StaRS FInE, Fall 2015

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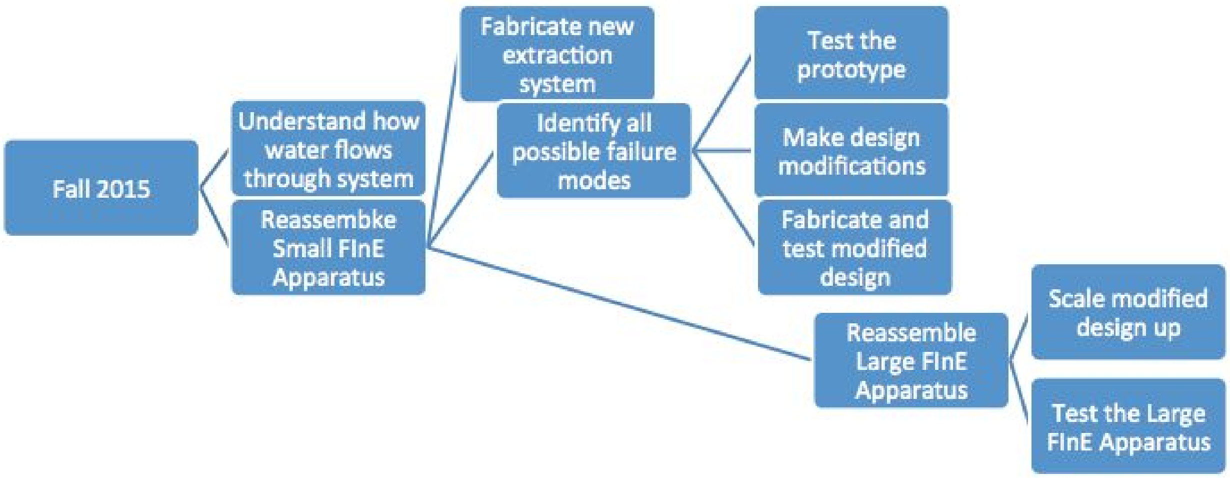
Abstract

AguaClara is a student project team in Cornell University. The main goal for this project team is to develop and implement water treatment solutions in Honduras and India. This subteam is Stacked Rapid Sand Filter Injection and Extraction (StaRS), and its goal is to find an alternative way for water to enter and exit the filter. The filtration system currently uses slotted pipes for injection and extraction; these pipes are susceptible to clogging and can consequently require replacement. The extraction system that is currently being tested uses a PVC pipe with open orifices that are protected by angled wings attached to the pipe. These wings were designed to generate a gravity-based sand exclusion zones to prevent possible filtration failure. Research completed this semester indicates that the current winged design in its existing form is not a viable design, because the necessary filtration velocity cannot be reached before failure occurs. In the final week of the semester, the team tested the strength of construction alternatives for the wings on the inlet pipes.

Table of Contents

Task List

Task Map



Task Details

1. Understand how water filters through system/September 14 - Michelle. Gain a deeper understanding of how water is filtered through the proposed injection and ejection units by conducting filter runs at normal conditions.

2. Reassemble smaller FInE apparatus/September 18 - Subhani. Transport the apparatus to the AguaClara lab space. Install inlets and outlets, configure pumps, add sand, and add water to continue testing.

3. Figure out how to successfully fill and run the filter/September 25 - Mengqi. Using information from the Spring 2015 report, Ji Young's experience, and trial and error, successfully fill and operate the filter.

4. Identify all possible failure modes/September 30 - Michelle. Research and evaluate all possible moments when sand can infiltrate the system. Create a detailed procedure to avoid that possibility.

5. Test the prototype/October 9 - Mengqi. Run repeated trials to test whether the design works as predicted. Conduct filter runs in both filtration and backwash modes. Make frequent observations, especially during the transition from backwash to filtration. Follow the detailed procedure in order to avoid possibility of sand entering the injection system.

6. Make design modifications/October 16 - Subhani. Based on testing with the smaller FInE apparatus, modify any malfunctioning parts.

7. Fabricate and test modified design on small scale/October 28 - Michelle. Based on design modifications of original design, fabricate new design and test in the small scale filter.

8. Scale the smaller FInE apparatus and reassemble larger FInE apparatus/November 6 - Michelle. Calculate sizes and order materials for the larger FInE system. Carefully reassemble the apparatus with the modified inlet and outlet.

9. Test larger FInE apparatus/November 20- Mengqi. Conduct repeated tests modeling conditions in Honduras. Collect relevant data to test the efficiency of the injection and extraction system.

10. Prepare final report and finalize design for apparatus/December 4 - Subhani. Compile a final report and presentation. Fix apparatus for presentations.

Team Roles

<u>Team Coordinator</u>: Subhani

The Team Coordinator ensured that the team was on task during all meetings and steadily advancing in its goals for the semester. The Team Coordinator was also in charge of communicating with other teams, namely StaRS Filter Theory and EStaRS, Enclosed Stacked Rapid Sand Filter Injection and Extraction, to convey any pertinent findings with the FInE apparatus and try to implement it in their systems as well.

