National Energy Technology Laboratory

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Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash

A DOE Assessment

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DISCLAIMER

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EXECUTIVE SUMMARY

The Power Plant Improvement Initiative (PPII) is a follow-up to the U.S. Department of Energy's (DOE) Clean Coal Technology Demonstration Program (CCTDP) that was successfully implemented in the 1980s and 1990s. The purpose of the CCTDP was to offer the energy marketplace more efficient and environmentally friendly coal-fired power production options by demonstrating these technologies in commercial settings. On October 11, 2000, the PPII was established under U.S. Public Law 106-291 for the commercial-scale demonstration of technologies to ensure a reliable supply of energy from the Nation's existing and new electricity generating facilities.

One of the selected projects was titled "Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash." The proposal was submitted by Universal Aggregates, LLC (UA). The project was originally estimated to cost $19.5 million, of which DOE would provide $7.2 million (37 percent) with the remaining $12.3 million (63 percent) provided by UA. The UA manufactured aggregate facility, which occupies a total of approximately five acres, is located at the Birchwood Power Facility (BPF). The boiler is fired with a low-sulfur West Virginia bituminous coal. The BPF operates in a load-following mode.

The Cooperative Agreement was awarded on November 14, 2002, construction was completed in March 2004, and startup was initiated immediately thereafter. The plant first achieved integrated operation with mixing, extrusion, curing, crushing, and screening for aggregate production in December 2004; intermittent operation continued into January, February, and March of 2005. During this period, operation was limited to about 30 percent of capacity. Two no-cost extensions moved the completion date of the operating phase of the project to December 31, 2006.

During the 33 months from startup to project's end, UA encountered numerous equipment and operating problems that precluded reliable operation and limited operation

to values substantially below design levels. UA worked to modify or replace equipment for the duration of the project. The company reported that the plant was able to operate at approximately 50 percent capacity at the end of the project. In spite of the various equipment issues, the product performed well for customers and UA was able to sell all of the aggregate that was produced.

UA continued to address the equipment problems and, as of December 2007, UA reported that most of the plant could operate reliably at or near capacity, which is required to achieve a positive cash flow. UA is committed to solving any remaining problems and seeks to identify other locations suitable for the manufacture of aggregate from coal-fired electric generating station waste streams.

I. INTRODUCTION

The Power Plant Improvement Initiative (PPII) is a follow-up to the U.S. Department of Energy's (DOE) Clean Coal Technology Demonstration Program (CCTDP) that was successfully implemented in the 1980s and 1990s. The purpose of the CCTDP was to offer the energy marketplace more efficient and environmentally friendly coal-fired power production options by demonstrating these technologies in commercial settings. On October 11, 2000, the PPII was established under U.S. Public Law 106-291 for the commercial-scale demonstration of technologies to ensure a reliable supply of energy from the Nation's existing and new electric generating facilities. Congress directed that the PPII was to "demonstrate advanced coal-based technologies applicable to existing and new power plants… The managers expect that there will be at least a 50 percent industry cost share for each of these projects and that the program will focus on technology that can be commercialized over the next few years. Such demonstrations must advance the efficiency, environmental controls, and cost-competitiveness of coal-fired capacity well beyond that which is in operation now or has been operated to date."

To fund the PPII, $95 million in previously appropriated funds were transferred from the DOE's CCTDP. The PPII program solicitation was issued on February 6, 2001, and twenty four applications were received. On September 26, 2001, eight applications were selected for negotiation leading to a Cooperative Agreement. One of the projects selected was the "Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash." The proposal was submitted by Universal Aggregates, LLC (UA). UA was formed as a joint venture on January 1, 2000, between CONSOL Energy, Inc., and SynAggs LLC; however, in December of 2003, the interest of CONSOL Energy, Inc. was purchased by SynAggs LLC. The original project team consisted of UA, SynAggs, LLC; CONSOL Energy, Inc.; and P. J. Dick, Inc., and the Cooperative Agreement was awarded on November 14, 2002. The project was estimated to cost $19.5 million of which DOE would provide $7.2 million (37 percent) with the remaining $12.3 million (63 percent) provided by UA.

The project proposed by UA called for UA to design, construct, and operate a plant that would convert 115,000 tons of Birchwood Power Facility's (BPF) spray dryer ash (SDA) into 167,000 tons of lightweight aggregate. The design is based on converting all SDA output from BPF. During the course of the project, substantial quantities of lightweight aggregate were produced and sold. A number of problems that limited production were encountered and corrected; subsequently, when the project ended on December 31, 2006, the plant was still not able to consistently meet design production rates, although reliability and capacity were steadily increasing.

