# Advanced Multi-Product Coal Utilization By-Product Processing Plant

Technical Progress Report for the Period: 1 October 2005 to 31 December 2005

Principal Authors: John Groppo and Thomas Robl

January 2006

U. S. Department of Energy Cooperative Agreement No. DE-FC26-03NT41781

Center for Applied Energy Research
2540 Research Park Drive
University of Kentucky
Lexington, KY 40511

**DISCLAIMER**

**ABSTRACT**

The objective of the project is to build a multi-product ash beneficiation plant at Kentucky Utilities 2,200-MW Ghent Generating Station, located in Carroll County, Kentucky. This part of the study includes an investigation of the secondary classification characteristics of the ash feedstock excavated from the lower ash pond at Ghent Station.

The secondary classification testing was conducted using a continuous demonstration-scale lamella classifier that was operated at a feed rate of 0.3 to 1.5 tons/hr. Feed to the secondary classifier was generated by operating the primary classifier at the conditions shown to be effective previously. Samples were taken while the secondary classifier was operated under a variety of conditions in order to determine the range of conditions were the unit could be efficiently operated.

Secondary classification was effective for producing an ultra-fine ash (UFA) product. Inclined lamella plates provided an effective settling surface for coarser ash particles and plate spacing was shown to be an important variable. Results showed that the closer the plate spacing, the finer the size distribution of the UFA product.

A dosage of 2 g/kg of dispersant provided a UFA product with an average particle size of 4 to 6 µm. At lower dosages, UFA products were coarser ($d_{50}$ 6 to 10 µm).

Another important operating parameter for effective secondary classification was superficial velocity (SV), a parameter related to the feed rate and classifier geometry. Reducing the SV provided finer-sized products; however, it also reduced yield. In consideration of product grade and recovery, operating at a SV of less than 15 cm/min provided acceptable results ($d_{50}$ = 3 to 6 µm, 30-60% 5 µm recovery) with reasonable dispersant dosages.

**TABLE OF CONTENTS**

**LIST OF FIGURES**

## EXECUTIVE SUMMARY

The project area is located in Carroll County, Kentucky, approximately one mile northeast of Ghent, Kentucky. The lower ash pond is situated immediately adjacent to U.S. Highway 42 on the southwest corner of the Ghent power plant site. Disposal of ash into the 120-acre pond began when the Ghent power plant became operational in 1973 and continued over a period of 20 years until the upper ash pond became operational in 1993. The Ghent power plant has four separate generating units. Units 1 and 2 burn a high sulfur coal and an Appalachian low sulfur compliance coal. Units 3 and 4 have multi-fuel burners and have used subbituminous coal, but are currently fueled by bituminous coal. The coals burned within these units were subjected to major and trace elemental analyses, mercury analysis, and loss-on-ignition (LOI) tests.

Approximately 150 tons of pond ash were excavated from the Ghent site and processed to remove coarse bottom ash and vegetation that could cause plugging problems in the pilot demonstration unit. The excavated ash was dry-screened at 3/8”; the -3/8” ash was stockpiled adjacent to the pilot demonstration unit while the +3/8” was returned to the pond for storage.

Primary classification was shown to be effective for rejecting coarse (+100 mesh, ~150 µm) material from the pond ash while maintaining high recovery of -100 mesh and particularly -5 µm ash. The classifier used was capable of efficiently providing this separation under a variety of feed rates and pulp densities, but +100 mesh rejection decreased with increasing feed rate. Operating the classifier at a feed rate of 40 to 50 gpm provided the primary classification desired to meet the project objectives.

Froth flotation was evaluated to reduce the LOI of the primary classifier overflow to below 3%. A minimum retention time of 6 minutes was required to provide LOI reduction to 2.5% LOI using 1.2 lbs/ton collector and 0.23 lbs/ton frother. Reagent costs to provide acceptable grade tailings were 0.50 to 1.00 $/ton of flotation feed and longer retention times did not provide any significant benefit in terms of performance. Demonstration plant flotation results were consistent with release analysis results, indicating that no further significant improvement in flotation performance could be expected with optimization of other variables.

Secondary classification of the primary classification overflow was effective for producing an ultra-fine ash (UFA) product. Inclined lamella plates provided an effective settling surface for coarser ash particles and plate spacing was shown to be an important variable. A dosage of 2 g/kg NSF dispersant (naphthalene-sulfonate-formaldehyde concentrate, Handy Chemical Co. “Disal” product) provided a UFA product with an average particle size of 4 to 6 µm, while coarser ($d_{50}$[1] 6 to 10 µm) UFA products were generated at lower dosages. Reducing the Superficial Velocity (SV) provided finer-sized UFA products; however, lowering SV also reduced the yield. In consideration of product grade and recovery, operating at a SV of less than 15 cm/min provided acceptable results ($d_{50}$ = 3 to 6 µm, 30-70% 5 µm recovery) with reasonable dispersant dosages.

