Fabrication Team: Constant Head Tank

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Abstract

The main problem with the plastic Tupperware Constant Head Tank (CHT) containers that are currently used in the AguaClara water treatment plants is that they are not chlorine resistant so they have to be replaced frequently. This issue was addressed by the fabrication team this semester. New CHTs were designed, fabricated, and evaluated to determine the best design to be implemented at AguaClara treatment plants. The first design was fabricated from clear PVC sheets and constructed using PVC welding; the second design was constructed out of a PVC pipe and cap. The two designs were then compared in terms of ease of construction, functionality, and costs. Based on this analysis and the recommendations from AguaClara engineers, the second design was determined best and will be implemented in future AguaClara water treatment plants.

Introduction

Constant Head Tanks control the flow from the chemical stock tanks to the dosing tubes and deliver the correct dosage of chemicals to the plant. The main problem with the plastic Tupperware Constant Head Tank (CHT) containers currently being used in the plants is that they are not chlorine resistant and have to be replaced frequently.

Past designs have utilized a 3" PVC tee as the main body of the tank. However, these designs still required a modified float valve. During the semester, the team produced 2 new CHT designs. The first CHT was fabricated from clear PVC sheeting and constructed using PVC welding techniques. The second CHT was fabricated using a PVC pipe and cap. These new designs are chlorine resistant, transparent, and incorporate a new in-place cleaning system.

Previous Work

Constant Head Tank Theory

The Chemical Dose Controller (CDC) system in AguaClara water treatment plants automatically controls the chemical dosage entering the treatment train. An integral part of the CDC system is the Constant Head Tank (CHT), which contains chemical solutions of either coagulant or chlorine which dose the raw water entering the plant. CHTs are designed such that the flow of chemicals leaving the CHT is controlled only by the elevation difference between the free surface in the CHT and the dosing tube exit that is open to the atmosphere. The CDC system is shown below in Figure 1.

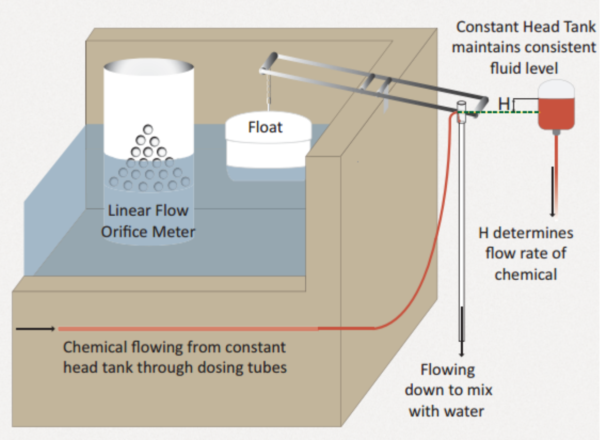


Figure 1: *A schematic of the Chemical Dose Control (CDC) system. The chemical flow rate into the treatment train is automatically controlled based on the elevation difference between the free surface in the CHT and the dosing tube level which is linearly correlated with water level in the Entrance Tank by a Linear Flow Orifice Meter.*

This elevation difference can change in two ways: (1) The operator slides the end of the dosing tube along the lever arm to set the dose. (2) The plant flow rate changes, causing a corresponding change in the entrance tank water level that in turn lifts the float and changes the inclination of the lever arm. This system automatically controls the chemical flow rate based on the influent plant flow rate (Castro et al., 2013).

Current Implementation Design

The current CHT design uses a plastic Tupperware container that is available in Honduras and is shown below in Figure 2. The outlet of the CHT is connected to a dosing tube which carries chemicals from the CHT to the lever arm. As mentioned above in the Constant Head Tank Theory section, the discharge flow of chemical leaving the CHT is determined by the elevation difference between the free surface in the CHT and the end of the drop tube that is open to the atmosphere.

Figure 2: *Current CHT design implemented in San Nicolás, Honduras. This CHT Design uses locally available plastic Tupperware as the tank with a custom float valve. There is evidence of chlorine stratification*

The CHT has an inlet that is fitted with a plastic float valve which connects the CHT to the chemical stock tanks. The float valve ensures a nearly constant head. However, the size of the CHT is restricted by the Tupperware sizes available on the market for the desired CHT volume. The CHT needs to have enough head in order to overcome the headloss leading to the dosing tubes. Additionally, the tank needs to be wide enough to fit an operator's hand during fabrication and maintenance. The available containers of this volume are not long enough to fit the float that originally comes with the 3/8" bulkhead float valves which are currently used. Rather than finding a new container to use as a tank, past CDC teams opted to replace the float with a cylindrical 2" diameter by 3/4" long 6-32 unthreaded polypropylene float. The original and replacement floats are shown below in Figure 3.(Cashon et al., 2015).

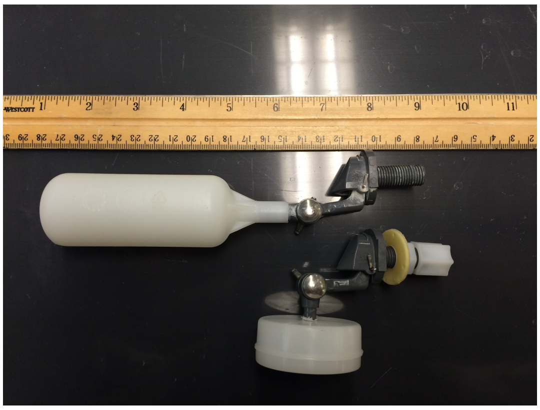


Figure 3: *The float that originally comes with the float valve is shown on top and the custom made float is shown on the bottom. The first iteration of the CHT design accommodates the larger original float valve.*

The Spring 2015 CDC team recognized the need for a new CHT system, because the plastic Tupperware and the O-ring were not chlorine resistant. The CDC system is used to dose coagulant and chlorine so it is important for the CHT to be chlorine resistant to avoid degradation of the tank over time.

Another problem with the existing CHT that the Spring 2015 CDC team discovered was the stratification of precipitates inside the CHT. This occurs when the calcium hypochlorite comes in contact with air. A chemical reaction, between carbon dioxide from the atmosphere and calcium in the calcium hypochlorite, produces calcium carbonate precipitate. Over time, the precipitated calcium carbonate builds up within the CHT and restricts flow through the float valve and the dosing tubes. Specifically, the orientation of the float valve in the existing CHT is right-side-up, exposing the float valve orifice to the atmosphere. This allows calcium carbonate to build-up and clog the float valve orifice. In addition, the bottom of the existing CHT is flat. This allows calcium carbonate precipitate to accumulate and leave the CHT as precipitate to the dosing tubes. Figure 2 above shows stratification of chlorine.

