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Ashes to Energy – The Coleman Power Plant Project

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ABSTRACT

A joint project is being conducted as a cooperative effort between the US Department of Energy (USDoE), the University of Kentucky Center for Applied Energy Research (CAER) and Western Kentucky Energy (WKE) to implement a technology to recover high quality fuel from stored coal combustion ash, referred to as the *Fuel-Float*^{TM} process. The process is also capable of recovering a marketable lightweight aggregate from the coarser size fractions. A discussion of various sampling techniques used to assess the amounts and quality of the ash in the ponds is given along with results from pilot-scale test testing of the process.

PROJECT DESCRIPTION

The project site is WKE's Coleman Station located in Hawesville, Kentucky, a 520 MW power plant on the Ohio River that provides power for nearby aluminum and manufacturing facilities as well as wholesale residential power. The facility generates approximately 100,000 tons/year of combustion ash that is stored in lined pond areas adjacent to the power plant. Preliminary studies conducted by CAER estimated that the Coleman site presently contains approximately 3.4 M tons of ash and the storage area is very close to full capacity. In order to maintain adequate capacity, it will be necessary to transport several hundred thousand tons of ash from the site and dispose of this material in area landfills.

The overall concept of the *Fuel-Float*^{TM} is to process the ash that has accumulated in coal burning utility ponds and landfills to recover unburned carbon as a fuel source. Recovering carbon from stored ash does not require the utilities to alter their ash disposal practice. It also avoids costly plant modifications and the construction of temporary ash storage facilities, as in the case for a dry process, and adds significantly to available disposal capacity.

The *Fuel Float*^{TM} approach is relatively simple and relies on proven components (Figure 1). It includes: the separation of the ash into narrow size ranges via hydraulic classification; the recovery of a coarse carbon product via gravity (or spiral) concentration; the recovery of a coarse lightweight aggregate as a by-product of the hydraulic classifier; and the recovery of a fine carbon product via froth flotation. The key innovative features of the approach includes a patented flotation reagent system[1] that results in the low cost recovery of the carbon by flotation and a unique patented[2] processing configuration that integrates hydraulic classification with flotation and centrifugal classification, which allows the concentration of pyrite for ash so contaminated.

An additional benefit of this technology is that the reject stream from recovering coarse carbon is marketable as a lightweight aggregate or “block sand”, while the reject stream from recovering fine carbon may be marketable as a pozzolan in concrete. This paper addresses the aspects of the technology associated with recovering of carbon as fuel and/or for environmental or industrial application, i.e. fine and coarse carbon and by-product aggregate from the hydraulic classifier.

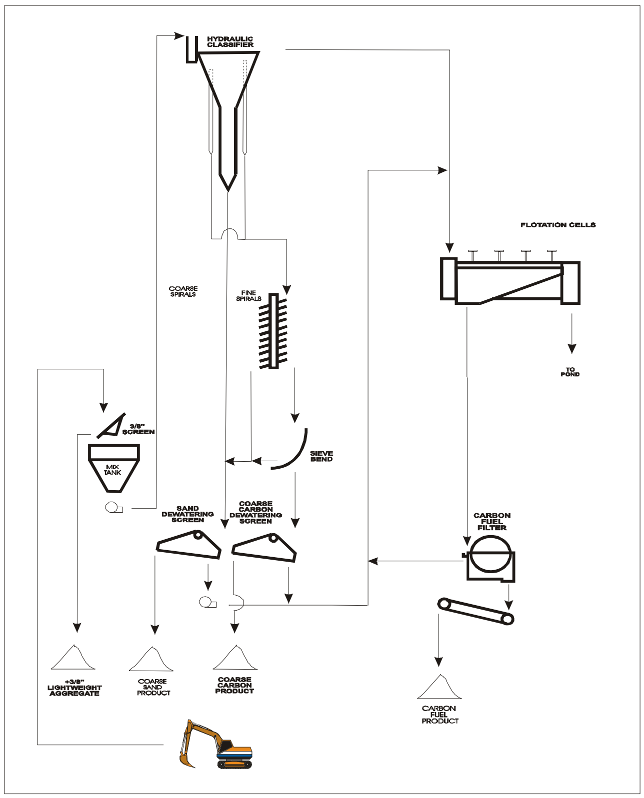

Figure 1. Schematic if Process Flowsheet.

