Design Team–Chemical Dose Controller, Fall 2015

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Table of Content

Part I: Problem Definition

Introduction

This semester, the Chemical Dose Controller (CDC) Team improved the AguaClara Automated Design Algorithm by updating the CDC drawing file to reflect recent updates in the CDC system design. Updating the CDC drawing code will allow clients and team members to obtain an accurate design of the current AguaClara plant designs using the AguaClara Design Tool. When the existing CDC drawing code was implemented with the most uptodate drawing at the beginning of the semester, AutoCAD outputted the design illustrated in Figure 2. As shown in Figure 2, with the existing code, the CDC system is located inside of the Flocculator even though it should be mounted on the outside wall of the Flocculator. This was the starting point of the challenge. By the end of the semester, the CDC dosing system and lever arm were mounted against the Entrance Tank and Flocculator wall.

Design Details

Renaming Variables

The current CDC design parameters are calculated in the CDC design file, and the CDC drawing script is located in the CDC drawing file. As the CDC system itself evolved, the CDC design file was also updated. However, the CDC drawing file was not updated. Thus, the team continued to use and reference the existing CDC design file when updating the CDC drawing file. The CDC system designed in the CDC drawing file was based on the photographs of operating plants in Honduras and dimensions offered by Drew Hart, an AguaClara Engineer. See Figure 1 for the desired CDC design that is used in San Nicolás, Honduras.

Figure 1: CDC system at San Nicolás, Honduras

Past team members who worked on the CDC drawing file did not follow a strict naming convention. The dimensions determined in the CDC design file were called in the CDC drawing file using different variable names. Thus, the team reevaluated each variable in the CDC drawing file and corrected the variable name to correspond to the updated CDC design file.

After renaming and correcting the variable names, the relevance of the existing CDC drawing file to the current CDC system was evaluated. If the design outputted by the existing CDC drawing file was deemed completely irrelevant because it barely reflected the current CDC system, the existing CDC drawing file would have been abandoned. Fortunately, much of the code seemed to be salvageable, so the team decided to update the existing CDC drawing file rather than starting with a blank worksheet. The CDC design outputted by the existing CDC drawing file is shown below in Figure 2.

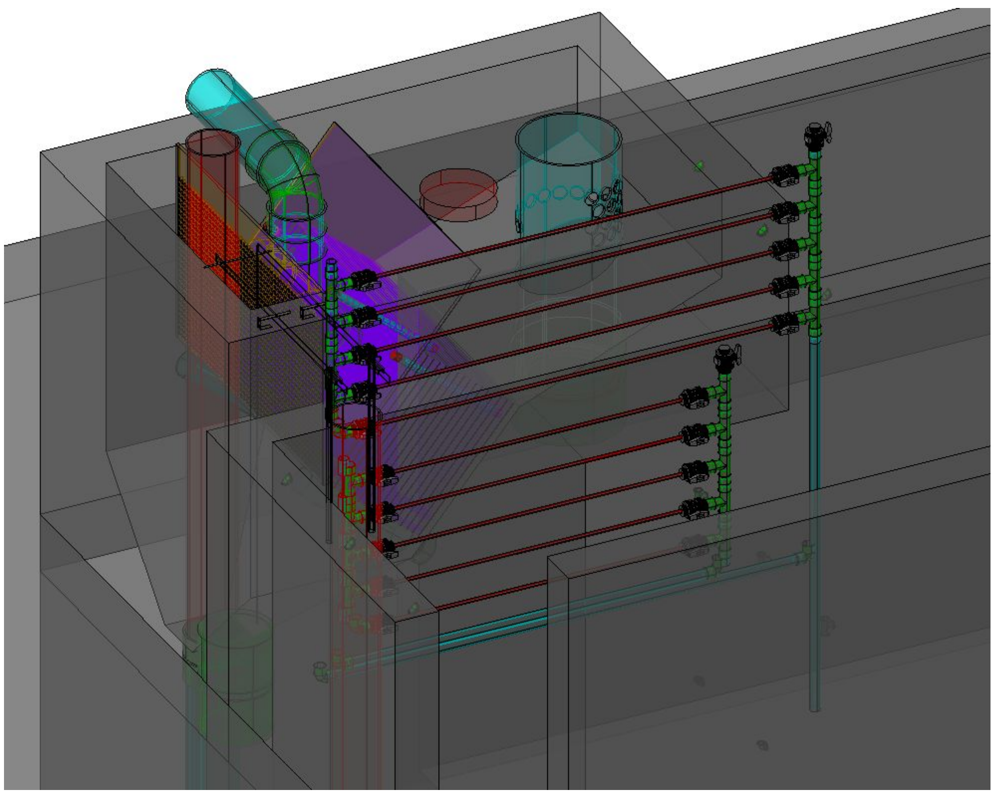

Figure 2: AutoCAD output of the CDC drawing Mathcad file merged with the rest of the plant AutoCAD drawing files

