

Weir Control System for Stacked Rapid Sand Filter (SRSF)

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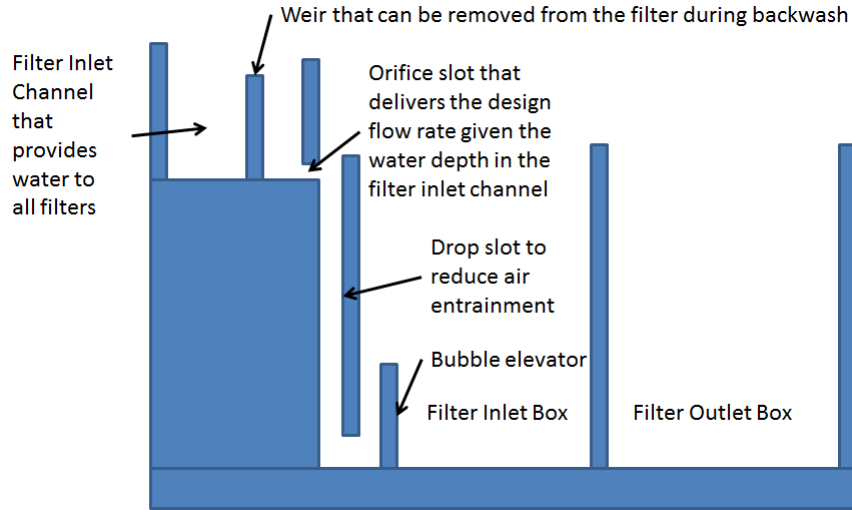
Problem Definition

Introduction

Under the current filter , the desired bed expansion in the filters is not achieved during backwash in cases when plants are operating at flow rates less than the design flow rate. Our goal this semester is to devise a means to increase the flow rate through a filter during backwash by slightly modifying the weir system for the filters. A generic configuration of the weir system is displayed below(see figure 1).

The first weir (filter inlet weir) will include a removable section. Under normal operation, the removable weir section will remain in place for all of the filters, and water will flow over the weir at a shallow depth. During backwash, a gate will be removed and water will flow through the opened section, allowing for the flow to the filter being backwashed to be increased. The second restriction (filter backwash flow control, shown as an orifice in Figure 1) will allow for adjustment at plant start-up using stop logs. This restriction delivers the target flow rate to the filters based on any adjustments (or lack there of) by the plant operator. This design is low-cost, allows the operator to simply adjust the flow rate, and emphasizes ease of construction.

Figure 1: Weir System on Filters



Design Details

Under the current design, the bottom elevation of the filter inlet channel is set as $FiInletChannel.Origin$, which is approximately 0.35 m below the centerline elevation of the 8-inch inlet pipe from the sedimentation tank ($FiInletPipe.Origin$). This design creates an operational problem since under the proposed changes, the plant operator would need to reach down the channel to remove a section of the filter inlet weir during backwash. Thus, the depth of the filter inlet channel ($H.FiInletChannel$) is to be limited to a maximum of 60 cm. A new design for this channel is proposed that features a vertical elbow at the end of the pipe from the sedimentation tank. This elbow would be buried by the bottom of the filter inlet channel, which would have to be raised approximately 0.6 m to an elevation of approximately 1.04 m. This elbow would create additional head loss, which is unfortunate since a deeper channel will be required. The proposed design is displayed below (see figure 2).

The proposed geometry of the filter inlet weir (FiInletWeir) is shown below (see figure3). This design features a removable section (FiBwGate) over the full depth of the weir. This gate is being modeled as a rectangular orifice, as it will be completely submerged on the downstream side. The height of this gate ($H.FiBwGate$) is being set as an expert input to 30 cm so that it can be easily constructed and operated. The head loss through this gate $HL.FiInletChannel$ is being set to 0.5 cm (also as an expert input). This small head loss assures that the change in water level (from upstream to downstream side) of this gate is small. As this head loss approaches 0, the change in water levels approaches 0, and the ability to increase the flow rate for backwash is highest (optimal). The area of this gate ($A.FiBwGate$) is calculated using the A.Orifice equation from

the Agua Clara fluids function. The required width of this gate ($W_{FiBwGate}$) can then be calculated by dividing this area by the height.

The proposed geometry of FiBwFlowControl (the second restriction) is shown below (see figure 4). This restriction is used for adjusting flow rate in backwash mode, which decides how much expansion is gained. The depth of this restriction will not be equal to the entire depth of the inlet channel. Rather, the restriction will be elevated above the maximum water level of the filter inlet box so that the hydraulics are not influenced by backwater and there is free fall. This height (equal to $H_{FiBwFlowControl}$) will be set as an expert input, with a value of 10 cm. Since there is free fall out of this weir into the filter box, the head loss $HL_{FiBwFlowControl}$ is equal to the depth of water entering the weir. This depth is calculated by subtracting $HL_{FiBwGate}$ from $H_{FiBwFlowControl}$. Then, $W_{FiBwFlowControl}$ can be calculated using the following W.RectWeir equation from the Agua Clara Fluids Function $W = \frac{3}{2} \frac{Q}{\Pi_{vc} \sqrt{2g} H^{3/2}}$ (H should be $HL_{FiBwGate}$).

