DEVELOPMENT OF METHODS TO AID IN FLOTATION CIRCUIT EVALUATIONS AND DRIP PAN DESIGN

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ABSTRACT

Field assessments were performed to establish the performance capabilities of a new flotation technology for fine coal upgrading, known as StackCell flotation. Flotation release analysis was performed on all samples to determine the amount of hydrophilic material present in the streams around the flotation cell. Data from this work supported recommendations from the equipment manufacturer that the wash water distribution system should be changed to a drip pan and that the design of the slurry-air distributor from the mixing chamber should be altered. The experimental data showed that as froth depth, rotor speed, and wash water rate changed, the performance of the cell followed expected trends with respect to product quality, but diverged from expected trends with respect to carbon recovery and yield. Other work performed includes the development of a new carbon partitioning test, which uses a blender to provide a high shear environment and uses oil to partition the slurry into a carbon rich oil phase and an ash rich pulp phase. This test is capable of producing results comparable to those of a traditional release analysis. Lastly, a spreadsheet program was developed that can aid users in designing drip pans. This program is capable of producing custom designs or unit cell designs. A study of the effect that plate thickness has on flow rate was performed in order to develop a model for flow through an orifice plate. The results of this work showed that plate thickness has little to no effect on the flow rate.

DEDICATION

To my parents, Joe and Kathy Kiser, who supported me every step of the way.

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1.0 INTRODUCTION

1.1 Background

In 2010, the United State produced approximately 1,085,000,000 tons of coal (U.S. Energy Informaiton Administration 2011b). This coal was produced from both surface and underground operations. Once coal is removed from the earth it is usually cleaned to remove impurities. This cleaning occurs at preparation plants located all over the country. These plants break and segregate the feed coal coming into the plant into different size classes. These size classes are handled by different circuits within the plant. The smallest size class, generally less than 100 mesh (150 μm), is often cleaned by froth flotation.

Froth flotation is employed by roughly half of all the preparation plants in the United States (Leonard 1991). Two types of machines designs are commonly used in the coal industry, mechanical and column. Usually, several mechanical cells are arranged in series. This combination is often referred to as a bank of flotation cells (see Figure 1.1).

Column cells (see Figure 1.2) are much larger than mechanical cells, but generally produce a cleaner product due to the use of froth washing which reduces nonselective hydraulic entrainment of ultrafine mineral matter.

Roughly 10% of the feed that enters a preparation plant is handled by the flotation circuit (Leonard 1991). In a plant with 900 tons per hour (TPH) of dry feed solids, this results in 90 TPH of feed to the flotation circuit. For this example, a one percentage point increase in flotation yield, while still meeting contract specifications, results in an increase of 0.9 TPH of clean product. This results in an extra 5,400 tons per year, assuming a 6,000 hr/year operating time. The metallurgical coal price as of June 2011 was approximately $184/ton (U.S. Energy

Figure 1.1: Bank of mechanical flotation machines.

Figure 1.2: Series of column flotation cells.

Informaiton Administration 2011a). Using this price, the preparation plant used in this example would produce an extra $993,600 in revenue for a one percent increase in yield of their flotation circuit. As a result of this financial incentive, new technology is constantly being added to the coal preparation industry in order to increase the overall yield of clean coal from the plant.

1.2 Objectives

Eriez Manufacturing recently introduced a new flotation technology, called the StackCell system, to the coal preparation industry. This technology has the potential to provide the superior separation performance of a column flotation machine within the compact footprint of a mechanical flotation cell. One objective of this study was to conduct a field assessment of the separation performance of this new technology for coal applications. This goal was accomplished through two series of field testing programs. The test data suggested areas of interest for improving cell performance. The major recommended changes involved (i) upgrading the wash water system from a piping network to a drip pan and (ii) modifying the air-slurry mixture distributor from the mixing chamber into the flotation tank. Other work accomplished during the project included (i) the development of a carbon partitioning test that can be performed with inexpensive and non-specialized equipment and (ii) the development of a spreadsheet-based computer program that can be used to aid in the design of wash water drip pans.

2.0 LITERATURE REVIEW

2.1 History of Flotation

Coal flotation was born from the groundwork laid by the mineral industries in the early 1900's. Although flotation was developed in 1902, the coal industry did not consider it for use until 1920. In fact during the early days of flotation it was believed that the process could only be used to separate sulfide or metallic minerals (Zimmerman 1948). The coal industry still resisted the process even after it was proven that flotation could be an effective method in separating coal (Ashmead 1921).

The necessity of coal flotation began to be apparent as coal processing shifted from dry to wet based processes. The waste water from these wet processes contained large amounts of fines. This loss of fines represented lost revenue for the companies, caused deterioration in the quality of the coal produced, and more importantly these fines polluted the local waterways. The fine coal issue was more pronounced in Europe where thin seams were being mined using mechanized techniques, which resulted in a large amount of fines being produced. During this time, mines in North America were still mining thick seams, which produced a much smaller amount of fine material (Lynch et al., 2010).

Although the fines per ton mined in the United States was relatively low, the overall amount was fairly high. In 1916, 600 million tons of coal was produced in the United States. A flotation chemicals group at Mellon University and a second group at the University of Washington both made attempts to solve the fines problem. Mellon University created a process where the coal was crushed to less than 0.3 mm and 1.0-1.5 pounds per ton (lb/ton) of pine oil was added to the slurry. The fines were then floated using a Callow cell. This process, while effective, was seen as too costly with respect to the value of the coal being recovered (Lynch et

al., 2010). The University of Washington group was partnered with the United States Bureau of Mines. This collaboration ran from 1918 to 1940 and became the authority on coal flotation (Aplan 1999). As the amount of fines produced in the United States increased the coal companies slowly began to recognize flotation's potential, and flotation would become a crucial process in recovering high grade coal fines by the end of the 1920's (Lynch et al., 2010).

The first large scale testing of coal flotation was performed in 1920 at Skinningrove Iron Company in the United Kingdom. The goal of this testing program was to improve the coke made for use in the iron furnaces by floating coal and rejecting ash. The program succeeded in obtaining a high coal recovery and producing a coking product with a higher strength (Lynch et al., 2010). The process made quite an impression as indicated in the quote:

"*The extraordinary flexibility of the flotation method of washing coal, which permits the treatment of all grades of fuel down to the smallest dust, will, in our opinion, become an asset of national importance. There is no pit heap containing coal, or washery heap, or fine dust, or other colliery waste, from which the coal cannot be completely recovered by this method of treatment(Bury et al., 1920-21).*"

The year 1920 also saw the installation of froth flotation plants in in France and Spain. Just a few short years later, in 1922, England would install a plant, and the next year Germany followed suit by installing its first plant as well. By 1925, flotation was cleaning approximately one million tons of coal per year in Europe (Chapman and Mott 1928).

Many of the flotation cells used during these early days of coal flotation were simply adapted mineral flotation cells. Arguably, the most important of these adapted cells was the Standard Minerals Separation cell. This was the cell used at the Skinningrove trials. This design

used strong agitation to beat air into the pulp. The aerated pulp was then discharged into a spitzkasten, where the froth and pulp phase separated.

Other early flotation cells included the Elmore Vacuum cell, and the Callow flotation Cell. The Elmore cell was met with limited success in the minerals industry, but it was widely used in England to process coal for several years. The Elmore cell had several benefits such as a low power requirement, an easily dewatered product, and the ability to float particles up to 4.8 mm.

The Callow cell created bubbles by forcing air through the bottom of the cell, which was made of canvas. The resulting bubbles would then rise to the froth collecting particles on their way. The Callow cell was capable of collecting large particles due to its quiescent contacting zone, but struggled in obtaining high mass recovery values.

The Ekof flotation cell was the first cell to be built in Germany, and was designed specifically for coal flotation. The Ekof cell used compressed air, which was directly injected into the pulp. This served to both agitate and aerate the pulp. The Ekof cell wasn't the only German invention of its time. The Humbolt cell, like the Ekof cell, used compressed air for mixing and aeration. In the Humbolt cell the compressed air impacted a plate upon entering the cell. This provided agitation for the slurry before entering the frothing chamber where the concentrate was removed from the cell.

Like modern day flotation, early coal flotation used reagents to aid in recovering coal. Unfortunately, early coal flotation economics did not encourage research into reagents. Any reagents that were used were culled from existing flotation chemicals. Cresol or creosote oil was a common frother, while kerosene, paraffin oil, gas oil, and tar oils were commonly used as collectors (Chapman and Mott 1928).

The cresol oil that was used was an impure byproduct of the coke making process. This frother had several issues. It adsorbed onto coal which lowered the concentration of frother in the flotation cell. Thus, large amounts of cresol had to be used to achieve the desired result. Cresol can also have a highly variable collecting power. Lastly, cresol can cause health and environmental problems (Leonard 1991).

The 1930's brought about a huge growth in flotation in Europe (Ralston 1937). The Dutch were influential in coal flotation gaining momentum during this era, and the Dutch State Mines were said to operate the three largest coal flotation plants in the world at the time. Due to the success of these three plants, all Dutch State Mine coal operations were required to use flotation on their washery wastes. This growth continued into the 1940's, when flotation was established in England by the National Coal Board. Lastly, Germany was operating 43 coal flotation plants by 1962 (Lynch et al., 2010).

During this time period major coal flotation work was being performed in the United States by the Pittsburgh Coal Company (Davis 1948). The weakness of the coal market following World War I forced the company to improve their production systems. The company began adding flotation systems to their plants in 1932. These flotation circuits were used to treat minus 300 mesh material, and proved that this material could be treated with flotation (Lynch et al., 2010).

When the basis for reagents choice switched from price based to quality based the common frothers and collectors, cresol and pine oil, were replaced by methyl isobutyl carbinol (MIBC) and diesel fuel oil. During this same time period a wide range of machines disappeared, and the sub aeration flotation machine became the dominant machine used in the industry by the 1960's (Lynch et al., 2010).

The 1960's signaled the peak of coal flotation in Europe where it would continue to decline over the next 40 years. During this period coal flotation in America saw a large growth. The growth seen in the United States was due to environmental awareness becoming a major issue. Sub-aeration flotation machines continued to be the dominant design during this time period. Although many different types of impeller and tank designs were introduced (Lynch et al., 2010).

Coal flotation benefitted from the oil crisis and an upswing in coal prices seen in the 1970's. This combination resulted in a surge of funding for coal flotation research. This research tended to focus on developing more efficient flotation machines. Early results included adapting the Canadian Column for use in coal and the Flotaire Column. The dominance of mechanical flotation cells in the industry was challenged by the arrival of the Jameson cell, Microcel, Ekof cell, and XPM cell in the 1990's (Lynch et al., 2010).

One of the largest changes occurred in Australia. Mechanically agitated sub aeration cells dominated the Australian coal industry before 1988. The introduction of the Jameson cell 1989 began a shift in Australia. The Jameson cell, Micocel, Centrifloat, Trubofloat, and Ekof Cells were all tested in Australia (Lynch et al., 2010). The Australian coal industry's shift to column flotation can be seen in Table 2.1.

Overall coal flotation has come a long way since its inception. Companies have gone from actively resisting the method to implementing it into a large portion of their preparation

Table 2.1: Changing percentage of installed capacity during 1980 to 2005 (Lynch et al., 2010). Reprinted with the permission of The Australasian Institute of Mining and Metallurgy.

	1980	1985	1990	1995	2000	2005
Mechanical	100	96	94	60	42	50
Column		1	1	20	27	27
Jameson		3	5	20	31	23

facilities. In 1995, a total of 345 coal preparation plants were operating in the United States. Of these, 110 used flotation, roughly 32%, a far cry from the origins of the process (Aplan 1999).

2.2 How Flotation Works

Wills (2006) states that "*Flotation is the most important and versatile mineral processing technique*." In the coal industry, flotation is generally used to treat material finer than 100 mesh, or less than 150 µm, but it can also be used to recover material finer than 200 mesh, or 74 µm. Generally 10% of the feed to preparation plant is treated by flotation (Leonard 1991). For a process that is so important in the processing industries, the idea behind it remains fairly simple. Flotation exploits the differences between the surface properties of the desired and unwanted materials. This means that flotation separates hydrophobic material from hydrophilic material.

Flotation consists of two major phases, the pulp phase, containing water and solids, and the froth phase, containing the floated material. The primary function of the pulp phase is to keep the solids in suspension and provide a favorable environment for bubble-particle collision to occur. The primary function of the froth phase is to upgrade the floated product. This is accomplished by reducing the recovery of entrained material, while retaining the material attached to the bubbles. Three mechanisms govern what is recovered in the froth.

1. True Flotation, or selective attachment of hydrophobic particles,
2. Entrainment of material in the water that passes from the pulp to the froth, and
3. Entrapment of material between particles in the froth attached to air bubbles.

Of the three mechanisms listed, true flotation is the dominant force driving the recovery of material (Wills 2006). Since minerals attach to the air bubbles due to hydrophobicity it is important to understand the contact angle of the mineral.

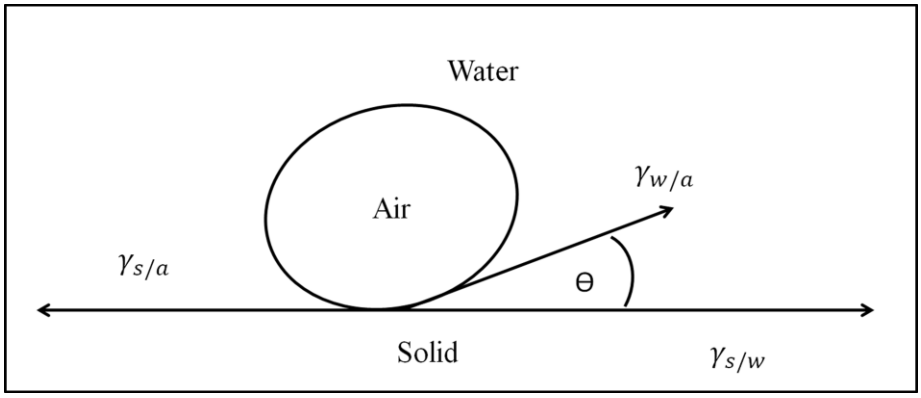

Figure 2.1: Contact angle between a bubble and a particle (Wills 2006) after.

Figure 2.1 shows a diagram of the bubble and particle attachment site. The tensile forces in play cause an angle to form between the mineral and the air bubble. [2.1] shows the balance of these forces at equilibrium, where $\gamma_{s/a}$, $\gamma_{s/w}$, and $\gamma_{w/a}$ represent the surface energies between solid and air, solid and water, and water and air respectively (Wills 2006).

$$\gamma_{\frac{s}{a}} = \gamma_{\frac{s}{w}} + \gamma_{\frac{w}{a}} \cos\theta \qquad \textbf{[2.1]}$$

The work of adhesion is defined as the force required to break the particle-bubble interface. This relationship is shown in [2.2], where $W_{s/a}$ represents the work required to create separate air-water and solid-water interfaces. A combination of these two equations results in [2.3]. This equation shows that larger contact angles create a larger work of adhesion. This makes the bubble particle aggregate more resilient (Wills 2006).

$$W_{\frac{s}{a}} = \gamma_{\frac{w}{a}} + \gamma_{\frac{s}{w}} - \gamma_{\frac{s}{a}} \qquad \textbf{[2.2]}$$

$$W_{\frac{s}{a}} = \gamma_{\frac{w}{a}} (1 - \cos\theta) \qquad \textbf{[2.3]}$$

The recovery of a given species in a slurry is controlled by three major factors. These factors are reaction rates, retention time and mixing conditions. The relationship between these

factors is represented in [2.4], where R represents the recovery of the species, k is the reaction rate, τ is the retention time, and Pe is the Peclet number.

$$R \propto k\tau Pe \quad \textbf{[2.4]}$$

The Peclet number is used to represent the amount of axial mixing in the flotation cell. A higher value represents more quiescent conditions and thus increases recovery (Levenspiel 1972).

The reaction rate, k, can be defined as seen in [2.5], where V_g represents the superficial gas rate, D_b is the diameter of the bubbles, and P is the probability of attachment.

$$k = \left(\frac{3V_g}{2D_b}\right)P \quad \textbf{[2.5]}$$

The probability of attachment is actually a function of other probabilities as show in [2.6] and [2.7].

$$P = P_c P_a (1 - P_d) \quad \textbf{[2.6]}$$

$$P_c \propto \frac{C_i D_p}{D_b^2} \quad \textbf{[2.7]}$$

In [2.6], P_c represents the probability of collision between a particle and bubble, P_a represents the probability of adhesion between the bubble and particle, and P_d is the probability of detachment of the particle from the bubble. In [2.7], C_i is concentration of particles in the flotation cell and D_p is the diameter of the particle. Generally P_a is a function of chemistry while turbulence in the cell is the driving force behind P_d (Yoon et al., 1988).

Retention time, τ in [2.4], is determined by identifying how long the particles remain in the flotation cell. Retention time is usually calculated using [2.8] and [2.9], where V is the

volume of the flotation cell, ε is the air hold-up, and Q is the flow rate into the cell. V_g and D_b still represent the superficial gas rate and bubble diameter respectively (Kohmuench et al., 2008).

$$\tau = \frac{V(1-\varepsilon)}{Q} \quad \textbf{[2.8]}$$

$$\varepsilon \propto \frac{V_g}{D_b} \quad \textbf{[2.9]}$$

The Peclet number can be calculated using [2.10]. Here, V_l and V_g represent the liquid and gas velocities respectively. The column diameter is represented by L, while D is the column diameter. The ε term is the air hold-up in the cell (Mankosa et al., 1992).

$$Pe \propto \left(\frac{V_l}{V_g}\right)\left(\frac{L}{D}\right)\left(\frac{1}{1-\varepsilon}\right) \quad \textbf{[2.10]}$$

All flotation machines use the relationships presented in the above equations to float a product. It should be noted though that changing one parameter to enhance one of the factors driving recovery can have a detrimental effect on different factor.

Chemicals can be added to aid the flotation process. These chemicals fall into three categories collectors, frothers, and regulators. The hydrophobicity of a mineral can be aided through the use of collectors. These chemicals will adsorb onto the surface of a mineral and make it more hydrophobic. Collectors are generally added to the pulp, and time must be allowed for the material to condition (Wills 2006). Theoretically, high rank coals should be floatable without the aid of a collector (Leonard 1991).

Frothers are used to accomplish several things. First, they are used to stabilize the formation of bubbles in the pulp phase. Second, frothers stabilize the froth, which allows entrained material to drain back into the pulp rather than be carried over into the concentrate.

Some frothers can create such a stable froth that it becomes an issue in further processing or transportation. Good frothers should have minimal collecting power, and create a froth just stable enough to transfer floated material to the launder (Wills 2006). Some of the most common frothers used in the coal industry include cresol, alcohols (MIBC), and polypropylene glycol ethers (Leonard 1991).

Regulators are used to change the effect of a collector, and can be further classified into activators or depressants depending on their function. Activators can be used to affect the surface of mineral in order to allow collector to adsorb onto the mineral, thus making it hydrophobic. Depressants serve the opposite function, rendering minerals hydrophilic (Wills 2006).

2.3 Factors Affecting Flotation

Several factors can affect the floatability of coal such as the feed's particle size distribution, applied reagent dosages, and operating parameters of the flotation cell itself. Changes in all of these factors can negatively or positively change the performance of the flotation process ultimately changing the quality of the floated product.

It has been shown that hydrophobic particles that are fine tend to be the first particles removed from a slurry, while large particles are only floated once the fines have been removed (Klassen 1963). The particle size effect can also be dependent on the applied reagents. It was shown by Rastogi and Aplan (1985) that in the presence of only frother that the flotation rate of coal increases with decreasing particle size, but when a significant amount of collector is added to the slurry the different particles sizes float in approximate proportion to their percentage in the pulp (Rastogi and Aplan 1985).

While it is possible to float material as large as 28 mesh (0.589 mm), the response of particles larger than 0.25 mm is mixed and depends on the coal source, Figure 2.2. High reagents

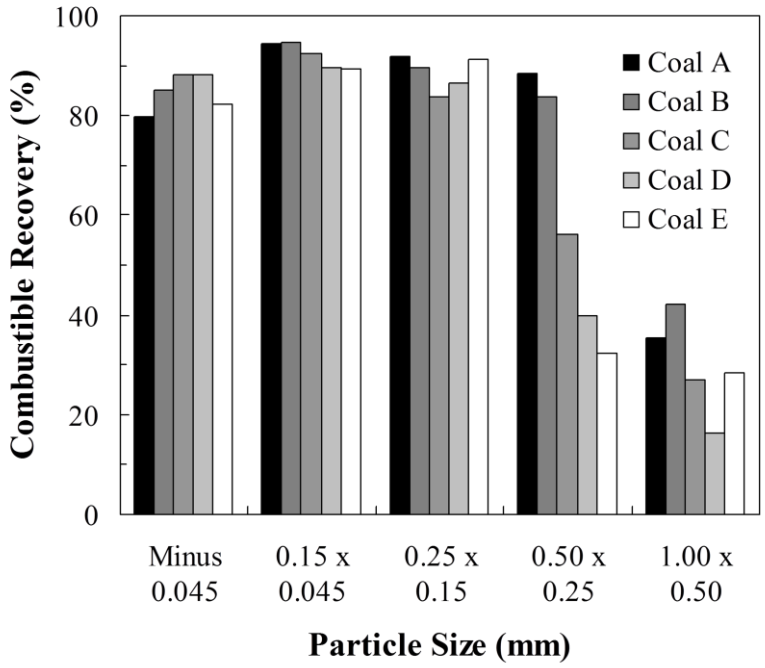

Figure 2.2: Size by size flotation recovery (Laskowski et al., 2007).
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dosages and air rates are required to float these larger particles. These conditions while able to float larger particles also favor flotation of impurities. Generally, these conditions are seen as unfavorable. Due to these hindrances, most flotation occurs below 100 mesh (0.15 mm), while spirals or water only cyclones are used to process the plus 100 mesh material (Laskowski et al., 2007).

Very fine particles, less than 30 µm, are called slimes. Entrainment allows these particles to report to the concentrate. These slimes can coat the surfaces of small particles and effectively render what was hydrophobic material hydrophilic. This phenomena can be partly countered by using a dispersing agent (Jowett et al., 1956).

For mechanical cells impeller speed can have an effect on the product ash and combustible recovery. A study performed by Jena et al. (2008) tested this parameter. The results of their work are show below in Table 2.2. Both combustible recovery and clean coal yield increased with increasing impeller speed. Clean coal ash saw a slight increase, 0.3 percentage

points, with increasing impeller speed up 1600 rpm. Here the ash jumped 1.2 percentage points higher than it was previously (Jena et al., 2008).

These results agree with a study performed by Sonmez et al. (2005) where they too found that combustible recovery and product ash both increased as the intensity of the agitation increased. Although the changes they observed were much more drastic. At 900 RPM, the flotation cell produced product of 15.40% ash with a recovery of 72%. This rose to a product ash of 22.68% with a combustible recovery of 90% at 1800 rpm (Sonmez et al., 2005). A third study also produced similar results, finding that increasing the impeller speed lead to an increase in water, ash, and coal recoveries (Akdemir and Sonmez 2003).

Wash water flow rate also has an effect on product ash and combustible recovery. A study performed on column flotation by Tao et al. (2000) shows the effect of wash water flow rate when frother dosage is kept constant. Figure 2.3 shows the results of this test. When frother dosage is kept constant the increasing wash water rate caused an initial dramatic reduction in water recovery which ultimately levels off. Increasing wash water under these conditions also shows a decrease in product ash and product recovery. These findings agree with the results published by Jena et al. (2008).

Table 2.2: Effect of impeller speed on flotation performance (Jena et al., 2008).

Impeller Speed (rpm)	Clean Coal Yield (%)	Clean Coal Ash (%)	Combustible Recovery (%)
1200	75.0	14.1	85.3
1300	77.1	14.3	87.4
1400	77.3	14.3	87.7
1500	78.0	14.4	88.4
1600	79.4	15.6	88.7

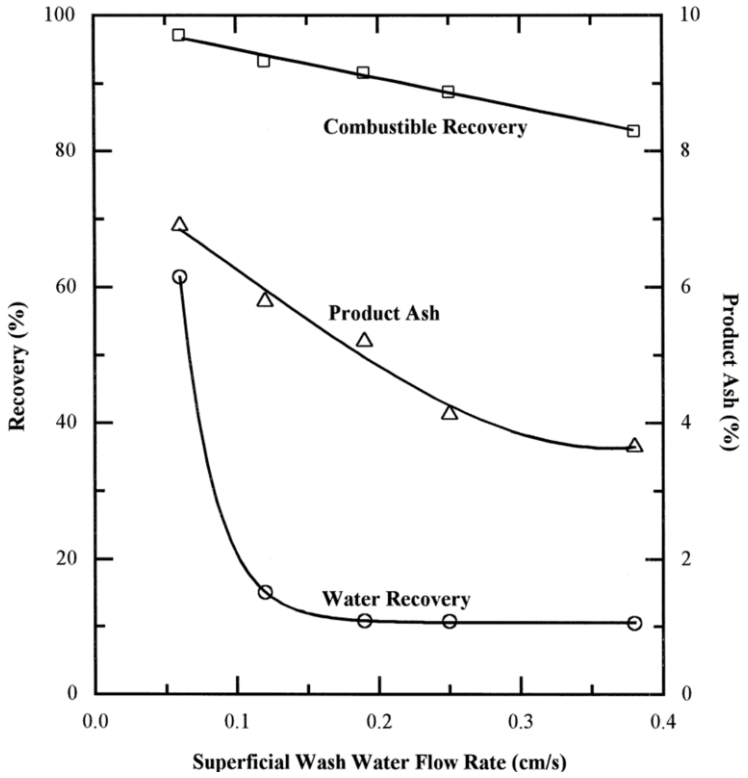

Figure 2.3: Results of wash water flow rate testing on constant frother dosage (Tao et al., 2000).

Reprinted from International Journal of Mineral Processing, Vol. 50, Tao et al., A parametric study of froth stability and tis effect on column flotation of fine particles, 2000, with permission from Elsevier.

The investigators found that a bias rate of greater than 0.2 cm/sec minimized the ash content of the product. Bias rate, V_b, is defined in [2.11], where V_w is the wash water flow rate and V_{wp} is the flow rate of water flowing into the froth product. The water flow rate in the feed is represented by V_{wf}, while R_w is the water recovery (Tao et al., 2000).

$$V_b = V_w - V_{wp} = (1 - R_w)V_w - R_w V_{wf} \quad \textbf{[2.11]}$$

It is believed that the reduction in water recovery is due to dilution of the frother from the addition of the wash water. This dilution can also be linked to the drop in combustible recovery. With a lower concentration of frother in the cell large bubbles will form. This will decrease bubble surface area and trigger a decrease in recovery (Tao et al., 2000).

Froth height was also investigated by Tao et al. (2000). It is generally known that a shallow froth depth will increase recovery but decrease grade, while a deep froth depth will increase grade, but decrease recovery. Recovery is less sensitive to this change, thus changes in depth will affect product ash more than recovery. Figure 2.4 confirms the general rule. As froth height increases product ash decrease along with a slight decrease in combustible recovery. Combustible recovery's lack of sensitivity can be explained through bubble coalescence in the deeper froths. As bubble surface area decrease the more hydrophobic particles stay attached to the bubbles. The now detached middling particles return to the collection zone for another attempt at bubble-particle attachment (Tao et al., 2000). A separate report confirms these findings (Hacifazlioglu and Sutcu 2007).

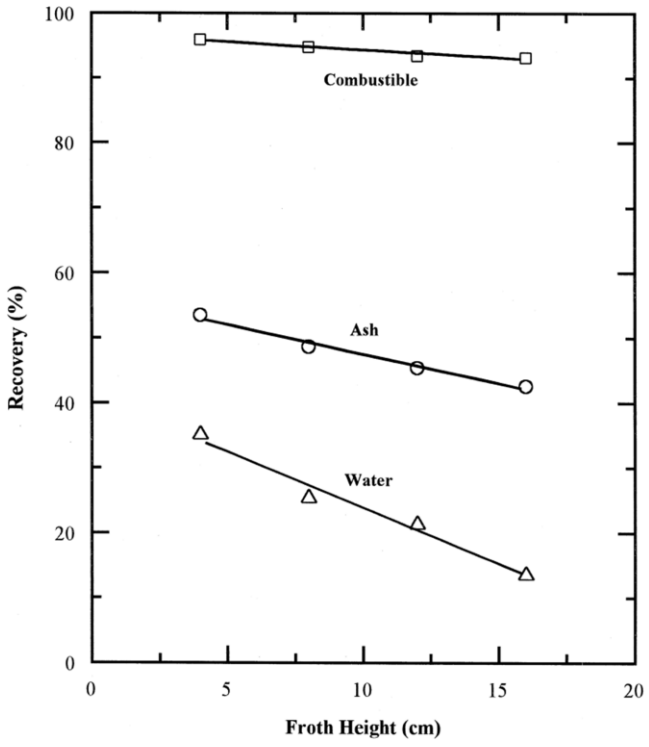

Figure 2.4: Effect of froth height flotation performance (Tao et al., 2000).

Reprinted from International Journal of Mineral Processing, Vol. 50, Tao et al., A parametric study of froth stability and tis effect on column flotation of fine particles, 2000, with permission from Elsevier.

Lastly, Tao et al. (2000) showed that water recovery is the driving factor behind ash recovery, entrainment, in the froth. Various operating conditions were tested such as gas flow rate, feed solid concentration, and froth height. The results of these tests are shown in Figure 2.5. This figure shows a linear dependence between ash recovery, product ash, and water recovery (Tao et al., 2000). This finding is in agreement with the findings of Akdemir and Sonmez (2003), where they found that gangue entrainment is proportional to the amount of water floated. But, the recovery of gangue material exceeded water recovery, which means other mechanisms are contributing to the recovery of gangue material. This illustrates the need to minimize the entrainment of hydrophilic particles in froth.

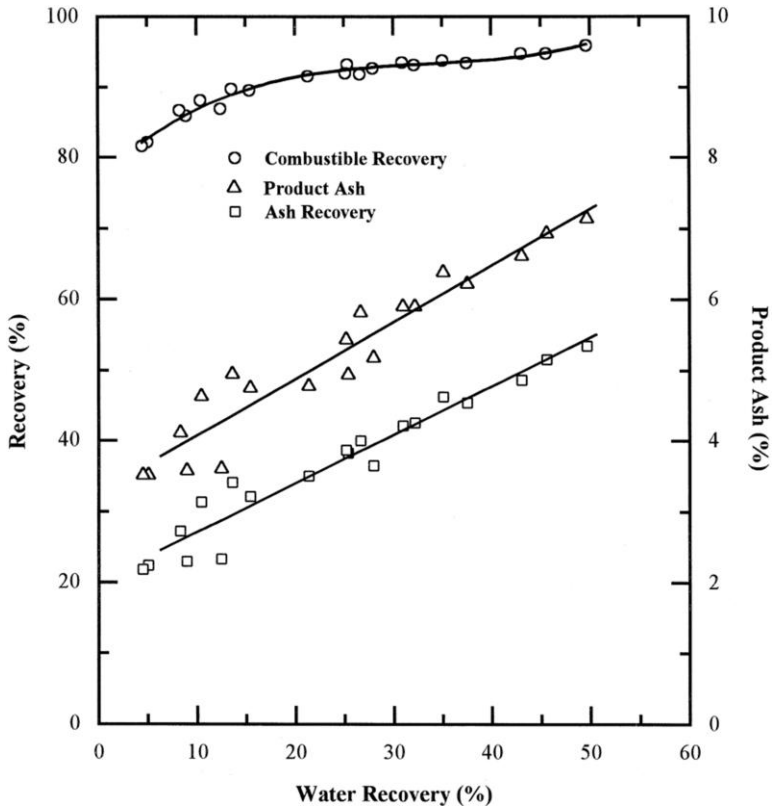

Figure 2.5: Ash recovery, product ash, and water recovery (Tao et al., 2000).

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2.4 Release Analysis

The release analysis is the flotation equivalent of the float and sink test for gravity concentrators (Dell 1964). Originally proposed in 1953 by C.C. Dell several forms of release analysis have developed over the years. The idea behind the release analysis is that once entrained material has been eliminated, changes in the operating conditions of the flotation machine can be used to create points along an ideal separation curve. The original release analysis called for the collection of froth in timed fractions. These fractions are then refloated in a predetermined sequence. Three concentrates and a final tailing are produced from a third iteration of the process, and a grade-recovery curve is produced from these samples (Forrest et al., 1994).

One of the alternate methods was put forth by Dell himself. A schematic of this procedure is show in Figure 2.6. Dell's method requires the use of a laboratory flotation cell with an adjustable impeller speed and air supply. Flotation begins following the conditioning of the sample. The first flotation is performed in a normal manner in order to obtain a high recovery. Once the froth has been exhausted, the cell is emptied and the tailings are saved. The concentrate is then returned to the flotation cell. The concentrate is then refloated in order to remove any clay present in the froth. The tailings from every flotation step are saved. This process is repeated until the amount of clays in the tailings is negligible (Dell 1964).

To start the second step the impeller speed should be reduced to the where the froth is no longer forming and the air should be shut off. Both variables are then increase carefully until flotation begins to occur. Once flotation begins occurring the froth or film should scraped from the cell until it no longer forms. The froth collection pan is then changed for a new one and the air and impeller speed are again increased until flotation begins to occur. Again, the froth is

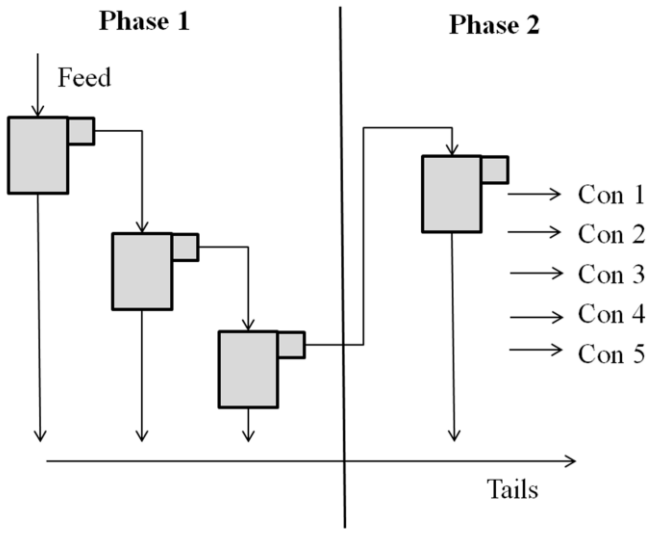

Figure 2.6: Schematic for a traditional release analysis (Mohanty et al., 1998b) after.

scraped from the cell until there is very little material floating. This process can be repeated at as many steps as desired. At the final step the impeller and air are allowed to operate at their maximums, and reagents can be added if necessary. Again, the froth is collected until it appears to be empty. The tailings are then combined and all of the samples are filtered, dried, weighed, and analyzed for ash content (Dell 1964).

Mohanty et al. (1988a) discussed an alternative to the traditional release analysis called the Advanced Flotation Washability (AFW). Figure 2.7 shows the setup of the apparatus used to perform the AFW. This method uses a batch operated column flotation cell that is 5 cm in diameter and 1.5 m tall. Stainless steel corrugated packing serve as vertical baffles within the column. The packing material creates a high length to diameter ratio, which results in a near plug flow environment within the cell. The feed slurry is continuously recirculated in order to ensure that the feed is flowing counter current to the rising bubbles. This also helps to combat the sanding of particles in the cell. The bubbles are created by air which is directly injected into the

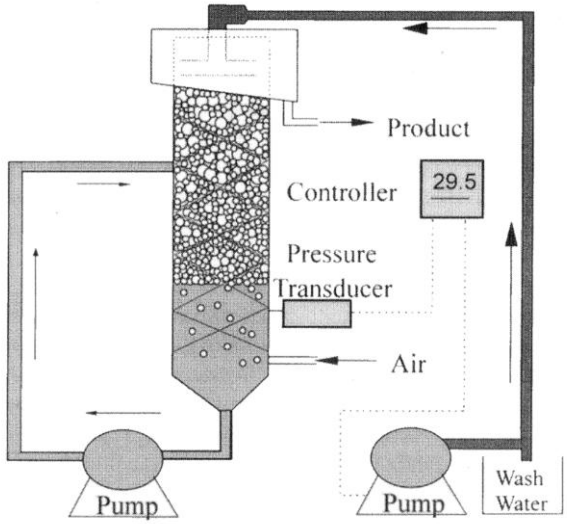

Figure 2.7: Schematic of AFW apparatus (Mohanty et al., 1998a).

Reprinted from Coal Flotation Washability: Development of an Advanced Procedure, Monhanty et al., Coal Preparation, 1998 permission of (Taylor & Francis, http://www.tandfonline.com).

column, while the wash water is adjusted by a PID controller. This allows the wash water to adjust the pulp level allowing the cell to operate at a desired froth depth (Mohanty et al., 1998a).

The AFW procedure shares the same structure as the traditional release analysis. Figure 2.8 shows the procedure used during an example Advanced Flotation Washability test. The first stage, separating the hydrophobic and hydrophilic material, was performed using a laboratory

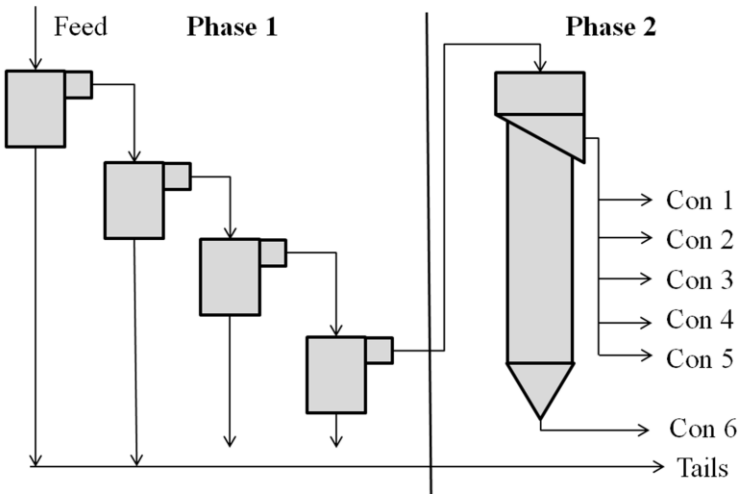

Figure 2.8: AFW procedure schematic (Mohanty et al., 1998a) after.

Denver flotation machine rather than the AFW apparatus. The concentrate from the first phase is then segregated by order of decreasing hydrophobicity. This was accomplished by collecting samples at air rates ranging from 1.5 liters/min to 2.5 liters/min. The material remaining in the column after collection of the highest aeration rate served as the final concentrate sample (Mohanty et al., 1998a).

The performance of the AFW was compared to the traditional release analysis proposed by Dell in 1964. Figure 2.9 shows the results for both tests, both of which level out in a similar fashion, but the AFW outperforms the traditional release analysis along the vertical portion of the curves. This means that middling particles are treated more efficiently by the AFW procedure. It should also be noted the AFW is a very repeatable process. The results for five tests performed under similar conditions are plotted in Figure 2.10.

Another alternate procedure to the traditional release analysis is the tree analysis. The procedure for the Tree Analysis is show in Figure 2.11. The tree analysis uses a regular

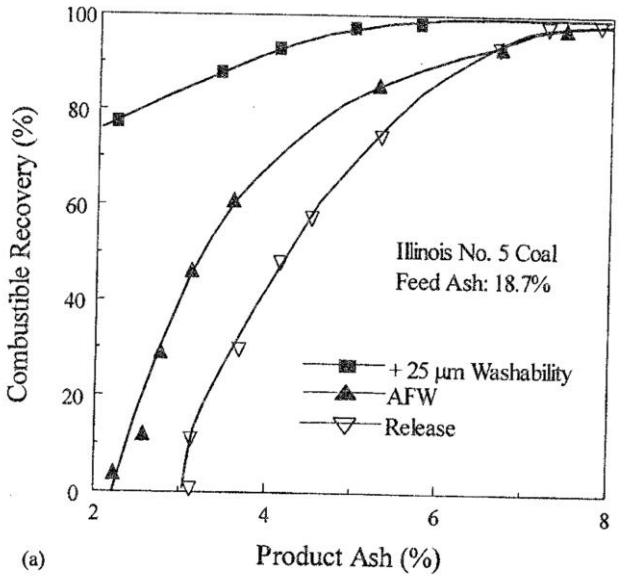

Figure 2.9: Comparison of the AFW and traditional release analysis (Mohanty et al., 1998a).

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laboratory flotation machine just as the traditional release analysis does. In this process flotation products are used to create branches. These branches are then refloated. The overall separation performance can be improved by continuing the branching process (Mohanty et al., 1998b).

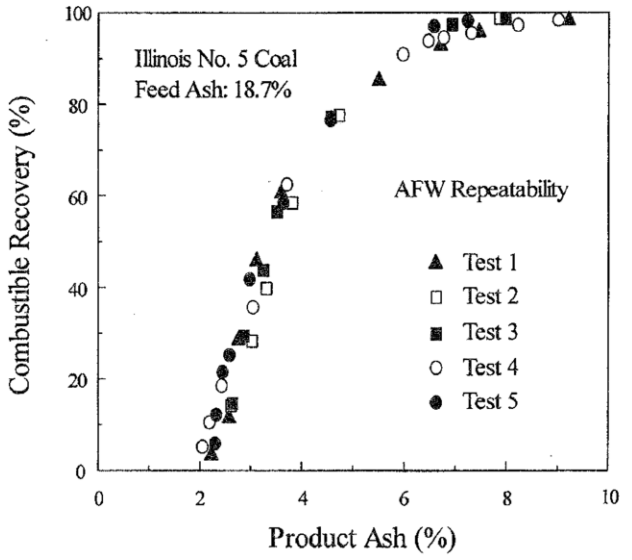

Figure 2.10: Separation performance data using the AFW Procedure (Mohanty et al., 1998a).

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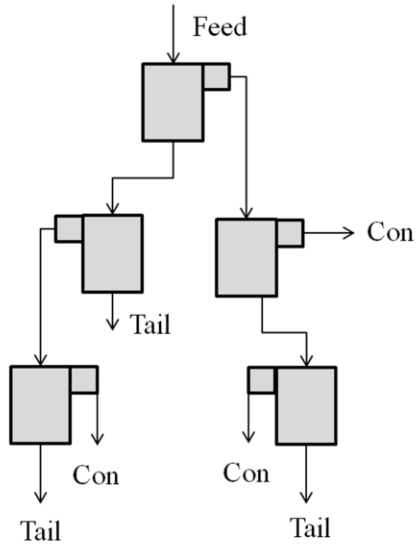

Figure 2.11: Schematic for a tree analysis (Mohanty et al., 1998b) after.

The tree analysis and release analysis were compared on the basis of product ash. The results are show in Figure 2.12. In the high recovery region of the graph the release analysis proved to the better of the two processes. The tree analysis was the superior of the two in the lower recovery regions. However, the presence of middling particles favors the release analysis since they are more effectively treated in that procedure. Figure 2.13 Shows the results of tests performed with -180 μm coal and micronized coal. By increasing the liberation of the ash particles the point at which the tree analysis becomes superior was increased from approximately 50% to 80% recovery. This indicates that the majority of the micronized sample is more effectively treated by the tree analysis (Mohanty et al., 1998b).

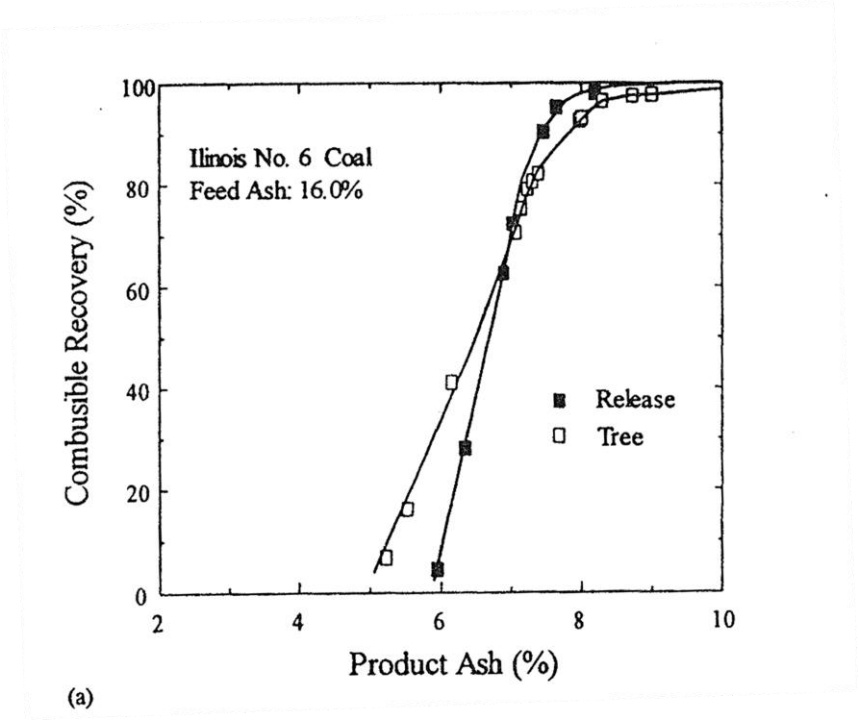

Figure 2.12: Comparison of the performance of the tree and release analyses (Mohanty et al., 1998b).

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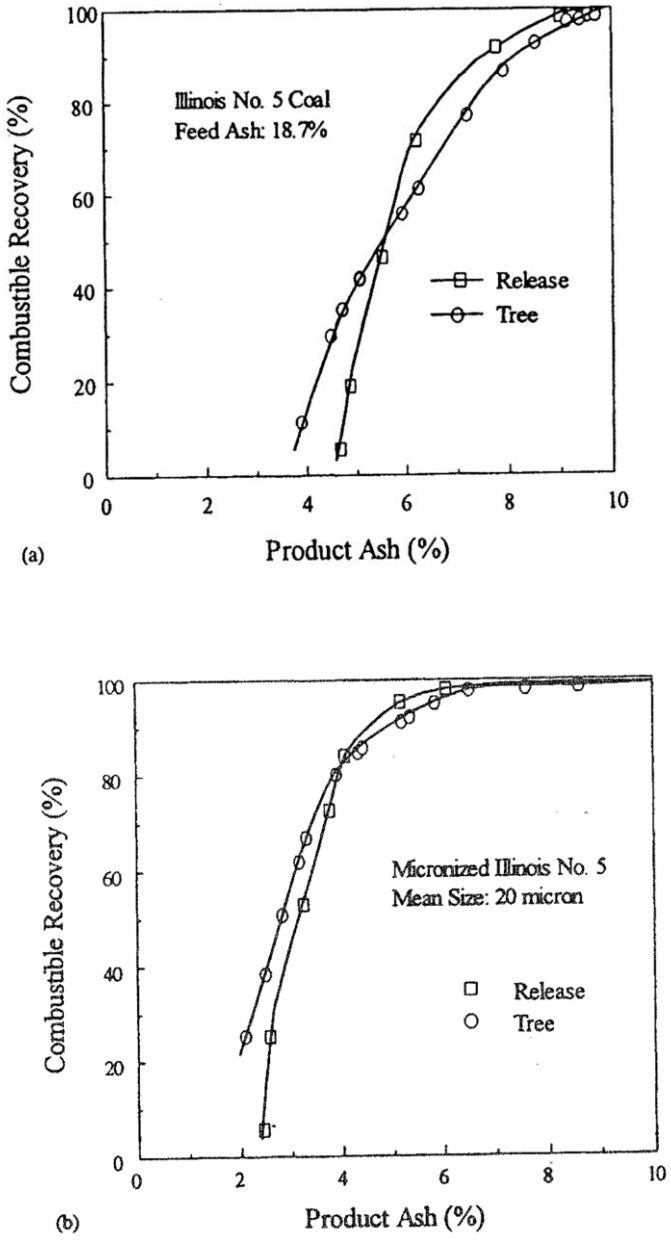

Figure 2.13: Comparison of tree and release analysis for (a) minus 180 µm material and (b) micronized material (Mohanty et al., 1998b).

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A recent study has shown that release analyses that use an initial step to remove entrained ash by refloating the concentrate before fractioning perform better than those that do not. The study also showed that while multiple tests performed by the same lab using the same technique are very repeatable, the industry as whole does not have a standardized procedure. The results of any analysis are very dependent on factors such as the technique used and the skill of the operator (Killmeyer et al., 2000).

2.5 Flotation Machines

Flotation machines are divided into four groups: mechanical, pneumatic, froth separators, and columns. Of these types, mechanical and column cells are the most popular in the United States and these two will be examined in more detail (Young 1982).

Mechanical cells use an impeller driven by a motor to agitate and disperse air into the pulp. The purpose of the agitation is to ensure that the solids stay in suspension in order to create a favorable bubble-particle collision environment. Figure 2.14 shows a cross section of a mechanically agitated flotation cell.

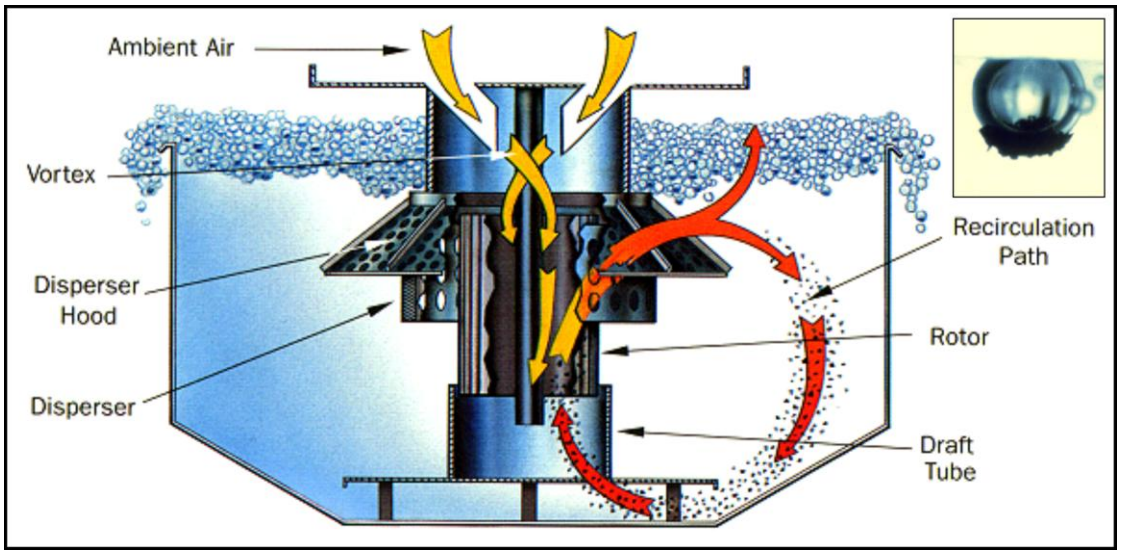


Figure 2.14: Mechanically agitated flotation cell (Courtesy of FLS Minerals).