Based on these issues, the Spring 2015 CDC team identified the following ideal CHT design characteristics in their final report:

1. Chlorine resistant: the body of the CHT, as well as the mini-float valve and fitting, will be completely chlorine resistant.

2. Transparent: the operator will be able to easily see if the system is working correctly and if maintenance is required.

3. Stratification control: the design of the CHT will be so that any coagulant stratification will not affect the efficiency or effectiveness of the system.

4. Locally-sourced: all materials can be found and purchased locally in Honduras. This will reduce issues associated with shipping materials from the United States.

The Spring 2015 CDC team determined that PVC was the most affordable and chlorine resistant material to use as a tank. Based on this decision, they developed a design, shown below in figures 4 and 6, that uses a white PVC tee as the CHT and a custom float, shown below in figure 5. This design is chlorine resistant, but it is difficult for the operator to see inside of the tank. In addition, it does not eliminate the problem of stratification or the settling of particles in the dosing tubes(Cashon et.al., 2015).

Figure 4: *The spring 2015 CDC teams chlorine resistant CHT design housed by a 3 inch PVC tee. The design does not prevent stratification and is in a white tank that makes it harder for the operator to see inside.*

Figure 5: *The aerial view of the custom made mini-float valve inside of the CHT.*

Figure 6: *Comparison of the original 5 inch float that comes with the float valve shown on top and the spring 2015 CHT designs 2.5 inch float shown on the bottom.*

Literature Review

PVC Welders

The fabrication team was interested in purchasing a PVC welder to weld PVC sheets together for the body of the CHT. However, there were many uncertainties involved. A literature review collecting information on the specifications and types of PVC welders was undergone.

The primary purpose of a PVC welder, as its name suggests, is to weld PVC. The most typical use for PVC welding involves joint configurations which are seams to join sheets or a patch which laps over the top of a rip or tear. For this type of connection, there are several advantages. PVC welding provides:

- High durability
- Oil and chemical resistance
- Exceptional mechanical and chemical strength
- Fire resistance

Prior to welding PVC, it is recommended to thoroughly clean and remove loose dirt or deleterious materials that could affect the weld area. There are different types of commercial solution (Formula 409®, Mr Clean, Fantastik®, Spray Nine, AllPurpose Cleaner or Zep) cleaner that can be purchased and mixed with water in a 1:1 ratio for cleaning. This should then be applied by wiping the solution on the surface and then rinsing it off.

The welding temperature of PVC is approximately 525°F. Because of the high intensity of heat, some sources suggest that welding PVC could be slightly hazardous. However, in the literature review performed, it seemed that these hazards could be avoided if there is good ventilation where the welding is occurring.

Several brands of welders were researched, including Forsthoff®, Kamweld® and Leister®. The main constraints for purchasing a welder include the price, the air supply, and the nozzle for tacking. The following specifications were considered:

- Voltage (V)
- Power (W)
- Temperature range (degrees F or C)
- Size and weight
- Price (around 500USD hopefully)
- Air supply (compressed air)

Voltage for hand-held welders tended to be either 120 or 230 V, with a power supply of 1600 W and a temperature range of approximately 68 to 1200°F. Price ranged from approximately 500ISD to 1000USD.

During the literature review, it was discovered that a PVC welder was purchased in the past. This welder can be found in the CEE machine shop. It is a Leister® welder whose air supply is compressed nitrogen as seen in Figure 7 and 8.

Figure 7: The plastic welder currently in the CEE machine shop

Figure 8: The compressed nitrogen tank that is the air supply for the plastic welder

A PVC welder was later purchased based on the recommendations and research conducted by the Fabrication team. The team also ordered supplies for working with the PVC welder, including 1/8" welding rod in both clear and white. The size of the PVC welding rod was based on the size of the welder available in the Hollister hall machine shop. In addition, clear and dark gray PVC sheeting was ordered. While the specifications of each sheet are similar, the dark gray PVC sheeting is less expensive because of how it is manufactured. Dark gray sheets were used to practice welding because they were less expensive.

Designs

0.1 PVC Welded Tank Design

The PVC welded CHT was designed to be constructed using a PVC welder. If implemented abroad, this tank would be fabricated in a major city and then sent to AguaClara plants. The team does not recommend this design for implementation because PVC welding is difficult to master and welders are expensive to purchase. If this design were to be implemented, the power of construction would be relocated from plant operators to welding professionals in major cities.

0.1.1 Tank Design

The team designed a CHT and fabricated the system using PVC sheets and PVC welding techniques. The CHT was designed with the following design parameters in mind: ease of maintenance; life time and costs of the materials used; stratification of chemicals; using the original dimensions of the float valve and; locally sourced materials.

The dimensions of the PVC welded tank were based on the dimensions of the float valve as well as the size of a human hand and PVC welder. The size of the human hand and PVC welder were considered in order to ensure that they could fit inside the tank during construction and maintenance. The tank design was drawn in AutoCAD (shown below in Figure 9) and the materials needed to construct the tank (PVC sheets, PVC rods, and ball valves) were purchased. The O-ring used to seal the inside of the tank wall surrounding the float valve is made out of aflas, a material resistant to calcium hypocrite.

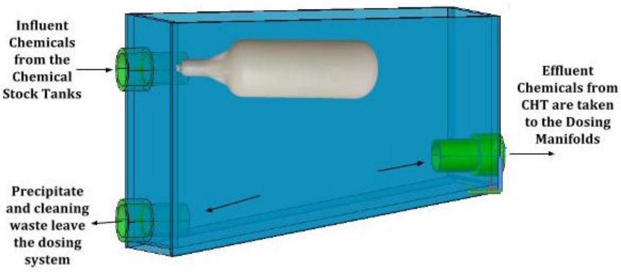


Figure 9: Original CHT design developed in the Spring 2016 semester. This preliminary design has a sloped bottom for suspended solids to settle out. Even with stratification, no solids will leave the exit of the tank as long as the exit is placed above the sloped bottom.

The PVC welded tank was designed to be drained and cleaned without needing to disconnect or move the tank. This means that plant operators would no longer need to readjust the float valve to clean the CHT. This would ensure that the proper flow rate is being maintained in order to provide constant chemical dosage to the plant. Operators would clean the tank by closing the influent and effluent valves and opening the drain valve (shown in Figure 10. Then, the operator would pour vinegar into the top of the tank in order to dissolve the scaling (shown in Figure 11. After the scaling is removed, water is used to flush out the tank. Finally, the influent and effluent valves are once again opened, and the drain valve is closed in order to reconnect the CHT to the chemical dosing system. This process is shown in Figure 12 below.