<u>Data Coordinator</u>: Michelle

The Data Coordinator was in charge of setting up Process Controller for the system, so that results were immediately analyzed and recorded in data sheets. Additionally, the Data Coordinator will make sure to record videos of trial runs and make detailed procedural notes for future reference.

<u>Materials Coordinator</u>: Mengqi

The Materials Coordinator was in charge of ordering materials for the team as well as keeping track of the materials that were used up in the lab. The Materials Coordinator was in direct contact with Cristina to order materials through McMaster-Carr.

Introduction

The StaRS Filter FInE team was focused on creating an alternative method to effectively insert and remove water into the filter bed. Currently, the filtration units in Honduras depend on slotted pipes to push water into and out of the sand bed. Slotted pipes are PVC pipes that have tiny slots cut into them to prevent sand from entering the pipes. This system may not filter as effectively as originally thought as it has been found that sludge builds up within the slots, thus drastically reducing the filtering abilities of the sand filters. The proposed replacement for slotted pipes was in the form of alternative filtration injection and extraction methods. The set-up for filtration injection and extraction (FInE) involved PVC pipes with orifices aligned along the sides of the pipes and wings that extend from the top of the pipe to the bottom. This method hinges on the use of gravity exclusion regions in the sand bed. The Fall 2015 Team tested the design that was designed and fabricated the by the previous semester's team and to see how well it actually worked at improving overall filter function. At the end of the semester, the team also tested fabrication methods for inlet wings.

Literature Review

StaRS FInE System

The StaRS FInE System is proposed as an alternative to the slotted pipe system. This system rests on the basis of gravity-based sand exclusion to prevent clogging of the pipe network. The gravity based sand exclusion FInES system has requirements to maintain the integrity of filtration. Such requirements include keeping manifolds and trunk lines clear of sand during filter operation, uniformly injecting and extracting water from the sand bed, and maintaining low velocities at the sand-water interface to "slow head loss development on the injection side and prevent localized sand bed fluidization on the extraction side". (Weber-Shirk, M., & Lion, L. 2015). After testing, it was found that even during backwash operation, the upward velocity at the sand-water interface was less than the fluidization velocity of the sand, meaning that the exclusion zone is not compromised (Weber-Shirk, M., & Lion, L. 2015).

Fall 2014 StaRS FInE Report

The team originally tested various models for the FInE system, including inverted U tubes. They concluded that the inverted U tubes would be appropriate, given that the branch height is sufficient enough to prevent sand from settling and plugging the inlet pipes. Alternate designs were tested, but the team ultimately concluded that the major problem with the FInE system is determining a method to prevent fluidization of the sand bed. The team's experiments showed that during the transition from backwash to filtration, the sand becomes fluidized and travels out through the outlet pipe until the water height dropped enough that no more fluidized sand could travel out the outlet pipes.

Spring 2015 StaRS FInE Report

The Spring 2015 Team conducted numerous experiments using the winged design with orifices to determine that this is a plausible option for the FInE system. The wings were an improvement on the previous semester's design, as it succeeded in its goal to keep sand out of the inlet and outlets pipes during both filtration and backwash modes, even though the sand bed was fluidized. Additionally, the team concluded that the designs for the injection and extraction system will be different, as fluidization during filtration is not as large a problem as it is during backwash. Therefore, the inlet pipes do not require the same interface area and the same set of wide wings that the outlet pipes need. They further concluded that the inlet design does not call for wings, as the wide angles of the wings blocks much of the filter area and thus makes it hard to initialize fluidization and consequently, reduces flow through the filter. The wings were ultimately removed in their final design and recommendations, as even though sand may enter the inlet system, it does not travels through up to the filter entrance and is thus filtered as influent water. The finalized AutoCAD drawings for the inlet and outlet pipe designs are shown below in Figure 1.

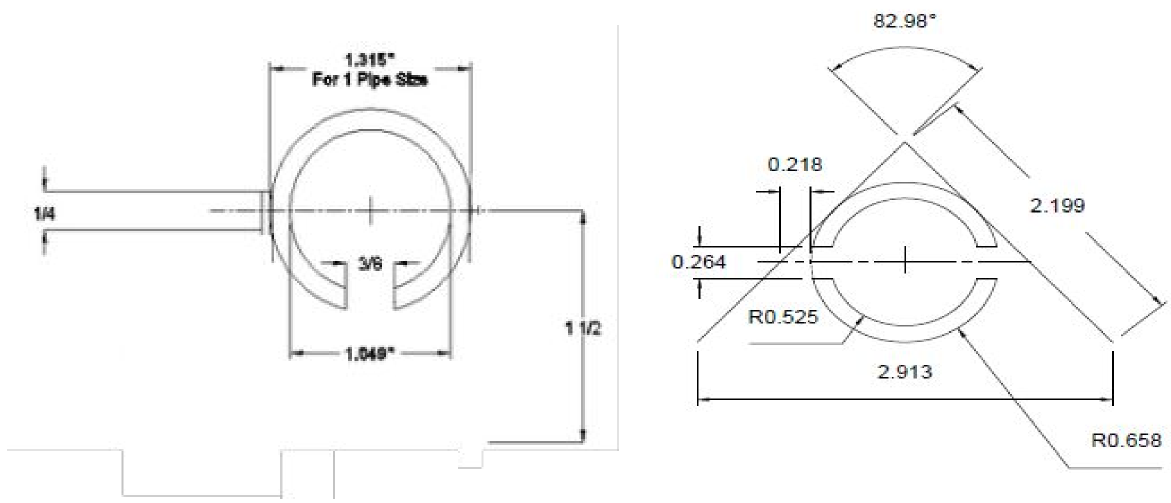


Figure 1: AutoCAD depictions of modified inlet and outlet designs proposed by FInE Spring 2015 Team.

