Chemical Dose Controller, Spring 2017

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Abstract

The Chemical Dose Controller (CDC) system was designed to maintain a constant chemical dose to the treatment train as the plant flow rate and influent turbidity change. This semester, the CDC team worked on expanding the modular design from previous semesters in order to in improve ease-of-use during operation, better access to the system for plant operators, and greater system efficiency overall. The team designed and fabricated a new and improved constant head tank and calibration columns systems. This semester the CDC team also collaborated with the 1 L/s plant sub-team to create a CDC system for low flow rates.

Introduction

One of the main goals for the Chemical Dose Controller (CDC) team this semester was to keep refining and improving the modular design that was adapted in Fall 2016 from previous semesters. The modular design greatly increases efficiency of the CDC system because it allows for all of the constant head tanks (CHTs) to be in one, accessible spot versus having four different CHTs located in various places around the entrance tank, as is seen in many of the current AguaClara plants. Not only will the modular design make it easier for plant operators to control and adjust the dosage of coagulant and chlorine into the plant, but it will also allow for less assembly when new systems are being installed and greater access to the system when maintenance or cleaning is required. In short, the modular CDC system should allow for increased transparency - a key part of the AguaClara mission - while operating the system.

Building off of the work that was completed in prior semesters, the CDC team this semester worked on adding several key features to the CHT model from Fall 2016. The first was two overflow weirs that will prevent chlorine from overflowing into the coagulant channels (and vice-a-versa) in the event that the float does not stop flow of chemicals from the stock tanks into the CHT; this could be due to particles stuck in the tubing or other maintenance concerns. Another feature of the CHT the team worked on this semester was connecting the PVC walls with dado joints - drilling a slot or trench into the surface - along with the traditional welding. This allows for increased stability and water tightness while also acting as a guide during assembly. The third feature that the team worked on this semester was modifying the float valve so that the orifice will always remain submerged.

Aside from building off of the previous work to make the CDC system more modular, the team this semester also worked closely with the 1 L/s plant sub-team to design a CDC system for low flow rates. This mainly involved decreasing the diameter of the tubing used in the CDC system to something more appropriate, and redesigning the calibration columns and manometers to be attachable to the 1 L/s plant. The 1 L/s CDC system is vital to the operation of the small drinking water treatment system, and will allow for AguaClara technologies to be implemented in small communities and villages around Honduras.

Literature Review

Traditional Chemical Dosing Technology

Traditional chemical dosing systems typically involve a dosing tank and dosing pump. The dosing pump traditionally is a solenoid pump, which regulates the chemical dose by adjusting stroke length and/or frequency. However, if it is necessary to reduce the stroke length, this will reduce dosing accuracy. Additionally, there may be times when the dosing pump cannot operate at 100 percent, which reduces the performance of the valves and reduces their life span (Grundfos, 2016).

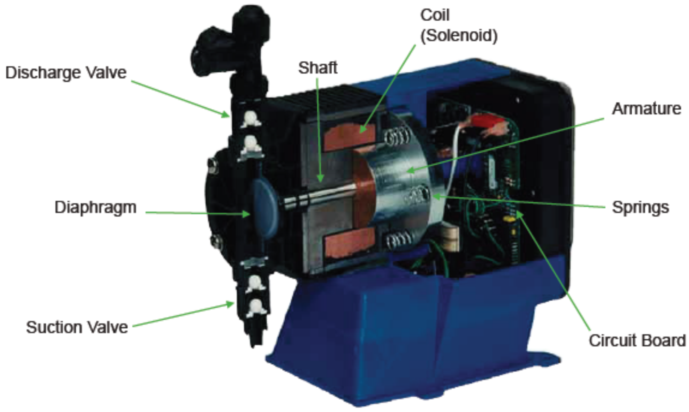

Figure 1: A traditional solenoid-powered diaphragm pump that could be used for chemical dosing. The solenoid valve regulates the chemical dose by adjusting stroke length and/or frequency.

There are also digital dosing pumps, which use a stepper motor to continuously operate at 100 percent, while adjusting the chemical dose by the discharge stroke speed. This leads to better dosing accuracy (Grundfos, 2016).

The disadvantage to both of these chemical dosing technologies is that they are expensive to both purchase initially and to replace. Additionally, they are made to dose for a constant amount of water, and as the amount of water in the entrance tank varies depending on incoming flow, they would have to be adjusted constantly by the plant operator.

AguaClara Chemical Dose Controller Theory

The Chemical Dose Controller (CDC) system was designed to maintain a constant chemical dose to the treatment train as the plant flow rate changes and as turbidity changes. A schematic of the CDC system can be seen in Figure 2.

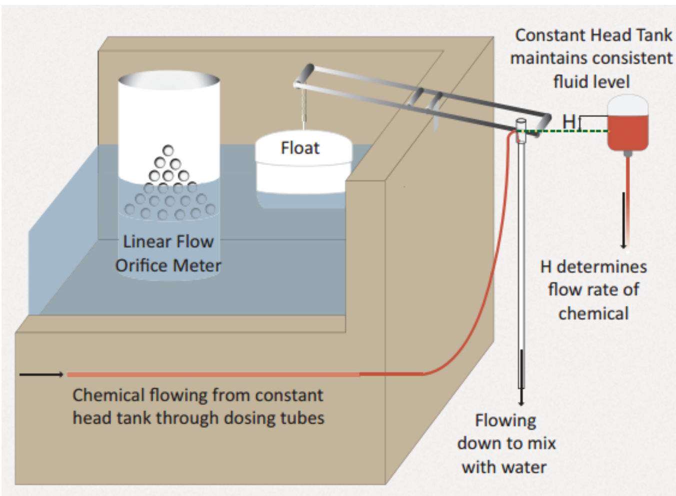

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Figure 2: A schematic of the Chemical Dose Control (CDC) system. The chemical flow rate into the treatment train is automatically controlled based on the elevation difference between the free surface in the CHT and the dosing tube level determined by the water level in the Entrance Tank.

The CDC system consists of the chemical stock tanks, the constant head tanks, the dosing manifold tubes, and the lever arm. The chemical stock tanks hold either coagulant (Polyaluminum chloride, or PACl) or disinfectant (Calcium hypochlorite). These stock tanks deliver chemical to the constant head tanks (CHTs). There are four constant head tanks, two for coagulant and two for chlorine. This is so that one tank can be closed off for cleaning/maintenance without interrupting the flow of chemicals to the plant. A float valve in each of the CHTs keeps the free surface of chemical in the CHT constant, thus maintaining constant head. Chemical then flows out of the CHT into the dosing tubes, and then up to the lever arm, where it flows into a drop tube that is open to the atmosphere. The chemical then flows down the drop tube to mix with water entering the treatment train (Cashon et al., 2015).

The CHT currently implemented is made of Type I PVC. Other common plumbing materials that are resistant to chlorine include Type II PVC and PTFE. Type I PVC is most commonly used for this team's purposes because of the low cost and lack of need for high impact resistant material. Type II PVC is strengthened to be more impact resistant and is therefore more expensive, but is unnecessary for this team's purposes. PTFE is a hard plastic that will be used in valves on the CHT which is more resistant to chlorine than HDPE, which tends to show wear after prolonged exposure.

