Demo Plant User's Manual

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1 Assembly

Note: All assembly can be done without tools, and a backdrop has been provided to aid in speedy assembly of the plant. These instructions are intended to clear up any additional confusion that may occur.

1.1 Frame

Below is a picture of the plant frame in Figure 1. It consists of 12 PVC Tubes, each of which is labeled in sharpie with a number, corresponding to the same number on another tube. Connect these tubes with their numbered partners and rotate the tubes until the labeled sides are facing the back of the plant.

Do not connect the outer portions of the frame (labeled 11 and 12) until the rest of the frame has been assembled. The Entrance tank's attachment, connected to tube 1-4 must be oriented as shown in Figure 2. Its height may be adjusted manually.

1.2 Tank Setup

Below is a table listing all of the tanks present in the Demo Plant, and how they are connected to the plant. Start with the clean water tank, SRSF, and Sedimentation tank - each of which connects to its spot in the plant by snapping into a slot on the PVC tubing. Consult the plant photo or backdrop to make sure the tanks are properly oriented. The sedimentation tank should have the vertical portion facing down, the filter should have the tube leading out of the top facing up and the clean water tank should have its open mouth facing up.

The remaining tanks must be secured to the plant frame by running a screw through a hole in the frame and tightening it with a wing nut. Start with the constant head tanks which are located in the top-right portion of the plant, when facing it from the front. The Coagulant stock tank should be towards the center of the plant, with the constant head tank (which may be connected) directly below it. The Raw Water tanks are oriented in the same manner, towards the edge of the frame. The Entrance tank connects to the frame on the opposite edge of the frame from the raw water and coagulant tanks. It is to be oriented so that the screw that connects it to the frame is on the side of the tank closest

Figure 1: Plant Frame

Figure 2: Entrance Tank

to the plant's frame, with the tubing connection directly opposite and facing the interior of the frame. For how each tank is connected to the plant's frame and the flow of water see table 1below.

1.3 Dosing Arm

The dosing arm should be secured to the plant in the same manner as the tanks - with a screw and wing nut. It is attached to the tube running through the center of the plant, just above the entrance tank. Make sure the labels on the tank are facing outward, and the float valve and chain are attached.

1.4 Tubing Setup

Many of the tubes for the plant should already be attached to at least one of its connections, such as tubes connecting the raw water and coagulant tanks. If a tube is not connected to any aspect of the plant, refer to the inventory list for reference or follow the steps below:

1. If the tube is 1/8" in diameter, it connects the coagulant constant head tank to the dosing arm. This tube has to be filed down on the ends to allow for smooth operation while the plant is in use. In the case of the existing plant, one side was found to be suitable for connection to the constant head tank, while one was not. The side that should be connected to the constant head tank has blue tape wrapped around it. The other side should be inserted into the small hole in the tubing connected to the dosing arm.

2. If the tube is very long and has no fittings it connects the raw water constant head tank and the entrance tank.

3. If the tube has 3 fittings on one end, it connects to the 3 brass tubes along the side of the SRSF. The other connects to the fitting on top of the

Table 1: Tanks and Connections

Tanks	Frame Connection	Plant Connection
Raw Water Stock Tank	Top right of frame, connected by bolt and wing nut	Tubing leads to the constant head tank
Coagulant Stock Tank	To the lef tof the raw water tank, connected by bolt and wing nut	Tubing leads to the constant head tank
Raw Water Constant Head Tank	Directly below the raw water stock tank, connected by bolt and wing nut	Tubing leads to the entrance tank
Coagualant Constant Head Tank	Directly below the coagulant stock tank, connected by bolt and wing nut	Tubing leads to the dosing arm
Entrance Tank	On the left side of the frame, connected to a sliding joint. Connected by bolt and wing nut	Tubing leads to the flocculator
Sedimentation Tank	Attached to the outer portion of the frame, on the far left. Connected by snap joints	Input from flocculator. Tubing leads to the SRSF
SRSF and Clean Water Tanks	Attached to the outer portion of the frame, in the middle and right. Connected by snap joints	Tubing leads to the clean water tank, then an output for treated water.

Figure 3: Dosing Arm

sedimentation tank.

4. If the tube has 2 fittings in one end, it connects to the 2 brass tubes on the other side of the SRSF. This tube's other end connects to the bottom of the clear water tank.

5. If the tube has only one fitting at the end, it connects to the top of the SRSF for backwashing. The fitting should be open to the atmosphere, while the other side connects to the SRSF

6. Only two tubes should remain at this point. The tube with a larger diameter connects the flocculator and the bottom of the sedimentation tank. The other tube inserts into the clean water tank for drainage. Make sure the T-connection at the bottom of the sedimentation tank has a stopper on one end, to prevent water from leaking out of the system.

