Linear Chemical Doser

Created by Nicole Ceci, last modified by Steve Mitchell on May 04, 2009

Linear Chemical Doser

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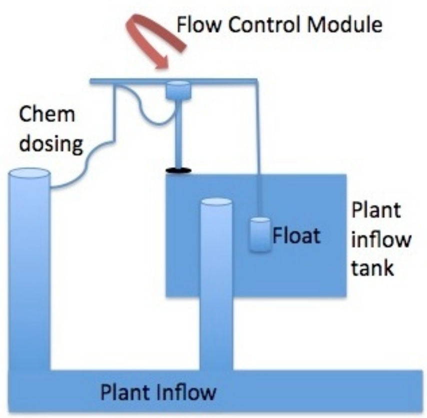

This research is focused on designing a linear automated chemical doser that can automatically adjust the head loss in the chemical dosing system in response to plant inflow changes. Currently plant chemical dosing is determined based on plant inflow and turbidity. The chemical doser (CD) will eliminate the need for plant operators to dose for inflow, reducing the number of variables and therefore opportunities for error.

One main reason for the focus on this doser is that it will allow the AguaClara plants to be more flexible. Plant inflow is largely variable with weather, both seasonally and hourly. In Honduras particularly there is a high frequency of late night rain storms, which appreciably increase plant inflow. Ideally the automated chemical dosing system will allow plants to respond to these weather-driven changes without an operator's presence.

Subteam semester goals
Weekly subteam progress

Linear Chemical Doser Research: Methods and Results

Fall 2008

Overall Data Analyses

- Data from all three experimental runs in Fall 2008 analyzed together

Lever arm height versus chem dosing

- The robust chemical doser from Fall 2008 was tested by fixing the lever arm height at multiple heights while measuring flow controller outflow at different locations along the lever arm (similar to float height vs. chem dosing experiment)

Float height versus chem dosing at multiple lever arm locations

- The chemical doser apparatus and prototype from Fall 2008 were tested by increasing the float height while measuring flow controller outflow at different locations along the lever arm

Additional Information

Chemical doser design

- Includes apparatus design and chronological modifications to the experimental set-up

Parts list

Setting up and calibrating a CD

- Includes specific instructions for setting up and calibrating a CD

Take the new member quiz to become better acquainted with the project

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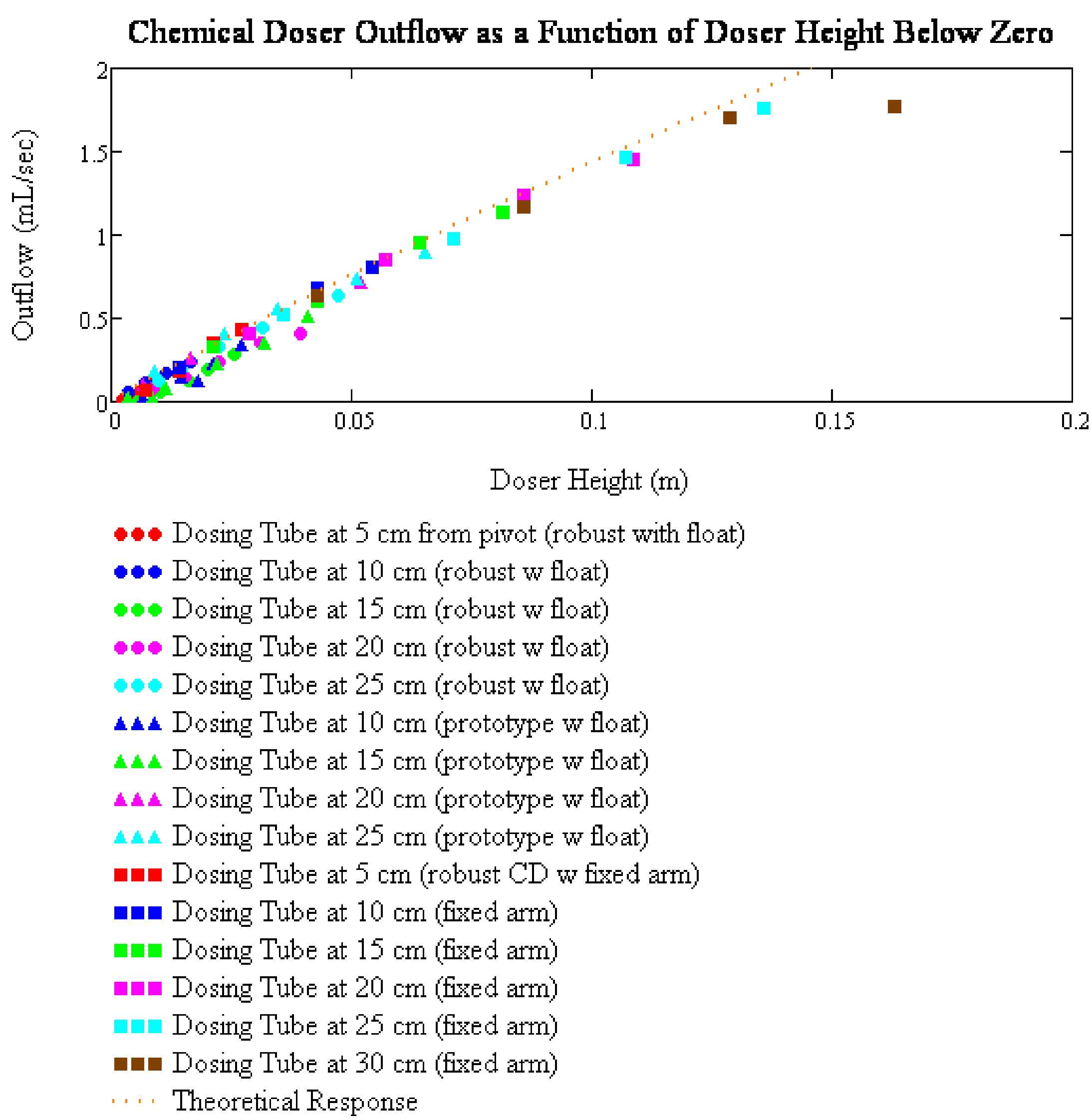
CD Fall 08 Overall Data Analyses