Pond ash is excavated by backhoe or dredge, slurried with water and fed into the process. Coarse ash (+3/8 inch) is removed by screening and is readily marketable as a lightweight aggregate. The ash that is finer than 3/8 inch is sized in a hydraulic classifier. The –3/8 inch +150 µm ash is separated by density using spiral concentrators to recover both a block sand product and a coarse carbon fuel. A fine carbon fuel is recovered from the ash finer than 150 µm by froth flotation. The remaining fine ash is returned to the pond for storage. Additional technology developed by CAER can be added onto the flowsheet to recover additional marketable products from the fine ash, but is not specifically addressed in this project.

RESOURCE ASSESSMENT

Characterization of the ash generated at any utility generating site is not a simple task. Collection of representative composite samples over a period of time can provide a good indication of what is being produced. This data along with historical sample logs can be combined to determine the amount and quality of ash in the disposal site. Unfortunately, this type of information is only of limited use since extensive classification takes place in the ponds. Development of a recovery strategy for pond ash requires extensive exploration and coring to identify areas and depths with enrichment of coarse ash, coarse carbon and fine carbon. This strategy is analogous to the exploration phase of a mineral deposit, whereby coring mapping techniques are necessary.

Coring in ash ponds presents a unique challenge given the large aerial extent of the ash ponds at Coleman Station (i.e. 180 acres) and the thixotropic properties of the un-drained ash. Several sampling techniques were attempted. The first was to drive hollow stem sampling tubes into the ash as shown in Figure 2. Both driving and hand-augering techniques were attempted with some success. Intact cores were retrieved for the top 2 ft. layers, however insertion of the sampling tube through compacted ash proved to be an arduous task.

Figure 2. Hand Augering with Hollow Tube Sampling System.

Another technique that was attempted was to use a gas powered post-hole digger with either 2 inch or 6 inch diameter augers as shown in Figure 3. This approach worked well as the ash was transported to the surface on the auger flights so that representative samples from depths up to 4 ft could be readily obtained. To drill to depths greater that 4 ft, extension bars were used but penetration was limited by the torque of the post-hole digger. In addition, the weight of the sample on the auger flights made it difficult to retrieve to sample. Continuous flight augers would certainly aid in removing the sample, but it became apparent that more torque would be necessary to drill to the 20 ft depth of the pond.

Figure 3. Auger Sampling with Post-Hole Digger.

Yet another difficulty encountered with sampling ash ponds is the existence of open water areas underlain by unconsolidated ash (Figure 4). These areas are accessible only by boat and present a unique challenge to sampling.

Figure 4. Surface Sampling in Open Water.

A thorough search was conducted to identify the type of equipment most suitable to safely retrieve core samples from all regions of the ash pond. The most desirable device would need to be lightweight, mobile, amphibious, have high torque drilling capabilities and adequate lifting capacity to retrieve cores from depths of 20 ft. A device meeting all of these criteria was found and purchased by CAER and is shown in Figure 5.

The amphibious vehicle is an 8 wheel-drive, 20 hp ARGO equipped with a Hammerhead hydraulic drill. The drill is powered by a 20 hp diesel engine with 1200 lbs pull down capacity, 260 ft/lbs torque and 1200 lbs lifting capacity. The drill is being used to extract cores from the entire pond depth on a grid system that has been established with a Global Positioning System (GPS). GPS coordinates will be recorded for each core and samples will be analyzed for size distribution and chemistry so that a detailed map of the ash ponds can be generated. This data will be used to assess the amount of ash in the ponds, the amount of recoverable material and most importantly, where to focus recovery activities.