Mechanical cells can be further divided into subcategories based on their pulp flow and aeration types. Cell to cell pulp flow machines use weirs between each impeller in a bank of cells, while an open flow machine operators without weirs. In coal flotation open flow machines are more common than cell to cell machines. Supercharged aeration machines use a blower to provide air to the impeller, while self-aerating machines use the depression created by the impeller motion to induce air into the slurry (Laskowski et al., 2007).

Common manufacturers of mechanical cells for coal flotation include WEMCO, Metso, Svedala, and Outokumpu. Commonly, machines with volumes up to 28 m^3 are used in coal flotation, although some manufacturers offer very large "Tank" cells. These cells are cylindrical in shape and use conventional impellers for agitation. Some tanks have been produced with volumes as large as 100 m^3 (Laskowski et al., 2007).

A distinguishing feature of column cells is the use of a counter current flow of slurry and air bubbles to create bubble-particle collisions. Also, column cells use wash water added through the froth bed to remove entrained pulp material (Young 1982). An example of the water flows in conventional and column cells can be seen in Figure 2.15. In a column cell that is being operated effectively, less than 1% of the feed water will report to the froth (Luttrell et al., 1999). In order to achieve this operating state, a sufficient amount of wash water must be added to ensure that the volume of feed water that would have reported to the froth has been replace by clarified water. In coal flotation this wash water requirement is usually 1.5 times the flow of water reporting to the product (Laskowski et al., 2007). It should also be noted that wash water alone will not completely eliminate entrainment. Column cells must be operated at a greater froth depth than conventional cells in order to promote optimal wash water distribution, resulting in the greatest cleaning action.

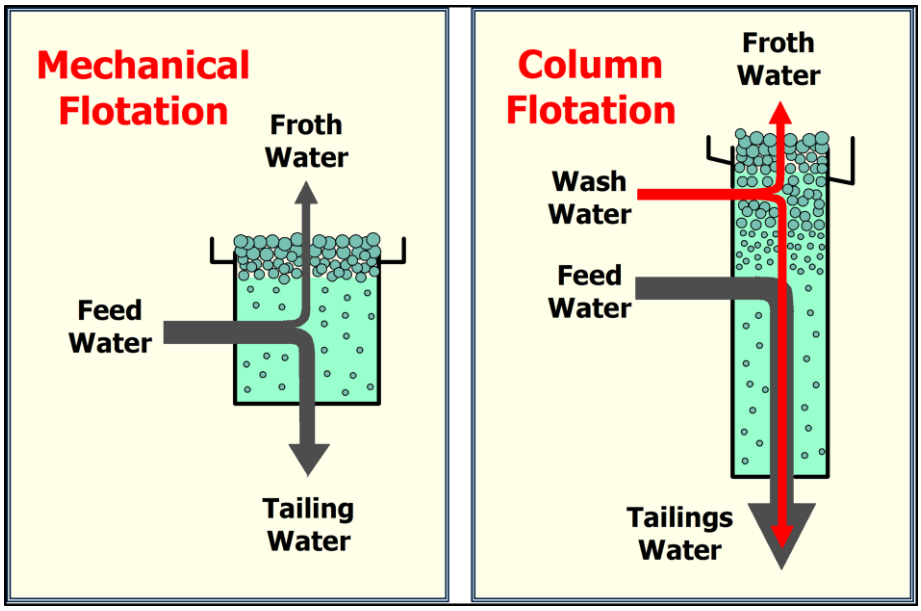


Figure 2.15: Water flows in conventional and column flotation (Laskowski et al., 2007). Reprinted from Froth Flotation: A Century of Innovation with permission from smenet.org.

Some of the common types of column cells used in the industry include the CoalPro, Jameson, and Microcel machines. It should be noted that the Jameson doesn't have the typical column geometry but often uses wash water to upgrade its froth, thus it is commonly included in this category. The most common difference amongst the various column designs is their air sparging system. These systems include porous bubblers, static mixers, and dynamic air injection, but ultimately each system's goal is to produce small bubbles of a uniform size distribution (Laskowski et al., 2007).

One of the major differences between mechanical and column flotation cells is the use of wash water. Column cells use wash water to upgrade the froth by removing entrained hydrophilic material. A study by Luttrell et al. (2000) investigated the use of wash water on mechanical flotation cells. At a combustible recovery of 90% the wash water addition resulted in an ash content of 8.2%, which was down from 9.6%, a difference of 1.4 points, for medium and deep froth depths. For a shallow froth depth the ash content was reduced from 9.6% to 8.8%. The

gains obtained from adding wash water were marginal when compared to the potential use of column flotation. A release analysis performed on the coal showed that at 90% combustible recovery a product ash of approximately 4% could be produced (Luttrell et al., 2000). It has been shown that column performance often approaches the results predicted by a release analysis, while mechanical flotation tends to fall short (Davis et al., 1992).

A byproduct of adding wash water to the mechanical cells was the stabilization of the froth. This resulted in more pulp water reporting to the froth which then required the addition of higher wash water rates than originally expected. Rates as high as 4.5 gallons per minute (GPM) per square foot (ft^2) of cell cross-sectional area could be expected. This value is much higher than the normal range used on columns, i.e., 3.0-3.5 GPM/ft^2. Adding wash water and running deeper froths results in a reduction of residence time for the flotation circuit. Most existing circuits in the coal industry are designed with residence times of 3.5-4.0 minutes when not using wash water. Calculations performed by the investigators showed that adding wash water to these circuits could drop the residence time below 1.0-1.5 minutes. Residence times this low would have pronounced negative impact on coal recovery (Luttrell et al., 2000).

Figure 2.16 shows a comparison of results obtained from a full scale column, a bank of mechanical cells, as well as a lab scale column cell. The concentrate ash was reduced by nearly 8 percentage points by using columns rather than conventional cells. This change was also met with an increase in combustible recovery of roughly 20 percentage points. The overall performance of the column nearly matched of the ultimate performance curve predicted by a release analysis (Davis et al., 1995). Other advantages offered by column flotation when compared to conventional flotation are listed below (Jena et al., 2008).

1. Better product without sacrificing recovery,
2. Reduction in the stages of operation needed,

3. Columns can handle a finer feed,
4. Columns require less collector,
5. Simpler to install and have no moving parts, and
6. Require less floor space.

However columns do have some drawbacks, such as mixing in the axis of the column, column height causing problems during installation, and plugging of the spargers (Jena et al., 2008).

The Microcel, a column flotation cell, developed by Dr. Yoon of the Virginia Polytechnic Institute and State University uses microbubble flotation in order to obtain high separation efficiencies in a single stage of flotation. For the most part the operation of the Microcel is very similar to that of most columns. Feed slurry enters just below the froth pulp interface, and the pulp then flows downward while encountering a countercurrent flow of air bubbles. Hydrophobic particles become attached to the bubbles as they collide. Once attached

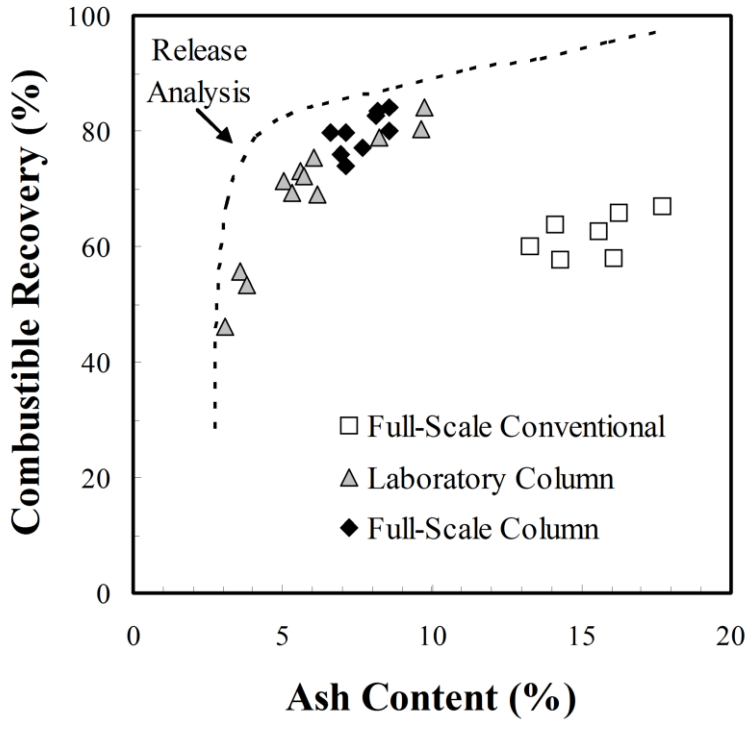


Figure 2.16: Comparison of column and conventional flotation cells (Davis et al., 1995). Reprinted from Froth Flotation: A Century of Innovation with permission from smenet.org.

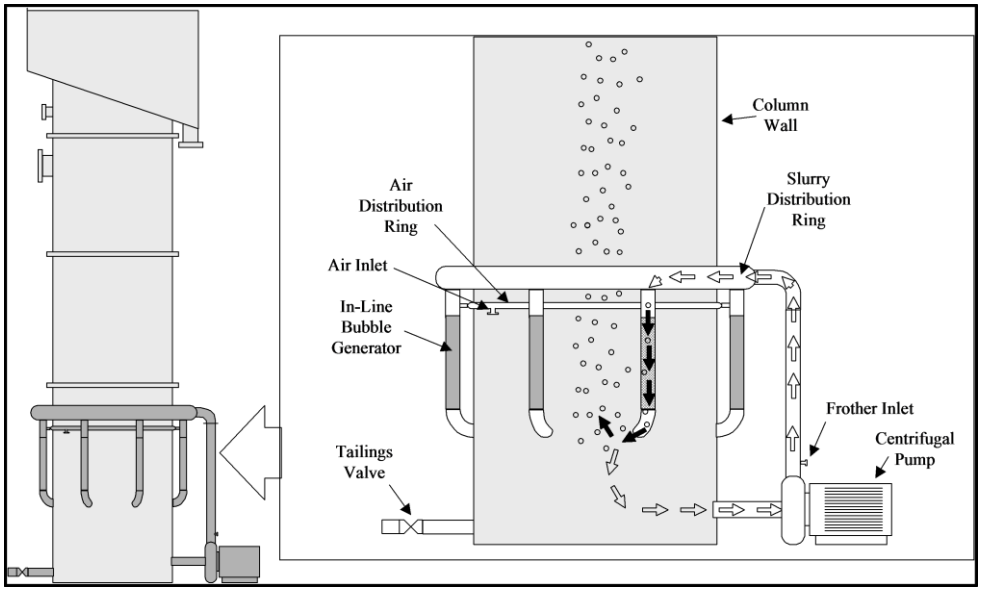


Figure 2.17: Schematic of the Microcel bubble generation system.

the bubble-particle aggregate rises to the froth phase where wash water is added to remove entrained hydrophilic material. The froth then spills into the launders and the product continues on to the next operation.

Where the Microcel differs is in the way it produces bubbles as seen in Figure 2.17. The sparging system used in the cell does not require fresh water, does not plug, and is externally mounted for easier maintenance. A portion of the refuse slurry is removed from the bottom of the column. Frother is then added to the slurry, and it is pumped through a static in-line mixer with the addition of compressed air. The mixer is used to create a high shear environment which produces microbubbles ranging from 0.1 – 0.4 mm in diameter. The slurry is then injected back into the column where bubbles begin their ascent to the froth phase. This recirculation also allows any misplaced coal particles a second chance to interact with air bubbles before exiting the system (Yoon et al., 1992).

The Jameson cell was developed by the University of Newcastle's Graeme Jameson in 1986 (Lynch et al., 2007). Like the Microcel, the Jameson cell is unique in the way it produces

air bubbles. A schematic of the Jameson flotation cell is presented in Figure 2.18. The cell consist of three major areas (Harbort et al., 1994).

1. The aeration and contacting zone, called the downcomer,
2. The tank's pulp area serves as a second recovery/bubble disengagement zone, and
3. The froth area of the tank serves as a cleaning zone.

The cell operates by pumping feed into the downcomer through an orifice plate. The feed travels down the pipe forming a high pressure jet as it goes. The vacuum created by the jet draws in air and then jet shears the air into bubbles with a mean diameter of 300 microns. This environment creates a high probability of bubble-particle contact and collection. The residence time of the downcomer can range from one to ten seconds. The slurry then exits the downcomer and is deposited into the tank. Mixing continues in the pulp area of the tank. Here contact continues to occur between the bubbles and particles. Residence time in this zone can last from two to five minutes. Once attached, the bubble-particle aggregates disengage from the pulp and rise to the

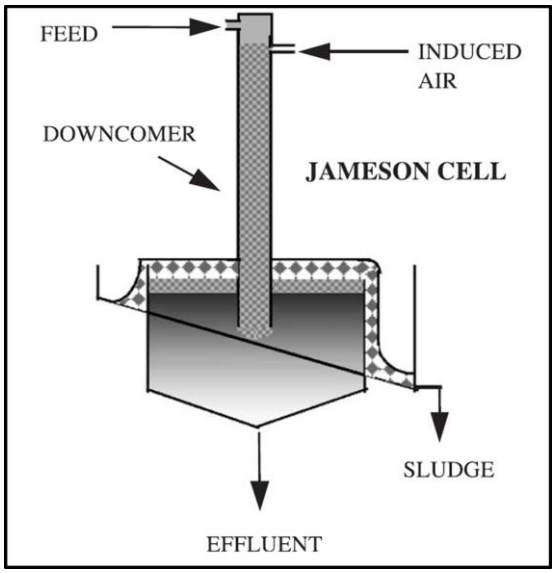


Figure 2.18: Schematic of the Jameson cell (Yan and Jameson 2004).

Reprinted from International Journal of Mineral Processing, Vol. 73, Yan and Jameson., Application of the Jameson Cell technology for algae and phosphorus removal from maturation ponds, 2004, with permission from Elsevier.

surface forming a froth zone. Wash water is added to the froth zone to enhance the product by removing entrained hydrophilic material (Lynch et al., 2007).

The WEMCO 1+1 machine, introduced in 1969, is a commonly used mechanical cell. The machine is called a 1+1 because the length of the rotor is equal to its diameter (Lynch et al., 2010). The machine shown in Figure 2.14 is a WEMCO 1+1 machine. This machine uses a vane type rotor with a star cross-section (Lynch et al., 2010). The rotor not only mixes the cell but also draws air into the cell. The rotor's mixing action helps to distribute the air and create a favorable environment for bubble-particle contact. Many of these cells use a false bottom and a draft tube to ensure the pulp recirculates and to minimize the sanding of particles. In order to reduce wear on the rotor, the WEMCI 1+1 has the rotor mounted above the bottom of the tank. This reduces or eliminates contact with oversized material. Wear life of 1+1 machine is two to four times that of a floor mounted rotor/stator machine (FLSmidth 2010). The stator on this machine contains holes shaped as ovals. Both the stator and the impeller consist of a steel frame coated with a wear resistant rubber or a similar material (Lynch et al., 2010).

The Eriez StackCell is a recent innovation in coal flotation technology. Seven characteristics were taken into account when designing the machine (Kohmuench et al., 2008).

1. Column-like performance,
2. Cell-to-cell circuit configuration,
3. Small cell volume,
4. High cell surface area,
5. Low energy input,
6. Low operation cost, and
7. Low capital cost.

A cell was produced, seen in Figure 2.19, using these requirements as a guideline. Like column cells, the StackCell utilizes wash water to reduce the amount of entrained material in the froth.

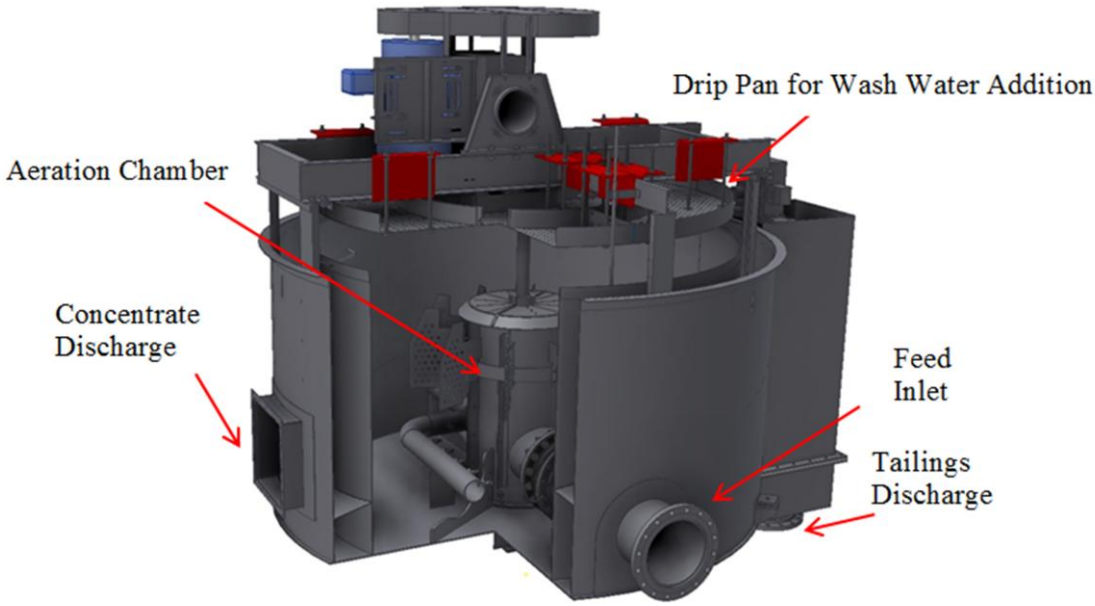


Figure 2.19: Schematic of Eriez StackCell (Provided by Eriez Magnetics).

The drip pan used on the cell forms a ring, and does not cover the interior of the cell. Since the entire froth product eventually moves to the launders it must also move through the wash water. This allows for less wash water to be used which reduces the impact on the retention time of the cell. The StackCell is designed to be used in series to reduce short circuiting and enhance cross sectional area. Three units in series with diameters of 3.4 meters and heights of 1.8 meters have the equivalent capacity of two 4.25 meter diameter column flotation cells, but the StackCell circuit is only 20% of the size of the column circuit (Kohmuench et al., 2008).

The StackCell takes a different approach to flotation than the normal column or mechanical cell. Instead of operating with a large quiescent zone like columns or keeping a tank mixed like a mechanical cell, the StackCell forces the bubbles and particles to contact in a small area. This is accomplished by using high concentrations of air bubbles and particles as well as applying significant energy into the bubble-particle contacting zone. Where most flotation machine's recovery is defined by [2.4], the StackCell's recovery is defined in [2.12], recovery in

a turbulent system, where C_b is the concentration of bubbles, C_p is the concentration of particles, and E is the specific energy imparted to the system (Kohmuench et al., 2008).

$$R \propto C_b C_p E \quad \textbf{[2.12]}$$

Exploiting [2.12], both the feed and air enter into an aeration chamber within the flotation cell. An impeller present in the chamber not only agitates the feed but also shears the air into extremely fine bubbles. This approach allows for the maximum particle concentration to be present during the formation of the bubbles. Also, the chamber operates with a very high air fraction to ensure that the concentration of bubbles is also maximized. Lastly, the agitator is designed in such a way as to impart as much energy into the system for the purpose of causing bubble-particle collision. Following the formation of bubble-particle aggregates, the slurry is discharged into the tank where it separates into a froth phase and a pulp phase. Wash water is then added to remove entrained hydrophilic material from the froth (Kohmuench et al., 2008).

2.6 Flow Through an Orifice Plate

The problem of determining the flow of liquid through an orifice plate is necessary in order to better understand the design criteria of wash water drip pans. Flow through an orifice requires that the flow fully cover the orifice; partial coverage would constitute a weir. The orifice cannot have sides with a length greater than two to three times the diameter of the hole, or else the orifice is considered a pipe. The depth of the standing liquid producing the jet from the orifice is called the head. If the jet is being expelled into the atmosphere it is considered a free discharge (Brater and King 1996).

An orifice is considered a sharp edged orifice if the inner edge of the orifice is made up of a sharp corner instead of a rounded edge. Jets from these types of orifice contract until they reach the point of vena contracta. At this point the pressure within the jet is assumed to be equal

to the pressure of the surrounding fluid, and all paths of the jet's elements are parallel. The area of the jet at the point of vena contracta is related to area of the orifice by [2.13]. In this equation, a_2 represents the area of the jet at the point of vena contracta, a is the area of the orifice, and C_c is the coefficient of contraction.

$$a_2 = C_c a \quad \textbf{[2.13]}$$

The contraction is caused by the flow paths around the hole. Any flow path that is not directly above the hole will have a velocity component perpendicular to the flow of the jet. This contraction can be minimized by rounding the inner edge of the hole or creating a roughness on the inner surface of the plate (Brater and King 1996).

[2.14] is obtained by using the Bernoulli equation between the point of vena contracta and another point in the fluid tank with the datum at the center of the orifice. The equation is then rearranged to solve for the velocity at the point of vena contracta, v_2.

$$v_2 = \sqrt{2g\left(\frac{p_1}{w} - \frac{p_2}{w} + \frac{{v_1}^2}{2g} - h_l\right)} \quad \textbf{[2.14]}$$

The variable p_2 can be neglected since it occurs at the point of vena contracta. At this point, the pressure in the jet is equal to that of the surrounding fluid. For discharge into atmosphere, that pressure is assumed to be zero. For a large tank, the velocity at a point inside the tank is very small and can be assumed as zero. The (p_1/w) term is replaced by the liquid head term h. Lastly, energy losses are rolled in the coefficient of velocity, C_v. These changes result in [2.15], where v_2 is the theoretical velocity of the liquid jet, where g is the acceleration due to gravity, and h is the liquid head (Brater and King 1996).

$$v_2 = C_v\sqrt{2gh} \quad \textbf{[2.15]}$$

[2.16] shows the calculation for flow rate of the jet, while [2.17] is obtained by substituting [2.13] and [2.15] into [2.16].

$$Q = a_2 \cdot v_2 \quad \textbf{[2.16]}$$

$$Q = C_c \cdot a \cdot C_v\sqrt{2gh} \quad \textbf{[2.17]}$$

This resulting equation can be further simplified to obtain [2.18], where C_d is the coefficient of discharge. This equation is the generalized equation for flow through an orifice plate (Brater and King 1996).

$$Q = C_d \cdot a\sqrt{2gh} \quad \textbf{[2.18]}$$

3.0 FIELD TESTING

3.1 Introduction

Two phases of field testing were performed to evaluate the performance capabilities of the StackCell technology. The first phase involved a long term monitoring test at a coal preparation plant located in eastern Kentucky. The second phase of the work involved a characterization study performed at a plant site located in southern West Virginia. At each site, flotation release analysis tests were conducted on all of the flotation products to determine the amount of floatable and non-floatable material present in each sample.

3.2 Experimental

3.2.1 Testing Sites

Representative samples were taken from two different coal preparation facilities. The first plant (Plant A), which was located in eastern Kentucky, has an annual capacity of approximately 2 million clean tons. This plant cleans coals from underground mines operating in the Amburgey, Elkhorn and Hazard seams. A high BTU and high sulfur coal is produced at this site, which is used primarily in the utilities industry. The flotation circuit at the plant consisted of two column flotation cells. It was common for the flotation circuit to become over loaded, depending on the blend of coal being run in the plant. At this site the StackCell technology was installed ahead of the column cells to act as a scalper for improving the overall coal recovery.

The second plant (Plant B), which is located in southern West Virginia, has an annual clean coal output of approximately 1 million tons. Coal cleaned in this plant comes from underground mines operating in the Glen Alum and Douglas seams. The product from this plant is generally a medium-volatile metallurgical grade coal used in the domestic market.

3.2.2 Sampling Procedures

Samples of the flotation feed, concentrate, and tailings were collected at both plant locations. Long term weekly samples were collected from Plant A to evaluate the performance over time of the newly installed flotation system. The information collected along with the samples is shown in Table 3.1, while Table 3.2 shows the collection dates for every sample tested. Eight samples were taken at this site in early 2011 to help optimize the performance of the StackCell and obtain a baseline for performance. Later, two additional samples were taken in August of 2011 to provide a comparison to the baseline data. No specific operating conditions were requested for these samples.

All of the plant samples were collected by the plant workers during their routine sampling programs. The samples were taken and placed into standard five- or two-gallon buckets, depending on the volume of sample collected. These buckets were then secured with non-spill lids which were duct taped down before transport. Once prepared the buckets were either shipped to Virginia Tech or picked up and brought back to Virginia Tech. The samples were then left unopened in the Minerals Research Laboratory until they were tested.

The Plant B samples were obtained by a team from Virginia Tech. These samples were

Table 3.1: Parameters reported along with the weekly samples at Plant A.

Parameter	Units
Coal Blend	---
Frother Addition Rate	ml/min
Collector Addition Rate	ml/min
Blower Motor	Hz
Agitator Motor	Hz
Plant Feed Rate	tph
Wash Water Rate	gpm
Air Flow Rate	scfm
Froth Depth	in.

Table 3.2: Weekly sample test dates at Plant A.

Dates Tested
11 January 2011
19 January 2011
01 February 2011
10 February 2011
16 February 2011
8 March 2011
14 March 2011
24 March 2011
11 August 2011
30 August 2011

taken over a wide sweep of operating conditions. A list of the operating conditions sampled is provided in Table 3.3. Chemical additions during the tests were held constant at 160 ml/min of frother while no collector was added. These samples were collected using five quart buckets for the feed and tailings samples and two-and-a-half quart buckets for the concentrate samples. Samples were collected by passing the buckets under the appropriate stream several times until the bucket had reached capacity. The lid for each sample was then securely placed on the bucket using duct tape. Fifteen minutes were allotted for the cell to come to a steady-state operating condition following the change of any operating condition. This period of time represented at least three residence times for the cell, which as a rule-of-thumb is normally sufficient for a flotation system to equilibrate at a new operating condition. Most of the operating conditions were monitored in the control room of the plant, but some were directly monitored during testing. A water bottle and tape measure was used to determine the froth depth before each test, while a gauge attached to the wash water feed pipe displayed the wash water flow rate. Once again, the samples were brought back to the Minerals Research Laboratory at Virginia Tech where they were left sealed.

Table 3.3: Operating conditions sampled at Plant B.

Test Number	Agitator Motor (Hz)	Froth Level (in.)	Wash Water Rate (gpm)
1	45	30	360
2	45	24	360
3	45	18	360
4	45	12	360
5	0	24	360
6	30	24	360
7	45	24	360
8	60	24	360
9	45	24	0
10	45	24	260
11	45	24	345
12	45	24	400

3.2.3 Sample Processing

Flotation release analyses were performed on samples from both plant sites. This was done in order to identify the amount of floatable and non-floatable material present in the concentrate and tails of each sample. The samples were then screened to obtain particle size distributions. Lastly, ash analyses were performed on the resulting size fractions. It should be noted that a release analysis was not performed on the feed for a set of samples. Instead a feed was reconstituted from the product samples and then compared to the actual feed sample to ensure that a good mass balance was maintained.

To begin, a sample date (or identification number) was chosen and the feed, concentrate, and tailings samples were set aside for the test in question. After opening the sample, it was placed in a four-liter flotation cell. If possible, the entire sample was used. In cases were too much sample was collected, it was split into representative lots using a rotary slurry splitter (see Figure 3.1). The sample was then diluted with tap water to fill the four-liter flotation cell.

Figure 3.1: Slurry splitter used during sample processing

A Denver flotation machine was used to perform the release analyses. This machine is shown in Figure 3.2. Approximately 60 microliters of collector was added to the Plant A samples, while no collector was added to the Plant B samples. The sample was then allowed to condition for approximately five minutes. A few drops of frother were added to the cell before opening the air valve. As the concentrate formed, it was scraped into pans and set aside. The rotor speed and aeration rate were adjusted as necessary to obtain a stable and steady froth. Each sample was floated until exhaustion, at which point the flotation machine was cleaned and that tailings from the flotation test were placed into a five-gallon bucket. The concentrate collected during the test was poured back into the flotation cell and diluted as necessary to fill the cell. The sample was then placed back under the flotation machine and a small amount of collector was

Figure 3.2: Denver flotation machine used to perform release analyses.

added, approximately 10 microliters for the Plant A samples, and the sample was allowed to condition for five minutes. After conditioning, a few drops of frother were added to the flotation cell before the air valve was opened.

The concentrate was again scraped into pans until the froth was exhausted. The tailings sample was then placed with the previous flotation stage's tailings and the concentrate was again placed back into the flotation cell. This process was repeated until the flotation tailings were

visibly clear. This indicated that the majority of the hydrophilic material had been removed, and only hydrophobic material remained in the concentrate. Typically, four stages of flotation were necessary for most samples to reach a good separation bewtween the hyrophobic and hydrophilic material.

The concentrate and tailings from the flotation process were wet-screened along with the feed for the appropriate test. In total, five sets of material were screened for a given set of samples. The five sample are the feed (Feed), floated froth concentrate (Con Float), nonfloating froth concentrate (Con Sink), floatable tails (Tail Float), and nonfloating tails (Tail Sink). The samples from the two plants were screened at different sizes. Table 3.4 shows the screen sizes used for the samples from both locations. The resulting size classes from the screening process were then filtered to remove standing water and placed in an oven to dry overnight. The dried samples were weighed and recorded using a Denver Instruments model P-4002 scale (see Figure 3.3). The material was then placed in sample bags for storage.

Ash analysis was the final step in the laboratory processing of the material. A LECO model 601-400-600 ash analyzer was used for ash analysis (see Figure 3.4). A small amount of material was removed from the bagged samples, less than one gram, and loaded into the ash analyzer. The ash analysis was performed in two steps. First, nitrogen was used to remove the

Table 3.4: List of Screens used during sample processing.

Plant A	Plant B
48	65
100	100
200*	325
325	---
***** Screen size eliminated in later tests	
(All sizes are Tyler Mesh)	

Figure 3.3: Denver Instrument scale used during testing.

inherent moisture in the coal. Next, oxygen was used to burn of the carbon, leaving the ash material behind. The dry ash values from the process were used in the subsequent calculations.

3.2.4 Data Processing

The dry ash values for a set of samples were fed into an Excel spreadsheet where they were used to determine the overall ash of the concentrate and tailings, as well as to reconstitute the feed ash. The spreadsheet was used to calculate the percent weight and cumulative percent weight for each size class, as well as the percent ash and cumulative percent ash for each size class. An example of this spreadsheet is provided in Table 3.5 and Table 3.6. The raw data for the Plant A - 8/30/11 sample is presented in Table 3.5, while the reconstituted data is presented in Table 3.6. Figure 3.5 is a visual representation of the data. It shows how breaking down the concentrate and tailings samples into floatable and non-floatable allows the user to see if there is material present in the samples that is negatively influencing the overall quality of the product.

Figure 3.4: LECO ash analyzer used during sample processing.

The remaining raw and reconstituted data for the Plant A samples can be found in Appendix A, while the raw data and reconstituted data for the Plant B samples can be found in Appendix B.

Most of the values calculated in the spreadsheet were simple relationships. The dry weight was simply the amount of material in the given size class. The cumulative weight was the addition of each size class's dry weight as particle size decreases. The weight percent was calculated by dividing the weight in the given size class by the total weight of the given sample's size classes. Cumulative weight percent was the addition of the each weight percent as particle size decreases. Ash percent was the dry ash value output from the ash analysis. Lastly, the cumulative percent ash was calculated as shown in [3.1], where W is the dry weight of the size class and A is ash percent for the size class.

$$Cum.\,Ash\,\% = \frac{\sum_{i=1}^{n} W_i A_i}{\sum_{i=1}^{n} W_i} \qquad \textbf{[3.1]}$$

The yield and combustible recovery values were calculated using [3.2] and [3.3]. Table 3.7 contains a list showing what each variable means with respect to which part of the sample, feed, concentrate, or tail, was being examined.

$$Yield = \frac{f - t}{c - t} \quad \textbf{[3.2]}$$

$$Rec. = Y\left(\frac{1 - \frac{c}{100}}{1 - \frac{f}{100}}\right) \quad \textbf{[3.3]}$$

Ash recovery for the cell was calculated using [3.4], where *c* was the reconstituted concentrate ash, *f* was the feed ash, and *Y* was the yield.

$$Ash\ Rec. = Y\left(\frac{\frac{c}{100}}{\frac{f}{100}}\right) \quad \textbf{[3.4]}$$

The ash recovery was then used to calculate the separation efficiency of the cell as seen in [3.5]. The separation efficiency is calculated by simply subtracting the ash recovery from the carbon recovery.

$$Sep.Eff. = Carbon\ Rec. - Ash\ Rec. \quad \textbf{[3.5]}$$

Table 3.5: Raw Data for Plant A 8/30/11.

Test Conditions

Location:	Plant A	Date:	8/30/2011
Frother:	944	Dosage:	225 ml/min
Collector:	Diesel	Dosage:	500 ml/min
Blower:	24 Hz		
Agitator:	44 Hz		
Plant Feed:	900 tph		
Wash Water:	450 gal/min		
Air Rate:	568 scfm		
Froth Depth:	22 in.		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.36	11.39	5.03	5.03	2.45	2.45	6.90	6.90
48 x 100	6.17	26.28	20.11	25.14	9.80	12.25	11.99	10.97
100 x 325	6.24	51.83	45.59	70.73	22.21	34.45	26.29	20.85
-325	6.16	140.72	134.56	205.29	65.55	100.00	53.29	42.11
		Total	205.29		100.00		42.11	

Total Yield (%)	**21.20**	**Cons Yield (%)**	**92.70**
Total Recovery (%)	**33.35**	**Cons Recovery (%)**	**97.52**
Ash Recovery (%)	**4.50**	**Tails Yield (%)**	**44.27**
Sep. Eff.	**28.85**	**Tails Recovery (%)**	**80.86**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.30	30.25	23.95	23.95	6.91	6.91	3.65	3.65
48 x 100	6.26	84.03	77.77	101.72	22.43	29.34	4.09	3.99
100 x 325	6.28	121.55	115.27	216.99	33.24	62.58	4.15	4.07
-325	6.26	136.00	129.74	346.73	37.42	100.00	4.45	4.21
		Total	346.73		100.00		4.21	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
+100	2.03	2.28	0.25	0.25	0.92	0.92	20.56	20.56
100 x 325	6.31	7.02	0.71	0.96	2.60	3.52	63.71	52.47
-325	6.15	32.48	26.33	27.29	96.48	100.00	69.62	69.02
		Total	27.29		100.00		69.02	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.28	8.67	2.39	2.39	3.37	3.37	7.77	7.77
48 x 100	6.27	17.56	11.29	13.68	15.93	19.30	11.32	10.70
100 x 325	6.21	29.63	23.42	37.10	33.04	52.33	13.28	12.33
-325	6.29	40.08	33.79	70.89	47.67	100.00	8.64	10.57
		Total	70.89		100.00		10.57	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.33	6.68	0.35	0.35	0.39	0.39	66.15	66.15
48 x 100	6.22	6.93	0.71	1.06	0.80	1.19	79.87	75.34
100 x 325	6.19	12.60	6.41	7.47	7.18	8.37	81.99	81.05
-325	6.21	87.97	81.76	89.23	91.63	100.00	83.38	83.18
		Total	89.23		100.00		83.18	

Table 3.6: Reconstituted value for Plant A 8/30/11.

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	2.71	2.71	2.71	2.71	9.42	9.42
48 x 100	10.33	13.03	10.33	13.03	10.57	10.33
100 x 325	21.25	34.29	21.25	34.29	20.77	16.80
-325	65.71	100.00	65.71	100.00	55.32	42.11
Total	100.00		100.00		42.11	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	23.95	23.95	6.40	6.40	3.65	3.65
48 x 100	78.02	101.97	20.86	27.26	4.14	4.03
100 x 325	115.98	217.95	31.01	58.27	4.51	4.29
-325	156.07	374.02	41.73	100.00	15.44	8.94
Total	374.02		100.00		8.94	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	2.74	2.74	1.71	1.71	15.23	15.23
48 x 100	12.00	14.74	7.49	9.21	15.38	15.35
100 x 325	29.83	44.57	18.63	27.84	28.04	23.85
-325	115.55	160.12	72.16	100.00	61.52	51.04
Total	160.12		100.00		51.04	

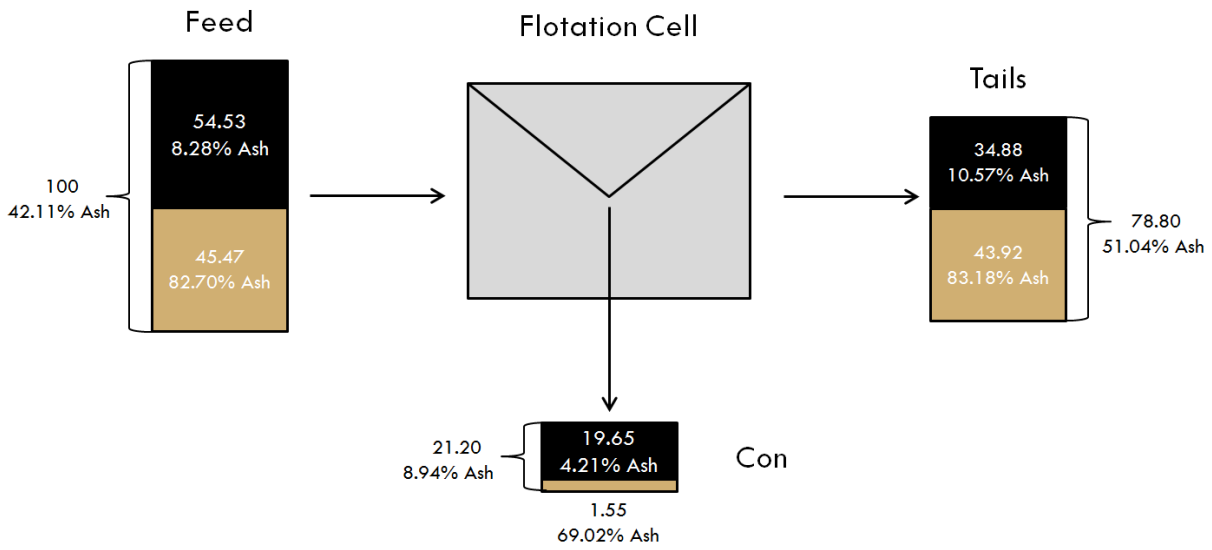


Figure 3.5: Carbon partitioning of the Plant A – 8/30/11 sample.

The reconstituted concentrate and tails were calculated in a similar manner as previously discussed. However, obtaining the reconstituted feed was more complex. [3.6] was used to calculate the dry weight for each size class, where W_{rc} and W_{rt} are the weights of the reconstituted concentrate and tails, respectively, for the given size class. The variables W_{rct} and W_{tct} represent the total weights of the reconstituted concentrate and tails, respectively. Lastly, the yield was represented by the variable Y.

$$Recon.\ Feed\ Weight = \left(\left(\frac{W_{rc}}{W_{trc}} \cdot \frac{Y}{100}\right) + \left(\frac{W_{rt}}{W_{trt}} \cdot \left(1 - \frac{Y}{100}\right)\right)\right) 100 \quad \textbf{[3.6]}$$

The ash percent of a given size class in the reconstituted feed was calculated using [3.7]. The variables A_{rc} and A_{rt} represent the percent ash of the reconstituted concentrate and tails for the given size class. The weight of material in the given size class was represented by the variable W_{rf}. All other variables are as previously defined.

$$Recon.\ Feed\ Ash = \left(\left(\frac{W_{rc}}{W_{trc}} \cdot \frac{Y}{100} \cdot A_{rc}\right) + \left(\frac{W_{rt}}{W_{trt}} \cdot \left(1 - \frac{Y}{100}\right) \cdot A_{rt}\right)\right) \cdot \frac{100}{W_{rf}} \quad \textbf{[3.7]}$$

Lastly, the amount of dilution washes was calculated for each of the Plant B samples. To accomplish this, several relationships were used. [3.8] shows the calculation for percent solids where W_s is the weight of the solids and W_w is the weight of the water.

Table 3.7: Defining variables used to calculate yield and recovery.

Variable	Feed	Concentrate	Tailing
f	Feed % Ash	Recon. Con % Ash	Recon Tail % Ash
c	Recon. Con. % Ash	Con Float % Ash	Tail Float % Ash
t	Recon. Tail % Ash	Con Sink % Ash	Tail Sink % Ash

$$\% \, Solids = \frac{W_s}{W_s + W_w} \quad \textbf{[3.8]}$$

[3.9] shows the mass balance equation for a flotation cell where W_f is the weight of the feed, W_c is the weight of the concentrate, and W_t is the weight of the tailings.

$$W_f = W_c + W_t \quad \textbf{[3.9]}$$

The relationship shown in [3.10] was obtained by dividing one of the terms shown in [3.9] by their respective percent solids. The W_{fw} term in this equation represents the amount of water present in the feed, while the 100 shown in [3.10] represents 100 units of feed. The correct amount of material was used for the concentrate and tailings based on this 100 units of feed. This can be easily calculated using the yield of the cell.

$$\frac{W_f}{\%S_f} = W_f + W_{fw} = 100 + W_{fw} \quad \textbf{[3.10]}$$

[3.11] shows the new mass balance around the flotation cell, where the W_{ww} term has been added. This term represents the amount of wash water added to the system.

$$W_{fs} + W_{fw} = W_{cs} + W_{cw} + W_{ts} + W_{tw} + W_{ww} \quad \textbf{[3.11]}$$

By substituting in the appropriate values the amount of wash water added can be found, and then used to calculate the dilution washes as shown in [3.12].

$$Dilution \; Washes = \frac{W_{ww}}{W_{cw}} \quad \textbf{[3.12]}$$

3.3 Results and Discussion

3.3.1 Long Term Monitoring

Table 3.8 shows a summary of the concentrate data for the first sample obtained from Plant A, taken on January 11, 2011. Analyzing the release analysis data from this test shows a significant amount of hydrophilic material reported to the froth concentrate. This hydrophilic material was primarily located in the minus 325 mesh size class. Roughly 13% of the total sample weight is non-floatable material less than 325 mesh in size, and this material is approximately 87% ash. This result lead to an investigation of the wash water system present at Plant A. Figure 3.6 shows the original wash water "ring" system installed at Plant B. This system was very similar to the one installed at Plant A. The figure illustrates the inability of the ring distributor to provide adequate and even coverage of the froth. Also of note is the way the water is applied to the surface of the froth. The flow of water from the wash rings acts more like a jet, which can kill the froth, rather than like a gentle rain that distributes the water. Moreover, this turbulence could lead to some unwanted froth mixing, which would reduce the effectiveness of the wash water and result in a worse product. Lastly, the wash rings plug easily. With so few

Table 3.8: Summary of concentrate data for the January 11, 2011 sample.

	Total Concentrate		Floatable		Non-floatable	
Size Class (Mesh)	**Weight (%)**	**Ash (%)**	**Weight (% of Total)**	**Ash (%)**	**Weight (% of Total)**	**Ash (%)**
+48	14.18	4.39	13.02	3.51	1.16	14.25
48 x 100	25.97	4.57	25.47	3.94	0.50	36.75
100 x 200	20.76	6.87	20.20	5.26	0.57	64.35
200 x 325	10.13	10.62	9.49	6.15	0.64	77.03
− 325	28.96	43.39	15.97	8.01	12.99	86.90
Total	100.00	16.88	84.14	5.21	15.86	78.79

holes per unit surface area of the cell, a few plugged holes greatly impact the performance of the wash water system. Thus, maintenance of the wash rings is crucial, but this maintenance can also be difficult and time consuming for the plant personnel.

After recognizing the poor performance of the wash rings, work was performed to ensure proper coverage and flow rate for the Plant A cell. As a result of this effort, an improvement in performance from the first sample was observed (Figure 3.7). An immediate drop occurs in concentrate ash and the amount of hydrophilic material present in the concentrate. The data then fluctuates around approximately 9% concentrate ash and 5% total weight of minus 325 mesh

Figure 3.6: Poor coverage of wash rings at Plant B.

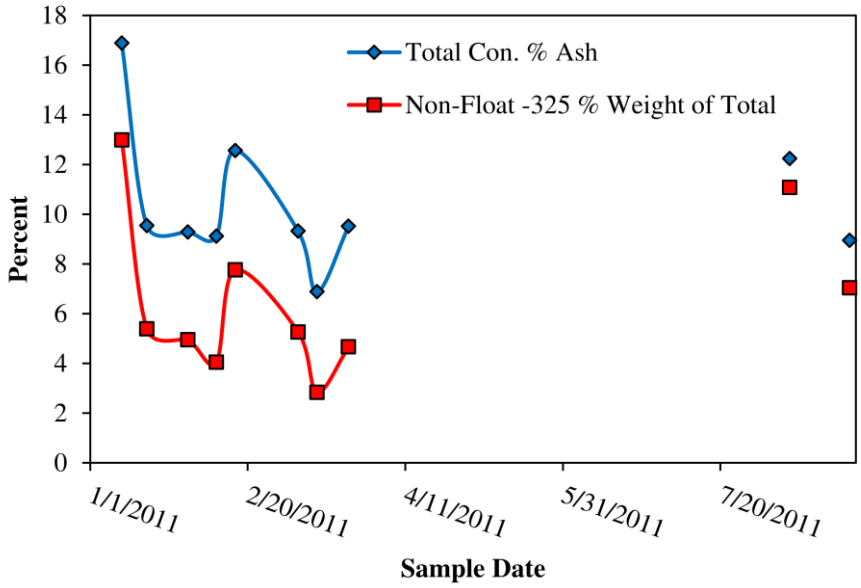


Figure 3.7: Concentrate Ash and % Weight of minus 325 mesh non-floatable material.

non- floatable material. Table 3.9 provides a numerical summary of the data shown in Figure 3.7.

A summary of the concentrate quality data for the March 24th data set is shown in Table 3.10. The total amount of non-floatable material present in the concentrate was reduced approximately ten percentage points from 15.86% on January 11th to 5.71% on March 24th. The

Table 3.9: Summary of total con. ash and non-floatable minus 325 mesh material for the Plant A Samples.

Sample #	Total Con Ash (%)	Non-Float - 325 Weight (% of Total Con)
1/11/2011	16.88	12.99
1/19/2011	9.54	5.38
2/1/2011	9.29	4.94
2/10/2011	9.11	4.05
2/16/2011	12.56	7.76
3/8/2011	9.32	5.26
3/14/2011	6.88	2.84
3/24/2011	9.51	4.66
8/11/2011	12.24	11.08
8/30/2011	8.94	7.04

Table 3.10: Summary of concentrate data for the March 24, 2011 sample.

	Total Concentrate		Floatable		Non-floatable	
Size Class (Mesh)	**Weight (%)**	**Ash (%)**	**Weight (% of Total)**	**Ash (%)**	**Weight (% of Total)**	**Ash (%)**
+48	8.02	6.16	7.31	4.69	0.71	21.26
48 x 100	19.67	5.91	19.58	5.67	0.09	59.36
100 x 325	36.42	5.83	36.18	5.35	0.25	76.19
minus 325	35.88	15.97	31.22	5.48	4.66	86.22
Total	100.00	9.51	94.29	5.41	5.71	77.25

concentrate ash was similarly reduced from 16.88% on January 11th to 9.51% on March 24th, a drop of approximately seven percentage points.

The two tests taken later in the year show a jump in ash, although it is not as high as the original peak obtained from the first sample. Interestingly, both samples contain a much higher percent of minus 325 mesh non-floatable material than the earlier samples. This could be due to the later samples being a different blend of coal than the earlier samples. The first eight samples were all taken when the plant was running coal from one mine, while the two later samples were taken while the plant was running a blend of coals from two mines.

It should also be noted that increasing the rate of wash water to the cell had little to no effect on the quality of the floated product. Samples from January 11th to March 8th had wash water rates ranging from 274 to 330 GPM, with an average of approximately 311 GPM. Samples from March 14th forward have higher wash water flow rates ranging from 450 to 530 GPM, with an average of 495 GPM. Generally, it is accepted that higher wash water flow rates positively impact the product quality. Figure 3.7 shows that, for the same blend of coal, the March 14th point provided the lowest overall ash of the samples tested, but the following week saw the ash rise back to up to the same level obtained with the lower wash water rates.