---

[1] d50 is sometimes represented as “$D_{50}$” and is the mean particle diameter on a volumetric basis.

## INTRODUCTION

This project will complete the final design and construction of an ash beneficiation plant that will produce a variety of high quality products including pozzolan, mineral filler, fill sand, and carbon. All of the products from the plant are expected to have value and be marketable. The ash beneficiation process uses a combination of hydraulic classification, spiral concentration and separation, and froth flotation. The advanced coal ash beneficiation processing plant will be built at Kentucky Utility's 2,200 MW Ghent Power Plant in Carrollton, Kentucky. The technology was developed at the University of Kentucky Center for Applied Energy Research (CAER) and is being commercialized by CEMEX Inc. with support from LG&E Energy, Inc., the UK CAER, and the U.S.DoE.

This technical report includes research that was conducted during the fourth quarter of 2005. The focus of the effort was on secondary classification to produce an ultra-fine ash (UFA) product. The feed to the secondary classifier was the overflow from the primary classifier, which was essentially -100 mesh (<150 μ). The finest particles were dispersed using "Disal" (a NSF dispersant (naphthalene-sulfonate-formaldehyde concentrate), from Handy Chemical Co.), a commercially-available surfactant commonly used as a water reducer. The dispersed particles were classified in a secondary classifier, which effectively sorted the suspended particles. Operating conditions were evaluated which allowed the coarser particles (>10 μm) to settle while the finer particles remained in suspension. Lamella plates were installed in the secondary classifier to provide a settling surface for the coarser particles.

## FIELD DEMONSTRATION TESTING

### Secondary Classification

Testing efforts focused on producing ultra-fine ash (UFA) using secondary classification. The equipment used to complete this testing is shown in Figure 1. Feed ash was conveyed into the slurry mix tank and mixed with water to prepare a slurry with the desired pulp density (~15% solids w/w). The prepared slurry was then pumped into the feed tank over a screen to remove a small amount of +6 mesh material in order to prevent plugging. The -6 mesh slurry was then pumped into the primary classifier at the desired rate to effectively reject +100 mesh material. The -100 mesh slurry overflowed the primary classifier and was used as feed to the secondary classifier. Preliminary testing was conducted by preparing a large volume of the -100 mesh slurry and retaining it in a 1500 gallon tank that was mixed with a re-circulating pump.

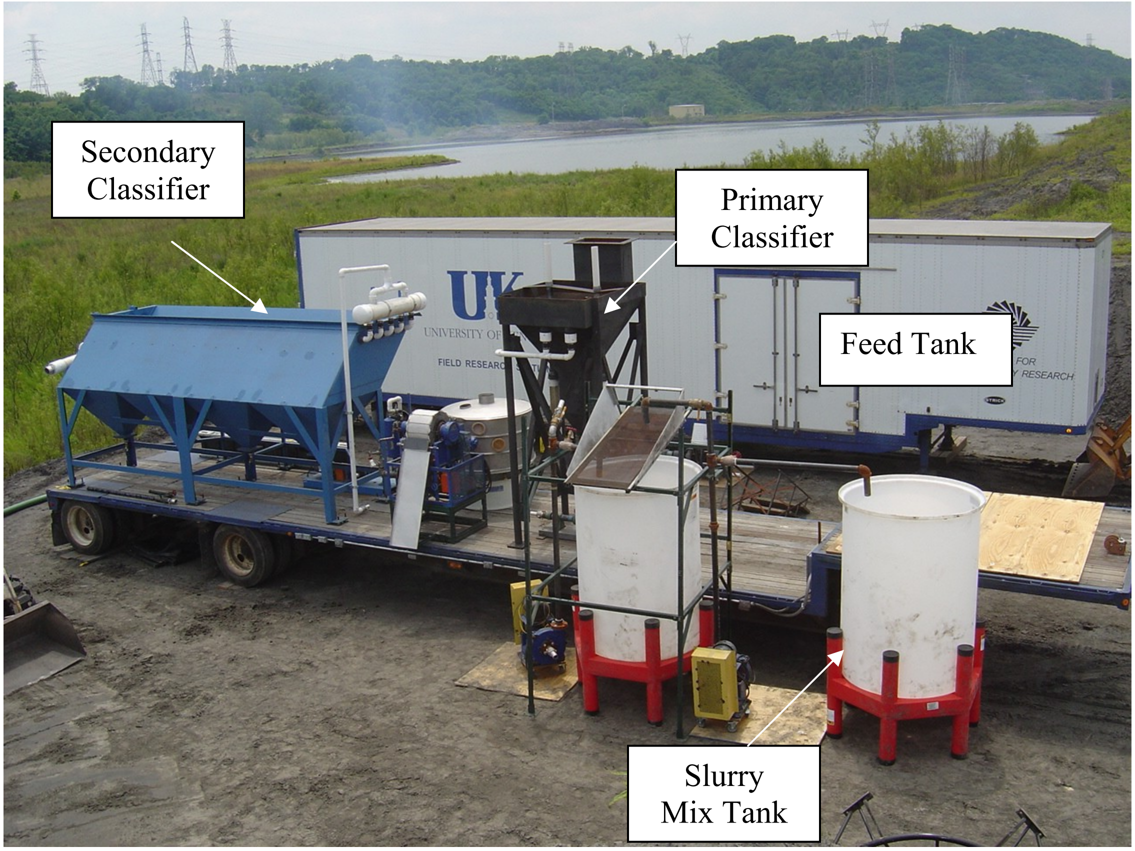


Figure 1. Equipment Layout for Slurry Preparation, Primary Classification and Secondary Classification