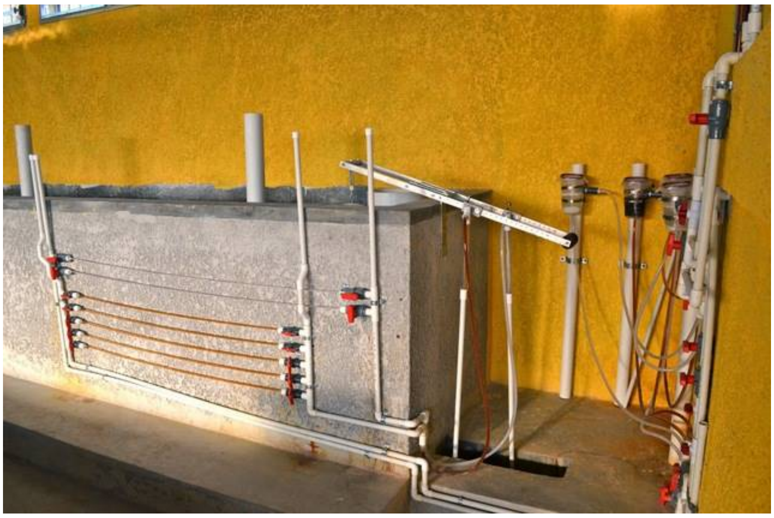

Figure 3: A view of the CDC in an AguaClara treatment plant. All components of the chemical dosing system can be seen, including the CHTs, the dosing tubes, and the lever arm. (Weber-Shirk, 2016)

The dose of chemical added to the plant is based on influent turbidity, and is set by the plant operator using a slider mechanism attached to the lever arm, as can be seen in Figure 4. The chemical flow rate into the treatment train is automatically controlled based on the elevation difference between the free surface in the CHT and the dosing tube. This height difference can either be changed manually by the plant operator moving the slider and therefore adjusting the dose, or will be changed automatically by a change in the flow rate into the plant. Any change in the flow rate into the plant will cause the float in the entrance tank to either rise or fall, which adjusts the lever arm (Chan et al., 2016).

Figure 4: The slider attached to the lever arm is used to set the dose of chemical being added to the plant. It can be adjusted by the plant operator in the event that the turbidity of the influent water changes. (Weber-Shirk, 2016)

Governing Equations

The chemical flow rate through the system is a function of major loss, the kinematic viscosity of the chemical, the length of the dosing tubes, and the diameter of the tubing (Cashon et al., 2015).

$$Q_C = \frac{h_f g D_{Tube}^4}{128 \nu L_{Tube}} \tag{1}$$

The relationship between major head loss and the chemical flow rate is given by the Hagen-Poiseuille equation, which assumes laminar flow. Rearranged in terms of major head loss, the Hagen-Poiseuille equation is a function of the length of the tubes in the dosing manifold, the diameter of the tubing, the kinematic viscosity of the chemical used, and the chemical flow rate (Cashon et al., 2015).

$$h_f = \frac{128 Q_c \nu L_{Tube}}{g D_{Tube}^4} \tag{2}$$

Total head loss through the CDC system is the sum of the major losses due to friction shear, and the minor losses due to flow expansions (Cashon et al., 2015).

$$h_{total} = \frac{128 Q_c \nu L_{Tube}}{g D_{Tube}^4} + \frac{8 Q_C 2 K_e}{g \pi^2 D_{Tube}^4} \tag{3}$$

Previous Work

Current Implementation Design

Currently, a wide variety of CDC systems are implemented across the plants in Honduras. Many are still using Tupperware containers, as shown in 5 to hold chlorine and coagulant which is problematic because the material fails quickly and needs to be taken down and replaced. The tubing at the inlet of the container, shown at the right side, connects the chemical feed stock and the custom float valve. To the left is the outlet tube, which transports chemicals from the CHT to the lever arm.

At the bottom of the CHT is the drain tube, which serves maintenance purposes. When sediment, namely calcium carbonate, builds up and settles at the base of the CHT, the CHT is taken off line and flushed with vinegar to clear off the calcium deposits. At this point, the inlet and outlet tubes are closed off and the drain tube is open to clean out the tank.

Figure 5: The currently implemented CHT design

Although the CHT in Figure 5 uses locally available materials, the Tupperware is not chlorine resistant and must be replaced periodically. (Cashon et al., 2015)

Spring 2015: Chemical Dose Controller Version 1.0

The Spring 2015 CDC team designed a vertical CDC, with the hope that the new orientation would reduce the amount of space the CDC system takes up in the plants. Although headway was made on the rest of the CDC system, the CHT was not modular or chlorine resistant.

Figure 6: The vertical manifold system the Spring 2015 CDC team designed. The goal was to make the system more spatially efficient by having the dosing tubes run vertically instead of horizontally.

Spring 2016: Chemical Dose Controller Version 2.0

The Spring 2016 CDC team addressed the non chlorine resistant nature of the CHT that was being used in Honduras at the time. CDC 2.0, shown in Figure 7 was made of large diameter pipe and utilized modified floats.

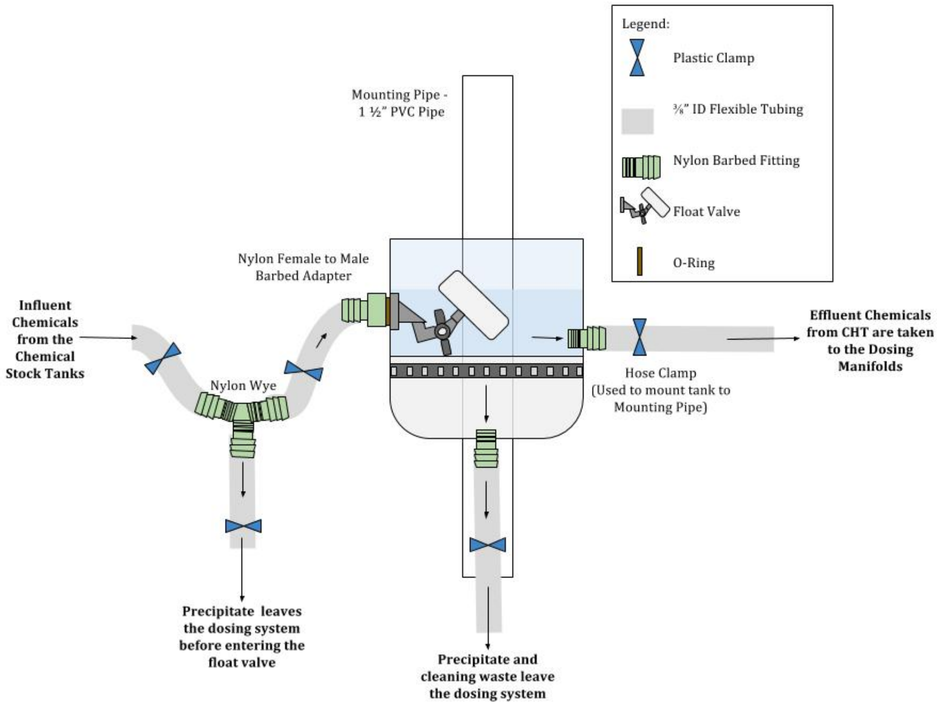

Figure 7: Spring 2016's PVC Pipe Tank Schematic

CDC 2.0 was the first to be chlorine resistant and the rounded bottoms made maintenance to clean calcium build up much easier. Some issues with CDC 2.0 are that it is not modular, it requires modified floats, and it utilizes tube clamps that deform the flexible tubing. There are four separate tanks that all need to be carefully mounted as opposed to one unified CHT with four compartments. The modified floats are also cumbersome as an additional step in fabrication. The CHT tubes use tube clamps to keep fluid passing though the CHT, but over time, these clamps have shown to deform the tubing. Additionally, CDC 2.0 does not have a top so particulates may fall into the tank (Doyle et al., 2016).

