Chemical Dose ControllerFinal Report Fall 2010

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AguaClara Reflection Report
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Abstract

The Fall 2010 Chemical Dose Controller team has focused on designing the dose controller to be visually accessible, more aesthetically attractive, and robust. The apparatus will be mounted on a plywood board secured to the plant wall. The team has begun construction on a prototype for the design. In this report we have documented the design process and all of the component parts used in the prototype.

Introduction

AguaClara plants rely on a coagulant to facilitate the formation of flocs during particle collisions in the flocculator. The coagulant must be administered at an appropriate concentrationdetermined by the turbidity of the plant influent. The AguaClara chemical dose controller is a system which delivers the rightflow rate of chemical stock solution proportional to the plant flow rate to obtain the desired concentration. The flow rates are linked by connecting the surface elevation of the stock solution to the water level in the plant entrance tank through the use of a float in the entrance tank. In the most recent version of the design, the *nonlinear* dose controller, the flow rates of both the stock solution and the plant flow in the entrance tank are related to their respective elevation head by a square root relationship dictated by the orifice through which each must ultimately flow (Equation 1). The result is a semi-automated system in which the plant operator only needs to find the desired coagulant dose on a slider bar in order for the appropriate flow rate of stock solution to be administered.

$$Q = K_{VC}\frac{\pi}{4}D_{or}^2\sqrt{2gh} \qquad (1)$$

Here, Q is flow rate, D_{or} is the diameter of the orifice flow restriction, K_{VC} is the vena contracta coefficient (approximately equal to 0.62 for anopening in a flat surface), g is the acceleration due to gravity, and h is the elevation head above the orifice.

The chemical dose controller was designed to facilitate the job of the plant operator by automating the chemical dosing process. However, the current system, mounted somewhat awkwardly above the entrance tank and built from components which are not all easily understood or locally available, may still be intimidating to some plant visitors and workers. Because the chemical dose controller is one of the signature components of the AguaClara plant design, we would like it to be attractive aesthetically and in terms of ease of use and required training time.

The objective of the Fall 2010 Chemical Dose Controller team has been to redesign the apparatus to make it more visually accessible and simpler to work with. The components will be mounted on a plywood board attached to the plant wall. The board will contain the doser lever arm and slider, the constant head tank, and hanging points for tubing that is not in use. Because the doser assembly will no longer be mounted directly above the entrance tank, a pulley system is needed to connect the position of the lever arm to the position of the float in the entrance tank (Figure 1).