The desired dosage of dispersant (Disal) was mixed with the slurry and feed was metered into the secondary classifier at the desired rate. The feed entered the secondary classifier through a manifold (Figure 2). The secondary classifier was a rectangular tank (16' long x 4' wide x 2' deep) inclined on a 45$^{o}$ angle. A series of parallel lamella plates were installed along the length of the device at a plate spacing of 7 cm. The primary purpose of the lamella plates was to provide a settling surface to reduce the distance that coarse particles would need to settle in order to be rejected from the final product. The distance between the plates determine the particle diameters that are rejected for any retention time.

Coarse particles accumulate on the lamella plates and flow to the bottom of the device where they are collected in prism-shaped hoppers (Figure 3). Accumulated coarse solids were removed from the collection hoppers with variable speed pumps. The product slurry containing the UFA overflowed the device at the end opposite the feed point (Figure 4) through overflow ports. The overflow ports were submerged to prevent cenospheres from overflowing with the UFA product. During testing, the overflow slurry and all of the underflow slurries were combined and re-circulated back to the classifier feed tank. The system was allowed to operate for a length of time at least twice the retention time of the secondary classifier before all product streams were sampled.

Figure 2. Feed to Secondary Classifier

Figure 3. Collection Hoppers under Secondary Classifier

Figure 4. Top View of Secondary Classifier Showing Lamella Plates

The first objective of testing was to determine the proper feed rate and Disal dosage. Laboratory testing provided guidelines for both of these parameters. Since the volume of the pilot secondary classifier was so much larger than what was used in the laboratory, data is reported as superficial velocity (SV) or the average velocity of suspended particles in the slurry flowing through the device from the feed end to the discharge end corrected for the underflow from each section or “cell”. Or, $SV = \Sigma (U_I + U_O)/2$ where $U_O = U_I - U_U$. The feed rate to a given cell is $U_I$, $U_O$ is the outflow rate from a cell and $U_U$ is the underflow rate from a cell. There were either 4 or later 2 cells in the tested configuration. As shown in Figure 5, at minimal dosage, increasing SV increased the 5 µm recovery, yield and average particle size (d50) or “grade” of the product. At this dosage, increasing the SV from 5 to 25 cm/min increased the 5 µm recovery, (defined here as the feed solids rate of the -5 µm particles/product solids rate of the -5 µm particles) from 18% to 32% while the product grade also improved, from 5.5 µm to 8.8 µm.

Increasing the Disal dosage to 1.5 g/kg provided similar trends with better results (Figure 7). Over the same SV range (5 to 25 cm/min), the d50 of the product was smaller (5.1 µm to 7.7 µm) than for the lower dosage. Recovery was also higher (22% to 38%).

Further increasing the Disal dosage to 2.5 g/kg provided further improvement in terms of recovery, yield and grade. At a SV of 4 cm/min, a product with a d50 of 4.6 µm was produced with a recovery of 31%. Increasing the SV to 10.5 cm/min increased the product d50 to 5.9 µm, but the recovery of 5 µm particles improved to 70%.