Fall 2016: Modular Constant Head Tank Version 1.0

The Fall 2016 team designed and fabricated a chlorine resistant modular constant head tank (MCHT), but did not work on the rest of the CDC system.

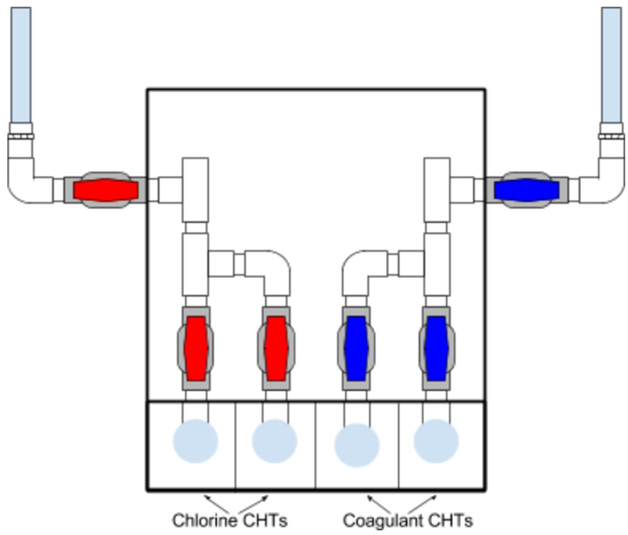

Figure 8: Front view of MCHT 1.0. The design is able to be mounted against a wall. Note: This figure does not show the outlet and drain tubing.

MCHT 1.0, shown in Figure 8, improved upon the previous CHT design in the following ways: combined four chemical tanks into one modular unit, used standard purchasable floats, and switched to rigid PVC to prevent flexible tube deformation. The CHT unit had a large back which allowed it to be mounted to a wall, eliminating the need for a vertical manifolds. Additionally, having the CHT in one modular unit decreased the spatial footprint of the CDC system since all four CHTs are usually spread out around the plant. Furthermore, the modular nature of MCHT 1.0 also eliminated the error that arises from having the tanks at varying heights, which can result in varying pressure and volumetric flow.

For ease of fabrication, the tanks in MCHT 1.0 were set to the length of a standard float. The flexible tube deformation seen in several plants was addressed by utilizing barbed valves instead of tube clamps. Additionally, MCHT 1.0 continued to be chlorine resistant but did not address potential overflow of chlorine or coagulant in the system. The CHT was also left uncovered, allowing debris to potentially fall in and cause clogging or other issues. (Chan et al., 2016)

Methods

Chemical Dose Controller Version 3.0

CDC 3.0 consists of modular constant head tank (MCHT) version 1.1 and modular calibration columns (MCC) version 1.1.

Improvements on CDC 2.0

- Resolution of MCHT 1.0 problems
  - Incorporation of modified float valves
  - Addition of overflow weirs
  - Use of grooves for improved fabrication
  - Addition of clear lid for debris protection
- Inclusion of calibration columns
  - Use of rigid PVC pipe for increased stability and robustness
  - Change column from flexible tubing to clear PVC pipe for better accuracy
  - Inclusion of flexible tubing section to make system height adjustable

Modular Constant Head Tank Version 1.1

Modified Float Valves

The objective of creating a modified float valve was to prevent clogging in the orifice that lets chemicals into the CHT by submerging the apparatus. Existing float valves are intentionally not designed with submerged orifices because they increase the risk of backflow into the chemical stock tanks. The team designed three potential modifications.

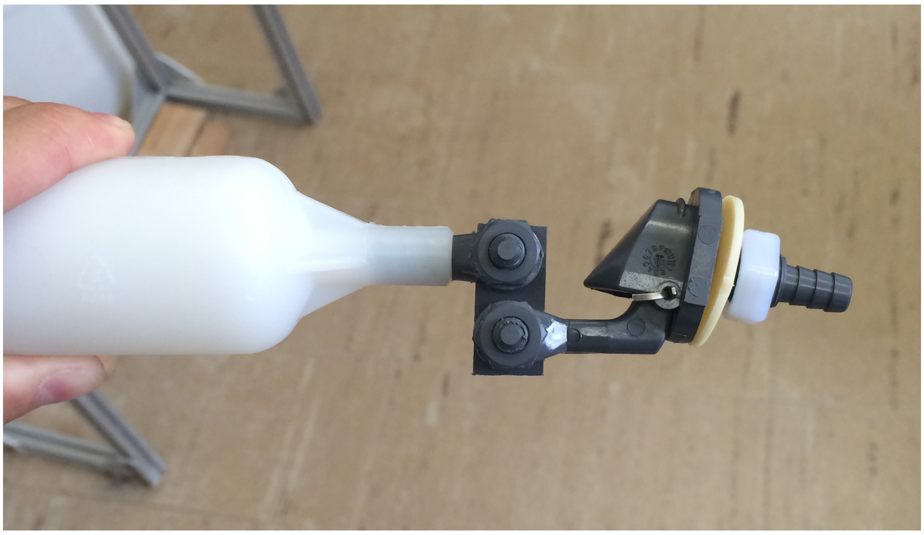

Figure 9: Modified float valve design proposed by Spring 2014 CDC team.

The first modified float valve design was based on the Spring 2014 CDC team's idea, shown in Figure 9, which was not implemented because the configuration would not fit into the non-modular CHT containers. The modified float valve featured an additional vertical component of PVC that raised the float approximately one inch higher than it would normally be.

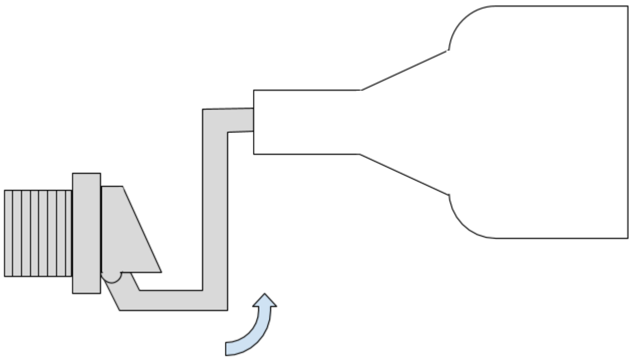

Figure 10: Float Option 1: This modified float valve includes a prefabricated vertical component.