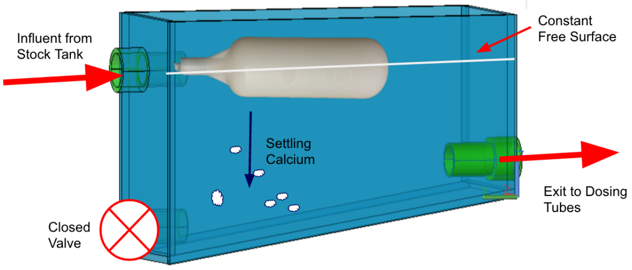


Figure 10: The first step to the cleaning process of the PVC Welded Tank Design. The effluent connected to the chemical dosing tubes and the influent from the chemical stock tanks are closed off.

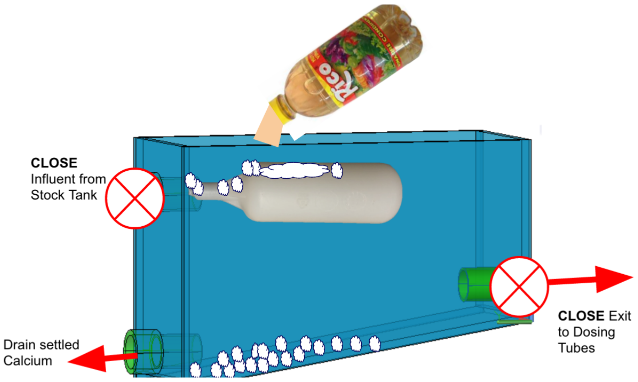


Figure 11: The second step to the cleaning process of the PVC Welded Tank Design. Vinegar is poured into the tank to dissolve calcium scaling.

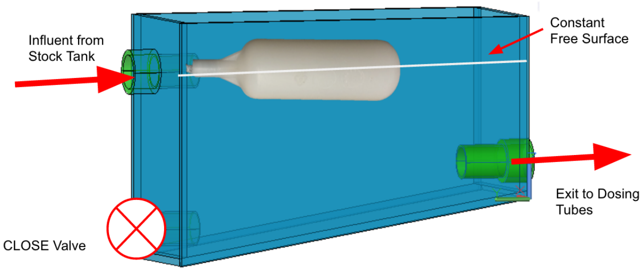


Figure 12: The last step to the cleaning process of the PVC Welded Tank Design. The influent and effluent valves are opened, the drain valve is closed in order to reconnect the CHT to the chemical dosing system

Another design feature of the new CHT is that it has a sloped bottom so that solids that precipitate in the tank will settle out. This will keep the particles from flowing into the dosing tubes or causing blockages. A drain located on the vertical tank wall just above the sloped bottom will be used to clear the settled material. The angle of the slope was selected arbitrarily to 30 degrees to start with. Had this design been pursued further, the team would have performed experiments to evaluate the optimal slope angle for the precipitate to collect.

Table 1: Fabrication Materials for Preliminary Tank Design (available from McMaster-Carr and US Plastic)

Part Description	**Item Number**	**Quantity**	**Price per Unit**
Clear PVC Welding Rod	7889A18	1	13.06
Clear PVC Sheeting, 24 x 36 inches	87545K441	1	66.42
PVC Float Valve	23174	1	8.54
Aflas O-Rings	5240T49	1	8.62/package of 15
Average Total Costs		**1**	**70/CHT tank**

0.1.2 Fabrication

The team spent the first few weeks of the semester researching PVC welders. The first objective was to purchase a welder that would suit the construction needs of the Fabrication Team. Different brands and welder specifications were analyzed, and a list of considerations was created. During the research phase, a PVC welder was found in the machine shop and the CHT sub-team decided that this welder would suit their needs. Research on the specific welder model was conducted, and rods were purchased to be used with the welder. However, a new PVC welder was purchased by Monroe in order to meet the needs of the Pre-Fabrication 1 L/s Team. The CHT sub-team chose to use the new Leister® PVC welder, because it does not require compressed air, allowing for increased mobility when welding.

After the new Leister® PVC welder arrived, the Fabrication Team received a crash course from a trained professional on the basics and safety precautions for using the welder. The key takeaway from this training was to hold the PVC welder at a 45° angle in relation to the PVC sheet. This can be seen in the figure above (Figure 13).

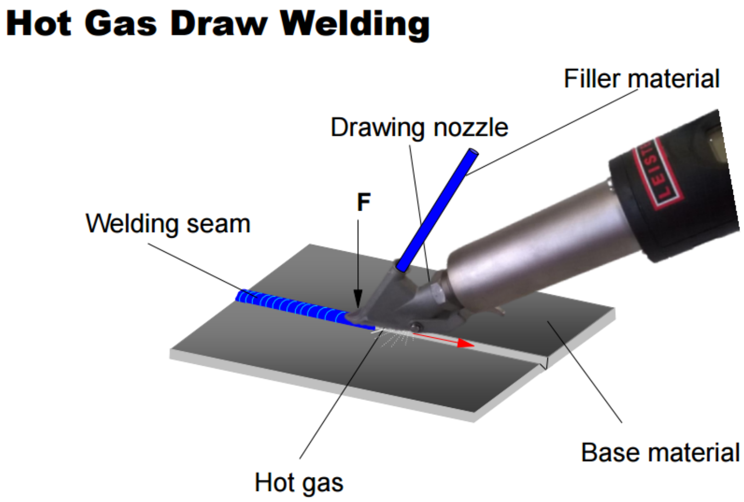


Figure 13: This diagram shows how hot gas welding works. The filler material (welding rod) is fed through the nozzle into the seam created by tacking, in order to form a watertight seal

The first task was to try welding two PVC sheets together at a simple 90° angle. The optimal welding temperature was provided by Leister® in their *Plastic Fabrication Basic Training* materials in *Part 4: Hot Gas Welding* which is available on the AguaClara wiki on the *Plastic Fabrication Basic Training by Leister* page. This temperature is important because if the temperature is too low, the PVC does not melt. On the other hand, if it is too high, the PVC will scorch and burn. For tacking, the initial process of melting and joining two pieces, the best temperature is 550°F. In this step, the welder is slowly traced along the seams until a connection is visible.

When adding the PVC filler rod, the best temperature is 520°F. The team tried using two different filler rods. The team had difficulty incorporating the white rod; it jammed up the welder nozzle and did not melt as easily. However, the team had much more success with the clear rod. As practice, the team made several 90° angle sample PVC sheet connections to become familiar with the PVC welder and develop welding skills and techniques.

