Reflection Report 3

Chemical Dose Controller Reflection Report

Primary Authors: Michael DeLucia, Aditi Naik, Ritu Raman

Primary Editor: Monica Hill

AguaClara Reflection Report
Cornell University
School of Civil & Environmental Engineering
Ithaca , NY 14853-3501

Date Submitted: 23/07/2010

Date Revised: DD/MM/YYYY

Abstract

The Summer 2010 CDC Team has spent the semester exploring the challenges associated with manufacturing precise orifices. After discovering that orifices manufactured from polyamide were inadequate, the team decided to determine the feasibility of using orifices made from machinable metals such as brass. This report describes the results of the team's experiments on three different types of brass orifices and endeavors to set future goals for next semester's CDC Team.

Introduction

After testing four Legris polyamide orifices of 1 and 2 mm diameters, the Summer CDC team determined that this was an unsuitable material. The data collected on the Legris caps showed standard deviations exceeding 15 mL/min and relative standard errors of nearly 70%. The low range of tests in the 0-4 cm of head was eliminated due to noted issues of surface tension in this range. The high range, 36-40 cm, was also eliminated due to drops in the level of the constant head tank during tests.

Due to the wide variance shown within an individual orifice, the CDC team decided to modify the testing apparatus by increasing the diameter of the tubing from the entrance tank to the head tank and by using a more reliable method to establish the zero mark on the linear bar as discussed in the CDC team's second Reflection Report.

This report describes the CDC team's experiments with orifices manufactured from brass. Of the three types of orifices tested, two (Refrigerator Tubing Endcaps and SAE Flare Caps) were manufactured in-house and one (Carburetor Jets) was purchased off-the-shelf. The team hypothesizes that the brass orifices manufactured in-house will prove to be more reliable than those made from polyamide as metals possess better machinability characteristics than plastics. Additionally, the team believes the carburetor jets will prove to be the most precise orifices tested as they will be bought from a vendor with strict machining tolerances.

Experimental Design

The modified experimental setup and procedure described in the previous reflection report provided consistent and satisfactory results. For this reason, the team saw no need to change the experimental design for the subsequent rounds of testing.

The unsuitability of Legris Polyamide caps led the team to consider manufacturing orifices out of more machinable materials. Two types of brass caps were thus chosen for validation: Refrigerator Tubing caps and SAE Flare caps. Two caps of each type were drilled with 2mm diameter orifices in the direction of flow. The results of this test, which shall be discussed in greater detail in the next section of this report, showed large inconsistencies between different orifices. The team's first solution to this problem was to remove the copper ferrules and rubber grommets from the caps thus creating more consistent entrance regions. However, this proved to have no effect whatsoever on the data. The team then determined that the inconsistencies could be attributed to the centering bit creating a different shaped entrance region, and thus a different vena contracta coefficient, in each cap. Since drilled brass does not create significant burrs at drill-bit break-through, the next round of tests was conducted on caps drilled against the direction of flow. This design was based on the assumption that the bevel created by the centering bit would only occur at the exit region thus keeping the entrance region consistent between orifices. This theory seems to be validated by the data. For this reason, the team manufactured two more orifices of each type of cap and gathered data on these as well. This increased the amount of confidence that could be placed in the results.

The team then decided to investigate the feasibility of using off-the-shelf orifices such as carburetor jets. Four brass carburetor jets of 0.040in (approximately 1mm) diameter were tested in the same way as the refrigerator and flare caps. These proved to be the most precise metering orifices tested thus far by the CDC team.

Results and Discussion

The results of the first trial of refrigerator and flare caps drilled in the direction of flow can be seen in Figures 1 and 2. The caps show a percentage variation up to 9% and thus were deemed unacceptable as they fell below the team's benchmark of no greater than 5% variation between orifices. The line showing calculated values of flow rate uses an arbitrary value of K_{vc} that best fits the data.

