Reflection Report - 2

Chemical Dose Controller Reflection Report

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AguaClara Reflection Report
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Abstract

During the past two weeks, the CDC Summer 2010 Team ran a series of five tests on four different 1mm and 2mm orifices. These tests showed inconsistent results within each orifice. In an effort to minimize this error, the team replaced the old soft tubing from the stock tank to the constant head tank with clean rigid tubing of a larger diameter and also changed the zero point on the dosing scale to a more precise location. Next, the team ran a smaller subset of three tests on all the orifices to see whether the testing set-up provided more consistent results. Looking forward, the team hopes to run a similar series of tests using carburetor jets as orifices and in-house fabricated brass orifices. Brass should not rust in water; however, it is unsure if the material will be durable enough for chlorine dosing as well.

Introduction

The nonlinear Chemical Dose Controller, designed in the fall of 2009, 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. Over the past few weeks, the CDC Team has been concerned with creating a precise and accurate orifice using the best material and manufacturing methods. The orifices that the Team tested were made from a bio-based polyamide material, which came from the company Legris. If the results from the testing were acceptable, then the Legris material would be used for the orifices as well as other fittings throughout the chemical doser.

Based on the results, the Legris orifices were found unsatisfactory for permanent use on the doser, due to the large standard deviations of the dosing capabilities between both large and small-scale orifices. Under the drill, the Legris material would heat up and deform, which would cause dosing to become slightly unpredictable. **The CDC Team's new hypothesis is that a more precise material is needed for the orifices in place of Legris. Our current method is to drill appropriately sized holes in the end of polyamide "quick connect" tubing caps. We have found drilling into plastic produces unsatisfactory results. The Team is now considering manufacturing the orifices from metal, such as brass or using carburetor jets as they are manufactured to a higher standard of degree of precision and durability.**

Experimental Design

Tests were run to measure the flow rates produced by 1 and 2 millimeter diameter orifices. These orifices were manufactured in-house from "quick connect" polyamide tubing caps. The lever arm and float were removed from the experiment to eliminate as many sources of error as possible. Instead, the dosing tube was connected directly from the constant head tank to a simple linear bar marked from 0 to 40 cm. Fo ur caps of each of the two sizes were tested randomly throughout this range. The collected data was stored in a spreadsheet where average flow, variance and standard deviation as well as the upper and lower limits for a 95% confidence interval were calculated. The set up can be seen in Figure 1 below.