When connecting the tubes and fittings, be sure that they are secure. When inserting the tubes or fittings, one should feel a slight resistance before the tube or fitting is fully inserted. If you do not feel this resistance, then the tube/filter is not secure and will leak during operation.

1.4.1 Removing Tubing

If a tube or other fitting needs to be removed from its spot in the plant, locate the point where the tube meets a fitting with a gray ring around it. Simultaneously push in on the ring, while pulling to remove the tube. It is not always easy to do, but it should not require too much exertion. Be careful not to pull too hard and risk breaking any fittings.

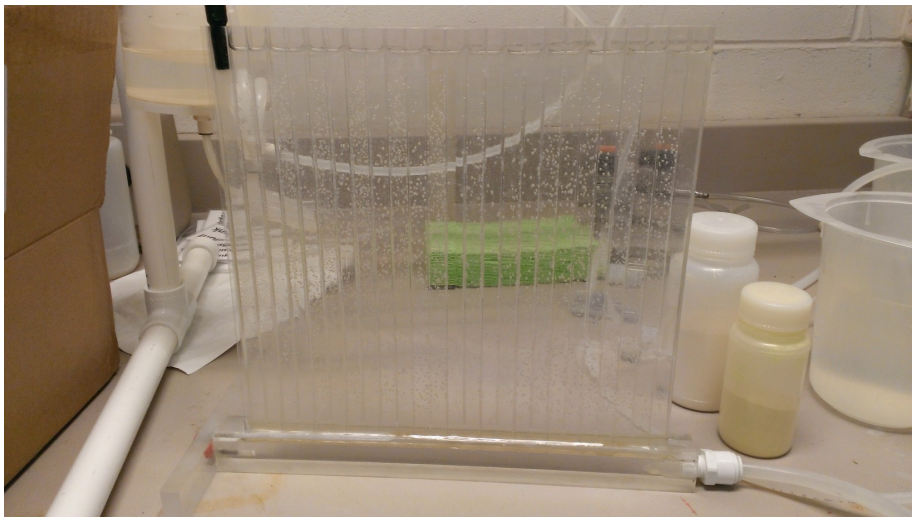

Figure 4: Flocculator

1.5 Flocculator

The Flocculator has two distinct sides, which may be distinguished by looking at the ends of its base. One side should have a "foot" or rectangular piece of Polycarbonate that should lay flat along its length to help anchor the flocculator. (See bottom left of 4) This side is where water enters the flocculator. Insert the tapered black fitting into the top of the flocculator at the point closest to the "foot". The other side has a plastic fitting for tubing to connect it to the sedimentation tank.

2 Preparation

Note: Make sure all valves are CLOSED (pointing perpendicular to the fitting), before proceeding. Figure 5 is an example of a valve that is OPEN.

2.1 Create the stock solutions:

The concentrations should be 1g/L of clay in the raw water and 150 mg/L of PACl in the coagulant solution.

Raw Water:

Fill one of the plastic containers accompanying the plant with a liter of water. Then add 1 gram of clay to the water and stir. 1 gram should be equivalent to 6 spoonfuls of the small spoon labeled "0.25g" (Note: don't pay attention to the spoon's labeled mass per scoop), or 1 spoonful of the larger spoon.

Fill the raw water tank by filling a 1L container with tap water and adding 1 gram of clay. Be sure to stir both to mix the clay and to prevent it from settling

Figure 5: Open Valve

on the bottom of the container.

Coagulant Water:

Fill another one of the plastic containers accompanying the plant with another liter of water. Then add 150mg of PACl to the water and stir. 150mg should be equivalent to 6 spoonfuls of the small spoon labeled "0.25g" or 1 spoonful of the larger spoon. Fill another container with 1L of water and add 150mg of PACl. Stir to mix the materials and pour into the stock tank. When pouring the coagulant solution, use a funnel to prevent excess spills.

2.2 SRSF Preparation

Before the SRSF is ready to use, it must be filled with sand. Start by removing the soft plastic piece attached to the top of the SRSF. Then fill the SRSF with water up above the highest brass tube on its side. Next, using a dry funnel, carefully pour sand into the SRSF. It is very important that the sand be sprinkled in or poured little-by-little, and not as one bunch. This allows the sand to serve as a porous media without air bubbles, that the water can pass through. Once the SRSF has been filled with sand up to the highest fitting, replace the soft plastic cap and it is ready for use.