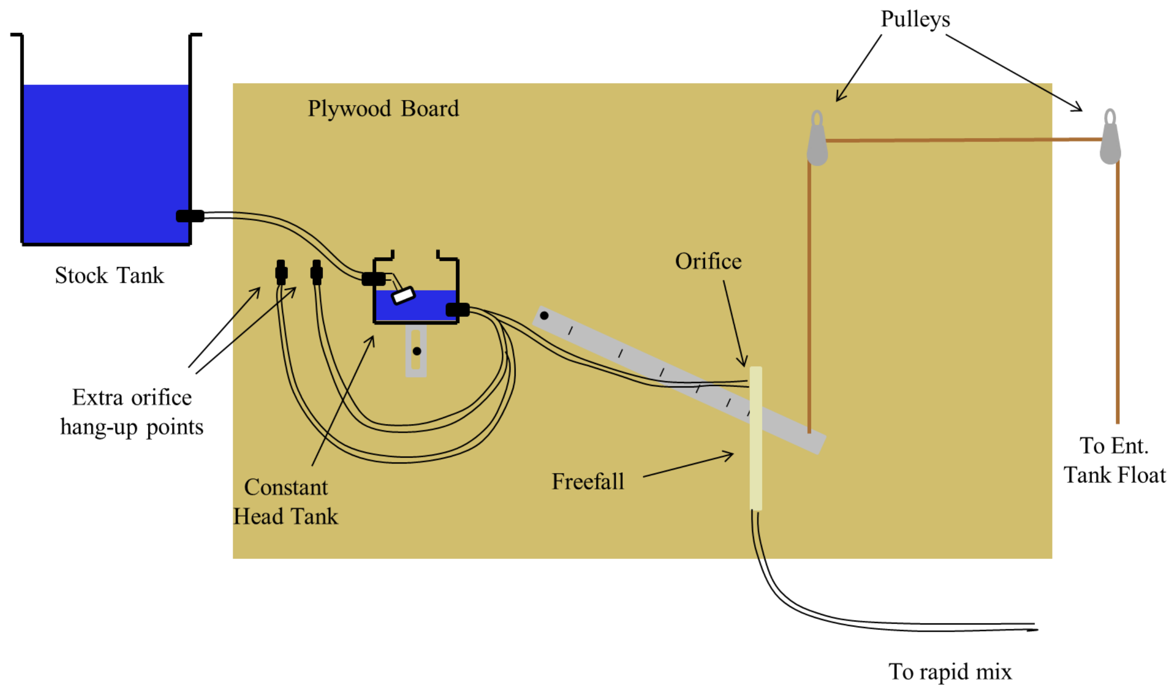


Figure 1. The new CDC assembly will be mounted on a plywood board to make it visually accessible. Note that this schematic does not show the details of the slider assembly (Figure 2) or the flow measurement column.

In selecting components for the system, the team followed the overall goals of making all parts visible to facilitate understanding among users and avoiding small parts which can fall apart and be lost. Other practical considerations were specific to the components being chosen, as detailed in the Design and Construction process below.

The nature of the Fall 2010 CDC team's work has generally been more design-oriented than experimental, as the majority of time was spent finding appropriate parts from those available and finding ways to make them compatible through trial and error. Therefore, this report focuses on the documentation of the design process and the specific parts the team chose. However, the team did conduct one experiment to test the behavior of flow rate through the orifice caps we machined as a function of pressure head. The test was necessary because the team created new orifice caps which fit the apparatus without the use of push-to-connect fittings or complex machining. The team needed to recreate the results of the Summer 2010 CDC team, which was successful in creating several orifices which provided consistent flow rates, with the materials ordered during the fall.

Design and Construction

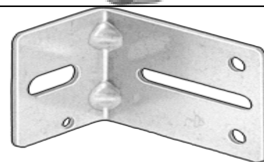
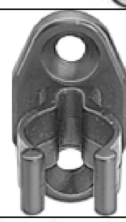
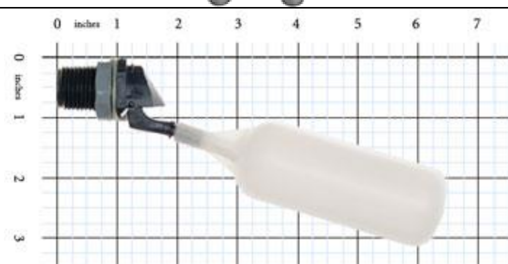
Constant Head Tank Assembly.

The Constant HeadTank (CHT) needs to be securely attached to the plywood on the wall. To keep the CHT in place we are using a hose clamp (Table1.a) that is also attached to the plywood. This clamp can easily be adjusted to tighten or lose the tank if needed to be removed from its mount. The level of the CHT is initially determined when mounting the whole CDC and calibrating it. For this reason the CHT support needs to be able to adjust to a certain height. To do this we are using an L-bracket (Table 1.b) as a bottom support. As seen in the picture, this L-bracket has a gap in the middle that allows the height of the CHT to be adjusted, once the height is set, a carriage bolt (Table 1.c) is nailed from the back of the plywood and used to keep the bracket in place.

Since the upgraded CDC has three different orifice sizes, three different holes were drilled at the bottom of the CHT, each one with a respective bulkhead from which three different flexible tubes come off to each of the orifices. Only one orifice will be used at a given time, therefore, while one is in use, the other two will be clamp on to the plywood with plastic tool holders (Table 1.d). We chose these holders because the tubing easily clamps on and unclamps off them.

Another component of the CHT is the Float valve (Table 1.e), we decided to use the same model used for the previous doser since the prototype is being constructed for the same flow as Agalteca. It also fits in the 64 oz bottle (Table 1.f) used for the CHT.

Table 1.Constant Head Tank Assembly Parts.