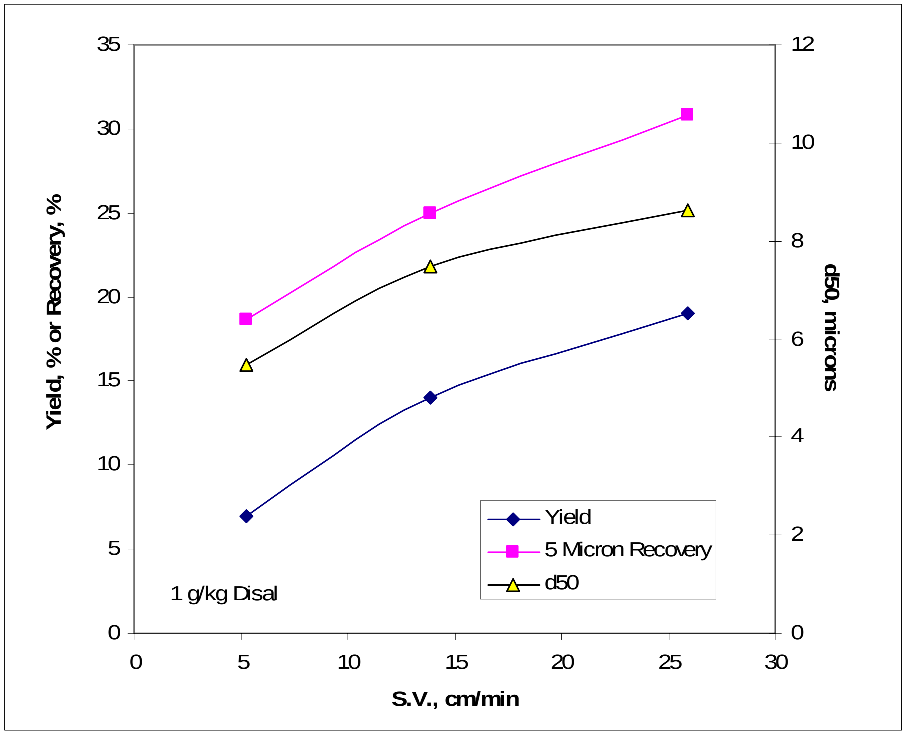


Figure 5. Effect of Superficial Velocity on Yield, Recovery and Average Particle Size for 1 g/kg Disal Dosage

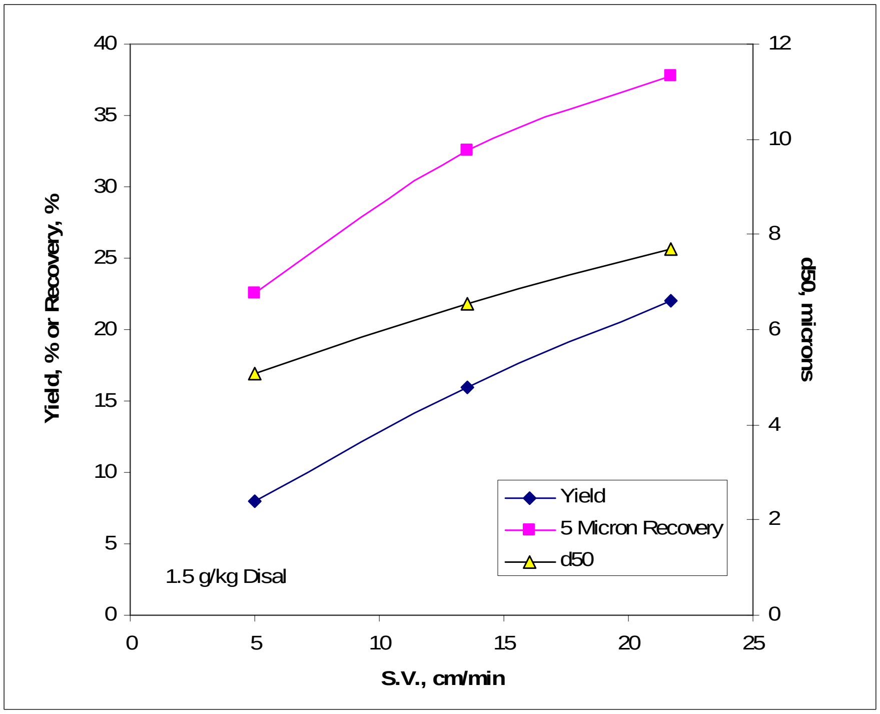


Figure 6. Effect of Superficial Velocity on Yield, Recovery and Average Particle Size for 1.5 g/kg Disal Dosage

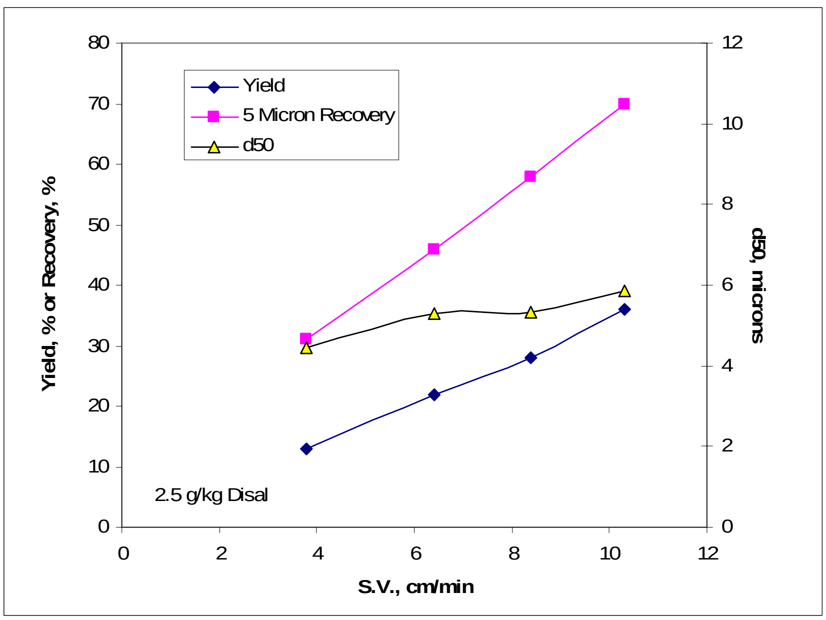


Figure 7. Effect of Superficial Velocity on Yield, Recovery and Average Particle Size for 2.5 g/kg Disal Dosage

The results shown in Figures 8, 9 and 10 clearly show that increasing Disal dosage has a beneficial effect on the product size, recovery and yield. Also apparent from these results is that operating at lower SV proves the best product grades, but not the best recoveries and yields.