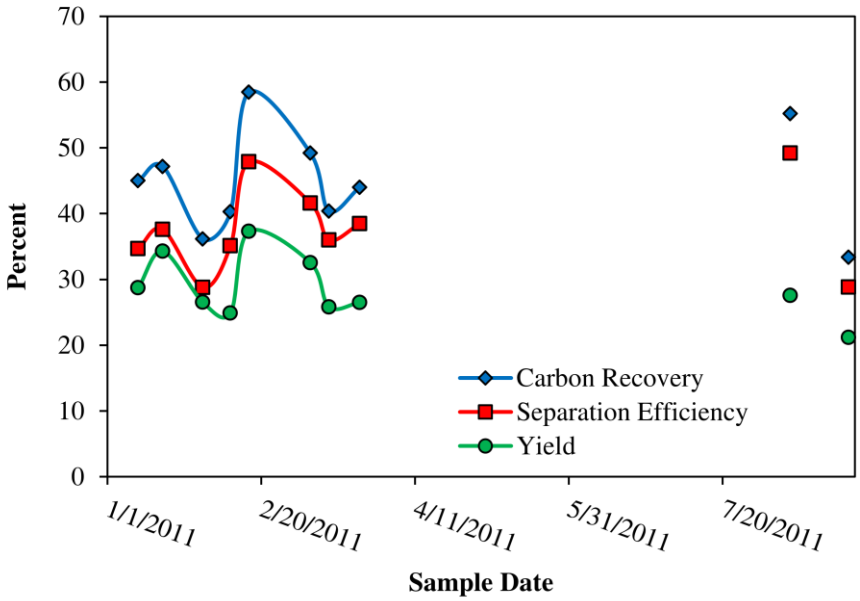


Figure 3.8: Carbon recovery, separation efficiency, and yield for the Plant A data.

Figure 3.8 shows the clean coal yield, combustible recovery, and separation efficiency for the Plant A samples. The numerical data is summarized in Table 3.11 for reference. The data shows fluctuations in all three parameters. Recovery ranged from a low value of 33.35% on the August 30th sample to a high value of 58.47% on the February 16th sample, and has an average value of 44.92%. The average separation efficiency for the cell was 37.82%, with a high value of 49.20% occurring on August 11th and a low value of 28.80% occurring on February 1st. The maximum yield value of 37.32% occurred on February 16^{th,} while the minimum value of 21.20% occurred on August 30th. The average yield of the cell was 28.54%.

Examining combustible recovery and separation efficiency information shows the cells improvement in rejecting ash as time progressed. The gap between the recovery line and the separation efficiency line narrows, and the gap becomes fairly consistent starting with the March 14th sample. This narrowing indicates a reduction in ash recovery. The ash recovery values for these last points ranged from 4.39% to 6.01%., whereas the earlier samples ranged from 5.1% to

Table 3.11: Combustible recovery, separation efficiency, and yield for Plant A.

Sample	Carbon Rec. (%)	Ash Rec (%).	Sep. Eff. (%)	Yield (%)
1/11/2011	45.01	10.32	34.70	28.72
1/19/2011	47.17	9.56	37.62	34.30
2/1/2011	36.16	7.37	28.80	26.53
2/10/2011	40.29	5.17	35.12	24.89
2/16/2011	58.47	10.61	47.86	37.32
3/8/2011	49.19	7.58	41.61	32.55
3/14/2011	40.37	4.39	35.97	25.81
3/24/2011	44.00	5.54	38.46	26.50
8/11/2011	55.21	6.01	49.20	27.58
8/30/2011	33.35	4.50	28.85	21.20

10.6%. It also important to note there is roughly a five month separation between the March and August samples, indicating the cell performance stabilized during this period with respect to ash recovery.

3.3.2 Modification of the Wash Water Distributor

One of the significant problems identified during the test program was the poor overall performance of the wash water distribution system. A decision was made to replace the original wash water ring distributor with a new drip pan system due to the difficulties in trying to maintain adequate coverage using a wash water ring system. Drip pans provide a much larger number of holes per unit area. Thus, if one hole plugs, it does not greatly reduce the overall coverage of the cell. Also, drip pans are much easier to clean and maintain than wash rings, which is a substantial advantage for the plant personnel that have to operate and maintain the flotation equipment. Figure 3.9 shows the new drip pan installed at Plant B. This photograph easily demonstrates the superior coverage obtained by using a drip pan design over the original wash water ring design.

Figure 3.9: Drip pan installed at Plant B.

3.3.3 Characterization Testing & Modification to the Air-Slurry Distributor

Significant surface turbulence was another issue discovered with early testing at Plant A. Very large slugs of undispersed gas appeared to be making it to the surface of the froth. Figure 3.10 shows the initial slurry distribution design used on the Plant A unit. This design utilizes pipes connected to the top of the mixing chamber to distribute the air-slurry mixture into the tank where it separates into the froth and pulp zones.

After investigating the issue it was determined that the surface turbulence was connected to the slurry distribution design. Large air bubbles were forming inside the mixing chamber near the exit point. These pockets of gas would not exit the chamber until they had formed large slugs. Then, when sufficiently large, some portion of the gas would exit with the slurry and travel through the pipes down into the pulp. The slugs would then report to the froth zone and burst, thereby causing the observed surface turbulence and adversely impacting the ability of the wash water to remove entrained high-ash clay.

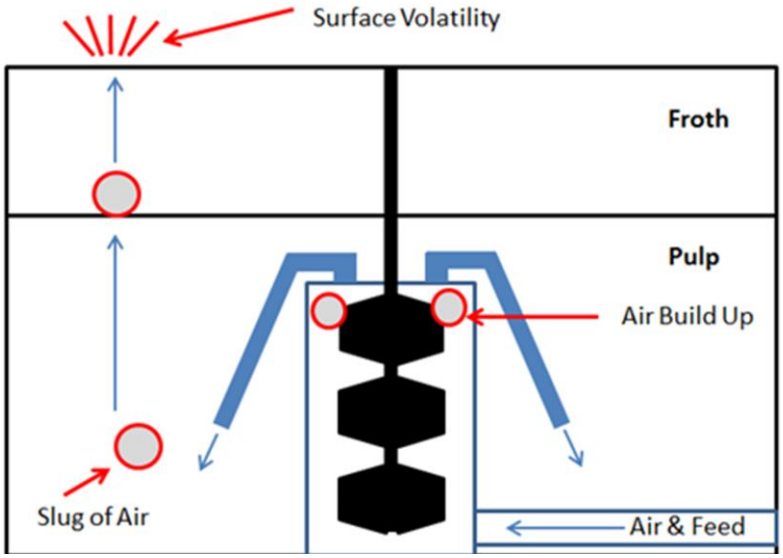


Figure 3.10: Initial Plant A slurry distribution design.

To alleviate the surface turbulence, the slurry distribution design was altered by the manufacturer. Figure 3.11 shows the altered slurry distribution design. As shown, the new design incorporated a spinning distributor plate in place of the distribution pipes. This plate sits at the top of the mixing chamber and throws the slurry into the tank. The gap between the disc and mixing chamber could be easily adjusted to simultaneously provide a small amount of back-pressure needed to obtain good distribution without allowing air pockets to accumulate at the top of the mixing chamber. This new design was installed at Plant B and was in place during all of the test work conducted during that phase of the project.

As stated earlier, a total of 12 tests were performed on the Plant B flotation unit. Table 3.3 provides a complete listing of the testing conditions. Table 3.12, Table 3.13, and Table 3.14 each contain a summary of the results for the each parameter sweep. Table 3.12 contains the froth depth data, while Table 3.13 contains the agitator motor speed data, and Table 3.14 contains the wash water rate data. These tables contain information on total concentrate ash,

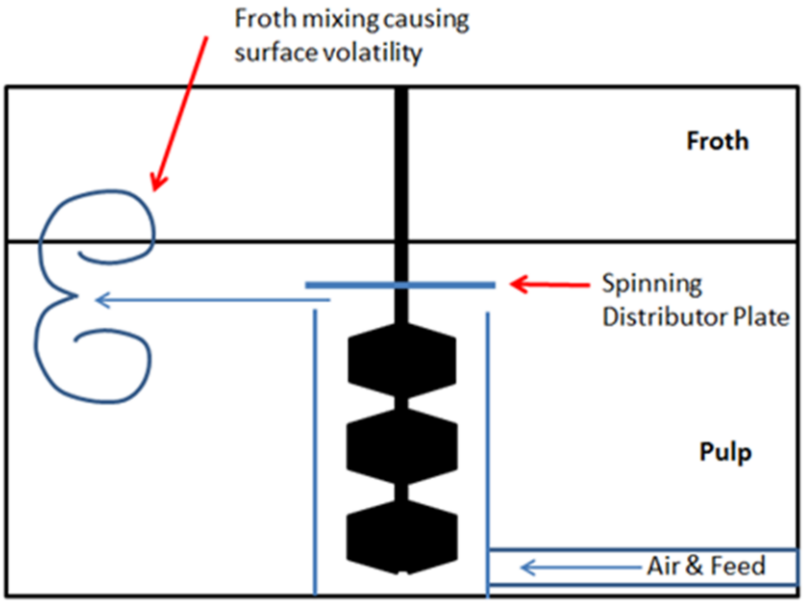


Figure 3.11: Altered slurry distribution design using spinning distribution plate.

percent weight for the minus 325 mesh non-floatable material, dilution washes, carbon recovery, ash recovery, separation efficiency, and yield.

Similarly, Figure 3.12, Figure 3.13, and Figure 3.14 graph the total concentrate ash, percent weight of total concentrate for the minus 325 mesh non-floatable material, and dilution washes data for the froth depth tests, agitator motor speed sweep, and wash water tests respectively. Lastly, the data for recovery, separation efficiency, and yield are plotted in Figure 3.15, Figure 3.16, and Figure 3.17 for the froth depth sweep, agitator motor speed sweep, and wash water rate tests respectively.

Table 3.12: Summary of the froth depth sweep for the Plant B samples

Test #	Froth Depth (in.)	Total Con. % Ash	Non-Float minus 325 %Weight of Total	Dilution Washes	Carbon Rec. (%)	Ash Rec (%).	Sep. Eff. (%)	Yield
1	30	5.42	3.53	4.96	20.54	1.27	19.28	11.27
2	24	7.12	4.88	2.00	35.91	3.03	32.87	20.26
3	18	7.37	5.41	1.44	34.98	3.04	31.94	19.71
4	12	8.37	6.61	1.77	31.56	3.22	28.34	18.17

Table 3.13: Summary of the agitator motor speed sweep for the Plant B samples

Test #	Agitator Motor Speed (Hz)	Total Con. % Ash	Non-Float minus 325 %Weight of Total	Dilution Washes	Carbon Rec. (%)	Ash Rec (%).	Sep. Eff. (%)	Yield
5	0	6.39	4.53	3.21	38.01	3.07	34.94	22.01
6	30	6.88	5.19	2.55	38.26	3.61	34.65	23.04
7	45	7.12	4.73	1.45	36.08	3.72	32.36	22.28
8	60	7.65	6.54	7.70	19.77	2.13	17.64	12.09

Table 3.14: Summary of the wash water rate sweep for the Plant B samples

Test #	Wash Water Rate (gpm)	Total Con. % Ash	Non-Float minus 325 %Weight of Total	Dilution Washes	Carbon Rec. (%)	Ash Rec (%).	Sep. Eff. (%)	Yield
9	0	10.99	8.74	0.00	37.07	5.66	31.42	23.02
10	260	6.94	5.16	1.20	31.04	2.82	28.23	18.31
11	345	6.76	4.68	1.94	39.32	3.59	35.73	23.50
12	400	7.94	5.60	1.92	33.25	3.03	30.22	18.55

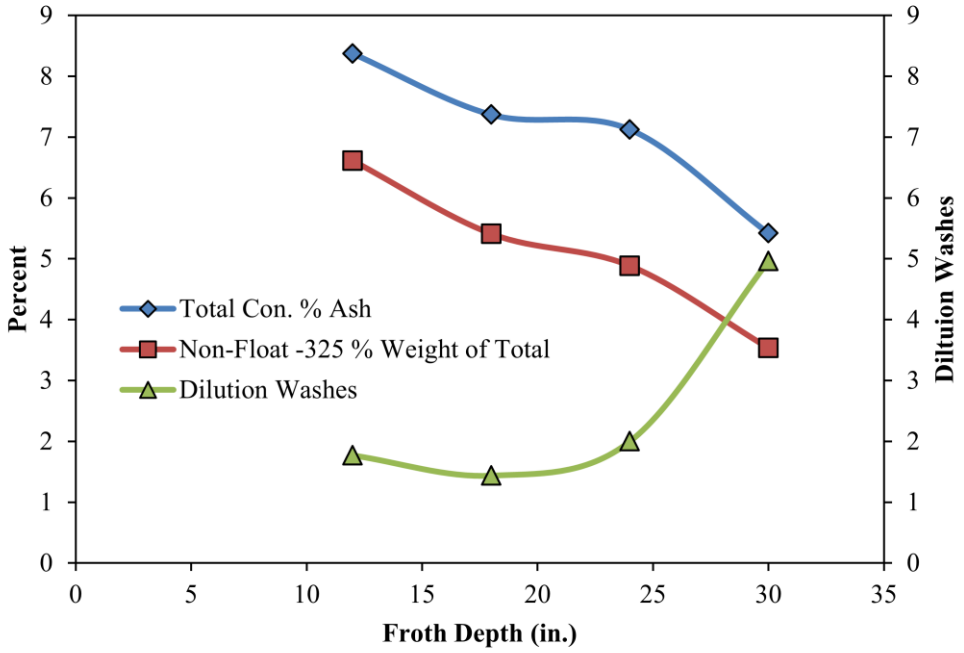


Figure 3.12: Concentrate ash, non-floatable minus 325 mesh % weight of total, and dilution wash data for the froth depth samples.

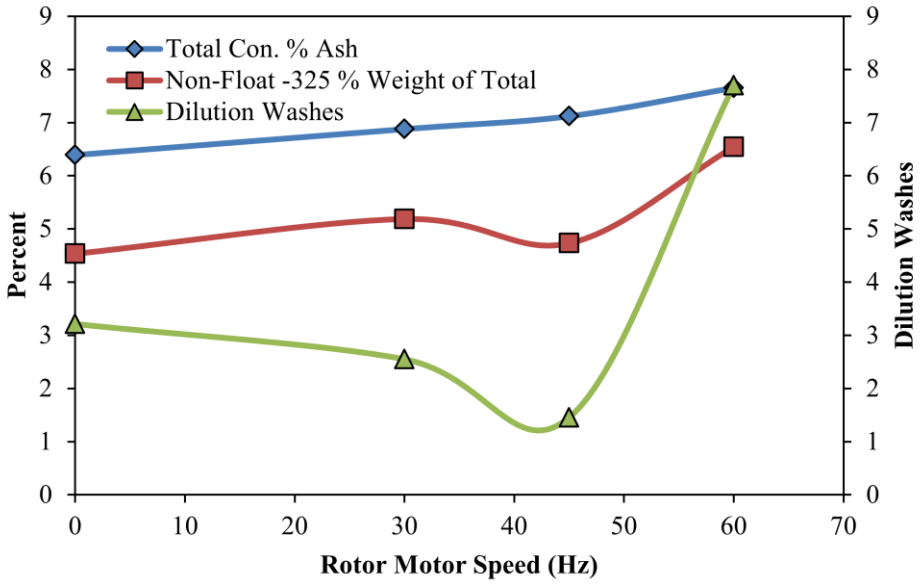


Figure 3.13: Concentrate ash, non-floatable minus 325 mesh % weight of total, and dilution wash data for the agitator motor speed samples.

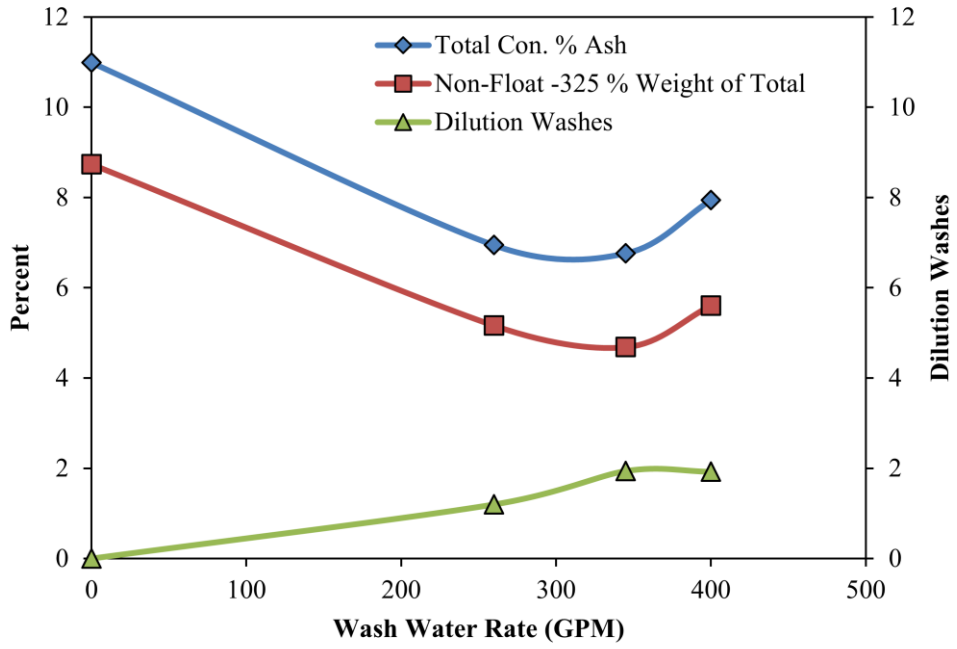


Figure 3.14: Concentrate ash, non-floatable minus 325 mesh % weight of total, and dilution wash data for the wash water rate samples.

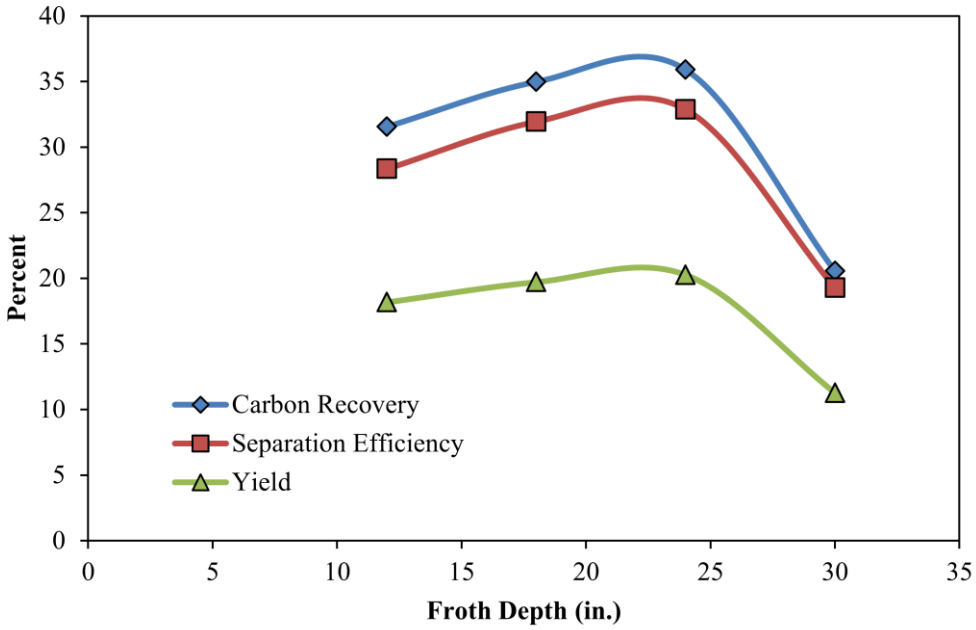


Figure 3.15: Carbon recovery, separation efficiency, and yield for the froth depth samples.

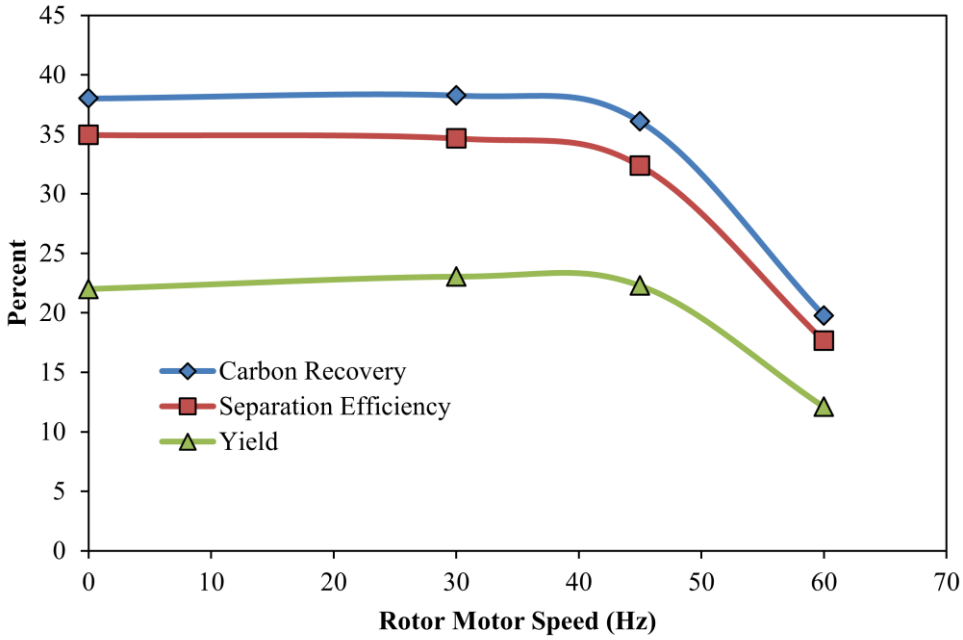


Figure 3.16: Carbon recovery, separation efficiency, and yield for the agitator motor speed samples.

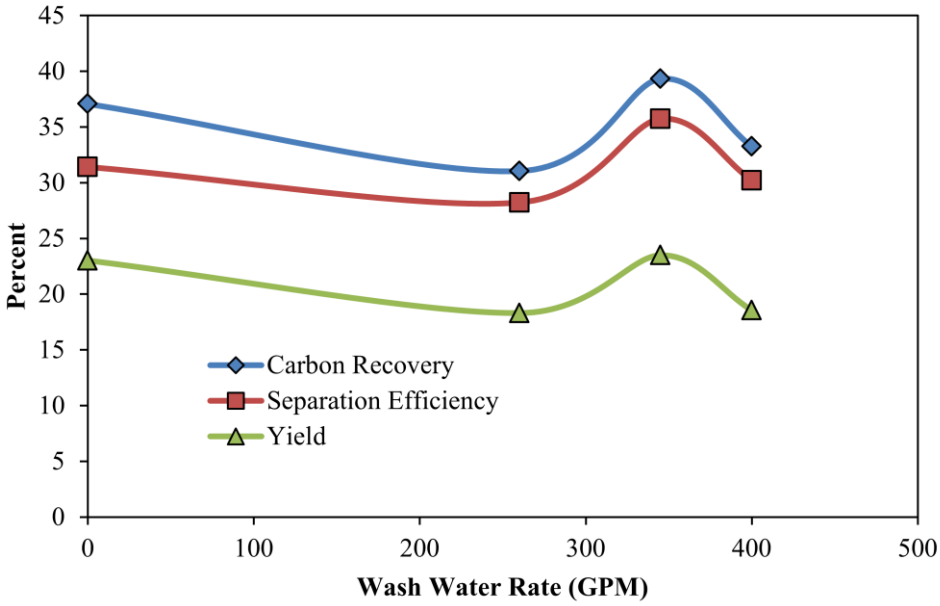


Figure 3.17: Carbon recovery, separation efficiency, and yield for the wash water rate samples.

Table 3.12, Figure 3.12, and Figure 3.15 show how the cell performs with respect to changing froth depths. Increasing froth depth lead to an improved concentrate ash and reduced the amount of non-floatable material present in the concentrate. The minimum froth depth tested, 12 inches, produced the highest concentrate ash, 8.37%, and contained the largest amount of minus 325 mesh hydrophilic material, 6.61% of the total concentrate weight. As froth depth increased the flotation process became more selective. A more traditional froth depth of 24 inches produced a concentrate ash of 7.12%, while the minus 325 mesh hydrophilic material in this sample only made up 4.88% of the total concentrate weight. As expected the deepest froth depth test, 30 inches, produced the best results with respect to concentrate ash and hydrophilic material present in the concentrate. This deep froth resulted in a concentrate ash of 5.42%, and the minus 325 mesh hydrophilic material comprised only 3.53% of the total concentrate weight. The spike seen in the dilution washes data is likely linked to the drop in recovery and yield for that point. A smaller amount of very high percent solids product is being produced. This results in less water reporting to the concentrate.

Figure 3.15 shows trends that go against what is commonly accepted with respect to coal flotation. It is commonly held that shallower froth depth provide a greater recovery. These tests show that for the cell the optimum froth depth, with respect to maximizing recovery, occurs somewhere around 22 inches. The data does suggest that extreme froth depths do decrease the recovery. This extreme froth depth does provide the lowest ash recovery, which is to be expected since this is when the flotation process is the most selective. Another way that the data conflicts with the commonly held conventions is the sensitivity of the data to changes in froth depth. It has been shown that as froth depth increases both product ash and carbon recovery decrease for a typical flotation column, but that product ash is more sensitive to this change than carbon

recovery. For the StackCell, the data suggests that both factors are sensitive to a change in froth depth. As stated earlier the product ash ranges from 8.37% to 5.42%, a variation of 2.95 percentage points. The recovery on the other hand varies from a maximum of 35.91% at 24 inches of froth depth to 20.54% at 30 inches of froth depth, a change of 15.36 percentage points.

Investigating Table 3.13, Figure 3.13, and Figure 3.16 reveals how the StackCell performs with changes in agitator motor speed. The cell operates as expected when considering concentrate ash. As the agitator motor speed increases so does the concentrate ash. A 0 Hz motor speed results in concentrate ash of 6.39%. This ash increase to a maximum of 7.65% at 60 Hz, the highest speed tested. This results in a total change of 1.26 percentage points in the concentrate ash. Also as expected the increased turbulence resulted in an increasing amount of minus 325 mesh material reporting to the concentrate. At 0 Hz 4.53% of the concentrate is made of minus 325 mesh hydrophilic material. This value increases to 6.54% at a motor speed of 60 Hz. Very little confidence should be placed in the dilution washes data for this set of samples. It is believed that samples used to calculate the percent solids for this set of data became diluted during the testing process. This dilution ultimately affects only the dilution washes data.

Once again, the StackCell seems to follow the known trends with respect to concentrate ash, but deviates when examining carbon recovery and yield. Commonly for mechanical cells, both recovery and yield increases as agitator speed increases. The data shows that as the agitator motor speed increase, thus increasing the speed of the agitator, the carbon recovery, separation efficiency, and yield, all hold fairly constant until the speed exceeds 45 Hz. At 45 Hz, the cell produced a carbon recovery 36.08%, a separation efficiency of 32.36%, and yield of 22.28%. At 60 Hz these values fall to 19.77%, 17.64%, and 12.09% respectively. This results in decreases of 16.31 percentage points for carbon recovery, 14.72 percentage points for separation efficiency,

and 10.19 percentage points for yield. The drop in separation efficiency is linked to the drop in carbon recovery, because carbon recovery is used to calculate separation efficiency. The 60 Hz actually produced the lowest ash recovery value. Thus, if carbon hadn't dropped drastically it's likely that this point would have produced the highest separation efficiency.

Table 3.14, Figure 3.14, and Figure 3.17 show how StackCell performance changes with varying wash water rates. As with the previous two sets of data, the cell follows the known trend with respect to total concentrate ash. As wash water rate increase concentrate ash decreases except for the highest wash water rate tested. In this case an increase in concentrate ash is observed. During the testing fluctuations in the wash water rate did occur due to pump cycling in the preparation plant. While this could be a contributing factor to this high value it is unlikely that it is solely responsible since the other data points were subjected to the same testing conditions. A more likely scenario is short circuiting of the wash water into the concentrate. This belief is supported by the fact that the dilution washes did not increase with the increase to the highest wash water rate. Thus, more of the wash water must have reported to the concentrate, which reduced the dilution washes for that test. This short circuiting could have also created a flow in froth, pulling unwashed material into concentrate thus driving up the concentrate ash.

Overall, the concentrate ash was a maximum, 10.99%, when there was no wash water added. The minimum ash occurred with the addition of 345 GPM of wash water, resulting in a 6.76% concentrate ash. The 260 GPM test also produced a very similar concentrate ash, 6.94%. The minus 325 mesh hydrophilic material present in the concentrate was highest, 8.74%, at 0 GPM. All of the other rates tested produced similar results ranging from 4.68% at 345 GPM to 5.60% at 400 GPM.

The recovery, separation efficiency, and yield data for the StackCell starts off following the known trend but it does contain an anomaly. Generally as wash water rate increases the carbon recovery decreases. This holds true for the first two data points tested, but the 345 GPM data point spikes the recovery, separation efficiency, and yield. The highest GPM value test still resulted in higher carbon recovery, separation efficiency, and yield values than the data point directly before the spike. The cause of this anomaly is unknown and it is unlikely that it is solely the result of the wash water addition rate. It is possible a slight change in froth depth occurred, which resulted in the higher recovery.

The highest carbon recovery, 39.32 %, occurred at 345 GPM, while the lowest, 31.04%, occurred at 260 GPM, resulting in a range of 8.27 percentage points. The highest ash recovery value, 5.66%, occurs at 0 GPM, and lowest value, 2.82%, occurs at 260 GPM, resulting in a range of 2.84 percentage points. All of the data points, except for the 0 GPM point, produced very similar ash recovery values ranging from 2.82% to 3.59%. The yield follows the same pattern as the recovery with the highest value, 23.50%, occurring at 345 GPM, while the minimum value, 18.31%, occurs at 260 GPM, a range of 5.19 percentage points.

Surface turbulence, similar to that observed at Plant A, was present during the Plant B testing. After investigating the resulting data and continued monitoring, the cell manufacturer chose to further change the slurry distribution design used in the cell. It is believed that the jet exiting the mixing chamber caused a large amount of turbulence at or near the froth-pulp interface which resulted in froth mixing.

Figure 3.11 shows the design in question. To alleviate this issue, the cell manufacturer placed a shroud around the mixing chamber. The jet interacts with the shroud and is forced deeper into the cell and away from the froth pulp interface. Not only does this help to reduce or eliminate the

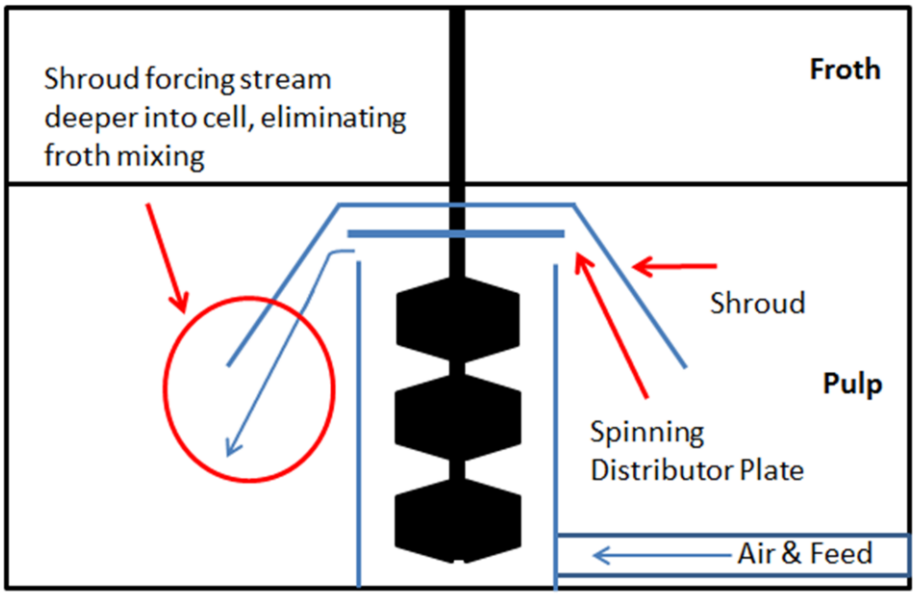


Figure 3.18: Spinning plate distributor with shroud.

surface turbulence, it also gives the air more time distribute throughout the cell rather than immediately reporting to the froth. This new distribution design can be seen in Figure 3.18.

3.4 Conclusions

The testing work performed on the StackCell at the Plant A and Plant B sites resulted in three major design changes. The first of these changes being the use of drip pans rather than wash rings. Drip pans are easier to operate and maintain, and provide better water coverage than wash rings. The second change to the design of the StackCell was the use of a spinning distributor plate rather than distributor pipes in order to transfer the slurry from the mixing chamber to the tank for pulp-froth separation. This design change was made in an effort to reduce surface turbulence, but unfortunately did not alleviate the symptoms entirely. Another change to the slurry distribution system was required. This change added a shroud around the mixing chamber in order to force the exiting jet deeper into the cell and away from the froth-pulp interface.

Long-term testing of the StackCell showed that it had stabilized with respect to ash recovery, and fluctuates between 4.39% and 6.01% for the Plant A coal. Likewise, after correcting the wash water issue, the concentrate ash fluctuates around approximately 9.5%. Average recovery for these tests was 44.92% with no major outliers, while the average yield was 28.54% with no major outliers.

The characterization testing at Plant B showed that the design of the tested StackCell produced numerous anomalies when compared to accepted conventions of flotation. In most cases the concentrate ash followed the known trends, except for higher wash water rates where concentrate ash increased rather than decreasing.

The major breaks from the traditional theory came with respect to carbon recovery. It has been shown that as froth depth increase recovery decrease. In the Plant B froth depth tests carbon recovery increased to a maximum value of 35.91% at a froth depth of 24 inches. Although, this value then immediately fell to 20.54% at a froth depth of 30 inches.

It has also been shown that, for mechanical cells, increasing rotor speed results in increases in recovery and yield. Not all of the data collected in this study follows this trend. Instead, as the agitator motor speed increased the carbon recovery and yield held fairly constant at approximately 38-36% and 22%, respectively. Although, once the highest agitator motor speed was achieved, both values fell sharply to a carbon recovery of 19.77% and a yield of 10.19%.

Lastly, it is generally held that as wash water rate increases carbon recovery decreases. This holds true for the 0 GPM and 260 GPM Plant B data sets, which achieved carbon recoveries of 37.07% and 31.04% respectively. In contrast, a spike in carbon recovery, 39.32%, occurs at

345 GPM. The carbon recovery then drops to a value of 33.25% at 400 GPM. The cause of the spike at 345 GPM is unknown.

The anomalies listed above in combination with visual observation of surface turbulence were driving factors in adding the shroud to the current slurry distribution design.

4.0 CARBON PARTIONING TEST

4.1 Introduction

Normally, a release analysis requires an expensive flotation machine and flotation chemicals to perform. On top of these costs, it is also a time consuming procedure to perform properly. During a trip to Plant B, an interesting idea was proposed. Could a process be developed that would allow plant operators to perform a quick spot check of the flotation product or tails? With this idea in mind, an oil-pulp separation was chosen as the most likely candidate for a spot check test. Figure 4.1 shows an in-plant proof-of-concept test, where a sample of froth product was mixed in a test tube with torch oil and dilution water. This photograph shows that the hydrophobic and hydrophilic material easily partitions into an oil zone and a pulp zone. This separation is the driving force behind the development of the carbon partitioning test.

Figure 4.1: Proof of concept for oil release test.

4.2 Experimental

4.2.1 Processes Used

Samples were spilt out from the Plant B and Plant A flotation samples in order to compare the carbon partitioning test to the standard release analysis. The samples used in the development of the carbon partitioning test can be seen in Table 4.1. The Plant B samples were split out using the same slurry splitter seen in Figure 3.1. The Plant A samples were well mixed and then sample splits were poured out from the main sample.

The first attempt at obtaining results comparable to that of a release analysis utilized the separatory funnel seen in Figure 4.2. Concentrate and tailings samples from Plant B tests #5, #6, and #8 were used during this phase of development. These samples were well mixed and then smaller samples were removed from them by dipping a beaker into the parent sample. It was assumed that concentrate samples were initially at 14% solids, and then they were diluted to less than 5% solids. Tailing samples were assumed to already be less than 5% solids. The samples were then placed in the separatory funnel and more dilution water was added. Approximately 10 ml of oil per 300 ml of slurry was added to separatory funnel. The funnel was then capped and shaken vigorously. The shaking caused the slurry and oil to mix, and this mixing allowed the oil to coat the coal particles. After ceasing the agitation the coal and clay particles separated into an oil phase and a pulp phase. The tap on the separatory funnel was used to drain the pulp away

Table 4.1: Samples used to develop the carbon partitioning test.

Samples Tested
Plant B Test #5
Plant B Test #6
Plant B Test #8
Plant A 8/11/11
Plant A 8/30/11

Figure 4.2: Separatory funnel used in the development of the carbon partitioning test.

while leaving the oil phase in the separatory funnel. Dilution water was then reintroduced to the system and the process was repeated until the tailings were visibly clear. This process resulted in a total of twelve samples, a float and sink product for each of the six Plant B samples tested. The samples were then filtered, dried, weighed, and analyzed for ash content. The ash analysis was performed using the same ash analyzer seen in Figure 3.4.

The second method tested used a blender in place of the separatory funnel. The blender used in this test can be seen in Figure 4.3 and is a model 54618Z Hamilton Beach blender. This model was chosen because it was cheap and had a built in tap that could be used to drain the pulp away from the oil phase.

Samples for these tests were obtained using the same method as described for the separatory funnel tests. The samples used for these tests were once again concentrate and tailings from the Plant B #5, #6, and #8 tests. In this procedure the sample was placed in the blender and diluted with water until the blender was full. No assumptions were made about the sample's percent solids, nor was a desired percent solids obtained prior to loading the sample into the blender. Instead, 10 ml of oil were initially added to both the concentrate and tailing samples for

Figure 4.3: Hamilton Beach model 54618Z blender used during testing.

the Plant B #5 and #6 tests. The Plant B #8 concentrate had an initial oil addition of 10 ml as well, but the tailings had only 5 ml of oil added initially.

After the initial oil additions, the blender was run for approximately 30 seconds. At this point, the material was allowed to separate into an oil phase and a pulp phase. If the separation was not acceptable, an additional 2 ml of oil was added to the system and the process was repeated until either an acceptable separation was obtained or there was no visible improvement after several oil additions. The total amount of oil added for each test can be seen in Table 4.2.

Once an acceptable separation had been obtained, the tailings were drained from the blender using the built in tap. This allowed the concentrate to remain in the blender. The tailings were then set aside to be combined with future tailings. The concentrate was then diluted and the process was repeated. No oil was added to system once an acceptable separation had been obtained. The concentrate was then blended again and allowed to separate into an oil phase and a pulp phase. The tails were then drained and set aside with the previous iteration's tails. This

Table 4.2: Amounts of oil added to the Plant B blender tests.

Sample Tested	Initial Oil (ml)	Oil Addition Rate (ml/addition)	Additions	Total Oil Added (ml)
Test #5 Con	10	2	1	12
Test #5 Tail	10	2	2	14
Test #6 Con	10	2	1	12
Test #6 Tail	10	2	0	10
Test #8 Con	10	2	1	12
Test #8 Tail	5	1	1	6

process continued until the tailings were visibly clear. At this point the concentrate and combined tailings were filtered, dried, weighed, and analyzed for ash content.

The third attempt to simulate a release analysis used the same blender as the previous method, but in this set of tests the starting samples were not diluted to fill the blender. Instead the blender was filled to capacity with slurry. Plant A samples were used for these tests due to the quantity of sample available, but the procedure remained the same. The sample was well mixed, and then poured into the blender until it was approximately 3/4 full. A similar approach to oil addition was implemented on the Plant A samples. Although, the starting amount of oil varied as the procedure became more familiar. A summary of the oil added to the Plant A samples can be seen in Table 4.3

Another change from the previous blender tests was the use of a different tap as seen in Figure 4.4. A fine adjustment tap was added to the blender in place of the older tap. The new tap allows for water to be drained out of the blender while the operator is not present. The previous tap required the operator to be present in order to hold it open.

Table 4.3: Amounts of oil added to the Plant A blender tests.

Sample Tested	Initial Oil (ml)	Oil Addition Rate (ml/addition)	Additions	Total Oil Added (ml)
8/11/11 Con A	12	2	19	50
8/11/11 Tail A	10	2	4	18
8/11/11 Con B	20	2	5	30
8/11/11 Tail B	2	2	3	8
8/30/11 Con A	20	2	3	26
8/30/11 Tail A	2	2	1	4
8/30/11 Con B	20	2	3	26
8/30/11 Tail B	2	2	1	4

Once enough oil had been added to the system to obtain an acceptable separation between the pulp and oil phases, it was drained from the system using the new tap. The tap was opened until a steady stream of tailings was flowing from the blender. Once a steady stream had been obtained, the operator was not required to be present. The tailings drained from the blender on their own. It should be noted that some hydrophobic material was removed along with the hydrophilic. This can be seen floating on top of the water in Figure 4.5. Usually this material reports to the tailings when a change in flow rate occurs or the blender is disturbed. The amount of hydrophobic material that reports the tailings should not be enough to skew the results.

After removing the tailings the concentrate is diluted and blended again. The tailings are

Figure 4.4: New and old tap used on the blender.

Figure 4.5: Hydrophobic material reporting to the tailings.

removed and the process continues until the tailings are visibly clear. Four sequential blends were performed on the Plant A samples in order to obtain clear tailings. As stated earlier, the resulting concentrate and combined tailings were filtered, dried, weighed, and analyzed for ash content.

4.2.2 Data Processing

Once the dry weights and dry ash values were obtained for each set of tests, they were entered into a spreadsheet where combined percent ash, yield, and a reconstituted feed ash were all calculated. The combined concentrate ash was calculated by using the cumulative ash formulae, [3.1], along with the float and sink products for the appropriate sample. This same procedure was followed for calculating the combined tailings ash. The yield was calculated by using the feed ash from the appropriate release analysis, the combined concentrate ash, and the combined tailings ash along with [3.2]. Lastly, the feed was reconstituted using [3.6] and [3.7] in the same manner as was described with the characterization samples. Table 4.4 shows the raw

and reconstituted data for the Plant A August 30th sample. The rest of the raw and reconstituted data for all three attempted methods can be found in Appendix C.

Table 4.4: Results of the Plant A 8/30/11 - A blender test.

Yield	23.66

Concentrate

	Paper (g)	**Paper & Dry (g)**	**Dry Weight (g)**	**Cum. Weight (g)**	**Weight %**	**Cum. Weight %**	**Ash %**	**Cum. Ash %**
Float	6.05	156.73	150.68	150.68	94.45	94.45	4.83	4.83
Sink	6.11	14.96	8.85	159.53	5.55	100.00	84.21	9.23
		Total	159.53		100.00		9.23	

Tailings

	Paper (g)	**Paper & Dry (g)**	**Dry Weight (g)**	**Cum. Weight (g)**	**Weight %**	**Cum. Weight %**	**Ash %**	**Cum. Ash %**
Float	6.17	25.33	19.16	19.16	45.09	45.09	10.31	10.31
Sink	5.97	29.30	23.33	42.49	54.91	100.00	86.79	52.30
		Total	42.49		100.00		52.30	

Feed (Reconstituted)

	Dry Weight (g)	**Cum. Weight (g)**	**Weight %**	**Cum. Weight %**	**Ash %**	**Cum. Ash %**
Float	56.77	56.77	56.77	56.77	8.15	8.15
Sink	43.23	100.00	43.23	100.00	86.71	42.11
	100.00		100.00		42.11	

4.3 Results and Discussion

The results for each carbon partitioning test were compared to those of their respective release analysis samples. Table 4.5 contains the data for the Plant B separatory funnel samples and the appropriate release analysis data. Table 4.6 shows the data for the Plant B blender tests and their respective release analysis samples. Lastly, Table 4.7 contains the results for the Plant A blender samples and their respective release analysis samples. The data has also been graphed and can be seen in Figure 4.6, Figure 4.7, and Figure 4.8, respectively.

Table 4.5 and Figure 4.6 show that the spearatory funnel was capable of producing results comparable to those of a release analysis for each component except for concentrate sink. In this

Table 4.5: Percent ash results for the separatory funnel tests for Plant B.

Sample Tested	Sep. Fun. (% Ash)	Release (%Ash)
Test #5 Con Float	2.82	2.93
Test #5 Con Sink	14.58	76.91
Test #5 Con (Recon)	4.11	6.39
Test #5 Tail Float	5.24	6.63
Test #5 Tail Sink	79.40	88.04
Test #5 Tail (Recon)	54.68	56.93
Test #5 Feed (Recon)	45.81	45.81
Test #6 Con Float	2.83	3.01
Test #6 Con Sink	18.71	75.19
Test #6 Con (Recon)	4.46	6.88
Test #6 Tail Float	5.09	6.55
Test #6 Tail Sink	78.19	87.98
Test #6 Tail (Recon)	53.20	55.01
Test #6 Feed (Recon)	43.92	43.92
Test #8 Con Float	2.79	3.04
Test #8 Con Sink	20.40	71.64
Test #8 Con (Recon)	5.11	7.65
Test #8 Tail Float	4.72	6.08
Test #8 Tail Sink	74.24	86.08
Test #8 Tail (Recon)	45.90	48.45
Test #8 Feed (Recon)	43.52	43.52

Table 4.6: Percent ash results for the Plant B blender tests.

Sample Tested	Blender (% Ash)	Release (%Ash)
Test #5 Con Float	3.56	2.93
Test #5 Con Sink	24.51	76.91
Test #5 Con (Recon)	6.10	6.39
Test #5 Tail Float	5.52	6.63
Test #5 Tail Sink	77.05	88.04
King Test #5 Tail (Recon)	59.82	56.93
Test #5 Feed (Recon)	45.20	45.81
Test #6 Con Float	2.71	3.01
Test #6 Con Sink	21.02	75.19
Test #6 Con (Recon)	5.42	6.88
Test #6 Tail Float	5.67	6.55
Test #6 Tail Sink	78.06	87.98
Test #6 Tail (Recon)	57.68	55.01
Test #6 Feed (Recon)	40.82	43.92
Test #8 Con Float	2.66	3.04
Test #8 Con Sink	26.14	71.64
Test #8 Con (Recon)	5.04	7.65
Test #8 Tail Float	4.32	6.08
Test #8 Tail Sink	74.38	86.08
Test #8 Tail (Recon)	51.71	48.45
Test #8 Feed (Recon)	40.04	43.52

case, the separatory funnel under estimated the percent ash present in the sample. It is believed that this variation is due to incomplete recovery of the hydrophobic material to the concentrate float sample.

These promising initial results lead to the idea of increasing the shear force present in the mixture, allowing for a better separation between the hydrophobic and hydrophilic material. The blender was used to produce this high shear environment. Examining Table 4.6 and Figure 4.7 show that these initial blender tests produced similar results to that of the separatory funnel. The concentrate sink component did shift closer to the results of the release analysis, but are still a gross under estimate.

Table 4.7: Percent ash results for the Plant A blender tests.

Sample Tested	Blender (% Ash)	Release (%Ash)
8/11 Con Float A	4.91	4.68
8/11 Con Sink A	88.81	71.36
8/11 Con (Recon) A	12.08	12.24
8/11 Tail Float A	25.16	11.61
8/11 Tail Sink A	91.37	91.38
8/11 Tail (Recon) A	76.10	72.89
8/11 Feed (Recon) A	56.16	56.16
8/11 Con Float B	5.13	4.68
8/11 Con Sink B	90.35	71.36
8/11 Con (Recon) B	12.14	12.24
8/11 Tail Float B	21.48	11.61
8/11 Tail Sink B	91.46	91.38
8/11 Tail (Recon) B	74.67	72.89
8/11 Feed (Recon) B	56.16	56.16
8/30 Con Float A	4.83	4.21
8/30 Con Sink A	84.21	69.02
8/30 Con (Recon) A	9.23	8.94
8/30 Tail Float A	10.31	10.57
8/30 Tail Sink A	86.79	83.18
8/30 Tail (Recon) A	52.30	51.04
8/30 Feed (Recon) A	42.11	42.11
8/30 Con Float B	4.49	4.21
8/30 Con Sink B	79.99	69.02
8/30 Con (Recon) B	9.91	8.94
8/30 Tail Float B	11.50	10.57
8/30 Tail Sink B	87.32	83.18
8/30 Tail (Recon) B	51.98	51.04
8/30 Feed (Recon) B	42.11	42.11

The third attempt at producing comparable results used a blender full of slurry rather than a diluted slurry. Table 4.7 and Figure 4.8 show that this combination of a high shear environment and higher percent solids present in the blender produces results comparable to those of the release analysis. In fact, in the case of the concentrate sink component the full blender tests produced a higher ash than those of the release analysis. This indicates that a better separation

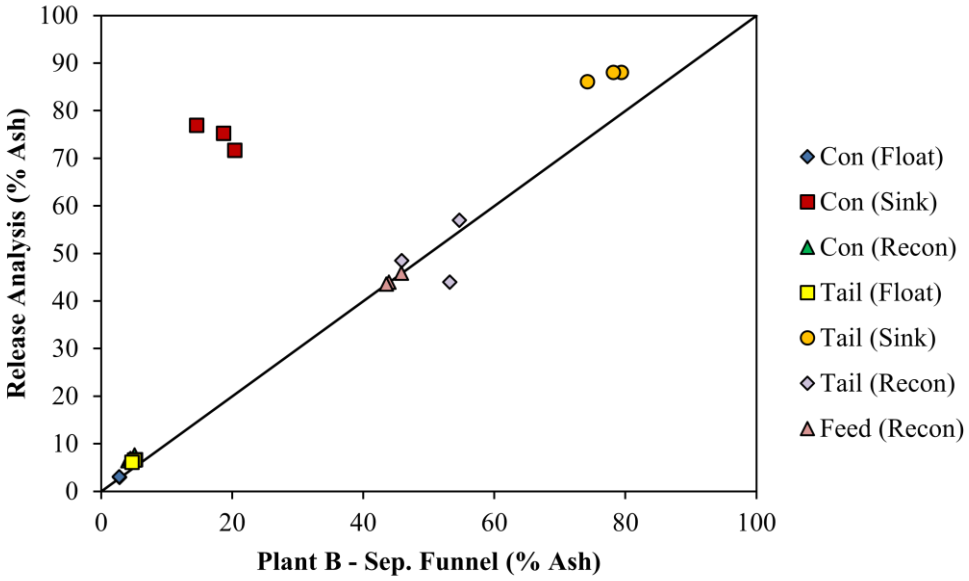


Figure 4.6: Results of the separatory funnel tests compared to those of the release analysis.