Coring techniques utilize continuous flight augers for the granular material near the surface (depths 0 to 6 ft). The solids are transported to the surface on the auger flights and the hole is reamed to recover any additional sample remaining in the hole. At depths greater than 6 ft, the mud-like consistency of the sample prevents the use of augers for core retrieval and a hollow core barrel is used instead. Samples are retrieved from the core barrel liner in 3 ft increments, capped and logged for analysis. Thus, a core of the entire cross section is recovered.

Figure 5. Amphibious Drill for Pond Ash Coring

EVALUATION OF THE *Fuel-Float*^{TM} TECHNOLOGY

Parametric studies were performed on pilot plant scale unit processes of samples retrieved from the ash ponds at Coleman Station. Hydraulic classification research was performed first. After the unit operation was adjusted to acceptable limits, bulk samples were run and the various splits were saved for testing in the spiral and froth flotation circuits.

Hydraulic Classification

Several bulk samples (1/2 ton each) were run and analyzed in a pilot scale (6ft x 6ft) Lewis Econosizer.[3] The co-current flow classifier is capable of producing multiple mid sized materials in addition to coarse underflow and fine overflow material. One middling product was chosen for this application with a cut targeted at 30 x 100 mesh. The overall feed was deslimed at 100 mesh and the top size was set at 8 mesh.

The wide range of particle sizes and densities found in the ponded ash samples were, after some period of testing and adjustment, successfully processed in the unit. The hydraulic classifier enabled separation into 3 narrowly sized products with a minimum amount of misplaced material. Most importantly, there was almost no -100 mesh material in the coarse product and the fines were essentially -100 mesh solids. The critical parameter for the hydraulic classifier was the control of flow in the middlings streams. Optimization of this parameter reduced the amount of -100 mesh solids in the middlings from 25%- 40% to as low as 6%.

Spiral Concentration

Spiral testing was conducted on the classifier middling product (-30+100 mesh) using Mineral Deposits Ltd. Reichert Coal spirals equipped with adjustable splitters. The spirals did not always produce concentration profiles as expected. Based on our coal experience, we thought that the spiral profile would consist of (from the outside of the race to the inside), carbon, dense ash and an iron-rich dense magnetic fraction and/or pyrite. A profile that was obtained with some of the samples tested however consisted of (again, outside to inside) light frothy ash, carbon, dense ash and a dense magnetic fraction. The presence of light frothy ash on the outside of the spiral profile presented an obstacle to concentrating a high quality carbon fraction. A careful analysis of the size distribution of the frothy ash indicated that it was almost entirely +28 mesh in size. The inclusion of a 28 mesh sieve bend on the outside of the race product resulted in a substantial improvement in the grade of the spiral carbon produced for materials where frothy ash is present to acceptable levels.

Spiral results obtained on the classifier middlings product are shown in Figure 6. The highest grade products were obtained at the lowest feed rate and the lowest feed solids. In general, increasing feed rate and/or feed solids lowered product grade. A product grade of greater than 9000 Btu/lb was obtained at all of the feed rates tested for feed solids of up to 10%. Further increases in feed solids reduced product grade.

Flotation

Flotation testing was conducted on the fine ash substrates using conventional batch methods. Several combinations of frother and collector dosages were tested as well as feed density and retention time variations. Release analyses were conducted to determine the limits of separation that could be achieved with froth flotation.[4] The release analyses for the –100 mesh fraction is shown in Figure 7 along with some of the batch flotation results. The release analysis indicated that froth grades up to 9000 Btu/lb were achievable by flotation, however, the highest froth grades achieved using conventional flotation were 6500 Btu/lb. It is likely that in order to achieve significantly higher froth grades, cleaner conventional flotation or column flotation would be necessary. It is also apparent that the highest grade froth products were achieved with either glycol-based F948 or MIBC as frothers .

