Demo Plant User's Manual

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1 Assembly

All assembly can be done without tools. 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 23 PVC pieces that are numbered in layers. The numbering begins on the bottom layer of the plant, at the table level. The first three pieces are the back supports that extend towards the back of the plant. The following is a description of the numbered pipe connections:

- Pipe #3 should be the back support on the far right of the plant, and it connects to pipe #4 that also lies flat on the table extending forward.
- Pipe #5 connects to the L-connection and forms the front loop of the plant.
- Piece #6 consists of two T-connections and a small pipe between them. The unattached T-connection connects to pipes 7 and 8.
- Pipe #7 extends perpendicularly to the front loop and attaches to pipe #2.
- Pipe #8, which is connected to the SRSF, attaches to the other open T-connection.
- Pipe #9 is on the other side of the SRSF and then connects to the clean water pipe, #10.
- Pipe #11 connects to pipe #1 on the other side, forming a full loop.
- The T-connection between #11 and #1 will then have pipe #12 extending upward.
- The T-connection between #7 and #2 will then have pipe #13 extending upward, and the T-connection between #3 and #4 has pipe #14 extending upward.

- Pipe #15 has two 2-inch pipes jutting outward. The orientation of pipe #15 should be so that the number is facing the back of the plant and upright.
- Pipe #16 includes the clamps for the head tanks and connects to the open T-connection that extends horizontally across the plant forming a middle row. On the other end of pipe #16 is a four-way T connection labeled #17. A short PVC pipe is already glued to this four-way T-connector; that pipe should extend upward.
- The bottom of the four-way connector should attach to pipe #13.
- On the left-hand side of the four-way connector is pipe #18, which includes the chemical dose controller. It attaches to a T-connection labeled #19, the bottom of which attaches to pipe number #12 which includes the entrance tank.
- Directly above the chunk labeled #19 is pipe #20, which is glued to the L-connector.
- Pipe #21 extends to the right from there, where the AguaClara Plant sign is located.
- The T-connection and pipe labeled #22 includes the stock tanks.
- Pipe #23 forms another L-loop and connects back to the top of connection #15.

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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 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 tightening the hose clamps around their middle until secure. 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 fastened in the hose clamp closest to the center of the plant, with its constant head tank fastened in the hose clamp 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 left-hand side of the frame when facing the demonstration plant from the front. It is to be oriented so that the exit valve on the bottom is on the right-most side when the viewer is facing the front of the plant. For how each tank is connected to the plant's frame and the flow of water see table 1below.

Figure 1: Plant Frame

Figure 2: Entrance Tank

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 left. Connected by snap joints	Tubing leads to the clean water tank, then an output for treated water.

Figure 3: Dosing Arm

1.3 Dosing Arm

The dosing arm should be secured to the plant 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 raw water constant head tank to the entrance tank. This tube first extends to the right of the tank and loops around the bottom of the 2-inch PVC pipe jutting towards the back of the plant. There is a small yellow clamp attached to the horizontal pipe that the 1/8" tube should clip into. The tube then loops once over the top of the identical PVC pipe at the left column of the plant, and then feeds directly into the connection at the entrance tank.
2. The longest tube, which is 1/16" in diameter, connects from the coagulant

constant head tank to the dosing drop tube. One end of this tube has been filed down to a point for attachement to the drop tube. Attach the other end to the exit of the coagulant constant head tank, wrap the tubing around the jutting supports on the back of the plant frame. You will need to wrap the tubing around twice. There is a clip connection attached to the support; secure the two strings of 1/16" tubing into this clip together. They should fit securely and maintain a relatively straight path from one end of the frame to the other.

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 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.

1.5 Flocculator

The flocculator has two fittings near the bottom, one on each side. The two sides are distinct and you can tell by looking at the top portions of the baffles. One baffle on the upper right side will extend up to the top of the flocculator. This is the baffle into which the pipe from the entrance tank must be inserted. The bottom connection directly beneath that baffle is the overflow pipe. It is long and has a valve on one end but does not attach to anything; it should be left in an empty bucket in case of overflow in the flocculator. The other 1/8" tube that extends from the lower left part of the flocculator goes into the bottom of the sedimentation tank. A reducer is placed on the appropriate valve so that the 1/8" tube will fit into the sed tank tube, which is larger in diameter.