It should be noted that most of the test work on the secondary classifier was done in a recirculation mode. All of the products were recycled to the feed in order to preserve sample and provide consistent operating parameters. Thus the dispersant is in contact with the sample for a much longer time than would be the operational case and some of it will be "lost", most likely due to adsorption. The field test results at 2.5 mg/g were achievable at lower dosages (2.0 mg/g) in non-recirculated lab tests.

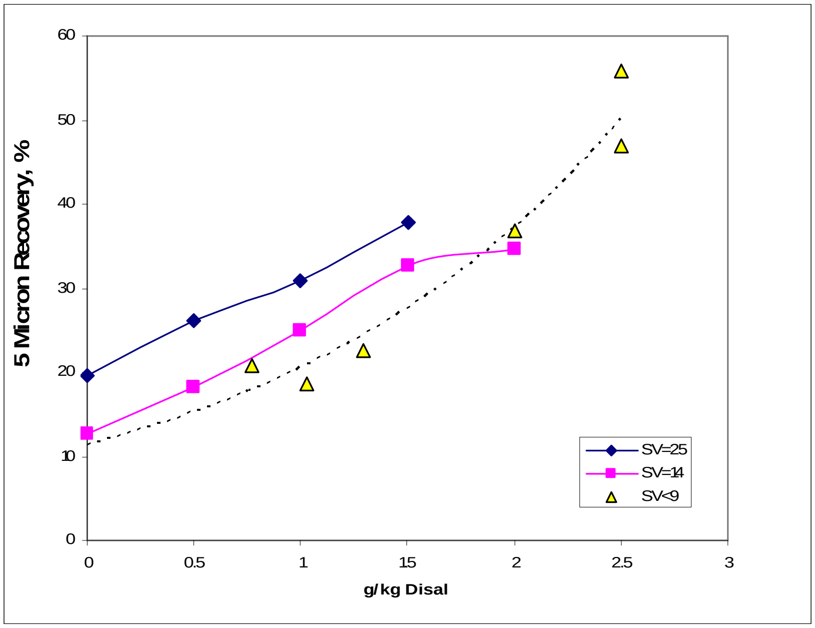


Figure 8. Effect of Disal Dosage on 5 μm Recovery

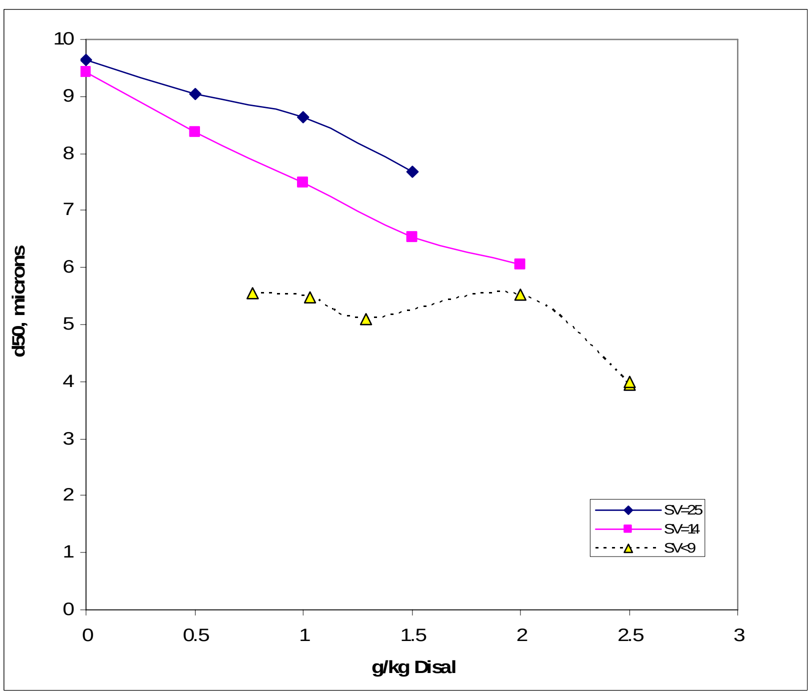


Figure 9. Effect of Disal Dosage on Product Size

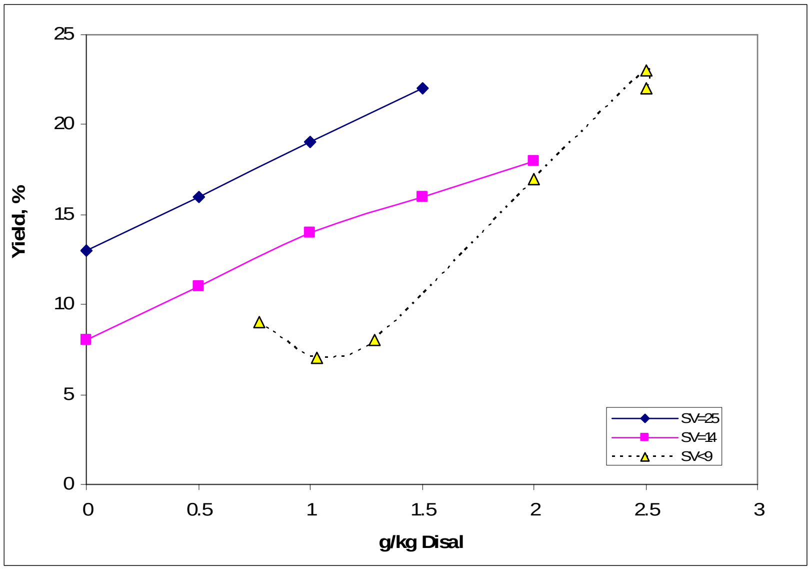


Figure 10. Effect of Disal Dosage on Yield

*Effect of Plate Spacing:* As described previously, the secondary classifier contains a series of inclined lamella plates aligned parallel with the flow of the feed slurry. The results reported thus far were obtained with a lamella spacing of 7 cm. An additional series of tests were conducted to determine if closer lamella spacing would be beneficial; the results are shown in Figure 11. When additional plates were