Spring 2015 EStaRS Report

The Enclosed Stacked Rapid Sand (EStaRS) filter is a small scale variation of a typical StaRS filter that is designed for low-flow, standalone operation. EStaRS filters are currently being used to treat well water in India for rural villages of ~600 people. These filters will be used in small, rural communities, so the EStaRS team aims to design a filter that uses accessible materials, simple construction, and straightforward operation. During Spring 2015, the team changed the system for attaching the filter cap to prevent it from dislodging. The team also changed the process of backwash to prevent air from entering the inlet pipe. Due to the research of past StaRS FInE teams, the EStaRS team is currently using the new injection system, pipes with open orifices on the bottom, in place of slotted pipes.

Methods

Filter Assembly

At the beginning of the semester, the Fall 2015 team transported the previous semester's model from the upstairs lab to the newly renovated AguaClara lab. The team also did readings of previous teams' reports to gain a thorough understanding of how the FInE system is meant to work. As the weeks progressed, the team worked to reassemble the filter, determining the best method for filling the filter with sand. In the process of filling the filter, it was erroneously decided that the valves connected to the upper inlet and outlet should be opened as soon as the pump began to put water into the filter. This led to sand entering the inlet and outlet system as filtration occurred with higher than normal water height. With this setback, the team was forced to empty the filter column of sand and water, flush out the sand from the inlet and outlet, and then reassemble the filter to its original status. Figure 2 below shows the structure of the filter apparatus.

Figure 2: Constructed 10 cm x 86 cm filter apparatus. From top to bottom, the pipes are: backwash outlet, inlet, filtration outlet, inlet. The bottom inlet is within the sand layer.

Filter Modifications

The testing apparatus was set-up in Hollister B60. Compared to its previous location in the Hollister teaching lab, the filter was raised at a higher height from the floor. The change in height required the team to adjust the pump height and elongate the inlet and outlet pipes. The pump was raised by adding a thick sheet of PVC to the bottom of the influent water bucket. The inlet and outlet pipes had to be extended to make the pipes level. Initially, the outlet pipe tended to slant down due to the lack of support. To amend this issue, the team had to move the entire filter system away from the edge of the workstation in order to construct a support system. The team then added PVC couplings along with PVC pipe stubs so that the pipes will be extend to the edge of the workstation (which was increased due to pushing the station back) and into the bucket. Later in the semester, the team will installed an 80x20 support structure for the outlet pipe. The outlet pipe was attached to the structure using zip ties initially and later rope.

Flow Rate Calculations

Early in the semester, the team had to calculate the target flow rates for filtration and backwash. The basis for these calculations was the Q = V*A equation, where V = velocity and A = cross sectional area. The filtration velocity is 1.85 mm/s, which is a constant for AguaClara filters. The length of the filter is 86 cm, and the width is 10 cm. Additionally, the flow rate has to be doubled to get the actual flow rate, because the water passes through two layers of the filter bed.

$V_{Fi} = 1.85\ mm/s$ $L_{Fi} = 86\ cm$ $W_{Fi} = 10\ cm$ $n_{layers,Fi} = 2$

$$Q_{Fi} = V_{Fi} * L_{Fi} * W_{Fi} * n_{layers,Fi} = 318.2\ mL/s$$

For backwash, the filter dimensions are the same. The backwash velocity is 11 mm/s, and the number of layers is 1.

$V_{BW} = 1.85\ mm/s$ $L_{Fi} = 86\ cm$ $W_{Fi} = 10\ cm$ $n_{layers,BW} = 1$

$$Q_{BW} = V_{BW} * L_{Fi} * W_{Fi} * n_{layers,BW} = 946\ mL/s$$

Problems with Filter

After conducting preliminary filter runs without sand in the filter, the team found multiple points of weakness in the design. Firstly, due to the setup of the PVC, the portions extending outside the filter column and into the entrance bucket often slanted downward due to inefficient support structures. The only mechanism supporting these portions was the entrance bucket, but this was not enough to keep the system stable.

The team also ran into problems with the filter column emptying into the entrance bucket when the filter was turned off. This problem occurred because sand entered into the gate valve and check valve attached to the pump, making it impossible to completely close these valves and thus enabling reverse flow through the pump. After experimenting with a check valve, it was also found that check valves are not effective at stopping slow trickles of water. Because of these problems, water slowly dripped out of the filter body and through both valves into the water supply bucket. The team solved these problems by adding a ball valve to the inlet pipe to prevent the sand from entering the pump again and to prevent the filter from draining. Figure 3 below shows the modification.