2.3 Stock Tanks

Mix the stock solutions of 1g/L clay water, and 150 mg/L PACl solution. Fill both the PACl and clay stock tanks with their respective solutions. Make sure that neither empties during the course of operation. The coagulant stock tank should be filled using a funnel, to prevent spills. If either constant head tank begins to overflow, check the operation of the float valve, and manually close the tank's valve if necessary.

3 Operation

Note: Now open ALL valves, including the valve on the tube connected to the top of the SRSF. These are needed to keep consistent flow and to open the plant to the atmosphere at specific points in order to maintain flow due to pressure head differences.

3.1 Chemical Doser

Verify that the tube leaving the constant head PACl tank has no air bubbles. If there are air bubbles, detaching one end of the tube and lowering it until water flows through will eliminate them. Verify that the weights on the lever are at the desired dosage level. After the plant is turned on, make sure that the tubing from the coagulant head tank to the dosing arm has no air bubbles (again, detaching and lowering the tubing should eliminate them). It may take a few minutes for the alum to start flowing, as the alum level must rise enough to give sufficient head in the drop tube. Make sure that the float is responding properly to the water level changes.

3.2 Flocculator

Once the plant is turned on, the flocculator should not need any adjustments. If water doesn't flow from the entrance tank into the flocculator when the plant is turned on, check for and eliminate air bubbles in the tubing: take the tubing out of the flocculator and lower it until water begins to flow, then replace it.

3.2.1 Troubleshooting

If the flocculator begins to back up with flocs, check flow through the sedimentation tank. Floc back-up is likely due to floc build-up in the tube connecting it to the sedimentation tank. If the flocculator begins to overflow, turn the water off, lower the entrance tank and check flow through the sedimentation tank. Also check to make sure the relative height of the sedimentation tank is not too high: the center of the T-connection sedimentation tank should be about level with the desired height of water in the flocculator. That height should be about 1-2 cm above the baffles in the flocculator, in order to prevent floc break-up. This includes the last column of the flocculator, which will be lower than the rest of the levels until the sedimentation tank fills up. After the plant has been running long enough that the sedimentation tank is full, the water level in the flocculator should be essentially constant across its width, with a decrease of $<$1 cm from its highest point at the entry to its lowest point at the exit. In case of flocculator overflow, lowering the sedimentation tank to its lowest allowable height is usually enough to solve the problem.

3.3 Sedimentation Tank and Drop Tube

Figure 6: Sed Tank

Once the plant is turned on, the sedimentation tank will slowly fill with water from the flocculator. Eventually, the water will begin flowing out of the T-connection. (See the top right of Figure 6) Leave it in that position for all operation. If the flow through the sedimentation tank stops, it is probably due to either air in the tube from the flocculator, or floc build-up in the bottom of the tank. Flocs will tend to build up not in the sedimentation tank, but in the tube connecting it to the flocculator. If this occurs to an unacceptable extent, close the valve at the bottom of the sedimentation tank and remove the stopper. This will drain the tube and some of the flocculator, removing the excess flocs. Leaving the valve open will drain the sedimentation tank, as well.

3.4 Stacked Rapid Sand Filter and Clearwell

The SRSF should not require very much troubleshooting. Once the sedimentation tank is full, water should flow into the SRSF, then to the clean water tank. If the water level drops too low in the SRSF, this can be resolved by closing the 2 valves leading out of the SRSF and allowing it to refill with water from the Sedimentation Tank.

3.4.1 Backwashing

Confirm that the 3-way connector is connected to the bottom of the drop tube after the sedimentation tank. Make sure all connections are watertight (especially the manual valve at the top of column. Make sure this valve is screwed tightly enough to the column to prevent leakage). Switching from filtration to backwash: close the upper two inlet tubes and the two outlet tubes. Open the backwash valve. Only after the valves have been changed, move the filter to a lower position (lower the SRSF to the ground). Be careful to not let any sand out. Allow the sand to fluidize via high water flow, and make sure air bubbles are worked through the SRSF. You should observe dirty water exiting through the backwash tube. To help remove air bubbles more efficiently, gently tap the column or remove it from the clamps and hold it horizontally while gently shaking it. Another option is to squeeze the soft plastic tubing at the top of the SRSF a few times to further agitate the system and create new routes for the air to escape through. Holding this soft palstic tubing vertically also helps. Make sure that the sand doesn't get high enough to get washed out through the backwash tube and make sure the backwash tube leads to waste bucket to prevent spills. Time of backwash is dependent on clay and alum concentrations fed into demo plant. Under our dosing conditions of 0.9 g/L of clay water and 6.5 mg/L of PACl solution, it should last approximately 7 minutes.You may have to open and close the bottom inlet tube while doing this. Once you observe that all layers of sand are fluidized with only the bottom inlet tube open, you are ready to start filtration again.