Lever System Updates

The existing CDC drawing file outputted an oversimplified CDC system, especially for the lever system. Hence, the team decided to create a new lever drawing script in the CDC drawing file. The dimensions of the new lever design were based on the levers currently used in operating

AguaClara water treatment plants located in Honduras. The new design of the lever is shown in Figure 3. The theory used to design the lever arm can be found in the Spring 2013 Linear Chemical Dose Controller Final Report(Castro, A., Chan, K., & Ghimire, S. 2013).

In AutoCAD, the new lever system is first drawn in the XY plane as shown in Figure 4. Then, the lever is rotated about its pivot such that the float cable connects to the float when the float is positioned at the maximum Entrance Tank water level. This angle of the lever arm was calculated using trigonometry, head loss equations, and the geometry of the lever as seen in Figure 5.

During the rotation, any parts of the lever system directly attached to the lever are rotated as well. The drop tubes are examples of components that are rotated with the lever. This is shown in Figure 6 below.The ultimate goal is to have these components oriented orthogonal to the XY plane. Thus, the team decided to draw these components on an angle, then rotate them with the rest of the lever. When writing the drawing script for the lever system, initially drawing these parts on an angle simplifies the process of determining their origin points.

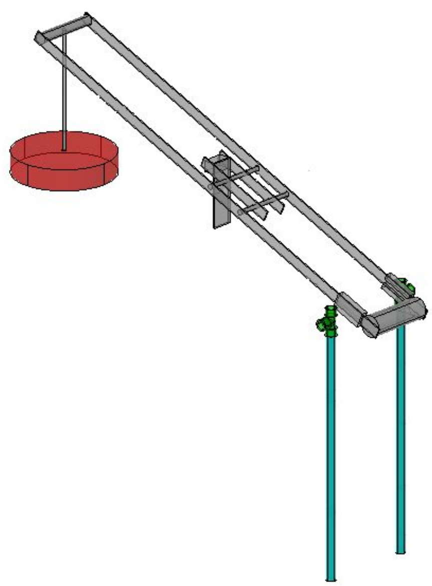

Figure 3: Updated lever design based on levers currently used in Honduras

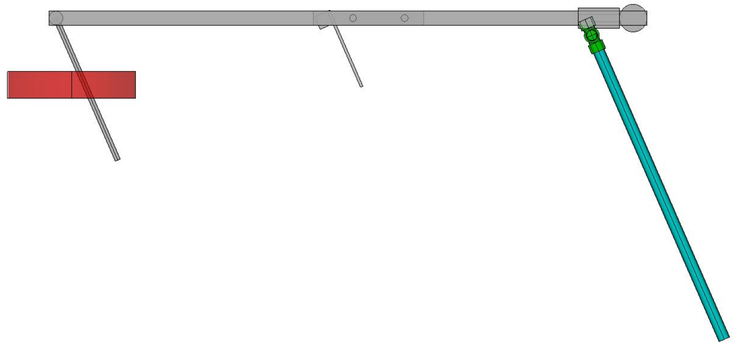

Figure 4: Lever system originally drawn in the XY plane

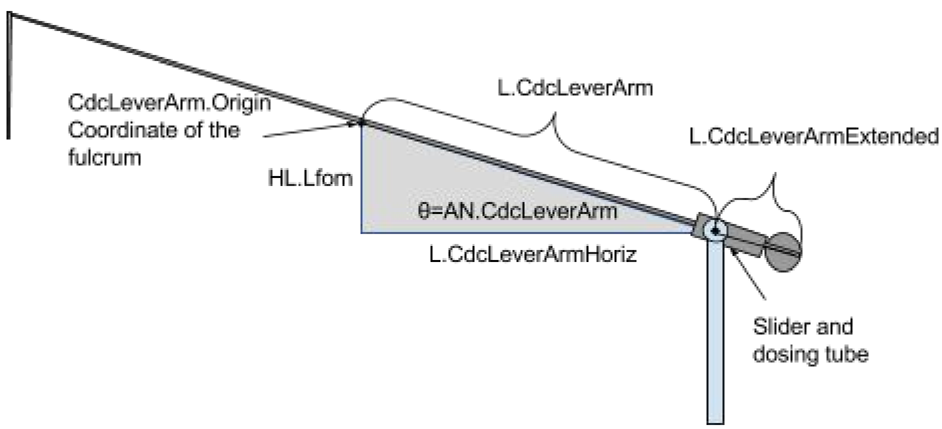

Figure 5: Geometry of the new lever design

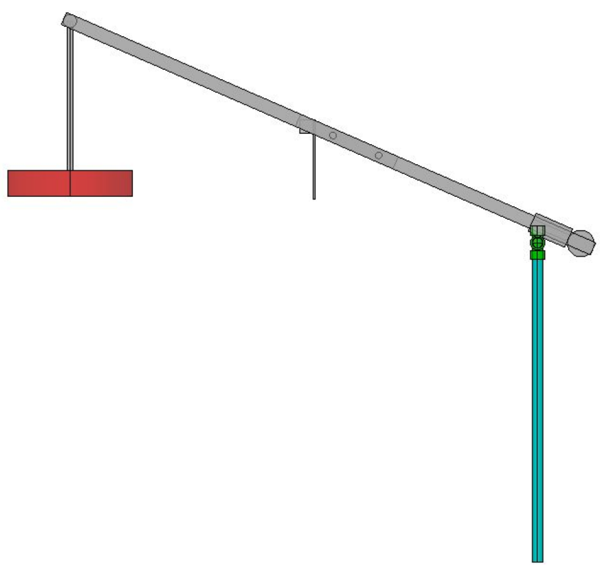

Figure 6: Lever system after it is rotated about the pivot point