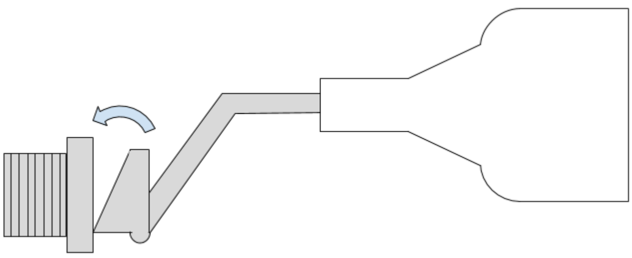

Figure 11: Float Option 2: This modified float valve flips the stopper apparatus.

The other two modifications, shown in Figure 10 and 11, required new injection molded parts that would have needed to be fabricated by a plastics company. The design for option 1 involved a vertical component manufactured as a single piece, which required less engineering time but still required tooling. The design for option 2 flipped the stopper apparatus upside-down, which required the most engineering design time. Since the valve operation is different than the current design, significant design time and testing would be necessary to ensure a robust design is achieved. The team contacted a representative at Control Devices, LLC, the company that AguaClara purchases float valves from, to see if these parts could be constructed. Unfortunately, the cost of injection molding was too high, which effectively left the lab-fabricated design, shown in Figure12 as the only feasible option.

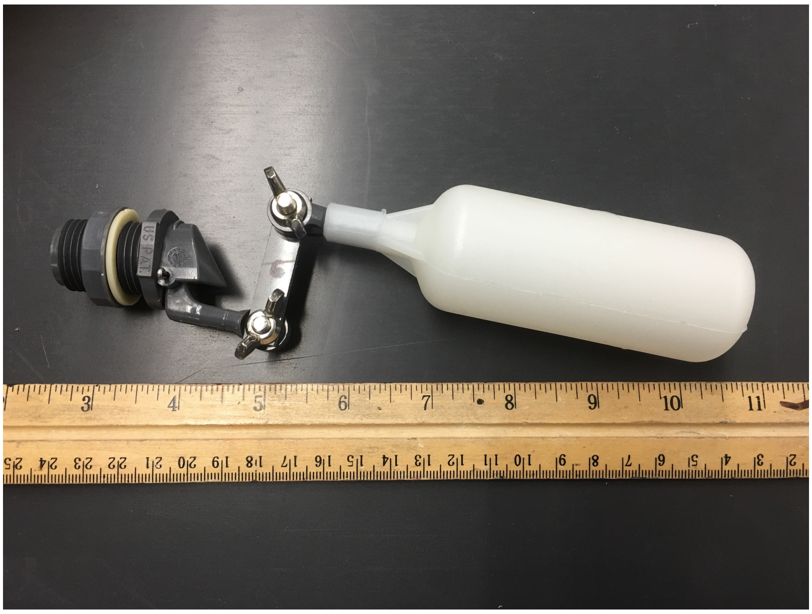

Figure 12: Float Option 3: This modified float valve includes a lab fabricated vertical component connected by nut and bolt.

The only material needed for the modified float valve design was a 1.75 inch by 0.375 inch piece of 1/8 inch thick PVC sheeting, which was cut using the table saw. A quarter inch hole was then drilled into each end of the rectangular piece (0.175 inches away from edges) to attach via the float valve screws.

Overflow Weirs

It was requested that the new CHT design include overflow weirs to drain any excess liquid that could build up as a result of malfunctions in the plumbing system.

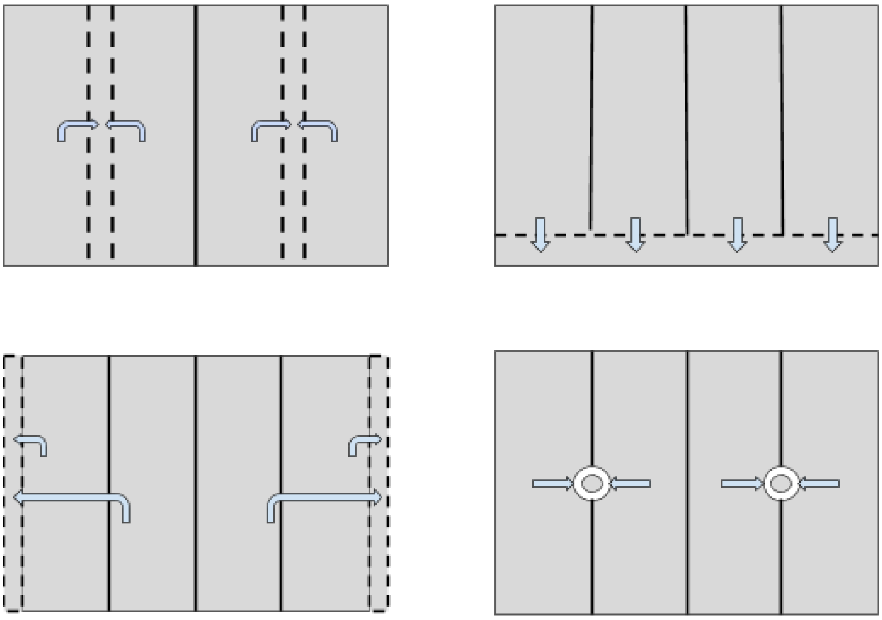

Figure 13: Potential Weir configurations for the CHT.

The bottom right configuration in Figure 13 was selected as the best option because it required only two weirs for four tanks and did not increase the overall CHT area. The weirs were constructed using half inch diameter PVC pipe and were centered in the middle of the tank dividers. The holes were cut using a 13/16 inch hole saw.

The fabricated overflow weir is shown below in Figure 14. The weir was placed 3/4 inch below the height of the tank dividers, and extended 1 inch past the bottom of the CHT. The extension through the bottom accounts for the length of pipe that was needed to go into a pipe coupling.

Figure 14: View of one completed overflow weir.

Grooves

MCHT 1.1 further improved on watertightness and ease of fabrication with the addition of grooves that run fully through the length of PVC sheeting. The grooves were 1/4 inch wide by 1/8 inch deep, which allowed the CHT walls to be slid into place. Inserting the CHT front wall and tank dividers into grooves along the bottom and back faces also provided enough stability to eliminate the need for PVC welding. For watertightness, PVC glue was sufficient to seal any small gaps and was therefore applied at each joint in the CHT. This glue coating can be seen in Figure 14.