Created by Nicole Ceci, last modified on Apr 30, 2009

Overall Data Analyses and Conclusions

Data from the lab prototype and robust CD designs collected in the Fall 2008 experiments here and here were analyzed. Both lab set ups used the same FC so the doser tubing lengths were the same, making analysis simpler.

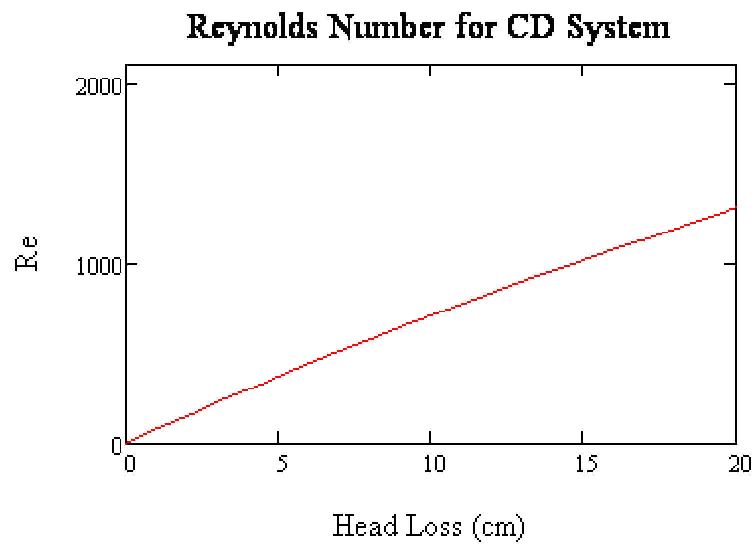
All data was corrected in MathCAD so that float heights and lever arm positions were converted into chem doser heights at each position out from the pivot. The chem doser height is actually the change in height downward from the zero level, which corresponds to the driving head on the system being applied by the moving lever arm. This was then plotted on a graph to show the relationship between doser height and outflow measured, which can be seen below.



The data fall along a nearly-linear path with a spread of about 0.2 mL/sec that appears to fall off around 1.1 mL/sec outflow. There is relatively little data collected at the heigher flowrates, though, so this conclusion is not very concrete. It is important to note that the data clusters very strongly around the theoretical performance for the system using head loss equations for both major and minor losses in the FC outflow tubing (graphed as the dashed line).

