Linear Flow Orifice Meter

For Use In Water Treatment Plants

By Leah Buerman

Introduction

- The Linear Flow Orifice Meter, LFOM, consists of a riser pipe and an entrance tank.
- The device will lead to greater automation of the water treatment facility.
- Provides information on flow rate that dosing systems can use through float systems.

Need

- Automation provides greater security in water quality.
- Non-electrical constraint excludes common solutions.

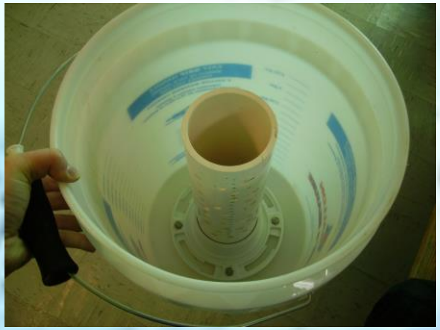
Overview

- Location in the plant

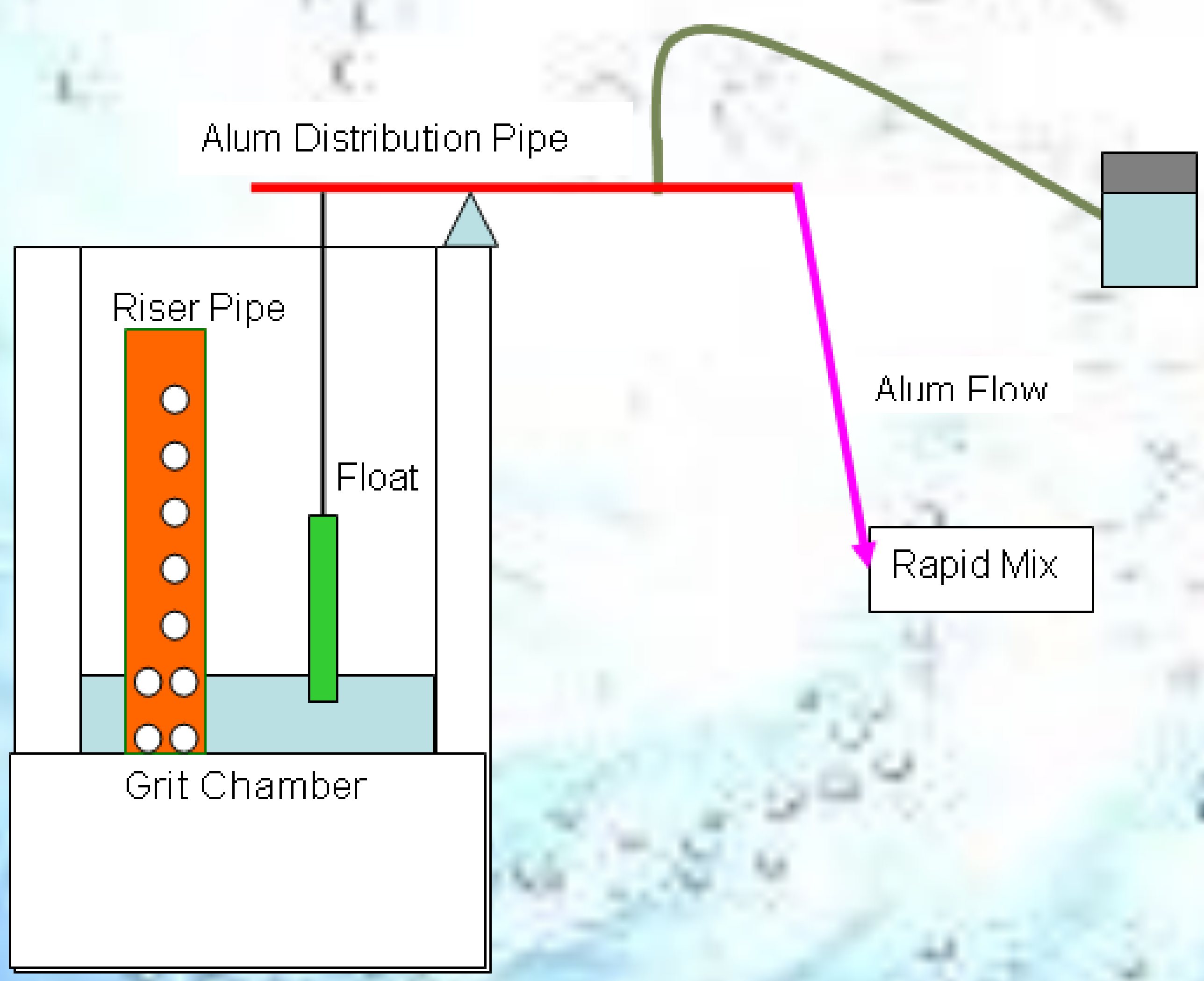
- Components:

  Riser pipe

  Entrance tank



Implementation

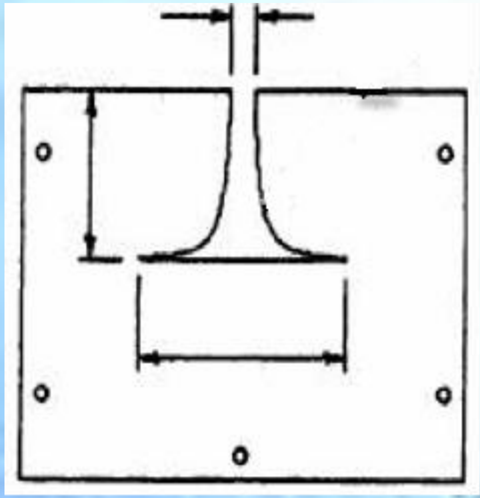


Linearize Relationship between Water Height and Flow Rate

- Without interference relationship is exponential.

Background

- Riser pipe designed after the Sutro Weir developed by Victor Sutro in 1915.



- The equation for the width of the weir as a function of height

$$y = \frac{W}{2}\left[1 - \frac{2}{\pi}\tan^{-1}\sqrt{\frac{x}{s}}\right]$$

Accuracy Experiment

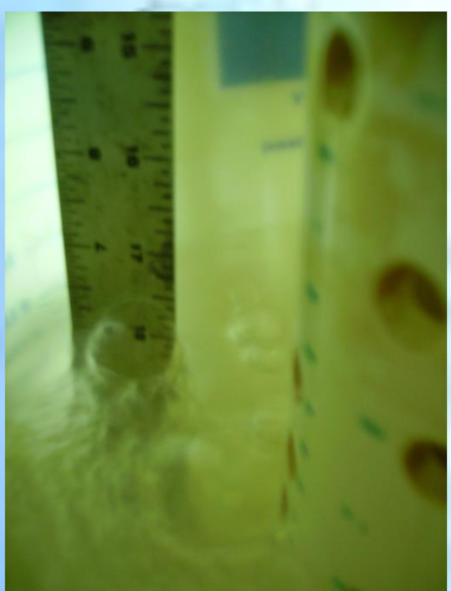
- The computer program modeling the LFOM computes the predicted flow rates based on the pattern of orifices.
- A prototype was tested in a pilot plant to verify the efficacy of the design and compare predicted results with actual performance.