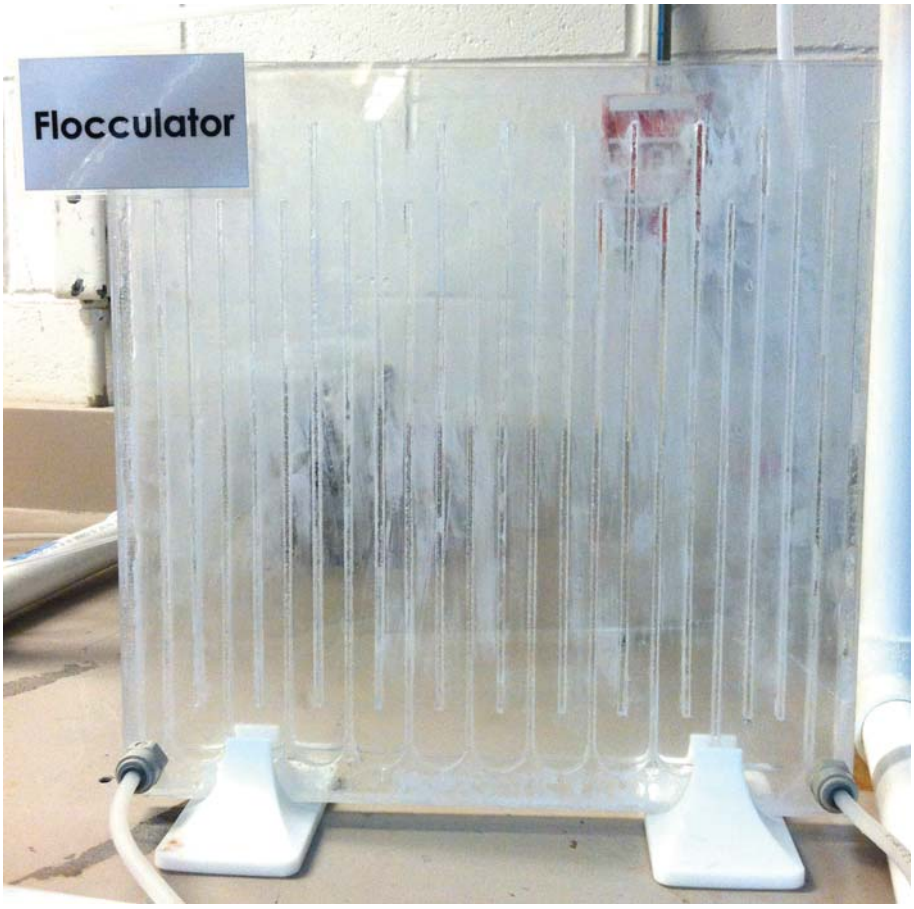

Figure 4: Flocculator

Figure 5: Open Valve

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 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. If air bubbles can be seen within the sand, a solution is to rinse the SRSF with a soapy water mixture before use. The t-connection at the lowest brass connection into the SRSF is for the purpose of running this cleanse: close the other valves first and then attach the T-connected tube to the bottom of a bucket with a soapy water mix. Elevation might have to be adjusted in order to achieve flow. Once the sand is mixed, it should be rinsed through with water to get rid of the soap residue.

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.

2.4 Sed Tank Preparation

This semester's team found that the time it took to ready the plant for a full run decreased significantly if the sedimentation tank was filled with clean water before the plant was run. This also prevents overflow in the flocculator. One side of T-connection at the bottom of the sed tank connects to the flocculator and has a valve. Close that valve and open the valve on the tube on the other side of the T-connection. That tube should connect to the bottom of a bucket filled with clean water, which will fill the sed tank. Once the water level hits the diagonal bend, the valve can be closed and the plant can be run.

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.

Note: before any operation begins, air must be cleared from the pipes. Air bubbles tend to accumulate especially in the 1/16" tube extending from the coagulant head tank to the chemical dose tube. Use a pipette bulb to suck out the air in these tubes before inserting them into the appropriate connections.

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.

The flocculator, due to micro cracks between the baffles, has internal leaking throughout every turn. This causes nearly every baffle to fill before the water even reaches the top of the first baffle. This is problematic because the overflow tube that we implemented does not help, it actually hurts because water flows through that tube before it is supposed to, draining the flocculator and preventing water from filling in the right direction. Therefore, we usually have to keep the overflow valve closed, unless overflow is imminent. The height of the sed tank must also be adjusted occasionally to keep flow through the flocculator constant.

Figure 6: Sed Tank

3.3 Sedimentation Tank and Drop Tube

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

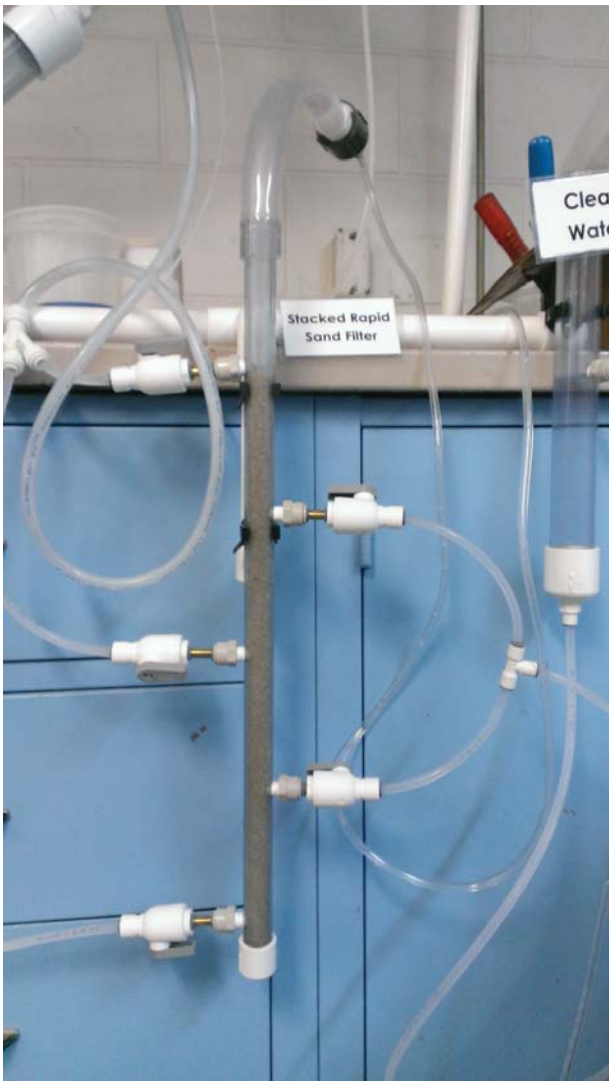

Figure 7: SRSF

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.

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.