To make sure that the system was tested in the laminar flow range, the following Reynold's Number analysis was performed. As can be seen in the graph, the system should not have approached the turbulent transition during testing with head losses of

0-20 cm.



The MathCAD program (CDFall08LeverT) used to analyze this data can be found attached here.

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CD float height to outflow Fall 08

Created by Nicole Ceci, last modified on Apr 30, 2009

Experimental Methods

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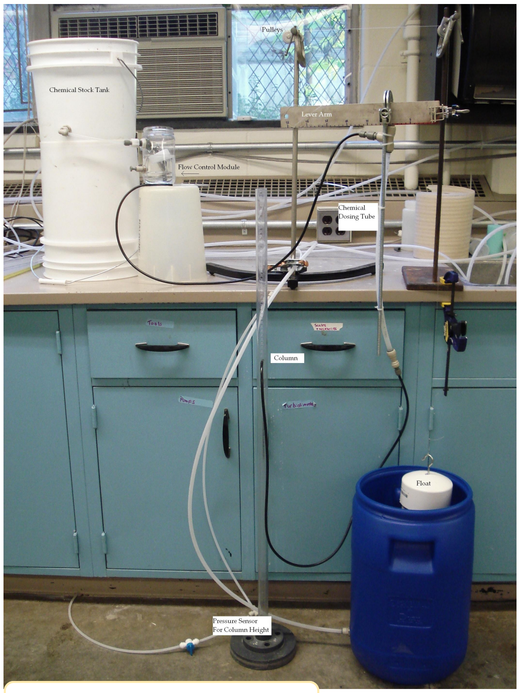

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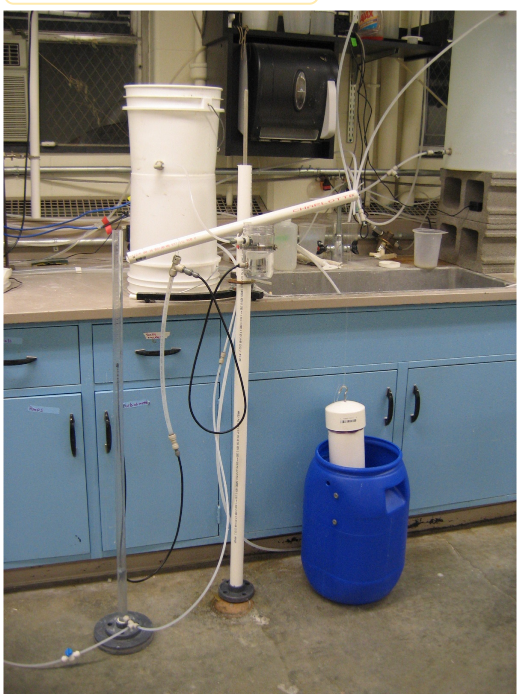


Two CD experimental set ups (the lab prototype and the robust CD) were used in identical experiments to collect data sets relating change in float height to dosing in Fall 2008. First the chemical doser was positioned at 5 cm intervals along the lever arm. The water level in the grit chamber bucket was varied while readings were taken of the changing water height in the collection column (explained below).

The 7 kPa pressure sensor at the base of the bucket was calibrated to read in centimeters of water and it was zeroed for the condition when the float just became buoyant and was no longer resting on the bottom of the bucket. The lever arm was made horizontal at the point by adjusting the length of fishing line tied to its end. This was checked with a level. By zeroing the pressure sensor at a lever arm height of zero all readings from the bucket pressure sensor were then equivalent to change in float height, which was also equal to negative change in the height of the end of the lever arm because of the fishing line connecting the float to the end of the lever arm.

A flow controller (FC) was connected to the chemical dosing tube at the T as is described in the CD experimental set up. The FC was fed from a bucket of water less than 1 m above it at all times, ensuring that there were not significant changes in water level within the FC. The FC was positioned at a level even with the lever arm such that it dosed no water when the lever arm was zeroed. The FC began to dose with a change in driving head of 1mm from that zero.

