at lower flow rates, where the entrance tank is relatively small in size. In order to solve this problem, I added 0.4 m to the height of entrance tank if the plant flow rate is less or equal to $35L/s$. A comparison of the drawing before and after the change is shown in Figure5. The wall height of a 35 L/s plant after the addition is 1.37 m, which is about the same as that of a 60 L/s plant. Therefore the added height to the entrance tank should not hinder the maintenance. However I would like to emphasize that a better solution that doesn't involve height change should be sought due to constraints in construction costs.

Air removal design

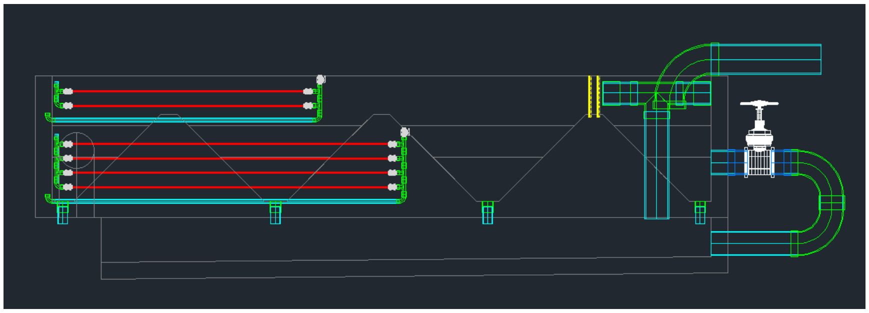
In order to incorporate the air removal device to the CDC drawing, we added a ball valve to the top right side of each manifold system. However, the CDC team had updated the design for air removel since the connecting pipe between the dosers and the drop tube was removed at the end of last semester. In addition, the ball valve is not in the right place in the chlorine manifold system, because an extra dosing tube was designed to be added if there was only one dosing tube required for the system. This problem was eliminated after redundancy was added to both manifold systems under all circumstances.

Lever arm drawing updates

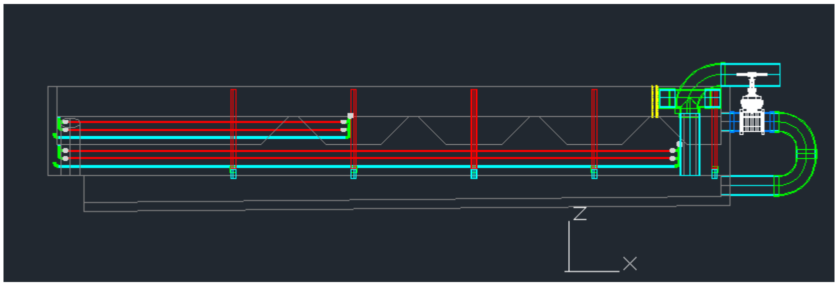
For the plants with only one dosing arm, such like the plants in India, it is not necessary to use a double sized lever arm. By using a single lever arm, we can reduce the weight and save money on shipping. Therefore, we will start working on the drawing of 4 possible types of lever arm: double full sized, double half sized, single full sized, and single half sized. And we will create a function that can help us easily switch among these four types. We were informed by the CDC team that the new single full sized lever will arrive soon. Meanwhile, we can base our updates on their design drawing, which can be found on the server and in Figure 7 below.



