Summer 2010 CDC Reflection Report I

Chemical Dose Controller Reflection Report

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AguaClara Reflection Report
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Abstract

Over the past two weeks, the CDC Summer 2010 Team has become more comfortable with the MathCAD software and theory behind the design of the nonlinear Chemical Dose Controller (CDC). The team learned and understood the workings of the CDC and practiced the method used for running tests on the orifices in the AguaClara Lab. Future work involves running a series of five tests on three different sized orifices to determine their precision and accuracy.

Introduction

The nonlinear Chemical Dose Controller, designed in the fall of 2008, has the ability to dose correctly both laminar and turbulent flow in contrast to the linear dose controller used in previous years. This new design uses an orifice to control the flow of alum into the water treatment plant. A float in the entrance tank raises or lowers the lever arm depending on the flow rate, which in turn, controls the height of the dosing tube. For example, an increase in plant flow rate will cause the float to move in the upward direction and the orifice to move in the downward direction. If the height of the doser were to decrease, a greater elevation difference would be created between itself and the constant head tank, increasing the chemical flow rate. At the moment, a dual scale with the possible chemical flow rates is attached to the lever arm from where the operator can slide the dosing tube to obtain the needed flow.

The theory behind the nonlinear CDC is based on the flow rate of the incoming water and the available head in the tank (Equation 1):

$$Q = K_{Orifice} * (2gh)^{1/2} \quad (1)$$

Where: Q is the flow rate of the alum, $K_{Orifice}$ is a coefficient related to entrance and exit losses, and h is the available head. This relationship holds true for both laminar and turbulent flow.

During the previous two semesters, a great deal of research has been done regarding the nonlinear CDC. Experimental data gathered in the lab shows that major losses account for roughly 2% of the total head loss. Therefore most energy loss in the plants can be accounted for by minor losses. There was also an issue of foam being created in the flocculator due to hydraulic jump of dosing the alum above the water intake. As a preventive measure, the entry point of the dosing tube was redesigned to be submerged in the entrance tank. Additionally, the team found that when trying to maintain flow at values of head below 4 cm, surface tension at the orifice from the alum and friction in the dosing tube itself was limiting flow.

In the last few semesters, the CDC Teams have continued to improve upon the design and efficiency of the nonlinear CDC which the summer CDC Team will continue to do by determining the precision and accuracy of the doser through a series of experiments.

The first experiment that shall be conducted is a validation test of the level of precision that can be expected from the dosing orifices. This is the first stage in a series of validation tests that will investigate orifice precision and accuracy.

The orifice equation that relates chemical flow rate to available head is straightforward, but non-ideal effects that occur at the entrance and exit regions of the orifices cannot be calculated theoretically. These non-ideal effects include the dependence of vena contracta at the entrance region on the shape of the inlet faces and the effects of head loss at the orifice exits as a result of swirling flow and turbulent motion. Once the data has been collected, empirical determination of an orifice discharge coefficient can be used to correct for these non-ideal effects.

Construction of a dosing orifice requires very specific conditions to ensure the greatest precision and accuracy possible, or “agreement with predicted values” (Munson 465). However, before accuracy can be investigated, the orifices must demonstrate an acceptable level of precision. This first experiment thus serves to demonstrate the repeatability of constructing reliable dosing orifices.

Literature Review

Team Member: Aditi Naik

Article: “Effects of aluminum sulfate and ferric chloride coagulant residuals on polyamide performance”

Although AguaClara does not use polyamide for the purpose of membranes, as examined in this article, the CDC team is considering using material from the company Legris for the orifices because the manufacturer of these polyamide caps claims Legris is more resistant to chlorine than the acetal caps that are currently being used in the chemical dose controller. Repeated reverse osmosis testing using alum and free chloride on polyamide membranes suggested that the membranes were degrading. For alum, there was a steady decline in reverse osmosis performance possibly due the presence of aluminum hydroxides or aluminum silicate fouling. If the process is not well monitored, aqueous and free chloride was shown to have harmful effects on the polyamide material (Gabelich).