Since this second restriction must be sized to accommodate for the maximum backwash flow rate, the Q value used to calculate this width must reflect the desired Q after removing the gate, rather than the plant flow rate. To address this issue, a new variable $\Pi_{QFiBwMax}$ was created to represent the ratio of the maximum backwash flow rate to the plant flow rate. As an expert input, this value has been set to 1.5, which indicates a 50% expansion due to this weir control system. This 50% increase is for the most extreme case. However, this system allows for the plant operator to adjust the level at which the backwash flow rate is increased by placing “stop logs” in the filter backwash flow control weir. Thus, the 50% expansion is for the case where no stop logs are used. Currently, the proposed design would allow the operator to adjust the backwash flow rate in 10% increments ($\Pi_{QFiBw}=1.5, 1.4 \dots 1.0$) with just five adequately sized stop logs. The required heights for these Π_{QFiBw} increments are calculated in our code as the difference in $HL_{FiBwFlowControl}$ due to the addition of the stop log. For more details and complete calculations, the Mathcad files with the updated design code (pcl59) for this weir control system are included in 'Final Designs' in the 'Under Development' folder. Along with the Stacked Rapid Sand Filter design code, the Expert Inputs code was also changed so that the additional head loss from the new elbow was accounted for.

Figure 2: Proposed Filter Inlet Channel

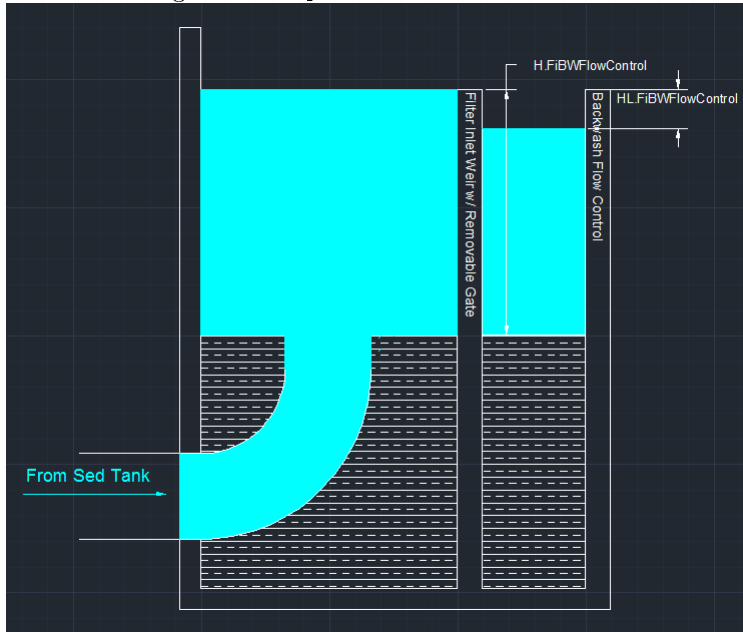


Figure 3: Filter Backwash Gate

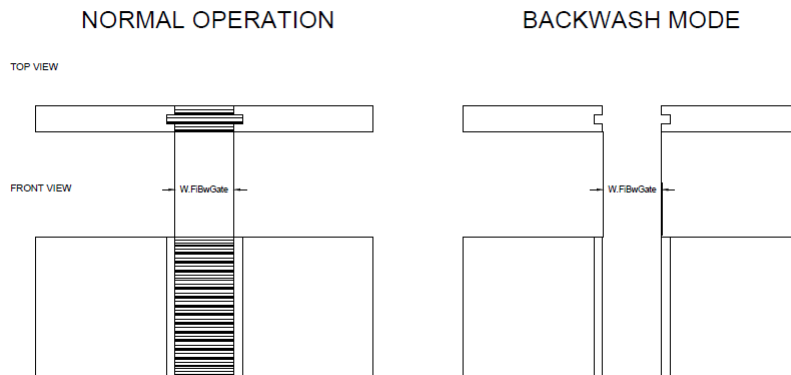
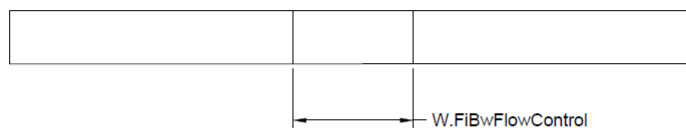
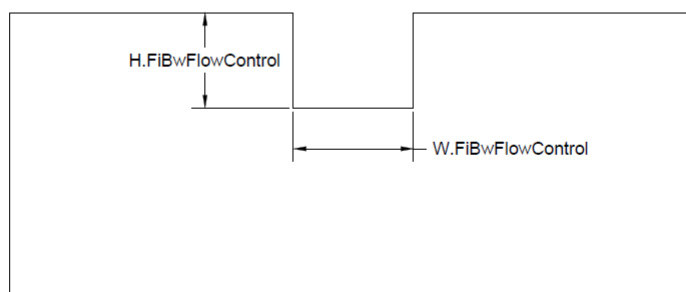