installed at 3 cm spacing, recovery of 5 µm particles decreased, but the average particle size of the product, or product grade, improved. For example, with a Disal dosage of 2.5 g/kg and a SV of 6 cm/min, 3 cm plate spacing provided a 5 µm recovery of 30% with a product grade ($d_{50}$) of 3.2 µm. Increasing plate spacing to 7 cm at the same SV increased the 5 µm recovery to 43%, but the size of the product grade increased to a $d_{50}$ of $_{5.2}$ µm. The data generated (Figure 12) clearly illustrates that closer plate spacing produces a finer product size distribution.

Since lower superficial velocities seemed to provide the most desirable results, it was determined that the length of the lamella plates should be decreased in order to simplify the secondary classifier operation. By shortening the length of the classifier, the number of underflow reject pumps would be reduced from 4 to 2. The results presented in Figure 13 show that reducing the length of the classifier from 16 ft to 8 ft did not adversely effect the average product size distribution.

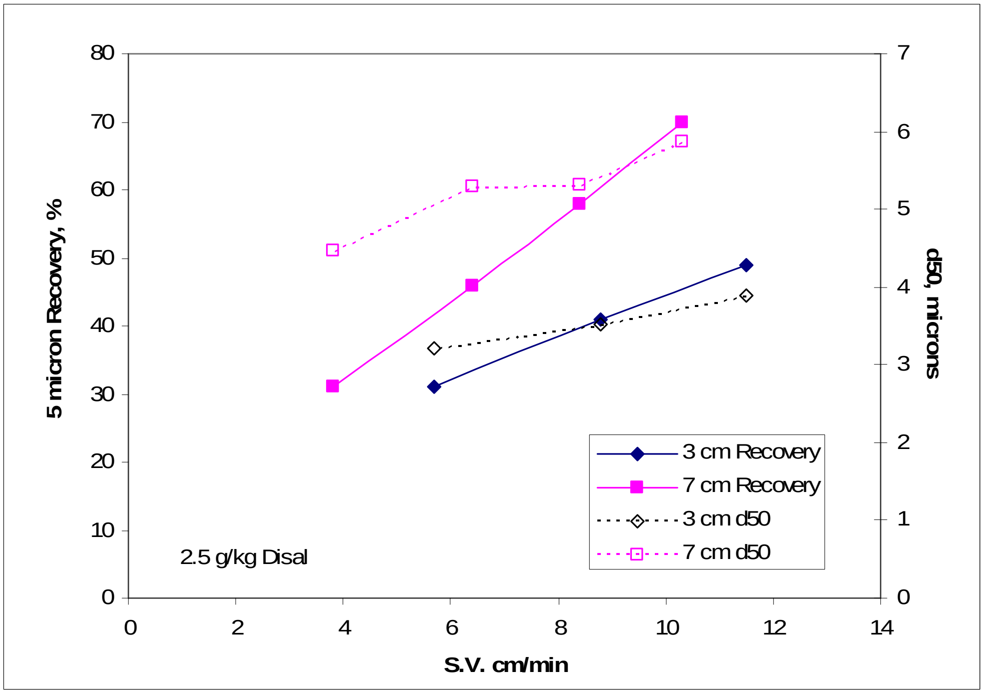


Figure 11. Effect of Plate Spacing and Superficial Velocity on Product Recovery and Size