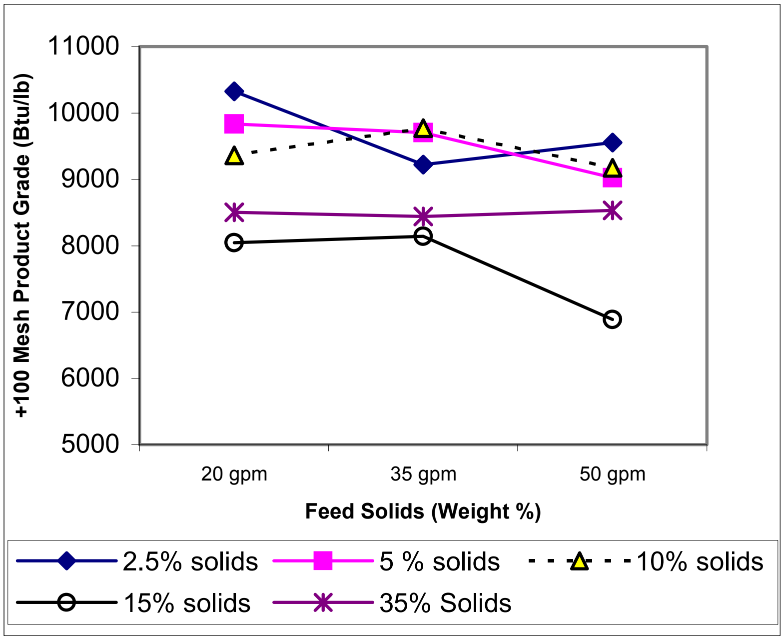

Figure 6. Effect of Feed Rate on Spiral Product Grade.

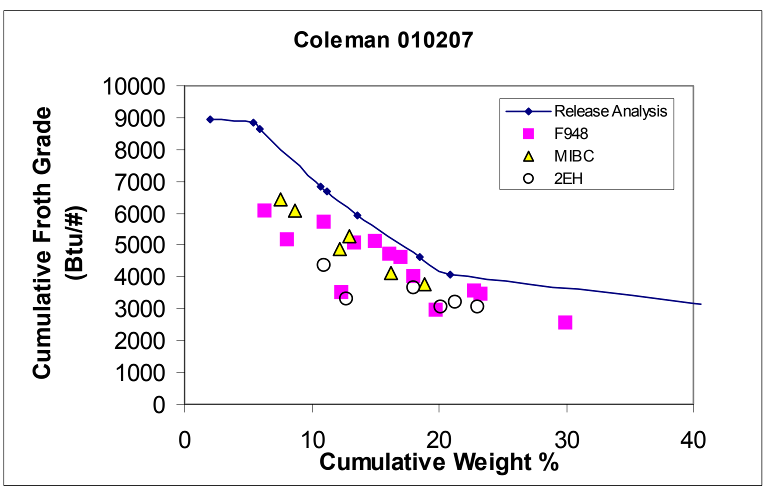

Figure 7. Flotation Release Analyses for –100 Mesh Size Fraction with Various Frothers..

CARBON TESTING

The combustion reactivity of the high-carbon fly ash product was assessed using thermogravimetric analysis (TGA) and an entrained flow reactor (EFR). The purpose of these experiments was to study the rate of fly ash carbon burn-out compared with that of bituminous coal, with the goal of estimating the proportion of fuel product that will combust in a pulverized coal combustion (PCC) boiler. TGA was employed to compare the intrinsic reactivity of the fly ash carbon with that of coal. The EFR was utilized to assess reactivity under high-temperature, short residence time conditions that are similar to a PCC flame zone.