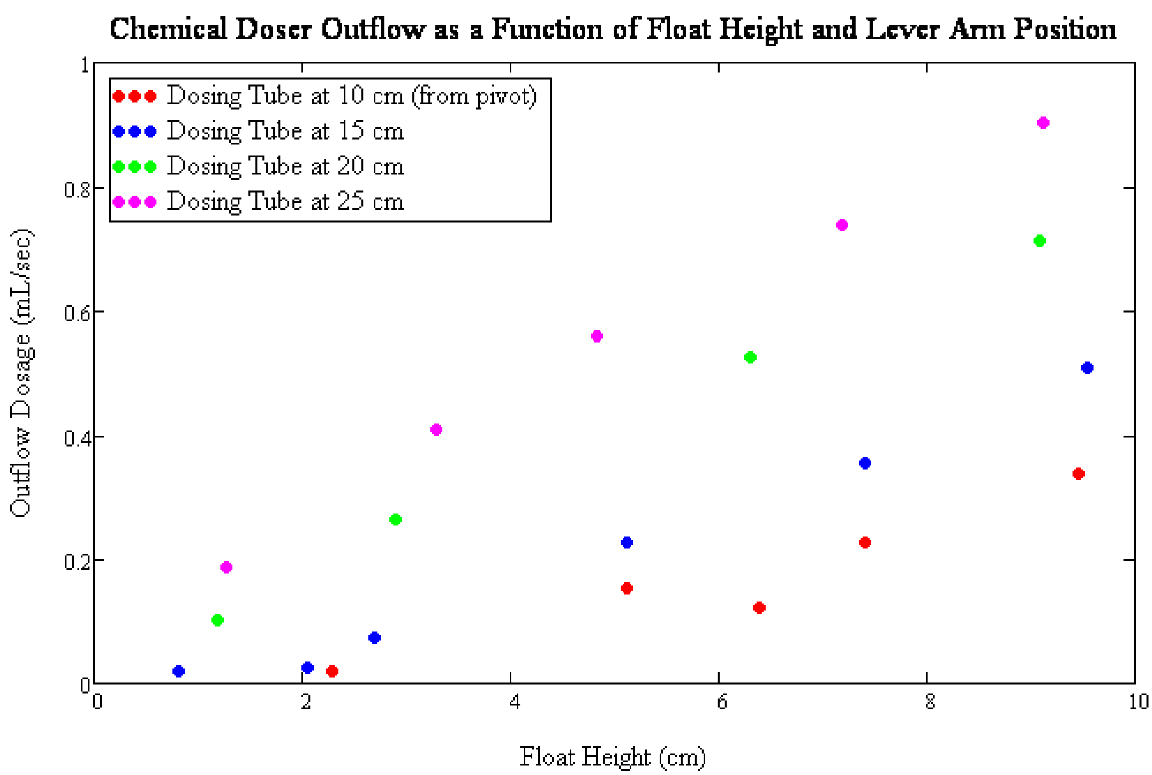
To measure flowrate from the FC through the CD a 7kPa pressure sensor was used at the bottom of the collection column. Water flowed from the FC through the T into the chemical dosing tube and then into the column. The pressure sensor at the base of the collection column was calibrated to read in centimeters of water, and it was zeroed after the valve at the base of the column had been opened and the water completely drained out. As water was dosed from the FC into the column, the pressure sensor transmitted data to a computer running the program Easy Data, which recorded both water level and time lapse in 1 second steps. Since the column dimensions are known, these variables can then be used to solve for a flowrate.

Concurrent data from the pressure sensor at the base of the bucket can be used to show the exact height of the float relative to the apparatus for each flowrate. Data was collected at several float heights for each distance the chemical dosing tube was attached along the lever arm or 10 cm, 15 cm, 20 cm, and 25 cm.

Experimental Results

All laboratory data was analyzed using the MathCAD program CDFall08LeverT, which can be found attached to the main CD page. Data arrays of column water height were transformed to flowrates at each float height and chem doser position studied. The data can be seen in the figure below. Each set of color coded data represents readings from one specific chem doser position along the lever arm, given in centimeters out from the pivot.