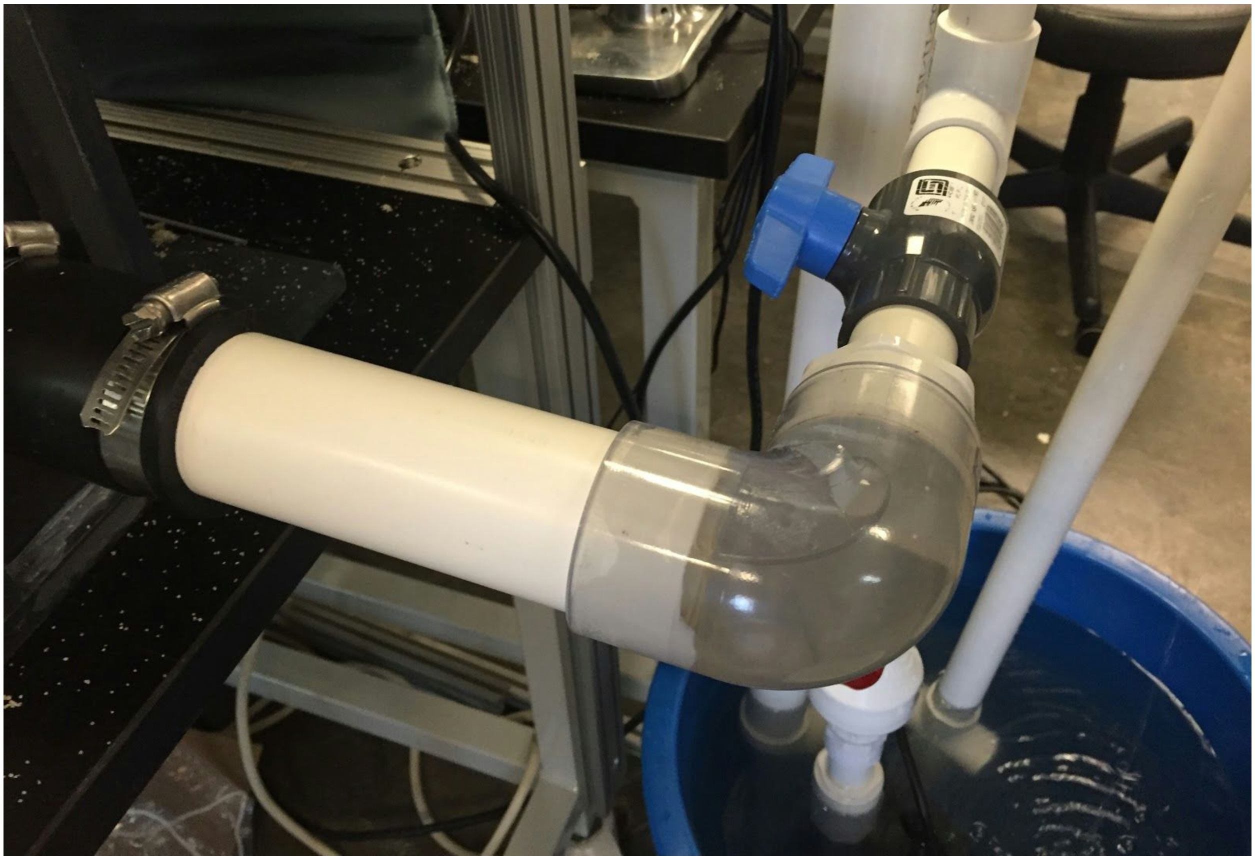


Figure 3: The bottom inlet modified by adding a valve.

Problems with leaks also occurred, as once the pump was on, leaks appeared near the flexible fittings and the PVC T-fittings. This was due to the improper tightening of the connections when the team assembled the filter. Once the connections were tightened this problem was solved.

When the team attempted to backwash the filter, the sand bed would only fluidize two-thirds of the length of the column. The remaining portion would remain stationary, even when the flow rate into the filter exceeded the predetermined backwash pump flow rate. This was caused by the bottommost inlet being full of sand.

Additionally, after reading through the past team's reports, the team determined that the sizing of orifices was done incorrectly. The Spring 2015 Team concluded that the total orifice area in the outlet pipe should be the same as the total orifice area in the inlet pipe. However, since the outlets will be fed water from two layers of sand, the total orifice area should be double the total orifice area of the inlet pipe. To achieve this orifice area new orifices were drilled between the existing orifices. This increased the number of orifices from 16 to 30. The calculations for initial orifice area and altered orifice area are in the "FInE Fall 2015 Calculations.xmcd" Mathcad file in the Fall 2015 Calculations folder. (https://drive.google.com/open?id=0B7rCHCKNVa2oT00yZC1IeDR3a28)

Furthermore, through makeshift measurements of flow rate (done by capturing the volume of water in a bucket and timing it), it was determined that the system could not reach the proper flow rate for filtration or backwash (340 mL/s required for filtration and 948 mL/s required for backwash). It may have been possible to reach the correct flow rates by reducing the system head loss, but it is also possible that the filter apparatus was simply not tall enough.

