Fabrication

***Abstract*—The Fabrication team focused on three main goals for the Summer 2011 semester. Firstly, we worked on developing a system to recharge a cordless power drill without using an electrical wall socket. Our solution was to connect the battery charger directly to a car battery, which may be easily brought to the site. Secondly, we researched more effective ways to remove plugs from hole saws. We determined that the commercially available Lenox speed-slot hole saws would best resolve this problem. Thirdly, we developed, tested, and improved a jig to help facilitate the assembly of plate settler modules.**

I. Recharging Battery Powered Drill from Car Battery

Our goal was to create a system that allowed cordless drills to be used at the construction site for a full day of work. The idea was to connect a drill directly to a large portable car battery.

Currently, Aguaclara uses the ubiquitous DeWalt 12V 3/8" cordless hand drill. Unfortunately, the price of extra battery packs for these drills remains around $50 (compared to the actual drill's cost of slightly over $100). This drill has two settings, low (0-400 RPM) for driving large screws and drilling large holes, and high (0-1,450 RPM) for drilling smaller holes and fasteners. The high setting on high torque is required in order to avoid the drillbit getting stuck when going through multiple plastic plates. Assuming the typical battery in use is a DeWalt DC9071, 12V 2.4 Ah Nickel Cadmium Battery, the drill has a maximum power of about 200-210W.

To implement our system, we intended to find a connection through the battery case into the drill (See Figure 1.1 on page 1), connecting the other end of a pair of jumper cables to the battery.

Figure 1.1: Disassembled Dewalt 12V Battery Pack

Upon further evaluation, however, we concluded that utilizing and modifying the DeWalt drill was not the best course of action. We opted to work with a Milwaukee 2411-22 instead, as this drill serves as both a driver and a hammer drill. To our knowledge, it is the only mass produced 12V cordless hammer drill.

Figure 1.2: Milwaukee 2411-22

We also discovered that Milwaukee manufactures a charger with a cigarette lighter plug for the M12 Red Lithium battery packs utilized in this drill. This, coupled with a simple cigarette lighter socket, could serve to charge the drill batteries directly from a car battery.

Figure 1.3: Milwaukee Car Charger & Adapter

We found this approach preferable to others due to its versatility and reliability. This configuration requires no modification (and the resultant risk of permanent damage) to the battery or any drill components. Since Milwaukee manufactures the charger, we can be certain of its safety and performance. Moreover, since the adapter is removable, it allows for various charging methods: one could utilize the power of a car directly from the cigarette lighter, or connect the jumper cables to an extra car battery that has been brought to the site.

A. Hammer Drill

Our secondary goal was to find a suitable hammer drill for drilling through concrete. The only available hammer drills from DeWalt are 18V, which would be troublesome to connect to a 12V car battery. As mentioned earlier, the only 12V cordless hammer drill currently available is the Milwaukee 2411-22.

Hence, we decided that it would be more economical to simply purchase the Milwaukee Hammer Drill. The Milwaukee 2411-22 M12 has multiple functions, and can serve as both a normal drill and as a hammer drill (which will help drill holes through concrete). It uses a 12V Milwaukee M12 Red Lithium battery pack, which is light and compact. It also has 2 speeds: 0-400rpm and 0-1500rpm. It takes roughly 30 minutes to charge a battery pack, which holds around 4.5AH of charge (See Figure 1.4 on the next page for disassembled battery pack). The complexity of the Milwaukee M12 Red Lithium battery pack was another reason we eventually chose not to wire the drill directly to a car battery. As seen in Figure 1.4 on page 2, the battery pack utilizes a printed circuit board, which would be hard to detach without damaging the connection.