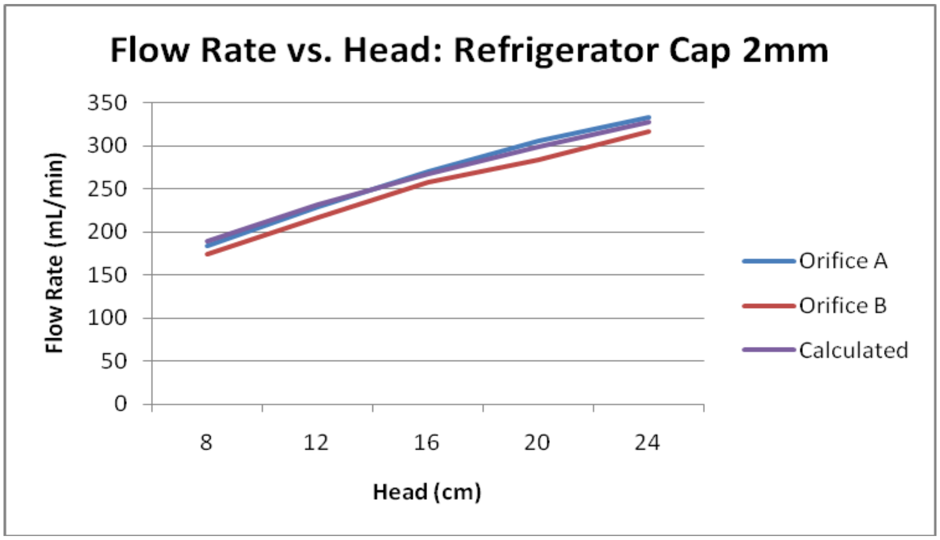

Figure 1: Refrigerator Cap 2mm Drilled in Direction of Flow, $K_{vc} = 0.8$

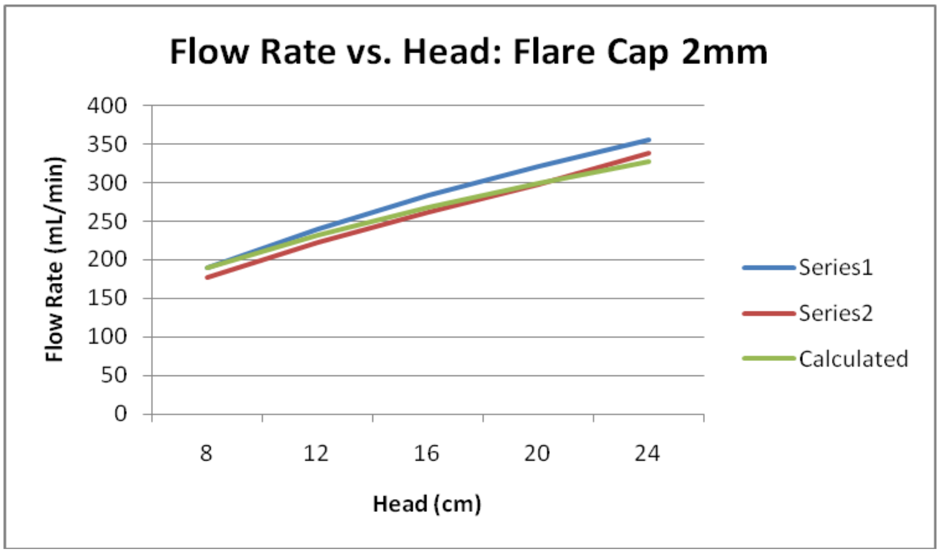

Figure 2: Flare Cap 2mm Data Drilled in Direction of Flow, $K_{vc} = 0.8$

The results of the second trial of refrigerator and flare caps drilled in the opposite direction of flow can be seen in Figures 3 and 4. These caps showed less than 5% variation between orifices and were thus proved satisfactory.