Experimental Procedure

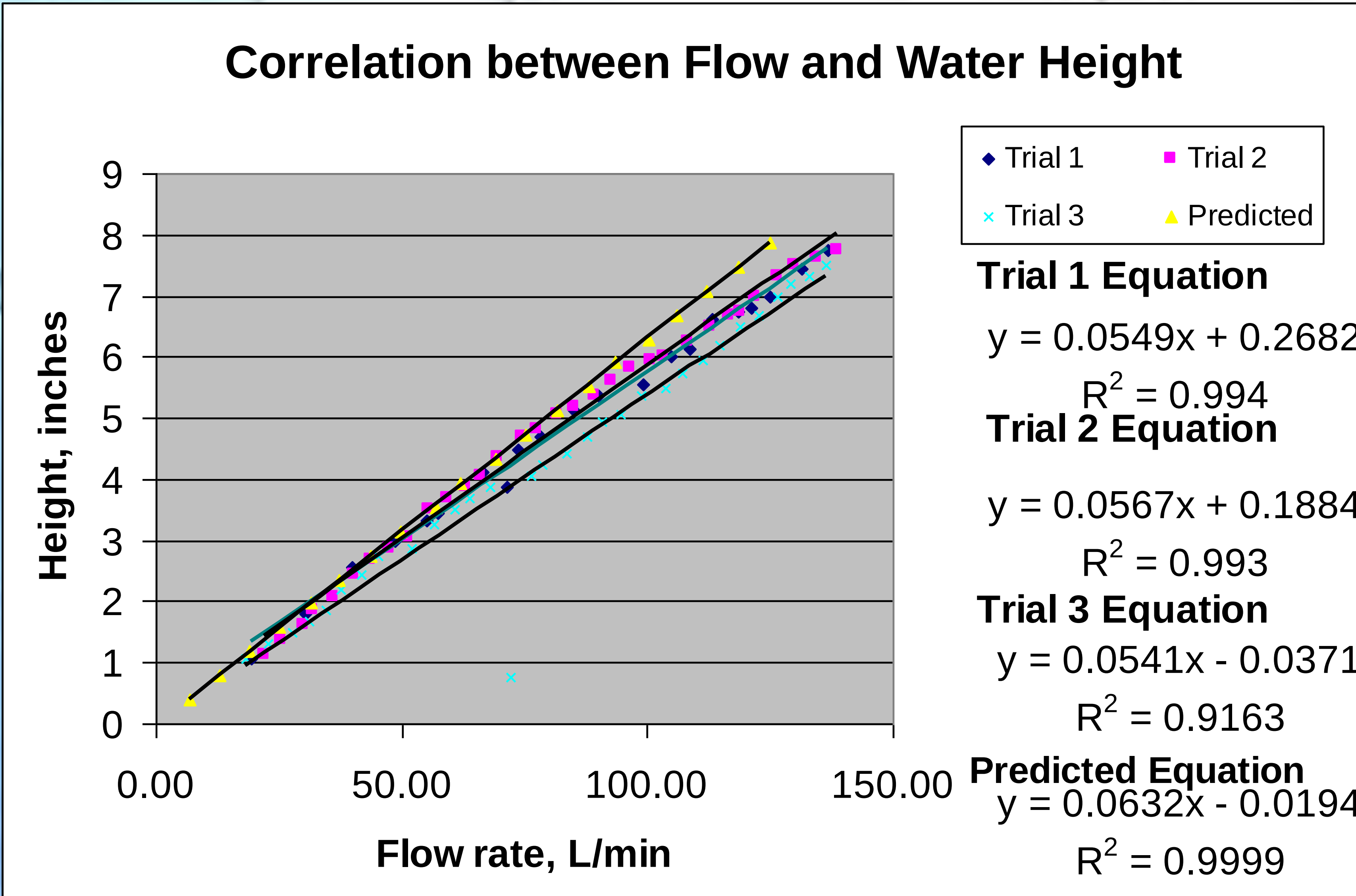
1) Clear all holes of Obstructions
2) Record the flow rate from the flow meter in GPM
3) Record the height of the water in the bucket using a ruler (inches), be sure to place the end of the ruler on the edge to ensure contact with the actual bucket base
4) For next reading change the flow rate manually and then wait approximately 5 minutes for the flow to acclimate.
5) Record the stabilized flow rate and the water height.

Record the water height for flows between 5 and 36 GPM in approximately 1 GPM increments

Measuring Height in Entrance Tank as a Function of Flow Rate



Results



Correlation between Flow and Water Height
Height, inches
0 1 2 3 4 5 6 7 8 9
0.00 50.00 100.00 150.00
Flow rate, L/min
Trial 1
Trial 2
Trial 3
Predicted
Trial 1 Equation
$y = 0.0549x + 0.2682$
$R^2 = 0.994$
Trial 2 Equation
$y = 0.0567x + 0.1884$
$R^2 = 0.993$
Trial 3 Equation
$y = 0.0541x - 0.0371$
$R^2 = 0.9163$
Predicted Equation
$y = 0.0632x - 0.0194$
$R^2 = 0.9999$