Part	Model	Note
a)Worm-Drive Hose clamp McMaster Catalog # 53388K14		Easy to adjust in case CHT needs to be demounted.
b)L-bracket McMaster Catalog #15275A66		Easy to adjust for initial calibration of CDC.
c) Carriage bolt McMaster Catalog # 93180A115		Very secured once nailed from the back of plywood.
d) Black thermoplastic **tool holder** **McMaster Catalog#** **1171A69**		-Lightweight, corrosion resistant, and can easily be secured to the plywood mount. -Tubes clamp and unclamp easily
e) Mini Float valve Kerick-Valve Catalog # M052. Orifice: 0.093 Flow rate: 1.5 GPM		Prototype flow is same as the previous CDC.
f)64 oz Wide-Mouth Plastic bottle. McMaster Catalog # 42955T2		Light, easily perforated.

Lever Arm and Slider Assembly

The final design for the Lever arm is that of a plain aluminum bar (Table 3.b) on which a section of a U-Shape bar slides (Table 3.a). Both pieces are corrosion resistant aluminum, easily obtained and moldable. This system has an easy to break mechanism since a screw is tightened and loosened to move the slider along the arm. A ½ inch PVC tube will be perpendicular to the slider on one of its ends; the dosing orifice will be clamped to this tube. Chemical flow should be unobstructed and easily observed down the PVC tube.

For the dose marks on the arm we used metal stamps found in Hollister's Machine Shop. We concluded that metal stamping was the best option since it is very durable and it can easily be done in Honduras. To make the CDC design universal, a multiplier will be used for the doses. The following distances were used for the scale on the arm. The distance from the slider screw to the dosing point of 4.3 cm was added later to these values since we want the screw aligned with the scale dose point.

Table 2. Lever arm scale distances from pivot point.

Number on Scale	Distance from pivot point (cm)
1	7.39
2	11.55
3	16.63
4	22.63
5	29.56
6	37.41
7	46.19

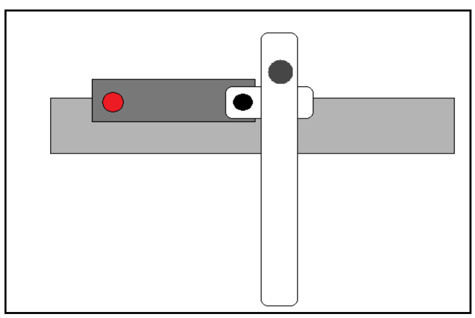
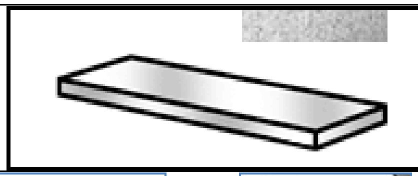
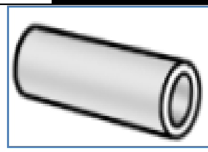
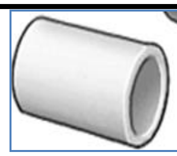
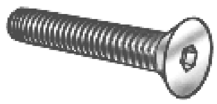
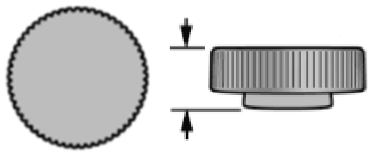


Figure 2. Lever arm, slider and dosing orifice assembly

The lever arm has an axle at the pivot point to allow rotation and a hole at the end of the scale to attach the pulley string coming from the float.

Table 2. Lever Arm and Slider Assembly Parts

Part	Model	Note
a)Aluminum U-Channel, 1/8" Thk, 3/4" Base X 1/2" Legs, 8' L McMaster Catalog # 9001K61		Fits around lever arm Easily moldable Corrosion resistant

b) Aluminum bar 1/8" McMaster Catalog # 9135K123		-Easily perforated, moldable. -Easy to stamp the scale numbers. -Light -Corrosion resistant.
c) 1/2" PVC tube. d)1/2" PVC Socket-Weld Coupling McMaster Catalog #4880K71	 c)  d)	-Used extensively in the plants already. - Easy to perforate. - Corrosion resistance
e) Cap Screw McMaster Catalog 92210A010		-Easy brake mechanism, the operator only needs to screw the bolt all the way until it reaches the lever arm and in a similar way unscrew it to loosen it.
f) Thumb Screw Knob McMaster Catalog 91165A880		-Facilitates the brake mechanisms of the slider for the operator. Instead of screwing/unscrewing the bolt head itself, they use the knob.