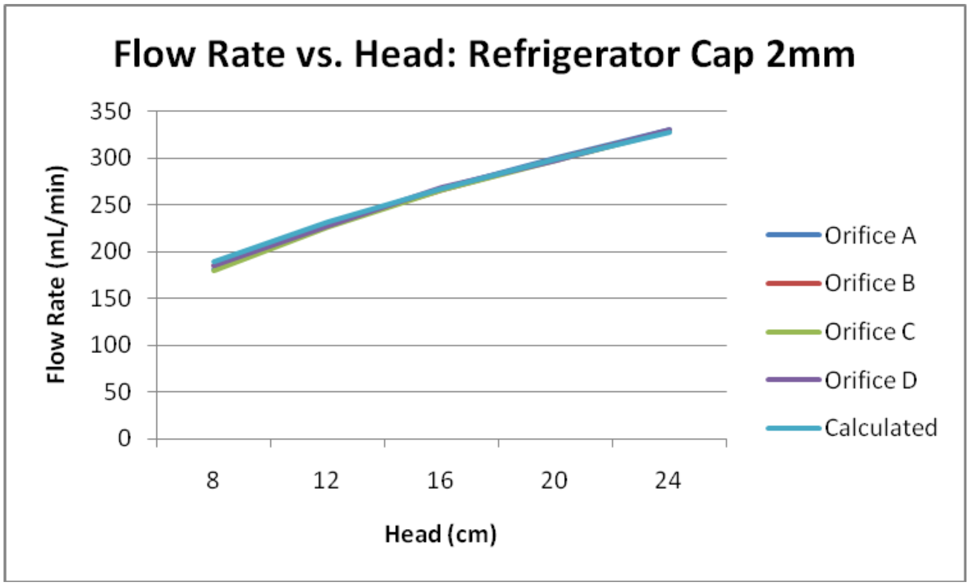

Figure 3: Refrigerator Cap 2mm Drilled Against Direction of Flow, $K_{vc} = 0.8$

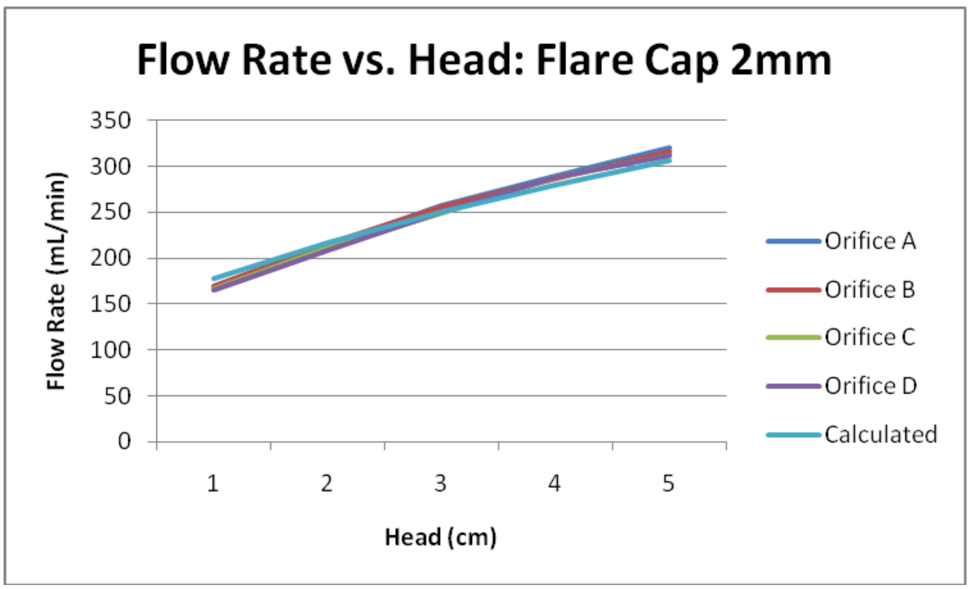

Figure 4: Flare Cap 2mm Data Drilled Against Direction of Flow, $K_{vc} = 0.75$

The results of the carburetor jet trial are shown in Figure 5. These caps showed a percentage variation of less than 5% between orifices and were the most precise metering orifices tested by the Summer 2010 CDC team.