Another key design constraint is that the length of the lever arm should not be split in half at the fulcrum. Rather, the the side of the lever with the dosing tube should be slightly longer such that the distance between the center of the dosing tube, when the sliders are positioned at maximum chemical concentration, to the float cable on the other end of the lever is split evenly by the fulcrum. This way, the change in height of the dosing tube attached to the lever will be equal to the change in height of the free surface in the Entrance Tank as shown in Figure 7 Below. The new extended length of the Lever Arm is defined as L.CdcLeverArmExtended. L.CdcLeverArmExtended is the sum of the diameter of the bottom most connecting cylinder and the length of the slider that is below the Z origin of the Drop Tube Tee. See Figure 5 above for the geometry of the new lever.

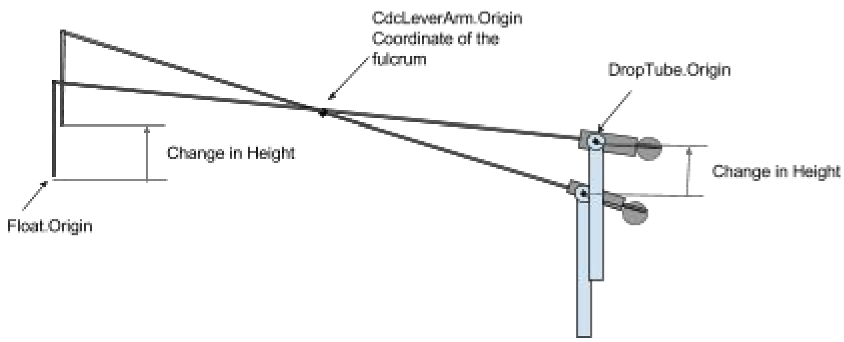

Figure 7: Free surface and dosing tube change in height

Fittings Update

The team noticed that the fittings for a 0.5 in nominal diameter, drawn using the AguaClara Design Tool, do not accurately reflect manufactured 0.5 in nominal diameter fittings. The team measured a 0.5 nominal diameter tee and elbow to get an accurate measurement for their socket depth, short tee length, and elbow radius. These measured values were updated in the Pipe Database. However, when the fittings were drawn with the new dimensions using the TeeF and ElbowF functions, the outer circumference of the sockets overlapped for the tee as shown in Figure 9 below. Thus, the team used trial and error to find the largest possible socket depth that could be used to make the short tee length large enough to avoid overlapping of parts within the tee. Calculations for these dimensions can be seen in Figure 9 below. The new 0.5 in nominal diameter fittings with no overlapping parts can be seen below in Figures 10 and 11 below.