For the Lab Prototype

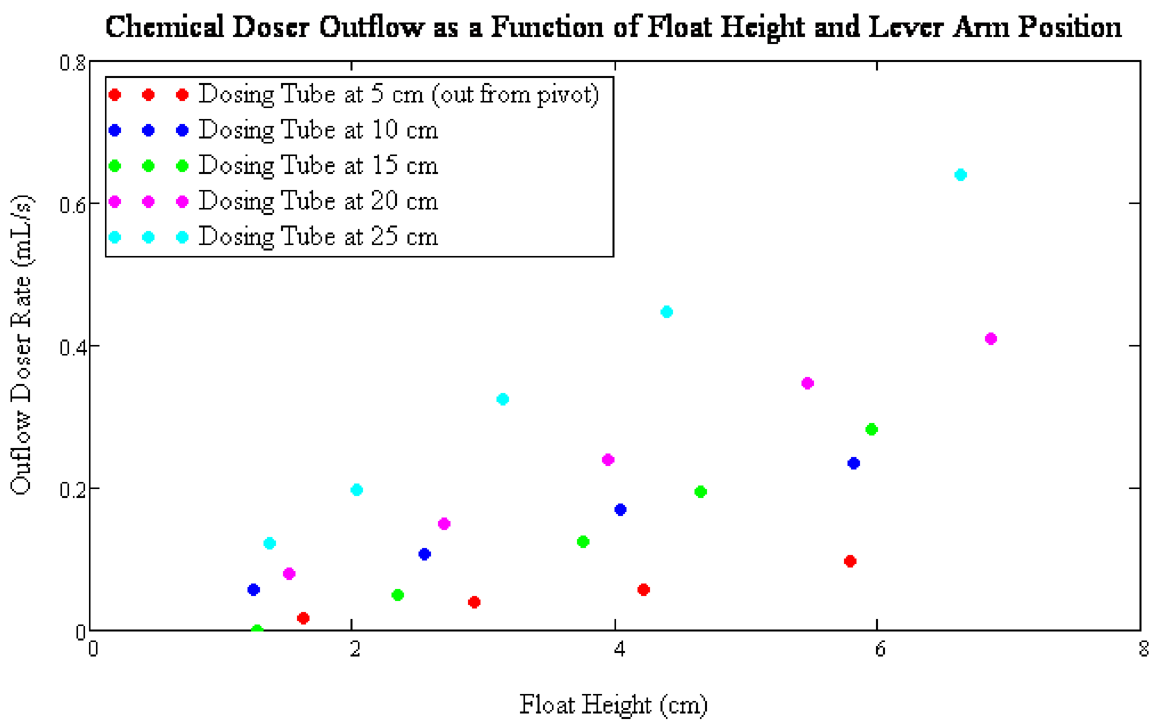


The data appears linear when the chem doser was placed 15 cm (pink points on graph below), 20 cm (green), or 25 cm (blue) from the pivot point, but it becomes less predictable at only 10 cm (red). The system also loses reliability around 0.08 mL/sec dosing, as can been seen in both the red and blue data sets below. This is a very low flow rate, and it is possible that surface tension and head loss are playing a significant role in the system at this point.

The final concern with this data is that there is not equal distance in the y-axis direction between the four lines. Theoretically we should expect the slope of each line to equal the sum of the slope of the line below it and the slope of the 5 cm line. In other words, moving out each 5 cm interval along the lever arm should result in a line that is rotated by a consistent angle around the origin. Visual inspection of the graph above shows that the data from the doser being located 15 cm from the pivot (shown in blue) appears to be translated downward slightly. The data does not appear to go through the origin, and it does not lie evenly between the 10 cm and 20 cm data lines when rotated around the origin.

Overall the data does follow an expected pattern, with a few unexpected readings. Flow rate increases as float height and distance from the pivot increases, allowing us to consider the CD reliable enough to dose alum to a precise enough degree.