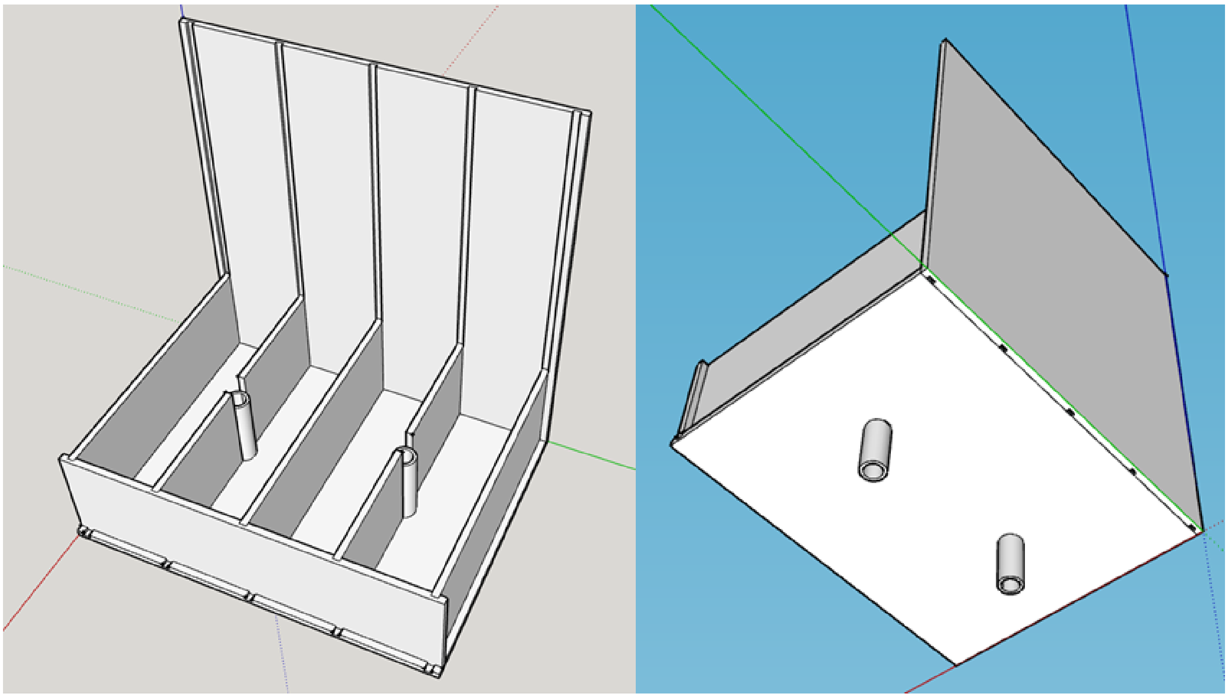

Figure 15: SketchUp model of CDC 3.1 constant head tank from above and below.

Five parallel grooves were cut in the continuous front wall, bottom, and back wall piece (13.75 inches wide) with center lines located 3/8 inches from the side edges and 3.25 inches between. These grooves were cut before the front wall, bottom, and back wall pieces are separated to ensure that the grooves will exactly match. The perpendicular groove cut across the bottom had a center line also located 3/8 inches from the front edge.

Outflow Piping

Chemicals leave the CHT via three different pathways: outflow, drainage, and overflow. For outflow, four holes were drilled into the front wall with a 9/16 inch drill bit. Measuring on the front wall piece, the holes were 0.875 inches from the bottom edge and centered in each tank (2 inches from the side edges, 3.25 inches center to center). Each hole was then threaded using a 3/8 inch tap and fitted with a 3/8 inch thread to 3/8 inch barbed adapter. After a short piece of 3/8 inch diameter clear flexible PVC tubing, a 3/8 inch barbed male (both sides) valve was added to allow for the pipeline to be shut off when necessary.

The drainage pipelines were exactly the same as the outflow, with the only difference being their location. The holes were also centered in each tank but this time on the bottom piece, 1.25 inches from the front edge. The overflow weirs were constructed as described above. The ends of the pipes that stick out from the bottom of the CHT were directly threaded with the 3/8 inch tap and the same 3/8 inch thread to 3/8 inch barbed adapter was fitted onto the end of each pipe. No valve was needed here because overflow should never be shut off.

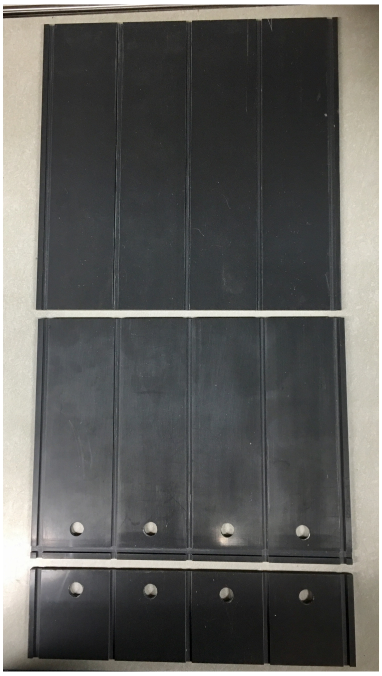

Figure 16: The back wall, bottom, and front wall (shown top to bottom) of the modular CHT with grooves and drainage holes.

CHT Lid

A clear lid was fabricated from 3/16 inch PVC for MCHT 1.1 in order to prevent debris from entering the tank. The lid was designed as a simple slide-on lid that covered slightly more than the entire top and extends partway down the sides of the CHT.

Figure 17: Completed CHT 3.1 with lid and drainage tubing and valves.

Modular Calibration Columns Version 1.0

Incorporating the calibration columns into CDC 3.1 reduced the amount of fabrication required for the pre-made CDC unit. This smaller sized unit has the potential to be very beneficial for the 1 L/s plant that was built in Cuatro Comunidades, Honduras over the 2017 winter break. The existing CDC system and older version of the calibration column made with flexible tubing can be seen in Figure 18.

Figure 18: Existing calibration column on the 1 L/s plant in Cuatro Comunidades. *Source: Anna Doyle*

A schematic of the modular calibration column version 1.0 (MCC 1.0) for CDC 3.1 is shown below in Figure 19. The schematic represents one modular calibration column unit that would be used for a single chemical (i.e. either chlorine or coagulant). Since most plants use both chlorine and coagulant, two of these units would be placed side-by-side in each plant. The design has one calibration column for each of the float valves (four in total) that were placed directly in front of the other piping in order to conserve both space and the total footprint of the CHT system. The ball valves attached to each calibration column control the flow into the column during calibration of the system. The ball valves attached to the piping leading to the stock tanks allow for the operator to shut off flow from the stock tanks during calibration.

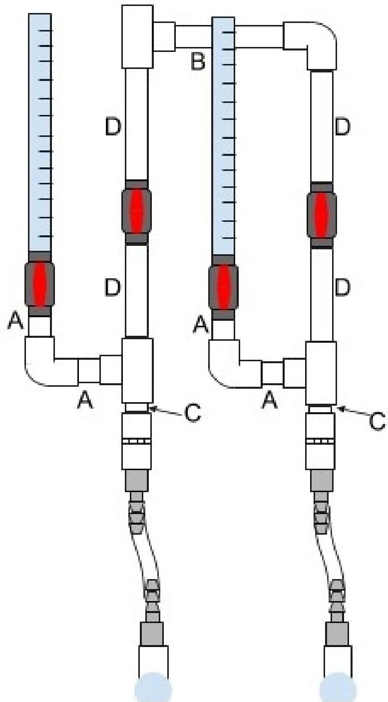

Figure 19: Front view of MCC 1.0. Because the plants use both chlorine and coagulant, there woule be four calibration columns in total, or two of these modular designs side-by-side in each plant. Note: not to scale.