After initial training with the PVC welder, the team tried to make a pilot-scale tank. Five walls were measured out and cut using a table saw. It was determined that for the final tank prototype, an additional 1/16" - 1/8" should be added to each length to account for the width of the saw blade. The pieces were then joined together using PVC welding techniques. With this experimental tank, the team had a lot of difficulty getting the corners of the tank to seal properly because of the shape and size of the welder nozzle. Several experimental corners were made using a number of different techniques. Eventually, the team was able to make a tight seal. The best method to get a water tight corner is to allow the filler rod to melt at the tip of the nozzle and slowly melt it into the corner before pressing it down and continuing along the seam.

0.1.3 Analysis

The team deemed the first CHT design to be unfeasible. The primary concerns with this design surrounded the difficulty of using a PVC welder and the limited access to PVC welders in Honduras. In addition, the time and financial expenses required to master PVC welding and assemble a single CHT when compared to the existing and alternative design would be impractical.

The team also had a difficult time sealing the PVC welded CHT to be water-tight, a critical characteristic for a constant head tank. In particular, the seals in the corners were extremely difficult. Thus, PVC welding will be eliminated in the second CHT design developed in the Spring 2016 semester.

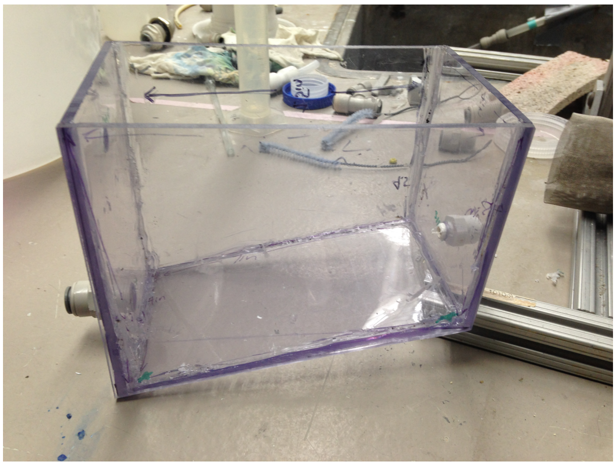


Figure 14: This picture shows the prototype of the welded CHT. While the float valve was not in place, the sloped bottom feature can be seen by this picture. In addition, the drainage hole on the opposite vertical walls at the top and bottom of the slope are visible.

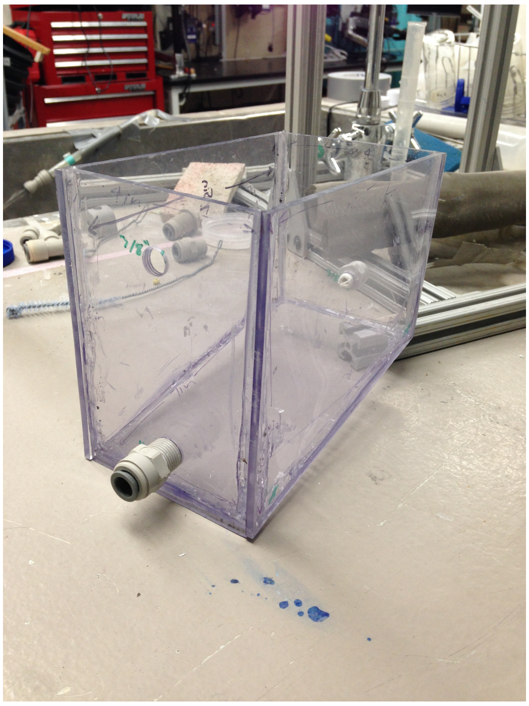


Figure 15: This picture shows an angled view of the tank. The biggest problem with this tank design was during the fabrication process, more specifically, welding the corners so that there would be a completely water tight seal.

0.2 PVC Pipe Tank Design

The PVC Welded Tank was not feasible because the fabrication of the tank was too difficult and required the use of a plastic welder. The PVC Pipe Tank design addresses this problem because there is no PVC welding involved in the fabrication of this tank. All of the components can be purchased in Honduras and fabricated using PVC cement glue. If implemented abroad, this tank could be fabricated and repaired at the implementation site, because there are no additional tools necessary to fabricate the tank.

0.2.1 Tank Design

The PVC Pipe Tank (shown in Figure 16)was designed to be fabricated using ordinary tools such as screw drivers, wrenches, and PVC cement. The tank was also designed to reduce the amount of time operators spend to maintain the CHT. This was ensured by applying the following design specifications: chlorine resistant material (PVC, nylon, aflas); sloped bottom for settled precipitate; a separate drain outlet used for in-place cleaning; easy elevation adjustment

In this design, the Fabrication Team decided not to focus on using the original float valve. Instead, the team decided to use the specially manufactured cylindrical 2" diameter by 3/4" long 6-32 unthreaded polypropylene floats.

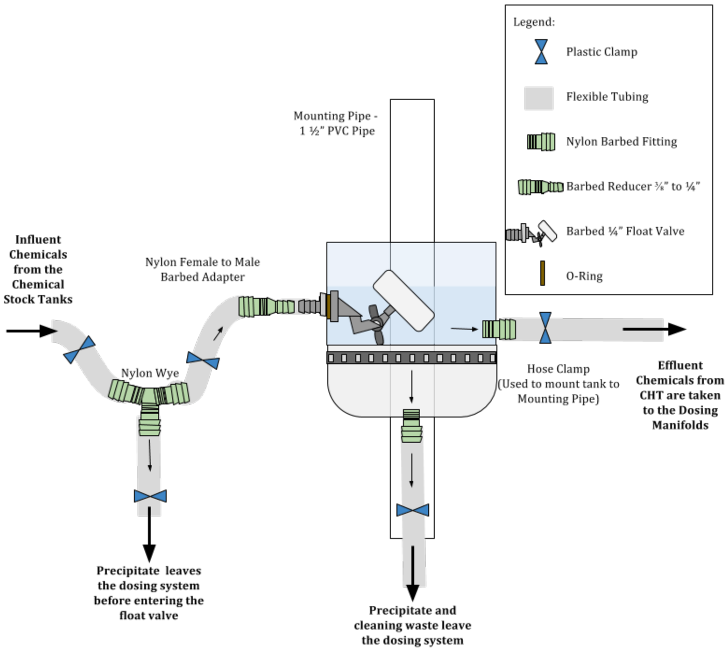


Figure 16: This schematic shows the design of the PVC Pipe Tank Design. The tank itself is constructed out of a 4" inner diameter clear PVC pipe attached to a 4" inner diameter white PVC cap. The nylon wye and appended piece of flexible tubing serves as a collection basin to capture any particles that precipitate before passing through the float valve. The barbed bulkhead float valve is oriented up-side-down in order to keep the float valve orifice submerged. Like the PVC Welded Tank Design, the bottom of the tank is sloped and there is an exit in the tank that serves as a drain which is used for in-place cleaning. The tank is attached to a pipe that will be to the wall. The tank is attached by a hose clamp which allows for easy adjustment of the height of the tank. There are plastic clamps on each piece of flexible tubing to prevent contamination during cleaning.