Point of Failure Experiment

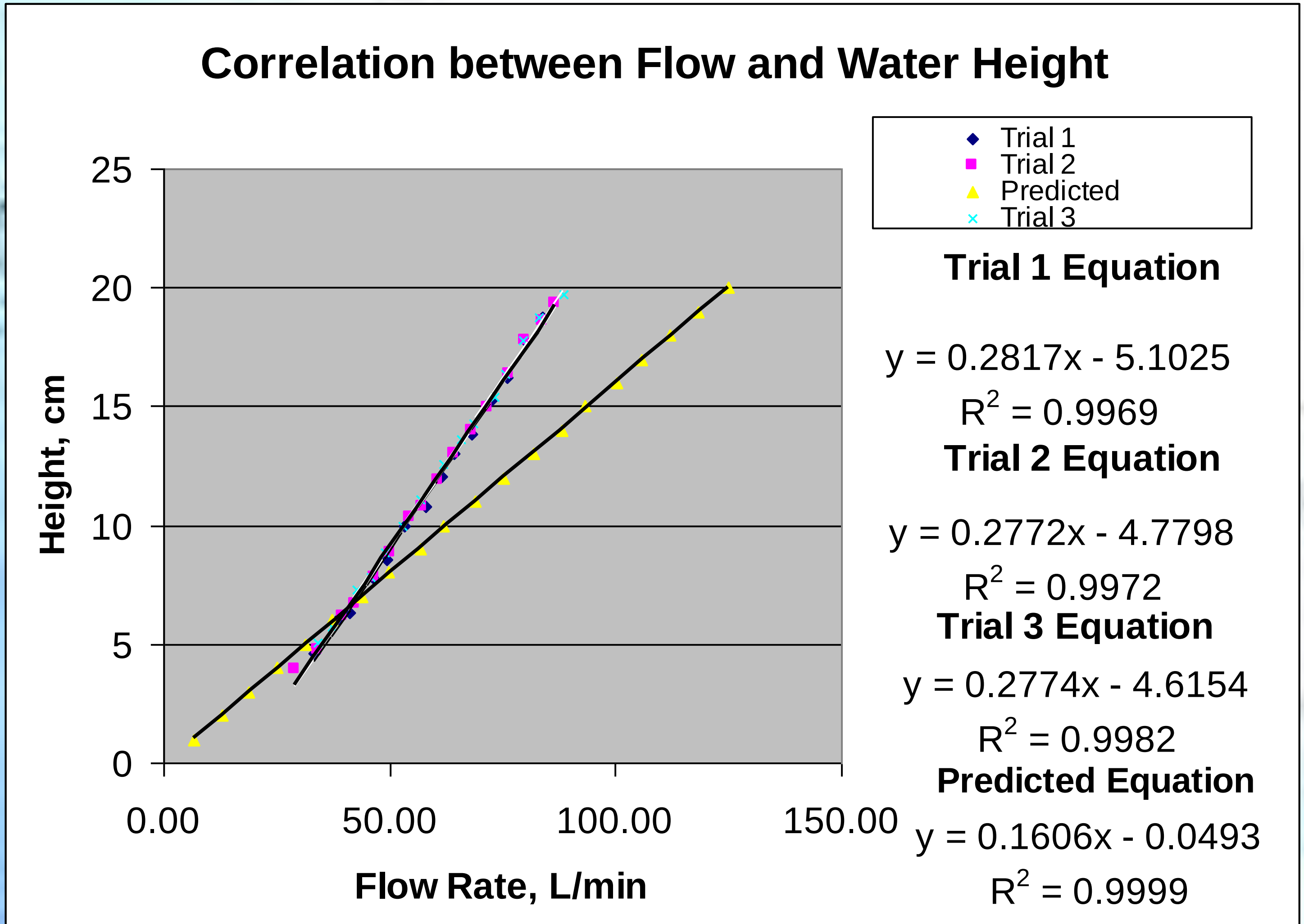
- The LFOM design constrains the diameter of the riser pipe by stability alone.
- It was hypothesized that at an elevated flow rate small diameter riser pipes would become backed-up.

Background

- The maximum exit velocity through the pipe was calculated assuming conservation of momentum.
- The exit velocity can be worked back to find the pipe area necessary to accommodate that velocity and then the diameter.
- The LFOM in the experiment was designed to fail at half of the maximum flow rate of the plant 62.5 L/min.
- The riser pipe was 1.5 inches in diameter.

The Riser Pipe in the Entrance Tank

Results



Correlation between Flow and Water Height
Trial 1
Trial 2
Predicted
Trial 3
25
20
15
10
5
0
Height, cm
0.00
50.00
100.00
150.00
Flow Rate, L/min
Trial 1 Equation
y = 0.2817x - 5.1025
$R^2 = 0.9969$
Trial 2 Equation
y = 0.2772x - 4.7798
$R^2 = 0.9972$
Trial 3 Equation
y = 0.2774x - 4.6154
$R^2 = 0.9982$
Predicted Equation
y = 0.1606x - 0.0493
$R^2 = 0.9999$

LFOM Design Code in MathCAD

- The Goal: to update the MathCAD code.
- Improve the method for determination of orifice diameter
- Explore the consequences of multiple riser pipes
- Evaluate the calculation of total riser pipe height