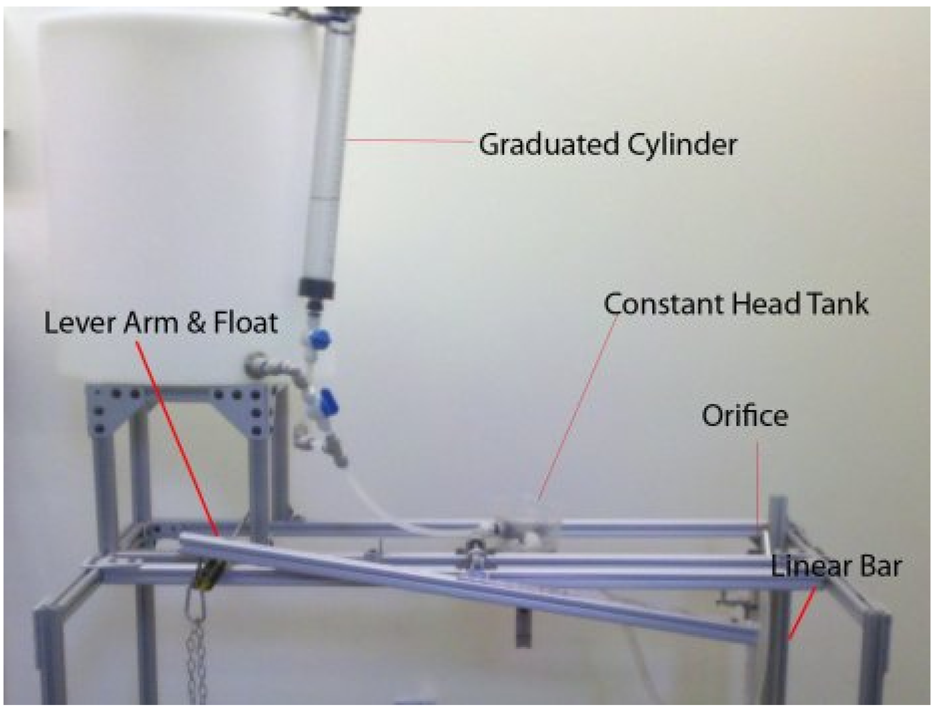

Figure 1: Experimental Design Setup

The first data set demonstrated wide variance within each orifice indicating that our testing apparatus or testing procedure was unreliable. In order to gain both better precision and accuracy, the set up of the experiment was modified to further eliminate sources of error. First, the tubing from both the stock tank and the graduated cylinder to the constant-head tank was increased from ¼” ID (inner diameter) to 3/8” ID to ensure that the flow into the head tank was enough to keep a constant head at all heights (Figure 2). The team also recognized that the procedure for setting the zero-mark was cumbersome and inaccurate. To mitigate errors from an incorrectly set zero, the linear bar was moved closer to the constant head tank and a ruler was used to ensure that a correct zero-mark was set. An abbreviated second series of tests was run to determine if the changes made to the testing procedure would have any impact on our data. The four 2 mm caps were tested three times, each through a range of 8 to 24 cm of head corresponding to a flow rate of approximately 140 to 290 mL/min.

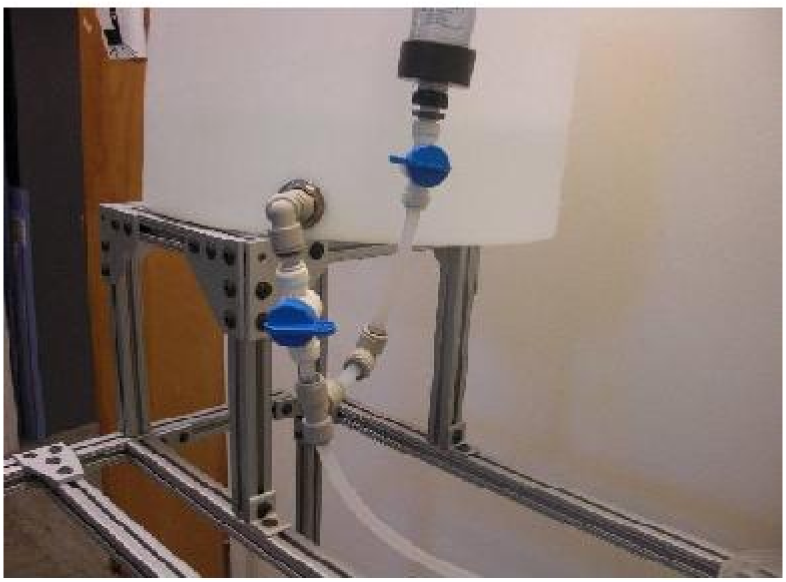

Figure 2: New Tubing (3/8” inner diameter)

Results and Discussion

As described in the previous section, four orifices were fabricated for each diameter (1 and 2 mm) out of Legris and the flow through each orifice was recorded incrementally throughout the 0 to 40 cm range. Each test was repeated 5 times for the same orifice in the hopes of uncovering yet undocumented problems with our testing procedure and to continue to check if precision was a problem.

Data from our first series of experiments showed considerable variance *within* each orifice. Ranges exceeding 28 mL/min were noted to have standard deviations exceeding 15 mL/min and a relative standard error of 69.6%. Team members collecting this data noted that at heights 0-4 cm, no flow or little flow was actually seen coming from the administering tube and that recorded values represented an increase in the level of the constant head tank. The team thus chose to eliminate the low range tests due to the issues of surface tension in this range. It was also noted that during the 2 mm orifices tests, the level in the head tank dropped when testing in the 36 - 40 cm range. Tests were run in this range in order to collect comprehensive data that would confirm any of the trends seen in the lower range heights. The reason for the drop in the constant head tank was attributed to the size of the orifice entering the constant head tank. The size of this orifice is 2.29 mm. Concern was also raised regarding how the zero-mark was established.

Because of the wide variance shown *within* an individual orifice, as shown by the figures given above, the team decided to modify the testing apparatus as described in the Experimental Design section of this report. Additionally, since at this time the focus is on precision and not accuracy, the test was simplified by reducing the number of measurements taken. The range of 8-24 cm (in 4 cm increments) was chosen because this range had shown the least amount of variance in previous tests, with an average standard deviation of 5 mL/min.

The second series of tests was performed with the linear bar moved closer to the constant head tank as seen in Figure 1 above. The statistics for each individual orifice have shown an acceptable level of variance with the calculated range. This validates the new testing procedure and allows the team to continue with the statistical analysis of the data.