The length of each section of pipe was determined based on space constraints set by the CHT 3.1 design. Pipe A was sized so that there would be adequate room for a plant operator to easily open and close the ball valves without obstruction from other plumbing. The length of Pipe B was based on the center-to-center distance between tanks in CHT 3.1; a length of 4 inches allows for the float valves to be positioned directly in the center of each tank. Pipe C is only used to connect the PVC elbow to the hex adapter, therefore the length is arbitrary and was minimized to conserve space. The length of Pipe D can be increased or decreased depending on what is desirable in each plant. In other words, there were no constraints or design considerations controlling the length. It was arbitrarily set to 6 inches to make the lab-scale model easy to test. The lengths of pipe used in MCC 1.0 are shown in Table 1.

Table 1: PVC Pipe Lengths for MCC 1.0

Label	**Quantity**	**Length (in)**
Calibration Column	2	12.00
A	4	2.00
B	4	6.00
C	2	1.75
D	1	2.75

As incorrectly depicted in Figure 19 due to drawing constraints, the calibration columns were actually placed directly in front of the tubing that leads from the stock tanks to the float valves. This is more accurately portrayed in the side view of the proposed system that is shown in Figure 20.

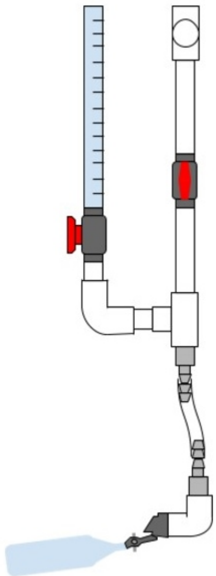

Figure 20: Side view of MCC 1.0 that accurately shows the calibration columns situated directly in front of the other tubing. Note: not to scale.

The fabricated modular calibration column unit is shown below in Figure 21. The calibration column components were attached using PVC glue and NPT thread tape to assure water-tightness of the system.

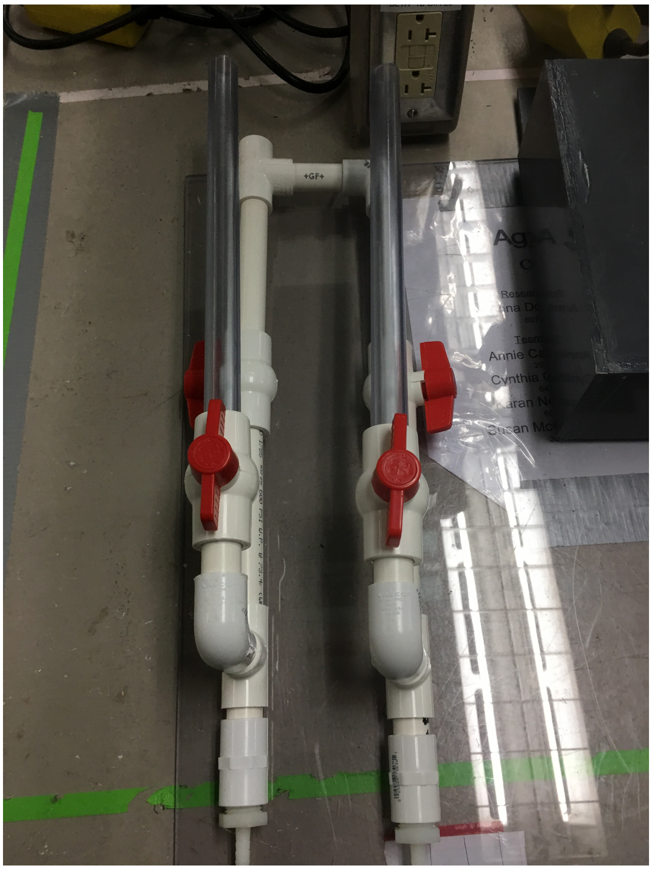

Figure 21: A single unit of the fabricated MCC 1.0.

MCC 1.0 Design Challenges

The team ran into several fabrication challenges when assembling MCC 1.0:

- Cutting PVC pipe with reciprocating saw did not result in 90-degree, straight cuts. This made it difficult to assemble all of the components so that adjoining piping was straight.
- Not completely hammering in PVC pipe sections after PVC glue was applied resulted in different sides of each unit being uneven lengths (seen in Figure 21. A lopsided system could adversely affect calibration or make attachment to the CHT 3.1 back wall difficult.
- Flexible tubing thought to allow the system to be adjustable immediately kinked when bent slightly. This was an issue since it altered the flow rate through the system.
- There was not enough room to turn to the ball valves because of the proposed length of pipe D. Trying to turn the ball valves resulted in hitting the back wall of the constant head tank (MCHT 1.1).
- The length of pipe C did not allow for the lower elbow of MCC 1.0 to clear the CHT lid.

Modular Calibration Columns Version 1.1

A new version of the modular calibration column system was created (MCC 1.1) in order to address the issues of the first design iteration.

Improvements on MCC 1.0

- The band-saw was used (instead of the reciprocating saw) to cut all pieces of PVC to ensure 90-degree, straight cuts.
- The flexible tubing and barbed fitting were replaced with PVC pipe and an unthreaded to threaded PVC elbow (where the float valves directly screw-in). Through lab testing, the flexible tubing was found to "kink" immediately when trying to adjust the float valves up and down.
- Length of pipe C was increased so that that lower elbow connecting to the clear calibration column would have enough clearance above the CHT lid.
- The bottom-most segment of pipe (depicted as Pipe D in Figure 19) was increased to allow enough room to turn the ball valves without hitting the back wall of MCHT 1.1.

Figure 22 below depicts a scale model of MCC 1.1 drawn using SketchUp.