Team Member: Ritu Raman

Article: “Investigation of the degradation of commercial polyoxymethylene copolymer in water service applications”

This article discusses the causes and effects of degradation on properties of commercial polyoxymethylene (POM) copolymer. Samples of POM fittings used for a five

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such as pits and cracks, features of surface erosion caused by chemical degradation. The article concludes that though the study clearly indicates the negative effect degradation has on the properties of POM, more study is needed before chlorine can be named the chief cause of the degradation (Oner). This article thus establishes

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Team Member: Monica Hill

Article: "Effect of Orifice Plate Manufacturing Variations."

In 2004, the American Petroleum Institute (API), along with the Gas Technology Institute, sponsored research for supporting the recent orifice plate expansion factor research performed at the Southwest Research Institute. The study showed that for several orifice plates, the discharge coefficient was outside of the 95% confidence interval of the Reader-Harris / Gallagher equation (RG equation.) The RG equation is used in gas applications where expansion of a compressible fluid is a concern and better defines a more representative discharge coefficient. Specifically not an appropriate equation for our concern, information regarding the importance of the discharge coefficient is still quite valid to us as we analyze our ability to precisely manufacture our own metering orifices (Nored).

As summarized in this paper bore diameter, eccentricity, plate thickness, bore edge thickness, bevel angle, edge sharpness and face flatness can all lead to metering errors in an orifice plate. The article also addresses the fact that present orifice meter standard does not sufficiently address a number of these above listed factors, specifically edge sharpness (Nored).

This paper reiterates our need to develop precise manufacturing techniques if we wish to provide precise metering orifices (Nored).

Team Member: Michael DeLucia

Article: Connex-Electronics' "Rigid PVC Resistance to Chemical Agents" Chart

According to multiple manufacturers of PVC piping, the material’s resistance to liquid chlorine is dependent on multiple factors including the temperature and concen tration of the chlorine. For instance, the manufacturer claims that the pipe is unsuitable for use when subjected to liquid chlorine at a temperature of 20C (68F). However, the

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From what the manufacturers of PVC and CPVC pipes have claimed, it seems that if PVC pipe were to be used it for chlorination, a special coating would be

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Detailed Task List

1. Validation Test I - Precision (1-2 weeks)
   a. Test precision of orifice. Will drilling technique play a roll in dosing reliability? Will $K_{orifice}$ change with different materials, or for that matter, different drilling techniques? Determine the precision of our manufacturing process by running a series of tests as outlined:

Procedural Outline:

- Test 3 different sized orifices, selecting a representative low, mid and high diameter. Although the upper and lower diameter will be dictated by drill bit size and float valve size, the actual sizes selected will be arbitrarily. We are testing manufacturing precision

- Push-connect caps manufactured by Legris, made of polyamide will be used for these tests.
- For each of the three sizes, 5 caps will be drilled. Each of the five caps in each group will be labeled with their size and a letter designation
- Each cap will be tested on the prototype chemical doser. The lever arm and float will not be used but instead a simple linear bar with specific h-values marked. Each cap will be tested throughout the range of 0 - 40 cm. The first 4 cm will be in 1 cm increments and afterwards in 4 cm increments.
- Each cap will be tested through this 0-40 cm range in a random -fashion to better replicate possible field operation.
- Each cap will be tested 5 times through the 0-40 cm range as described above so that we may gain confidence in our data. The orifice tube will be unclipped between each test set to better replicate real world operations and see if error of any significance could be originating from our method of attachment.
- All tests will be run with water.
- Results will be logged on an Excel spreadsheet. This spreadsheet has been set up to calculate standard deviation and confidence intervals. A standard error exceeding 5% will be considered cause for alarm and demonstrate the need to further evaluate our manufacturing technique.

2. Validation Test II - Accuracy (1 week)
   a. Comparing the data collected from precision testing, make a judgment based claim using calculated Q values. An outline of the testing method is shown below:

Procedural Outline

- No additional data need be collected for this experiment, this is only data processing
- Using average flow values from Validation Test I, compare calculated values of flow for each orifice size.
- Graph data over range of delta h 0 - 40 cm, with possible sub graphs showing problem areas.
- It is expected that errors resulting from surface tension will be demonstrated here.
- Additionally, our manufacturing technique may create a Vena Contracta Coefficient, K_{vc}, that differs from .62. Develop a new K_{vc} if proven necessary.