Pulley System

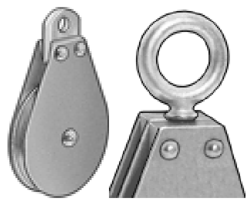
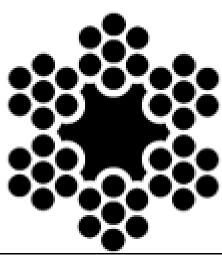
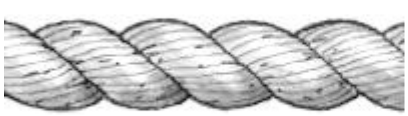
The pulley system ensures a simple yet accurate method of changing the elevation of the float in correspondence with the lever arm. A rope connects the lever arm to a pulley directly above it, extends to another pulley on the same horizontal plane as the first, and goes over and down to the float in the tank. Thus, it was necessary to investigate and design how and where these pulleys would be suspended.

One major constraint was that the pulleys should be at least three inches from the wall, because the tank, which is leaned up against the wall, is three inches in radius. In addition, the pulleys had to be somehow attached to the plywood along with the lever arm and the constant head tank.

Initially, we were investigating the possibility of attaching two simple pulleys to two respective axles, which would be mounted against the wall. The pulleys would be fixed in place by collars. After further investigation, however, it was realized that it would be more convenient and secure to buy a swivel-eye pulley, which would be attached to an L-bracket via a carabiner. A swivel-eye pulley also allows for more room for movement, because it can rotate about the vertical axis.

Therefore, we bought two zinc-plated steel pulleys, two stainless steel L-brackets, and two zinc-plated steel carabiners. Also, initially galvanized iron rope was also purchased, but it was discovered that it was far too thick and dense, and an impractical amount of force was required to make it taut. Eventually, we tried a quarter-inch polyester rope, and we bought clamps for the ends, which worked well with our purposes. The descriptions of the purchased supplies are listed below.

Table 3.Pulley System Parts.

Part	Model	Note
a) 2 Pulley Blocks McMaster Catalog #3099T14		Made of zinc-plated steel to ensure corrosion resistance. The actual pulley has a swivel eye for flexibility, as shown on the right.
b)2 L-Brackets McMaster Catalog #1556A39		Side Lengths = 5", 5" Width = 1" The actual L-bracket has three holes on each side.
c) 2 Carabiners McMaster Catalog #3933T22		Made of zinc-plated steel to ensure corrosion resistance.
d) 10-ft Galvanized Iron Rope McMaster Catalog #3449T18		3/16" Diameter 6X7 Fiber Core Too dense and thick to be used.
e) 50-ft Polyester Rope McMaster Catalog #3828T11		Low-Stretch 1/4” Diameter Used instead of iron rope

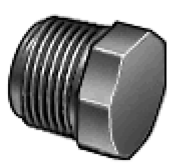
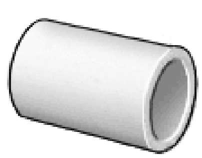
f) Rope Clamp McMaster Catalog #36815T12		Simple yet adjustable method of fixing rope length

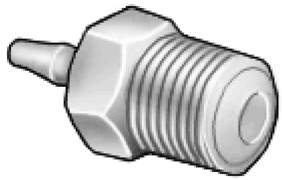
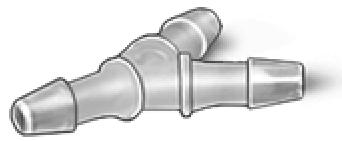
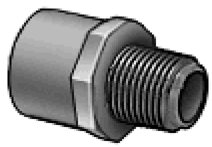
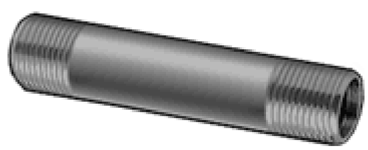
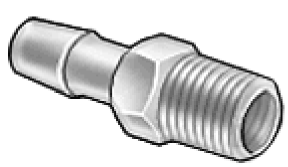
Tubing and Connections