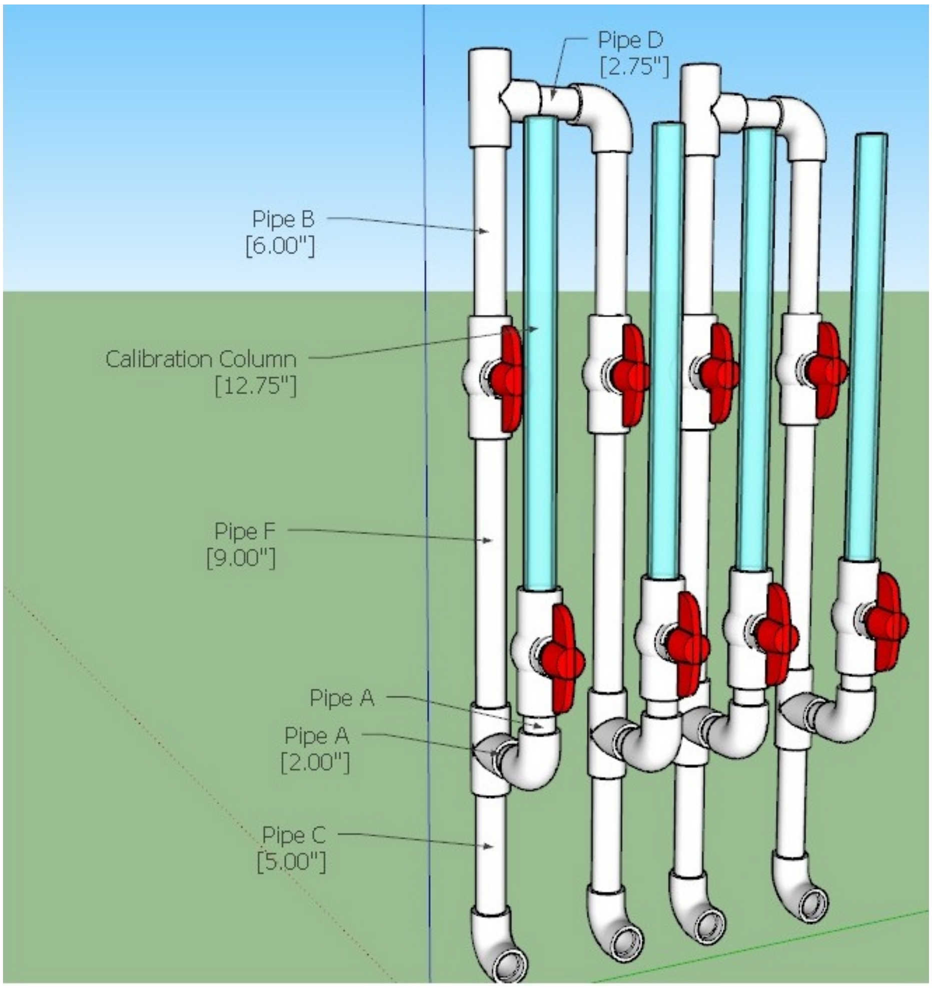

Figure 22: A SketchUp model of the modular calibration column 1.1 system showing pipe lengths.

A fabricated MCC 1.1 unit is shown below in Figure 23. This unit was not cemented together to allow for the pieces to be dissembled and packed when members of AguaClara travel to Honduras in the summer.

Figure 23: Finalized version of MCC 1.1. Please note that the float valves are not shown in this picture, but will be screwed into the PVC threaded elbows located at the bottom of the image.

Manometer Plumbing

Several discussions with Monroe determined that CDC 3.1 would not include the manometer plumbing that monitors chemical levels in the stock tanks. Instead, the manometers will be designed by the plant engineers and operators for each plant. This decision was mostly due to the fact that the modular CHT was already becoming crowded with the addition of the calibration columns. Trying to incorporate the manometers would over-complicate the system without providing any improvements to the current design.

Final Design Materials

The MCHT 1.1 was constructed using a 48x24 inch sheet of quarter inch PVC cut into pieces as specified in Table 2.

Table 2: MCHT 1.1 Component Specifications

Component	Quantity	Width (in)	Height (in)
Front Wall	1	13.75	3.625
Back Wall	1	13.75	13.75
Divider	5	10.25	3.625
Bottom	1	13.75	10.5

The overflow weirs consisted of half inch diameter PVC pipe, each cut to a total length of 4.75 inches. The lid was constructed using a 3/16 inch sheet of clear PVC cut into pieces as specified in Table 3

Table 3: CDC 3.1 CHT Lid Component Specifications

Component	Quantity	Width (in)	Height (in)
Top	1	14.0	8.5
Front	1	14.375	2
Side	2	8.5	2

Table 4: CDC 3.1 CHT Fittings

Part Description	Size	Item Number	Quantity	Price
Straight Threaded Male to Barbed Male Adapter	3/8 tube X 3/8 pipe	5372K118	10	$4.85 (pack of 10)
Barb to Barb Valve	3/8 tube X 3/8 tube	4757K18	8	$11.57
Clear Flexible Tubing	3/8"ID, 3/8"OD	5233K63	25 ft	$0.31/ft

The quantities of the materials for MCC 1.1 and their total cost are listed in Table 5. Note that this is only for one chemical unit (2 calibration columns). A unit is needed for both chlorine and coagulant in each treatment plant.

Table 5: CDC 3.1 Modular Calibration Column 1.1 Materials

Part Description	Manufacturer	Item Number	Quantity	Price
Unthreaded PVC Pipe (clear)	McMaster-Carr	49035K23	**	$9.60
Unthreaded PVC Pipe (White)	McMaster-Carr	48925K91	**	$2.88
Standard-Wall Unthreaded PVC Pipe Tee	McMaster-Carr	4880K41	3	$0.38
Standard-Wall Unthreaded PVC Pipe Elbow	McMaster-Carr	4880K21	3	$0.30
Standard-Wall Unthreaded to Threaded PVC Pipe Elbow	McMaster-Carr	4880K321	2	$0.38
1/2" Compact PVC Ball Valve	US Plastics	20467	4	$1.30
1/2" PVC Adjustable Float Valve	US Plastics	23136	4	$8.67
8-32 Thread Stainless Steel Wing Nut	McMaster-Carr	92001A291	4	$6.18 (pack of 25)
8-32 Thread Plastic Head Thumb Screw	McMaster-Carr	91185A297	4	$11.69 (pack of 25)
Total Costs				**$73.03**

** Quantity and length displayed in Table 6

The lengths of all of the PVC pipe segments (assigned letters in Figure 22) are shown in Table 6. Both the clear PVC pipe used for the calibration column itself and the white PVC pipe used throughout the rest of the design were 1/2" diameter.

Table 6: PVC Pipe Lengths for MCC 1.1

Label	Quantity	Cut Length (in)
Calibration Column	2	12.75
A	4	2.00
B	2	6.00
C	2	5.00
D	1	2.75
F	2	9.00

Results and Analysis

The final design of CDC 3.0 consists of MCHT 1.1 and MCC 1.1. Two full systems were fabricated: one will remain in the lab for testing the 1 L/s plant while the other will be brought to Honduras in parts and be constructed there. A SketchUp diagram depicting the finalized designs is shown below in Figure 24.

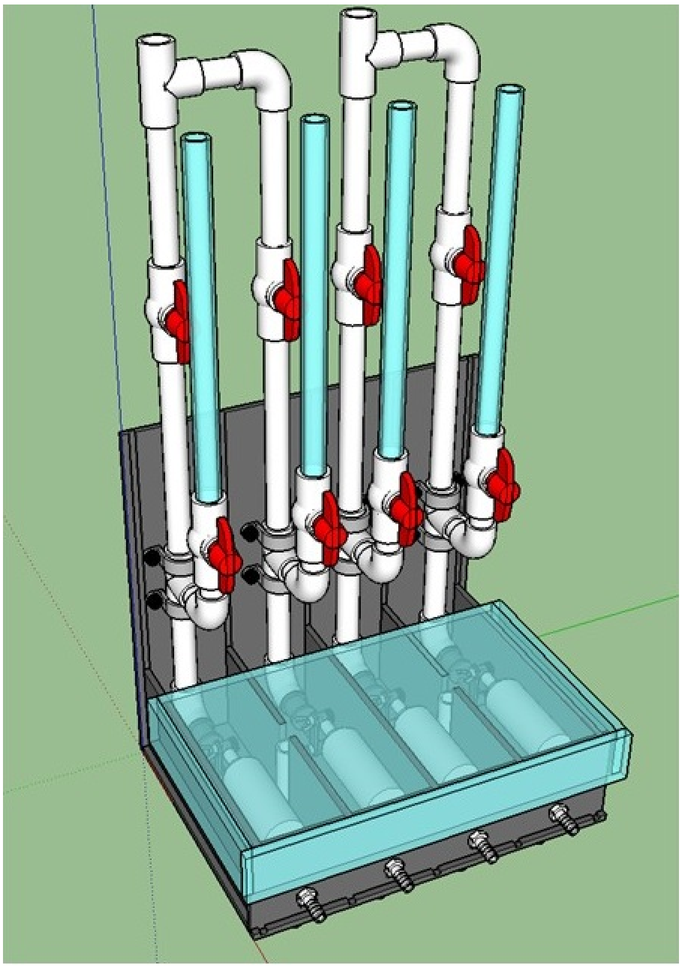

Figure 24: A SketchUp drawing depicting the finalized system, including MCHT 1.1 and MCC 1.1.