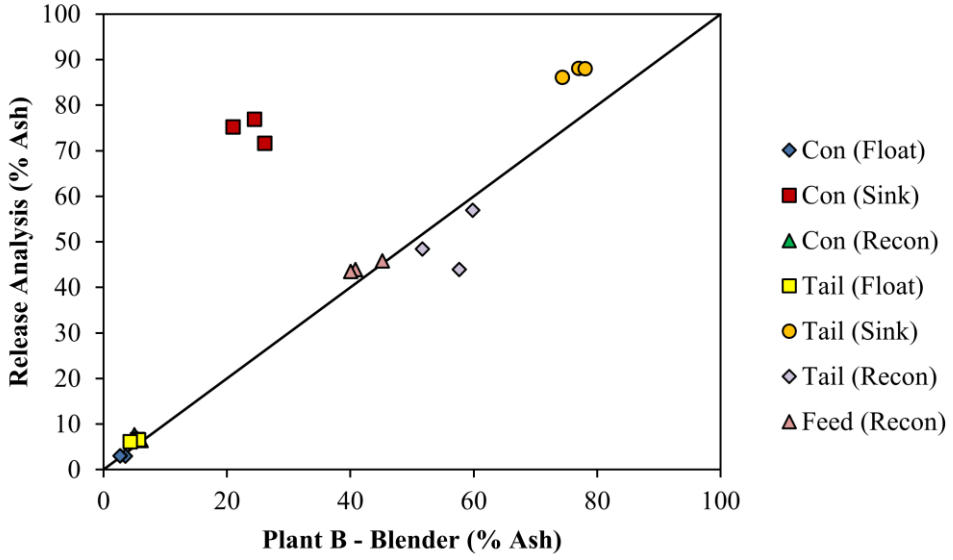


Figure 4.7: Results of the Plant B blender tests compared to those of the release analysis.

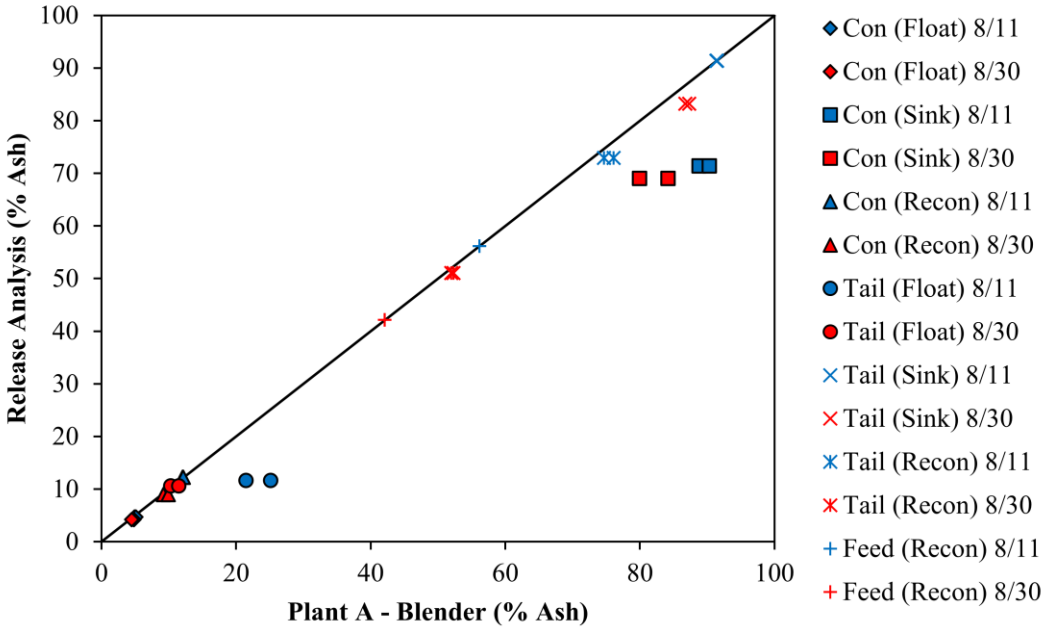


Figure 4.8: Results of the Plant A blender tests compared to those of the release analysis.

occurred using the blender than the flotation machine. The drift seen in the Tail Float 8/11 component is believed to be due to an over dosage of oil. Having too much oil in the 8/11 tailings sample allowed high ash particles to become coated and float along with the coal present in the sample. The recovery these high ash particles drove the ash content of the Tails Float component up. The 8/30 tailing sample used a lower level of oil addition and both the float and sink components from that test fall around the line.

Table 4.8 shows the weight of the oil added and the wieght of carbon present in each Plant A blender test. To perform this calculation it was assumed that the oil used in the test has a density of 0.8 g/ml. Examining this table confirms that the 8/11 tailings sample did have a much lower carbon to oil ratio than the rest of the tests. The results of all the 8/30 tests fell close to the release analysis values. The carbon to oil ratio of these samples all fell in the range of 6 to 7. Though it does appear that concnertrate samples can be tested with a much large amount of oil. Both of the 8/11 concetrate samples produced good results and had carbon to oil ratios of 4.22

Table 4.8: Carbon to oil comparison of each Plant A blender test.

Plant A Sample	Split	% Ash	Weight of Material (g)	Weight of Carbon (g)	Amount of Oil (ml)	Weight of Oil (g)	Carbon/Oil Ratio
8/11/2011	Con 1	12.08	192.09	168.88	50	40.00	4.22
8/11/2011	Tail 1	76.10	46.58	11.13	18	14.40	0.77
8/11/2011	Con 2	12.14	118.84	104.41	30	24.00	4.35
8/11/2011	Tail 2	74.67	49.72	12.59	8	6.40	1.97
8/30/2011	Con 1	9.23	159.53	144.80	26	20.80	6.96
8/30/2011	Tail 1	52.30	42.49	20.27	4	3.20	6.33
8/30/2011	Con 2	9.91	150.13	135.26	26	20.80	6.50
8/30/2011	Tail 2	51.98	41.81	20.08	4	3.20	6.27

and 4.35. This shows that concentrate samples are less susceptible to an over addition of oil than tailings samples.

During the data processing each set of carbon partitioning samples, concentrate and tailings, used the respective release analysis's feed sample to calculate the yield. This yield was then used to reconstitute a feed based on the concentrate and tailings results for the carbon partitioning test. It is understood that the feed ash for a given flotation circuit will not always been known. Instead, a yield value for circuit will commonly be reported and updated over time. With this knowledge in mind, a sensitivity analysis was performed on the Plant A August 30th A sample. The results of the sensitivity analysis can be seen in Table 4.9. As the table shows, a five percentage point change of the yield in either direction results in roughly a 2.15 percentage point change of the reconstituted feed ash in the opposite direction. If a 10 percentage point change of the yield occurs in either direction a 4.31 percentage point change in the reconstituted feed ash occurs in the opposite direction.

Table 4.9: Percent ash results for the separatory funnel tests.

Change in Yield	Recon. Feed Ash	Difference
+10	37.80	-4.31
+5	39.96	-2.15
0	42.11	0
-5	44.27	2.16
-10	46.42	4.31

4.4 Conclusions

A method for obtaining results comparable to those of a release analysis cheaply and quickly was developed. This method uses a blender with a tap installed for easy removal of the tailings material. The blender should be loaded to capacity with slurry, and no dilution water should be added initially. The amount of oil added to the system should be calibrated to each site, but a range of 6 to 7 when comparing the carbon weight to the weight of the oil can be used as a starting point. The data shows that concentrate samples are less susceptible to adding to much oil than tailings samples.

The test can be performed by starting with a very low initial amount of oil, and adding a small amount of oil to the system after each attempt to produce an adequate separation between the oil phase and pulp phase. This addition continues until the desired separation occurs or there is no visible improvement in the separation after a blend time of thirty seconds. After obtaining the proper amount of oil the process continues in a manner very similar to that of a traditional release analysis.

The method for reconstituting a feed ash was also tested in order to ensure that subtle variations in yield would not grossly affect the percent ash of the reconstituted feed. This highest variation tested, a change of ±10 percentage points, produced only a 4.31 percentage point change in reconstituted feed ash.

Based on the testing experience, some recommendations about the process can be made. The tap on the blender should be replaced or modified to allow for continuous flow without the operator being present. Allowing the sample to drain without the operator being present also frees up the operator to perform another task. A second suggestion would be to obtain a blender made of metal or glass. The blender used in the testing was made of plastic. Due to this the coal and oil agglomerations stuck to the sides and base of the blender. This made removing the concentrate sample from the blender very difficult, and sometimes the sides of the blender would become so coated that it obstructed the view into the blender. The final suggestion is to remember that some hydrophobic material will report to the tailings. To minimize this, users should avoid changing the flow rate on the tap once a steady stream has been obtained. Also, users should avoid contacting the blender during the draining process if possible.

5.0 DRIP PAN PROGRAM DEVELOPMENT

5.1 Introduction

The importance of adequate wash water distribution has been shown. Due to this importance, an effort was made to develop a program to aid in the design of drip pans. The program would take various inputs such as hole diameter, hole spacing, and pattern type, and output parameters such as required water head. An investigation was also performed to determine the effect plate thickness has on flow rate.

5.2 Experimental

5.2.1 Apparatus

In order to study the flow rate through an orifice plate an apparatus, shown in Figure 5.1, was constructed. The apparatus consisted of three major parts: the water intake pipe, the orifice plates, and the tank. The water intake pipe, Figure 5.2, consists of a downward flow pipe which empties into a cup. The water then flows upwards through holes cut in the top of the cup, seen in Figure 5.3. Three plates of separate thicknesses were produced. All three plates contain three sets of holes, a drilled set, a drilled and counter sunk set, and a plasma cut and counter sunk set. Each set of holes were cut in order to produce five unique hole sizes. The hole diameters used in the tests are 3/16-, 1/4-, 5/16-, 3/8- and 7/16-inch. Figure 5.4, Figure 5.5, and Figure 5.6 show the 1/8-, 3/16- and 1/4-inch thick plates, respectively. Lastly, the tank was equipped with a sight glass and a ruler, as seen in Figure 5.7, in order to measure the water level in the apparatus. Weirs were cut in the side of the tank to help regulate the water level present in the apparatus as well. These weirs were plugged using rubber stoppers during the testing.

Figure 5.1: Apparatus built to test flow through an orifice plate.

Figure 5.2: Water intake pipe.

Figure 5.3: Holes cut into the water intake pipe.

Figure 5.4: 1/8-inch thick plate.

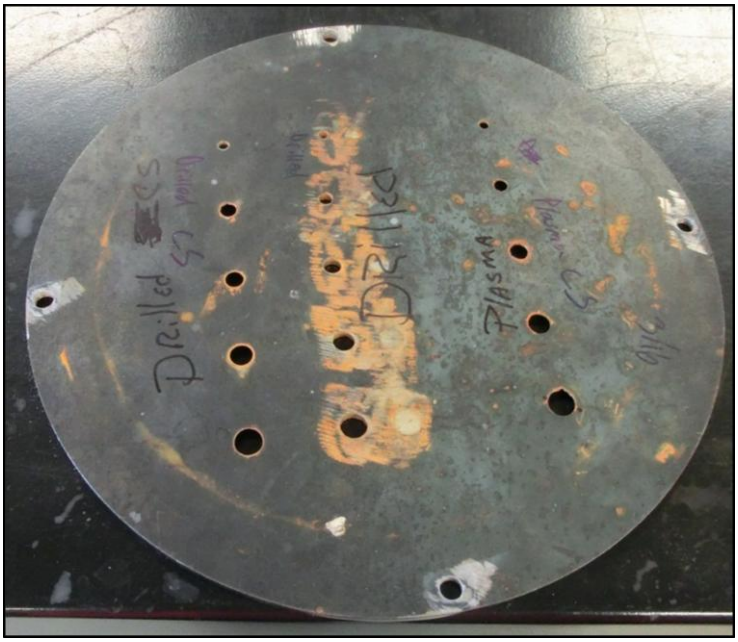


Figure 5.5: 3/16-inch thick plate.

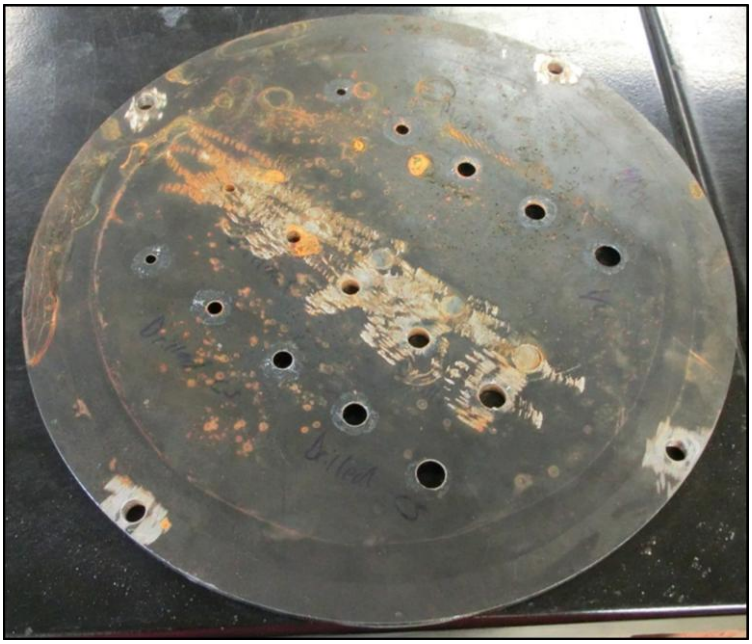


Figure 5.6: 1/4-inch thick plate.

Figure 5.7: Sight glass and ruler equipped to the tank.

5.2.2 Testing Procedure

Plumber's putty was used to stop up all but one hole before testing began on a particular plate. Other testing preparations included preparing three data sheets, one for each hole type, and obtaining the tare weights on three small buckets. Once all preparations were completed, the apparatus was assembled and filled with water up to the first weir level. At this point, the water level was read using the sight glass and ruler and this value was recorded on the appropriate data sheet. Next, three separate samples were collected of the flow emitting from the orifice plate. The sampling time for each of three samples was recorded along with the total weight of the bucket and water. The water was weighed using the same scale seen in Figure 3.3. Once all of

the necessary information had been recorded, the next hole was opened and the previous hole was plugged. For instance if the 3/16-inch drilled hole was being tested it would be plugged and the 3/16-inch drilled and counter sunk hole would be opened. This pattern continues until all three hole types have been tested for a given hole diameter.

The water level was allowed to come back to steady state following the opening of a new hole, and the same procedure was followed, with the data being recorded on the appropriate data sheet. Once all of the holes for a given diameter had been tested the next largest hole was opened and the previous hole was plugged. For instance if the 3/16-inch plasma cut and counter sunk hole has been completed and it was the last 3/16-inch hole the 1/4-inch drilled hole would be opened next. The water flow rate was then adjusted so that the water level reached the weir, and it was then allowed to stabilize. The same procedure as before was then followed, and the data was recorded on the appropriate data sheet. This pattern continued until all fifteen holes had been tests at the given weir level. A schematic of this procedure can be seen in Figure 5.8.

Once a weir level had been completed the pattern of testing repeated starting with the smallest hole sizes. The water addition would have to be adjusted in order to meet the second weir level and not exceed it. This pattern continued until all fifteen holes had been tested at all five weir levels. Once completed, the apparatus was disassembled and reassembled using a different orifice plate. Work continued until all three orifice plates had been tested.

Following the completion of the testing phase, the diameter of each individual hole was measured using a set of engineering calipers. Pictures of the holes were also taken and can be seen in Appendix D.

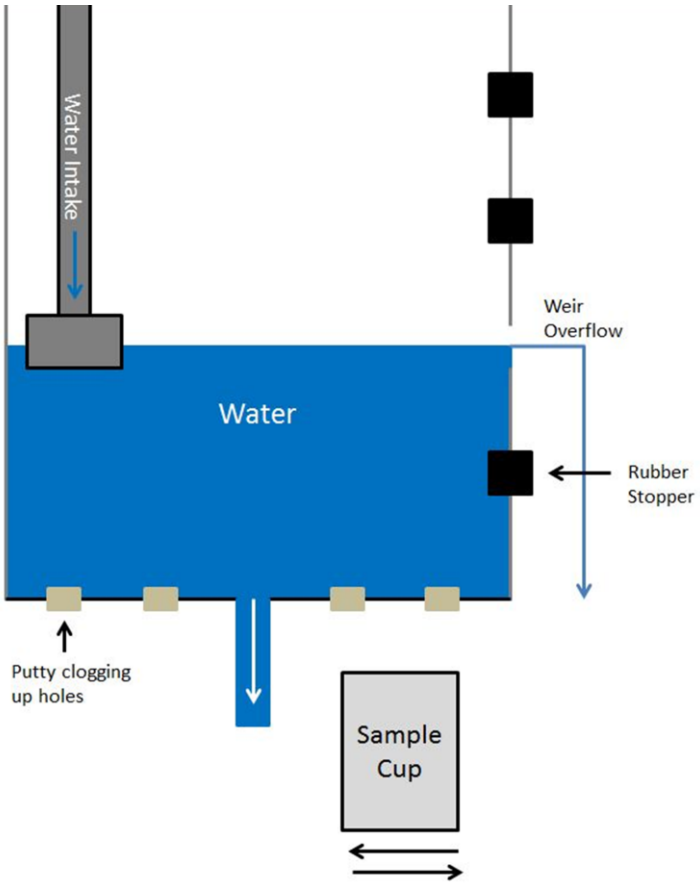


Figure 5.8: Flow through and orifice plate testing procedure.

5.2.3 Data Processing

The raw data from the flow rate experiments were input into a spreadsheet that calculated the gallon per minute flow rate of each hole diameter, hole type, and plate thickness combination. This process can be seen below in Table 5.1 and Table 5.2 for the 1/8-inch thick plate and drilled holes. The data for a set of three runs was averaged to produce one value for later use. The data for the remaining tests can be found in Appendix E.

These calculated results were then compared to the results from a purely theoretical model. The model was developed using the traditional flow through and orifice plate equation, [5.1]. Where n is the number of holes, A is the area of the hole, C_d is the coefficient of discharge, g is the force of gravity, and h is the water head.

$$Q = n \cdot A \cdot C_d \cdot \sqrt{2gh} \quad \textbf{[5.1]}$$

The coefficient of discharge can further be broken down into the coefficient of contraction and coefficient of velocity as shown in [5.2] (Lienhard V and Lienhard IV 1984).

$$C_d = C_c \cdot C_v \quad \textbf{[5.2]}$$

[5.3] shows the common coefficient of contraction used for ideal flows.

$$C_c = \frac{\pi}{\pi + 2} = 0.6110 \quad \textbf{[5.3]}$$

[5.4] shows a relationship that can be used to find the coefficient of velocity. In this equation, K_2 is a constant that has been calculated out to eight decimal places and was reported as 0.242738 for circular holes.

$$C_v = \sqrt{1 - \frac{K_2 \cdot C_d^{3/2}}{\sqrt{Re}}} \quad \textbf{[5.4]}$$

The *Re* term is the Reynolds number calculated using [5.5], where D_o is the diameter of the orifice and γ is kinematic viscosity. All other variables are as previously defined (Lienhard V and Lienhard IV 1984).

$$Re = \sqrt{2gh} \cdot \frac{D_o}{\gamma} \quad \textbf{[5.5]}$$

[5.6] is obtained by substituting the relationship shown in [5.2] into [5.4] and then rearranging the result. This form allows C_d to be solved using Newton's method.

$$0 = \frac{\sqrt{Re} \cdot {C_d}^2}{{C_c}^2} + K_2 {C_d}^{3/2} - \sqrt{Re} \quad \textbf{[5.6]}$$

Using [5.6], a C_d value was found for the results of each combination of parameters.

Table 5.1: Raw data for the 1/8-inch thick plate and drilled holes tests.

Date:	11/3/2011			Bucket 1 Weight (g):	33.35												
Plate Thickness:	0.125 in.			Bucket 2 Weight (g):	33.33												
Hole Style:	Drilled No CS			Bucket 3 Weight (g):	33.56												
Water Height (in.)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5			
		3/16"			1/4"			5/16"			3/8"			7/16"			
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	
1	2	2.250	2.250	2.250	2.625	2.625	2.625	2.250	2.250	2.250	2.250	2.250	2.250	2.250	2.250	2.250	
2	4	4.313	4.313	4.313	4.250	4.250	4.250	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313	
3	6	6.250	6.250	6.250	6.313	6.313	6.313	6.250	6.250	6.250	6.250	6.250	6.250	6.313	6.313	6.313	
4	8	8.313	8.313	8.313	8.250	8.250	8.250	8.313	8.313	8.313	8.250	8.250	8.250	8.313	8.313	8.313	
5	10	10.375	10.375	10.375	10.313	10.313	10.313	10.313	10.313	10.313	10.250	10.250	10.250	10.313	10.313	10.313	
Time (sec)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5			
		3/16"			1/4"			5/16"			3/8"			7/16"			
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	
1	2	20.00	19.91	19.91	19.93	19.94	20.00	15.03	14.97	14.93	12.00	12.06	11.97	10.03	9.82	9.16	
2	4	15.16	15.06	15.06	15.00	14.97	15.09	15.07	15.00	15.22	11.88	10.22	10.00	8.03	8.16	7.97	
3	6	15.28	15.07	15.12	14.97	14.97	15.22	12.19	11.97	12.00	10.10	10.09	10.16	6.06	6.00	6.09	
4	8	15.00	14.97	14.97	15.16	15.06	15.06	10.06	10.00	10.10	8.16	7.97	8.06	6.00	6.13	6.21	
5	10	15.12	15.03	14.94	11.87	12.03	11.97	8.09	7.97	8.10	6.09	6.09	6.15	4.28	4.07	4.22	
Water & Bucket Weight (g)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5			
		3/16"			1/4"			5/16"			3/8"			7/16"			
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	
1	2	314.52	312.78	312.61	584.16	584.76	584.40	590.78	581.60	585.63	681.18	682.21	679.29	746.70	723.93	667.22	
2	4	308.18	308.11	305.10	524.74	525.66	532.02	751.08	751.37	756.03	856.44	746.68	722.76	790.15	795.62	768.41	
3	6	351.45	343.76	344.89	596.13	599.86	613.73	701.43	690.23	696.48	836.30	847.70	843.73	697.97	698.52	692.63	
4	8	384.39	388.61	386.39	679.73	666.82	675.55	663.53	664.56	663.86	779.32	764.41	774.23	768.47	780.70	791.83	
5	10	420.24	415.25	416.38	588.69	596.17	594.35	592.78	592.74	598.50	649.19	651.74	651.66	610.82	583.51	610.66	

Table 5.2: Calculated results from the 1/8-inch thick plate and drilled holes tests.

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	281.17	279.45	279.05	550.81	551.43	550.84	557.43	548.27	552.07	647.83	648.88	645.73	713.35	690.60	633.66
2	4	274.83	274.78	271.54	491.39	492.33	498.46	717.73	718.04	722.47	823.09	713.35	689.20	756.80	762.29	734.85
3	6	318.10	310.43	311.33	562.78	566.53	580.17	668.08	656.90	662.92	802.95	814.37	810.17	664.62	665.19	659.07
4	8	351.04	355.28	352.83	646.38	633.49	641.99	630.18	631.23	630.30	745.97	731.08	740.67	735.12	747.37	758.27
5	10	386.89	381.92	382.82	555.34	562.84	560.79	559.43	559.41	564.94	615.84	618.41	618.10	577.47	550.18	577.10

1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.22	0.22	0.22	0.44	0.44	0.44	0.59	0.58	0.59	0.86	0.85	0.86	1.13	1.11	1.10
2	4	0.29	0.29	0.29	0.52	0.52	0.52	0.75	0.76	0.75	1.10	1.11	1.09	1.49	1.48	1.46
3	6	0.33	0.33	0.33	0.60	0.60	0.60	0.87	0.87	0.88	1.26	1.28	1.26	1.74	1.76	1.72
4	8	0.37	0.38	0.37	0.68	0.67	0.68	0.99	1.00	0.99	1.45	1.45	1.46	1.94	1.93	1.94
5	10	0.41	0.40	0.41	0.74	0.74	0.74	1.10	1.11	1.11	1.60	1.61	1.59	2.14	2.14	2.17

The experimental results were also compared to a fit equation, where the coefficient of contraction was allowed to change, thus changing the C_d value used in the flow rate equation. The same process as the theoretical model was followed to obtain these results, the only difference being C_c was a fitted value instead of being assumed as 0.6110.

5.3 Results and Discussion

5.3.1 Effect of Plate Thickness on Flow Rate

The comparisons between the theoretical and fit models can be seen below. Figure 5.9, Figure 5.10, and Figure 5.11 show the theoretical model compared to the measured data for the drilled holes of the 1/8-, 3/16-, and 1/4-inch thick plates, respectively. Similarly, Figure 5.12, Figure 5.13, and Figure 5.14 show the comparison between the measured flow rates and the predicted flow rates using the averaged best fit C_c data. This data uses a C_c value that is an average of the best fit C_c vales for each test. A total of nine values were used to develop this average C_c value. For example a best fit Cc value was determined for the 1/8-inch thick plate drilled holes test. A separate best fit Cc value was determined for 3/16-inch thick plate drilled holes test. The best fit Cc value for each of the nine hole type and plate thickness combinations were then averaged together to produce the averaged best fit Cc value. The plots for the remaining test can be found in Appendix F.

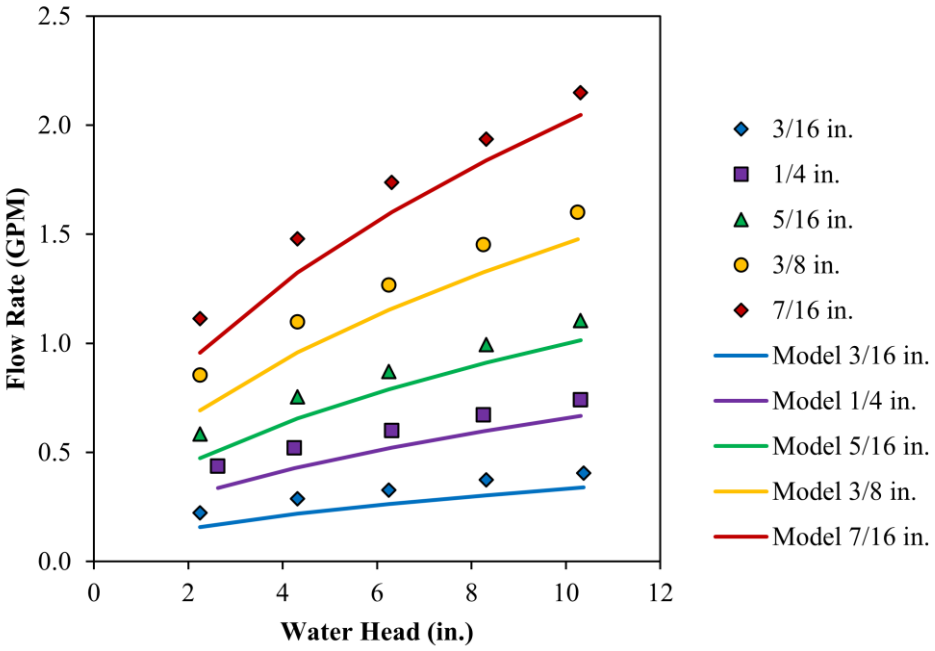


Figure 5.9: Comparison between theoretical model and measured data for drilled holes on the 1/8-inch thick plate.

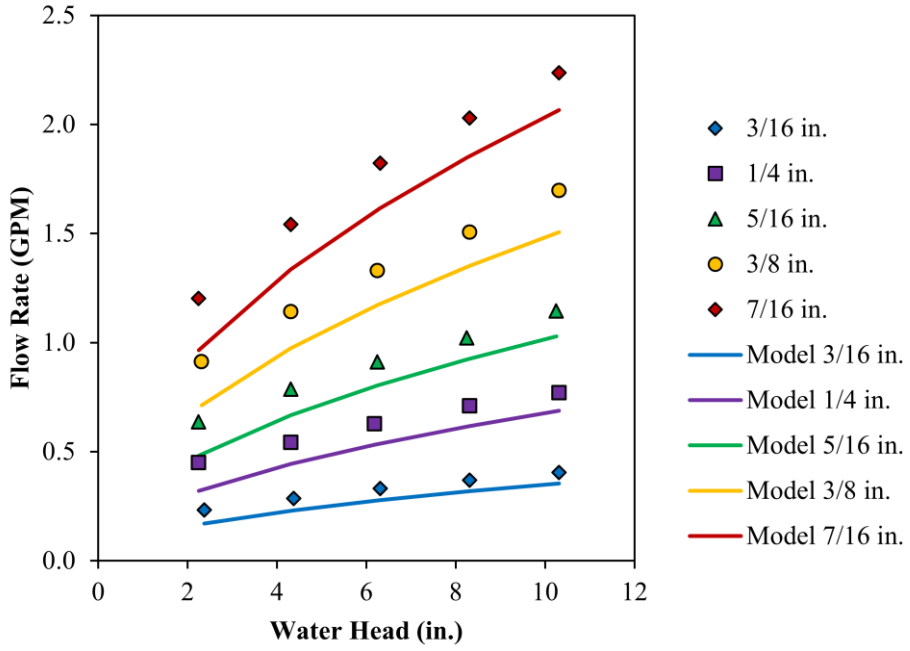


Figure 5.10: Comparison between theoretical model and measured data for drilled holes on the 3/16-inch thick plate.

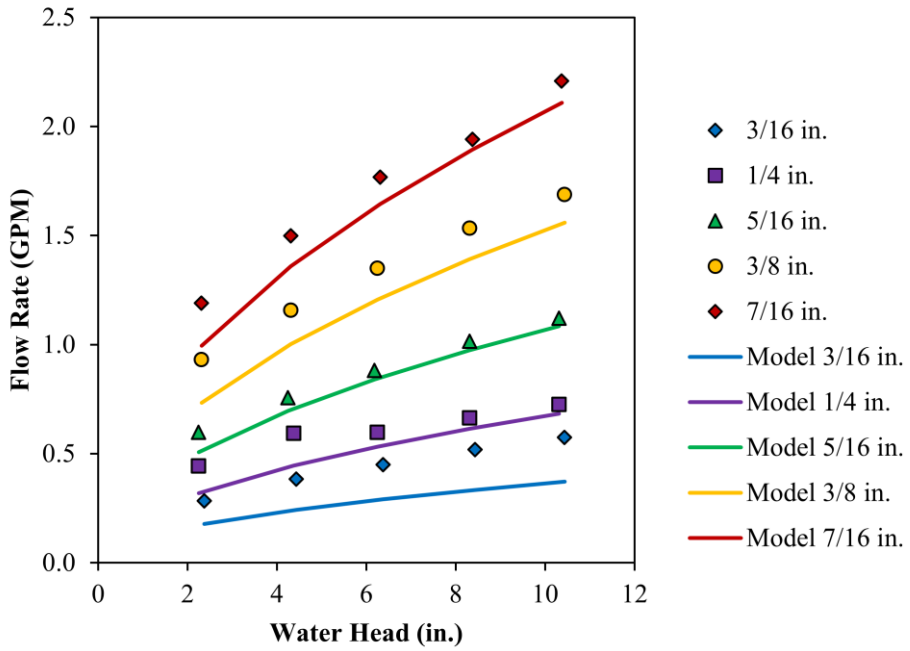


Figure 5.11: Comparison between theoretical model and measured data for drilled holes on the 1/4-inch thick plate.

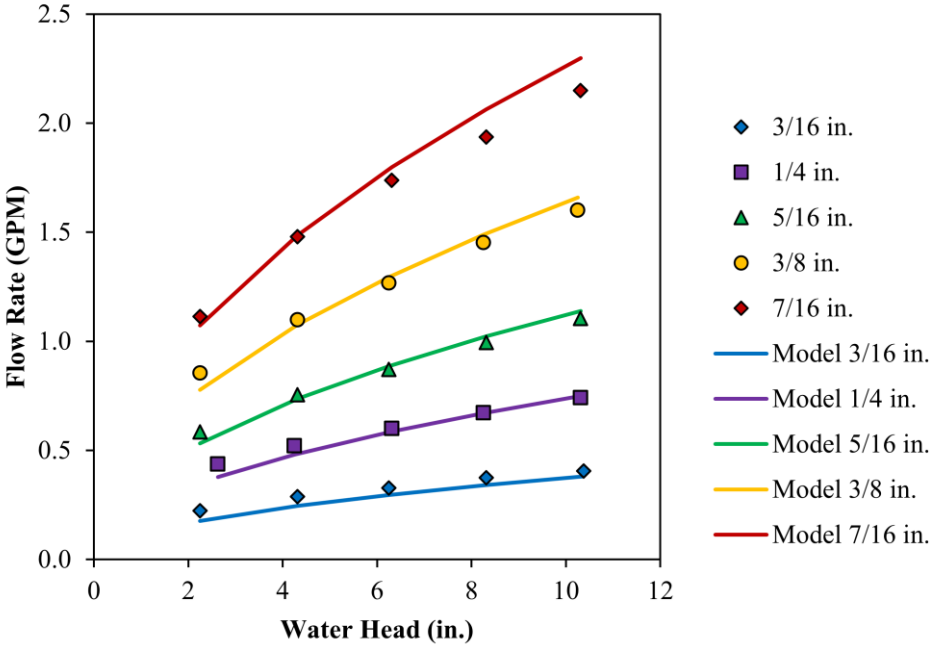


Figure 5.12: Comparison between fit averaged C_c model and measured data for drilled holes on the 1/8-inch thick plate.

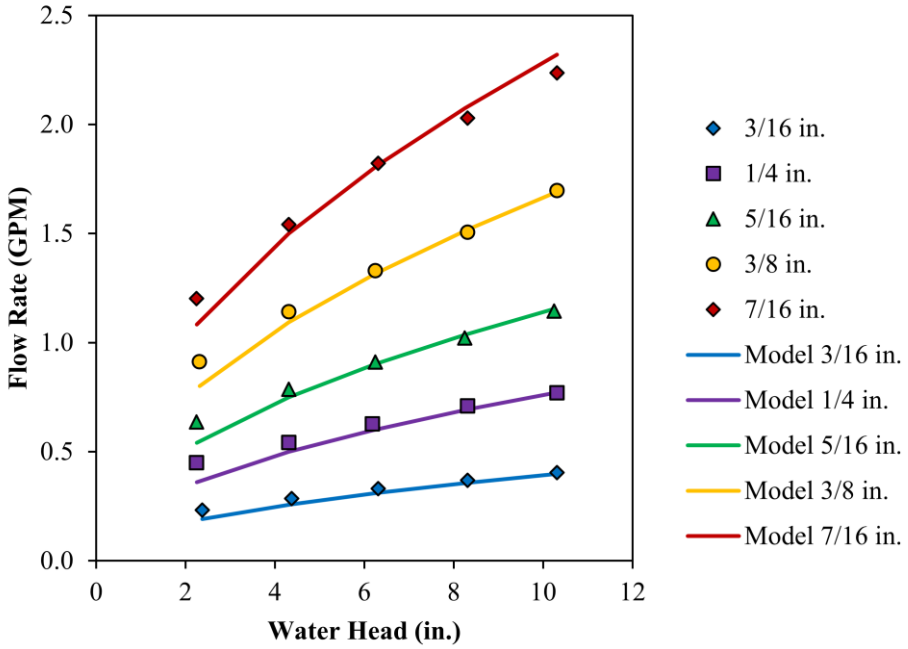


Figure 5.13: Comparison between fit averaged C_c model and measured data for drilled holes on the 3/16-inch thick plate.

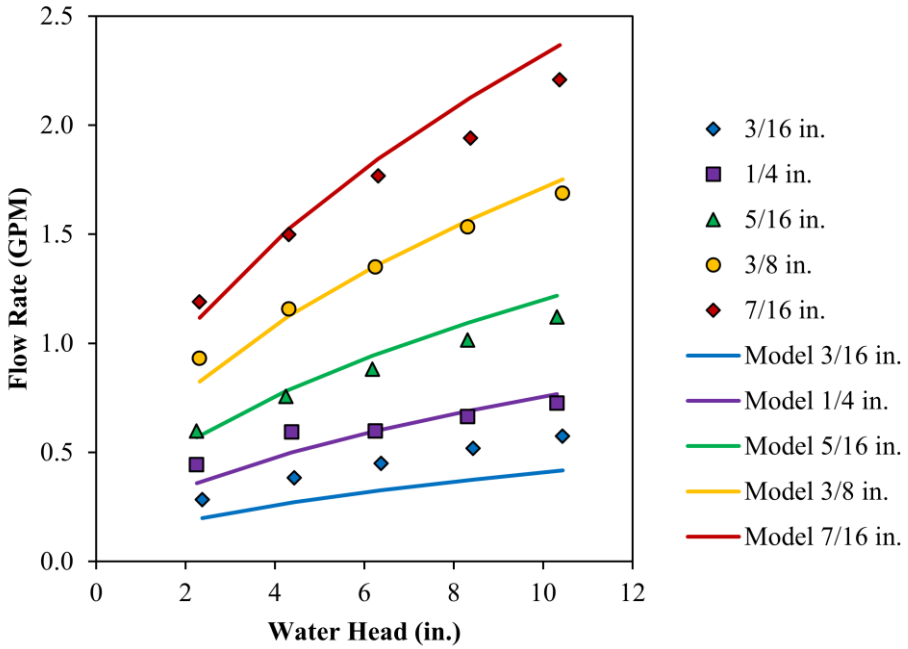


Figure 5.14: Comparison between fit averaged C_c model and measured data for drilled holes on the 1/4-inch thick plate.

In examining the plots, it is obvious that the theoretical model consistently underestimates the measured data. While only the data for the drilled holes are shown here, this trend holds true for both the drilled counter sunk and plasma cut counter sunk holes as well. This underestimation is believed to be caused by the low value of the coefficient of contraction. The value for C_c used in the theoretical mode is meant to represent an ideal flow. Examining the figures containing the averaged best fit C_c values shows a much more accurate prediction of the measured data. Thus, it is believed that the flow obtained during testing was not ideal and the fitted C_c values correct for this non-ideal flow.

The averaged best fit C_c value resulted in an averaged C_d value of 0.6856 for all of the different hole types. While this value provides an adequate fit of the data, C_d values were obtained for each hole type by averaging their best fit C_c values. For instance, the best fit C_c value for the 1/8-inch thick plate drilled holes, the 3/16-inch thick plate drilled holes, and the 1/4-inch thick plate drilled holes were average to produce a C_c value used specifically with the drilled holes. These specific averaged C_c values provided a slightly better fit to the data, and the resulting C_d values were used in the development of the drip pan design program. The three C_d values used in the drip pan design program are shown in Table 5.3.

The figures shown above, as well as those shown in Appendix F, demonstrate that plate thickness has little to no effect on flow rate. One equation, with no coefficient to correct for plate thickness, can be used to accurately predict the flow rate through each plate thickness. Slight

Table 5.3: Coefficient of discharge values used in the drip pan design program.

Hole Type	C_d
Drilled	0.6733
Drilled Counter Sunk	0.6819
Plasma Cut Counter Sunk	0.7017

variations in the flow rate do occur, but the variations are well within the experimental error and are likely due to oddities in the hole diameters.

5.3.2 Drip Pan Design Program

The drip pan design program consists of three major sections, the "Unit Cell" sheet the "Drip Pan" sheet, and the "Hole Spacing Calibration" sheet. The Unit Cell sheet is simply a sheet the allows the user to select a hole pattern from three common patterns. These patterns are a standard grid, a staggered grid, and a staggered equal distance grid. The diagrams used to define the input variables for each pattern can be seen in Figure 5.15, Figure 5.16, and Figure 5.17 respectively.

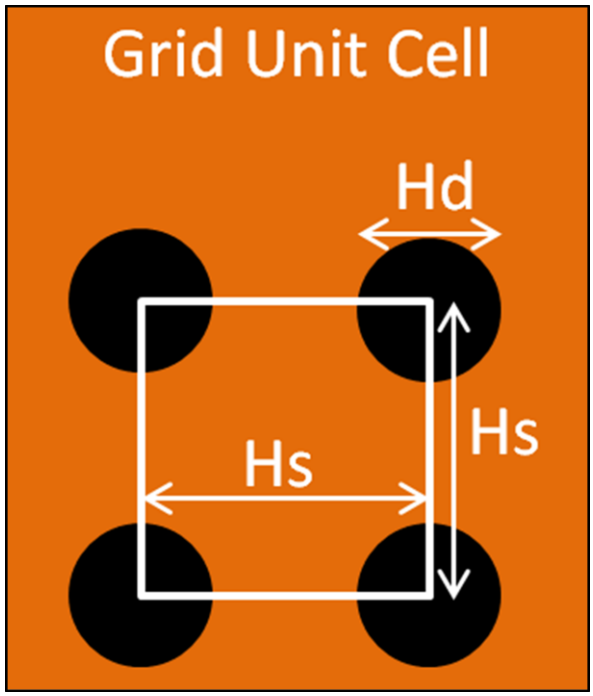


Figure 5.15: Standard grid unit cell.

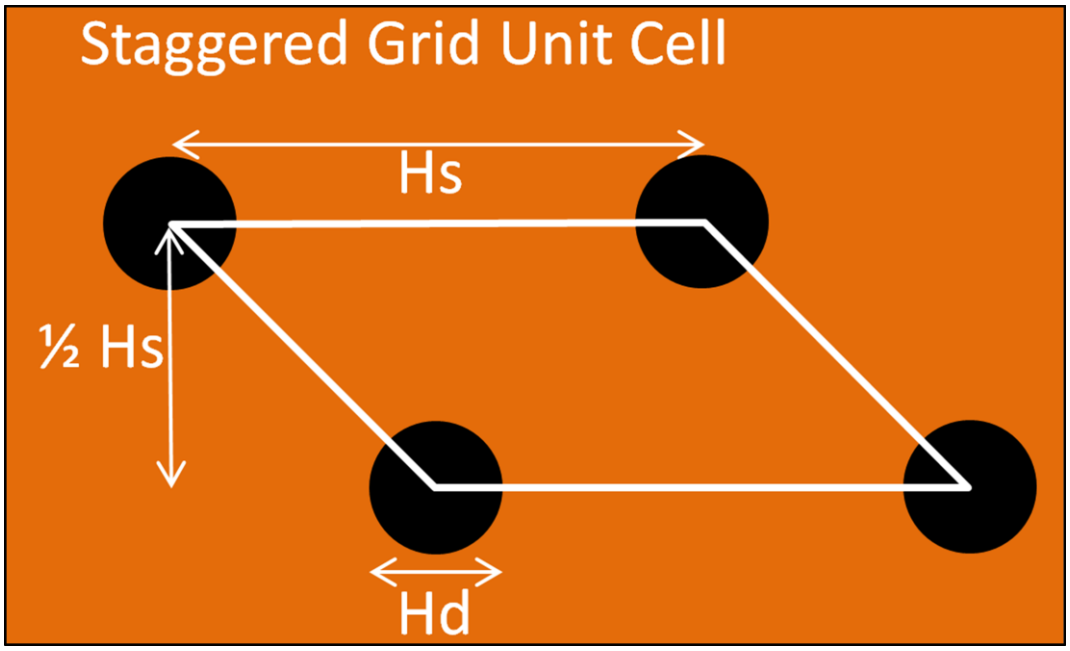


Figure 5.16: Staggered grid unit cell.

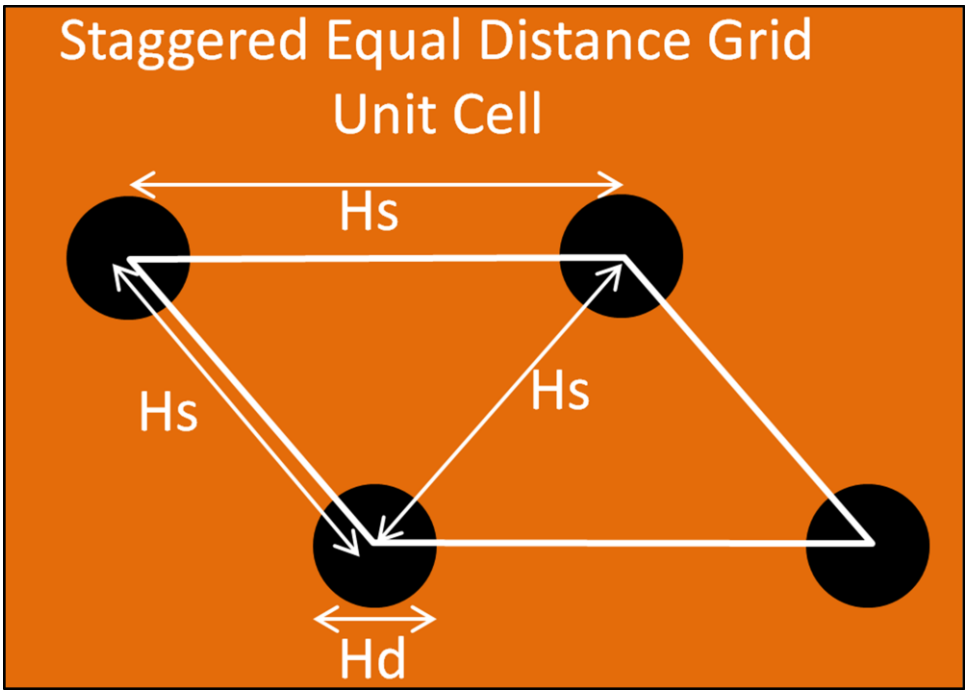


Figure 5.17: Staggered equal distance grid unit cell.

Figure 5.18 shows the user interface for the Unit Cell sheet. This sheet prompts the user to select a hole pattern from a drop down box containing the patterns listed earlier. The user also selects a hole type which determines which C_d value will be used in the flow rate calculation. Other user inputs include hole spacing, hole diameter, plate radius, and the desired flow rate in GPM per ft^2 of cell surface area. The unit cell sheet does not allow for annular designs.

Once the required information is entered into the inputs section of the sheet the unit cell area, hole area per cell, total plate area, number of cells, and the coefficient of discharge are all determined. Next, the user must click the "Solve for Water Head" button. This runs the solver subroutine which minimizes the error between the desired and estimated flows by changing the water head present in the drip pan. The flow rate equation used in this sheet and the DripPan sheet takes the same form as the general flow equation seen in [5.1]. The only thing that changes

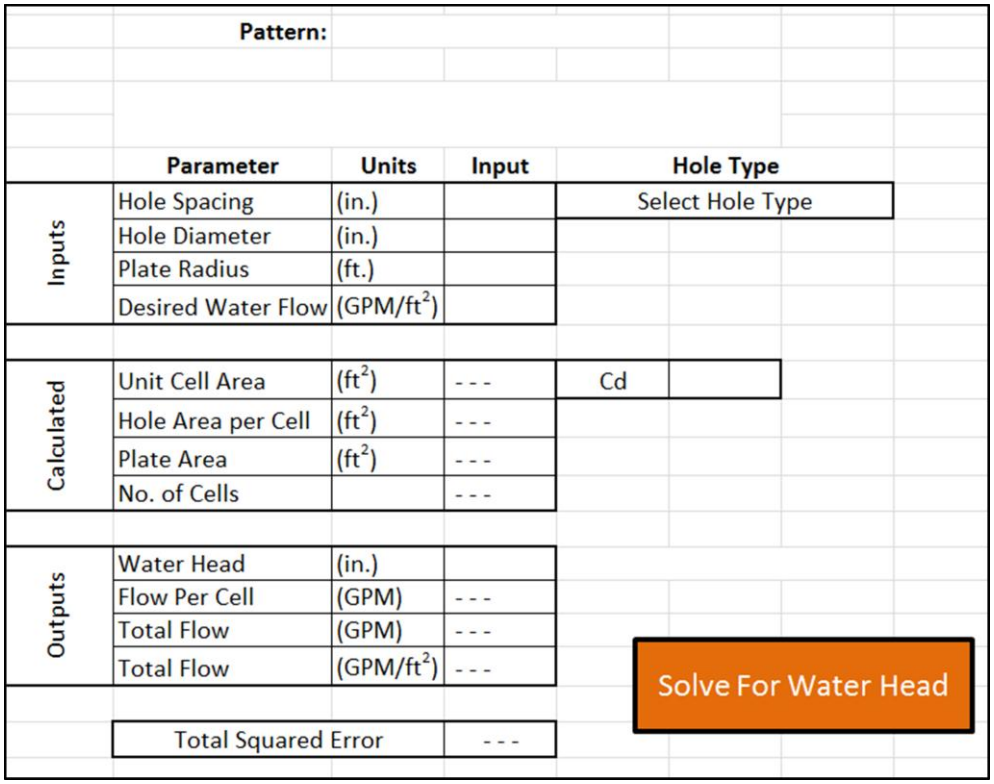


Figure 5.18: User interface for the Unit Cell sheet.

in this equation in the C_d value, which varies with different hole types.

The user interface for the DripPan sheet is a bit more complex than that of the Unit Cell sheet and can be seen in Figure 5.19. Once again, the user is asked to define several input parameters. The hole pattern and hole type are chosen from drop down menus. The hole patterns available consist of a standard grid, Figure 5.20, a staggered grid, Figure 5.21, a radial pattern, Figure 5.22, and a radial varying pattern. In the radial varying pattern the hole spacing changes as the holes gets closer to the edge of the plate. This will be discussed more in depth later. The amount of input parameters is dependent on the pattern chosen, but most input parameters have descriptions along with the schematics to help the user understand what each of the parameters represents.

The majority of the input parameters are the same as those used on the Unit Cell sheet with a few exceptions being the distance from edge, inner radius, and theta increment. The distance from edge allows the user to set where he or she wants the holes to stop. It essentially acts as a buffer zone from the edge of the plate. The inner radius allows for an annular design to be used. The inner radius determines how large the hole inside the drip pan will be. Finally, theta increment sets much theta will change for each loop of the system when running a radial pattern. A few other input parameters are unique to the Radial Varying pattern, but as stated before these will be discussed later.