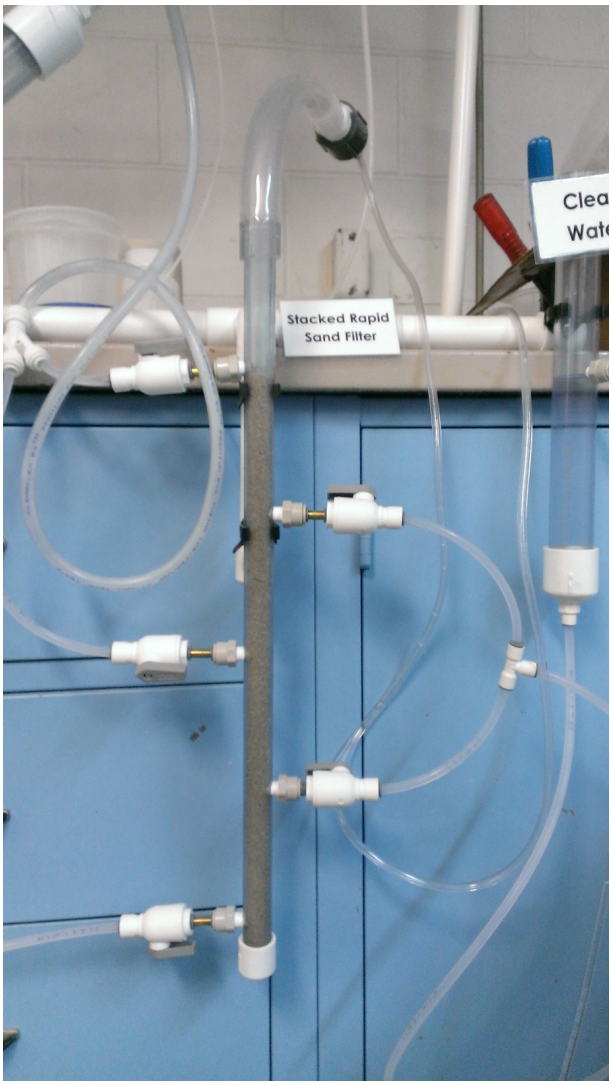

Figure 7: SRSF

3.4.2 Troubleshooting

Keep an eye on the height of water in the drop tube. Make sure it is not empty. If necessary, pour additional water to prevent air bubbles from entering the filter. If drop tube is about to overflow, turn off flow through plant or redirect flow from the sedimentation tank to the waste bucket.

3.5 General Troubleshooting:

Over the course of the semester, we found several odd problems that would occur while the plant was running. While past data gives consistent flow rates and other data, our time running the plant and measuring flow rates, etc has indicated that the Demo Plant, while functional, is very temperamental. Here are some little tips that should aid in your operation of the plant.

1. Fiddle with the tubes if flow if lagging or stopped: While all flow rates through the plant should be dictated by pressure head, head loss, etc. we have found that tube orientation has been a similarly significant contributor. If water is not flowing into the entrance tank or flocculator at an appropriate rate, sometimes all it takes to spur flow is a twist or lift and drop of the tubing. This tends to kick start flow by unjamming clogs or removing obstacles presented by the tube's orientation. This advice should only need to be applied to the tube connecting the entrance tank and raw water constant head tank, and the coiled tubing connecting the entrance tank and the flocculator.

2. Keep an eye on raw water levels: Raw water runs through the plant fast, depending on the overall plant flow rate. If flow is lagging, it may be because the stock tank drained and you didn't notice. Keep an eye out and refill it consistently if you are running the plant for an extended period of time.

3. Keep an eye on coagulant levels, too: For most of the semester, we worked with a plant with a dosing arm below the coagulant constant head level, creating overdoses of coagulant. This experience showed us that one of the biggest sources of clogs is too much coagulant entering the system early on. Make sure the system isn't too clogged to run.

4. Clean the plant from time-to-time: Disconnecting and cleaning all of the tubes and tanks should serve a similar purpose of preventing clogs in the system. Just be careful not to fill tubes with air bubbles, as a result.

5. Get Outside Feedback: Sometimes we addressed the same problem multiple times and could not find a solution until Monroe, Julia, or Casey had run the plant on their own and were forced to address the same problem. If/when anyone else has to use the plant, be sure to get their feedback on how the plant ran, what went wrong, and how it was fixed so that you can learn to solve that problem and apply the knowledge for future groups.