The PVC Pipe Tank design was fabricated using PVC parts available in Honduras. The team fabricated the tank (shown in Figure 16) using a clear PVC pipe (6" long and 4" inner diameter) and a 4" inner diameter schedule 40 white PVC pipe cap. The PVC pipe cap provided a sloped bottom where the precipitate would settle out over time. The pipe and cap were joined using PVC cement.

Three holes were drilled into the tank (One 7/16" diameter hole for the float valve and two 3/8" diameter threaded holes for fittings that lead to the exit to the Dosing Manifolds and to the Drain Channel). Nylon barbed fittings (3/8" outer diameter) were used to attach the flexible tubing that leads to the dosing manifolds and to the drain channel. An adjustable float valve with 1/4" barbed inlet (with the replaced float), in combination with a 1/4" to 3/8" outer diameter barbed reducer, bulkhead fitting and an o-ring, were used at the entrance to the tank (shown in Figure 17). The float valve is oriented up-side-down in order to keep the float valve orifice submerged and not exposed to the atmosphere. The pipe wall around the float valve hole was flattened out (using the heat from a PVC welder) in order to have a straight surface that will ensure that the O-ring provides a water tight seal (shown in Figure 18).

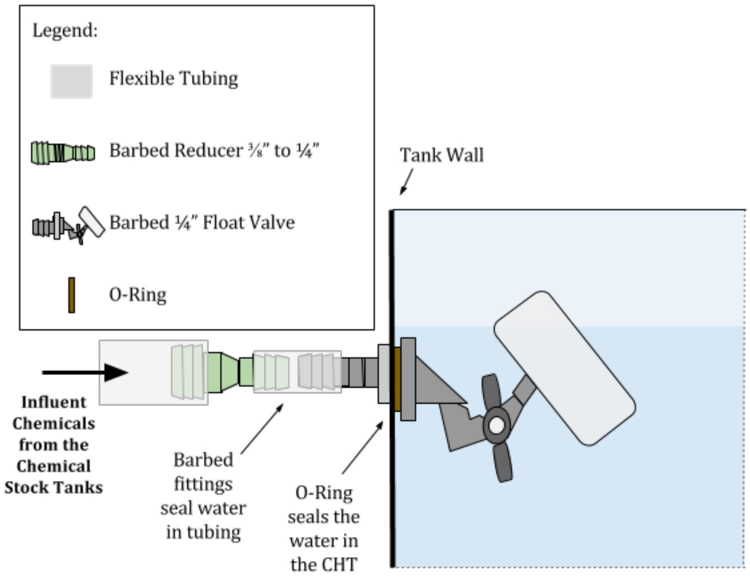


Figure 17: This schematic shows the connection between the mini adjustable PVC float valve with 1/4" barbed inlet and the flexible tubing from the Chemical Stock Tanks. The barbed fittings and the O-Ring provide a water tight seal.

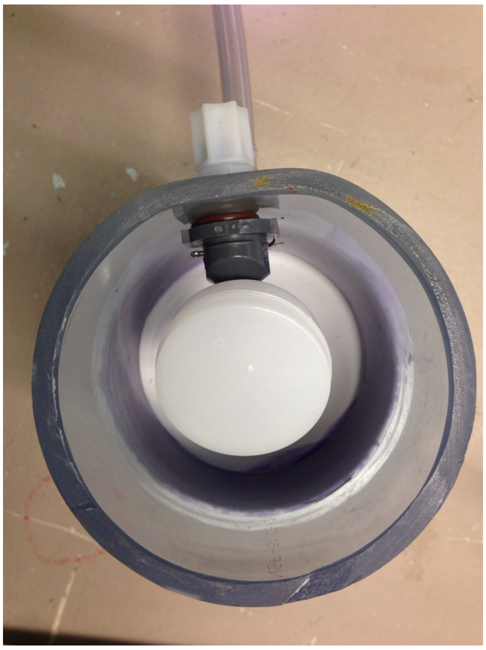
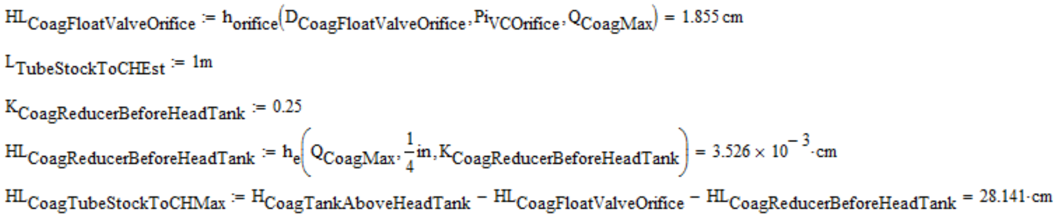


Figure 18: This photo shows the flattened portion of the outer tubing. This was done in order to increase the contact between the fitting and the wall. During the fabrication process, the team used a PVC welder to heat up the PVC pipe. However, this molding step can also be done without a PVC welder. PVC molding is currently done in Honduras by heating up the PVC in vegetable oil and the molding the shape.

The team was concerned that the head loss through the smaller float valve would exceed the 30 cm head loss limit set by the elevation difference between the Chemical Stock Tank exit orifice and the float valve orifice. However, the team calculated that the additional head loss through the reducer and the float valve did not exceed 30cm as shown below in Figure 19.



$$HL_{CoagFloatValveOrifice} := h_{orifice}(D_{CoagFloatValveOrifice}, Pi_{VCOrifice}, Q_{CoagMax}) = 1.855\,cm$$

$$L_{TubeStockToCHEst} := 1m$$

$$K_{CoagReducerBeforeHeadTank} := 0.25$$

$$HL_{CoagReducerBeforeHeadTank} := h_e\left(Q_{CoagMax}, \frac{1}{4}in, K_{CoagReducerBeforeHeadTank}\right) = 3.526 \times 10^{-3} \cdot cm$$

$$HL_{CoagTubeStockToCHMax} := H_{CoagTankAboveHeadTank} - HL_{CoagFloatValveOrifice} - HL_{CoagReducerBeforeHeadTank} = 28.141 \cdot cm$$

Figure 19: Calculations to confirm that the additional head loss through the reducer and smaller float valve does not exceed the available head between the Chemical Stock Tanks and the CHT.