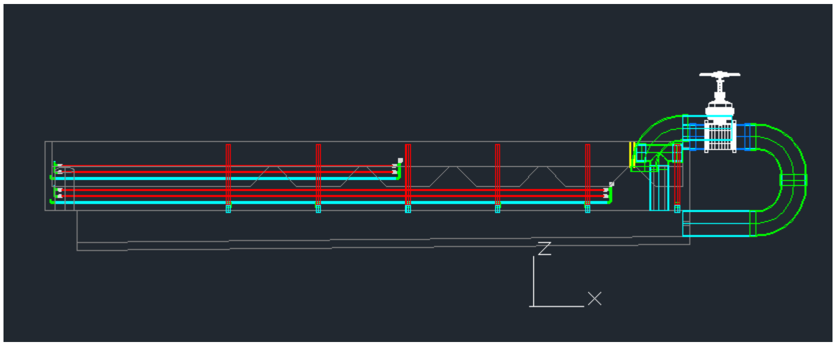
(a) Plant flow rate: 20 L/s



(b) Plant flow rate:40 L/s

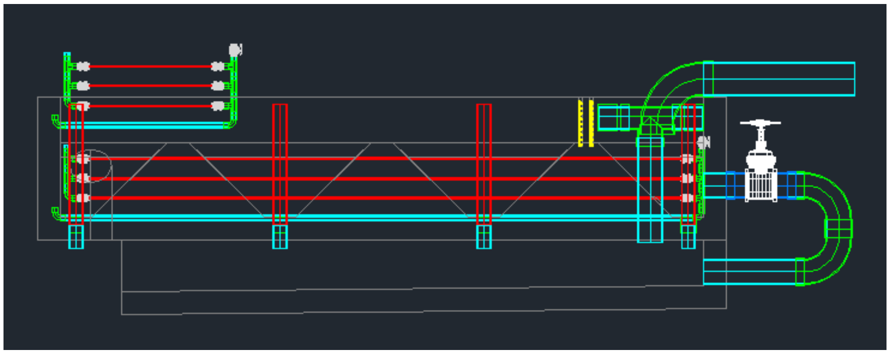


(c) Plant flow rate: 120 L/s

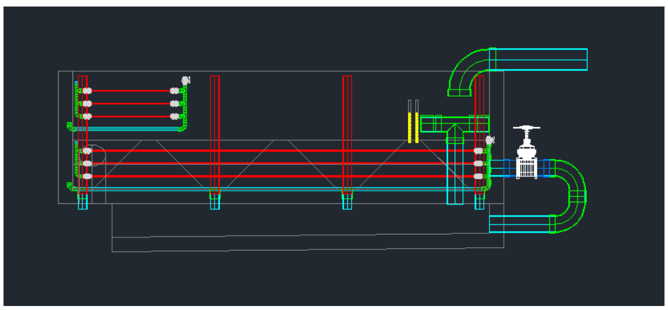


(d) Plant flow rate: 200 L/s

Figure 4: Manifold systems on entrance tank wall at different flow rates

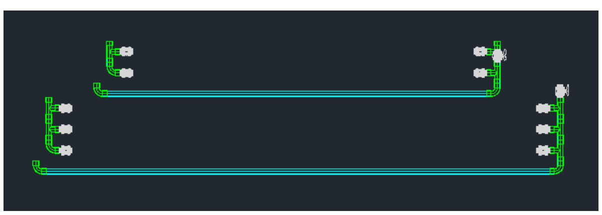


(a) Pre-change 20L/s

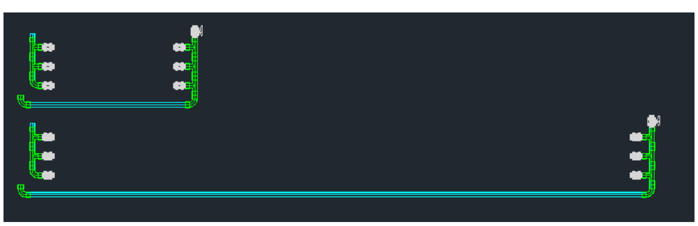


(b) Post-change 20L/s

Figure 5: Entrance wall space adjustment



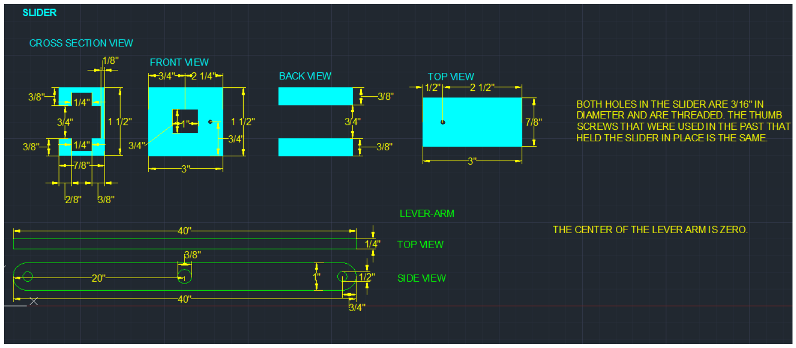
(a) Pre-change



(b) Post-change

Figure 6: Air removal ball valve

Figure 7: Single Lever Arm



rounded edges

Figure 8: Single Lever Arm and Double Lever Arm

Based on the figure, I drew a single lever arm system. We created both the single lever arm and the double lever arm MathCAD code so either design can be chosen based on the type of design.

The figure below shows how the single lever arm looks like in the AguaClara plant system.The drawing still need some details, such as adding the slider and makeing the connections look better.