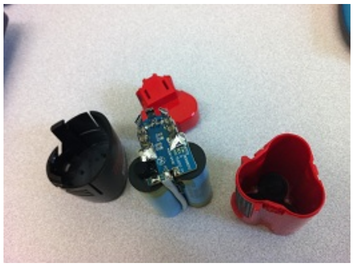

Figure 1.4: Disassembled Milwaukee 12V M12 red Lithium Battery Pack

II. Improved Hole Saw

Numerous parts of the AguaClara plant require us to drill holes through plastic. For instance, several holes must be drilled through PVC to create the launder. Most notably, though, many holes must be drilled through lamella plastic to create the plate settler modules. Overall, the process can be tedious and time consuming. Although the existing hole saws quickly and cleanly drill holes through plastic, it is very difficult to remove the plug that gets stuck in the saw after drilling is complete (See Figure 2.1 on page 2 and Figure 2.2 on on page 2). As it is, the plug must be pried out from an angle. The Spring 2011 team suggested that we try out using a self-ejecting hole saw arbor. However, such arbors can only be found for hole saws exceeding 1½ inches in diameter. Hence, we needed to find a better way to drill through PVC or a better way to remove the plug left over.

Figure 2.1: Vertical view of plug stuck in hole saw

Figure 2.2: Horizontal view of plug stuck in hole saw

A. Self-Ejecting Arbors

There are not many self-ejecting arbors available, and it is unlikely that there will be any at the places where plants will be built. The machine shop in Hollister had some ejecting mandrils, but these did not really help with the removal of plugs from the hole saw since the mandril arms did not extend far enough. Hence, we decided to look for alternatives for simplifying the removal of plugs.

B. Different Types of Drill Bits

As most holes in an Aguaclara plant are usually less that 1½ inch in diameter, with the ½ inch plate settler holes being by far the most common, we tried to find a more efficient way of drilling smaller holes. Numerous online forums made different recommendations. Ideally, a simple drill bit could be used for the large number of plate settler holes. This would avoid the need to remove a large number of plugs. We researched and evaluated the following types of drill bits for different sized holes.

- Forstner Bit: This drill bit is very effective for making perfectly shaped holes. However, it is usually used for wood, and requires the head to be perfectly aligned with the surface. In most of the examples we found, machine drills were used since it requires a lot of force.
- Step Bit: This drill bit was recommend for PVC tubes on several on-line forums. However, as it is more expensive, less readily available, and would probably require a prolonged application of perfectly vertical force, we decided not to pursue this option.
- Spade Bit: This bit uses a flat head to carve a hole in surfaces. We tried the spade bit from the machine shop on PVC pipe. It was extremely difficult to align the bit with the surface and the pipe eventually spun out of control.
- Plastic Bit: This bit can only be used for up to ¾ inch holes. We tried a plastic bit on the plate settlers. It drilled through relatively easily, but left a more jagged rough edge than the hole saw.

None of the drill bits we tried were able to drill through plastics as cleanly or as easily as a hole saw. While the hole saw simply cuts a hole in the material, the other drill bits literally shave through the entire hole. Hence, hole saws greatly reduce the amount of force required to drill through the material.

C. New Hole Saw Kit

There are some hole saws available with slanted slits and grooves at the side that make it easier to pry out plugs. However, these may not be available everywhere. If at all possible, we strongly encourage the purchase of Lenox speed-slot hole saws in the future. We purchased a 7/8 inch Lenox speed-slot hole saw (See Figure 2.3 on the next page). It was very effective in cutting through the lamella plate modules, and removal of the plug was made easier by the groove.

Figure 2.3: Lenox 7/8 inch Speed-slot Hole Saw

D. *Specialized Tool*

We worked on developing a specialized tool to help us remove the plugs from the hole saws. One idea was to use a bent metal rod to pry the plug out (See Figure 2.4 on page 3). Another idea was to somehow elevate the pivot in order to use a regular screwdriver to pry the plug out (See Figure 2.5 on page 3).

Figure 2.4: Bent prying end of tool

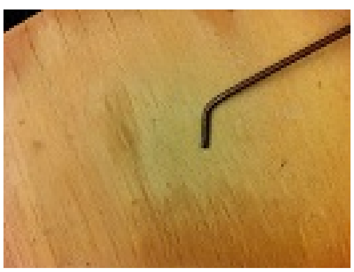

Figure 2.5: Lever end of tool

Initially, both of these tools worked effectively. However, with the introduction of Lenox Speed-Slot holesaw, the lever tool has become less relevant. The bent prying end of the tool also proved to be inadequate as the flimsy metal bent in the opposite direction when we tried to pry plugs out. This problem may be solved by creating a tool from a less malleable metal.