A Nylon Wye barbed fitting (3/8") and an appended piece of flexible tubing serve as a collection basin to capture any particles that precipitate before passing through the float valve. During regular operation, this appended piece of tubing will be clamped with a plastic tube clamp.

In-place cleaning will be performed in the same way as the PVC Welded Tank Design. However, the valves are replaced with plastic clamps and rather than pouring the vinegar directly into the tank, it will be poured into the appended piece of flexible tubing located before the float valve on the outside of the tank. When cleaning, the appended piece of tubing will be pointed towards the ceiling. Then, the clamp will be removed and vinegar will slowly be poured into the tube. This process will remove any scaling on the float valve orifice without the need to remove the float valve from the tank. When the float valve and the tank are clean, water is flushed down the same tubing and the clamp can be returned to its original position. There are plastic tube clamps on each piece of flexible tubing that are closed during cleaning in order to prevent contamination during cleaning.

In an AguaClara water treatment plant, there are at least two sets of chlorine CHTs and coagulant CHTs. This is done so that at least one of each CHT will be connected to the system during the maintenance of the other set of CHTs. In this design, all of the CHTs will be attached to a frame made of 1" PVC pipes, elbows and tees. The complete system will be mounted to a wall using hooks and is shown below in Figure 20 below.

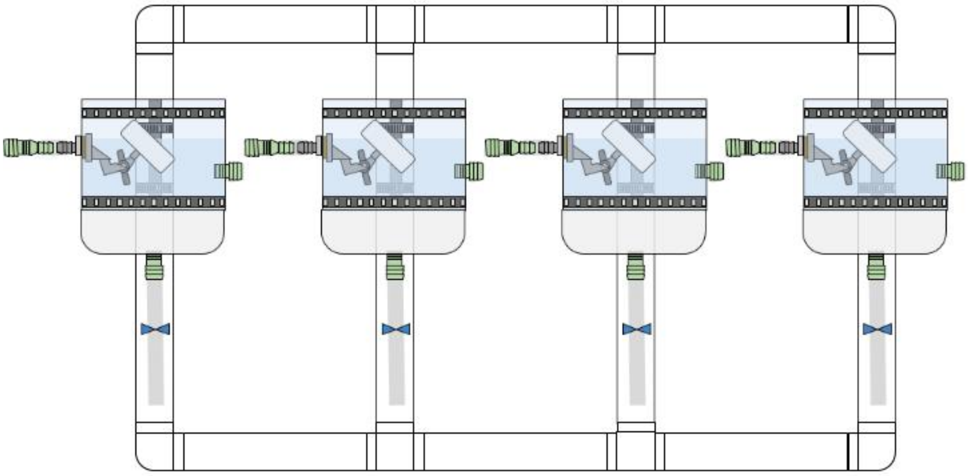


Figure 20: Schematic of the PVC Pipe Tank Design showing the entire mounting system of multiple CHT. The CHTs are attached to the frame which is mounted to the wall using hooks. For simplicity, the tubes attached the CHTs are not shown in this drawing.

To attach each CHT to the PVC frame, there is a 1/4" by 1/4" gray rectangular PVC bar between each individual tank and pipe. There are two small hose clamps that attach the PVC bar to the 1" mounting pipe and two large hose clamps that attach the PVC bar to the tank as shown in Figure 22 below. This system reduces the spaces between the hose clamps and the system when the hose clamps are tightened as shown in Figure 21 below. With this method, the tanks are well secured to the PVC frame.

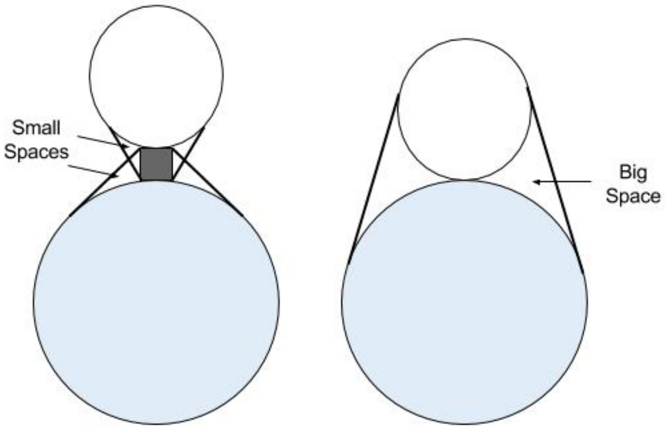


Figure 21: Adding a rectangular PVC bar between the mounting pipe and the CHT reduces the space created between the hose clamp and anything it is surrounding. The system on the left uses a small hose clamp around the white PVC mounting pipe and the gray rectangular bar. It also has a hose clamp around the gray rectangular bar and the CHT. The system on the right only uses a large hose clamp around both the mounting pipe and CHT, making the system looser and less secure.

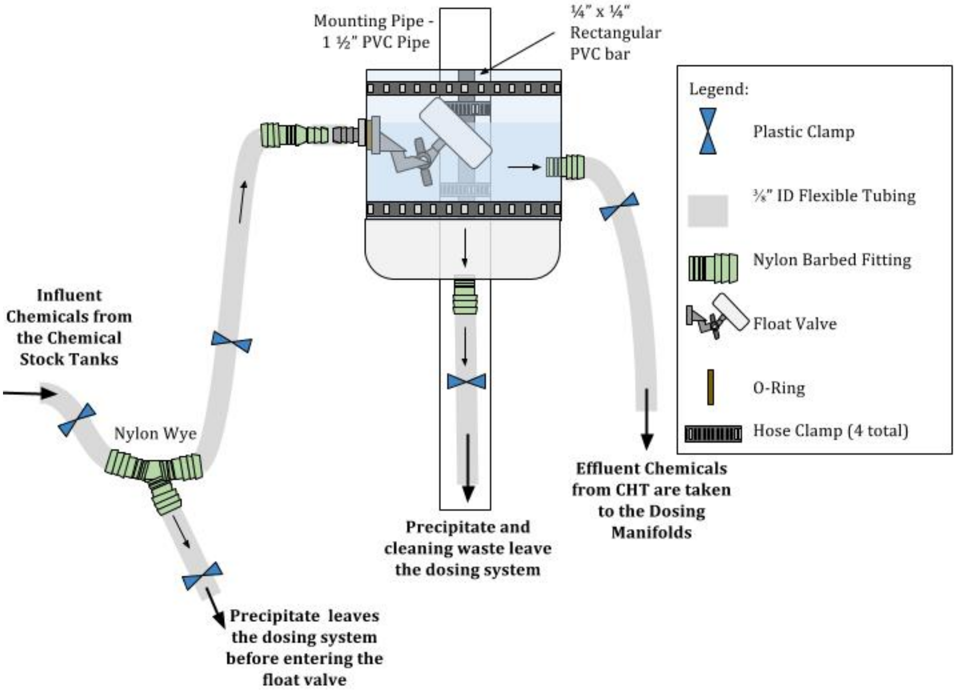


Figure 22: Schematic of the PVC Pipe Tank Design showing the mounting system of an individual CHT. The CHT is attached to a rectangular PVC bar using two large hose clamps. This PVC bar is secured to the 1" mounting pipe .