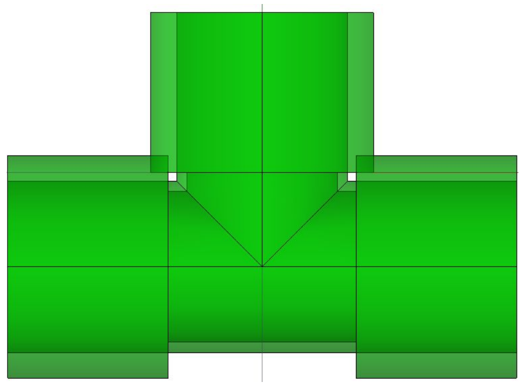

Figure 8: 0.5 in Nominal diameter tee with overlapping sockets. Socket Depth = 2 cm

$$SocketDepth_{Actual} := 2cm$$

$$TeeLength_{Actual} := 2.5in$$

$$ShortTeeLength_{Actual} := \frac{TeeLength_{Actual} - \left(SocketDepth_{Actual} \cdot 2\right)}{2} = 1.175\,cm$$

$$SocketDepth_{NoOverlap} := 1.7cm$$

$$ShortTeeLength_{NoOverlap} := \frac{TeeLength_{Actual} - \left(SocketDepth_{NoOverlap} \cdot 2\right)}{2} = 1.475\,cm$$

$$ElbowLength_{Actual} := 1.25in$$

$$ElbowRadius_{Actual} := ElbowLength_{Actual} - SocketDepth_{Actual} = 1.175\,cm$$

$$ElbowRadius_{NoOverlap} := ElbowLength_{Actual} - SocketDepth_{NoOverlap} = 1.475\,cm$$

Figure 9: Calculations for short tee length and elbow radius as a function of socket depth

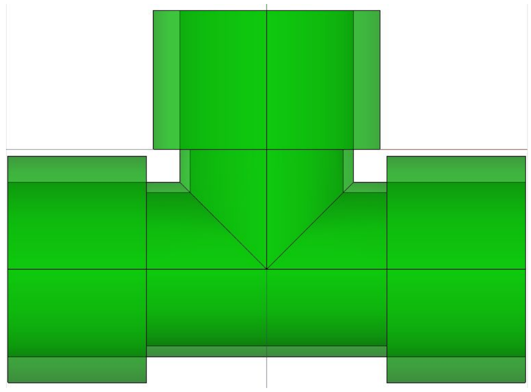

Figure 10: 0.5 in Nominal diameter tee with no overlapping sockets. Socket Depth = 1.70 cm

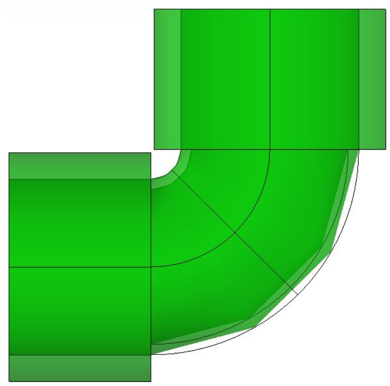

Figure 11: 0.5 in Nominal diameter elbow with no overlapping sockets. Socket Depth = 1.70 cm

Chemical Manifolds and Dosing Tubes

Similar to how the lever arm was relocated, the chemical dosing system was also relocated to be mounted on the Flocculator wall. The original AutoCAD output of the dosing system did not accurately reflect the current dosing design so details were also added to the design.

First, in order to move the system out of the Flocculator and onto the Flocculator wall, the origins were altered such that all of the dosing origins are based on the location of the fittings attached to the dosing tubes that are closest to the lever arm. In Figure 12, the top set of dosing tubes are closer to the lever arm. The outermost point of the fittings attached to these dosing tubes are a set distance from the lever arm.

Then, air release pipes were added to the top of the chlorines manifold. The air release pipes provide an escape route for any air that enters the dosing system. The lower dosing system needs to have a series of 45 degree elbows that are attached to a set of air release pipes. This piping design is necessary to ensure that the air release pipes do not choke the flow of chemicals through the top set of dosing tubes. The new parameters defined for the lever arm and dosing system have been added to the ExpertInputs Mathcad file.

