Challenges Stacked Filtration Spring 2011

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Summary

This team will work best if there is a very tight integration between the design team and the research team. To accomplish that integration this team will include members from the design team (who will go through the design training) and members from the research team (who will go through the research training). The goal of the team is to provide a basis for all of the design inputs so that a full scale stacked rapid sand filter can be built starting late spring.

Research Goals for the spring

1. Measure the minimum fluidization velocity. This will be needed to determine the head loss required to initiate backwash.
2. Do a hydraulic analysis of backwash initiation. Our previous estimates of backwash head loss assume that the bed is already fluidized and do not account for the fact that enough water must be flowing through the none fluidized bed to begin the fluidization process. Our experiences with testing the SRSF in Honduras suggest that the most difficult phase of backwash is the fluidization of the bottom two layers (40 cm) of the filter. At the instant that the sand at 40 cm from the bottom of the filter begins to fluidize the head loss through the expanded bed is 80 cm and the minimum head loss through the unexpanded 40 cm of sand is equal to (the head loss at the end of filtration in one filter layer) * (2 sand layers) * (minimum fluidization velocity) / (filtration velocity). Calculate this value as a potential critical parameter to ensure that backwash can be initiated.
3. Determine the range of acceptable backwash velocities. Plot bed expansion as a function of backwash velocity. Test backwash effectiveness using very low backwash velocities. We need to know the acceptable range to guide how we design the controls for backwash flow. If the backwash velocity can be varied by a factor of 2 or more while obtaining good (or at least adequate) bed cleaning, then it won't be necessary to provide flow control to individual filters and that will simplify filter design.
4. Build a lab scale version of the siphon control system including the inlet and outlet control boxes.
5. Determine maximum allowable head loss during filtration. Note that at 20 cm of head loss the upflow sections of the bed experience a reversal in the net force acting on the bed. This change could cause the bed to shift. (It is possible that we already have enough data to know the maximum head loss. I think that 20 cm of head loss through a filter bed is probably close to the maximum.)
6. Design a method to dump all of the sand from the filter using a drain during backwash. It may be possible to have a second siphon tube installed for this purpose. Minimize water consumption during this drain stage by minimizing backwash flow to barely fluidize the bed. Design the drain to empty the sand from the filter in less than 5 minutes. Test this at lab scale.
7. Evaluate methods to prevent backwash water from entering filtered water manifolds. For example, would there be a way to generate a low flow of settled water into the filtered water manifolds during backwash? Evaluate this problem after building the siphon control system to determine if that system does a better job of keeping backwash water out of the manifolds.
8. We need to minimize the wasting of water for backwash. Many communities are short on water and will be reluctant to use filters if they waste much water. Measure the turbidity of the backwash water as a function of time and determine the minimum length of backwash that you would recommend. Assess the filter ripening period duration after very short backwash cycles. Can backwash time be reduced to approximately 3 minutes (2 residence times)? Test the effect of leaving relatively dirty backwash water on top of the filter at the end of the backwash cycle. Is there any harm in leaving dirty water on top of the filter as a way to reduce wasting of water?

9. Develop a more robust method to measure the distribution of flow between the layers. Suggestions…
    a. Have the peristaltic dye pump running somewhere in the range of 10 to 100 rpm to eliminate any effect from pulsing input.
    b. Use smaller peristaltic pump tubing to reduce the amount of dye stock and to compensate for the higher rpm.
    c. Use very small diameter tubing for the dye all the way to the port where it blends with the main flow so that it doesn't take much time to load the tubing with dye.
    d. Measure the time required for a pulse of dye to get through each layer. If the sample delay time is kept constant, then this technique could be fast and accurate.
10. Create a movie showing a red dye pulse passing through the filter to demonstrate how the water flows up and down in the filter layers. (post on youtube)
11. Create a movie of the entire backwash process (showing the switch between filtration and then all of the steps to get back to filtration again.
12. Compare performance of standard filter with 20 cm of filter media with stacked filter.
13. Become experts on filter underdrains and guide the design of the full scale underdrain system.
14. Investigate the possibility of manufacturing the slotted pipes in Honduras.