This analysis reveals that the calculated range *between* orifices is quite high with standard deviations are nearing 15 mL/min (Figure 3,4). This proves that this type of material and manufacturing process does not provide reliable and precise orifices.

p= 0.05

cm	Avg Flow Rate - mL / min					Q		95%	Upper	Lower	mL/min
h	Orifice A	Orifice B	Orifice C	Orifice D	Range	Avg	Std Dev	CI			Q Calc
8	149.33	164.00	137.00	145.00	27.00	148.83	9.81	8.60	157.43	140.23	146.41
12	180.33	200.67	175.00	185.00	25.67	185.25	9.58	8.40	193.65	176.85	179.32
16	209.00	234.00	201.33	217.00	32.67	215.33	12.12	10.62	225.95	204.71	207.06
20	236.67	262.00	226.67	246.00	35.33	242.83	13.01	11.40	254.23	231.43	231.50
24	260.67	292.00	252.03	270.67	39.97	268.84	14.91	13.07	281.91	255.77	253.59

Figure 3: Summary Data

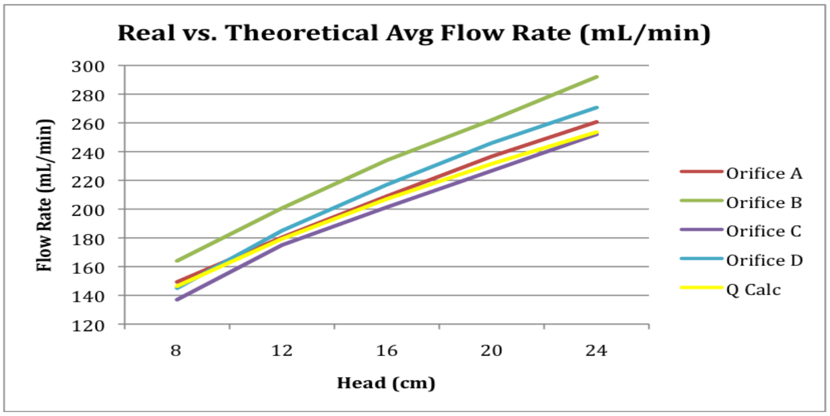

Figure 4: Comparison of Flow Rates of Experimental Data and Calculated Values

Future Work

As demonstrated in this report, the team is unable to precisely manufacture metering orifices from the Legris polyamide caps. The Spring 2010 team indicated difficulty with precision when machining acetal caps. For this reason, the team is concluding that fabricating a metering orifice from plastic materials will not produce the desired results and alternatives must be considered. One approach is to continue to manufacture the orifices in-house but instead use material that is better suited to drilling, such as brass or stainless steel. A second solution is to find an "off-the-shelf" orifice that will meet our needs.

Carburetor jets will be the first type of off-the-shelf manufactured orifice tested by the CDC team. This particular application of orifices was chosen because they are available in appropriate sizes and may be commonly available in the Honduras (e.g. motorcycles, street bikes and other gas engines).

Four Holley carburetor jets with an orifice diameter of approximately 1 mm (.040”) will be tested by the same methods as the Legris caps (Figure 5). After each of the orifices has been tested five times, the team will compile the data and determine the feasibility of using this type of manufactured orifice.

Figure 5: Brass Carburetor Jet - 0.040in Diameter

Additionally, two different styles of brass pipe caps have been ordered. The team will attempt to fabricate a precise metering orifice from these caps and will gather data using the same testing methods as previously discussed (Figure 6,7).

Figure 6: Brass Refrigerator Cap

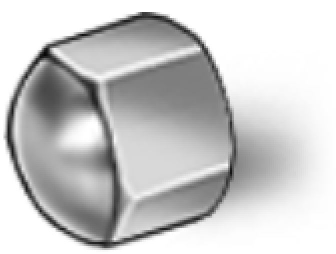

Figure 7: Brass SAE Flare Cap

The team will then compare the data between the off-the-shelf orifices and in-house orifices and hopes to make a final recommendation from this information.

Team Reflections

The validation tests conducted over the past two weeks revealed several problems which have been discussed in the Experimental Design section of this report. Many of these were solved by changing the experimental procedure. Some problems, however, could only be solved by an alteration in the physical setup of the experiment. These developments shall be the topic of this section.

The first problem encountered was the difficulty in determining an accurate zero level for the linear bar marking head levels. The method initially used to accomplish this involved moving the bar up and down until the orifice started to drip. This proved to be an unreliable approach as it could not take into account the effect of surface tension (a phenomenon that prevents liquid from flowing through the orifice at small values of head). This problem was resolved by moving the bar closer to the constant head tank. This tank has the zero level marked on it and the team was able to line up the zero levels of the tank and the bar, thus establishing a more reliable basis for the remainder of the experiment.

The second problem the team faced was the inability of the constant head tank to 'keep up with' orifice flow rates at large values of head (28 – 40 cm). The water level in the tank would steadily decrease as the tests were being conducted thus establishing a constantly changing and erroneous zero level. To correct for this fault, the team decided to disassemble the existing tubing from the water source to the constant head tank and replace it with tubing of a larger diameter. This new tubing is expected to provide a larger flow rate that will be able to match the flow rate from the orifice at large values of head.