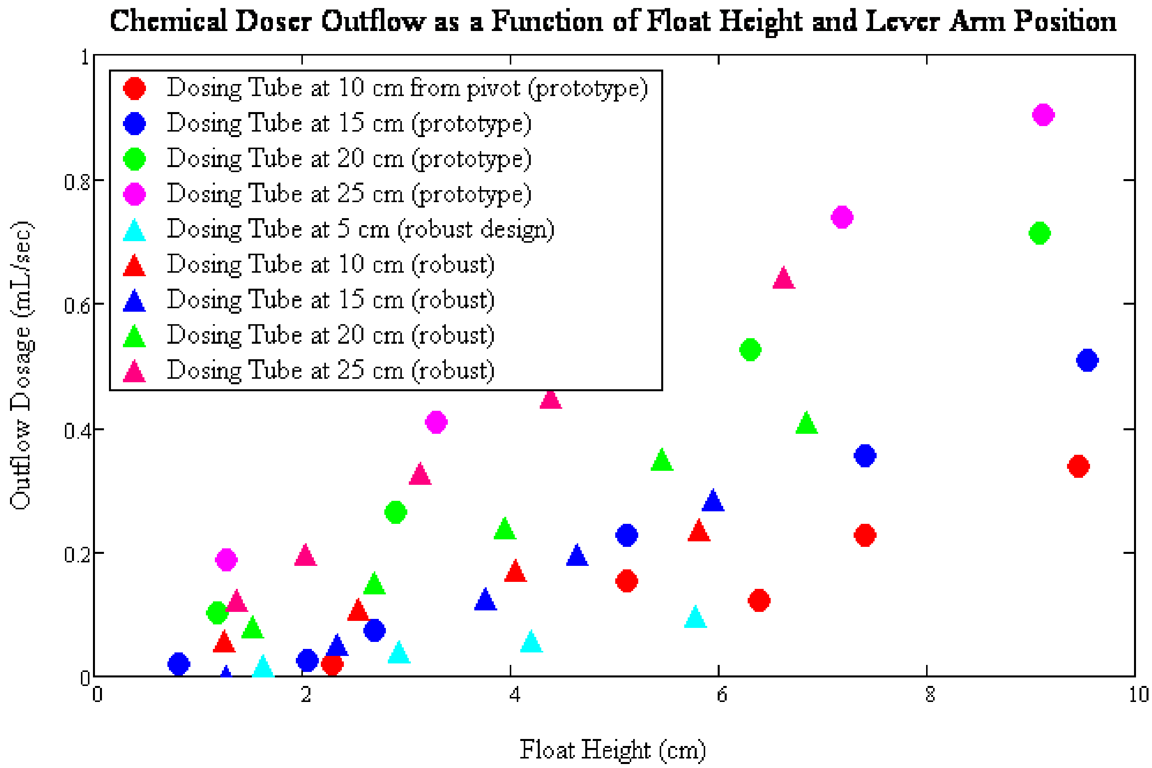
For the Robust System



Data for the robust CD system is much less accurate than for the prototype. Data for the doser at 5 cm from the pivot (in red points), at 20 cm (in pink), and at 25 cm (in teal) appears to be linear, passing through the origin, and approximately evenly spaced. On the other hand the data from 10 cm and 15 cm out (in blue and green respectively) do not fit the expected pattern. The 10 cm data appears to be higher than expected, with a less steep slope. Similarly to the prototype testing, the 15 cm data appears to have too high of a slope and be translated downwards.

Comparing Both Systems

The inconsistencies become apparent when the data sets are laid on top of one another. In the graph below, the triangle points are data collected with the robust set up, while the circular points are from testing the prototype. Theoretically the two data sets should lay on identical trajectories, but only the 15 cm and 25 cm data sets are close. The 15 cm data sets fit the best, but they are also the farthest off of the theoretical trajectory anticipated.



Sources of Error

The largest source of error is that the system may not have had enough time to come to equilibrium each time it was moved. Changing the position of the dosing tube changed the driving head, which takes an unknown amount of time to re-equilibrate. Also each time the bucket water level was changed, it took and unknown amount of time for the float to come completely back to rest. The bucket was small enough that any mixing from adding or removing water would send relatively large ripples throughout. These visibly caused the float to move, which would in turn directly effect the doser for some period of time.

Another major issue with the experimental set up was that the pressure sensors were not reliable. The pressure sensors became unresponsive and had to be re-zeroed at least twice while testing the robust set up. This may indicate that the sensors were not producing accurate data at other points during the experiment without our noticing.

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CD lever arm to outflow Fall 08

Created by Nicole Ceci, last modified on Dec 20, 2008

Experimental Background

The deep bucket being used for the virtual grit chamber in the float height versus chemical dosing experiment was not deep enough to allow testing of the full 20cm range of dosing motion.

Experimental Methods

To test the full range of motion of the CD efficiently the experiment was modified so that the lever arm was held in place by a ringstand and clamp. The ringstand was marked with a centimeter scale with zero being marked where the clamp help the lever arm such that no liquid came out the pressure break T, but any lower clamp position caused flow to occur.