Flexible tubing function

The FlexTubingF uses the FlexCylinderF to draw the inner and outer tubes, therefore I decided to test first whether FlexCylinderF could function properly. When I used FlexCylinderF to draw the inner and outer tubes connecting the

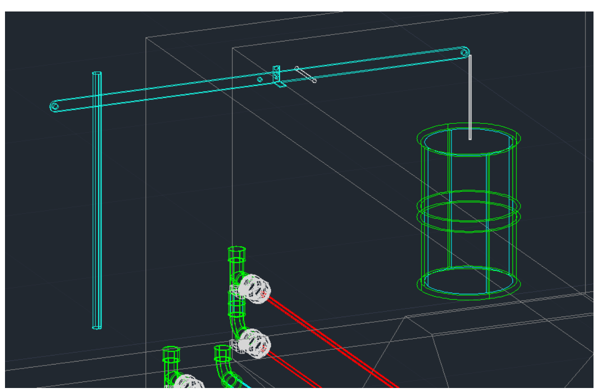


Figure 9: Single Lever Arm in AguaClara Plant

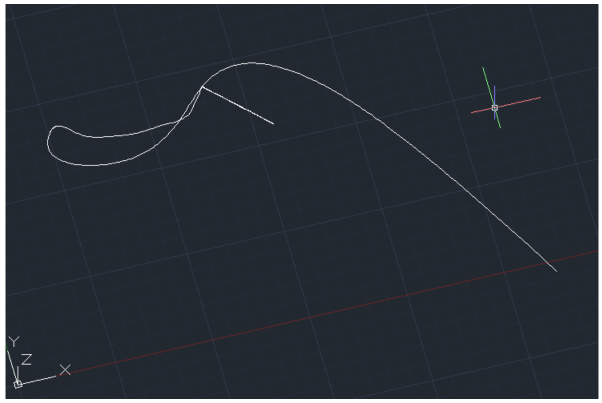


Figure 10: FlexCylinderF used on tubing fromCHT to Manifold

constant head tank to manifold, the sweep function would fail due to the self connection of the spline line, as shown in Figure 10.

Despite that a parabolic curve can be recognized from the drawing, the spline was not properly drawn between the two end points. In order to find the source of the error, I replicated the inlet and outlet points used in the function (CoagCHTtoManifold$_{Inlet}$and CoagCHTtoManifold$_{Outlet}$), and changed the names to “Inlet1” and “Outlet1” while keeping the points the same. This change of the names of the inlet and outlet points eliminated the errors previously observed, Figure **??** shows a drawing of the flexible tubing after the name change. I did the same exercise with the flexible tubing connecting the coagulant manifold and the drop tube, and the tubing could only be drawn when the names of the inlet and outlet points were changed to “Inlet2” and “Outlet2”. I also tried to shorten the name, for example, from “CoagCHTtoManifold” to “CoagCtoM”, but the same error occured. It’s not clear to me why using the AguaClara conventional names for the inlet and outlet points would prevent the flexible tubing being drawn, so future teams would need to examine this issue more closely.

Once the flexible tubing is drawn, two more problems with the function were observed. Firstly, the subtract command was supposed to make the tubing hollow for aesthetic reasons, but instead it subtracted out one of the tubing layers, resulting in a single flexible cylinder. Secondly, the flexible cylinders were first drawn in negative x-axis, and the mirror function was supposed to reverse it to the correct direction, but the mirror function would only work when I manually put in the code line by line. In addition, the original tubing would not disappear after it had been reversed, because the subtract function would only erase the inner tube, which is being mirrored later while the outer tube is left on the opposite side. This problem was fixed by changing the mirror function used from $MirrroLast\left[\begin{pmatrix}0\\0\end{pmatrix}m,\begin{pmatrix}0\\100\end{pmatrix}m\right]$ to “mirror”, and then input the