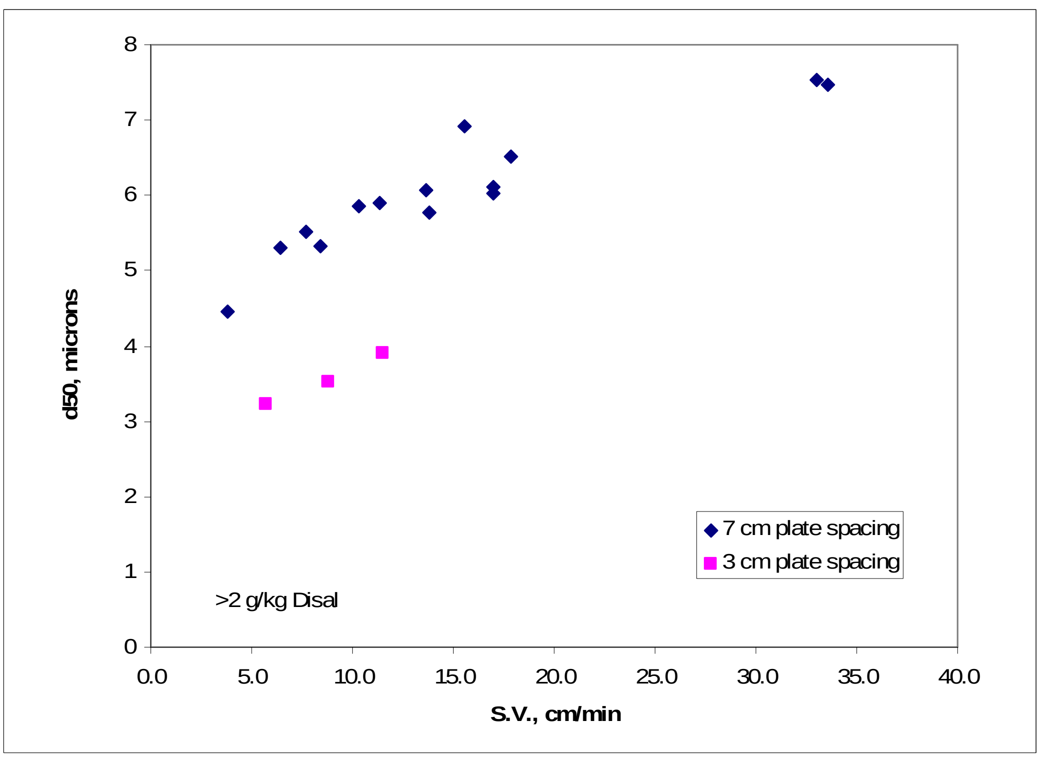


Figure 12. Effect of Plate Spacing and Superficial Velocity on Product Size

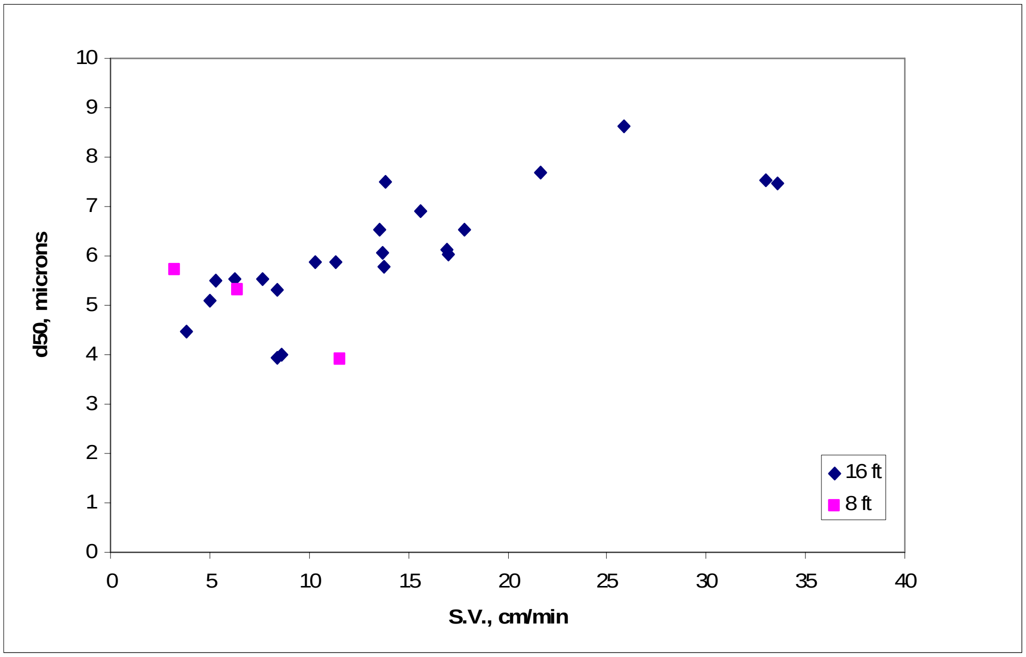

Figure 13. Effect of Superficial Velocity and Lamella Length on Product Size

*Effect of Disal Dosage*: The principle function of the dispersant used in UFA production is to effectively disperse the finest ash particles in the slurry to enable recovery of these particles in the classifier overflow. It is desirable to minimize the dispersant dosage from a cost perspective. The data shown in Figure 14 shows that the minimum dosage of Disal was approximately 2 g/kg, as determined by the average particle size ($d_{50}$) of the product. As the superficial velocity (SV) was increased from 4 to 35 cm/min, the $d_{50}$ of the product increased from 4.3µm to 7.6 µm, for results generated with a Disal dosage of 2 to 2.5 g/kg. At lower dosage (0.5 to 1.5 g/kg), the $d_{50}$ of the product was higher for a given SV. For example, at an SV of 14 cm/min. the $d_{50}$ of the product was 9.5 µm when no Disal was used. As the dosage was increased to 0.5, 1.0, 1.5 and 2.0 g/kg, the $d_{50}$ decreased from 8.6 to 7.5 to 6.3 to 5.8 µm, respectively.