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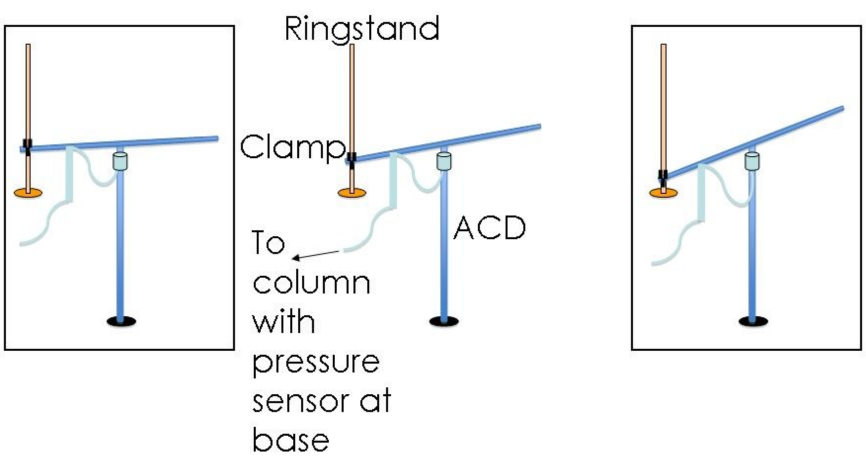
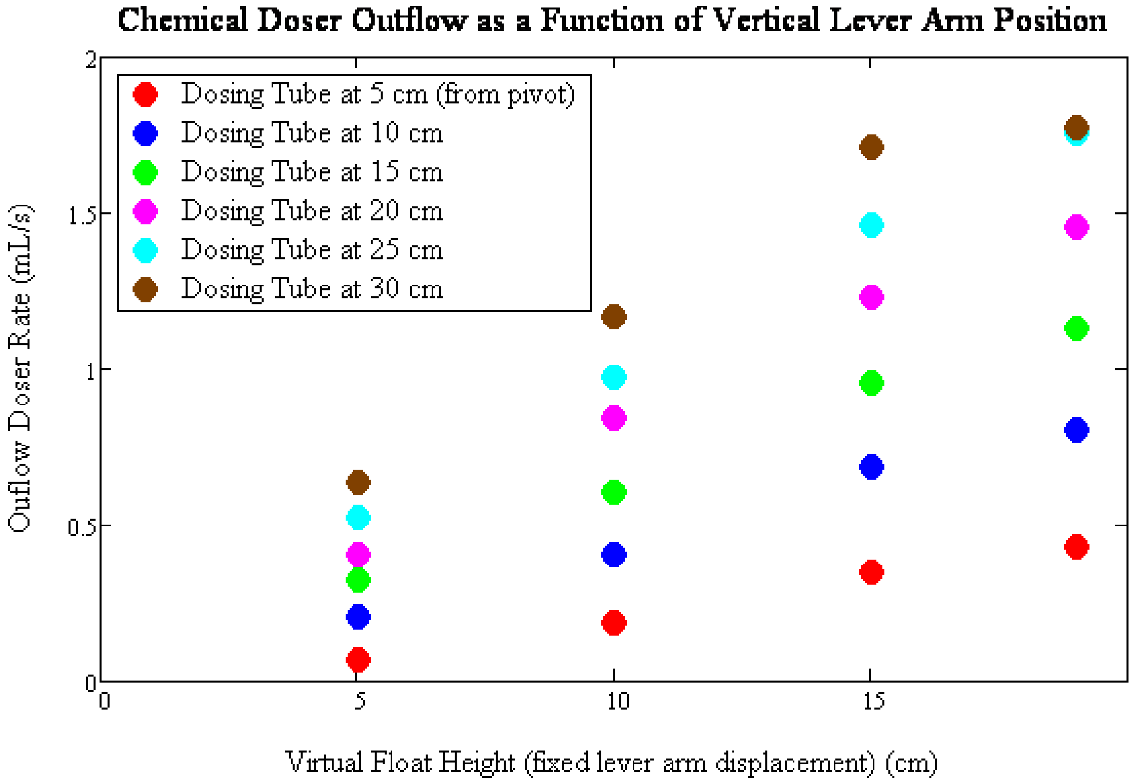


By securing the lever arm at precise heights, an exact float height could be simulated. The rest of the experimental method remained the same from the outflow to float height experiment. Namely, the chemical dosing tube was positioned at 5 cm intervals along the lever arm while outflow was measured by the pressure sensor in the base of the collection column. Data from the sensor was recorded in centimeters of water by using the Easy Data software.