3. Validation Test III - Surface Tension
   a. Validation Test II will show inaccuracies in the low range that we attribute to surface tension. The current solution to this problem is to add yet another scale and orifice to the system. Evaluate whether or not this is the best solution.
   b. Understand and accommodate surface tension issue. Is the triple scale the solution? Is there are simpler solution available? Perform literature survey of alum and chlorine to see if these fluids would have a different effect.

4. Validation Test IV - Clogging
   a. At this point, we will postpone clogging experiments. I have discussed this issue with the engineers in Honduras and it appears this problem has been reduced with the addition of a sedimentation tap. Additional clogging results from precipitant forming along the walls of the tubes, which builds up until a small piece breaks off and leads to clogging. They will be playing with a preventative maintenance program that may improve or eliminate this problem.

5. Validation Test V - Moment Errors
   a. The above experiments will be performed without using the float and lever arm. This will allow us to keep any possible errors isolated. The sixth validation test will be done using the lever arm and float to ensure that no other errors are incorporated into the chemical doser. Use aquarium to simulate water level changes in entrance tank. Compare readings with those from previous Validation Test I and from calculated values

b. Analyze any possible error caused by moving the slider to higher or lower concentrations. This movement shifts the moment around the pivot point and effects dosing

6. Research Items - Materials
    a. Convert as practically as possible to locally available materials
    b. Eliminate components that have small pieces that can easily be lost (i.e. no more compression fittings)
    c. Convert to materials that are suitable for both alum and chlorine dosing
    d. What can't be obtained locally to be made of high quality, reliable components that will reduce down time / lead time resulting from component failure
    e. Modify administering tube so that a positive visual indication of flow can be seen

Material Selection Process:

Survey peer-reviewed articles or manufacturer data sheets of the materials listed below to determine their suitability for use with alum and chlorine. Please note that although Wikipedia is a great source for initial information gathering, it is generally not considered peer-reviewed.

Components:

- PVC and CPVC
- Acetal
- Polypropylene
- Polyamide (Legris)
- PVDF (Kynar)

Piping / Tubing:

- PVC rigid piping
- PVC soft flex tubing
- Vinyl tubing
- Pex tubing

Materials suitable for our application will then be analyzed for cost and ease of availability.

We will not be ab

le to readily determine which materials are available in Honduras but we do have two people in Honduras who ca n suss-out materials for us. In addition to material selection, we will discuss different fitting styles an

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- Barbed
- Compression
- Quick-Connect

Once material and component selection is made, we will create a standardized material list for installation of the chemical doser.

Future Objectives (Fall 2010 and beyond):

- Automate selection of orifice and design of scale. From a given plant flow rate, we should be able to produce the two (or three) orifice sizes and the two (or three) scales.
- Incorporate rotometers in design between stock tank and constant head tank to allow quick and accurate visual indication of dosages. Determine the effect on the location of the stock tanks. Note that this will require the stock tanks to be elevated to accommodate head loss in the rotometers.
- Generate a parts list of all components. Work with engineers in Honduras to determine which components need to be compromised to allow local material access.
- Work with the design team to create a float valve database of the Kerick valves that we will use for larger plants. Also, find different fittings for valve so that we are using a barbed connection instead of compression Create the design algorithm that will choose the correct float valve
- Create a poster and presentation to display P3 competition and award
- A second acrylic model plant needs to be constructed. Also modifications need to be made to the first one: a larger manifold in the bottom of the sed. tank.

Experimental Design

The orifices shall be drilled into polyamide push-connect caps manufactured by Legris. Preliminary research shows that polyamide is compatible with both alum and chlorine and is thus a suitable material for the chemical dose controller. However, detailed research on materials will more fully determine the applicability of this material.