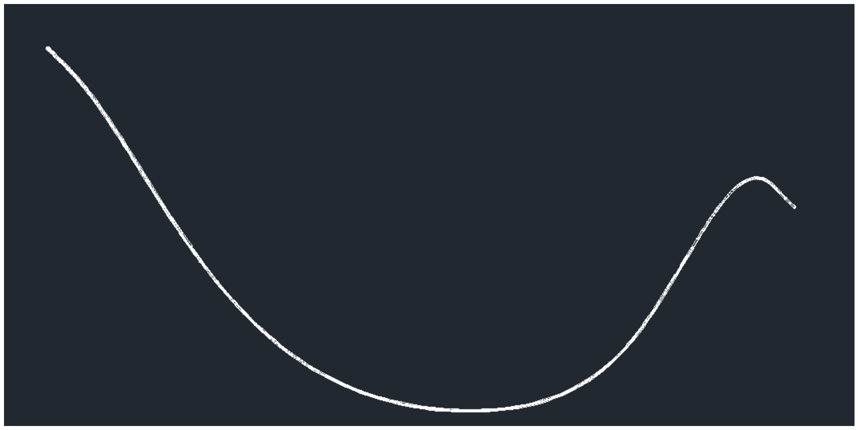
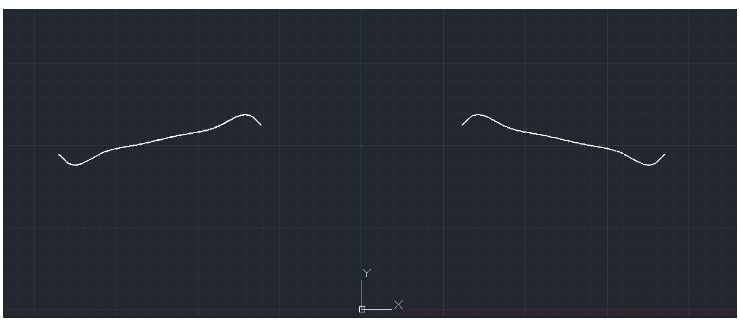
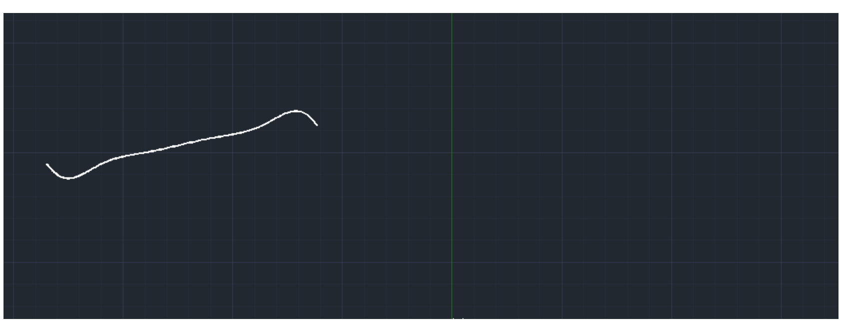


Figure 11: Flexible tubing connecting CHT and manifold



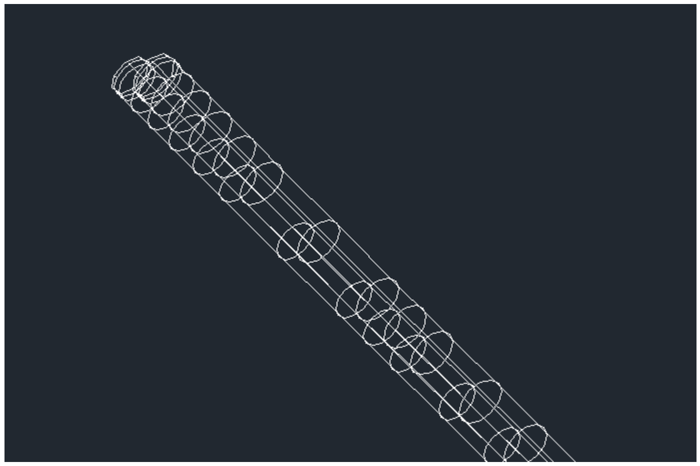
(a) Before the function is fixed



(b) Drawn using current function

Figure 12: FlexTubeF Mirror command

Figure 13: Mismatch of inner and outer tubes



"outlet" point to select the object to be mirrored. The first point and second point of mirror line are still (0,0) and (0,100). The subtract command seemed not to be doing anything because both inner and outer tubes were mirrored no matter if the "SubtractInner" command was used or not. If the inner tube needs to be subtracted out in the future, subtract command should be fixed or we can simply use the FlexCylinderF.

If we zoom in on the tubing drawing shown in Figure **??**, a discrepancy in the inner and outer tube curvatures can be observed, as shown in Figure 13. This mismatch of the inner and outer tubes can either be attributed to the errors in the calculation of points of parabola, or simply due to an error in mirroring the image. Again, this problem can be fixed if we use FlexCylinderF instead of FlexTubeF, because after all the goal is to be able to represent the flexible tubing in the plant drawing.

Future Work

Drawing updates

Since the CDC team is still finalizing their design of lever arm as well as other components, future teams need to work closely with the CDC members to incorporate the most recent changes to the drawings. The current lab set up of the manifold is different from what is used in our plants in Hondurus, so it is necessary to check with the AguaClara engineer first before incoporating changes made to delivery pipe and the air removal device. The plumbing connecting dosers to dosing points should be drawn, which includes the drop tubes, the flexible tubing continuing from the drop tubes, and the 2 inch diameter conduit between the flexible tubing and the filter boxes for chlorine feed.

The Flexible tubing function needs more thorough error checking. Firstly, the tangent point should be fixed so that the segments on the ends are aligned with the inlet and outlet. The naming and stacking problems also need to be solved if we want to incorporate the flexible tubings into the CDC drawing. In addition, future teams should also look into an alternative approach such as using polyline instead of spline, or using FlexCylinderF instead of FlexTubeF.