The team has avoided the use of push-to-connect fittings in putting together the tubing components of the CDC because they have small parts which can be lost. Therefore all of our connections are either barbed for flexible tubing or are NPT threads for PVC components. The only pipe used is between the stock tank and the ball valve which controls flow from the stock tank. This section is ½" PVC. In addition, the female threads at either end of the flow measurement column are also ½" NPT threads, so all of our thread sizes are consistent. Beyond the ball valves (Table 4f) which control the flow from the stock tank and flow measurement device, all tubing is flexible (3/8" for our prototype), which means barbed connections were used. A wye connection (Table 4d) is used to combine the flow from the measurement column and the stock tank.

Both of our orifice caps are threaded with 1/8" NPT threads (Table 4 i and j). This allows them to fit onto the ends of the 3/8" flexible tubing using the barbed fitting adapter (Table 4h).

Table 4.Tubing and Connection Parts.

Part	Model	Note
a)1/2" Threaded Plug McMaster Catalog #4596K73		Made of PVC Used for Eye-Bolt Flow Measurement Hanger
b)1/2" PVC Socket-Weld Coupling McMaster Catalog #4880K71		Used for stock tank pipe/ball valve connection

c) 1/2" NPT threaded to single barbed 3/8" tubing adapter McMaster Catalog #5116K88		Used for ball valve/flexible tubing connection
d) Single-barbed wye fitting for 3/8" tubing McMaster Catalog #53415K241		Used for stock tank/flow measurement/constant head tank junction
e) Male 1/2" NPT thread PVC adapter McMaster Catalog #4596K661		Used for stock tank/ball valve connection
f) 1/2" female threaded PVC ball valves McMaster Catalog #4876K71		Used for stock tank and flow measurement
g) 1/2" threaded PVC nipple McMaster Catalog #4882K24		Used for flow measurement/ball valve connection
h) 3/8" flexible tubing (barbed) to 1/8" male NPT threads adapter McMaster Catalog #2974K132		Used for connecting orifice caps to tubing
i) 1/8” NPT threaded brass pipe cap McMaster Catalog #4429K149		Machined into 2 mm orifice cap

j) 1/8" NPT threaded chrome-plated brass pipe cap McMaster Catalog #9162K161		Machined into 2 mm orifice cap

Experimental Design

The Summer 2010 CDC team conducted flow tests with a number of orifices in order to determine which materials could be machined into flow restrictions which provided consistent flow rates. The Fall 2010 team conducted the same test to check whether the new orifice caps, which fit the NPT threads of our tubing adapters, would perform well.

In these tests, flow rate data is collected for a variety of pressure head values in the range of zero to 40 cm. The orifice is secured at an elevation dictated by a vertical scale attached to the experimental setup. The scale is zeroed at the level of the water surface in the constant head tank. Flow is measured by filling a graduated cylinder which is the source water for the constant head tank and marking off the volume which leaves over a timed interval on the stopwatch (Figure 3).

Flow rate as a function of pressure head for the orifice is then plotted and compared with the theoretical values for flow rate described by Equation 1. For the experiments during the fall, the team machined orifice caps with 2 mm diameter openings.