Once all of the input parameters have been entered, the user clicks the appropriate "Solve For" button depending on which pattern was chosen. The program then runs through a subroutine which generates coordinates for each possible hole based on the user's inputs. These coordinates are listed in X Coordinate and Y Coordinate sections of the sheet. The coordinate (0, 0) represents the center of the plate, or the origin.

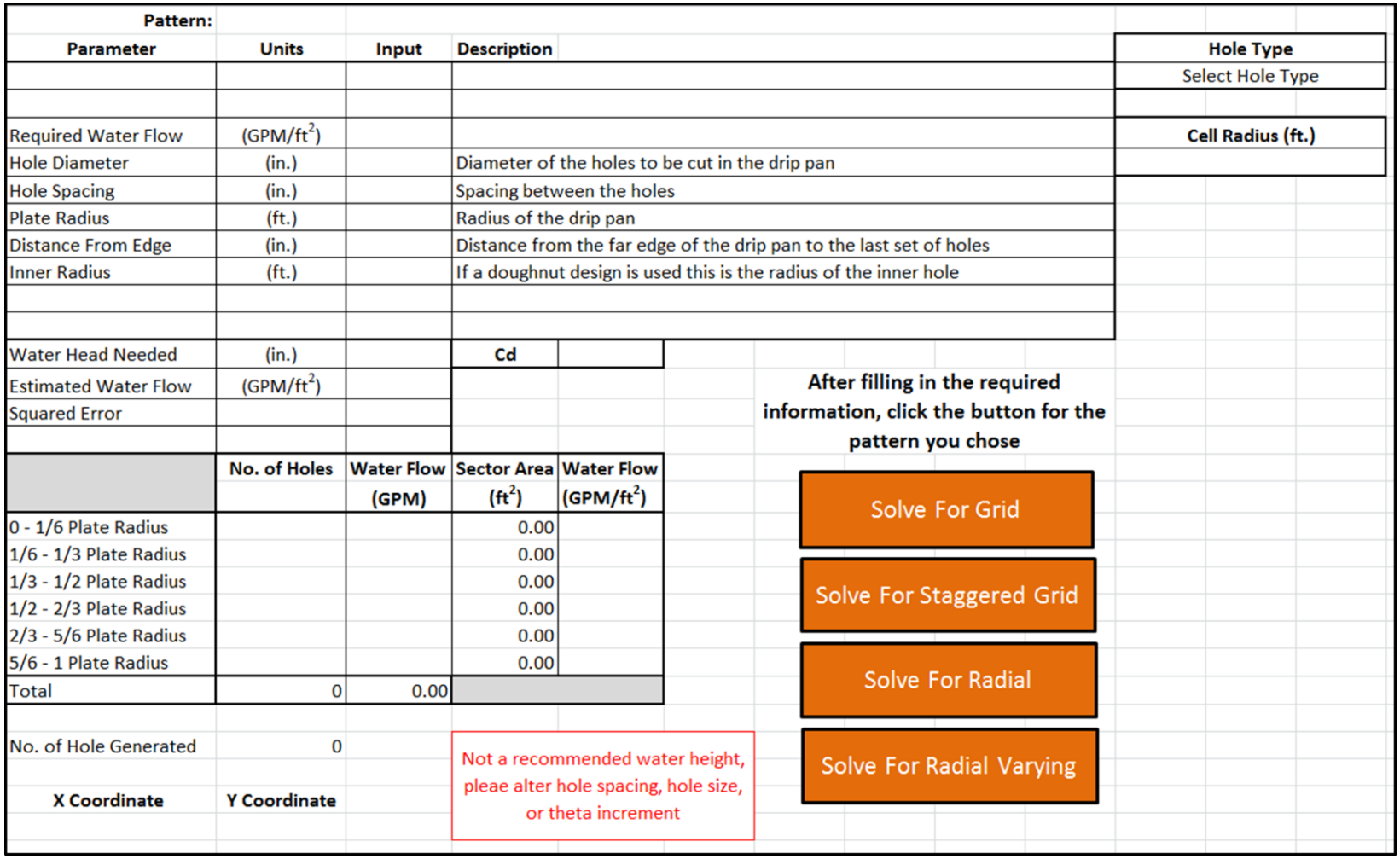


Figure 5.19: User interface for the DripPan sheet.

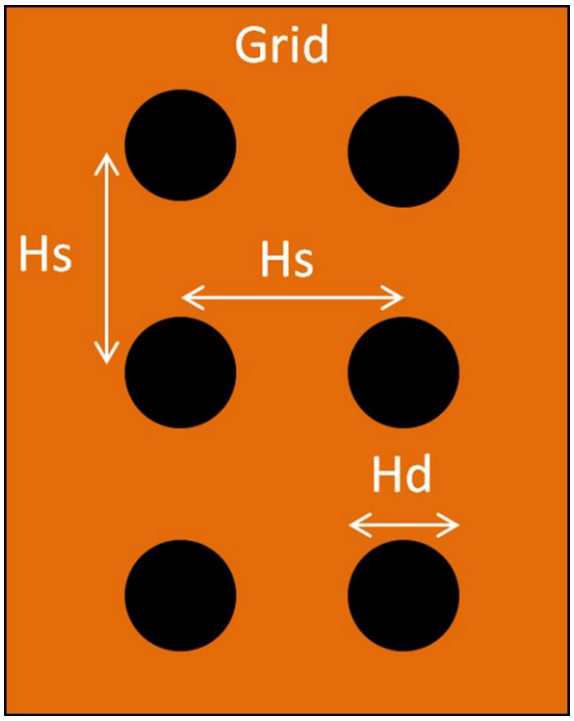


Figure 5.20: Standard grid design used on the DripPan sheet.

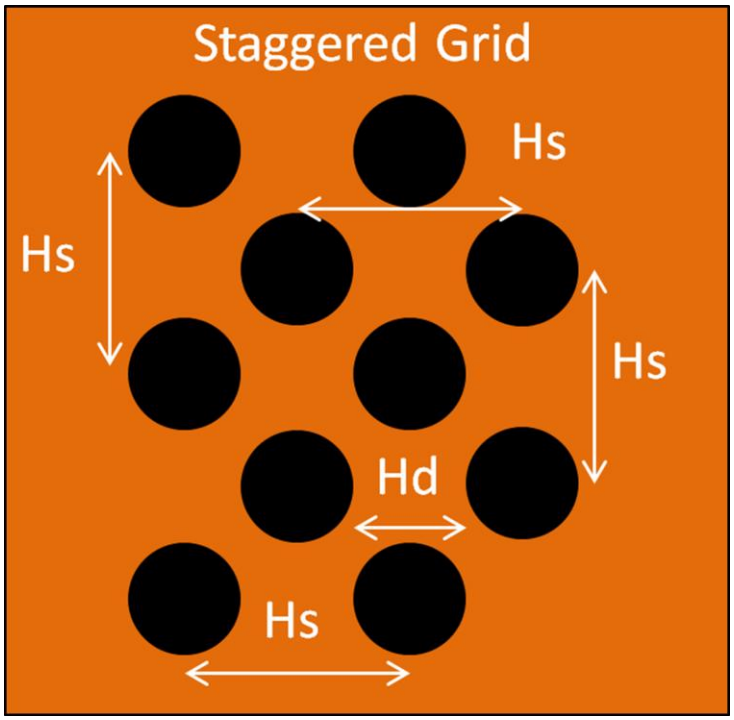


Figure 5.21: Staggered grid design used on the DripPan sheet.

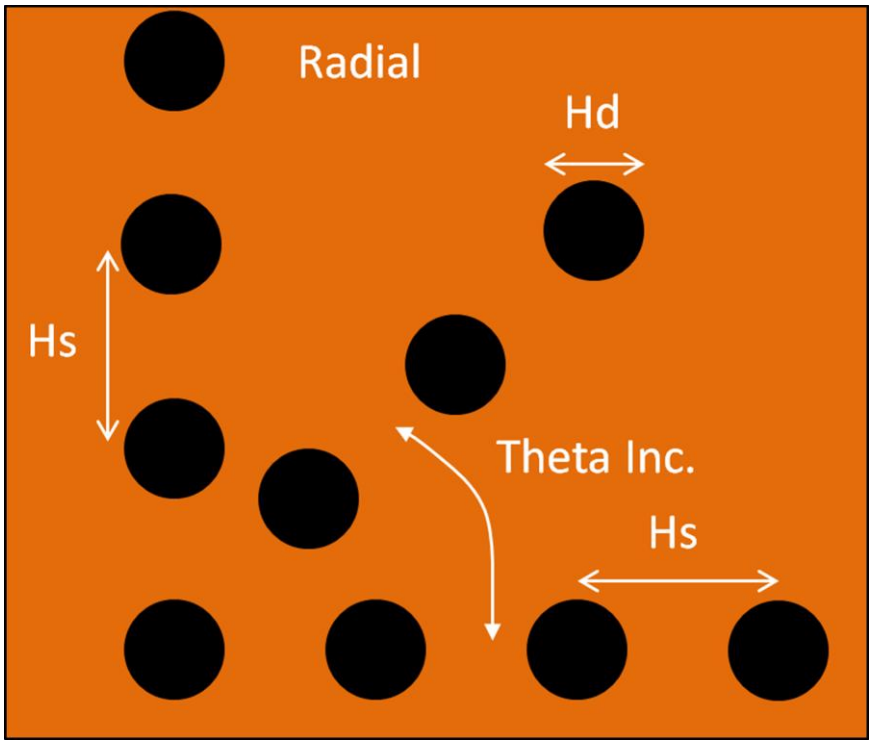


Figure 5.22: Radial pattern used on the DripPan sheet.

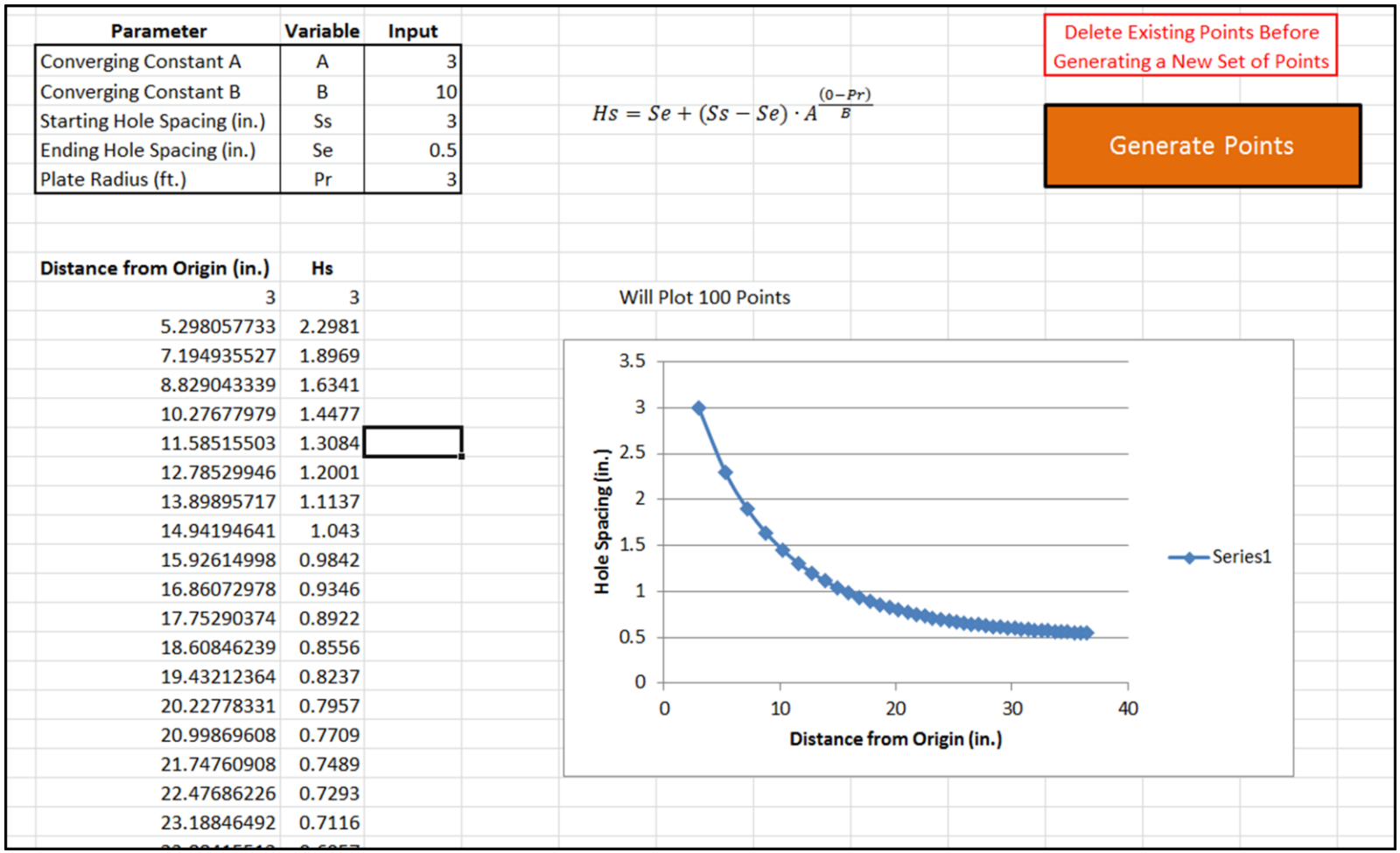
Once all of the possible holes have been generated they are counted based on their position on the plate. The plate is divided into 6 sectors from 0 to 1/6 plate radius up to 5/6 to 1 plate radius. The number of holes present in each sector is reported in the "No. of Holes" column. Lastly, the hole locations are plotted on a chart not shown in Figure 5.19. This allows the user to preview the pattern and make changes if necessary. If changes are made the process must be repeated and any holes previously generated must be deleted.

After the hole generation process is finished the user must click the "Solve for Water Head" button. This button minimizes the error between the desired GPM/ft^2 value and the estimated GPM/ft^2 value. A message box will appear if a water head of less than 1 inch is solved for. This low of a water head will be difficult to monitor and maintain. The message will ask the user to change the hole spacing, hole size, or theta increment. Altering these variables and rerunning the program should result in changes in the flow rate through the plate.

The flow rate across the plate is graphed, not show in Figure 5.19, after obtaining the water head value. This graph shows the water flow rate in GPM/ft^2 for each of the six sectors defined earlier. Normally, holes are evenly spaced on a drip pan. This creates an uneven distribution of water per unit of cell area. Studies have shown that changing the number of holes per unit cell area, changing hole size, or the arrangement of the holes can lead to benefits. A study performed by (Neethling and Cilliers 2001) found the when water is added above a cell more water should be added near the center of the cell. This is more effective because some of the water added near the edge of the cell will simply flow over the weir with the product instead of penetrating the froth. In a separate study (Neethling et al., 2006) found that for submerged water distribution systems it is more effective to have an even distribution per unit of cell area.

The Hole Spacing Calibration sheet helps the user develop an equation that defines hole spacing based on the distance from the origin. This allows for hole spacing to be smaller near the center of the plate and increase towards the edge of the plate or vice versa. Ultimately, this is used to affect the number of holes per unit area of cell surface. The user can obtain a more skewed or even distribution of the water depending on what constants are input in the system.

Figure 5.23 shows the user interface for this portion of the program. The equation that is used to define the hole spacing is presented to the user. The user is then asked to input two converging constants. These constants affect how quickly the hole spacing changes from the starting hole spacing to the ending hole spacing. Large values of constant A will cause the hole spacing to converge quicker, while smaller values of constant B will cause the hole spacing to converge quicker. Once the user has found a set of constants that provide the desired behavior the values are then input into the DripPan sheet using the Radial Varying pattern. Several attempts might be necessary to obtain the desired distribution of water per unit cell area.



Parameter	Variable	Input
Converging Constant A	A	3
Converging Constant B	B	10
Starting Hole Spacing (in.)	Ss	3
Ending Hole Spacing (in.)	Se	0.5
Plate Radius (ft.)	Pr	3

Distance from Origin (in.)	Hs
3	3
5.298057733	2.2981
7.194935527	1.8969
8.829043339	1.6341
10.27677979	1.4477
11.58515503	1.3084
12.78529946	1.2001
13.89895717	1.1137
14.94194641	1.043
15.92614998	0.9842
16.86072978	0.9346
17.75290374	0.8922
18.60846239	0.8556
19.43212364	0.8237
20.22778331	0.7957
20.99869608	0.7709
21.74760908	0.7489
22.47686226	0.7293
23.18846492	0.7116

Figure 5.23: User interface example for the Hole Spacing Calibration sheet.

5.4 Conclusions

The experimental data shows that flow rate through an orifice plate is not dependent on plate thickness for the hole size and plate thickness combinations tested. A fitted model used to predict flow rates was developed based on this data. This model more accurately predicted the flow rates than a purely theoretical model.

Also, a program was developed to aid in the design of drip pans. The program can either be used to design a drip pan based on an existing unit cell, or it can be used to make more customized designs. The program also has the ability to change hole spacing based on the distance from the origin. This allows the user to place more holes near the center or edge of the plate to meet the desired flow per unit of cell area.

6.0 SUMMARY OF CONLCUSIONS

Three distinct phases of work were performed, field testing of the Eriez StackCell, development of the Carbon Partitioning Test, and development of a program to aid in the design of drip pans. The results of the Stack Cell testing showed that changing operating conditions such as froth depth, motor speed, and wash water rate affected concentrate ash as expected with respect to known trends. Changing these conditions had an unexpected effect on the carbon recovery and yield of the StackCell.

It has been shown that that as froth depth increases carbon recovery decreases. The StackCell did not follow this trend. The cell was tested across a froth depths ranging from 12 to 30 inches. The carbon recovery of the cell increased with increasing froth depth up to a maximum of 35.91% at a froth depth of 24 inches. The recovery then immediately fell to 20.54% at the maximum froth depth of 30 inches.

With mechanical cells it is expected that as rotor speed increases so should carbon recovery and yield. As the agitator motor of the StackCell sped up the carbon recovery and yield of the cell held fairly constant at approximately 38-36% and 22% respectively. At the highest agitator motor speed tested, 60 Hz, both recovery and yield plummeted to values of 19.77% and 10.19% respectively.

Lastly, it is generally accepted that as wash water rate increases carbon recovery decreases. This trend holds true for the half of the wash water data collected. The 0 and 260 GPM data sets showed a reduction in carbon recovery from 37.07% to 31.04%. The following data point, 345 GPM, spiked the carbon recovery at 39.32%. The highest wash water rate tested,

400 GPM, saw a drop in carbon recovery back to a value of 33.25%. This recovery is still higher than the pre-spike value.

During testing of the StackCell a large amount of surface turbulence was observed. The anomalies discussed above along with the observation of surface turbulence led to changes in the slurry-air distribution system. Testing of the StackCell also identified that a large portion of high ash material was present in the concentrate. This material was mostly located in the -325 mesh size class, and was having a negative effect on product quality. It was determined that the wash water rings installed on the cells were not adequately providing coverage of the cell's surface area. Due to this, the design of the StackCell was changed to incorporate a drip pan rather than wash water rings. The drip pan provides much better coverage of the cell surface area than the previous design and washes the froth more like a rain rather than jets penetrating the froth.

The Carbon Partitioning Test produces results comparable to those of a traditional release analysis and uses non-specialized equipment to do so. The test uses a blender with a tap which allows for the drainage of material. To perform the test the blender should be loaded to near capacity with slurry, and an initial oil addition should be performed. The total oil added to the slurry should be calibrated to each coal being tested, but initial tests show that a 6 to 7 ratio by weight of carbon to oil provides good results. The blender provides a high shear environment which mixes the oil and slurry. The slurry can then partition into an oil phase and a pulp phase, and the pulp phase can be drained away using the tap. If a good separation is not achieved a small amount of oil can be added and the process can be repeated.

After draining the pulp away, the process continues by introducing dilution water to refill the blender and process is repeated, although no addition oil should be added once a good separation between the carbon and high ash material has been achieved. These additional blends

are used to remove any entrained material from the concentrate, just like refloating the concentrate does in a release analysis. This process should continue until the pulp is visibly clear or an acceptable state of separation has been achieved.

In designing the DripPan program test work was performed to determine the effect that plate thickness has on flow rate. The experimental data showed that flow rate through and orifice plate is not dependent on plate thickness for the hole size and plate thickness combinations tested. Based on this data a fitted model was developed to predict flow rates, and this model proved to be more accurate than a purely theoretical model.

The program itself is meant to aid in the design of drip pans. The program allows the users to design a drip pan based on an existing unit cell, or it can be used to make a more customized design. The program also has the ability to change hole spacing based on the distance from the origin. This allows the user to place more holes near the center or edge of the plate to meet the desired flow per unit of cell area.

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APPENDIX A

Raw and Reconstituted Data for Plant A

Raw Data for the January 11th Sample

Test Conditions

Location:	Plant A	Date:	1/11/2011
Frother:	944	Dosage:	200 ml/min
Collector:	Diesel	Dosage:	480 ml/min
Blower:	50 Hz		
Agitator:	40 Hz		
Plant Feed:	900 TPH		
Wash Water:	320 gal/min		
Air Rate:	460 scfm		
Froth Depth:	21 in.		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.28	8.91	2.63	2.63	3.04	3.04	14.76	14.76
48 x 100	6.18	15.18	9.00	11.63	10.39	13.43	16.78	16.32
100 x 200	6.20	17.01	10.81	22.44	12.48	25.91	28.28	22.08
200 x 325	6.23	15.06	8.83	31.27	10.19	36.10	36.49	26.15
-325	6.33	61.68	55.35	86.62	63.90	100.00	58.74	46.98
		Total	86.62		100.00		46.98	

Total Yield (%)	**28.72**	**Cons Yield (%)**	**84.14**
Total Recovery (%)	**45.01**	**Cons Recovery (%)**	**95.95**
Ash Recovery (%)	**10.32**	**Tails Yield (%)**	**42.55**
Sep. Eff.	**34.70**	**Tails Recovery (%)**	**86.16**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.24	31.71	25.47	25.47	15.47	15.47	3.51	3.51
48 x 100	6.24	56.06	49.82	75.29	30.27	45.74	3.94	3.79
100 x 200	6.29	45.80	39.51	114.80	24.00	69.74	5.26	4.30
200 x 325	6.29	24.85	18.56	133.36	11.28	81.02	6.15	4.56
-325	6.18	37.43	31.25	164.61	18.98	100.00	8.01	5.21
		Total	164.61		100.00		5.21	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.23	8.50	2.27	2.27	7.32	7.32	14.25	14.25
48 x 100	6.24	7.22	0.98	3.25	3.16	10.48	36.75	21.03
100 x 200	6.21	7.32	1.11	4.36	3.58	14.06	64.35	32.06
200 x 325	6.31	7.56	1.25	5.61	4.03	18.09	77.03	42.08
-325	12.58	37.99	25.41	31.02	81.91	100.00	86.90	78.79
		Total	31.02		100.00		78.79	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.27	13.04	6.77	6.77	11.06	11.06	5.68	5.68
48 x 100	6.21	18.77	12.56	19.33	20.52	31.58	12.16	9.89
100 x 200	6.24	18.21	11.97	31.30	19.56	51.14	19.57	13.59
200 x 325	6.20	14.26	8.06	39.36	13.17	64.31	22.60	15.44
-325	6.22	28.06	21.84	61.20	35.69	100.00	20.30	17.17
		Total	61.20		100.00		17.17	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.18	6.76	0.58	0.58	0.70	0.70	77.11	77.11
48 x 100	6.25	7.02	0.77	1.35	0.93	1.63	87.24	82.89
100 x 200	6.19	9.70	3.51	4.86	4.25	5.88	88.55	86.98
200 x 325	6.21	10.45	4.24	9.10	5.13	11.01	90.46	88.60
-325	18.57	92.11	73.54	82.64	88.99	100.00	90.34	90.15
		Total	82.64		100.00		90.15	

Reconstituted Data for the January 11th sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	7.71	7.71	7.71	7.71	7.66	7.66
48 x 100	14.06	21.78	14.06	21.78	10.17	9.28
100 x 200	13.63	35.41	13.63	35.41	22.82	14.49
200 x 325	9.00	44.41	9.00	44.41	34.57	18.56
-325	55.59	100.00	55.59	100.00	69.68	46.98
Total	100.00		100.00		46.98	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	27.74	27.74	14.18	14.18	4.39	4.39
48 x 100	50.80	78.54	25.97	40.15	4.57	4.51
100 x 200	40.62	119.16	20.76	60.91	6.87	5.31
200 x 325	19.81	138.97	10.13	71.04	10.62	6.07
-325	56.66	195.63	28.96	100.00	43.39	16.88
Total	195.63		100.00		16.88	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	7.35	7.35	5.11	5.11	11.32	11.32
48 x 100	13.33	20.68	9.27	14.38	16.50	14.66
100 x 200	15.48	36.16	10.76	25.14	35.21	23.46
200 x 325	12.30	48.46	8.55	33.69	45.99	29.18
-325	95.38	143.84	66.31	100.00	74.30	59.10
Total	143.84		100.00		59.10	

Raw Data for the January 19th Sample

Test Conditions

Location:	Plant A	Date:	1/19/2011
Frother:	944	Dosage:	240 ml/min
Collector:	Diesel	Dosage:	360 ml/min
Blower:	50 Hz (Off)		
Agitator:	43 Hz		
Plant Feed:	800 TPH		
Wash Water:	330 gal/min		
Air Rate:	465 scfm (Air Compressor)		
Froth Depth:	12 in.		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.31	10.66	4.35	4.35	4.24	4.24	11.96	11.96
48 x 100	6.25	19.07	12.82	17.17	12.49	16.73	12.17	12.12
100 x 200	6.15	22.80	16.65	33.82	16.23	32.96	17.18	14.61
200 x 325	6.27	15.77	9.50	43.32	9.26	42.22	19.56	15.70
-325	6.26	65.55	59.29	102.61	57.78	100.00	47.77	34.23
		Total	102.61		100.00		34.23	

Total Yield (%)	**34.30**	**Cons Yield (%)**	**93.96**
Total Recovery (%)	**47.17**	**Cons Recovery (%)**	**98.78**
Ash Recovery (%)	**9.56**	**Tails Yield (%)**	**55.93**
Sep. Eff.	**37.62**	**Tails Recovery (%)**	**90.13**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.23	23.48	17.25	17.25	6.78	6.78	3.88	3.88
48 x 100	6.14	76.63	70.49	87.74	27.69	34.46	4.57	4.43
100 x 200	6.23	66.11	59.88	147.62	23.52	57.98	4.63	4.51
200 x 325	6.21	42.90	36.69	184.31	14.41	72.39	4.70	4.55
-325	6.27	76.55	70.28	254.59	27.61	100.00	5.82	4.90
		Total	254.59		100.00		4.90	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.23	7.25	1.02	1.02	6.23	6.23	14.18	14.18
48 x 100	6.22	6.42	0.20	1.22	1.22	7.46	51.50	20.30
100 x 200	6.17	6.43	0.26	1.48	1.59	9.05	66.62	28.44
200 x 325	6.23	6.53	0.30	1.78	1.83	10.88	72.76	35.91
-325	12.33	26.91	14.58	16.36	89.12	100.00	87.28	81.69
		Total	16.36		100.00		81.69	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.20	10.94	4.74	4.74	7.19	7.19	8.50	8.50
48 x 100	6.19	17.09	10.90	15.64	16.53	23.71	11.13	10.33
100 x 200	6.26	24.11	17.85	33.49	27.07	50.78	14.03	12.30
200 x 325	6.24	15.40	9.16	42.65	13.89	64.67	16.64	13.23
-325	6.23	29.53	23.30	65.95	35.33	100.00	17.63	14.79
		Total	65.95		100.00		14.79	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.12	6.29	0.17	0.17	0.33	0.33	70.95	70.95
48 x 100	6.22	6.52	0.30	0.47	0.58	0.90	75.92	74.12
100 x 200	6.18	7.72	1.54	2.01	2.96	3.87	80.87	79.29
200 x 325	6.18	7.98	1.80	3.81	3.46	7.33	81.03	80.11
-325	12.45	60.60	48.15	51.96	92.67	100.00	88.79	88.15
		Total	51.96		100.00		88.15	

Reconstituted Data for the January 19th sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.05	5.05	5.05	5.05	7.82	7.82
48 x 100	15.19	20.24	15.19	20.24	8.06	8.00
100 x 200	18.42	38.66	18.42	38.66	13.37	10.56
200 x 325	10.79	49.44	10.79	49.44	17.68	12.11
-325	50.56	100.00	50.56	100.00	55.86	34.23
Total	100.00		100.00		34.23	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	18.27	18.27	6.74	6.74	4.46	4.46
48 x 100	70.69	88.96	26.09	32.83	4.70	4.65
100 x 200	60.14	149.10	22.20	55.03	4.90	4.75
200 x 325	36.99	186.09	13.65	68.68	5.25	4.85
-325	84.86	270.95	31.32	100.00	19.82	9.54
Total	270.95		100.00		9.54	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	4.91	4.91	4.16	4.16	10.66	10.66
48 x 100	11.20	16.11	9.50	13.66	12.87	12.19
100 x 200	19.39	35.50	16.44	30.11	19.34	16.10
200 x 325	10.96	46.46	9.30	39.40	27.22	18.72
-325	71.45	117.91	60.60	100.00	65.58	47.12
Total	117.91		100.00		47.12	

Raw Data for the February 1st Sample

Test Conditions

Location:	Plant A	Date:	2/1/2011
Frother:	944	Dosage:	250 ml/min
Collector:	Diesel	Dosage:	480 ml/min
Blower:	23 Hz		
Agitator:	43 Hz		
Plant Feed:	700 TPH		
Wash Water:	274 gal/min		
Air Rate:	470 scfm		
Froth Depth:	12 in.		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.26	12.57	6.31	6.31	6.59	6.59	8.72	8.72
48 x 100	6.14	18.39	12.25	18.56	12.78	19.37	8.70	8.71
100 x 200	6.28	20.22	13.94	32.50	14.55	33.92	15.67	11.69
200 x 325	6.22	14.83	8.61	41.11	8.99	42.90	20.52	13.54
-325	6.22	60.93	54.71	95.82	57.10	100.00	48.41	33.45
		Total	95.82		100.00		33.45	

Total Yield (%)	**26.53**	**Cons Yield (%)**	**94.50**
Total Recovery (%)	**36.16**	**Cons Recovery (%)**	**98.86**
Ash Recovery (%)	**7.37**	**Tails Yield (%)**	**60.59**
Sep. Eff.	**28.80**	**Tails Recovery (%)**	**91.78**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.21	28.76	22.55	22.55	11.35	11.35	3.73	3.73
48 x 100	6.19	52.44	46.25	68.80	23.28	34.64	5.19	4.71
100 x 200	6.14	57.70	51.56	120.36	25.96	60.59	5.01	4.84
200 x 325	6.23	31.96	25.73	146.09	12.95	73.55	4.72	4.82
-325	6.29	58.84	52.55	198.64	26.45	100.00	5.88	5.10
		Total	198.64		100.00		5.10	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.14	6.95	0.81	0.81	7.01	7.01	14.39	14.39
48 x 100	6.18	6.26	0.08	0.89	0.69	7.70	42.45	16.91
100 x 200	6.24	6.36	0.12	1.01	1.04	8.74	69.88	23.21
200 x 325	6.28	6.44	0.16	1.17	1.38	10.12	0.00	20.03
-325	6.16	16.55	10.39	11.56	89.88	100.00	88.16	81.26
		Total	11.56		100.00		81.26	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.31	13.24	6.93	6.93	12.21	12.21	6.49	6.49
48 x 100	6.16	18.86	12.70	19.63	22.37	34.58	8.83	8.00
100 x 200	6.19	20.26	14.07	33.70	24.78	59.36	15.42	11.10
200 x 325	6.29	14.61	8.32	42.02	14.66	74.02	14.00	11.67
-325	6.28	21.03	14.75	56.77	25.98	100.00	14.52	12.41
		Total	56.77		100.00		12.41	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.18	6.63	0.45	0.45	1.22	1.22	47.28	47.28
48 x 100	6.19	6.54	0.35	0.80	0.95	2.17	67.77	56.24
100 x 200	6.22	7.47	1.25	2.05	3.39	5.55	85.16	73.88
200 x 325	6.18	7.71	1.53	3.58	4.14	9.70	85.62	78.90
-325	6.22	39.56	33.34	36.92	90.30	100.00	88.91	87.94
		Total	36.92		100.00		87.94	

Reconstituted Data for the February 1st sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	8.74	8.74	8.74	8.74	7.33	7.33
48 x 100	16.08	24.82	16.08	24.82	8.54	8.11
100 x 200	18.54	43.35	18.54	43.35	15.50	11.27
200 x 325	10.99	54.34	10.99	54.34	19.05	12.84
-325	45.66	100.00	45.66	100.00	57.98	33.45
Total	100.00		100.00		33.45	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	23.36	23.36	11.11	11.11	4.10	4.10
48 x 100	46.33	69.69	22.04	33.15	5.25	4.87
100 x 200	51.68	121.37	24.59	57.74	5.16	4.99
200 x 325	25.89	147.26	12.32	70.06	4.69	4.94
-325	62.94	210.20	29.94	100.00	19.46	9.29
Total	210.20		100.00		9.29	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	7.38	7.38	7.88	7.88	8.98	8.98
48 x 100	13.05	20.43	13.93	21.81	10.41	9.89
100 x 200	15.32	35.75	16.35	38.16	21.11	14.70
200 x 325	9.85	45.60	10.51	48.67	25.12	16.95
-325	48.09	93.69	51.33	100.00	66.09	42.18
Total	93.69		100.00		42.18	

Raw Data for the February 10th Sample

Test Conditions

Location:	Plant A	Date:	2/10/2011
Frother:	944	Dosage:	225 ml/min
Collector:	Diesel	Dosage:	460 ml/min
Blower:	22.9 Hz		
Agitator:	44.6 Hz		
Plant Feed:	680 TPH		
Wash Water:	312 gal/min		
Air Rate:	484 scfm		
Froth Depth:	Not Reported		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.20	14.62	8.42	8.42	5.61	5.61	16.99	16.99
48 x 100	6.21	22.19	15.98	24.40	10.65	16.26	11.53	13.41
100 x 200	6.19	24.83	18.64	43.04	12.42	28.69	24.01	18.00
200 x 325	6.18	19.74	13.56	56.60	9.04	37.72	24.55	19.57
-325	6.28	99.72	93.44	150.04	62.28	100.00	58.55	43.85
		Total	150.04		100.00		43.85	

Total Yield (%)	**24.89**	**Cons Yield (%)**	**95.84**
Total Recovery (%)	**40.29**	**Cons Recovery (%)**	**99.53**
Ash Recovery (%)	**5.17**	**Tails Yield (%)**	**44.48**
Sep. Eff.	**35.12**	**Tails Recovery (%)**	**87.86**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.25	68.45	62.20	62.20	8.36	8.36	5.63	5.63
48 x 100	6.12	299.41	293.29	355.49	39.42	47.78	5.57	5.58
100 x 200	6.18	262.95	256.77	612.26	34.51	82.30	5.53	5.56
200 x 325	6.29	78.44	72.15	684.41	9.70	92.00	5.56	5.56
-325	6.27	65.80	59.53	743.94	8.00	100.00	6.20	5.61
		Total	743.94		100.00		5.61	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.22	6.43	0.21	0.21	0.65	0.65	24.82	24.82
48 x 100	6.22	6.30	0.08	0.29	0.25	0.90	38.41	28.57
100 x 200	6.29	6.56	0.27	0.56	0.84	1.73	69.17	48.14
200 x 325	6.21	6.52	0.31	0.87	0.96	2.69	78.14	58.83
-325	12.27	43.69	31.42	32.29	97.31	100.00	90.61	89.75
		Total	32.29		100.00		89.75	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.22	12.73	6.51	6.51	6.76	6.76	8.17	8.17
48 x 100	6.27	22.99	16.72	23.23	17.37	24.13	8.95	8.73
100 x 200	6.21	30.07	23.86	47.09	24.78	48.91	12.06	10.42
200 x 325	6.23	20.20	13.97	61.06	14.51	63.42	10.69	10.48
-325	6.21	41.43	35.22	96.28	36.58	100.00	14.14	11.82
		Total	96.28		100.00		11.82	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.28	8.62	2.34	2.34	1.95	1.95	56.67	56.67
48 x 100	6.16	7.40	1.24	3.58	1.03	2.98	84.01	66.14
100 x 200	6.16	10.54	4.38	7.96	3.64	6.62	89.18	78.82
200 x 325	6.07	10.13	4.06	12.02	3.38	10.00	89.46	82.41
-325	6.24	114.40	108.16	120.18	90.00	100.00	91.11	90.24
		Total	120.18		100.00		90.24	

Reconstituted Data for the February 10th sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.07	5.07	5.07	5.07	14.96	14.96
48 x 100	15.64	20.71	15.64	20.71	8.99	10.45
100 x 200	18.04	38.75	18.04	38.75	15.60	12.85
200 x 325	8.58	47.33	8.58	47.33	22.32	14.56
-325	52.67	100.00	52.67	100.00	70.16	43.85
Total	100.00		100.00		43.85	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	62.41	62.41	8.04	8.04	5.69	5.69
48 x 100	293.37	355.78	37.79	45.83	5.58	5.60
100 x 200	257.04	612.82	33.11	78.95	5.60	5.60
200 x 325	72.46	685.28	9.33	88.28	5.87	5.63
-325	90.95	776.23	11.72	100.00	35.36	9.11
Total	776.23		100.00		9.11	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	8.85	8.85	4.09	4.09	20.99	20.99
48 x 100	17.96	26.81	8.30	12.39	14.13	16.40
100 x 200	28.24	55.05	13.05	25.43	24.02	20.31
200 x 325	18.03	73.08	8.33	33.76	28.43	22.31
-325	143.38	216.46	66.24	100.00	72.20	55.36
Total	216.46		100.00		55.36	

Raw Data for the February 16th Sample

Test Conditions

Location:	Plant A	Date:	2/16/2011
Frother:	944	Dosage:	180 ml/min
Collector:	Diesel	Dosage:	460 ml/min
Blower:	27.9 Hz		
Agitator:	46.1 Hz		
Plant Feed:	680 TPH		
Wash Water:	315 gal/min		
Air Rate:	715 scfm		
Froth Depth:	15 in.		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.19	14.81	8.62	8.62	4.47	4.47	19.39	19.39
48 x 100	6.27	25.11	18.84	27.46	9.78	14.25	9.18	12.39
100 x 200	6.30	30.67	24.37	51.83	12.65	26.90	21.08	16.47
200 x 325	6.25	23.38	17.13	68.96	8.89	35.79	23.00	18.09
-325	6.27	129.98	123.71	192.67	64.21	100.00	58.75	44.20
		Total	192.67		100.00		44.20	

Total Yield (%)	**37.32**	**Cons Yield (%)**	**91.50**
Total Recovery (%)	**58.47**	**Cons Recovery (%)**	**98.65**
Ash Recovery (%)	**10.61**	**Tails Yield (%)**	**37.64**
Sep. Eff.	**47.86**	**Tails Recovery (%)**	**84.98**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.22	37.95	31.73	31.73	7.65	7.65	4.36	4.36
48 x 100	6.28	88.94	82.66	114.39	19.93	27.58	5.43	5.13
100 x 200	6.20	108.93	102.73	217.12	24.76	52.34	5.55	5.33
200 x 325	6.18	64.18	58.00	275.12	13.98	66.32	5.87	5.44
-325	6.25	145.96	139.71	414.83	33.68	100.00	6.31	5.74
		Total	414.83		100.00		5.74	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.28	8.32	2.04	2.04	5.30	5.30	13.63	13.63
48 x 100	6.13	6.43	0.30	2.34	0.78	6.07	49.33	18.21
100 x 200	6.18	6.61	0.43	2.77	1.12	7.19	77.86	27.47
200 x 325	6.26	6.83	0.57	3.34	1.48	8.67	83.80	37.08
-325	6.19	41.37	35.18	38.52	91.33	100.00	90.74	86.09
		Total	38.52		100.00		86.09	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.23	10.10	3.87	3.87	8.26	8.26	9.51	9.51
48 x 100	6.23	13.59	7.36	11.23	15.72	23.98	12.90	11.73
100 x 200	6.28	18.05	11.77	23.00	25.13	49.11	16.29	14.06
200 x 325	6.09	13.54	7.45	30.45	15.91	65.02	18.98	15.27
-325	6.17	22.55	16.38	46.83	34.98	100.00	18.87	16.53
		Total	46.83		100.00		16.53	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.18	8.06	1.88	1.88	2.42	2.42	70.37	70.37
48 x 100	6.25	6.97	0.72	2.60	0.93	3.35	86.07	74.72
100 x 200	6.20	8.14	1.94	4.54	2.50	5.85	89.72	81.13
200 x 325	6.25	8.82	2.57	7.11	3.31	9.16	90.19	84.40
-325	6.29	76.78	70.49	77.60	90.84	100.00	91.77	91.10
		Total	77.60		100.00		91.10	

Reconstituted Data for the February 16th sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.68	5.68	5.68	5.68	17.42	17.42
48 x 100	10.90	16.58	10.90	16.58	10.75	13.04
100 x 200	15.40	31.97	15.40	31.97	15.19	14.08
200 x 325	9.87	41.84	9.87	41.84	22.29	16.01
-325	58.16	100.00	58.16	100.00	64.48	44.20
Total	100.00		100.00		44.20	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	33.77	33.77	7.45	7.45	4.92	4.92
48 x 100	82.96	116.73	18.30	25.75	5.59	5.40
100 x 200	103.16	219.89	22.76	48.50	5.85	5.61
200 x 325	58.57	278.46	12.92	61.42	6.63	5.82
-325	174.89	453.35	38.58	100.00	23.29	12.56
Total	453.35		100.00		12.56	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.75	5.75	4.62	4.62	29.41	29.41
48 x 100	8.08	13.83	6.49	11.11	19.42	23.57
100 x 200	13.71	27.54	11.02	22.13	26.68	25.12
200 x 325	10.02	37.56	8.05	30.19	37.24	28.35
-325	86.87	124.43	69.81	100.00	78.02	63.03
Total	124.43		100.00		63.03	

Raw Data for the March 8th Sample

Test Conditions

Location:	Plant A	Date:	3/8/2011
Frother:	944	Dosage:	200 ml/min
Collector:	Diesel	Dosage:	480 ml/min
Blower:	24 Hz		
Agitator:	45 Hz		
Plant Feed:	N/A		
Wash Water:	317 gal/min		
Air Rate:	600 scfm		
Froth Depth:	18 in.		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.18	16.73	10.55	10.55	5.56	5.56	13.05	13.05
48 x 100	6.31	29.36	23.05	33.60	12.14	17.70	11.09	11.71
100 x 325	6.21	55.75	49.54	83.14	26.09	43.79	23.78	18.90
-325	6.16	112.87	106.71	189.85	56.21	100.00	56.44	40.00
		Total	189.85		100.00		40.00	

Total Yield (%)	**32.55**	**Cons Yield (%)**	**93.67**
Total Recovery (%)	**49.19**	**Cons Recovery (%)**	**98.26**
Ash Recovery (%)	**7.58**	**Tails Yield (%)**	**45.00**
Sep. Eff.	**41.61**	**Tails Recovery (%)**	**87.24**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.21	26.72	20.51	20.51	8.30	8.30	3.85	3.85
48 x 100	6.10	63.58	57.48	77.99	23.25	31.55	4.49	4.32
100 x 325	6.27	106.47	100.20	178.19	40.54	72.09	5.02	4.71
-325	6.32	75.31	68.99	247.18	27.91	100.00	5.27	4.87
		Total	247.18		100.00		4.87	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.27	8.25	1.98	1.98	11.86	11.86	9.93	9.93
48 x 100	6.19	6.44	0.25	2.23	1.50	13.35	42.90	13.63
100 x 325	6.22	6.81	0.59	2.82	3.53	16.89	71.28	25.69
-325	6.36	20.24	13.88	16.70	83.11	100.00	85.18	75.13
		Total	16.70		100.00		75.13	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.21	10.46	4.25	4.25	7.82	7.82	8.13	8.13
48 x 100	6.28	16.96	10.68	14.93	19.64	27.46	10.07	9.52
100 x 325	6.25	25.71	19.46	34.39	35.79	63.25	14.20	12.17
-325	6.27	26.25	19.98	54.37	36.75	100.00	12.75	12.38
		Total	54.37		100.00		12.38	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.17	7.30	1.13	1.13	1.70	1.70	55.67	55.67
48 x 100	6.18	6.75	0.57	1.70	0.86	2.56	82.40	64.63
100 x 325	6.23	11.24	5.01	6.71	7.54	10.10	89.71	83.36
-325	18.60	78.34	59.74	66.45	89.90	100.00	90.21	89.52
		Total	66.45		100.00		89.52	

Reconstituted Data for the March 8th sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.78	5.78	5.78	5.78	11.52	11.52
48 x 100	13.40	19.18	13.40	19.18	8.91	9.70
100 x 325	26.09	45.27	26.09	45.27	18.11	14.54
-325	54.73	100.00	54.73	100.00	61.06	40.00
Total	100.00		100.00		40.00	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	22.49	22.49	8.52	8.52	4.39	4.39
48 x 100	57.73	80.22	21.88	30.40	4.66	4.58
100 x 325	100.79	181.01	38.20	68.60	5.41	5.04
-325	82.87	263.88	31.40	100.00	18.65	9.32
Total	263.88		100.00		9.32	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.38	5.38	4.45	4.45	18.12	18.12
48 x 100	11.25	16.63	9.31	13.76	13.73	15.15
100 x 325	24.47	41.10	20.25	34.02	29.66	23.79
-325	79.72	120.82	65.98	100.00	70.80	54.81
Total	120.82		100.00		54.81	

Raw Data for the March 14th Sample

Test Conditions

Location:	Plant A	Date:	3/14/2011
Frother:	944	Dosage:	200 ml/min
Collector:	Diesel	Dosage:	480 ml/min
Blower:	24 Hz		
Agitator:	45 Hz		
Plant Feed:	660 tph		
Wash Water:	530 gal/min clear		
Air Rate:	600 scfm		
Froth Depth:	28 in.		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.23	18.22	11.99	11.99	7.10	7.10	12.99	12.99
48 x 100	6.17	24.29	18.12	30.11	10.74	17.84	13.25	13.15
100 x 325	6.17	45.59	39.42	69.53	23.36	41.20	24.39	19.52
-325	6.09	105.34	99.25	168.78	58.80	100.00	55.11	40.45
		Total	168.78		100.00		40.45	

Total Yield (%)	**25.81**	**Cons Yield (%)**	**95.78**
Total Recovery (%)	**40.37**	**Cons Recovery (%)**	**98.14**
Ash Recovery (%)	**4.39**	**Tails Yield (%)**	**48.99**
Sep. Eff.	**35.97**	**Tails Recovery (%)**	**89.00**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.21	29.98	23.77	23.77	8.93	8.93	4.00	4.00
48 x 100	6.19	68.15	61.96	85.73	23.27	32.20	4.11	4.08
100 x 325	6.20	123.05	116.85	202.58	43.89	76.09	4.84	4.52
-325	6.08	69.75	63.67	266.25	23.91	100.00	4.82	4.59
		Total	266.25		100.00		4.59	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.21	9.62	3.41	3.41	29.10	29.10	7.63	7.63
48 x 100	6.11	6.28	0.17	3.58	1.45	30.55	29.46	8.67
100 x 325	6.22	6.47	0.25	3.83	2.13	32.68	52.50	11.53
-325	6.30	14.19	7.89	11.72	67.32	100.00	81.89	58.90
		Total	11.72		100.00		58.90	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.05	10.71	4.66	4.66	8.48	8.48	8.13	8.13
48 x 100	6.24	17.00	10.76	15.42	19.58	28.06	9.56	9.13
100 x 325	6.25	27.09	20.84	36.26	37.93	65.99	14.86	12.42
-325	6.25	24.94	18.69	54.95	34.01	100.00	14.22	13.03
		Total	54.95		100.00		13.03	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.14	7.95	1.81	1.81	3.16	3.16	64.61	64.61
48 x 100	6.17	6.76	0.59	2.40	1.03	4.20	83.64	69.29
100 x 325	6.16	10.85	4.69	7.09	8.20	12.39	89.55	82.69
-325	12.31	62.43	50.12	57.21	87.61	100.00	90.67	89.68
		Total	57.21		100.00		89.68	

Reconstituted Data for the March 14th sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.80	6.80	6.80	6.80	16.71	16.71
48 x 100	13.28	20.08	13.28	20.08	9.40	11.87
100 x 325	27.76	47.84	27.76	47.84	19.32	16.20
-325	52.16	100.00	52.16	100.00	62.70	40.45
Total	100.00		100.00		40.45	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	27.18	27.18	9.78	9.78	4.46	4.46
48 x 100	62.13	89.31	22.35	32.13	4.18	4.26
100 x 325	117.10	206.41	42.13	74.26	4.94	4.65
-325	71.56	277.97	25.74	100.00	13.32	6.88
Total	277.97		100.00		6.88	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.47	6.47	5.77	5.77	23.93	23.93
48 x 100	11.35	17.82	10.12	15.89	13.41	17.23
100 x 325	25.53	43.35	22.76	38.65	28.58	23.91
-325	68.81	112.16	61.35	100.00	69.90	52.13
Total	112.16		100.00		52.13	

Raw Data for the March 24th Sample

Test Conditions

Location:	Plant A	Date:	3/24/2011
Frother:	944	Dosage:	200 ml/min
Collector:	Diesel	Dosage:	480 ml/min
Blower:	24 Hz		
Agitator:	44 Hz		
Plant Feed:	620 tph		
Wash Water:	500 gal/min		
Air Rate:	599 scfm		
Froth Depth:	24 in.		