The Japan Woodworker

This dovetail saw has a kerf of 0.2 mm. (see http://www.japanwoodworker.com/product.asp?pf_id=18.210.0&dept_id=13085

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Figure 1.)

15. Consider using a smaller size of sand to enhance performance. Note that a different sand size will COMPLETELY change the design because backwash velocity will change and that will decrease the filtration rate (assuming we keep 6 layers). Filter run time and filter head loss will change as well. Evaluate the tradeoffs and provide us with some guidance on how to choose the best sand diameter. One tradeoff is that smaller sand will develop higher head loss sooner and thus will have shorter runtimes. The goal is to maintain adequate particle removal and then minimize backwash water wastage. It is possible that the optimal solution to this problem is to use larger sand size and a deeper filter bed. This will require a deeper filter box, but that means that during backwash we will be using the same water to wash more sand. Thus the backwash water will have a higher solids concentration and thus be a more efficient use of the wash water.

Design Goals for the spring

1. Identify the constraints and create the design algorithms for all relevant dimensions for the filter control system (inlet box, outlet box, siphon box, siphon pipe, etc). Create a full hydraulic analysis of water levels, siphon air volumes, required flow rates for each element of the filter.
2. Determine what flow rate controls are required for the filter for the case of multiple filters at a water treatment plant.
3. Create an algorithm to determine how many filter boxes to build based on plant flow rate or whatever factors seem to determine the optimal number of filter boxes.
4. Design a filter box for one [Cuatro comunidades] by spring break.
5. Evaluate plant layout options for best location of the filter units and integration with the overall facility. Options include
    a. placing the filters next to the settled water channel so that the settled water channel would be the inlet control boxes for the filters. This layout could return the filtered water to a location close to the entrance tank so that the chlorinator could be controlled by the entrance tank water level.
    b. placing the filters next to the last sedimentation tank (opposite end from the flocculator).
6. Evaluate options for regulating the flow to a filter when there are multiple filters operating in parallel. One possibility would be to have one filter per sedimentation tank. Thus if the flow rate through the plant is reduced an entire sed tank/filter could be taken off line to maintain the required backwash velocity in the remaining filters.
7. Finalize the automated design algorithms for integration with the design tool. This must include hydraulic and component dimension constraints for all of the channels
8. Create a design that minimizes head loss between sed tank and clearwell while utilizing the control system that doesn’t require the operator to open and close inlet and outlet manifold pipes.
9. Design the method of assembling the filter and holding the manifolds in place. The manifolds must be firmly held in place to prevent both upward (during backwash) and downward forces (after backwash).
10. Determine what sets the upper limit on the size of stacked filters. When should we simply start making more filters rather than increasing their size?

Advice to the Future Filtration Team Member:

1. If you are not proficient in process controller, MathCAD, and wiki, find help early and learn.
2. I ntroduce yourself to Paul Charles and Tim Brock at the shop early. Who are they? Go find out.
3. Even when you are split into various different sub teams, meet every week to share progress and get feed back. We found that members from different subteams can provide insight and synergy and fair, fresh, and impartial evaluations. We also ended up switching team members between sub teams so it is good for team members to periodically meet each other.
   Set up a rountine where you meet with Monroe and Matt periodically as you make progress. They can catch mistakes that you miss and save you a lot of time and headache. This is a good way to avoid group think.
4. This search engine is great for articles related to hydraulics and filtration: http://www.jstor.org/action/doBasicSearch?Query=water+wire+filtration&wc=on&dc=All+Disciplines
5. If possible, take Monroe's Sustainable Water Supply Class and Professor Bisogni's Physical Chemical Process class. If not possible, get the notes.
6. Be flexible and proactive! It is hard doing all this initial research, but stay on top of it and document through out the process, otherwise it will be hard at the end .
7. Stay in constant communication with Monroe and Matt- they are filled with great ideas and will keep you focused.