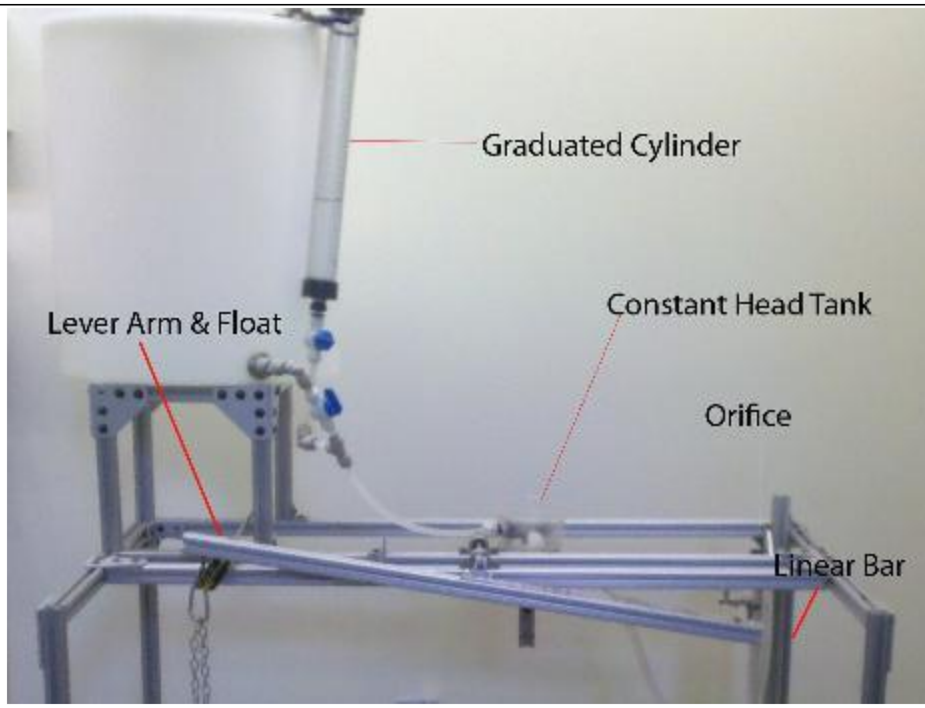


Figure 3. The experimental setup for orifice flow tests consists of a constant head tank connected to the orifice flow restriction, set at a measured elevation below the free surface as indicated by the scale labeled "Linear Bar", which has marks for elevation in centimeters. Flow through the system for a given orifice elevation can be measured using the flow meter labeled "Graduated Cylinder".

Results and Discussion

The team had time for only one flow test during Fall 2010, done with the 2 mm orifice machined from a brass pipe cap (Table 4i). The results are displayed in the plot in Figure 4.