Modification of Backwash Weir

In order to solve the problem of backwash pipe sucking water and failing to flow efficiently, the team replaced an elbow with a straight pipe which directly leads to the bucket. Further, the end of the backwash pipe was extended to prevent the air getting into the system as shown in Figure 4 below.

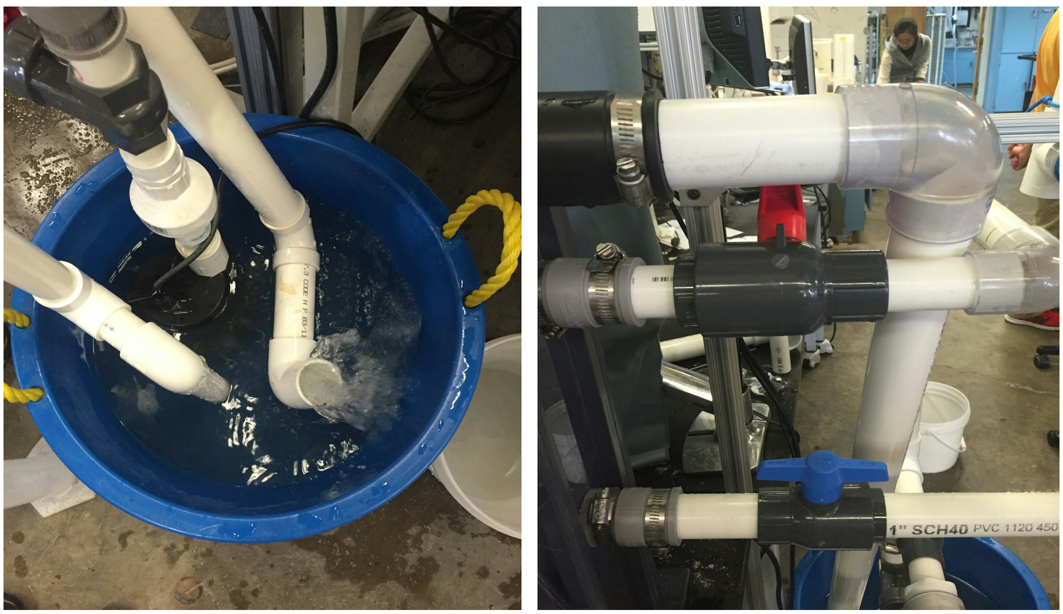


Figure 4: Pictures showing the modifications to our lab setup.

Extension of Wings

One of the major points for evaluation of the FInE system is the maintenance of the sand-water gravity exclusion zone. If the filter is able to operate without failure, the gravity exclusion zone should be maintained at all times. In order to see the gravity exclusion zone, the winged design should extend the entire length of the filter setup. The addition of the cap in the beginning of the semester created a region of wingless outlet pipe, preventing the team from seeing if we were getting sand in our outlet pipes. To remedy this issue, the team extended the wings over the cap to make the gravity exclusion zone visible.

Finalized Filter Setup

Modifications have been implemented into the filter setup to create the most efficient version of the FInE system. Firstly, the team replaced the multiple PVC sheets with a single thick PVC sheet to rest the entrance bucket on. This elevated the pump to the appropriate height. To amend the problem of the weakly supported PVC pipes (the portion that extends out of the filter body and into the entrance bucket), Professor Weber-Shirk suggested attaching pieces of 80x20 rods to the existing workstation and then zip tieing the PVC to the 80x20. Additionally, the reverse flow problem was resolved by installing a ball valve at the bottommost inlet, eliminating the possibility of water to flow backwards through the pump when the filter is not operating. The leaks were fixed by further tightening the hose clamps and ensuring a tight fit of all PVC connections. Finally, to fix the problem of inefficiency of sand bed fluidization, the team disassembled the filter body and emptied the bottom inlet of sand. As an additional precaution, the team washed out all other inlets and outlets. Once this was done, the team reassembled the filter, being extremely careful not to let sand into any of the inlets and outlets. The finalized set-up of the FInE system is shown in Figure 5 below.