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.20	14.60	8.40	8.40	5.12	5.12	16.47	16.47
48 x 100	6.15	21.79	15.64	24.04	9.54	14.66	14.37	15.10
100 x 325	6.20	42.39	36.19	60.23	22.06	36.72	25.42	21.30
-325	6.10	109.89	103.79	164.02	63.28	100.00	59.54	45.50
		Total	164.02		100.00		45.50	

Total Yield (%)	**26.50**	**Cons Yield (%)**	**94.29**
Total Recovery (%)	**44.00**	**Cons Recovery (%)**	**98.56**
Ash Recovery (%)	**5.54**	**Tails Yield (%)**	**40.53**
Sep. Eff.	**38.46**	**Tails Recovery (%)**	**84.47**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.20	34.48	28.28	28.28	7.75	7.75	4.69	4.69
48 x 100	6.24	82.01	75.77	104.05	20.77	28.52	5.67	5.40
100 x 325	6.30	146.26	139.96	244.01	38.37	66.89	5.35	5.37
-325	6.22	127.00	120.78	364.79	33.11	100.00	5.48	5.41
		Total	364.79		100.00		5.41	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.10	8.86	2.76	2.76	12.49	12.49	21.26	21.26
48 x 100	6.02	6.36	0.34	3.10	1.54	14.03	59.36	25.44
100 x 325	6.24	7.20	0.96	4.06	4.35	18.38	76.19	37.44
-325	6.23	24.26	18.03	22.09	81.62	100.00	86.22	77.25
		Total	22.09		100.00		77.25	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.22	9.60	3.38	3.38	6.28	6.28	7.41	7.41
48 x 100	6.23	15.35	9.12	12.50	16.95	23.23	11.95	10.72
100 x 325	6.35	26.53	20.18	32.68	37.50	60.72	14.64	13.14
-325	6.16	27.30	21.14	53.82	39.28	100.00	13.97	13.47
		Total	53.82		100.00		13.47	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.08	8.01	1.93	1.93	2.44	2.44	45.87	45.87
48 x 100	6.15	6.94	0.79	2.72	1.00	3.44	77.38	55.02
100 x 325	6.03	11.71	5.68	8.40	7.19	10.64	89.54	78.36
-325	6.09	76.65	70.56	78.96	89.36	100.00	90.44	89.16
		Total	78.96		100.00		89.16	

Reconstituted Data for the March 24th sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.07	5.07	5.07	5.07	15.00	15.00
48 x 100	10.70	15.76	10.70	15.76	11.68	12.75
100 x 325	23.97	39.73	23.97	39.73	20.92	17.68
-325	60.27	100.00	60.27	100.00	63.84	45.50
Total	100.00		100.00		45.50	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	31.04	31.04	8.02	8.02	6.16	6.16
48 x 100	76.11	107.15	19.67	27.70	5.91	5.98
100 x 325	140.92	248.07	36.42	64.12	5.83	5.90
-325	138.81	386.88	35.88	100.00	15.97	9.51
Total	386.88		100.00		9.51	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.31	5.31	4.00	4.00	21.39	21.39
48 x 100	9.91	15.22	7.46	11.46	17.17	18.64
100 x 325	25.86	41.08	19.48	30.94	31.09	26.48
-325	91.70	132.78	69.06	100.00	72.81	58.48
Total	132.78		100.00		58.48	

Raw Data for the August 11th Sample

Test Conditions

Location: Plant A
Date: 8/11/2011

Frother: 944
Dosage: 225 ml/min
Collector: Diesel
Dosage: 500 ml/min

Blower: 24 Hz
Agitator: 44 Hz
Plant Feed: 900 tph
Wash Water: 500 gal/min
Air Rate: 568 scfm

Froth Depth: 22 in.

Notes: 0.08 g of mater in the Con Sink +100

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.33	8.99	2.66	2.66	1.81	1.81	7.10	7.10
48 x 100	6.34	14.95	8.61	11.27	5.87	7.68	10.98	10.06
100 x 325	6.21	34.13	27.92	39.19	19.03	26.71	28.01	22.85
-325	6.25	113.79	107.54	146.73	73.29	100.00	68.30	56.16
		Total	146.73		100.00		56.16	

Total Yield (%)	**27.58**	**Cons Yield (%)**	**88.67**
Total Recovery (%)	**55.21**	**Cons Recovery (%)**	**96.30**
Ash Recovery (%)	**6.01**	**Tails Yield (%)**	**23.18**
Sep. Eff.	**49.20**	**Tails Recovery (%)**	**75.57**

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.33	16.92	10.59	10.59	5.40	5.40	3.90	3.90
48 x 100	6.22	42.67	36.45	47.04	18.60	24.01	4.59	4.43
100 x 325	6.19	93.05	86.86	133.90	44.33	68.34	4.85	4.70
-325	6.31	68.35	62.04	195.94	31.66	100.00	4.64	4.68
		Total	195.94		100.00		4.68	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.15	6.70	0.55	0.55	2.20	2.20	69.92	69.92
-325	6.27	30.75	24.48	25.03	97.80	100.00	71.39	71.36
		Total	25.03		100.00		71.36	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.16	7.41	1.25	1.25	4.24	4.24	6.95	6.95
48 x 100	6.23	10.27	4.04	5.29	13.71	17.96	11.50	10.42
100 x 325	6.29	17.65	11.36	16.65	38.56	56.52	13.69	12.65
-325	6.30	19.11	12.81	29.46	43.48	100.00	10.26	11.61
		Total	29.46		100.00		11.61	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48 x 100	6.33	6.71	0.38	0.38	0.39	0.39	87.83	87.83
100 x 325	6.20	12.04	5.84	6.22	5.98	6.37	91.43	91.21
-325	6.34	97.75	91.41	97.63	93.63	100.00	91.39	91.38
		Total	97.63		100.00		91.38	

Reconstituted Data for the August 11th sample

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	2.03	2.03	2.03	2.03	4.97	4.97
48 x 100	7.07	9.10	7.07	9.10	9.39	8.40
100 x 325	20.71	29.81	20.71	29.81	21.74	17.67
-325	70.19	100.00	70.19	100.00	72.51	56.16
Total	100.00		100.00		56.16	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	10.59	10.59	4.79	4.79	3.90	3.90
48 x 100	36.45	47.04	16.50	21.29	4.59	4.43
100 x 325	87.41	134.45	39.56	60.85	5.26	4.97
-325	86.52	220.97	39.15	100.00	23.53	12.24
Total	220.97		100.00		12.24	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	1.25	1.25	0.98	0.98	6.95	6.95
48 x 100	4.42	5.67	3.48	4.46	18.06	15.61
100 x 325	17.20	22.87	13.53	18.00	40.09	34.02
-325	104.22	127.09	82.00	100.00	81.42	72.89
Total	127.09		100.00		72.89	

APPENDIX B

Raw and Reconstituted Data for Plant B

Raw Data for Plant B Test #1

Test Conditions

Location: Plant B
Date: 8/16/2011
Notes: Tail Sink +100 weighed 0.09 g, did not Ash

Frother:
Dosage: 160 ml/min
Collector:
Dosage: 0 ml/min

Air: 107%, 9.2 psi
Agitator: 45 Hz
Plant Feed:
Wash Water: 360 gal/min

Froth Depth: 30 in.

Feed

Bucket and Slurry (g)	3867.67		
Bucket (g)	182.69	**% Solids**	5.60
Total Solids (g)	206.37		

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.34	14.96	8.62	8.62	4.18	4.18	4.79	4.79
65 x 100	6.43	10.75	4.32	12.94	2.09	6.27	5.30	4.96
100 x 325	6.50	52.70	46.20	59.14	22.39	28.66	16.74	14.16
-325	6.48	153.71	147.23	206.37	71.34	100.00	61.78	48.13
		Total	206.37		100.00		48.13	

Total Yield (%)	**11.27**	**Cons Yield (%)**	**96.32**
Total Recovery (%)	**20.54**	**Cons Recovery (%)**	**99.30**
		Tails Yield (%)	**43.86**
Ash Recovery (%)	**1.27**	**Tails Recovery (%)**	**88.74**
Sep. Eff.	**19.28**		

Cons

Bucket and Slurry (g)	1955.17		
Bucket (g)	97.21	**% Solids**	16.65
Total Solids (g)	309.27		

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.42	52.73	46.31	46.31	15.55	15.55	1.93	1.93
65 x 100	6.48	26.50	20.02	66.33	6.72	22.27	2.03	1.96
100 x 325	6.50	156.95	150.45	216.78	50.51	72.77	2.31	2.20
-325	6.53	87.64	81.11	297.89	27.23	100.00	3.26	2.49
		Total	297.89		100.00		2.49	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
+100	2.05	2.29	0.24	0.24	2.11	2.11	5.90	5.90
100 x 325	6.48	6.69	0.21	0.45	1.85	3.95	58.61	30.50
-325	6.53	17.46	10.93	11.38	96.05	100.00	84.17	82.05
		Total	11.38		100.00		82.05	

Tails

Bucket and Slurry (g)	3573.76		
Bucket (g)	178.89	**% Solids**	4.44
Total Solids (g)	150.77		

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.41	12.62	6.21	6.21	9.39	9.39	4.64	4.64
65 x 100	6.46	9.27	2.81	9.02	4.25	13.64	4.85	4.71
100 x 325	6.52	34.41	27.89	36.91	42.17	55.81	5.61	5.39
-325	6.51	35.73	29.22	66.13	44.19	100.00	6.85	6.03
		Total	66.13		100.00		6.03	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.46	10.27	3.81	3.81	4.50	4.50	95.31	95.31
-325	6.52	87.35	80.83	84.64	95.50	100.00	90.47	90.69
		Total	84.64		100.00		90.69	

Reconstituted Data for Plant B Test #1

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.34	5.34	5.34	5.34	3.78	3.78
48 x 100	2.39	7.73	2.39	7.73	3.99	3.85
200 x 325	24.14	31.88	24.14	31.88	13.21	10.94
-325	68.12	100.00	68.12	100.00	65.54	48.13
Total	100.00		100.00		48.13	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	46.31	46.31	14.97	14.97	1.93	1.93
48 x 100	20.26	66.57	6.55	21.52	2.08	1.97
200 x 325	150.66	217.23	48.71	70.24	2.39	2.26
-325	92.04	309.27	29.76	100.00	12.87	5.42
Total	309.27		100.00		5.42	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.21	6.21	4.12	4.12	4.64	4.64
48 x 100	2.81	9.02	1.86	5.98	4.85	4.71
200 x 325	31.70	40.72	21.03	27.01	16.39	13.80
-325	110.05	150.77	72.99	100.00	68.27	53.56
Total	150.77		100.00		53.56	

Raw Data for Plant B Test #2

Test Conditions

Location:	Plant B	Date:	8/16/2011	Notes:	Con Sink +100 weighed 0.13 g, did not Ash
					Tail Sink +100 weighed 0.11 g, did not Ash
Frother:		Dosage:	160 ml/min		
Collector:		Dosage:	0 ml/min		
Air:	107%, 9.2 psi				
Agitator:	45 Hz				
Plant Feed:					
Wash Water:	360 gal/min				
Froth Depth:	24 in.				

Feed

	Bucket and Slurry (g)	3898.53							
	Bucket (g)	184.14	**% Solids**	5.51					
	Total Solids (g)	204.56							

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.38	15.25	8.87	8.87	4.34	4.34	4.74	4.74
65 x 100	6.28	10.69	4.41	13.28	2.16	6.49	5.51	5.00
100 x 325	6.32	57.86	51.54	64.82	25.20	31.69	17.33	14.80
-325	6.37	146.11	139.74	204.56	68.31	100.00	62.79	47.58
		Total	204.56		100.00		47.58	

Total Yield (%)	**20.26**	**Cons Yield (%)**	**95.02**
Total Recovery (%)	**35.91**	**Cons Recovery (%)**	**99.43**
		Tails Yield (%)	**40.32**
Ash Recovery (%)	**3.03**	**Tails Recovery (%)**	**89.06**
Sep. Eff.	**32.87**		

Cons

	Bucket and Slurry (g)	2035.99			
	Bucket (g)	105.75	**% Solids**	14.21	
	Total Solids (g)	274.31			

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.41	45.09	38.68	38.68	14.84	14.84	2.26	2.26
65 x 100	6.42	34.98	28.56	67.24	10.96	25.80	2.47	2.35
100 x 325	6.43	132.42	125.99	193.23	48.34	74.14	2.65	2.55
-325	6.28	73.69	67.41	260.64	25.86	100.00	3.58	2.81
		Total	260.64		100.00		2.81	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.34	6.61	0.27	0.27	1.98	1.98	46.33	46.33
-325	6.30	19.70	13.40	13.67	98.02	100.00	90.17	89.30
		Total	13.67		100.00		89.30	

Tails

	Bucket and Slurry (g)	3847.36			
	Bucket (g)	180.39	**% Solids**	4.16	
	Total Solids (g)	152.46			

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.36	9.72	3.36	3.36	5.47	5.47	6.74	6.74
65 x 100	6.34	9.13	2.79	6.15	4.54	10.00	5.74	6.29
100 x 325	6.37	33.27	26.90	33.05	43.76	53.77	7.09	6.94
-325	6.31	34.73	28.42	61.47	46.23	100.00	6.93	6.94
		Total	61.47		100.00		6.94	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.43	10.74	4.31	4.31	4.74	4.74	92.55	92.55
-325	6.25	92.93	86.68	90.99	95.26	100.00	92.26	92.27
		Total	90.99		100.00		92.27	

Reconstituted Data for Plant B Test #2

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	4.61	4.61	4.61	4.61	3.97	3.97
48 x 100	3.57	8.18	3.57	8.18	3.81	3.90
200 x 325	25.65	33.83	25.65	33.83	13.02	10.81
-325	66.17	100.00	66.17	100.00	66.39	47.58
Total	100.00		100.00		47.58	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	38.68	38.68	14.10	14.10	2.26	2.26
48 x 100	28.56	67.24	10.41	24.51	2.47	2.35
200 x 325	126.26	193.50	46.03	70.54	2.74	2.61
-325	80.81	274.31	29.46	100.00	17.94	7.12
Total	274.31		100.00		7.12	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	3.36	3.36	2.20	2.20	6.74	6.74
48 x 100	2.79	6.15	1.83	4.03	5.74	6.29
200 x 325	31.21	37.36	20.47	24.50	18.89	16.82
-325	115.10	152.46	75.50	100.00	71.19	57.87
Total	152.46		100.00		57.87	

Raw Data for Plant B Test #3

Test Conditions

Location: Plant B
Date: 8/16/2011
Notes: Tail Sink +100 weighed 0.11 g, did not Ash

Frother:
Dosage: 160 ml/min
Collector:
Dosage: 0 ml/min

Air: 107%, 9.2 psi
Agitator: 45 Hz
Plant Feed:
Wash Water: 360 gal/min

Froth Depth: 18 in.

Feed

Bucket and Slurry (g)	3717.7		
Bucket (g)	180.38	**% Solids**	5.30
Total Solids (g)	187.62		

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.61	14.26	7.65	7.65	4.08	4.08	5.01	5.01
65 x 100	6.37	10.03	3.66	11.31	1.95	6.03	6.12	5.37
100 x 325	6.51	51.11	44.60	55.91	23.77	29.80	18.14	15.56
-325	6.58	138.29	131.71	187.62	70.20	100.00	61.50	47.81
		Total	187.62		100.00		47.81	

Total Yield (%)	**19.71**	**Cons Yield (%)**	**94.40**
Total Recovery (%)	**34.98**	**Cons Recovery (%)**	**98.97**
		Tails Yield (%)	**38.48**
Ash Recovery (%)	**3.04**	**Tails Recovery (%)**	**84.92**
Sep. Eff.	**31.94**		

Cons

Bucket and Slurry (g)	2195.76		
Bucket (g)	106.79	**% Solids**	14.20
Total Solids (g)	296.65		

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.51	58.00	51.49	51.49	18.39	18.39	2.24	2.24
65 x 100	6.33	26.72	20.39	71.88	7.28	25.67	2.29	2.25
100 x 325	6.35	139.21	132.86	204.74	47.44	73.11	2.78	2.60
-325	6.44	81.75	75.31	280.05	26.89	100.00	3.69	2.89
		Total	280.05		100.00		2.89	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
+100	2.08	2.30	0.22	0.22	1.33	1.33	5.42	5.42
100 x 325	6.33	6.66	0.33	0.55	1.99	3.31	64.32	40.76
-325	6.40	22.45	16.05	16.60	96.69	100.00	84.35	82.91
		Total	16.60		100.00		82.91	

Tails

Bucket and Slurry (g)	4014.76		
Bucket (g)	176.74	**% Solids**	4.19
Total Solids (g)	160.70		

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.49	10.84	4.35	4.35	7.03	7.03	5.84	5.84
65 x 100	6.41	9.63	3.22	7.57	5.21	12.24	6.02	5.92
100 x 325	6.29	29.80	23.51	31.08	38.02	50.26	6.98	6.72
-325	6.39	37.15	30.76	61.84	49.74	100.00	6.74	6.73
		Total	61.84		100.00		6.73	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.38	10.90	4.52	4.52	4.57	4.57	91.30	91.30
-325	6.47	100.81	94.34	98.86	95.43	100.00	89.56	89.64
		Total	98.86		100.00		89.64	

Reconstituted Data for Plant B Test #3

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.59	5.59	5.59	5.59	3.64	3.64
48 x 100	2.98	8.57	2.98	8.57	4.32	3.88
200 x 325	22.85	31.42	22.85	31.42	13.75	11.05
-325	68.58	100.00	68.58	100.00	64.65	47.81
Total	100.00		100.00		47.81	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	51.49	51.49	17.36	17.36	2.24	2.24
48 x 100	20.61	72.10	6.95	24.30	2.32	2.26
200 x 325	133.19	205.29	44.90	69.20	2.93	2.70
-325	91.36	296.65	30.80	100.00	17.86	7.37
Total	296.65		100.00		7.37	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	4.35	4.35	2.71	2.71	5.84	5.84
48 x 100	3.22	7.57	2.00	4.71	6.02	5.92
200 x 325	28.03	35.60	17.44	22.15	20.58	17.46
-325	125.10	160.70	77.85	100.00	69.20	57.73
Total	160.70		100.00		57.73	

Raw Data for Plant B Test #4

Test Conditions

Location:	Plant B	Date:	8/16/2011	Notes:	Con Sink +100 weighed 0.19 g, did not Ash
					Tail Sink +100 weighed 0.17 g, did not Ash
Frother:		Dosage:	160 ml/min		
Collector:		Dosage:	0 ml/min		
Air:	107%, 9.2 psi				
Agitator:	45 Hz				
Plant Feed:					
Wash Water:	360 gal/min				
Froth Depth:	12 in.				

Feed

Bucket and Slurry (g)	4052.46				
Bucket (g)	186.24	**% Solids**	5.72		
Total Solids (g)	221.34				

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.50	16.86	10.36	10.36	4.68	4.68	4.72	4.72
65 x 100	6.44	11.28	4.84	15.20	2.19	6.87	5.36	4.92
100 x 325	6.34	49.35	43.01	58.21	19.43	26.30	18.13	14.68
-325	6.35	169.48	163.13	221.34	73.70	100.00	58.86	47.24
		Total	221.34		100.00		47.24	

Total Yield (%)	**18.17**		**Cons Yield (%)**	**93.18**	
Total Recovery (%)	**31.56**		**Cons Recovery (%)**	**98.62**	
			Tails Yield (%)	**40.59**	
Ash Recovery (%)	**3.22**		**Tails Recovery (%)**	**86.04**	
Sep. Eff.	**28.34**				

Cons

Bucket and Slurry (g)	2146.83				
Bucket (g)	112.25	**% Solids**	14.27		
Total Solids (g)	290.37				

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.53	45.50	38.97	38.97	16.15	16.15	2.17	2.17
65 x 100	6.49	23.05	16.56	55.53	6.86	23.01	2.25	2.19
100 x 325	6.44	110.26	103.82	159.35	43.03	66.04	2.90	2.65
-325	6.44	88.39	81.95	241.30	33.96	100.00	3.74	3.02
		Total	241.30		100.00		3.02	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
+100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.40	6.95	0.55	0.55	3.11	3.11	63.15	63.15
-325	6.47	23.59	17.12	17.67	96.89	100.00	81.99	81.40
		Total	17.67		100.00		81.40	

Tails

Bucket and Slurry (g)	3958.36				
Bucket (g)	180.68	**% Solids**	4.51		
Total Solids (g)	170.55				

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.48	10.01	3.53	3.53	5.77	5.77	6.00	6.00
65 x 100	6.51	8.99	2.48	6.01	4.06	9.83	5.90	5.96
100 x 325	6.40	28.97	22.57	28.58	36.92	46.75	6.76	6.59
-325	6.47	39.03	32.56	61.14	53.25	100.00	6.33	6.45
		Total	61.14		100.00		6.45	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.33	10.65	4.32	4.32	4.83	4.83	89.91	89.91
-325	12.84	98.02	85.18	89.50	95.17	100.00	89.62	89.63
		Total	89.50		100.00		89.63	

Reconstituted Data for Plant B Test #4

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	4.65	4.65	4.65	4.65	3.75	3.75
48 x 100	2.51	7.16	2.51	7.16	4.21	3.91
200 x 325	21.93	29.09	21.93	29.09	14.47	11.87
-325	70.91	100.00	70.91	100.00	61.75	47.24
Total	100.00		100.00		47.24	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	38.97	38.97	15.05	15.05	2.17	2.17
48 x 100	16.56	55.53	6.39	21.44	2.25	2.19
200 x 325	104.37	159.90	40.30	61.74	3.22	2.86
-325	99.07	258.97	38.26	100.00	17.26	8.37
Total	258.97		100.00		8.37	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	3.53	3.53	2.34	2.34	6.00	6.00
48 x 100	2.48	6.01	1.65	3.99	5.90	5.96
200 x 325	26.89	32.90	17.85	21.84	20.12	17.53
-325	117.74	150.64	78.16	100.00	66.59	55.87
Total	150.64		100.00		55.87	

Raw Data for Plant B Test #5

Test Conditions

Location:	Plant B	Date:	8/16/2011	Notes:	Con Sink +100 weighed 0.15 g, did not Ash
					Tail Sink +100 weighed 0.11 g, did not Ash
Frother:		Dosage:	160 ml/min		
Collector:		Dosage:	0 ml/min		
Air:	107%, 9.2 psi				
Agitator:	0 Hz				
Plant Feed:					
Wash Water:	360 gal/min				
Froth Depth:	24 in.				

Bucket and Slurry (g)	4061.98			
Bucket (g)	181.74	**% Solids**	5.24	
Total Solids (g)	203.20			

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.47	16.38	9.91	9.91	4.88	4.88	5.66	5.66
65 x 100	6.42	9.20	2.78	12.69	1.37	6.25	4.86	5.48
100 x 325	6.42	48.46	42.04	54.73	20.69	26.93	16.70	14.10
-325	6.45	154.92	148.47	203.20	73.07	100.00	57.50	45.81
		Total	203.20		100.00		45.81	

Total Yield (%)	**22.01**	**Cons Yield (%)**	**95.32**
Total Recovery (%)	**38.01**	**Cons Recovery (%)**	**98.85**
		Tails Yield (%)	**38.21**
Ash Recovery (%)	**3.07**	**Tails Recovery (%)**	**82.84**
Sep. Eff.	**34.94**		

Cons

	% Solids	7.31	

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.48	43.75	37.27	37.27	15.49	15.49	2.32	2.32
65 x 100	6.49	35.67	29.18	66.45	12.13	27.62	2.29	2.31
100 x 325	6.36	110.01	103.65	170.10	43.09	70.71	2.74	2.57
-325	6.34	76.80	70.46	240.56	29.29	100.00	3.80	2.93
		Total	240.56		100.00		2.93	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
+100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.35	6.71	0.36	0.36	3.05	3.05	52.89	52.89
-325	13.03	24.47	11.44	11.80	96.95	100.00	77.67	76.91
		Total	11.80		100.00		76.91	

Tails

	% Solids	3.11	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.55	9.02	2.47	2.47	4.45	4.45	6.43	6.43
65 x 100	6.45	8.34	1.89	4.36	3.40	7.85	7.01	6.68
100 x 325	6.34	28.47	22.13	26.49	39.85	47.70	7.10	7.03
-325	6.40	35.45	29.05	55.54	52.30	100.00	6.27	6.63
		Total	55.54		100.00		6.63	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.37	10.97	4.60	4.60	5.12	5.12	89.93	89.93
-325	6.37	91.57	85.20	89.80	94.88	100.00	87.94	88.04
		Total	89.80		100.00		88.04	

Reconstituted Data for Plant B Test #5

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	4.58	4.58	4.58	4.58	3.51	3.51
48 x 100	3.56	8.13	3.56	8.13	3.64	3.57
200 x 325	23.41	31.55	23.41	31.55	14.21	11.47
-325	68.45	100.00	68.45	100.00	61.64	45.81
Total	100.00		100.00		45.81	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	37.27	37.27	14.77	14.77	2.32	2.32
48 x 100	29.18	66.45	11.56	26.33	2.29	2.31
200 x 325	104.01	170.46	41.21	67.55	2.91	2.68
-325	81.90	252.36	32.45	100.00	14.12	6.39
Total	252.36		100.00		6.39	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	2.47	2.47	1.70	1.70	6.43	6.43
48 x 100	1.89	4.36	1.30	3.00	7.01	6.68
200 x 325	26.73	31.09	18.39	21.39	21.35	19.30
-325	114.25	145.34	78.61	100.00	67.17	56.93
Total	145.34		100.00		56.93	

Raw Data for Plant B Test #6

Test Conditions

Location:	Plant B	Date:	8/16/2011	Notes:	Con Sink +100 weighed 0.17 g, did not Ash
					Tail Sink +100 weighed 0.14g, did not Ash
Frother:		Dosage:	160 ml/min		
Collector:		Dosage:	0 ml/min		
Air:	107%, 9.2 psi				
Agitator:	30 Hz				
Plant Feed:					
Wash Water:	360 gal/min				
Froth Depth:	24 in.				

Bucket and Slurry (g)	4092.01			
Bucket (g)	180.76	**% Solids**	5.50	
Total Solids (g)	215.29			

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.56	15.14	8.58	8.58	3.99	3.99	4.71	4.71
65 x 100	6.41	10.16	3.75	12.33	1.74	5.73	5.26	4.88
100 x 325	6.46	53.35	46.89	59.22	21.78	27.51	13.18	11.45
-325	6.45	162.52	156.07	215.29	72.49	100.00	56.24	43.92
		Total	215.29		100.00		43.92	

Total Yield (%)	**23.04**	**Cons Yield (%)**	**94.64**
Total Recovery (%)	**38.26**	**Cons Recovery (%)**	**98.57**
		Tails Yield (%)	**40.48**
Ash Recovery (%)	**3.61**	**Tails Recovery (%)**	**84.09**
Sep. Eff.	**34.65**		

Cons

% Solids	6.98		

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.47	47.75	41.28	41.28	17.26	17.26	2.44	2.44
65 x 100	6.43	24.89	18.46	59.74	7.72	24.98	2.31	2.40
100 x 325	6.51	110.88	104.37	164.11	43.63	68.61	2.90	2.72
-325	6.46	81.54	75.08	239.19	31.39	100.00	3.64	3.01
		Total	239.19		100.00		3.01	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
+100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.52	6.96	0.44	0.44	3.25	3.25	54.09	54.09
-325	6.51	19.62	13.11	13.55	96.75	100.00	75.90	75.19
		Total	13.55		100.00		75.19	

Tails

% Solids	3.39		

Tails Floatable

Sep. Funnel	Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
	+65	6.60	9.03	2.43	2.43	4.27	4.27	7.10	7.10
	65 x 100	6.33	8.27	1.94	4.37	3.41	7.67	7.04	7.07
	100 x 325	6.46	28.65	22.19	26.56	38.97	46.65	6.81	6.85
	-325	6.52	36.90	30.38	56.94	53.35	100.00	6.28	6.55
			Total	56.94		100.00		6.55	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.47	10.22	3.75	3.75	4.48	4.48	89.81	89.81
-325	6.43	86.39	79.96	83.71	95.52	100.00	87.89	87.98
		Total	83.71		100.00		87.98	

Reconstituted Data for Plant B Test #6

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.09	5.09	5.09	5.09	3.66	3.66
48 x 100	2.74	7.84	2.74	7.84	4.14	3.83
200 x 325	23.75	31.59	23.75	31.59	12.49	10.34
-325	68.41	100.00	68.41	100.00	59.42	43.92
Total	100.00		100.00		43.92	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	41.28	41.28	16.33	16.33	2.44	2.44
48 x 100	18.46	59.74	7.30	23.64	2.31	2.40
200 x 325	104.81	164.55	41.47	65.11	3.11	2.86
-325	88.19	252.74	34.89	100.00	14.38	6.88
Total	252.74		100.00		6.88	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	2.43	2.43	1.73	1.73	7.10	7.10
48 x 100	1.94	4.37	1.38	3.11	7.04	7.07
200 x 325	25.94	30.31	18.44	21.55	18.81	17.12
-325	110.34	140.65	78.45	100.00	65.42	55.01
Total	140.65		100.00		55.01	

Raw Data for Plant B Test #7

Test Conditions

Location: Plant B
Date: 8/16/2011
Notes: Con Sink +100 weighed 0.08 g, did not Ash
Tail Sink +100 weighed 0.11 g, did not Ash

Frother:
Dosage: 160 ml/min
Collector:
Dosage: 0 ml/min

Air: 107%, 9.2 psi
Agitator: 45 Hz
Plant Feed:
Wash Water: 360 gal/min

Froth Depth: 24 in.

Feed

Bucket and Slurry (g)	4342	
Bucket (g)	181.39	**% Solids** 5.22
Total Solids (g)	217.05	

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.24	16.23	9.99	9.99	4.60	4.60	6.09	6.09
65 x 100	6.39	10.79	4.40	14.39	2.03	6.63	6.42	6.19
100 x 325	6.27	58.00	51.73	66.12	23.83	30.46	14.92	13.02
-325	6.28	157.21	150.93	217.05	69.54	100.00	55.63	42.65
		Total	217.05		100.00		42.65	

Total Yield (%)	**22.28**	**Cons Yield (%)**	**95.18**
Total Recovery (%)	**36.08**	**Cons Recovery (%)**	**99.43**
		Tails Yield (%)	**44.34**
Ash Recovery (%)	**3.72**	**Tails Recovery (%)**	**88.34**
Sep. Eff.	**32.36**		

Cons

Bucket and Slurry (g)	2190.38	
Bucket (g)	106.06	**% Solids** 13.05
Total Solids (g)	272.01	

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.43	39.05	32.62	32.62	12.60	12.60	2.39	2.39
65 x 100	6.44	29.68	23.24	55.86	8.98	21.58	2.49	2.43
100 x 325	6.28	126.24	119.96	175.82	46.34	67.91	2.78	2.67
-325	6.28	89.35	83.07	258.89	32.09	100.00	3.59	2.96
		Total	258.89		100.00		2.96	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.35	6.60	0.25	0.25	1.91	1.91	63.97	63.97
-325	6.28	19.15	12.87	13.12	98.09	100.00	89.60	89.11
		Total	13.12		100.00		89.11	

Tails

Bucket and Slurry (g)	3787.68	
Bucket (g)	174.49	**% Solids** 3.96
Total Solids (g)	143.13	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.32	10.66	4.34	4.34	6.84	6.84	6.69	6.69
65 x 100	6.46	9.64	3.18	7.52	5.01	11.85	4.99	5.97
100 x 325	6.34	34.44	28.10	35.62	44.27	56.12	6.03	6.02
-325	6.30	34.15	27.85	63.47	43.88	100.00	6.06	6.04
		Total	63.47		100.00		6.04	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.33	9.53	3.20	3.20	4.02	4.02	90.34	90.34
-325	6.23	82.69	76.46	79.66	95.98	100.00	90.11	90.12
		Total	79.66		100.00		90.12	

Reconstituted Data for Plant B Test #7

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.03	5.03	5.03	5.03	4.41	4.41
48 x 100	3.63	8.66	3.63	8.66	3.68	4.10
200 x 325	26.84	35.50	26.84	35.50	10.34	8.82
-325	64.50	100.00	64.50	100.00	61.27	42.65
Total	100.00		100.00		42.65	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	32.62	32.62	11.99	11.99	2.39	2.39
48 x 100	23.24	55.86	8.54	20.54	2.49	2.43
200 x 325	120.21	176.07	44.19	64.73	2.91	2.76
-325	95.94	272.01	35.27	100.00	15.13	7.12
Total	272.01		100.00		7.12	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	4.34	4.34	3.03	3.03	6.69	6.69
48 x 100	3.18	7.52	2.22	5.25	4.99	5.97
200 x 325	31.30	38.82	21.87	27.12	14.65	12.97
-325	104.31	143.13	72.88	100.00	67.67	52.83
Total	143.13		100.00		52.83	

Raw Data for Plant B Test #8

Test Conditions

Location:	Plant B	Date:	8/16/2011	Notes:	Con Sink +100 weighed 0.08 g, did not Ash
					Tail Sink +100 weighed 0.10 g, did not Ash
Frother:		Dosage:	160 ml/min		
Collector:		Dosage:	0 ml/min		
Air:	107%, 9.2 psi				
Agitator:	60 Hz				
Plant Feed:					
Wash Water:	360 gal/min				
Froth Depth:	24 in.				

Bucket and Slurry (g)	4047			
Bucket (g)	182.93	**% Solids**	5.75	
Total Solids (g)	222.23			

Feed

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.55	17.25	10.70	10.70	4.81	4.81	4.65	4.65
65 x 100	6.41	11.73	5.32	16.02	2.39	7.21	4.21	4.50
100 x 325	6.41	58.14	51.73	67.75	23.28	30.49	14.67	12.27
-325	6.53	161.01	154.48	222.23	69.51	100.00	57.22	43.52
		Total	222.23		100.00		43.52	

Total Yield (%)	**12.09**	**Cons Yield (%)**	**93.27**
Total Recovery (%)	**19.77**	**Cons Recovery (%)**	**97.93**
		Tails Yield (%)	**47.04**
Ash Recovery (%)	**2.13**	**Tails Recovery (%)**	**85.70**
Sep. Eff.	**17.64**		

Cons

	% Solids	9.34	

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.43	43.27	36.84	36.84	15.81	15.81	2.25	2.25
65 x 100	6.38	28.88	22.50	59.34	9.66	25.47	2.13	2.20
100 x 325	6.46	107.46	101.00	160.34	43.36	68.83	2.94	2.67
-325	6.51	79.13	72.62	232.96	31.17	100.00	3.86	3.04
		Total	232.96		100.00		3.04	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
+100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.37	6.83	0.46	0.46	2.74	2.74	38.99	38.99
-325	6.48	22.82	16.34	16.80	97.26	100.00	72.56	71.64
		Total	16.80		100.00		71.64	

Tails

	% Solids	3.50	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.43	9.84	3.41	3.41	5.24	5.24	6.85	6.85
65 x 100	6.44	8.59	2.15	5.56	3.30	8.54	5.92	6.49
100 x 325	6.52	33.74	27.22	32.78	41.81	50.35	6.23	6.27
-325	6.48	38.81	32.33	65.11	49.65	100.00	5.88	6.08
		Total	65.11		100.00		6.08	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.52	9.51	2.99	2.99	4.08	4.08	87.33	87.33
-325	6.53	76.84	70.31	73.30	95.92	100.00	86.03	86.08
		Total	73.30		100.00		86.08	

Reconstituted Data for Plant B Test #8

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	3.95	3.95	3.95	3.95	4.77	4.77
48 x 100	2.45	6.40	2.45	6.40	4.24	4.57
200 x 325	24.10	30.50	24.10	30.50	11.98	10.43
-325	69.50	100.00	69.50	100.00	58.04	43.52
Total	100.00		100.00		43.52	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	36.84	36.84	14.75	14.75	2.25	2.25
48 x 100	22.50	59.34	9.01	23.76	2.13	2.20
200 x 325	101.46	160.80	40.62	64.38	3.10	2.77
-325	88.96	249.76	35.62	100.00	16.48	7.65
Total	249.76		100.00		7.65	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	3.41	3.41	2.46	2.46	6.85	6.85
48 x 100	2.15	5.56	1.55	4.02	5.92	6.49
200 x 325	30.21	35.77	21.83	25.84	14.26	13.05
-325	102.64	138.41	74.16	100.00	60.78	48.45
Total	138.41		100.00		48.45	

Raw Data for Plant B Test #9

Test Conditions

Location:	Plant B	Date:	8/16/2011	Notes:	Con Sink +100 weighed 0.06 g, did not Ash
					Tail Sink +100 weighed 0.13 g, did not Ash
Frother:		Dosage:	160 ml/min		
Collector:		Dosage:	0 ml/min		
Air:	107%, 9.2 psi				
Agitator:	45 Hz				
Plant Feed:					
Wash Water:	0 gal/min				
Froth Depth:	24 in.				

Feed

Bucket and Slurry (g)	4201		
Bucket (g)	174.74	**% Solids**	5.92
Total Solids (g)	238.23		

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.35	16.97	10.62	10.62	4.46	4.46	4.71	4.71
65 x 100	6.38	9.53	3.15	13.77	1.32	5.78	5.62	4.92
100 x 325	6.22	65.08	58.86	72.63	24.71	30.49	13.77	12.09
-325	6.21	171.81	165.60	238.23	69.51	100.00	59.03	44.72
		Total	238.23		100.00		44.72	

Total Yield (%)	**23.02**	**Cons Yield (%)**	**91.19**
Total Recovery (%)	**37.07**	**Cons Recovery (%)**	**99.12**
		Tails Yield (%)	**42.76**
Ash Recovery (%)	**5.66**	**Tails Recovery (%)**	**88.67**
Sep. Eff.	**31.42**		

Cons

Bucket and Slurry (g)	1959.33		
Bucket (g)	109.85	**% Solids**	20.78
Total Solids (g)	384.25		

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.43	50.77	44.34	44.34	12.65	12.65	2.41	2.41
65 x 100	6.29	26.18	19.89	64.23	5.68	18.33	2.24	2.36
100 x 325	6.25	188.77	182.52	246.75	52.09	70.42	2.92	2.77
-325	6.26	109.91	103.65	350.40	29.58	100.00	4.39	3.25
		Total	350.40		100.00		3.25	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.22	6.50	0.28	0.28	0.83	0.83	75.21	75.21
-325	6.25	39.82	33.57	33.85	99.17	100.00	91.22	91.09
		Total	33.85		100.00		91.09	

Tails

Bucket and Slurry (g)	3970.02		
Bucket (g)	180.38	**% Solids**	4.91
Total Solids (g)	185.94		

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.31	11.74	5.43	5.43	6.83	6.83	5.66	5.66
65 x 100	6.33	8.70	2.37	7.80	2.98	9.81	5.57	5.63
100 x 325	6.48	43.42	36.94	44.74	46.46	56.27	6.18	6.08
-325	6.32	41.09	34.77	79.51	43.73	100.00	6.57	6.30
		Total	79.51		100.00		6.30	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.43	10.49	4.06	4.06	3.81	3.81	91.33	91.33
-325	6.22	108.59	102.37	106.43	96.19	100.00	91.04	91.05
		Total	106.43		100.00		91.05	

Reconstituted Data for Plant B Test #9

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	4.90	4.90	4.90	4.90	3.90	3.90
48 x 100	2.17	7.08	2.17	7.08	3.74	3.85
200 x 325	27.93	35.00	27.93	35.00	10.07	8.81
-325	65.00	100.00	65.00	100.00	64.06	44.72
Total	100.00		100.00		44.72	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	44.34	44.34	11.54	11.54	2.41	2.41
48 x 100	19.89	64.23	5.18	16.72	2.24	2.36
200 x 325	182.80	247.03	47.57	64.29	3.03	2.86
-325	137.22	384.25	35.71	100.00	25.63	10.99
Total	384.25		100.00		10.99	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.43	5.43	2.92	2.92	5.66	5.66
48 x 100	2.37	7.80	1.27	4.19	5.57	5.63
200 x 325	41.00	48.80	22.05	26.25	14.61	13.18
-325	137.14	185.94	73.75	100.00	69.62	54.81
Total	185.94		100.00		54.81	

Raw Data for Plant B Test #10

Test Conditions

Location:	Plant B	Date:	8/16/2011	Notes:	Con Sink +100 weighed 0.12 g, did not Ash
					Tail Sink +100 weighed 0.20 g, did not Ash
Frother:		Dosage:	160 ml/min		
Collector:		Dosage:	0 ml/min		
Air:	107%, 9.2 psi				
Agitator:	45 Hz				
Plant Feed:					
Wash Water:	260 gal/min				
Froth Depth:	24 in.				

Feed

Bucket and Slurry (g)	3954.85		
Bucket (g)	178.22	**% Solids**	5.24
Total Solids (g)	198.08		

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.45	15.73	9.28	9.28	4.68	4.68	4.45	4.45
65 x 100	6.40	10.96	4.56	13.84	2.30	6.99	6.64	5.17
100 x 325	6.42	52.21	45.79	59.63	23.12	30.10	13.38	11.47
-325	6.46	144.91	138.45	198.08	69.90	100.00	59.61	45.12
		Total	198.08		100.00		45.12	

Total Yield (%)	**18.31**	**Cons Yield (%)**	**94.71**
Total Recovery (%)	**31.04**	**Cons Recovery (%)**	**99.02**
		Tails Yield (%)	**42.72**
Ash Recovery (%)	**2.82**	**Tails Recovery (%)**	**86.97**
Sep. Eff.	**28.23**		

Cons

Bucket and Slurry (g)	2112.88		
Bucket (g)	105.8	**% Solids**	15.13
Total Solids (g)	303.66		

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.37	60.44	54.07	54.07	18.80	18.80	2.24	2.24
65 x 100	6.51	33.33	26.82	80.89	9.33	28.13	2.29	2.26
100 x 325	6.54	138.22	131.68	212.57	45.79	73.91	2.46	2.38
-325	6.51	81.54	75.03	287.60	26.09	100.00	3.62	2.71
		Total	287.60		100.00		2.71	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.45	6.84	0.39	0.39	2.43	2.43	50.74	50.74
-325	6.67	22.34	15.67	16.06	97.57	100.00	83.61	82.81
		Total	16.06		100.00		82.81	

Tails

Bucket and Slurry (g)	4040.07		
Bucket (g)	185.46	**% Solids**	4.28
Total Solids (g)	164.97		

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.36	13.69	7.33	7.33	10.40	10.40	5.27	5.27
65 x 100	6.42	10.92	4.50	11.83	6.38	16.78	4.71	5.06
100 x 325	6.45	38.58	32.13	43.96	45.59	62.37	5.52	5.40
-325	6.55	33.07	26.52	70.48	37.63	100.00	6.21	5.70
		Total	70.48		100.00		5.70	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.52	10.72	4.20	4.20	4.44	4.44	89.44	89.44
-325	6.54	96.83	90.29	94.49	95.56	100.00	89.46	89.46
		Total	94.49		100.00		89.46	

Reconstituted Data for Plant B Test #10

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	6.89	6.89	6.89	6.89	3.84	3.84
48 x 100	3.85	10.74	3.85	10.74	3.69	3.78
200 x 325	25.95	36.69	25.95	36.69	11.35	9.14
-325	63.31	100.00	63.31	100.00	65.97	45.12
Total	100.00		100.00		45.12	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	54.07	54.07	17.81	17.81	2.24	2.24
48 x 100	26.82	80.89	8.83	26.64	2.29	2.26
200 x 325	132.07	212.96	43.49	70.13	2.60	2.47
-325	90.70	303.66	29.87	100.00	17.44	6.94
Total	303.66		100.00		6.94	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	7.33	7.33	4.44	4.44	5.27	5.27
48 x 100	4.50	11.83	2.73	7.17	4.71	5.06
200 x 325	36.33	48.16	22.02	29.19	15.22	12.72
-325	116.81	164.97	70.81	100.00	70.56	53.68
Total	164.97		100.00		53.68	

Raw Data for Plant B Test #11

Test Conditions

Location: Plant B
Date: 8/16/2011
Notes: Con Sink +100 weighed 0.08 g, did not Ash
Tail Sink +100 weighed 0.16 g, did not Ash

Frother:
Dosage: 160 ml/min
Collector:
Dosage: 0 ml/min

Air: 107%, 9.2 psi
Agitator: 45 Hz
Plant Feed:
Wash Water: 345 gal/min

Froth Depth: 24 in.

Feed

Bucket and Slurry (g)	4288	
Bucket (g)	182.37	**% Solids** 5.52
Total Solids (g)	226.57	

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.42	17.58	11.16	11.16	4.93	4.93	5.07	5.07
65 x 100	6.51	11.80	5.29	16.45	2.33	7.26	4.99	5.04
100 x 325	6.46	61.61	55.15	71.60	24.34	31.60	15.65	13.21
-325	6.41	161.38	154.97	226.57	68.40	100.00	58.63	44.28
		Total	226.57		100.00		44.28	

Total Yield (%)	**23.50**	**Cons Yield (%)**	**95.19**
Total Recovery (%)	**39.32**	**Cons Recovery (%)**	**99.15**
		Tails Yield (%)	**40.36**
Ash Recovery (%)	**3.59**	**Tails Recovery (%)**	**85.34**
Sep. Eff.	**35.73**		

Cons

Bucket and Slurry (g)	2329.31	
Bucket (g)	112.09	**% Solids** 14.27
Total Solids (g)	316.48	

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.47	60.91	54.44	54.44	18.07	18.07	2.46	2.46
65 x 100	6.58	25.21	18.63	73.07	6.18	24.25	2.28	2.41
100 x 325	6.53	155.31	148.78	221.85	49.39	73.64	2.78	2.66
-325	6.46	85.87	79.41	301.26	26.36	100.00	3.50	2.88
		Total	301.26		100.00		2.88	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.50	6.90	0.40	0.40	2.63	2.63	60.89	60.89
-325	6.47	21.29	14.82	15.22	97.37	100.00	84.20	83.59
		Total	15.22		100.00		83.59	

Tails

Bucket and Slurry (g)	3973.47	
Bucket (g)	177.54	**% Solids** 3.98
Total Solids (g)	151.15	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.46	9.91	3.45	3.45	5.66	5.66	7.08	7.08
65 x 100	6.48	9.08	2.60	6.05	4.26	9.92	6.68	6.91
100 x 325	6.42	30.20	23.78	29.83	38.98	48.90	7.07	7.04
-325	6.42	37.59	31.17	61.00	51.10	100.00	6.05	6.53
		Total	61.00		100.00		6.53	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.52	11.27	4.75	4.75	5.27	5.27	90.01	90.01
-325	6.45	91.85	85.40	90.15	94.73	100.00	89.09	89.14
		Total	90.15		100.00		89.14	

Reconstituted Data for Plant B Test #11

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.79	5.79	5.79	5.79	3.85	3.85
48 x 100	2.70	8.49	2.70	8.49	4.43	4.04
200 x 325	25.52	34.00	25.52	34.00	13.09	10.83
-325	66.00	100.00	66.00	100.00	61.51	44.28
Total	100.00		100.00		44.28	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	54.44	54.44	17.20	17.20	2.46	2.46
48 x 100	18.63	73.07	5.89	23.09	2.28	2.41
200 x 325	149.18	222.25	47.14	70.23	2.94	2.76
-325	94.23	316.48	29.77	100.00	16.19	6.76
Total	316.48		100.00		6.76	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	3.45	3.45	2.28	2.28	7.08	7.08
48 x 100	2.60	6.05	1.72	4.00	6.68	6.91
200 x 325	28.53	34.58	18.88	22.88	20.88	18.43
-325	116.57	151.15	77.12	100.00	66.89	55.80
Total	151.15		100.00		55.80	

Raw Data for Plant B Test #12

Test Conditions

Location: Plant B
Date: 8/16/2011
Notes: Con Sink +100 weighed 0.12 g, did not Ash
Tail Sink +100 weighed 0.12 g, did not Ash

Frother:
Dosage: 160 ml/min
Collector:
Dosage: 0 ml/min

Air: 107%, 9.2 psi
Agitator: 45 Hz
Plant Feed:
Wash Water: 400 gal/min

Froth Depth: 24 in.