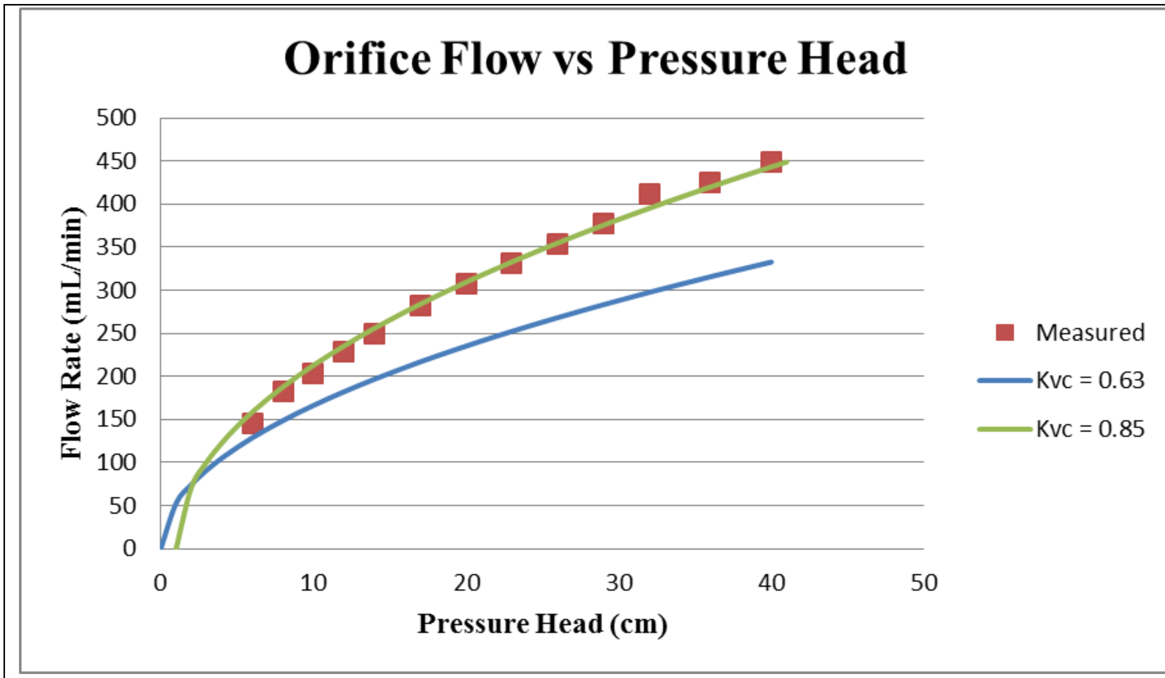


Figure 4. The results of the first flow test suggest that the vena contracta coefficient for our orifice caps is close to 0.85. The measured values deviate too much from the predicted flow rates, however, which the team believes is due to experimental error.

As can be seen, the data did not fit the curve for the predicting flow rates using a vena contracta coefficient of 0.63. This value should be accurate for an opening in a flat wall. However, both of the orifice caps the team has used have tapered interiors guiding the flow into the orifice so that a 90 degree turn is not necessary. This reduces the vena contracta effect significantly.

The team calculated curves for a range of vena contracta coefficients and matched the data to the closest curve qualitatively by looking at the curve overlays on the plot. A vena contracta coefficient of 0.85 was the closest to matching the data. However, the data at the lower end of the range of the pressure heads deviates significant from the predicted values, with a 16% error on the first data point. With such a small number of data points, the team believes this may be due to experimental error rather than a fundamental flaw in the design. The two likely sources of this error are failure to secure the orifice precisely at the marked elevation and imprecision with the flow measurement column. The team plans to perform another flow test with the other orifice cap (Table 4j) before the end of the Fall 2010 semester.

Future Work

The prototype that will be presented in the final presentation of the CDC team for this semester is still subject to change after receiving feedback from our colleagues in Honduras. The CDC team has already been asked to consider modifying the current design for use with a linear doser for low flow plants because of the problems encountered with the nonlinear doser at the Agalteca plant. Our counterparts in Honduras have been somewhat hesitant about implementing NCDC in future plants because of some issues that the NCDC has had in Agalteca such as: 1) Surface tension: (on the dosing orifice) which prevents chemical from flowing at low dosages and 2) Grit clogging at the beginning of the focculator which disrupts the relationship between head loss in the plant and flow rate.

The surface tension problem has already been addressed by having three orifices instead of two, thus, having a low dosage scale. Since this problem does not actually mean that the chemical dose controller is failing to do its job, hopefully the newly constructed triple orifice nonlinear doser will be received optimistically and can be implemented in future plants. Hopefully the plant operators will be happy to see that many of the components of the nonlinear doser have been upgraded so as to minimize the cost and the number of components, especially the number of small parts that are easy to lose when disassembled.

As for the grit clogging issue, it is a problem that the upcoming semester team can work on. Right now in Agalteca, there is grit clogging up at the beginning of the flocculator which disrupts the correlation between plant head loss and flow rate. The next semester team needs to work on designing a system to capture the grit which implies redesigning the Entrance tank. The next team can review the results obtained by the CEE 4540 class - Fall 2010 final group projects on Entrance Tank design.

Current plan is to install the NCDC prototype built this semester in the new plant. If this plan is achieved then another task for the upcoming team would be to get feedback from the AguaClara engineers and the operators about how the doser is performing.

There is still work to be completed by our team this semester. One decision that still needs to be finalized is what kind of orifice cap the doser will use and how the final orifice cap will be connected to the PVC tube. The CDC team should continue to investigate possible orifice caps using the results from the Summer 2010 team flow rate tests as well as the flow rate tests conducted this semester using the two new brass orifice caps that were recently ordered. In addition, the issue of how to integrate the chlorine doser is still to be resolved.

Team Reflections

The CDC team has made great progress in the past couple of weeks and was able to develop an upgraded chemical dose controller prototype using the recently ordered parts from McMaster Carr previously mentioned in the report. Now the CDC team will have to wait and see how the upgraded nonlinear doser will be received in Honduras, then additional modifications can be made to the chemical dose controller where necessary.