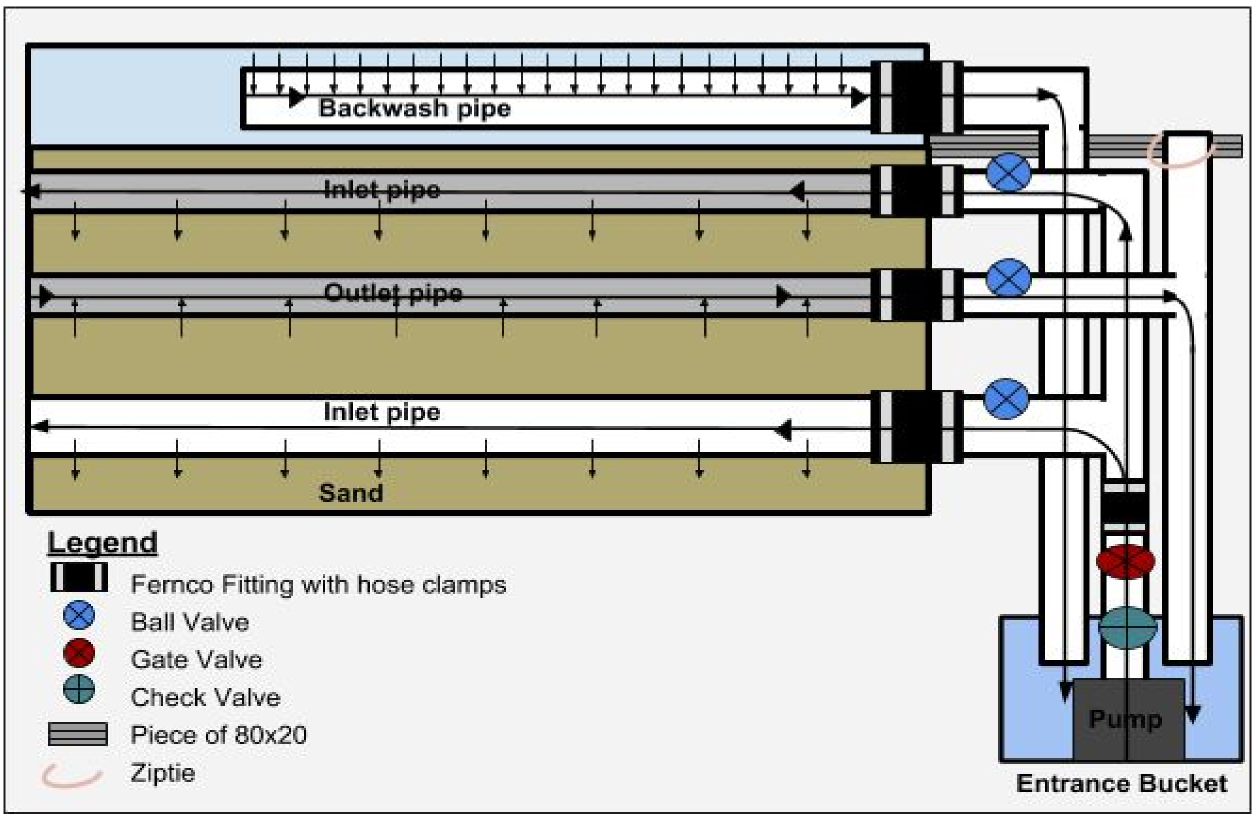


Figure 5: Detailed schematic of the 10 cm x 86 cm filter setup, including legend of parts and direction of flow.

Flow Rate and Head Loss Calculations

To examine why the system was initially failing repeatedly, the team explored the possibilities that the the FInE system had accumulated additional head loss from flow through the orifices and was possibly dampening the flow rate. The change in flow rate through the filter is very crucial, because if it lowers enough that the upflow velocity at the sand-water interface is too low to maintain a partition of layers, then the FInE system fails and sand will enter the outlet piping.

Using the equations for orifice head loss and comparison to the head loss through slotted pipes, the team determined that the orifice system had higher head loss through it. To reduce the head loss, the team drilled additional holes in the outlet pipe so that the total orifice area in the outlet pipe was equal to the total combined orifice area of the inlet pipes. This fixed the flow rate problem as well as reduced the head loss in our system.

Filling Filter with Sand

Initially, the team decided that it was best to fill the filter with sand by running it in filtration mode (with both inlets and the outlet valves opened) with a flow rate lower than filtration to prevent any possible fluidization of the sand bed. Testing under this presumption, the team achieved multiple failures. While the pump was set at a rate lower than filtration, sand was slowly added to the filter. The sand bed covered the outlet pipe without a problem, but when sand got a few inches higher the exclusion zone failed. After further evaluation and consultation with Monroe, it was determined that filling the filter with sand is best accomplished during backwash.

Modification of Outlet

In the initial trials of backwash with the filter column full of sand, extreme fluidization occurred above the outlet at the end of the filter where the pipes enter. In order to remediate this problem, the team added a PVC plate cap to the end of the outlet pipe in order to complete the triangular sand exclusion zone. This alteration stopped the extreme fluidization from occurring. It is predicted that before the cap was installed water was getting trapped beneath the wings of the outlet and exiting out the end of the sand exclusion zone near the Fernco fitting.

Filter Run Trials

The team ran multiple trials after filling the filter with sand successfully during backwash. The purpose of this was to determine if the filter setup can handle the proper flow rates as determined by MathCAD calculations (312 mL//s for filtration and 948 mL/s for backwash). After multiple filter runs, it was found that filter failure occurs around flow rates of 180 mL/s during filtration, while proper flow rate was achieved during backwash. Filter failure is defined as the moment when sand enters the clear elbow of the outlet, which is evidence that the sand-water interface has been disturbed. Failure may occur before this, but the clear elbow is the first place where failure can be spotted.

Filter Operation Manual

This manual details the operating procedure given that the filter is initially empty or sand is below the level of the outlet. This is a theoretical procedure that was not able to be replicated in the lab setting due to the fact that the filter could not reach the proper filtration mode flow rate calculated previously. The inability to reach this flow rate is a result of failure mode occurring (sand in the outlets) and an improper filter height (headloss was too high to support this flow rate at the given filter height).