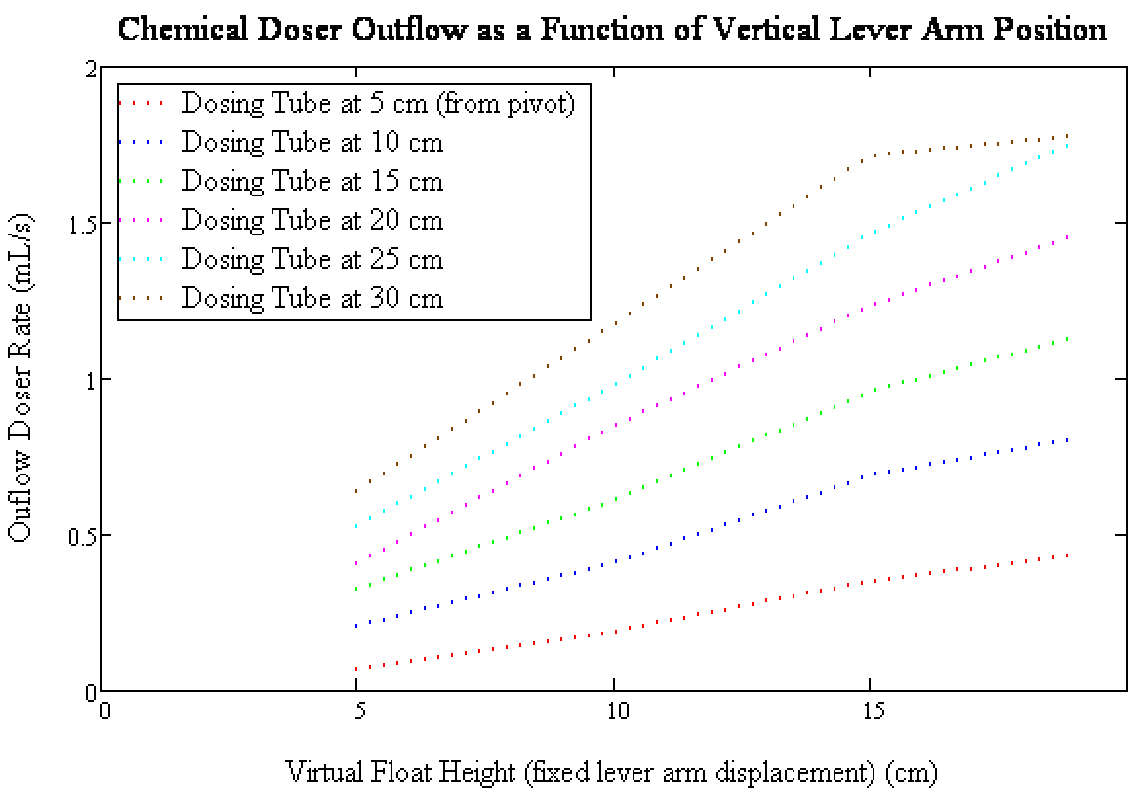
The lever arm was positioned at heights of 5 cm, 10 cm, 15 cm, and 19 cm, and the doser was positioned at a distance from the pivot of 5 cm, 10 cm, 15 cm, 20 cm, 25 cm, and 30 cm. Data was collected at every combination of those parameters, producing 24 flow rate data points.

Results

The results for this experiment show data that is mostly consistent with theoretical projections. The data sets for each distance away from the pivot show a clear linear trend, with the slope increasing by a constant factor with each 5 cm increment of distance added. When projected leftward, the data all approaches the origin. The only unexpected data point is at (19, 1.777) in the 30 cm data set.



Similarly to data collected with the lab prototype and the robust CD with the float attached, the system appears to be less responsive when used farther away from the pivot. The graph below replaces data points with lines, which shows this trend more clearly. The lines of data further from the pivot (20 cm, 25 cm, 30 cm) are closer together than the lines representing data close in to the pivot (5 cm, 10 cm, 15 cm).



This inconsistency is relatively small, though, and indicates that the robust design of the CD may be capable of dosing relatively precise amounts of fluid.

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