Manual

For members of APP and other AguaClara engineers who intend on building a weir system, this manual contains important calculations and analysis of various designs. Although the FTTFC team has suggested that most plants use the hinge design, it is possible another design could be better suited.

Base Calculations

The base design consisting of two weirs with a concrete slab is a modification on previous filter entrance tank designs. The concrete slab is an addition that will improve ease of constructibility for masons since there will be no deep slot between the two weirs. The height of the slotted weir relative to the concrete slab is calculated using assumptions of open channel flow above the slab.

$$y_c = \frac{2E}{3} \tag{5}$$

$$\frac{E}{3} = \frac{v^2}{2g} \tag{6}$$

Where;
y_c = the critical depth
E = specific energy
v = velocity
g = acceleration due to gravity

Based on this equation, it was found that for a 20 L/s plant, the required height difference between the concrete slab and the slotted weir should be 13 cm. This height prevents flow from going over the sides of the slotted weir. These dimensions were tested physically in a 20 L/s flow and were verified. For plant sizes besides 20 L/s, a MathCad file available in the AguaClara drive calculate be used to calculate height for the second weir. All other dimensions besides the concrete slab width were scaled from the 2017 AutoCad files for AguaClara plants.

If ease of construction is a concern, the concrete weir can be widened by a few inches, while decreasing the adjacent walkway width by the same magnitude. This would allow masons to fit more easily into the space to construct the weir.

Acceptable Gap Size Between Flap and Weir

Due to error in construction/fabrication and irregularities in concrete, there is expected to be a small space between the PVC flap and the concrete of the first weir. The percentage of total flow lost to leakage is a function of the size of this gap. The flow lost due to leakage was calculated using the orifice equation (equation 7), which assumes that the gap formed by the bottom of the flap and the first weir forms a slot-like orifice. The graph in figure 23 below represents the relationship between percentage of flow lost to leakage and gap width for a 20 L/s flow. For different flow rates, the MathCad file located in the AguaClara Drive may be used to calculated required gap size to maintain a desired maximum leakage rate. The FTTFC arbitrarily chose an acceptable leakage rate of five percent of the total flow. For a 20 L/s plant this would be a gap of 3.5 mm. The maximum allowable leakage percentage can be decided during plant design and construction.

$$Q = \Pi_V * A * \sqrt{2 * g * h} \tag{7}$$

Where;
Π_V = vena-contracta coefficient for an orifice (0.63)
A = area of the rectangular gap based on gap width and flap width
g = acceleration due to gravity
h = height of the flap relative to the bottom of the flap (i.e head)

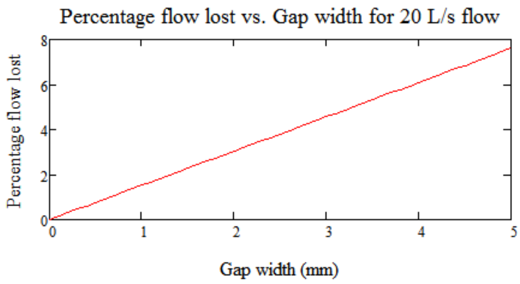

Figure 23: Leakage vs Gap size

Hinge Force Calculation

These forces were calculated from the hydrostatic pressures associated with holding the water in the tank.

$$\rho := 1000 \cdot \frac{kg}{m^3} \qquad H_{weir} := 10 \cdot in \qquad L_{weir} := 10 \cdot in \qquad g = 9.807 \frac{m}{s^2}$$

$$F_{total} := 0.5 \cdot \rho \cdot g \cdot H_{weir} \cdot H_{weir} \cdot L_{weir} = 80.351\,N$$

$$F_{resultant} := F_{total} \cdot \left(\frac{2}{3}\right) \cdot H_{weir} = 13.606\,J$$

$$F_{counter} := \frac{F_{resultant}}{H_{weir}} = 53.567\,N$$

Figure 24: Force needed to open hinge

Figure 24 shows that it takes approximately 54 N or 12.5 pounds to open the hinge by pulling at the end of the wall. This amount of force is easily manageable by the operators.

Hinge Design Analysis

When considering a final design, many criteria were considered including ease of constructibility, ease of use, cost and availability of parts, structural stability, water tightness, professional aesthetic, and longevity. The final design that the FTTFC team decided was a top sided hinge for its simplicity and ease of use. One of the main reasons for picking the hinge design over the horizontal and vertical sliding designs was that it eliminates all sliding surfaces. The vertical and horizontal designs consist of PVC sliding along the concrete surface of the weir. These two surfaces sliding against each other would create friction, making it harder to open and close. This friction also reduces the life of the weir since it will wear away the material. It is also difficult to create a watertight seal between two surfaces that have to slide across each other, so the hinge design will be more watertight than the other two designs. The hinge design is also very easy to construct and requires few components compared to the sliding designs.

Two methods of attaching the hinge to the concrete were also designed. These designs can be seen in the figures 15,16 and 17. The first attachment method, Hinge Design One, consists of a strip of PVC and a hinge (15). Cheap aluminum hinges are relatively easy to acquire in Honduras. If a specific plant location was unable to acquire aluminum hinges, it is possible to make simple PVC hinges, as shown in Hinge Design Two (16 & 17). This design simply requires two PVC elbows and a loose fitting PVC tube to connect them. Two bolts can be drilled through the tube and act as a rigid connector between the wall and tube. This design is also very adjustable because the bolts can hold spacers that make sure the wall is always flush to the weir.