Feed

Bucket and Slurry (g)	4207	
Bucket (g)	181.67	**% Solids** 6.17
Total Solids (g)	248.32	

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.28	16.48	10.20	10.20	4.11	4.11	5.96	5.96
65 x 100	6.25	9.82	3.57	13.77	1.44	5.55	4.90	5.69
100 x 325	6.40	65.31	58.91	72.68	23.72	29.27	14.74	13.02
-325	6.23	181.87	175.64	248.32	70.73	100.00	63.37	48.63
		Total	248.32		100.00		48.63	

Total Yield (%)	**18.55**	**Cons Yield (%)**	**94.31**
Total Recovery (%)	**33.25**	**Cons Recovery (%)**	**99.36**
		Tails Yield (%)	**39.85**
Ash Recovery (%)	**3.03**	**Tails Recovery (%)**	**88.14**
Sep. Eff.	**30.22**		

Cons

Bucket and Slurry (g)	2299.99	
Bucket (g)	110.82	**% Solids** 12.94
Total Solids (g)	283.25	

Cons Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.19	45.33	39.14	39.14	14.65	14.65	2.23	2.23
65 x 100	6.21	25.47	19.26	58.40	7.21	21.86	2.10	2.19
100 x 325	6.37	143.96	137.59	195.99	51.51	73.37	2.90	2.69
-325	6.18	77.32	71.14	267.13	26.63	100.00	3.91	3.01
		Total	267.13		100.00		3.01	

Cons Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.17	6.42	0.25	0.25	1.55	1.55	70.13	70.13
-325	6.54	22.41	15.87	16.12	98.45	100.00	89.90	89.59
		Total	16.12		100.00		89.59	

Tails

Bucket and Slurry (g)	3817.54	
Bucket (g)	190.04	**% Solids** 4.74
Total Solids (g)	172.00	

Tails Floatable

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	6.18	11.20	5.02	5.02	7.32	7.32	6.23	6.23
65 x 100	6.16	8.84	2.68	7.70	3.91	11.23	5.29	5.90
100 x 325	6.25	36.46	30.21	37.91	44.08	55.31	7.08	6.84
-325	6.40	37.03	30.63	68.54	44.69	100.00	6.94	6.89
		Total	68.54		100.00		6.89	

Tails Sink

Size Class (Mesh)	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 x 100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100 x 325	6.34	11.37	5.03	5.03	4.86	4.86	91.72	91.72
-325	6.43	104.86	98.43	103.46	95.14	100.00	91.70	91.70
		Total	103.46		100.00		91.70	

Reconstituted Data for Plant B Test #12

Feed (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	4.94	4.94	4.94	4.94	4.15	4.15
48 x 100	2.53	7.47	2.53	7.47	3.70	4.00
200 x 325	25.72	33.19	25.72	33.19	13.50	11.36
-325	66.81	100.00	66.81	100.00	67.15	48.63
Total	100.00		100.00		48.63	

Cons (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	39.14	39.14	13.82	13.82	2.23	2.23
48 x 100	19.26	58.40	6.80	20.62	2.10	2.19
200 x 325	137.84	196.24	48.66	69.28	3.02	2.77
-325	87.01	283.25	30.72	100.00	19.59	7.94
Total	283.25		100.00		7.94	

Tails (Reconstituted)

Size Class (Mesh)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
+48	5.02	5.02	2.92	2.92	6.23	6.23
48 x 100	2.68	7.70	1.56	4.48	5.29	5.90
200 x 325	35.24	42.94	20.49	24.97	19.16	16.78
-325	129.06	172.00	75.03	100.00	71.58	57.90
Total	172.00		100.00		57.90	

APPENDIX C

Carbon Partitioning Test Data

Plant B Test #5 Separatory Funnel

Yield	17.54

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.41	12.60	6.19	6.19	89.06	89.06	2.82	2.82
Sink	6.50	7.26	0.76	6.95	10.94	100.00	14.58	4.11
		Total	6.95		100.00		4.11	

Tailings

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.47	8.40	1.93	1.93	33.33	33.33	5.24	5.24
Sink	6.31	10.17	3.86	5.79	66.67	100.00	79.40	54.68
		Total	5.79		100.00		54.68	

Feed (Reconstituted)

	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	43.11	43.11	43.11	43.11	4.36	4.36
Sink	56.89	100.00	56.89	100.00	77.21	45.81
Total	100.00		100.00		45.81	

Plant B Test #6 Separatory Funnel

Yield	19.04

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.42	13.08	6.66	6.66	89.76	89.76	2.83	2.83
Sink	6.45	7.21	0.76	7.42	10.24	100.00	18.71	4.46
		Total	7.42		100.00		4.46	

Tailings

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.39	8.39	2.00	2.00	34.19	34.19	5.09	5.09
Sink	6.37	10.22	3.85	5.85	65.81	100.00	78.19	53.20
		Total	5.85		100.00		53.20	

Feed (Reconstituted)

	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	44.77	44.77	44.77	44.77	4.23	4.23
Sink	55.23	100.00	55.23	100.00	76.09	43.92
Total	100.00		100.00		43.92	

Plant B Test #8 Separatory Funnel

Yield	5.84

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.46	14.88	8.42	8.42	86.80	86.80	2.79	2.79
Sink	6.52	7.80	1.28	9.70	13.20	100.00	20.40	5.11
		Total	9.70		100.00		5.11	

Tailings

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.46	9.00	2.54	2.54	40.77	40.77	4.72	4.72
Sink	6.38	10.07	3.69	6.23	59.23	100.00	74.24	45.90
		Total	6.23		100.00		45.90	

Feed (Reconstituted)

	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	43.46	43.46	43.46	43.46	4.49	4.49
Sink	56.54	100.00	56.54	100.00	73.51	43.52
Total	100.00		100.00		43.52	

Plant B Test #5 Blender

Yield	26.08

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.41	12.60	6.19	6.19	89.06	89.06	2.82	2.82
Sink	6.50	7.26	0.76	6.95	10.94	100.00	14.58	4.11
		Total	6.95		100.00		4.11	

Tailings

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.35	7.82	1.47	13.05	25.39	225.39	5.52	49.14
Sink	6.17	10.56	4.39	17.44	75.82	301.21	77.05	56.17
		Total	5.86		101.21		59.82	

Feed (Reconstituted)

	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	41.84	41.84	41.84	41.84	4.43	4.43
Sink	58.16	100.00	58.16	100.00	74.54	45.20
Total	100.00		100.00		45.20	

Plant B Test #6 Blender

Yield	26.33

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.28	14.46	8.18	23.02	110.24	310.24	2.71	3.84
Sink	6.30	7.16	0.86	23.88	11.59	321.83	21.02	4.45
		Total	9.04		121.83		5.42	

Tailings

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.29	8.39	2.10	13.80	35.90	235.90	5.67	45.97
Sink	6.32	10.49	4.17	17.97	71.28	307.18	78.06	53.41
		Total	6.27		107.18		57.68	

Feed (Reconstituted)

	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	48.50	48.50	48.50	48.50	4.22	4.22
Sink	51.50	100.00	51.50	100.00	75.29	40.82
Total	100.00		100.00		40.82	

Plant B Test #8 Blender

Yield	17.57

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.29	14.53	8.24	27.64	84.95	284.95	2.66	4.38
Sink	6.21	7.24	1.03	28.67	10.62	295.57	26.14	5.16
		Total	9.27		95.57		5.04	

Tailings

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.28	8.89	2.61	15.07	41.89	241.89	4.32	38.70
Sink	6.09	10.27	4.18	19.25	67.09	308.99	74.38	46.44
		Total	6.79		108.99		51.71	

Feed (Reconstituted)

	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	47.30	47.30	47.30	47.30	3.77	3.77
Sink	52.70	100.00	52.70	100.00	72.59	40.04
Total	100.00		100.00		40.04	

Plant A 8/11/11 A Blender

Yield	31.15

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.07	181.74	175.67	175.67	91.45	91.45	4.91	4.91
Sink	6.11	22.53	16.42	192.09	8.55	100.00	88.81	12.08
		Total	192.09		100.00		12.08	

Tailings

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.16	16.90	10.74	10.74	23.06	23.06	25.16	25.16
Sink	6.07	41.91	35.84	46.58	76.94	100.00	91.37	76.10
		Total	46.58		100.00		76.10	

Feed (Reconstituted)

	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	44.36	44.36	44.36	44.36	12.16	12.16
Sink	55.64	100.00	55.64	100.00	91.25	56.16
Total	100.00		100.00		56.16	

Plant A 8/11/11 B Blender

Yield	29.60

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.14	115.20	109.06	109.06	91.77	91.77	5.13	5.13
Sink	6.06	15.84	9.78	118.84	8.23	100.00	90.35	12.14
		Total	118.84		100.00		12.14	

Tailings

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.16	18.09	11.93	11.93	23.99	23.99	21.48	21.48
Sink	6.12	43.91	37.79	49.72	76.01	100.00	91.46	74.67
		Total	49.72		100.00		74.67	

Feed (Reconstituted)

	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	44.06	44.06	44.06	44.06	11.40	11.40
Sink	55.94	100.00	55.94	100.00	91.41	56.16
Total	100.00		100.00		56.16	

Plant A 8/30/11 B Blender

Yield	23.45

Concentrate

	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.14	145.50	139.36	139.36	92.83	92.83	4.49	4.49
Sink	6.07	16.84	10.77	150.13	7.17	100.00	79.99	9.91
		Total	150.13		100.00		9.91	

Tailings

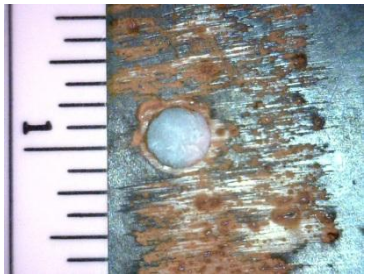
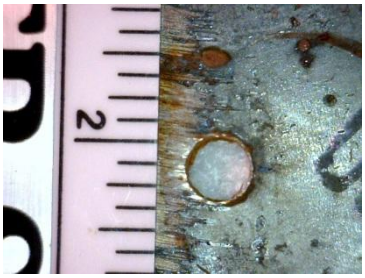
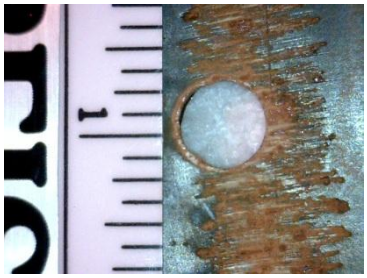
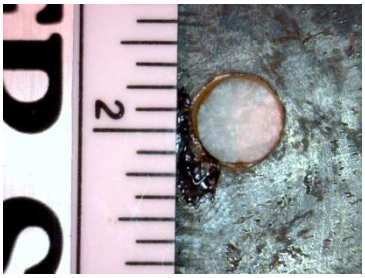
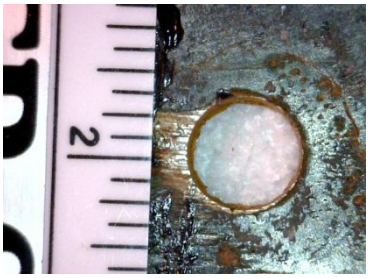
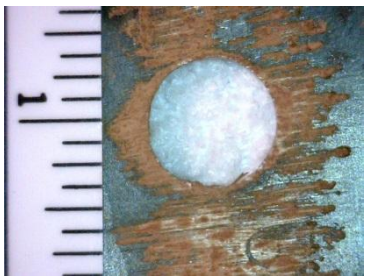
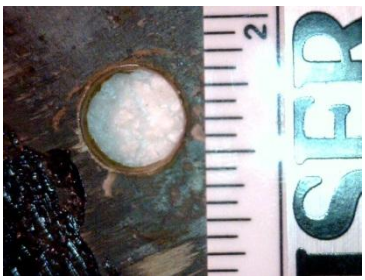
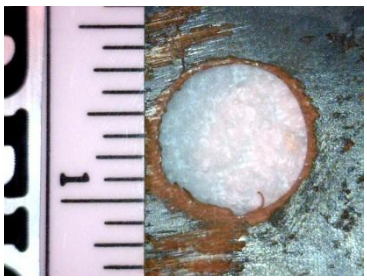
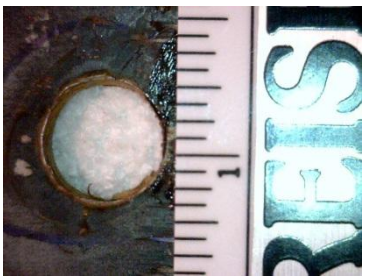
	Paper (g)	Paper & Dry (g)	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	6.07	25.56	19.49	19.49	46.62	46.62	11.50	11.50
Sink	6.04	28.36	22.32	41.81	53.38	100.00	87.32	51.98
		Total	41.81		100.00		51.98	

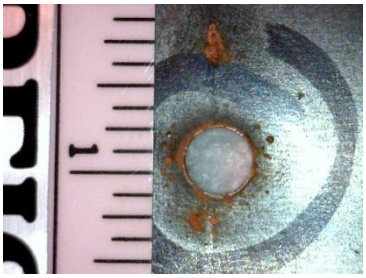
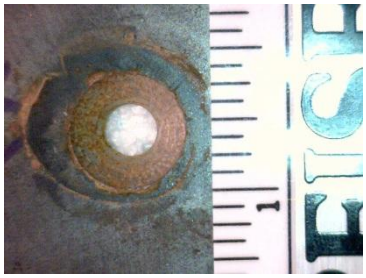
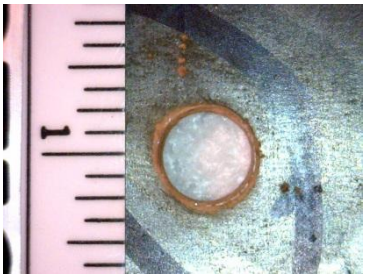
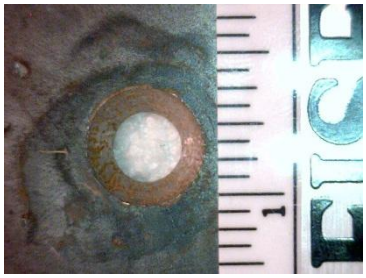
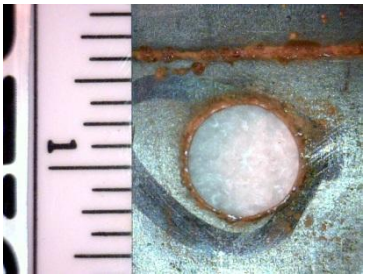
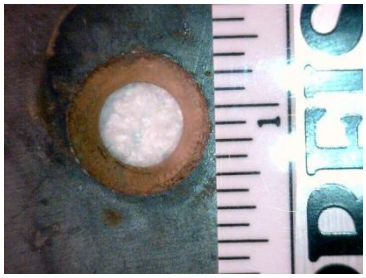
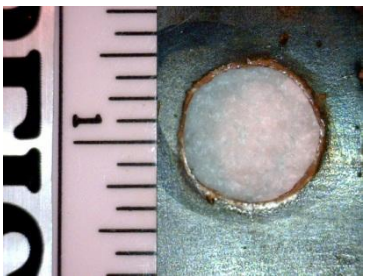
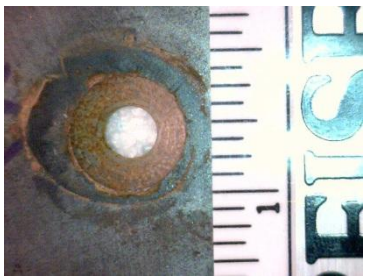
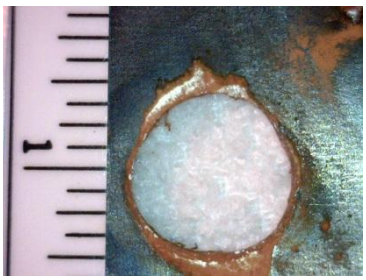
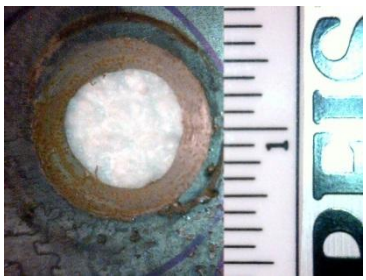
Feed (Reconstituted)

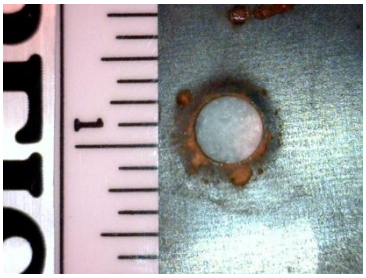
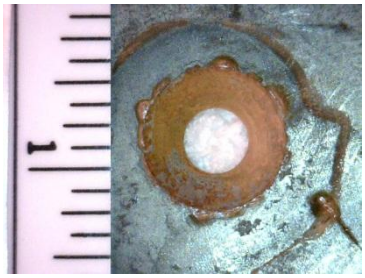
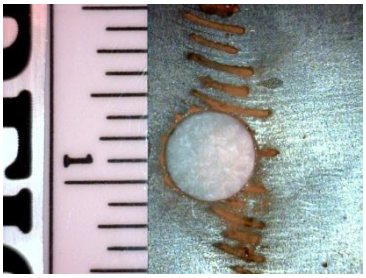
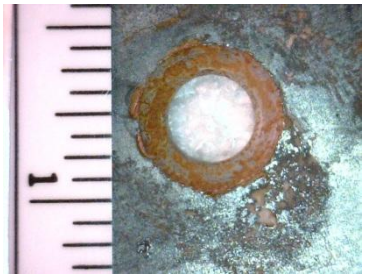
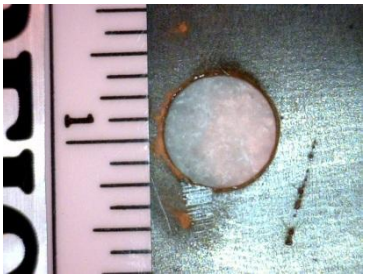
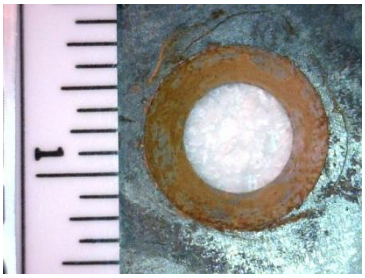
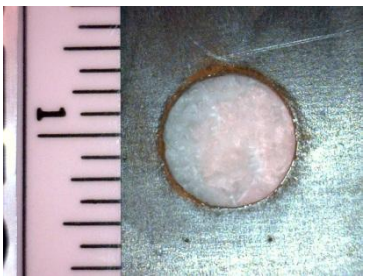
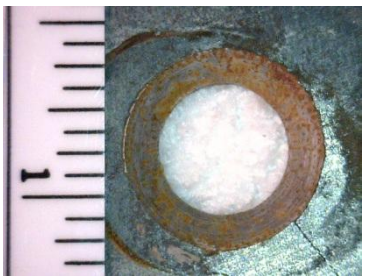
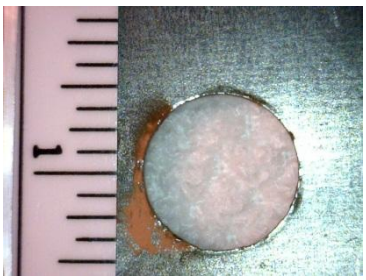
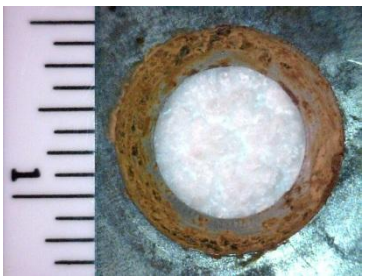
	Dry Weight (g)	Cum. Weight (g)	Weight %	Cum. Weight %	Ash %	Cum. Ash %
Float	57.45	57.45	57.45	57.45	8.84	8.84
Sink	42.55	100.00	42.55	100.00	87.03	42.11
Total	100.00		100.00		42.11	

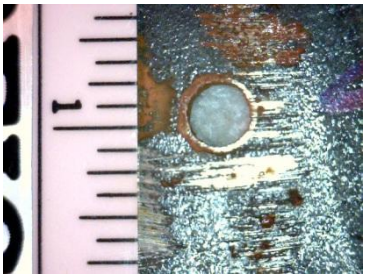
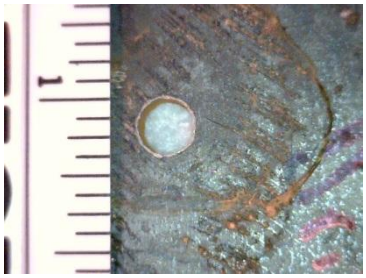
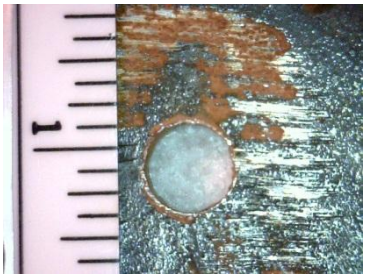
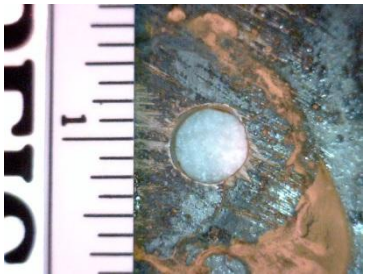
APPENDIX D

Pictures of Holes on Orifice Plates

Drilled Holes 1/8” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
5/16		
3/8		
7/16		

Drilled Counter Sunk Holes 1/8” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
5/16		
3/8		
7/16		

Plasma Cut Counter Sunk Holes 1/8” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
5/16		
3/8		
7/16		

Drilled Holes 3/16” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
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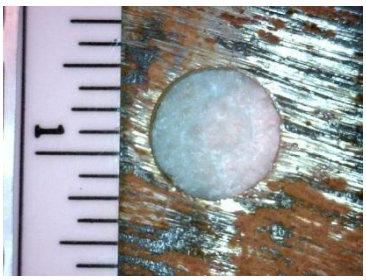
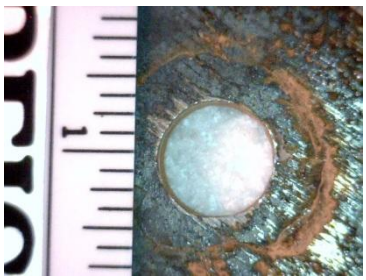
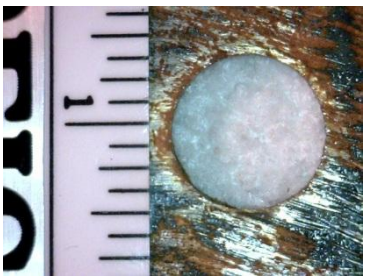
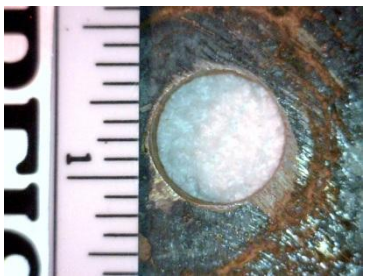
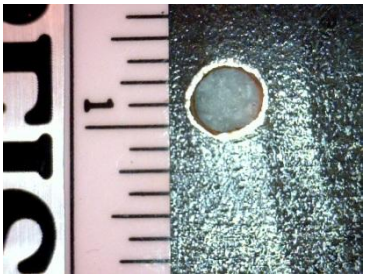
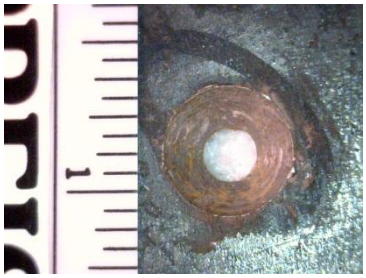
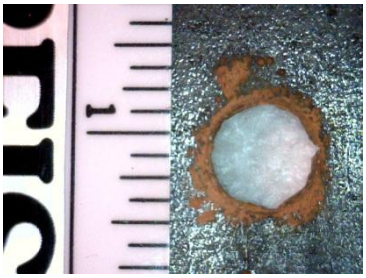
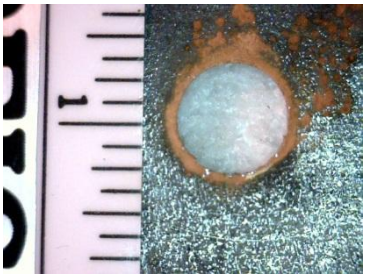
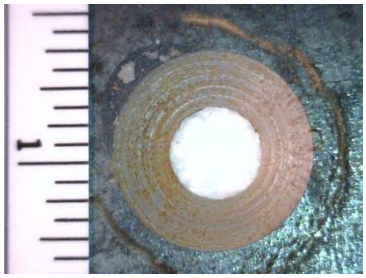
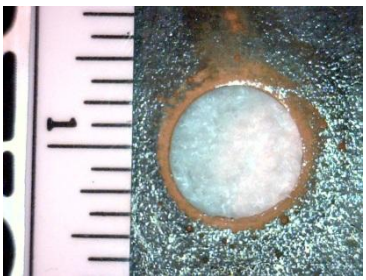
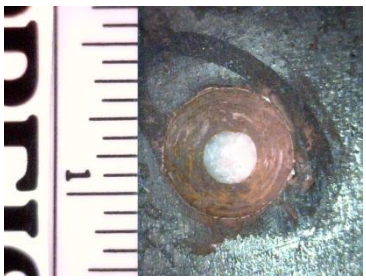
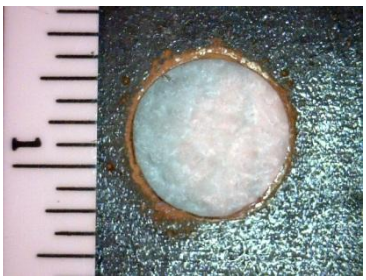
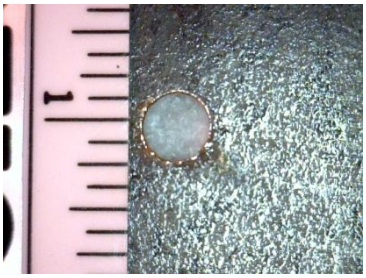
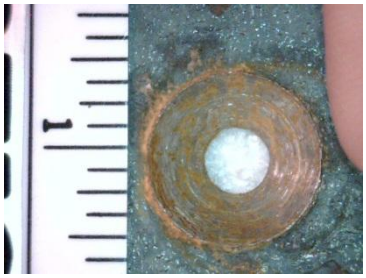
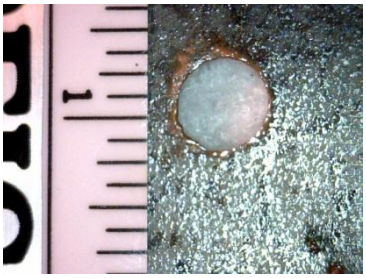
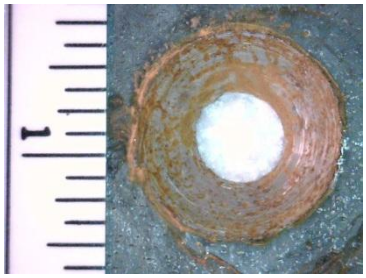
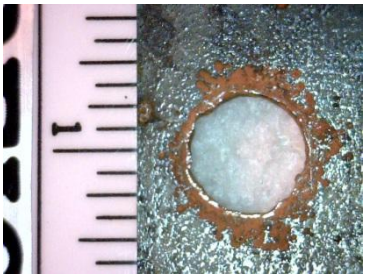
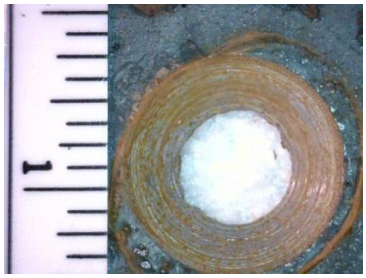
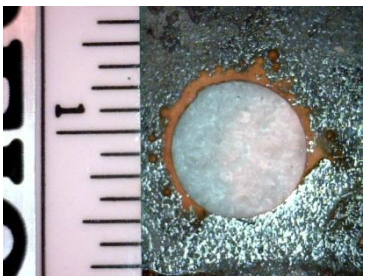
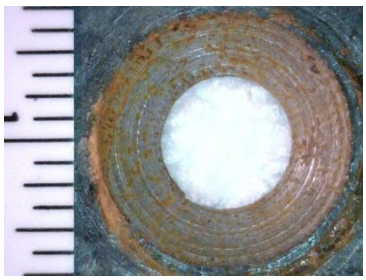
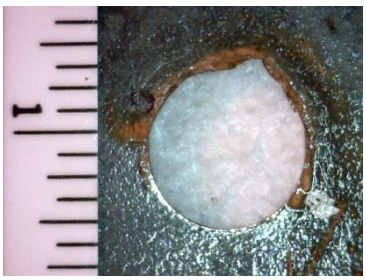
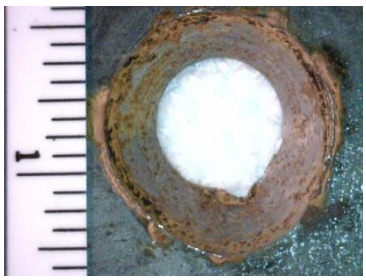
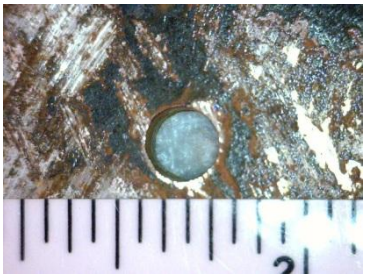
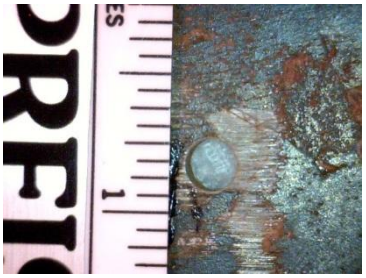
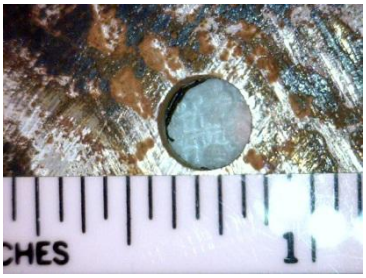
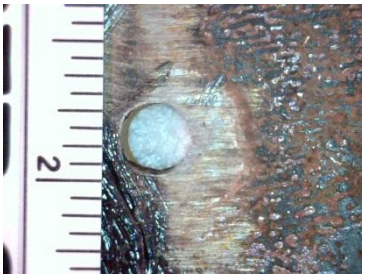
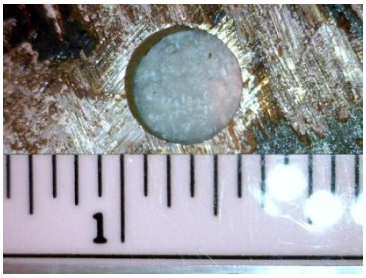
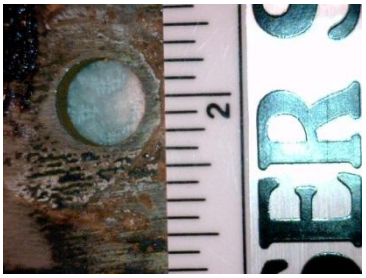
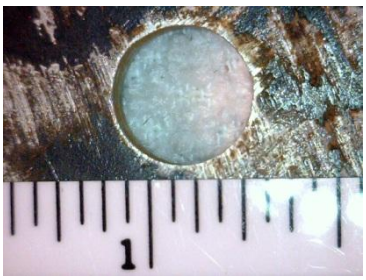
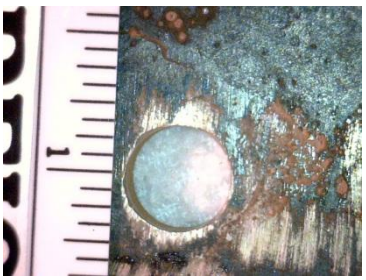
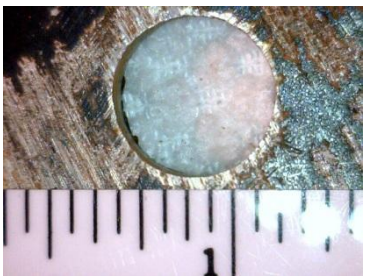
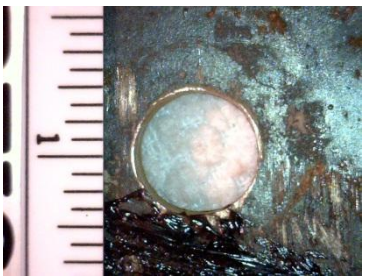
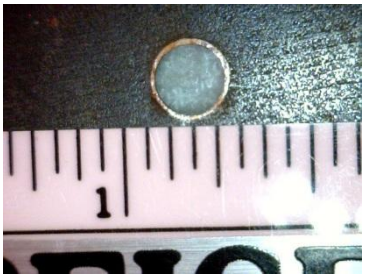
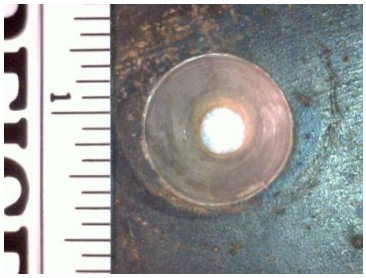
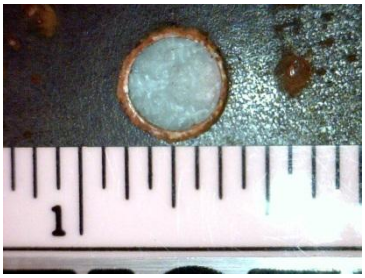
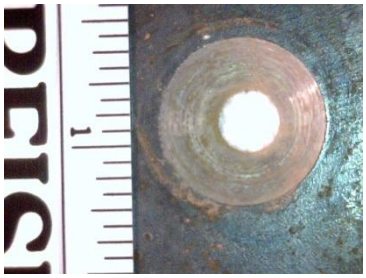
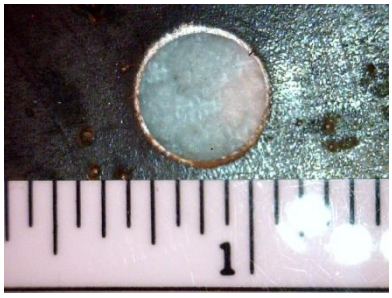
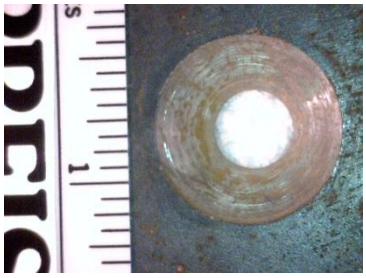
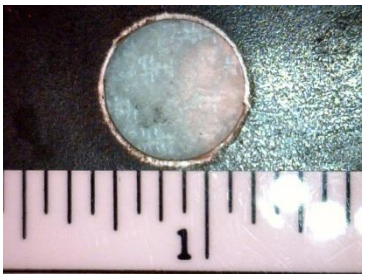
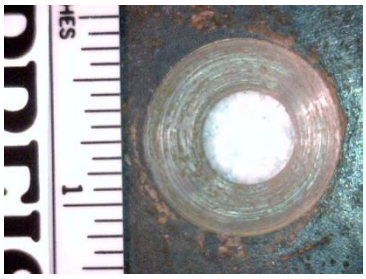
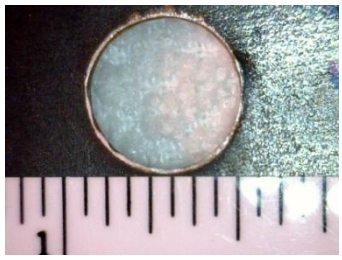
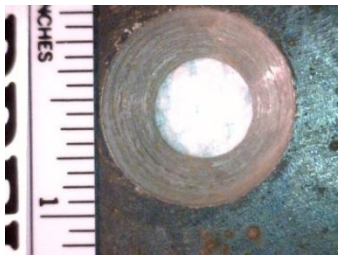
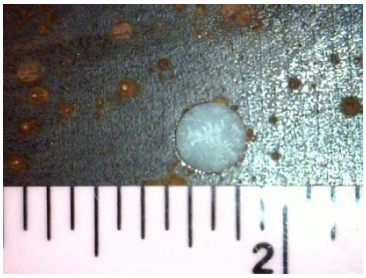
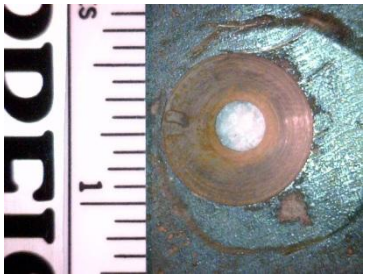
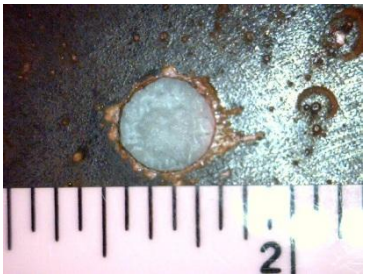
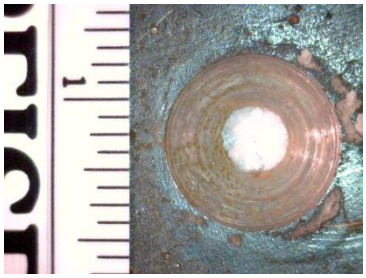
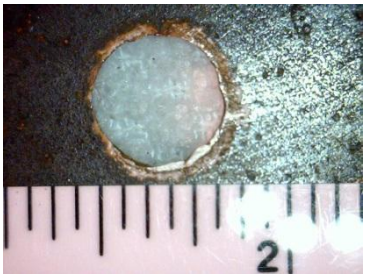
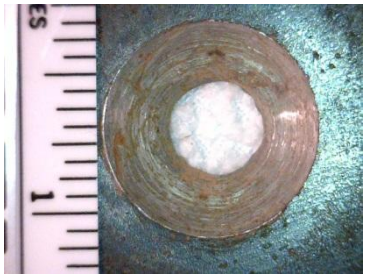
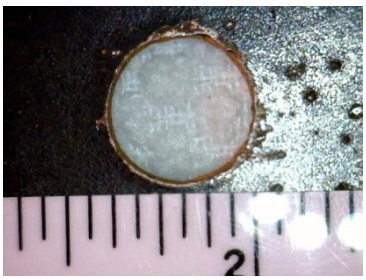
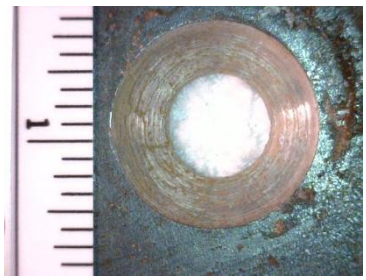
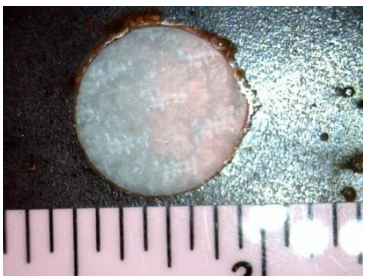
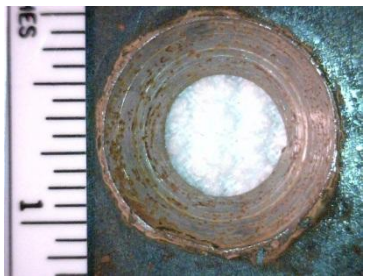
3/8		
7/16		

Drilled Counter Sunk Holes 3/16” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
5/16		
3/8		
7/16		

Plasma Cut Counter Sunk Holes 3/16” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
5/16		
3/8		
7/16		

Drilled Holes 1/4” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
5/16		
3/8		
7/16		

Drilled Counter Sunk Holes 1/4” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
5/16		
3/8		
7/16		

Plasma Cut Counter Sunk Holes 1/4” Thick Plate		
Hole Diam. (in.)	**Top**	**Bottom**
3/16		
1/4		
5/16		
3/8		
7/16		

APPENDIX E

Drip Pan Test Data

Raw Data for the 1/8” Drilled Counter Sunk Holes

Date:	11/3/2011	Bucket 1 Weight (g):	33.35
Plate Thickness:	0.125 in.	Bucket 2 Weight (g):	33.33
Hole Style:	Drilled CS Down	Bucket 3 Weight (g):	33.56

Water Height (in.)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	2.125	2.125	2.125	2.250	2.250	2.250	2.250	2.250	2.250	2.250	2.250	2.250	2.188	2.188	2.188
2	4	4.313	4.313	4.313	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250
3	6	6.250	6.250	6.250	6.250	6.250	6.250	6.313	6.313	6.313	6.250	6.250	6.250	6.250	6.250	6.250
4	8	8.313	8.313	8.313	8.313	8.313	8.313	8.250	8.250	8.250	8.313	8.313	8.313	8.313	8.313	8.313
5	10	10.313	10.313	10.313	10.313	10.313	10.313	10.375	10.375	10.375	10.250	10.250	10.250	10.375	10.375	10.375

Time (sec)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	19.78	19.87	19.85	19.82	19.97	20.10	15.03	14.97	14.97	11.94	11.87	11.97	10.00	10.00	10.16
2	4	15.16	14.94	15.03	15.07	15.13	15.06	15.06	15.31	14.97	9.97	9.88	9.94	7.94	7.78	7.97
3	6	15.13	15.03	15.03	15.06	15.12	15.10	11.94	11.94	11.97	8.07	8.00	8.13	5.97	6.09	6.03
4	8	15.09	15.19	15.07	15.13	15.16	15.03	9.97	10.07	10.06	7.97	8.09	7.88	6.13	5.07	5.13
5	10	15.19	15.12	14.94	12.10	12.00	12.15	8.00	8.15	8.09	6.19	6.03	6.00	4.31	3.94	4.10

Water & Bucket Weight (g)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	306.13	306.19	305.50	620.96	626.37	629.57	611.68	608.21	608.51	695.28	689.69	691.87	809.01	797.55	817.24
2	4	308.82	307.40	309.69	623.28	628.50	621.05	799.59	818.03	803.39	760.60	749.56	747.66	856.69	839.49	857.37
3	6	360.58	361.14	359.23	735.02	741.11	739.64	772.54	768.10	773.60	743.11	741.50	745.18	777.94	774.49	777.09
4	8	414.83	417.65	415.01	843.36	852.74	840.87	733.60	730.60	734.36	826.84	843.77	820.73	898.49	758.22	758.07
5	10	460.83	457.79	452.09	750.02	739.07	751.09	652.79	657.72	657.24	704.83	683.29	686.43	704.01	649.87	675.90

Calculated Results for the 1/8” Drilled Counter Sunk Holes

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	272.78	272.86	271.94	587.61	593.04	596.01	578.33	574.88	574.95	661.93	656.36	658.31	775.66	764.22	783.68
2	4	275.47	274.07	276.13	589.93	595.17	587.49	766.24	784.70	769.83	727.25	716.23	714.10	823.34	806.16	823.81
3	6	327.23	327.81	325.67	701.67	707.78	706.08	739.19	734.77	740.04	709.76	708.17	711.62	744.59	741.16	743.53
4	8	381.48	384.32	381.45	810.01	819.41	807.31	700.25	697.27	700.80	793.49	810.44	787.17	865.14	724.89	724.51
5	10	427.48	424.46	418.53	716.67	705.74	717.53	619.44	624.39	623.68	671.48	649.96	652.87	670.66	616.54	642.34

1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.22	0.22	0.22	0.47	0.47	0.47	0.61	0.61	0.61	0.88	0.88	0.87	1.23	1.21	1.22
2	4	0.29	0.29	0.29	0.62	0.62	0.62	0.81	0.81	0.82	1.16	1.15	1.14	1.64	1.64	1.64
3	6	0.34	0.35	0.34	0.74	0.74	0.74	0.98	0.98	0.98	1.39	1.40	1.39	1.98	1.93	1.95
4	8	0.40	0.40	0.40	0.85	0.86	0.85	1.11	1.10	1.10	1.58	1.59	1.58	2.24	2.27	2.24
5	10	0.45	0.44	0.44	0.94	0.93	0.94	1.23	1.21	1.22	1.72	1.71	1.72	2.47	2.48	2.48

Raw Data for the 1/8” Plasma Cut Counter Sunk Holes

Date:	11/3/2011	Bucket 1 Weight (g):	33.35
Plate Thickness:	0.125 in.	Bucket 2 Weight (g):	33.33
Hole Style:	Plasma CS Down	Bucket 3 Weight (g):	33.56

Water Height (in.)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	2.125	2.125	2.188	2.625	2.625	2.625	2.188	2.188	2.188	2.250	2.250	2.250	2.188	2.188	2.188
2	4	4.313	4.313	4.313	4.313	4.313	4.313	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250
3	6	6.188	6.188	6.188	6.250	6.250	6.250	6.313	6.313	6.313	6.250	6.250	6.250	6.250	6.250	6.250
4	8	8.313	8.313	8.313	8.313	8.313	8.313	8.313	8.313	8.313	8.250	8.250	8.250	8.375	8.375	8.375
5	10	10.313	10.313	10.313	10.375	10.375	10.375	10.375	10.375	10.375	10.375	10.375	10.375	10.375	10.375	10.375

Time (sec)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	19.88	19.75	19.91	19.91	19.97	19.87	14.91	14.88	14.91	12.03	12.00	11.81	10.00	10.07	9.91
2	4	15.09	15.06	15.00	14.87	15.03	15.06	15.00	15.09	14.94	10.03	9.97	10.07	7.88	7.97	7.91
3	6	15.16	15.04	15.03	15.00	15.04	15.16	11.97	12.28	12.06	8.09	8.03	7.97	6.03	6.00	6.03
4	8	15.19	14.87	14.94	15.09	15.22	15.06	9.97	10.00	10.06	7.97	7.91	8.00	5.04	5.00	4.97
5	10	15.03	15.10	15.12	11.97	12.00	12.06	8.06	8.13	8.10	6.03	6.28	6.07	4.12	4.00	4.25

Water & Bucket Weight (g)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	331.85	334.30	334.22	613.27	613.03	612.48	619.84	623.02	624.22	714.54	704.59	703.04	787.69	782.39	775.28
2	4	344.04	344.46	344.66	580.11	582.47	588.71	833.39	836.63	828.36	798.19	796.00	794.38	847.50	835.75	841.71
3	6	396.00	390.03	392.21	687.18	683.66	685.87	790.12	818.13	794.20	755.34	756.96	754.80	756.63	752.44	755.60
4	8	448.55	440.76	445.56	776.88	776.81	776.48	751.87	765.09	765.70	849.16	839.85	828.42	711.29	732.88	710.38
5	10	494.23	493.21	493.39	675.39	673.37	674.26	686.53	683.94	682.36	710.53	733.97	706.39	652.01	641.39	678.94

Calculated Results for the 1/8” Plasma Cut Counter Sunk Holes

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	298.50	300.97	300.66	579.92	579.70	578.92	586.49	589.69	590.66	681.19	671.26	669.48	754.34	749.06	741.72
2	4	310.69	311.13	311.10	546.76	549.14	555.15	800.04	803.30	794.80	764.84	762.67	760.82	814.15	802.42	808.15
3	6	362.65	356.70	358.65	653.83	650.33	652.31	756.77	784.80	760.64	721.99	723.63	721.24	723.28	719.11	722.04
4	8	415.20	407.43	412.00	743.53	743.48	742.92	718.52	731.76	732.14	815.81	806.52	794.86	677.94	699.55	676.82
5	10	460.88	459.88	459.83	642.04	640.04	640.70	653.18	650.61	648.80	677.18	700.64	672.83	618.66	608.06	645.38

1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.24	0.24	0.24	0.46	0.46	0.46	0.62	0.63	0.63	0.90	0.89	0.90	1.20	1.18	1.19
2	4	0.33	0.33	0.33	0.58	0.58	0.58	0.85	0.84	0.84	1.21	1.21	1.20	1.64	1.60	1.62
3	6	0.38	0.38	0.38	0.69	0.69	0.68	1.00	1.01	1.00	1.41	1.43	1.43	1.90	1.90	1.90
4	8	0.43	0.43	0.44	0.78	0.77	0.78	1.14	1.16	1.15	1.62	1.62	1.57	2.13	2.22	2.16
5	10	0.49	0.48	0.48	0.85	0.85	0.84	1.28	1.27	1.27	1.78	1.77	1.76	2.38	2.41	2.41

Raw Data for the 3/16” Drilled Holes

Date:	11/3/2011	Bucket 1 Weight (g):	33.35
Plate Thickness:	0.1875 in.	Bucket 2 Weight (g):	33.33
Hole Style:	Drilled No CS	Bucket 3 Weight (g):	33.56

Water Height (in.)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	2.375	2.375	2.375	2.250	2.250	2.250	2.250	2.250	2.250	2.313	2.313	2.313	2.250	2.250	2.250
2	4	4.375	4.375	4.375	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313
3	6	6.313	6.313	6.313	6.188	6.188	6.188	6.250	6.250	6.250	6.250	6.250	6.250	6.313	6.313	6.313
4	8	8.313	8.313	8.313	8.313	8.313	8.313	8.250	8.250	8.250	8.313	8.313	8.313	8.250	8.250	8.250
5	10	10.313	10.313	10.313	10.313	10.313	10.313	10.250	10.250	10.250	10.313	10.313	10.313	10.313	10.313	10.313

Time (sec)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	15.19	15.00	14.94	15.00	14.91	15.13	15.19	15.10	15.06	12.03	11.97	12.16	10.07	9.91	10.03
2	4	15.22	15.00	15.00	14.97	15.03	15.00	15.03	14.94	15.06	10.19	10.00	10.06	8.03	8.00	7.97
3	6	15.22	15.28	15.03	14.96	15.09	15.12	11.87	11.97	12.03	8.03	8.03	8.06	6.10	6.03	6.15
4	8	15.10	15.07	15.09	15.13	14.97	15.06	9.87	9.97	9.94	8.00	7.96	8.03	5.25	5.19	5.07
5	10	14.94	15.03	15.09	12.07	11.97	11.97	10.06	8.09	8.00	6.22	5.62	6.09	4.16	4.00	4.10

Water & Bucket Weight (g)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	255.69	253.40	252.31	453.20	450.44	471.11	629.97	645.89	642.21	716.75	721.81	743.27	797.54	783.59	794.57
2	4	307.18	302.61	303.18	545.90	547.04	546.18	775.89	772.56	781.69	766.53	748.92	762.17	813.49	813.71	805.45
3	6	351.52	349.40	346.10	626.17	630.67	630.75	713.72	720.12	726.51	705.22	706.16	711.73	731.30	728.10	741.64
4	8	382.88	382.39	384.86	709.24	704.84	707.32	666.58	677.15	674.73	791.06	793.91	793.52	694.53	695.23	694.80
5	10	414.29	414.97	417.34	621.08	616.55	612.35	758.23	621.33	607.07	687.98	644.76	685.32	619.83	601.68	607.83

Calculated Results for the 3/16” Drilled Holes

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	222.34	220.07	218.75	419.85	417.11	437.55	596.62	612.56	608.65	683.40	688.48	709.71	764.19	750.26	761.01
2	4	273.83	269.28	269.62	512.55	513.71	512.62	742.54	739.23	748.13	733.18	715.59	728.61	780.14	780.38	771.89
3	6	318.17	316.07	312.54	592.82	597.34	597.19	680.37	686.79	692.95	671.87	672.83	678.17	697.95	694.77	708.08
4	8	349.53	349.06	351.30	675.89	671.51	673.76	633.23	643.82	641.17	757.71	760.58	759.96	661.18	661.90	661.24
5	10	380.94	381.64	383.78	587.73	583.22	578.79	724.88	588.00	573.51	654.63	611.43	651.76	586.48	568.35	574.27