To fill the filter with sand:

1. Open all valves and plug the pump in (set pump speed to low filtration mode)
2. Once both the upper inlet and the outlet are full of water, close the valves on these pipes and increase pump speed to backwash mode speed
3. Add enough sand while in backwash that it covers the upper inlet

To switch to filtration:

1. Turn off pump and remove water to the appropriate filtration water height (right above the upper inlet)
2. Lower the pump speed to below filtration and simultaneously plug the pump back in while opening the valves for the upper inlet and the outlet
3. Slowly increase the pump speed to filtration mode speed
4. Once at filtration mode, keep the filter running until backwash is necessary

To switch to backwash:

1. Close the valves on the upper inlet and the outlet
2. Increase pump speed to backwash mode speed
3. Continue until the filter is backwashed

To turn filter off:

1. Make sure filter is in filtration mode
2. Slowly close the outlet and the inlets
3. Unplug the pump

Further information can be found in the user manual compiled following the work completed this semester, available here:

https://docs.google.com/document/d/1gH3qbbgklKoOBztc7vavMvCJUAzBlGFRJDln2qHLfl4/edit#

Wing Stress Testing Procedure

After determining that the FInE system is not likely the best option for the outlet design, the team turned to testing a new fabrication system for the inlet pipe wings. Since slotted pipes are prone to clogging and the FInE system works well for the inlets, the team will determine whether or not the new wing construction is strong enough to endure backwash. In the initial transition from filtration to backwash, there is a moment when the sand is not yet fluidized but the bottommost inlet is operating at a high velocity. This is when the pipes in the filter experience the highest amount of force. The purpose of this stress testing is to determine the upper bound the strength of the wings.

The inlet design with wings was initially used by the FInE team in the Spring 2015 semester, but it was concluded that the wings offered little in terms of improved performance at a laboratory scale. In the AguaClara plant in San Matias, the FInE system is currently implemented in the filter inlets as a safety measure. The inlets in the plant are similar to the design made by the Spring 2015 team, with the only difference being the attachment of the wings as shown below in Figure 6. The wings in the lab were attached by gluing two sheets of PVC plate to the side of a

PVC pipe with orifices along the bottom. The wings in Honduras were made by taking a PVC pipe, cutting a slit along the bottom, inserting it into hot oil, and immediately opening the slit and placing it in a mold to obtain the shape shown below. This is then glued to a PVC pipe with orifices along the bottom.

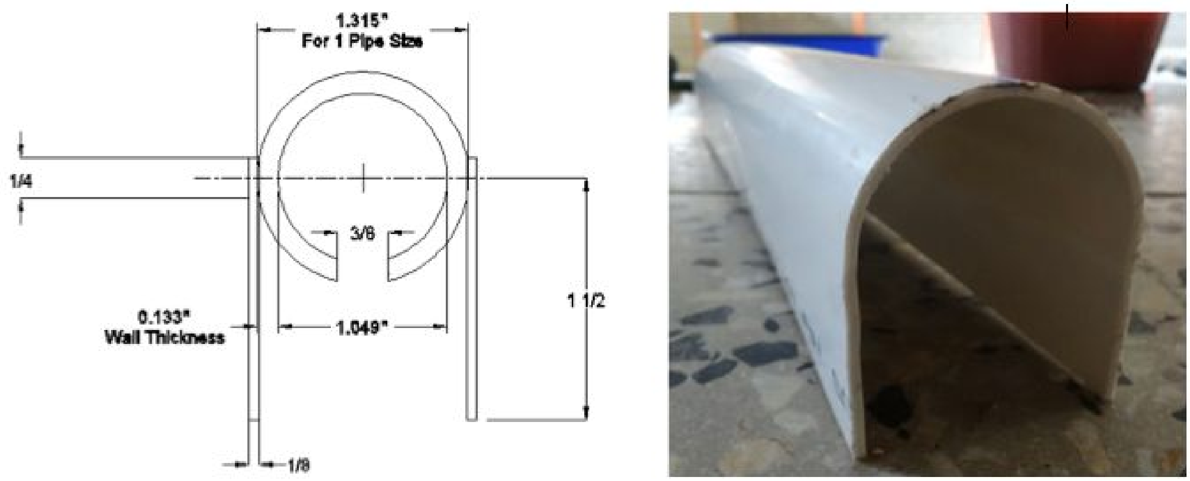


Figure 6: Side by side comparison of inlet design used in the lab (left) and in Honduras (right).

To conduct the stress test, the team fabricated multiple inlet pipes with wings to test different variables. These pipes were shaved by a wood planer to create ⅜" wide flat surfaces on the sides of the pipe to attach the wings. The variables tested were the thickness of the PVC plate (1/16" vs ⅛") and the length of the wing (1" vs 1 cm). The length of the wing was measured from the bottom of the pipe to the tip of the wing. The values for wing length were taken from the design in Honduras (1") and from a recommendation by Professor Monroe (1 cm). Additionally, the team constructed a 80x20 support structure to assist in the testing of the inlet. The testing was done by placing one end of the the inlet system on a scale and the other end on the 80x20 structure. In order to mimic the effect of the backwash velocity pushing up on the inlet structures in the filter, the team placed the inlet system upside down on the scale. A force was then applied to the center of the pipe, and the weight measured by the scale was used to determine the magnitude of the force being applied, depicted in Figure 7 below. A total of three inlets were tested of varying wing length and thickness (1/16" thickness of 1" length, 1/16" thickness of 1 cm length, and ⅛" thickness of 1" length). Additionally, to visibly see the moment the pipe failed, the team placed very fine pink sand in the area between the wings as shown in Figure 8 below. This sand leaked onto the floor when the wings reached irreversible failure.