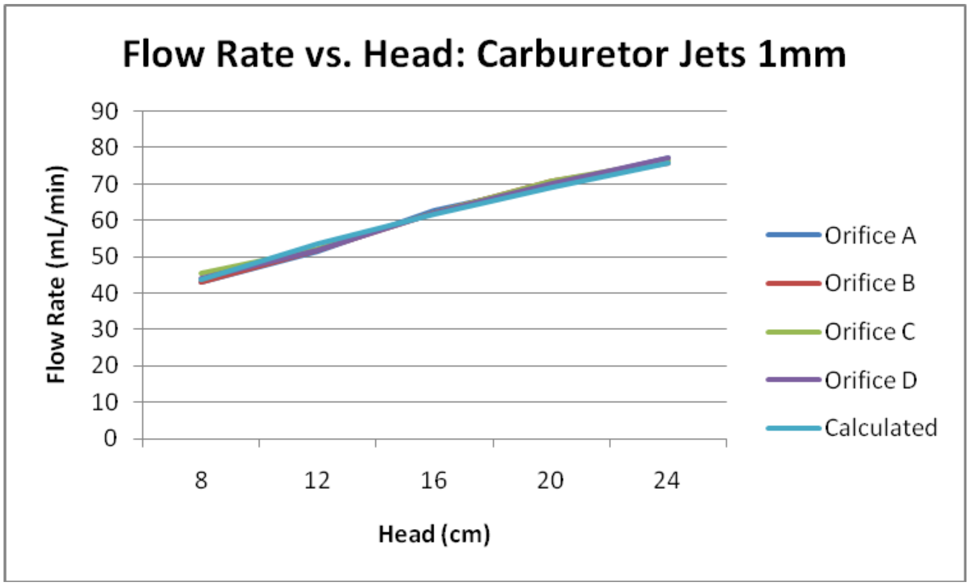

Figure 5: Carburetor Jet 1mm Data, $K_{vc} = 0.74$

The results of these three rounds of tests show that it is possible to machine reliable orifices from brass though slightly better results can be obtained from off-the-shelf brass orifices. However, since both the in-house and off-the-shelf orifices satisfy the criterion for less than 5% percent variation set by the team, the final decision on which would be more applicable in an AguaClara plant must be made after considering the local availability and ease of replacement of each of these types of orifices.

The primary reason for testing brass is that metals possess better machinability characteristics than plastics such as acetal and polyamide. If the team cannot machine parts from brass in-house, there is very little likelihood of finding a more suitable material. These tests have proven that it is possible to manufacture precise and reliable orifices from brass. However, the chemical compatibility of brass with alum, chlorine and saturated lime is suspect. For this reason, it is important to find a material that possesses desirable machinability characteristics as well as chemical compatibility. This challenge shall be considered in the next section of this report.

Future Work

As the last two weeks of this AguaClara summer internship quickly approach, the CDC Team has decided to do no more testing, but instead place all effort towards compiling their research on the CDC wiki page and creating their Final Presentation for next Thursday.

However, if the Team felt there was time to complete more testing, the next step would have been to create a PVC orifice. This orifice would be machined in-house with a 1mm and 2mm drill bit through a small cylindrical amount of PVC, which would be similar to the PVC used to create the connecter between the carburetor jet and the soft tube from the head tank. Again, a series of tests as done with the brass orifices would be conducted to determine the precision and accuracy of these PVC orifices. The reason for trying this new test even though the carburetor jets proved usable is that PVC would be able to dose chlorine as well without corroding.

Team Reflections

During the previous two weeks the CDC Team has tested a new material for the dosing orifice: brass. As seen in our results section, the brass orifices created from flare caps, refrigerator caps, and carburetor jets have all proved to show the precision and accuracy the Team has been looking for in the past seven weeks.

The only part with which the Team experienced a slight amount of difficulty was creating a connector between the new brass orifices and the original soft tubing coming from the constant head tank. A brass connector piece was ordered with the correct thread count, so the refrigerator caps and the flare caps could be connected to the doser with leaking. However, after originally trying this setup, it was quickly discovered that there was still water leaking from the connecter. After trying hose clamps to prevent this, the Team turned to using Teflon tape, which did stop the leaking (Figure 6). The only problem was that once during the testing, the results began to look very inaccurate, until it was discovered that a piece of the Teflon tape was blocking the orifice hole.

Figure 6: Teflon Tape on Connector

The carburetor jets were much smaller than originally expected. To create an adequate connector, the Team drilled through a piece of PVC to create the needed thread count to connect the carburetor jets to the soft tubing, which worked perfectly (Figure 7).

Figure 7: Carburetor Connector Manufactured from PVC