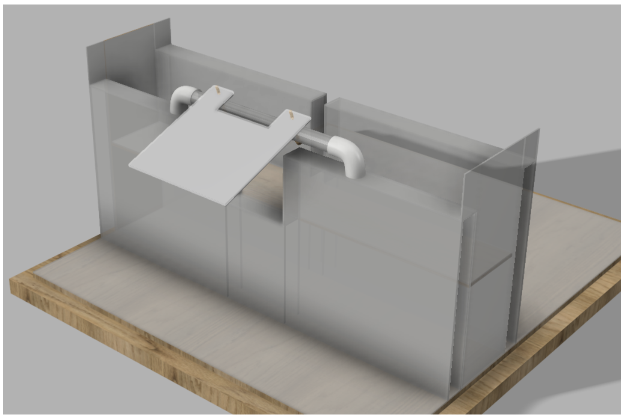

Figure 25: Hinge Design 1

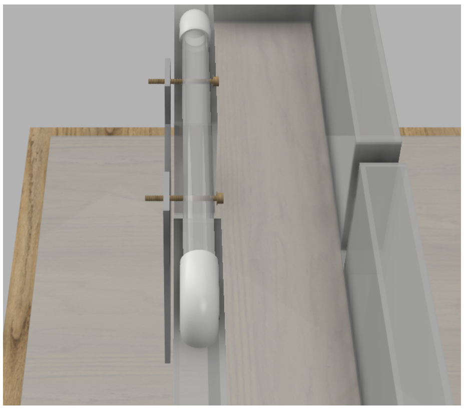

Figure 26: Hinge Design 1

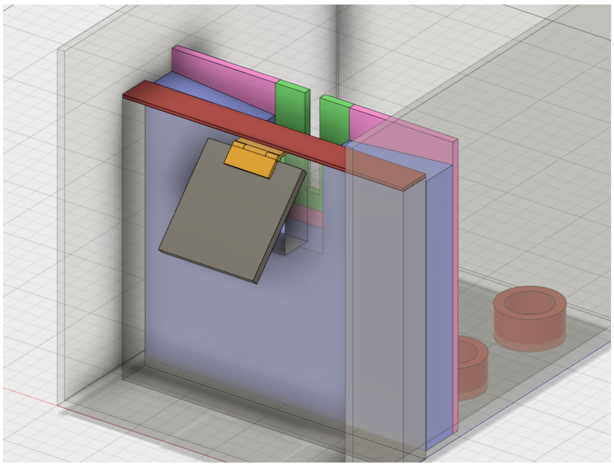

Figure 27: Hinge Design 2

There are several possible issues with the two hinge designs that should be considered. In Hinge Design One pictured in 15, water might be able to squeeze underneath the PVC strip and alter the effective height of the weir. A possible solution to this issue is using the same gasket or tile ideas recommended for the base design. Additionally finding a hinge strong enough to support the adjustable flap against the water pressure could be problematic. Aluminum hinges also have the problem of tarnishing over time and thus taking away from the professional aesthetic of the plant. Hinge Design Two solves the problem of tarnishing by using PVC elbows and a loose fitting PVC tube to connect them. It is unclear, however, how the PVC elbows will be attached to the concrete underneath. PVC tubes could be embedded and attached to the elbows but this takes up valuable space and may interfere with rebar in the concrete. This design is also less polished overall and not as visually appealing as the aluminum hinge design.

Non-Hinge Design Analysis

1. Vertical Slide
   - Description: Vertical sliding mechanism that would be held between two vertical tracks that would be bolted into the concrete. The design proposed by FTTFC Spring 2017 uses tracks that are flush to the front of the first weir extend all the way down to the floor of the tank (figure 14), as opposed to the design in the Las Vegas plant (figure 5), where the tracks are laid inside the weir opening. The proposed design is less reliant on accuracy of the concrete work to avoid leakage.
   - Pros: very watertight due to pre-built tracks, low friction inside tracks, could attach a pulley system easily to top
   - Cons: requires some system to hold it up, still some friction in between two surfaces, difficult to fabricate tracks
2. Horizontal Slide
   - Description: A wall attached with two clamps slides along a strip of PVC placed on top of the first weir
   - Pros: Very simple to use, would always stay in place (does not need a locking mechanism), easy to fabricate
   - Cons: not watertight, lots of friction, could be hard to reach the center of the first weir, may not have enough room to the left or right of the notch to fit
3. Valve
   - Description: A vertical column with vertical fins attached that when rotated 90 degrees opens or closes the slot
   - Pros: Simple to use, easy to fabricate, does not requirqe a lot of material
   - Cons: Fins might be flimsy, not very watertight, fins would have to be very wide to cover the whole slot,
4. Plug
   - Description: A solid piece of material that would simply slide into the slot to cover it (very similar to stop log design but on a larger scale)
   - Pros: Sturdy, easy to fabricate, watertight
   - Cons: Pieces would have to be very large, difficult to pick up on account of weight, would need to store them somewhere when not in use, operator would need to decide how many logs to use.

Scalability

The FTTFC team designed this weir for plants with flow rates of 20 L/s and has only tested the viability under this flow rate. It is possible issues may arise when scaling up; the main concerns would lie in the strength of the gate, ease of use, and leakages.

Despite these preliminary concerns, FTTFC is confident that the hinge design will work in other plants that have greater than 20 L/s. Many discoveries were made through the tests in the flume that reassured this confidence. The ease of operation was far better than expected and posed no difficulties for the operator. The 1/4" gate and 1/8" reinforced gate experienced little to no flex from the stress of the water when opening. Lastly, water leakage was fairly minimal and was primarily caused by fabrication errors. Because these equations will hold true for any sized plant, this leakage analysis can be done for any location.

Many of the calculations used for this particular gate design should also apply to ones with greater flow rates. This is because in plants with larger flow rates, there is also a higher quantity of filter entrance tanks, so the flow rate per tank should be similar. The combination of this information and the results found by the FTTC team suggests that no matter the plant this hinge design will be strong, easy to use, easy to fabricate, and sufficiently waterproof.