The completed design for this semester includes four tanks (two for chlorine and two for coagulant) as well as a wall-mounting system made of PVC pipes are shown below in Figure 23. A list of all of the materials purchased to produce this design are shown in Table 2

Figure 23: Schematic of the PVC Pipe Tank Design showing the mounting system of an individual CHT. The CHT is attached to a rectangular PVC bar using two large hose clamps. This PVC bar is secured to the 1" mounting pipe .

Table 2: Fabrication Materials for Second Iteration Design

Part Description	**Item Number**	**Quantity**	**Price per Unit**
PVC Pipe Cap	4880K58	4	5.38
Barbed Fitting	5463K85	8	12.86/package of 10
O-ring	5240T49	4	8.62/package of 15
Wye Barbed Tube Fitting	5372K187	4	14.88/package of 10
Barbed Reducer	5463K633	4	6.40/package of 10
Tube Clamp	5031K13	8	10.13/package of 5
PVC Float Valve	23174	4	8.54
Average Total Cost for System:		**1**	**93.08 USD/ 4 CHT Tanks and Mount**

Before the team decided on this PVC Pipe Tank Design, two alternatives were considered. The first was the design that is currently used in Honduras as shown in Figures 24 and 25. This design uses a bulkhead fitting 3/8" float valve with an O-Ring on the inside of the tank wall. This connection is problematic because it requires a coupling that takes the fine parallel male threading from the float valve on one side and pipe threaded male to barbed Nylon adapter on the other side. The connection between the coupling and the fine parallel male threading from the float valve is not water tight. Using Teflon can improve this seal but it is never completely sealed. The CHTs will eventually be filled with calcium hypochlorite which can be hazardous if not handled properly. Thus, it is important that the CHT system is completely water tight.

Figure 24: Photograph of a CHT used in Morocelí, Honduras which uses the first alternative connection between the mini adjustable PVC float valve with 3/8" parallel threaded inlet and the flexible tubing from the Chemical Stock Tanks. Unfortunately, the connection between the coupling and the float valve is not completely water tight.

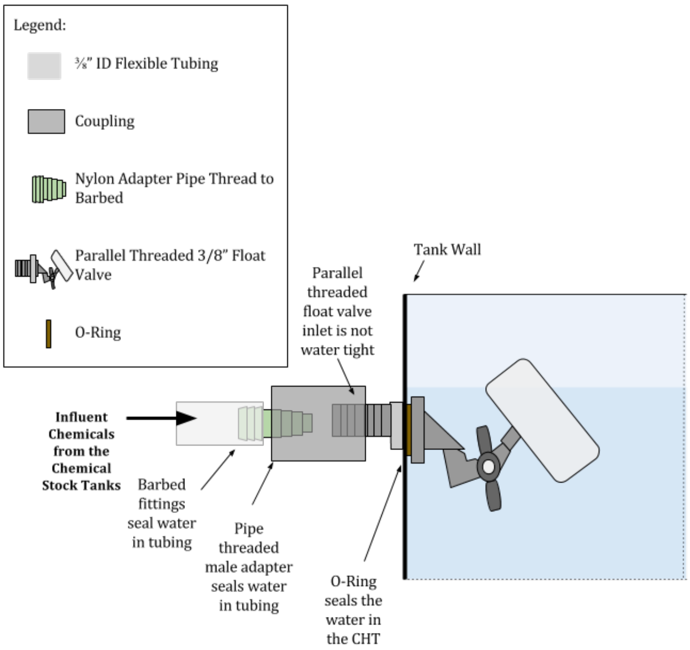


Figure 25: This schematic shows the first alternative connection between the mini adjustable PVC float valve with 3/8” parallel threaded inlet and the flexible tubing from the Chemical Stock Tanks that is currently used in Morocelí, Honduras. The connection between the parallel threaded float valve and the coupling does not provide a water tight seal.

The second design that the team explored, shown in Figure 26, uses a male pipe threaded float valve and a female pipe threaded to male barbed Nylon Adapter. Male pipe threaded float valves are not compatible with the PVC Pipe Tank Design because they require the hole in the tank wall to be threaded from inside the tank. This is not feasible because our 4” diameter PVC pipe is not large enough to fit a threading handle or a hand drill which are tools used to tap holes. Another way that male pipe threaded float valves are incompatible with the PVC Pipe Tank Design is because with tapered threads, there is no way to control the orientation of the float. In order to avoid any scaling on the orifice of the float valve, it is important to have the float valve oriented upside-down to keep the orifice submerged. With a pipe threaded, or tapered thread, there is no way to tap the hole in the wall perfectly to orient the float valve up-side-down.

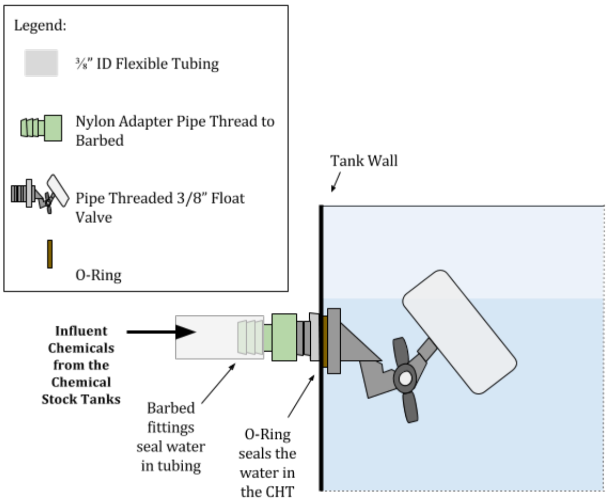


Figure 26: This schematic shows the second alternative connection between the mini adjustable PVC float valve with 3/8" male pipe threaded inlet and the flexible tubing from the Chemical Stock Tanks. The connection between the male threaded float valve and the Nylon adapter is water tight. However, it is nearly impossible to thread the hole in the tank wall to orient the float valve up-side-down.