1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.23	0.23	0.23	0.44	0.44	0.46	0.62	0.64	0.64	0.90	0.91	0.93	1.20	1.20	1.20
2	4	0.29	0.28	0.28	0.54	0.54	0.54	0.78	0.78	0.79	1.14	1.13	1.15	1.54	1.55	1.54
3	6	0.33	0.33	0.33	0.63	0.63	0.63	0.91	0.91	0.91	1.33	1.33	1.33	1.81	1.83	1.82
4	8	0.37	0.37	0.37	0.71	0.71	0.71	1.02	1.02	1.02	1.50	1.51	1.50	2.00	2.02	2.07
5	10	0.40	0.40	0.40	0.77	0.77	0.77	1.14	1.15	1.14	1.67	1.72	1.70	2.23	2.25	2.22

Raw Data for the 3/16” Drilled Counter Sunk Holes

Date:	11/3/2011	Bucket 1 Weight (g):	33.35
Plate Thickness:	0.1875 in.	Bucket 2 Weight (g):	33.33
Hole Style:	Drilled CS Down	Bucket 3 Weight (g):	33.56

Water Height (in.)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	2.375	2.375	2.375	2.188	2.188	2.188	2.375	2.375	2.375	2.313	2.313	2.313	2.250	2.250	2.250
2	4	4.375	4.375	4.375	4.250	4.250	4.250	4.313	4.313	4.313	4.250	4.250	4.250	4.250	4.250	4.250
3	6	6.250	6.250	6.250	6.313	6.313	6.313	6.250	6.250	6.250	6.250	6.250	6.250	6.313	6.313	6.313
4	8	8.313	8.313	8.313	8.313	8.313	8.313	8.438	8.438	8.438	8.250	8.250	8.250	8.250	8.250	8.250
5	10	10.313	10.313	10.313	10.313	10.313	10.313	10.250	10.250	10.250	10.313	10.313	10.313	10.250	10.250	10.250

Time (sec)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	15.12	15.07	15.03	15.09	14.94	15.07	14.90	14.91	15.15	11.85	12.06	12.07	9.97	9.87	10.07
2	4	15.09	15.00	15.09	12.12	14.97	15.00	15.00	15.00	15.12	9.84	10.00	10.06	8.07	8.00	8.00
3	6	15.12	15.07	15.16	15.13	14.94	15.00	12.03	12.00	12.06	8.00	7.97	7.84	5.94	5.97	6.29
4	8	15.19	15.10	15.13	15.03	14.09	12.06	9.93	10.00	10.03	8.22	8.06	8.00	5.19	5.00	4.88
5	10	15.15	15.03	15.03	12.06	12.15	12.06	8.06	8.09	8.00	6.16	6.09	5.97	4.22	4.10	4.13

Water & Bucket Weight (g)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	274.07	274.78	274.54	508.72	507.88	513.65	594.98	599.31	599.40	680.60	692.96	691.42	781.07	760.93	784.42
2	4	352.41	348.45	352.97	679.35	672.80	675.87	762.40	756.81	769.74	743.34	757.83	752.16	831.16	833.27	832.38
3	6	401.80	403.52	407.87	822.12	803.98	804.82	722.79	721.03	734.33	707.67	709.73	706.40	738.98	743.96	794.48
4	8	448.95	447.93	446.47	919.15	875.96	742.96	690.57	682.44	691.09	815.63	810.30	796.65	724.67	701.64	699.63
5	10	486.76	476.16	479.27	821.22	826.95	819.57	614.39	614.13	615.25	674.32	672.99	664.04	657.00	659.84	649.83

Calculated Results for the 3/16” Drilled Counter Sunk Holes

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	240.72	241.45	240.98	475.37	474.55	480.09	561.63	565.98	565.84	647.25	659.63	657.86	747.72	727.60	750.86
2	4	319.06	315.12	319.41	646.00	639.47	642.31	729.05	723.48	736.18	709.99	724.50	718.60	797.81	799.94	798.82
3	6	368.45	370.19	374.31	788.77	770.65	771.26	689.44	687.70	700.77	674.32	676.40	672.84	705.63	710.63	760.92
4	8	415.60	414.60	412.91	885.80	842.63	709.40	657.22	649.11	657.53	782.28	776.97	763.09	691.32	668.31	666.07
5	10	453.41	442.83	445.71	787.87	793.62	786.01	581.04	580.80	581.69	640.97	639.66	630.48	623.65	626.51	616.27

1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.25	0.25	0.25	0.50	0.50	0.50	0.60	0.60	0.59	0.87	0.87	0.86	1.19	1.17	1.18
2	4	0.34	0.33	0.34	0.84	0.68	0.68	0.77	0.76	0.77	1.14	1.15	1.13	1.57	1.58	1.58
3	6	0.39	0.39	0.39	0.83	0.82	0.81	0.91	0.91	0.92	1.34	1.35	1.36	1.88	1.89	1.92
4	8	0.43	0.44	0.43	0.93	0.95	0.93	1.05	1.03	1.04	1.51	1.53	1.51	2.11	2.12	2.16
5	10	0.47	0.47	0.47	1.04	1.04	1.03	1.14	1.14	1.15	1.65	1.66	1.67	2.34	2.42	2.37

Raw Data for the 3/16” Plasma Cut Counter Sunk Holes

Date:	11/3/2011	Bucket 1 Weight (g):	33.35
Plate Thickness:	0.1875 in.	Bucket 2 Weight (g):	33.33
Hole Style:	Plasma CS Down	Bucket 3 Weight (g):	33.56

Water Height (in.)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	2.375	2.375	2.375	2.313	2.313	2.313	2.188	2.188	2.188	2.313	2.313	2.313	2.250	2.250	2.250
2	4	4.500	4.500	4.500	4.375	4.375	4.375	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250
3	6	6.375	6.375	6.375	6.250	6.250	6.250	6.188	6.188	6.188	6.250	6.250	6.250	6.250	6.250	6.250
4	8	8.438	8.438	8.438	8.313	8.313	8.313	8.313	8.313	8.313	8.188	8.188	8.188	8.313	8.313	8.313
5	10	10.375	10.375	10.375	10.438	10.438	10.438	10.313	10.313	10.313	10.250	10.250	10.250	10.313	10.313	10.313

Time (sec)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	15.22	15.09	15.03	15.03	15.09	15.00	14.97	14.97	15.00	11.81	11.90	11.93	10.06	9.94	10.06
2	4	14.97	14.93	15.00	14.93	15.10	14.97	15.22	15.12	15.00	9.85	10.10	10.00	7.94	8.06	8.12
3	6	15.00	15.09	14.94	14.93	14.97	15.06	12.12	12.09	12.15	7.90	8.10	8.16	6.09	6.07	6.25
4	8	15.00	15.06	15.09	12.06	12.06	12.06	10.03	10.13	9.97	8.03	8.19	8.09	5.19	5.06	5.28
5	10	15.06	15.00	15.12	12.22	12.12	12.16	8.06	8.16	8.18	6.16	6.00	6.07	4.28	4.06	4.16

Water & Bucket Weight (g)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	275.23	270.55	272.05	450.60	449.04	444.52	700.69	698.34	700.72	723.59	729.67	734.98	782.45	786.02	797.64
2	4	347.55	348.13	348.21	577.83	584.39	576.84	916.95	909.08	914.10	784.02	799.49	796.30	831.26	837.75	851.59
3	6	402.37	404.60	402.30	679.58	683.17	689.79	878.41	883.08	882.29	753.71	768.63	786.55	756.91	763.10	776.59
4	8	451.26	454.39	456.82	621.82	625.17	621.30	819.09	826.27	829.33	854.82	871.21	856.04	740.14	716.41	769.31
5	10	483.23	481.84	485.52	656.22	652.31	660.09	743.75	751.64	743.74	729.50	713.59	724.17	646.97	663.13	676.71

Calculated Results for the 3/16” Plasma Cut Counter Sunk Holes

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	241.88	237.22	238.49	417.25	415.71	410.96	667.34	665.01	667.16	690.24	696.34	701.42	749.10	752.69	764.08
2	4	314.20	314.80	314.65	544.48	551.06	543.28	883.60	875.75	880.54	750.67	766.16	762.74	797.91	804.42	818.03
3	6	369.02	371.27	368.74	646.23	649.84	656.23	845.06	849.75	848.73	720.36	735.30	752.99	723.56	729.77	743.03
4	8	417.91	421.06	423.26	588.47	591.84	587.74	785.74	792.94	795.77	821.47	837.88	822.48	706.79	683.08	735.75
5	10	449.88	448.51	451.96	622.87	618.98	626.53	710.40	718.31	710.18	696.15	680.26	690.61	613.62	629.80	643.15

1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.25	0.25	0.25	0.44	0.44	0.43	0.71	0.70	0.70	0.93	0.93	0.93	1.18	1.20	1.20
2	4	0.33	0.33	0.33	0.58	0.58	0.58	0.92	0.92	0.93	1.21	1.20	1.21	1.59	1.58	1.60
3	6	0.39	0.39	0.39	0.69	0.69	0.69	1.11	1.11	1.11	1.45	1.44	1.46	1.88	1.91	1.88
4	8	0.44	0.44	0.44	0.77	0.78	0.77	1.24	1.24	1.27	1.62	1.62	1.61	2.16	2.14	2.21
5	10	0.47	0.47	0.47	0.81	0.81	0.82	1.40	1.40	1.38	1.79	1.80	1.80	2.27	2.46	2.45

Raw Data for the 1/4” Drilled Holes

Date:	11/3/2011	Bucket 1 Weight (g):	33.35
Plate Thickness:	0.25 in.	Bucket 2 Weight (g):	33.33
Hole Style:	Drilled No CS	Bucket 3 Weight (g):	33.56

Water Height (in.)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	2.375	2.375	2.375	2.250	2.250	2.250	2.250	2.250	2.250	2.313	2.313	2.313	2.313	2.313	2.313
2	4	4.438	4.438	4.438	4.375	4.375	4.375	4.250	4.250	4.250	4.313	4.313	4.313	4.313	4.313	4.313
3	6	6.375	6.375	6.375	6.250	6.250	6.250	6.188	6.188	6.188	6.250	6.250	6.250	6.313	6.313	6.313
4	8	8.438	8.438	8.438	8.313	8.313	8.313	8.313	8.313	8.313	8.313	8.313	8.313	8.375	8.375	8.375
5	10	10.438	10.438	10.438	10.313	10.313	10.313	10.313	10.313	10.313	10.438	10.438	10.438	10.375	10.375	10.375

Time (sec)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	15.06	15.06	16.10	15.03	15.06	15.00	15.09	14.94	15.13	12.13	12.03	11.94	10.03	9.96	9.94
2	4	15.03	15.06	15.06	15.07	15.19	15.07	14.25	15.00	15.07	10.09	10.25	9.90	8.10	8.10	8.10
3	6	15.12	15.07	15.16	15.28	15.31	15.21	11.97	11.91	11.96	8.00	8.00	8.06	6.13	6.00	6.15
4	8	14.97	15.09	15.03	15.19	15.25	15.13	9.96	10.00	10.12	7.28	7.09	7.07	5.12	5.13	5.12
5	10	15.03	15.03	15.09	12.04	12.03	12.09	8.09	8.00	8.06	6.21	6.09	6.18	4.10	4.47	3.97

Water & Bucket Weight (g)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	303.30	302.62	320.66	453.68	452.15	456.15	599.69	601.44	602.99	741.08	744.51	733.64	787.08	779.18	781.59
2	4	396.41	399.81	397.04	597.63	601.61	596.13	713.53	753.02	748.90	767.73	784.63	755.24	795.44	801.71	801.01
3	6	462.16	458.45	462.79	610.30	608.27	607.18	695.90	694.59	701.47	707.81	721.17	721.21	718.22	705.51	714.64
4	8	523.19	528.12	523.77	668.17	673.01	667.98	672.73	674.29	678.02	738.39	717.31	717.95	616.13	678.34	687.50
5	10	577.96	577.69	578.43	584.45	582.92	588.35	601.91	601.33	603.35	691.70	681.18	694.68	605.37	652.56	588.95

Calculated Results for the 1/4” Drilled Holes

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	269.95	269.29	287.10	420.33	418.82	422.59	566.34	568.11	569.43	707.73	711.18	700.08	753.73	745.85	748.03
2	4	363.06	366.48	363.48	564.28	568.28	562.57	680.18	719.69	715.34	734.38	751.30	721.68	762.09	768.38	767.45
3	6	428.81	425.12	429.23	576.95	574.94	573.62	662.55	661.26	667.91	674.46	687.84	687.65	684.87	672.18	681.08
4	8	489.84	494.79	490.21	634.82	639.68	634.42	639.38	640.96	644.46	705.04	683.98	684.39	582.78	645.01	653.94
5	10	544.61	544.36	544.87	551.10	549.59	554.79	568.56	568.00	569.79	658.35	647.85	661.12	572.02	619.23	555.39

1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.28	0.28	0.28	0.44	0.44	0.45	0.59	0.60	0.60	0.92	0.94	0.93	1.19	1.19	1.19
2	4	0.38	0.39	0.38	0.59	0.59	0.59	0.76	0.76	0.75	1.15	1.16	1.16	1.49	1.50	1.50
3	6	0.45	0.45	0.45	0.60	0.60	0.60	0.88	0.88	0.89	1.34	1.36	1.35	1.77	1.78	1.76
4	8	0.52	0.52	0.52	0.66	0.66	0.66	1.02	1.02	1.01	1.54	1.53	1.53	1.80	1.99	2.02
5	10	0.57	0.57	0.57	0.73	0.72	0.73	1.11	1.13	1.12	1.68	1.69	1.70	2.21	2.20	2.22

Raw Data for the 1/4” Drilled Counter Sunk Holes

Date:	11/3/2011	Bucket 1 Weight (g):	33.35
Plate Thickness:	0.25 in.	Bucket 2 Weight (g):	33.33
Hole Style:	Drilled CS Down	Bucket 3 Weight (g):	33.56

Water Height (in.)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	2.375	2.375	2.375	2.313	2.313	2.313	2.313	2.313	2.313	2.313	2.313	2.313	2.313	2.313	2.313
2	4	4.500	4.500	4.500	4.375	4.375	4.375	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313	4.313
3	6	6.375	6.375	6.375	6.313	6.313	6.313	6.313	6.313	6.313	6.250	6.250	6.250	6.250	6.250	6.250
4	8	8.438	8.438	8.438	8.313	8.313	8.313	8.250	8.250	8.250	8.313	8.313	8.313	8.375	8.375	8.375
5	10	10.375	10.375	10.375	10.438	10.438	10.438	10.250	10.250	10.250	10.375	10.375	10.375	10.313	10.313	10.313

Time (sec)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	15.16	15.03	15.13	15.06	15.00	14.97	14.97	15.03	15.10	12.00	12.12	12.07	10.03	9.96	10.10
2	4	14.97	14.97	15.03	15.03	15.06	15.19	15.10	15.10	15.07	10.09	10.03	10.07	7.97	7.97	8.03
3	6	15.03	15.06	15.06	14.97	15.97	15.12	12.12	12.00	12.15	8.06	7.97	8.06	6.18	6.19	6.06
4	8	15.12	15.16	15.09	15.07	15.16	15.16	10.00	10.28	10.03	7.13	7.25	8.12	5.06	5.09	5.00
5	10	15.13	15.19	15.10	12.13	12.12	12.09	8.07	7.97	8.12	6.16	6.06	6.03	4.53	4.44	4.34

Water & Bucket Weight (g)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	245.42	244.23	246.30	389.29	388.69	388.83	596.44	596.40	598.47	705.38	713.97	712.75	768.49	770.03	781.57
2	4	310.85	311.46	313.81	502.65	503.18	506.65	777.69	781.89	775.34	774.27	775.72	783.84	799.79	805.43	814.80
3	6	356.77	357.65	358.68	580.08	614.81	580.59	752.39	745.74	744.55	731.80	728.79	738.59	744.19	755.68	736.91
4	8	400.76	399.62	399.49	661.05	660.10	663.27	713.45	726.38	715.91	732.57	737.44	831.84	693.88	696.00	691.35
5	10	435.11	439.58	435.83	591.52	595.64	598.22	639.55	633.82	646.60	712.13	707.90	700.19	694.40	678.36	667.42

Calculated Results for the 1/4” Drilled Counter Sunk Holes

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	212.07	210.90	212.74	355.94	355.36	355.27	563.09	563.07	564.91	672.03	680.64	679.19	735.14	736.70	748.01
2	4	277.50	278.13	280.25	469.30	469.85	473.09	744.34	748.56	741.78	740.92	742.39	750.28	766.44	772.10	781.24
3	6	323.42	324.32	325.12	546.73	581.48	547.03	719.04	712.41	710.99	698.45	695.46	705.03	710.84	722.35	703.35
4	8	367.41	366.29	365.93	627.70	626.77	629.71	680.10	693.05	682.35	699.22	704.11	798.28	660.53	662.67	657.79
5	10	401.76	406.25	402.27	558.17	562.31	564.66	606.20	600.49	613.04	678.78	674.57	666.63	661.05	645.03	633.86

1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.22	0.22	0.22	0.37	0.38	0.38	0.60	0.59	0.59	0.89	0.89	0.89	1.16	1.17	1.17
2	4	0.29	0.29	0.30	0.49	0.49	0.49	0.78	0.79	0.78	1.16	1.17	1.18	1.52	1.54	1.54
3	6	0.34	0.34	0.34	0.58	0.58	0.57	0.94	0.94	0.93	1.37	1.38	1.39	1.82	1.85	1.84
4	8	0.39	0.38	0.38	0.66	0.66	0.66	1.08	1.07	1.08	1.55	1.54	1.56	2.07	2.06	2.09
5	10	0.42	0.42	0.42	0.73	0.74	0.74	1.19	1.19	1.20	1.75	1.76	1.75	2.31	2.30	2.31

Raw Data for the 1/4” Plasma Cut Counter Sunk Holes

Date:	11/3/2011	Bucket 1 Weight (g):	33.35
Plate Thickness:	0.25 in.	Bucket 2 Weight (g):	33.33
Hole Style:	Plasma CS Down	Bucket 3 Weight (g):	33.56

Water Height (in.)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	2.375	2.375	2.375	2.313	2.313	2.313	2.188	2.188	2.188	2.313	2.313	2.313	2.250	2.250	2.250
2	4	4.500	4.500	4.500	4.375	4.375	4.375	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250	4.250
3	6	6.375	6.375	6.375	6.250	6.250	6.250	6.188	6.188	6.188	6.250	6.250	6.250	6.250	6.250	6.250
4	8	8.438	8.438	8.438	8.313	8.313	8.313	8.313	8.313	8.313	8.188	8.188	8.188	8.313	8.313	8.313
5	10	10.375	10.375	10.375	10.438	10.438	10.438	10.313	10.313	10.313	10.250	10.250	10.250	10.313	10.313	10.313

Time (sec)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	15.16	15.00	15.22	15.00	15.12	15.12	14.93	14.97	14.97	12.10	11.94	12.06	9.94	9.94	9.07
2	4	15.03	14.97	15.19	15.47	14.93	15.03	12.25	11.97	11.97	10.03	9.88	10.03	7.91	8.16	8.28
3	6	15.13	15.15	15.07	15.12	15.09	14.97	12.04	11.03	11.09	8.10	8.44	8.32	6.09	6.16	6.22
4	8	15.16	15.16	15.07	15.12	15.18	15.13	10.13	10.15	10.06	7.00	7.06	7.12	5.09	5.09	5.06
5	10	15.03	15.12	15.06	12.18	12.16	12.03	8.16	8.06	8.03	6.09	6.16	6.18	4.68	4.34	4.62

Water & Bucket Weight (g)

		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	253.65	250.93	255.60	400.89	405.71	405.97	672.05	681.87	676.33	761.59	749.24	752.95	800.94	803.88	728.41
2	4	326.04	325.50	330.24	534.28	517.83	520.20	751.58	725.51	723.64	817.88	818.27	825.02	831.65	861.71	886.65
3	6	378.47	377.69	379.20	610.17	606.11	601.71	852.28	786.15	783.06	803.22	837.05	818.54	769.65	779.77	796.01
4	8	431.18	426.56	428.58	683.52	688.29	680.59	834.15	841.14	819.80	797.76	797.22	798.61	737.65	726.67	721.41
5	10	462.81	466.82	464.99	617.53	616.13	617.55	742.49	732.59	732.75	763.80	774.29	776.93	749.50	711.42	743.88

Calculated Results for the 1/4” Plasma Cut Counter Sunk Holes

Water Volume (ml)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	220.30	217.60	222.04	367.54	372.38	372.41	638.70	648.54	642.77	728.24	715.91	719.39	767.59	770.55	694.85
2	4	292.69	292.17	296.68	500.93	484.50	486.64	718.23	692.18	690.08	784.53	784.94	791.46	798.30	828.38	853.09
3	6	345.12	344.36	345.64	576.82	572.78	568.15	818.93	752.82	749.50	769.87	803.72	784.98	736.30	746.44	762.45
4	8	397.83	393.23	395.02	650.17	654.96	647.03	800.80	807.81	786.24	764.41	763.89	765.05	704.30	693.34	687.85
5	10	429.46	433.49	431.43	584.18	582.80	583.99	709.14	699.26	699.19	730.45	740.96	743.37	716.15	678.09	710.32

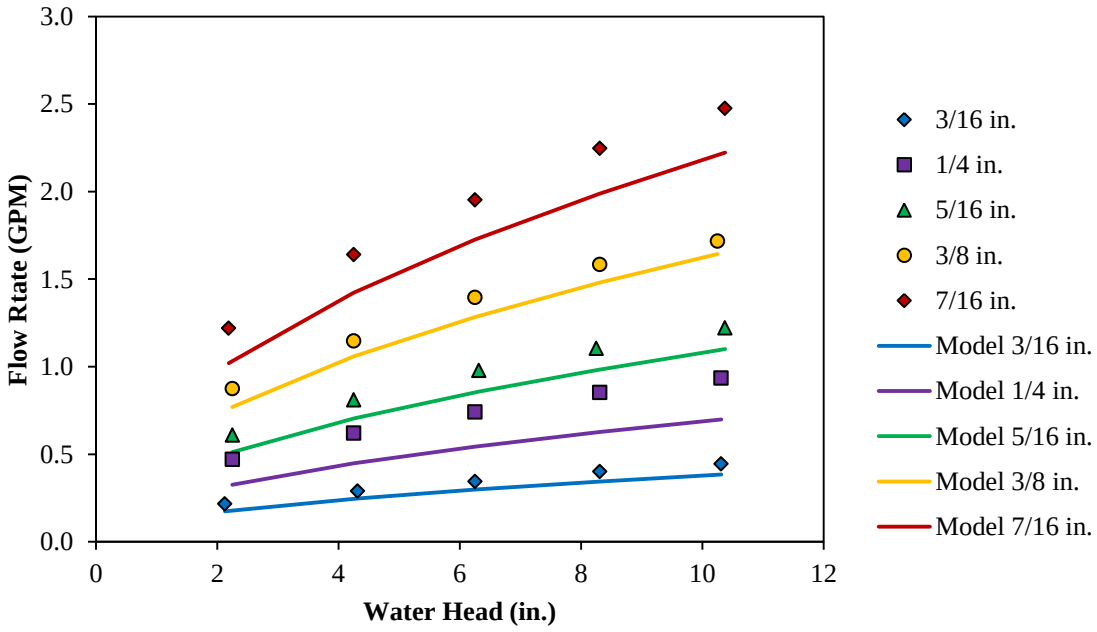
1 gal = 3785.41 ml

Flow Rate (GPM)		Hole #1			Hole #2			Hole #3			Hole #4			Hole #5		
		3/16"			1/4"			5/16"			3/8"			7/16"		
Test #	Approx. Water Height (in)	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
1	2	0.23	0.23	0.23	0.39	0.39	0.39	0.68	0.69	0.68	0.95	0.95	0.95	1.22	1.23	1.21
2	4	0.31	0.31	0.31	0.51	0.51	0.51	0.93	0.92	0.91	1.24	1.26	1.25	1.60	1.61	1.63
3	6	0.36	0.36	0.36	0.60	0.60	0.60	1.08	1.08	1.07	1.51	1.51	1.50	1.92	1.92	1.94
4	8	0.42	0.41	0.42	0.68	0.68	0.68	1.25	1.26	1.24	1.73	1.72	1.70	2.19	2.16	2.15
5	10	0.45	0.45	0.45	0.76	0.76	0.77	1.38	1.38	1.38	1.90	1.91	1.91	2.43	2.48	2.44

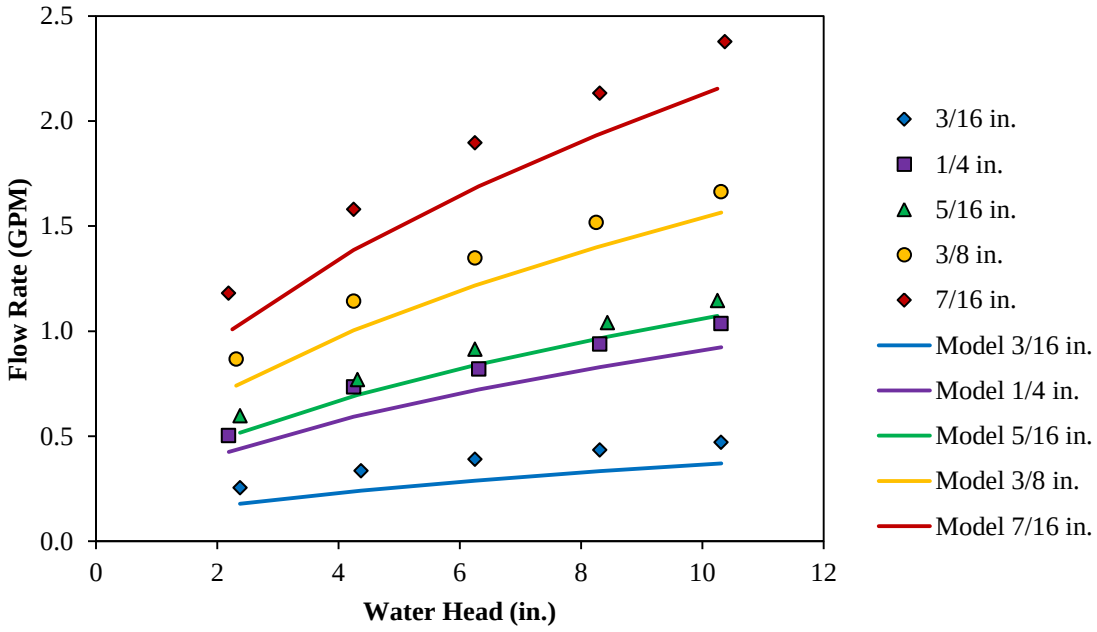
APPENDIX F

Drip Pan Model Plots

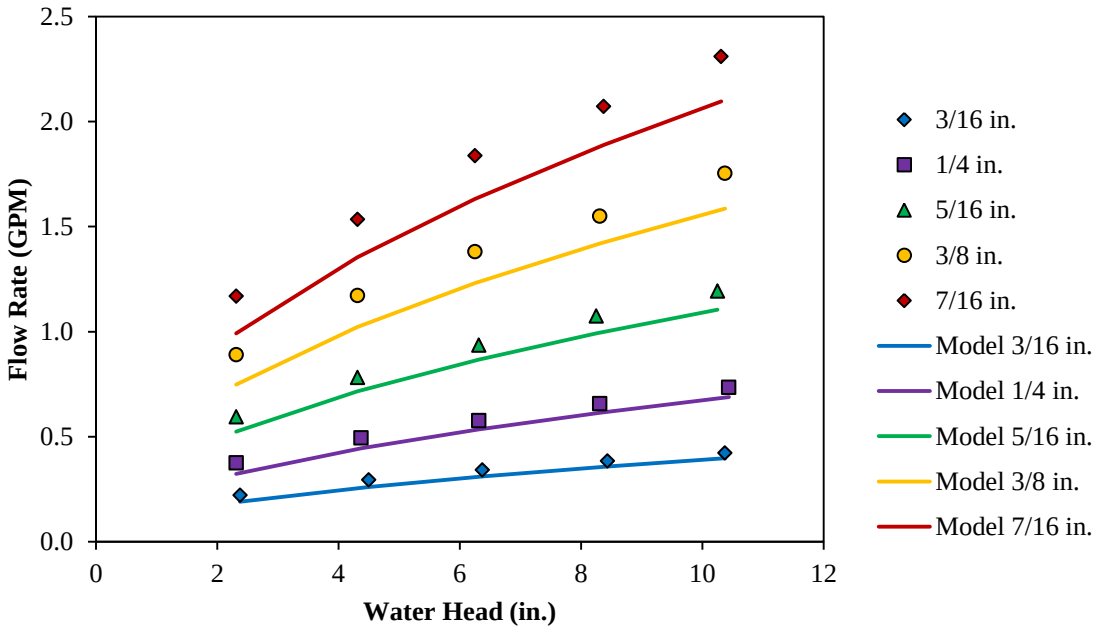
Comparison between the theoretical model and measured data for drilled and counter sunk holes for the 1/8” thick plate



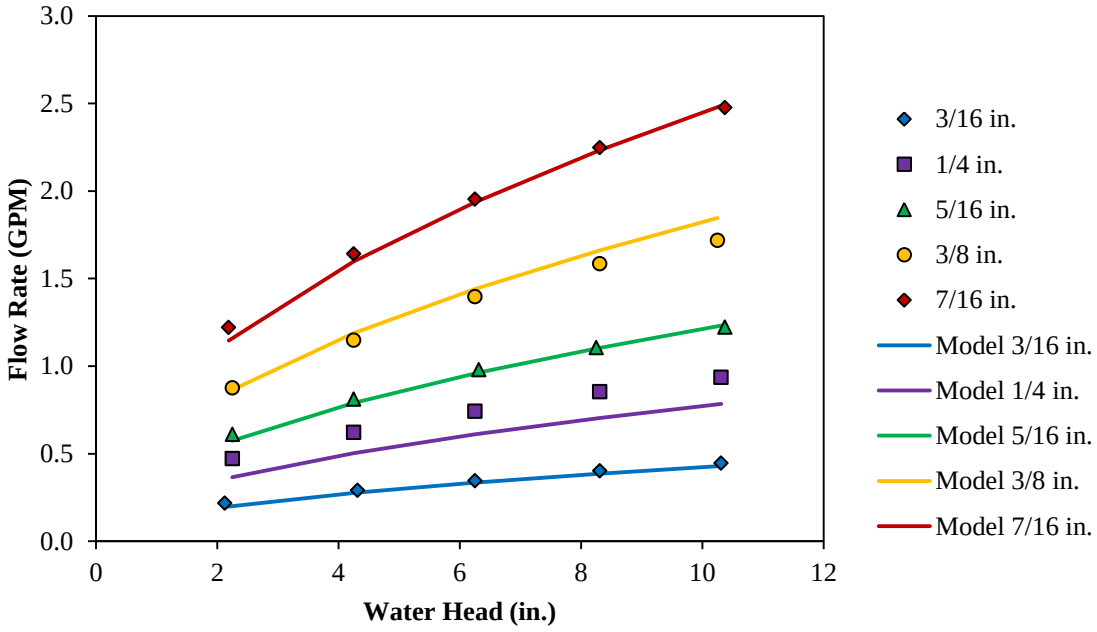
Comparison between the theoretical model and measured data for drilled and counter sunk holes for the 3/16” thick plate



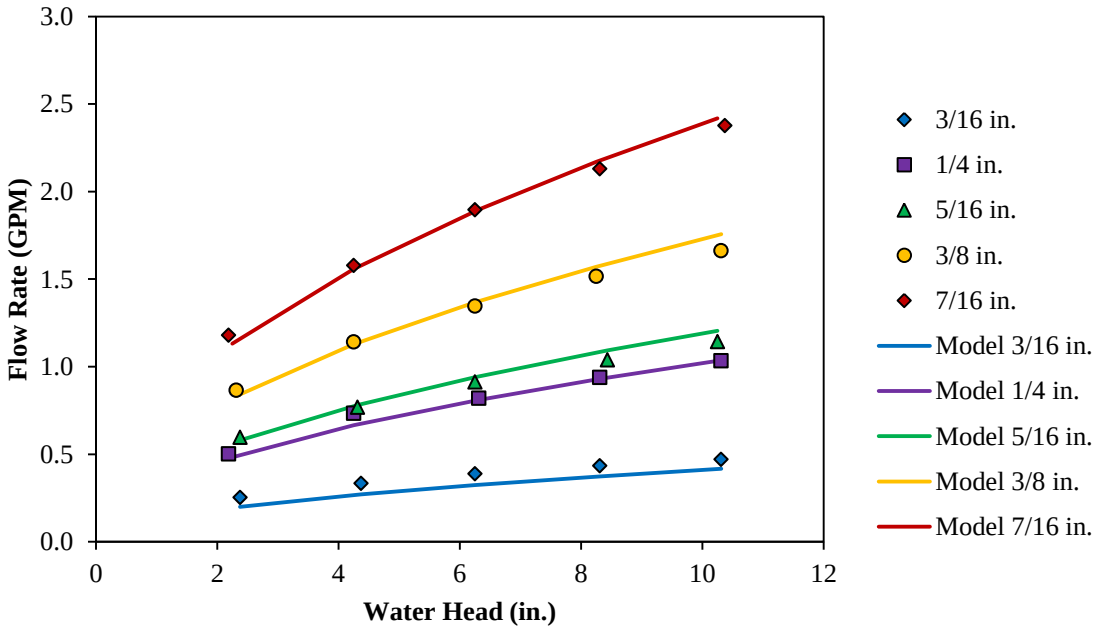
Comparison between the theoretical model and measured data for drilled and counter sunk holes for the 1/4” thick plate



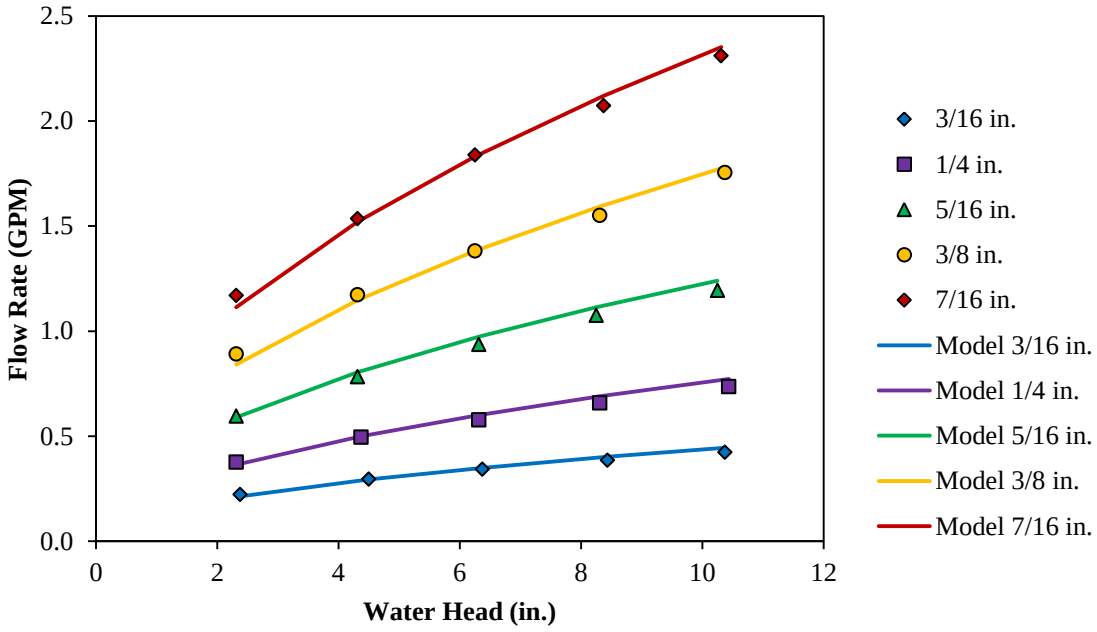
Comparison between the fit averaged C_c model and measured data for drilled and counter sunk for the holes 1/8” thick plate



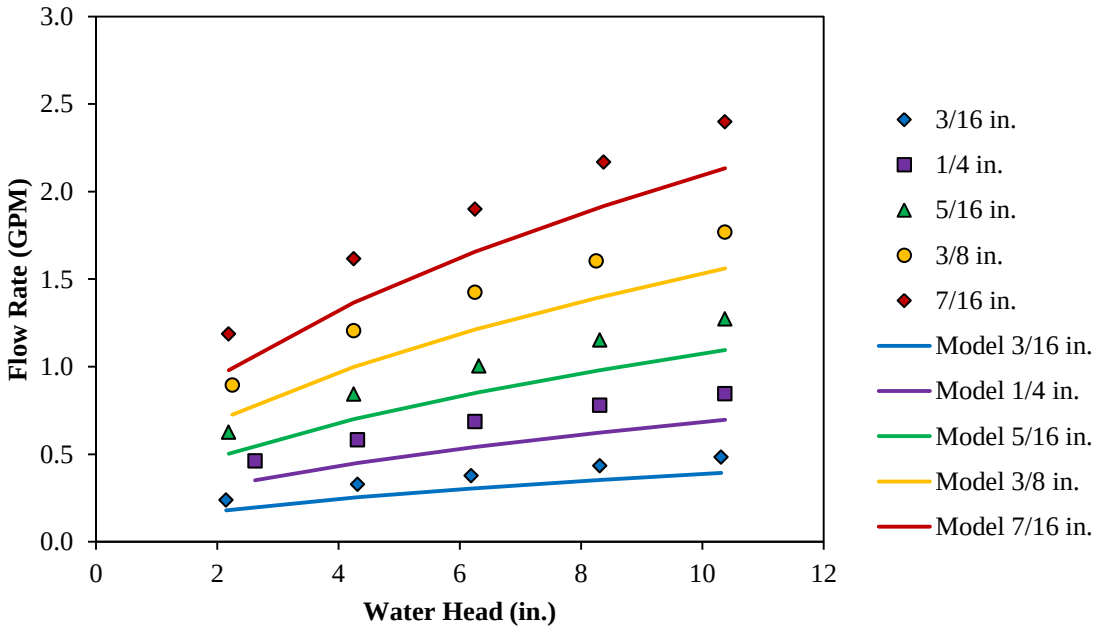
Comparison between the fit averaged C_c model and measured data for drilled and counter sunk for the holes 3/16" thick plate



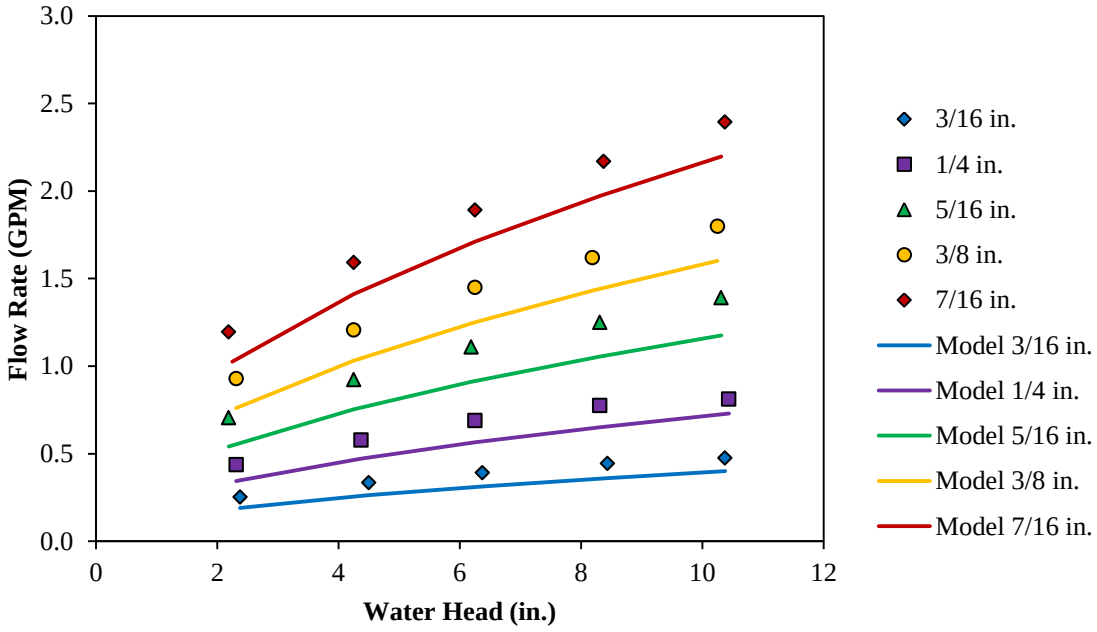
Comparison between the fit averaged C_c model and measured data for drilled and counter sunk for the holes 1/4" thick plate



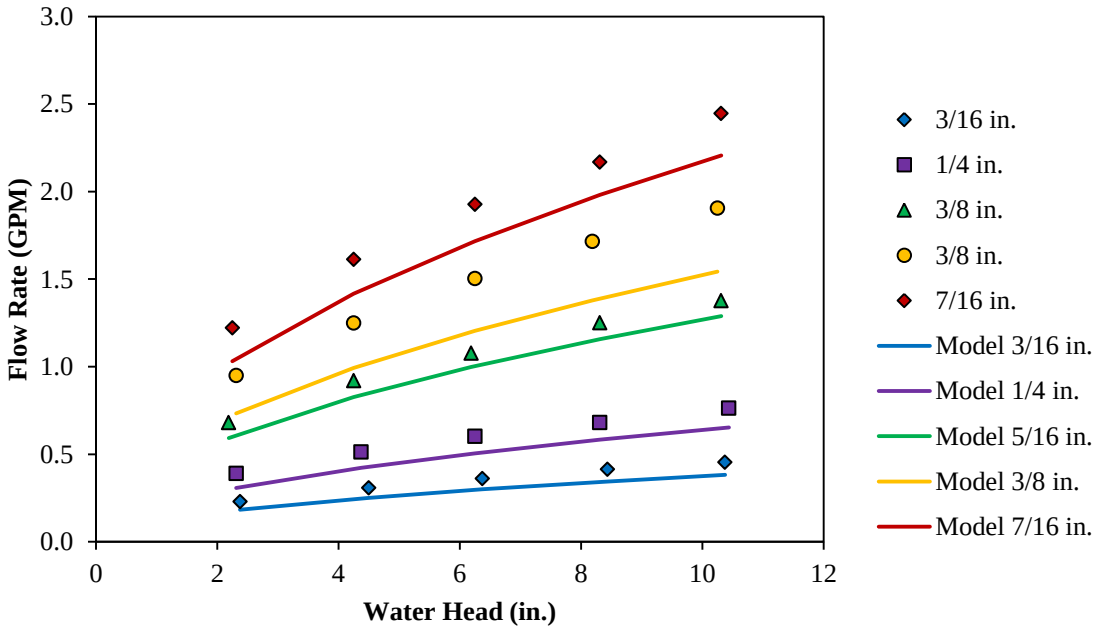
Comparison between the theoretical model and measured data for plasma cut and counter sunk holes for the 1/8” thick plate



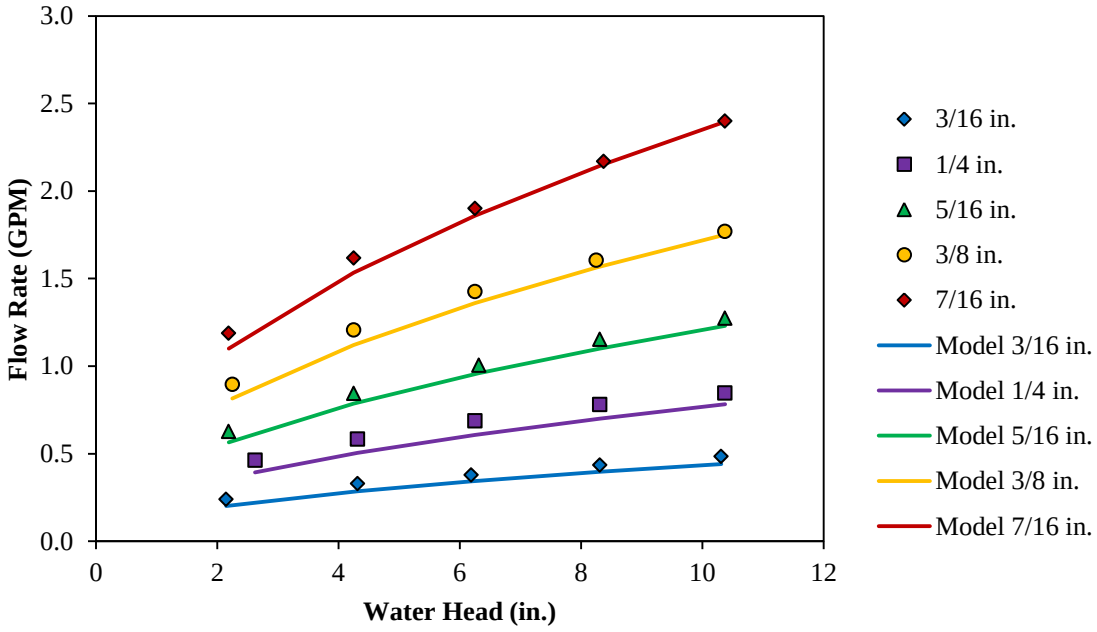
Comparison between the theoretical model and measured data for plasma cut and counter sunk holes for the 3/16” thick plate



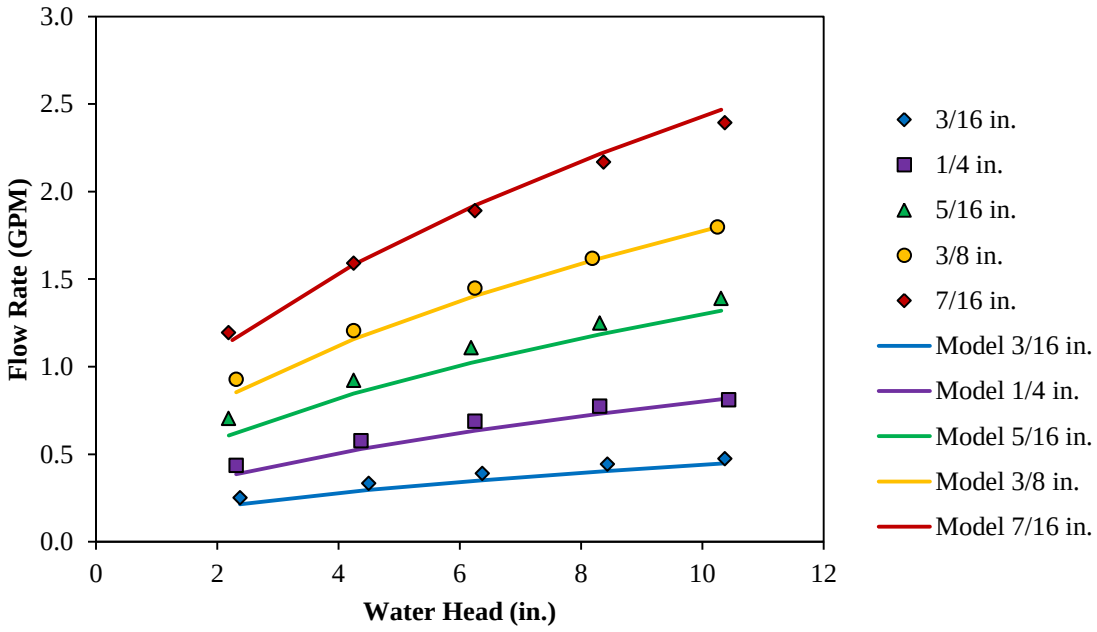
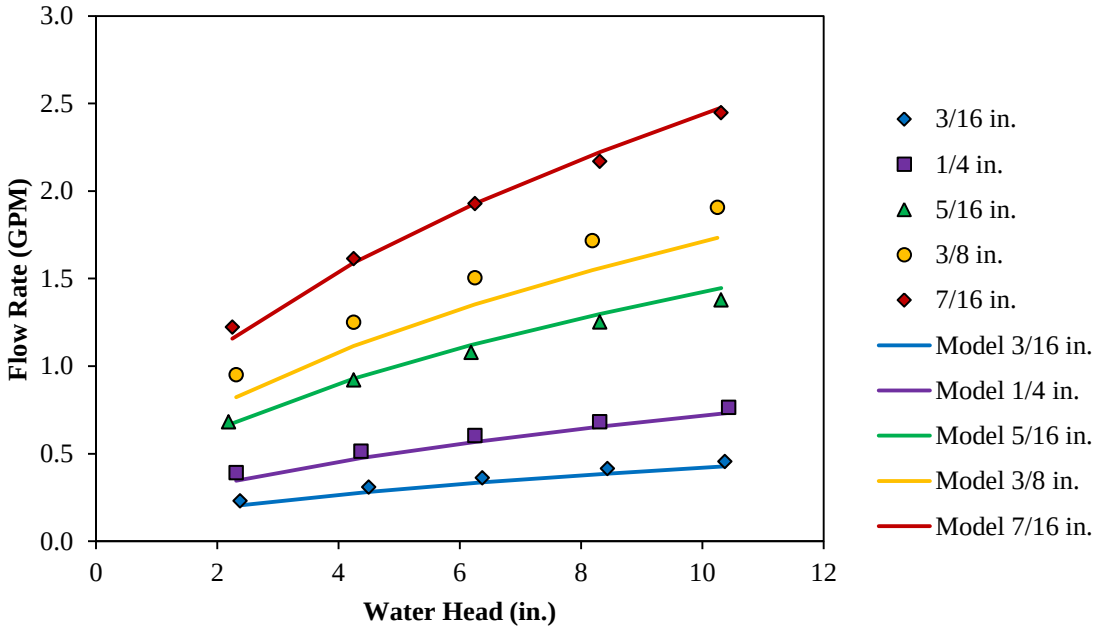
Comparison between the theoretical model and measured data for plasma cut and counter sunk holes for the 1/4” thick plate



Comparison between the fit averaged C_c model and measured data for plasma cut and counter sunk for the holes 1/8” thick plate



Comparison between the fit averaged C_c model and measured data for plasma cut and counter sunk for the holes 3/16" thick plate



Comparison between the fit averaged C_c model and measured data for plasma cut and counter sunk for the holes 1/4" thick plate