Figure 7: The inlet was placed on an 80x20 support on one side (shown on the right) and on the scale (shown of the left). A force was manually applied to the center of the inlet.

Figure 8: The pink sand leaked when the winged design failed..

Analysis

Filter Failure Modes

The FInE system may seem like a good alternative to slotted pipes in theory, but in practice it is very vulnerable. The vulnerabilities were most present during the transition from backwash to filtration mode and during filtration mode. During the transition from backwash to filtration, the water level was higher than the filtration level, and the only available exit is the outlet pipe. This additional head forced sand into the outlet when the valve is open, causing sand to leave the system with the effluent water. This was avoided by draining the excess water from the top of the filter before transitioning to backwash. However, operator error could have large consequences at this step, because if the water is not drained failure is almost certain to occur.

Additionally, our filter performance was not sufficient during filtration mode. After filling the filter in backwash mode and transitioning to filtration mode, the flow rate during filtration mode was slowly increased by adjusting the gate valve on the pump. To determine what the flow rate was at different valve positions, we measured the volume of water that left the outlet pipe for a short period of time (5-10 seconds). From these values the flow rate was calculated using Q = V/t. Over several runs in this manner, the flow rates measured at the time of filter failure ranged from 118 mL/s to 185 mL/s. These flow rates were all well below the necessary flow rate of 320 mL/s, so the filter performance during filtration is not sufficient.

To determine where the sand exclusion zone had failed, the team drained the tank slowly through the bottom inlet and took the pipe out to see what the sand bed looked like beneath the outlet. The result is shown in Figure 9 below.

Figure 9: Pictures of the sand exclusion zone and its point of failure.

Both images above show that the sand exclusion zone is intact for most of the length of the filter bed. The failure occurred at the end of the filter where the pipes enter the filter bed. This was most likely attributed to the higher upflow velocity through the sand exclusion zone at the end of the filter column nearest the Fernco Fitting. This higher velocity was likely due to the fact that the sand exclusion zone does not extend to the far wall of the filter. As long as the wings from the filter outlet cannot extend the entire length of the filter body, this failure will always occur.

Wing Stress Test Results

Through the calculation, the maximum force on the wing pipe for the inlet is 60 lbs. The wing stress test reflects the 1/16" thickness of 1" length, 1/16" thickness of 1 cm length, and ⅛" thickness of 1 cm length can bear the force of 80 lbs, 100 lbs and more than 130 lbs respectively.

To determine the proper wing length, the team calculated the height that sand would travel into the sand exclusion zone during backwash. Using the equation for kinematic head ($V^2/2g$), this height was calculated to be 6 micrometers. This shows that a winged design is probably not necessary, but can be used as a factor of safety.

Coupling the result of the maximum height that sand will travel into the sand exclusion zone during backwash and the results of the wing stress tests, the team determined that PVC plate wings of ⅛" thickness and 1 cm length was the strongest of the three wing designs tested. This could be used for the inlet systems in the laboratory setting, and possibly be scaled up to be used in Honduras as well.

Conclusions

After testing the filter multiple times, it was determined that the most vulnerable point of the FInE system is the transition from backwash to filtration. Since the water height in the filter was higher than the height needed for filtration, sand frequently entered the outlet system. This issue was initially remedied by opening the outlet valve very slowly after reducing the pump speed to the established filtration speed - this process will serve to lower the height of water in the filter, thereby reducing the headloss. However, the team still ran into problems with sand in the outlets. Once a method was established for filling the filter with sand, the team ran several trials with the same result of sand in the outlet pipes.

At this point, the team can safely conclude that the FInE system does not work for the outlet piping. Due to the fact that the wings cannot extend the entire length of the filter body in both a laboratory setting and in plants in Honduras, sand will inevitably end up in the effluent. As this is a major flaw and since slotted pipes are not a problem for receiving water that has been filtered, the team may suggest slotted pipes for outlet piping, while keeping the FInE system for the inlet piping.

The flow injection and extraction system is a novel idea for sand filtration. However, due to very strict guidelines for gravity exclusion zones and frequent failures occurring, this system was ultimately abandoned as an alternative to the slotted pipe outlet system.

Future Work

Future teams should look into further stress testing of the winged inlet design to draw concrete conclusions on the point of failure. This could be used to determine a stronger design for the inlet system and establish whether or not the winged design could withstand the forces present during backwash. Initial testing by the Fall 2015 team showed that the winged design was able to withstand backwash forces, but since only a couple of tests were conducted, a more definite answer is sought. Additionally, if the slotted pipe outlet design does have problems with clogging, future teams should look into a more feasible alternative. Currently, the slotted pipe outlet system does not clog since the water is clean before entering the outlet pipes, preventing the tendency of clogging. However, since slotted pipes require such tedious construction, an alternative would be optimal.

References

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