The high-carbon ash used in these experiments comprised the coarse carbon product from the spiral concentrators (nominally -28+100 mesh). Samples of crushed coal were obtained from an electric generating station burning high volatile bituminous coal. The high carbon fly ash and coal samples were pulverized in the laboratory to 80% passing 200 mesh. Table I presents selected properties of the coal and high-carbon fly ash utilized in these experiments.

Table I. Selected Properties of Coal and Fly Ash Carbon Used for Combustion Tests.

Sample	Moisture (%, a.r.)	Ash (% a.r.)	Volatile Matter (% a.r.)	Fixed Carbon (%,a.r.)	Sulfur (%,d.a.f.)	BTU/lb (a.r)
Coal	1.63	13.74	34.23	50.4	0.62	12,482
Fly Ash	0.94	52.75	3.13	43.2	0.30	6,957

High temperature combustion reactivity studies were conducted using an entrained flow reactor (EFR) and TGA results are described elsewhere.[5]. The reactor comprises an electrically-heated three-zone furnace into which air and coal are introduced. The total flow was adjusted to achieve a 2.5 second residence time at 1500°C in the combustion zone. The samples were introduced into the furnace top using an auger feeder, and the rate adjusted to achieve 2.5-3% oxygen content in the exit flue gas (12-13% excess air). After leaving the combustion zone, the flue gases were cooled and the ash residue collected on a filter. Three experiments were conducted on each of the fly ash and coal samples, and a loss on ignition (LOI) test performed on the ash residues to determine the degree of burn-out.

Results from the EFR experiments are summarized in Table II. Degree of burn-out was calculated using the ash tracer technique of Tsai and Scaroni [6]. The data suggest that the fly ash carbon combustion kinetics are similar to those of the bituminous coal under these high temperature, short residence time conditions that are ostensibly similar to the flame zone in a utility boiler. However, these conditions are not representative of low-NO_x burner firing conditions, where the flame is generally lower temperature and more fuel-rich.

The relatively high reactivity of the ash carbon product, at 1500°C, is probably a function of particle porosity. Compared to coal fly ash carbons are typically very porous, with a large proportion of macroporosity (>50nm diameter). During combustion at high temperatures, reaction occurs primarily on external particle surfaces and within the macropores, where oxygen can rapidly diffuse to active sites.[7,8] Consequently, fly ash carbon particles can exhibit a high degree of burn-out at high temperatures despite a significantly lower intrinsic reactivity compared with bituminous coal.

Table II. Entrained Flow Reactor Test Results.

Sample	Initial LOI (%)	Residue LOI (%)	Burn-Out (%, ash-free)
Coal	86.03	5.43	99.07
Fly Ash	46.75	0.37	99.58
Coal/Fly Ash Blend	84.07	5.88	98.82

The relatively high reactivity of the ash carbon product at 1500^{o}C is probably a function of particle porosity. Compared to coal, fly ash carbons are typically very porous, with a large proportion of macro porosity (>50nm diameter) and relatively high specific surface area (3.4 vs 24.2 m^2/g).

CONCLUSIONS

A cooperative effort between academic, industrial and government organizations is in progress to implement and evaluate a technology to recover high quality fuel and lightweight aggregate from utility ash ponds and landfills. Successful demonstration of this technology will provide high quality fuel for co-firing at the utility as well as marketable lightweight aggregate. Recovering both of these products will not only provide positive cash flow, valuable additional pond storage capacity will also become available.

Successful implementation will require a thorough assessment of the material currently in storage. Several techniques to accomplish this difficult task have been evaluated with limited success. A hydraulic drill mounted on an amphibious vehicle has proved to be the safest, most effective technique, although some modification was necessary. Continuous flight augers work well to sample the granular solids near the surface, but hollow core sampling is necessary to retrieve higher moisture samples.

Pilot scale testing of the *Fuel-Float*^{TM} process has yielded excellent quality fuel that has shown relatively high reactivity. The reactivity of the carbon is attributed to both the macro porosity and high surface area.

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