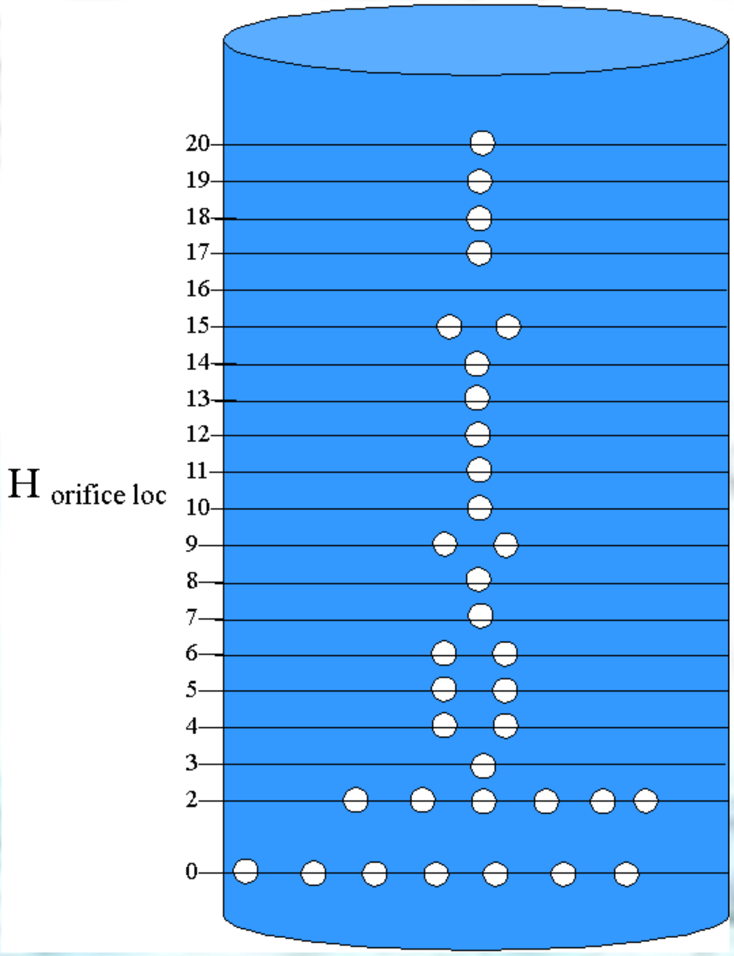
Optimal Orifice Diameter

- Steps
  - Integrate over row height to find row area
  - Calculate minimum number of orifices based on an orifice diameter equal to the row height
  - Calculate the optimal orifice diameter for each row.
  - Calculate the number of orifices in each row using the new diameter
  - Calculate the error associated with each design compared to the target values.

LFOM Designs for Pre-Set Flow Rates

- The MathCAD code was used to create LFOM designs for flow rates 100 L/min, 200 L/min, 300 L/min, 400 L/min, 500 L/min, 700 L/min,

  1000 L/min
- Variables: number of rows, initial height for $H_{flowloc}$.
- Evaluation Measures: maximum error, presence of major jumps



Results of Variable Variations

			1.5cm	Jump	2cm	Jump
	Flow Rate, L/min	$Pi_{Lfomorifices}$, #	Max Error, %	Y/N	Max Error , %	Y/N
	100	5	1.673	N	1.877	Y
	100	10	0.545	N	0.559	Y
	100	20	0.398	N	0.543	Y
	200	5	1.641		1.879	
	200	10	0.718	N	0.648	N
	200	20	0.14	N	0.14	N
	300	5	1.843		1.996	
	300	10	0.684	N	0.608	N
	300	20	0.195	N	0.124	Y
same orifice design created	400	5	1.481	N	1.481	N
	400	10	0.293	N	0.438	Y
	400	20	0.109	N	0.069	Y
same orifice design created	500	5	0.1949	N	1.949	N
	500	10	0.315	N	0.327	Y
	500	20	0.097	N	0.122	Y
	700	5	1.366	N	1.716	Y
	700	10	0.325	N	0.36	N
	700	20	0.046	N	0.119	Y
	1000	5	0.855	N	1.018	Y
	1000	10	0.125	N	0.218	Y
	1000	20	0.049	N	0.047	Y

Future Research

- Currently the drill size is based on the diameter that is the best fit for the top hole, it would be interesting to see what the effect is on the error if different rows were used to determine the diameter. The very top hole has a relatively small flow rate based on other rows - there may be a critical row.
- Also the point of failure experiment was conducted and the results were contrary to the expected hypothesis. Instead of the LFOM working to a certain flow rate and then failing the flow rates were linear but with a different slope than the predicted values. It would be useful to figure out what drives the effect witnessed with reduced diameter piping.
- Thirdly it is important to work on interface between the LFOM and the automated chemical doser.

Questions