Figure 4: Filter Backwash Flow Control

TOP VIEW



FRONT VIEW



Documented Progress

Creation of new design

Normally, the backwash flow rate is equal to the filtration flow rate. However, when the plant is running at less than design capacity, the new design will allow for the backwash flow rate to be increased past the filtration flow rate so that sand bed expansion is as close to desired design expansion as possible. But upon calculating $W.FiBwGate$ and $W.FiBwFlowControl$ based on the preliminary expert inputs, the required widths were much larger than the entire length of the filter inlet channel. Thus, the current must be modified such that the required widths are feasible and can fit within the inlet channel. We also need to locate the dimensions used by Agua Clara for 8-inch elbows so that we can set the vertical origin of the filter inlet channel correctly. So We discussed with Monroe and developed new variables in the SRSF code based on the proposed designs. After that, we set several preliminary values for expert inputs and assessed the feasibility of the proposed designs based on these values. However, the proposed design and the corresponding expert inputs resulted in an infeasible design. After another meeting with Monroe, it was concluded that our use

of the weir equation to determine the required widths was not accurate. We brainstormed with Monroe and created new code that involved range variables for our two expert inputs, we determined that *HL.FiBwFlowControl* must be at least 60 cm in order for the width of both restrictions to fit within the current inlet channel design (*L.FiInletChannel*=1.2m).

Finally, we finished our design with the help of Monroe and all prior confusion on this problem was cleared up. The new design code for an effective weir control system that is correct, complete, and applicable over a large range of plant flow rates. The code includes the calculation of dimensions for the filter backwash gate, the filter backwash flow control weir, and the “stop logs” for flow rate adjustment. The design code is in the Inlet Channel Design part of StackedRapidSandFilter (pcl59) in Under Development folder.

Modification in Filtration drawing code

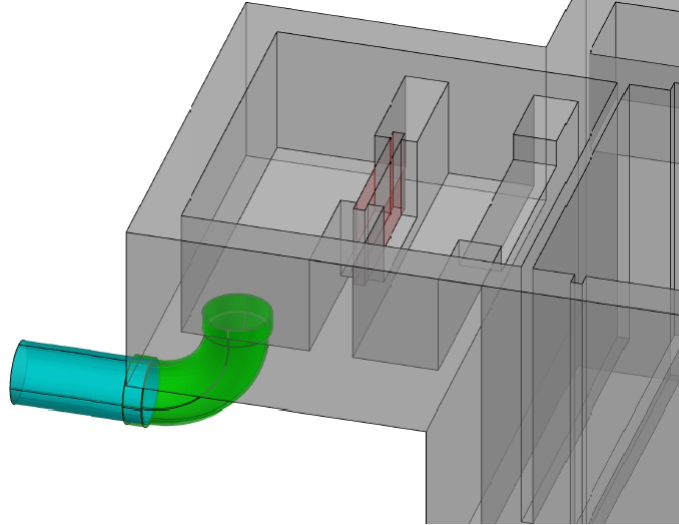
After the new design was finished, we worked on the filter drawing code. We had to go through all the codes to understand how the filter is drawn. Since we need two boxes for the filter inlet channel to fulfill the new design, the first step would be creating another filter inlet box in front of the previous one. We looked for the filter inlet channel origin and defined new variables: Inlet Channel Front Box. We set up the dimensions and origin of it and drew it using the boxF function.

The second step was to complete the elevation of the filter inlet channel, which would allow the plant operator to reach down the channel to remove a section of the filter inlet weir, and at the same time create enough space to fit an elbow which is buried in the concrete under the channel. We raised the origin of the filter inlet channel and Inlet Channel Front Box by about 60 cm. Since we were raising the filter inlet channel inner box not the outer box, we had to use the subtract function as well, which means we drew two boxes at the same time and subtract the inner box out of the outer one. And this would create a tank with different depth of the inner and the outer boxes.

The third step was to draw the filter inlet elbow and inlet pipe. Before that, we had to define the origin of them. Since we already determined the vertical rise required in the inlet channel to accommodate the new elbow, we calculated the dimensions of the elbow by adding the radius of the filter entrance elbow to the required socket depth. Then we found that there was not enough space for the elbow and coupling to fit because the elbow radius already exceeded the width of the filter inlet channel. We decided to not use a coupling and bury the elbow in the inlet pipe concrete so that the top of the elbow was flush with the bottom of the inlet channel and therefore we needed to shorten the inlet pipe.

The last step was to create the gates and slots in both weirs, and cut out part of the walls for overflow. We finished this part by creating boxes and subtracting them. The codes are saved in StackedRapidSandFilterAC (ry93) in the under development folder. The final drawing generated by this code is shown below (see figure 5).

Figure 5: Filter Inlet Channel in Normal Filtration Mode



Future Work

The design code for this system is complete and accurate. Problems arised when implementing the drawing code; there is an issue when using the stacking command. The drawing is only generated when inserting commands into AutoCad one-by-one. Also, this drawing code will likely cause problems when it is drawn with the entire plant. Elevation adjustments need to be checked, and the entire SRSF needs to be shifted either 30 or 45 cm to account for the width of the channel containing the new restrictions. Then, this design will be ready for laboratory testing or field implementation.