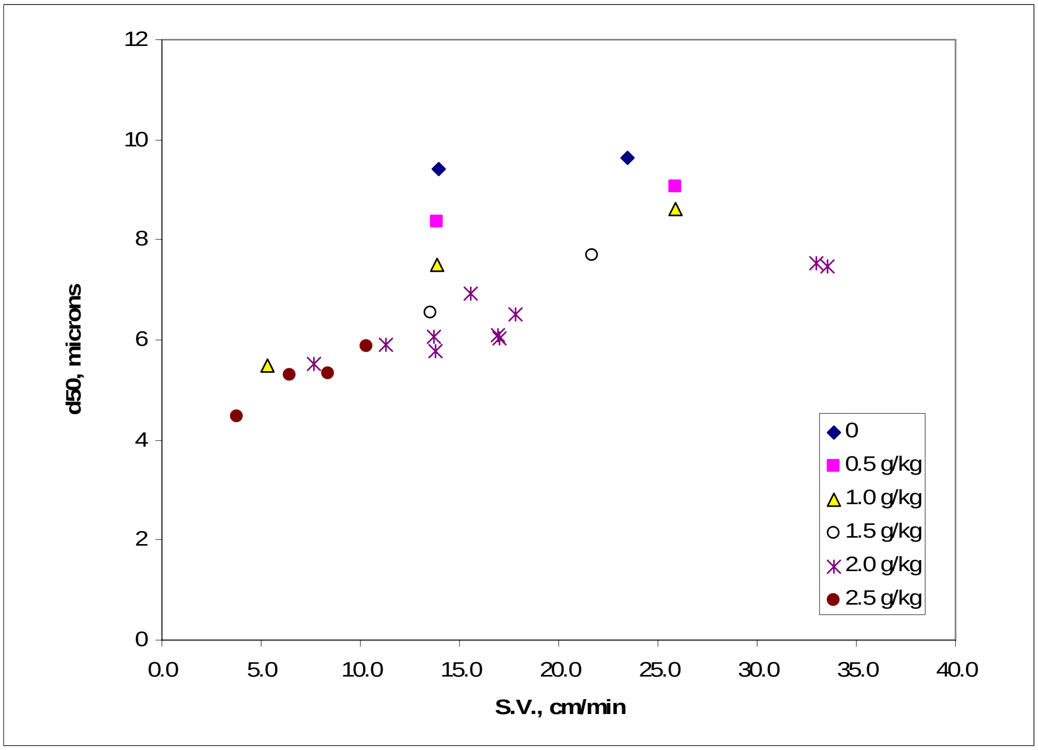


Figure 14. Effect of Disal Dosage and Superficial Velocity on Product Size

**CONCLUSIONS**

Secondary classification was shown to be effective for producing an ultra-fine ash (UFA) product. A classifier was used with inclined lamella plates to provide an effective settling surface for coarser ash particles. The plate spacing was shown to be an important variable; essentially the closer the plate spacing, the finer the size distribution of the UFA product. A dispersant was also shown to be beneficial to UFA recovery. A minimum dosage of 2 g/kg Disal effectively provided a UFA product with an average particle size of 4 to 6 µm. At lower dosages, UFA products were coarser ($d_{50}$ 6 to 10 µm).

Perhaps the most significant operating parameter for effective secondary classification was superficial velocity (SV). Reducing the SV provided finer-sized UFA products; however, lowering SV also reduced recovery and yield. In consideration of product grade and recovery, operating at a SV of less than 15 cm/min provided acceptable results ($d_{50}$ = 3 to 6 µm, 30-60% 5 µm Recovery) with reasonable dispersant dosages.