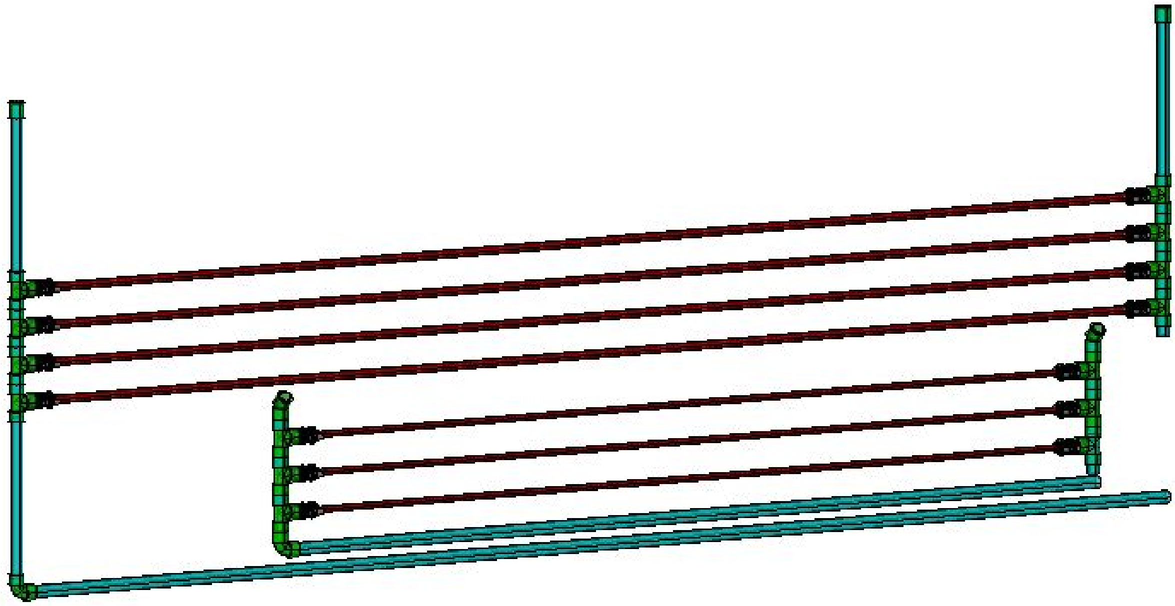

Figure 12: Dosing system mounted on Flocculator wall

Future Goals

Complete Dosing System

In future semester, the team should work on completing the design of the dosing system located on the Flocculator wall. This semester, when the team was working on drawing the 45 degree elbow design, it was determined that the 0.5 in 45 degree elbows have sockets that are overlapping due to the change in fitting dimensions made this semester. Thus, future teams should work on improving the 0.5 in fittings dimensions.

Ball Valve Drawing

In addition to improving the dimensions of smaller plumbing, future teams should find an AutoCAD ball valve drawing that more accurately depicts PVC ball valves used in Honduras.

Constant Head Tanks, Chemical Delivery

After the ball valve function is modified, the ball valve function should be used to complete the drawing code that connects the Chemical Storage Tanks to the Drain Channel and lever.

Additionally, the delivery pipes need to be piped to the Rapid Mix and Exit box of the Stacked Rapid Sand Filter. This piping should be located in the Drain Channel and below the walkway.

Chemical Stock Tank Update

Another update that needs to be coded is the rotation of the Chemical Stock Platform at large flow rates. The CDC drawing code should be modified to include a Chemical Stock function that determines the orientation and organization of Chemical Stock Tanks depending on the flow rate of water entering the plant. The orientation and organization of tubing connecting the Chemical Stock Tanks to the rest of the CDC system should also be adjusted to accommodate for the move of the Chemical Stock Tanks.

Low Flow Plant Lever Arm

At low plant flow rates, the the Entrance Tank design becomes very compact. In these designs, the plate settlers in the Entrance tank are so close to the Linear Flow Orifice Meter (LFOM) that there is not enough space to fit the float in the center of the tank. An alternative design for the Lever Arm or organization of the Entrance Tank needs to be developed to avoid overlap between the float and the LFOM

References

Castro, A., Chan, K., & Ghimire, S. (2013, May 10). Lever Arm Design. from https://confluence.cornell.edu/display/AGUACLARA/Chemical+Dose+Controller?preview=/89459913/218334252/Final%20Linear_Chemical_Dose_Controller_Spring%202013.pdf