III. Plate Settler Modules

A. *Aligning the Sheets with a Jig*

We liked the Spring 2011 team's idea of using a jig to align the plates before drilling. Assuming a plate seperation of 1 cm and an angle of 60 degrees with respect to ground, we found the desired gap between jig plates.

$$gap = \frac{1cm}{\tan 60} = 0.57735cm$$

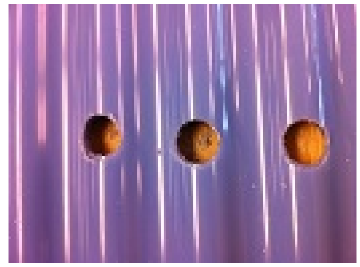

Figure 3.1: Sample Stacked Plate Settlers

We decided that a 1 cm spacing between plates, which would require a 0.577 cm gap between the top of each plate, would require an impractical level of precision. Given that we had to use scissors to make the jig, and that further alignment has to be done as the module is constructed, such precision was unrealistic. Instead, we chose to model a 2 cm seperation, which requires a 1.15 cm height difference. We constructed a new jig in accordance with these specifications (See Figure 3.2 on page 3).

Figure 3.2: New Plate Settler Jig

B. *Cutting through Plastic*

Cutting the plate settler material is a fairly difficult task as there isn't a specialized tool to cut through it. We attempted to use the machine saw in the machine shop to slice it into pieces. However, this shredded up, instead of snipped, the material. One sixteenth of the material was lost, leaving a jagged edge. A strong pair of scissors proved the most effective at slicing through the pastic sheets (See Figure 3.3 on page 3).

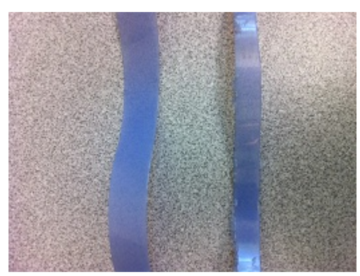

Figure 3.3: Comparison between scissors (left) and saw (right)

C. *Constructing a Mock Plate Settler Module*

We constructed an entire plate settler module using the jig we created (See Figure 3.4 on the following page for schematic). Although this does not adhere strictly to the specifications of current AguaClara plants, we feel that the process has demonstrated the efficacy of the jig. It increased our efficiency and accuracy greatly, eliminating the need to repetitively align each of the plates.

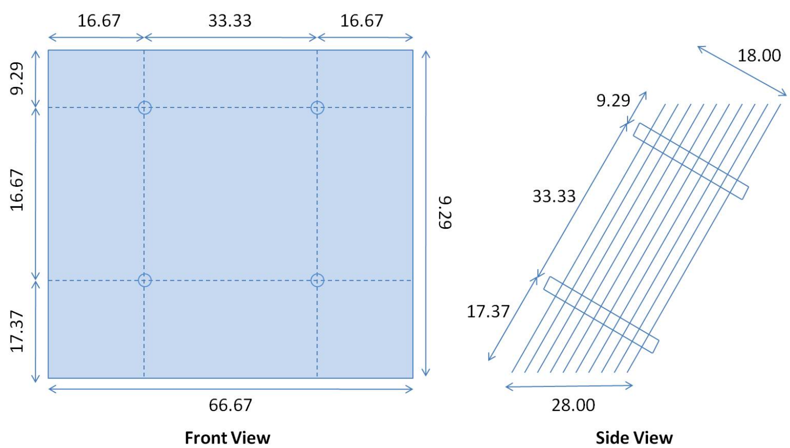

Figure 3.4: Schematic for plate settler module

The first step was to measure out the exact length of one plate (See Figure 3.5 on page 4), and subsequently cut a piece of that length.

Figure 3.5: Measuring and marking the length of a plate

Using this first piece as a template, we then drew a line to mark each subsequent plate (See Figure 3.6 on page 4) and proceeded to cut the initial sheet into multiple plates.