Analysis

Compared to the PVC Welded Tanks Design, the PVC Pipe Tank Design is simpler to fabricate. It requires parts that are available in Honduras and uses tools that are already used at AguaClara water treatment plants.

The fabrication process of the tank takes no longer than 24 hours, and the majority of this time is to assure that the PVC cement has properly dried (connecting the PVC pipe cap to the pipe and when connecting the PVC frame). Using PVC cement is simple and requires no professional assistance. Thus, compared to the PVC Welded Tank design, the plant operators will be able to fabricate the tank themselves and repair the tanks independently.

Finally, this alternative is less expensive than the PVC Welded Tank design because there are no professionals being hired to fabricate the tank. Also, PVC plumbing parts are less expensive than clear PVC sheets. Otherwise, the same tubing and connections are used so there is no difference in price.

Fabrication Manual

The team created a manual documenting the entire fabrication process of the PVC Pipe Tank design. This fabrication manual is written in Spanish and is intended for plant manufacturers in Honduras to use. It lists the materials and tools required as well as the fabrication steps and dimensions of the CHT. This manual can be found on the AguaClara Google Doc page under the CDC Spring 2016 folder.

Conclusions

Over the course of the Spring 2016 semester, the CHT sub-team designed two different CHTs. The first design consisted of PVC sheets welded together to form a box tank. This design was created in order to solve two main constraints in previous designs. First, the dimensions of the tank was large enough to fit the original float valve, a welder, and an operator's hand. This allowed the team to use the original float that the float valves come with and allowed the operators enough space to weld the tank. The second constraint of previous CHTs was that the materials were not chemical resistant; they would deteriorate over time. In the PVC Welded Tank design, the CHT was made completely out of PVC, a chlorine-resistant material. While this design incorporated a number of ideal CHT characteristics and solved previous constraints, it did not work well because it required PVC welding. PVC welding is extremely time intensive and costly. Most importantly, the finished product was not perfect, often containing leaks.

The second design was created in response to problems identified in the previous design. This PVC Pipe Tank design created a tank out of a 4" OD clear PVC tube and 4" ID white PVC pipe cap. Although the design continues to use a float that does not come with the original float valve, the entire design is much easier and faster to fabricate. The PVC Pipe Tank design can be fabricated and maintained on site by operators. Like the PVC Welded Tank Design, the PVC Pipe Tank Design can also be cleaned in place using vinegar. This will make sure that the free surface of the chemical in the CHT is not altered frequently.

Finally, the team wrote a new addition to the existing AguaClara water treatment plant fabrication manual for AguaClara engineers. In this manual the team detailed the fabrication, maintenance, and operation process of the PVC Pipe CHTs.

Future Work

Next semester, the PVC Pipe Tank design will be coded into the AguaClara Design code as a Design Challenge. After discussing with Jon and Walker, current AguaClara engineers, the PVC Pipe Tank design will be implemented in future AguaClara water treatment plants. If the CHTs need to be replaced at any existing AguaClara water treatment plants, they will be retrofitted into these plants. This can be done by preparing the PVC Pipe CHTs along with the PVC framing and connecting the tubing to the existing CDC system.

References

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Semester Schedule

Task Map

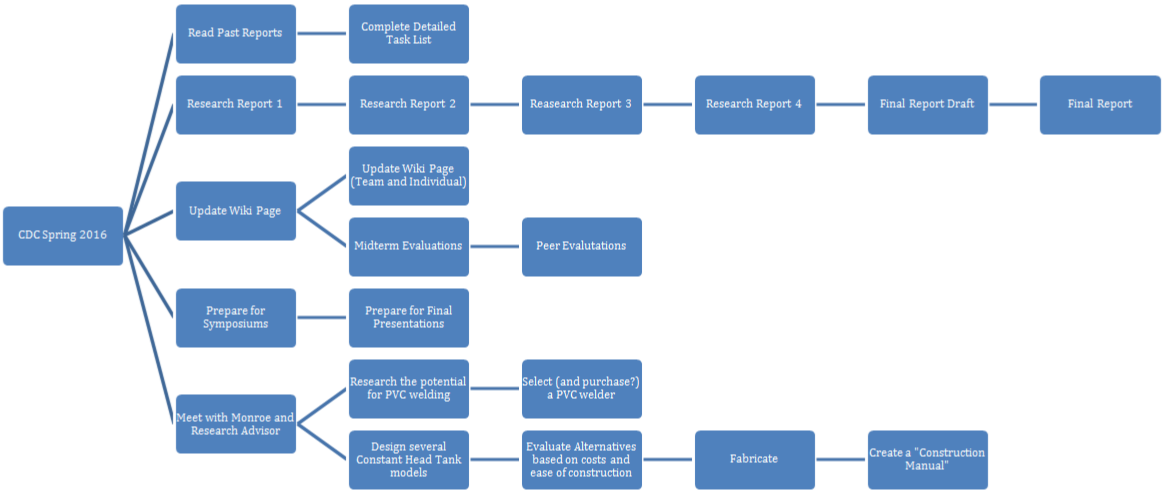

Figure 27: Constant Head Tank Sub-team Detailed Task Map

Task List

- **February 12:** Complete Detailed Task List and Update Wiki Page (individual and team) - Completed
- **February 19:** Complete Literature Review - Completed
- **February 24:** Complete research regarding PVC welding and determine which PVC welder to purchase. Discuss options with Monroe and purchase a welder - Completed
- **February 26:** Create 2-3 designs for Constant Head Tanks. Complete Research Report 1 - Completed
- **March 4:** Present designs to Monroe and AguaClara engineers. Select design to construct and purchase construction materials - Completed
- **March 11:** Construct prototype of first CHT design. Complete Research Report 2 - Completed
- **March 14:** Complete presentation for symposium - Completed
- **March 18:** Review prototype and designs with AguaClara engineers. Complete midterm peer evaluation. Update Individual Contribution Page. - Completed

- **March 25:** Design a second constant head tank. Present findings and model to Monroe and AguaClara engineers. Apply any feedback received.- Completed
- **April 8:** Complete construction of the new constant head tank model. Completed Research Report 3. - Completed
- **April 22:** Complete Research Report 4. - Completed
- **April 28:** Compare the two CHT designs and evaluate which should be implemented in Honduras. Construct the rest of the chemical dosing system. -Completed
- **May 11:** Complete Final Report draft. Clean up lab spaces. -Completed
- **May 18:** Complete Final Report and peer evaluations. Update individual wiki page and team page -Completed
- **May 20:** Upload Final Presentation and Final Report on team wiki page. -Completed

Report Proofreader: Anna and Val