Final photos

Conclusions

The overarching objectives for the CDC team this semester were to increase the modularity of the system and to develop techniques that decrease fabrication time while maintaining (or even increasing) structural integrity. These objectives served to increase the transparency and ease-of-use of the CDC system, which are two of the key goals behind the AguaClara project.

The modular design of the constant head tank from previous semesters was expanded to include the attachment of the calibration columns to the constant head tank. Not only did this serve to reduce the footprint of the system, but it also was thought to help plant operators in Honduras use, maintain, and troubleshoot the system by putting all of the major components in one accessible location.

This modular constant head tank (MCHT 1.1) improved upon the Fall 2016 team's design (MCHT 1.0) by adding overflow weirs and a protective cover. Additionally, the fabrication method was changed from using a PVC welder to simple PVC glue. This change was made possible by putting grooves in the walls and bottom of the CHT so that they could fit together like puzzle pieces. Not only did this increase ease of fabrication, it also improved watertightness.

Many specific improvements were made with regard to the calibration column system over the course of the semester. The biggest improvement was incorporating it into the modular design of the constant head tank by creating MCC 1.1. Instead of having four calibration columns scattered around the entrance tank, MCC 1.1 performs the same function while significantly decreasing the footprint of the system. Another significant improvement from the current CDC system implemented with the 1 L/s plant in Honduras was changing all of the flexible tubing to rigid PVC pipe. Not only did this increase the stability of the system, but it also addressed any potential calibration errors associated with accurately timing a known volume of liquid emptying out of a curved, flexible piece of tubing. Further conclusions were made with respect to fabrication techniques when building the modular calibration column system. The biggest conclusion was that it is imperative to make all pipe cuts using the band-saw instead of the reciprocating saw. Using the band-saw made it significantly easier to achieve 90-degree, straight cuts and to accurately cut all pipes to the desired length. Additionally, it was concluded that extra care should be taken when assembling the final system (i.e. connecting pipes to PVC tees, elbows, etc) to ensure that all pipes are hammered into connecting pieces until they reach the socket depth of 0.75 inches (i.e. the built-in ridge found inside all PVC tees, elbows, etc.). Fulfilling this objective during fabrication of the second modular calibration column iteration (MCC 1.1) resulted in a much more symmetric system than was built during the first iteration (MCC 1.0).

Future Work

At the end of the semester, the CDC team finalized the designs and fabrication for MCHT 1.1 and MCC 1.1. The next step for these components will involve bringing the pieces to Honduras and assembling them on-site for testing. Assembly in Honduras will require the following steps:

- Insert overflow pipes into the bottom piece of PVC and slide walls into grooves. Fit back wall onto the remaining side of the box, hammering in pieces as necessary. Use primer and glue on all joints, both between pieces and along seams to fill any cracks with glue.
- Screw outflow fittings into threaded holes and use short segments of flexible tubing to connect each barb to a valve (except for overflows).
- Connect all PVC pipes and connecting pieces (as depicted in the diagrams provided throughout this report) using PVC cement and NPT tape as deemed necessary. Make sure to fully hammer the PVC pipe segments into the connecting pieces (they should be able to be hammered in approximately 0.75 inches).
- Attach MCC 1.1 to MCHT 1.1 using plastic routing clamps and plastic head thumbscrews. The larger diameter clamps (ID = 1-1/16") should be used around the PVC tees, while the smaller diameter clamps (ID = 13/16") should be used around the PVC pipes. Holes should be drilled through the CHT back so that when MCC 1.1 is attached, the float valves are located approximately centrally in the tanks, and are roughly 1.5 inches above the bottom (or that they clear the bottom of the tank when fully lowered).

The future CDC team should also consider performing the following tasks in the AguaClara lab:

- Testing the feasibility of the MCC 1.1 design by performing lab testing. One concern is that the pipe diameter used (1/2") is too small and the calibration column will "fill-up" and "empty" too quickly for timing to be performed.
- Testing the endurance loading of the MCHT 1.1 design by holding the backboard and applying pressure to the front end to see how much pressure it can take before breaking. This will require fabricating a partial MCHT 1.1 unit using the same techniques as outlined in this report (since the result will permanently damage the system). Monroe believes that one student can hold the unit while standing on scale, another student can "push-down" on the front of the box, and a third student can record the scale-reading at the point that the box breaks.
- Collaborating with the 1 L/s sub-team to attach the finalized MCHT 1.1, MCC 1.1, and other components of the CDC system to the small-scale plant located in the lab. This process might reveal design constraints or changes that need to be made to the system.

References

Cashon, A., Leu, C., and Longo, A. (2015). Report CDC Spring 2015.

Chan, C., Doyle, A., and Sangai, A. (2016). Chemical Dose Controller, Fall 2016.

Doyle, A., Shao, V., and Takada, S. (2016). Fabrication Team CHT.

Grundfos, G. (2016). Grundfos Dosing and Disinfection.

Weber-Shirk, M. (2016). Flow Control and Measurement.

Semester Schedule

Task Map

Figure 25: CDC Task Map 2017

Task List

1. ✓Finalize float dimensions to send to Kerick Valve (Thursday 2/23/17) - All team members
    - Finish experimentation with the different PVC elbow lengths to see which allows for the orifice to remain submerged
    - Send the finalized dimensions to Kerick Valve for fabrication
2. ✓Fabricate new Constant Head Tank with overflow weirs (Tuesday 3/21/2017) - Cynthia Chan and Susan McGrattan
    - Finalize the design of the overflow weir geometry and the connections to the stock tanks, calibration columns, and dosing system (Tuesday 2/28/2017)
    - Order parts needed through Cristina (Tuesday 3/7/2017)
    - Fabricate Constant Head Tank using PVC welding techniques (Tuesday 3/21/2017)
3. ✓Determine and create the plumbing system for the calibration columns (Tuesday 3/21/2017) - Annie Cashon and Karan Newatia
    - Sketch calibration column design and write down parts list (Tuesday 2/28/2017)
    - Order parts needed through Cristina (Tuesday 3/7/2017)
    - Fabricate one calibration column that will attach to the CHT system (Tuesday 3/21/2017)
4. ✓Fabricate connections for stock tank manometers (Tuesday 4/25/2017) - All team members
5. ✓Test CDC individual parts as well as overall system for water tightness and design feasibility (Tuesday 5/2/2017) - All team members
6. ✓Have fully-functional CDC lab system for future experimentation and use as a learning tool for future subteams (Tuesday 5/9/2017) - All team members

Team Coordinator: Cynthia Chan
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