Figure 3.6: Using the first plate as a template

After cutting the desired number of sheets, we aligned them on the jig (See Figure 3.7 on page 4 and Figure 3.8 on page 4).

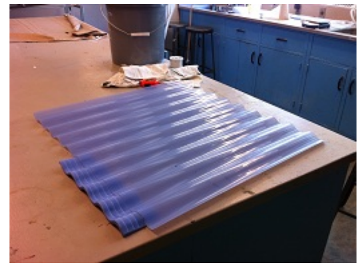

Figure 3.7: Aligning the plates on a jig

Figure 3.8: Cross-section view of aligning plates on jig

After marking out where each hole should go on the top plate, we proceeded to drill through the whole stack (See Figure 3.9 on page 4).

Figure 3.9: Stack of plates with holes drilled through

Finally, we slotted the pipes, spacers, and caps in to create the full module (See Figure 3.10 on page 4). Note that, as the spacers were of larger diameter than the structural pipe, they pushed the plates further apart than would be expected. To compensate, we used spacers that were not 2 cm in length, but 1.5 cm in length.

Figure 3.10: Cross-section view of complete plate settler module

Overall, we were satisfied with the jig. One reservation, however, is that, given the imperfections in the construction process, it would be hard to ensure precision while using the jig. As the jig levels are of exactly the same thickness as the plates, it would be easy for the plates to slide between different levels of the jig. In essence, although the jig did make the process of aligning the plates more efficient, it did not increase accuracy.

D. Alternative Jig

We decided that creating a jig with levels of a slightly greater thickness may be preferable. However, as it would be difficult to obtain materials of exactly the same curvature as the actual plates, we decided to implement this idea using flat material. This new jig was constructed using a transparent acrylic sheet roughly 1.5 times the thickness of the plates (See Figure 3.11 on page 5for how we cut through the new material and Figure 3.12 on page 5 for new Jig).

Figure 3.11: Cutting through new material

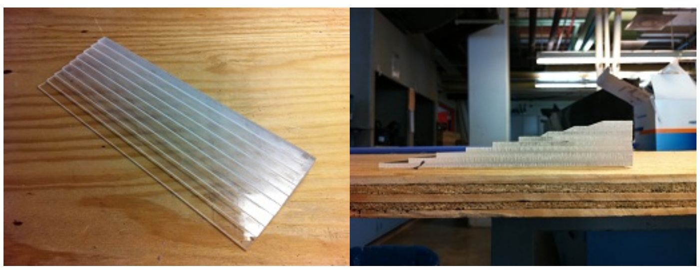

Figure 3.12: Re-engineered jig

This new jig proved to be extremely effective. There were no longer incidences of plates sliding between levels. Further, the flatness of the surface proved to be more of an advantage than a disadvantage, as it allowed us to better observe how the plate were lining up (See Figure 3.13 on page 5). Overall, this new implementation increased both accuracy and efficiency. The only shortcoming of this new jig is that it is both larger and heavier than the previous jig. However, given the jig's relatively small size compared to other tools and components, this should not be a significant issue on the site.

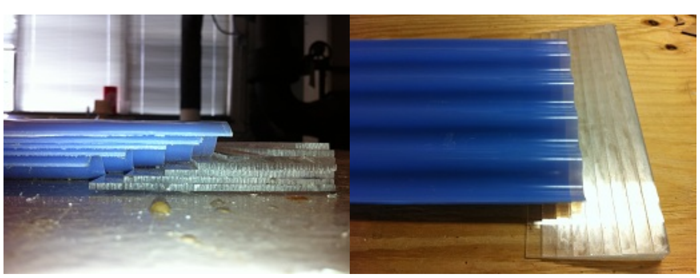

Figure 3.13: Alignment of plates with new jig

We then took the process a step further, using the same acrylic material to construct a longer jig, in line with the current specifications used in most AguaClara plants. This new jig is capable of accomodating 10 lamella sheets with an expected gap of 2.5 cm between them. In addition, the new jig has two vertical plates on its left and top edge. These will allow the user to simply shove the sheets into a corner, rather than aligning them by hand (See Figure 3.14 on page 5for image on new jig).

Figure 3.14: New Jig with alignment plates