Three different orifice sizes representing the low, medium, and high range of operation shall be tested. These shall vary in diameter from 1mm to 2.5mm. The low and high ends of this range have been determined after consideration of the results of experiments conducted by the previous Chemical Dose Controller Team from Spring 2010. These experiments show that, in general, orifice accuracy and precision seem to increase with decreasing size. However, there is a lower bound (approximately 1mm) below which orifices cease to function properly. Similarly, larger orifices, which are required when a greater concentration of alum is necessary, can cause a flow rate that the float valve in the constant head tank cannot match. This valve has an orifice diameter of approximately 2.6mm and sets the upper limit on the diameter of the dosing orifice.

Five caps of each of the three orifice sizes shall be drilled and tested on the prototype chemical doser. In order to remove all possible sources of experimental error caused by the lever arm and float, the experiment shall dispense of these intermediate mechanisms. Instead, the dosing tube shall lead directly from the constant head tank to a simple linear bar marked with head values in the range of 0-40 cm. (Figure 1) Each cap will be tested throughout this range in a random order. This avoids errors that could be caused by the flow rate at a prior height affecting the flow rate at the next height.

Figure 1: Experimental Setup

The experimenters will record the flow rate values in mL/min at each value of head. This data will be entered into a spreadsheet (Figure 2) that will calculate the variance and standard deviation of these flow rate values, indications of the level of precision that can be expected from the dosing orifices. The spreadsheet will also calculate upper and lower limits for a 95% confidence interval that can be used to compare the measured flow rate with a theoretically calculated value. This information will be utilized to determine the level of accuracy that can be expected from the orifices and assist in the derivation of an orifice discharge coefficient to correct for non-ideal effects.

Data Collection Form

Date

Orifice Size mm

Data Collectors

Orifice Des

alpha = 0.05

Random test order	cm	One minute test – flow rate –mL / min							Standard	95%	Upper	Lower
	Δ h	Test 1	Test 2	Test 3	Test 4	Test 5	Q bar	Std Dev	Error	CI		
	0						0.0000	0	0	0	0.0000	0.0000
	1						0.0000	0	0	0	0.0000	0.0000
	2						0.0000	0	0	0	0.0000	0.0000
	3						0.0000	0	0	0	0.0000	0.0000
	4						0.0000	0	0	0	0.0000	0.0000
	8						0.0000	0	0	0	0.0000	0.0000
	12						0.0000	0	0	0	0.0000	0.0000
	16						0.0000	0	0	0	0.0000	0.0000
	20						0.0000	0	0	0	0.0000	0.0000
	24						0.0000	0	0	0	0.0000	0.0000
	28						0.0000	0	0	0	0.0000	0.0000
	32						0.0000	0	0	0	0.0000	0.0000
	36						0.0000	0	0	0	0.0000	0.0000
	40						0.0000	0	0	0	0.0000	0.0000

Figure 2. Spreadsheet Form for Data Collection.

Future Work

During the coming two weeks, the CDC Team will be conducting tests on the precision and accuracy of the doser as outlined in the Experimental Design section. First, the design of the orifices will be tested to understand if the drilling of the orifice hole can be easily and precisely accomplished. This will answer the question of whether $K_{orifice}$ value will change depending on the drilling techniques and the orifice material as well. Then the accuracy of the orifices will be examined using the data collected from the precision testing.

Team Roles and Expectations

Team members for the summer 2010 Chemical Dose Controller team are Monica Hill, Aditi Naik, Ritu Raman and Michael De Lucia. Monica Hill has been designated as Team Leader with the expectation that she will not be here for the complete summer period and a new Team Leader will be designated toward the end of July. Monica has previous experience on the CDC team and will ensure this team is comfortable with the theories behind and application of the doser.

Aside from the regularly scheduled class time, we plan on meeting as a group weekly on Tuesdays and Wednesdays at 10AM. Additional meeting times will be determined as needed, from week to week.

Because of the unique nature of our team, we have not yet designated team roles. We expect our team roles to vary weekly as we progress. Currently, each team member is performing a literature review of different materials for application in both alum and chlorine. Additionally, each team member is testing a different sized orifice for precision.

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