This report is an assessment of the project that was conducted by UA through December 31, 2006.

II. PROJECT PROCESS DESCRIPTION

A. Project Site

The UA manufactured aggregate facility is located on approximately five acres, adjacent to the BPF. The BPF sits on approximately 345 acres in northwest King George County, Virginia. The BPF consists of a single steam turbine with a nameplate capacity of 250 megawatts. Steam is supplied by a tangentially fired dry-bottom boiler that came online in 1996. The host plant controls the emission of nitrogen oxides (NO_x) with low-NO_x burners and Selective Catalytic Reduction (SCR). A baghouse is used for particulate control, and a spray dryer absorber controls sulfur dioxide. The baghouse is located downstream of the spray dryer and removes both the sorbent and the fly ash from the flue gas. The boiler is fired with a low-sulfur West Virginia bituminous coal and the BPF operates in a load-following mode.

B. Project Goals

The primary goals of the project were that UA would design, construct, and operate a lightweight aggregate manufacturing plant at the Birchwood Power Plant, located in King George, Virginia. During operation as a full-scale commercial facility, the plant was to use up to 115,000 tons per year of SDA generated at the Birchwood facility to produce 167,000 tons of lightweight aggregate for use in the manufacture of lightweight/medium-weight concrete masonry block or lightweight concrete. The product had to meet the appropriate specification (ASTM C331) for these applications and be economically competitive with lightweight aggregate produced by conventional methods.

This project was carried out to demonstrate the technical and economic viability of large-scale integrated operation of mixing, extrusion, curing, crushing, and screening with weigh feeders, screw and belt conveyors, bucket elevators, silos, baghouses, and other material-handling equipment for aggregate production. The curing vessel (CV) was a new design for use in a large-scale application, and along with the plant design concept, had been verified previously in small-scale pilot plant operations in 1999 by SynAggs, LLC. During demonstration, modifications were required to “off-shelf” large-scale equipment, which was designed for applications other than the processing of SDA. Short-term tests were conducted to evaluate the effect of operating parameters on the performance of modified equipment and ash quality and the effect of mix design on extrusion performance, as presented in Table 1. From the results, UA learned the operating parameters and limitations required for continuous, integrated operation for aggregate production.

Table 1. Objectives of Planned Tests During the Demonstration Project

Equipment	Objectives
Pug Mill	To evaluate the effects of dam and bridge installations in pugmill and water spray system on mixing and extrusion
Pug Sealer	To evaluate the effects of pug sealer speed on pug sealer and extruder operations and on properties of green extrudates
Extruder	To evaluate the effects of die geometry, liner design, vacuum and additive addition on extruder performance
Curing Vessel	To evaluate the effects of operating throughput rate, rotary distribution chute, adjustable flow dampers, and QA/QC program on curing vessel performance
Screen, Crusher, and Air Classifier	To evaluate the effects of screen decks, rotor speed, and clearance between breaker bar and plate, opening of dampers and choke gate on size gradation and bulk density of aggregate products
Ash Quality	To evaluate the effects of hydrated lime and carbon content on mixing and extruder performance
Mix Design	To evaluate the effects of mix formulation (SDA, recycle, additive, and water) on pugmill, pug sealer, and extruder performance

C. Project Description

This project was selected for negotiations in September 2001. Negotiations were completed and a Cooperative Agreement was awarded on November 14, 2002; the engineering design of the demonstration plant began in November as well. Construction started in March 2003, the plant was completed in March 2004, and startup of the plant was initiated in April 2004.

The process comprises large-scale integrated operation of mixing, extrusion, curing, crushing, and screening operations. The new manufacturing facility also incorporates automatic programmable logic controls, process trending, and data recording.

The plant consists of two metal buildings: the Process Building and the Curing Vessel Building. These two buildings are connected by two conveyor belts; one conveyor takes green extrudates to the CV, and the other conveyor moves cured extrudates from the CV discharge back to the Process Building for crushing and screening. The finished aggregate is conveyed to a radial stacking conveyor to be stockpiled. Trucks enter the site and the tare weight is recorded by the automated scale and ticketing system. A front-end loader loads the trucks, which then return to the scale for gross weight measurement prior to delivery to the customer.

The Process Building is also connected to the power station's ash storage silo via an elevated pneumatic transfer line. The UA plant receives steam and process water from the BPF. The ash transfer pipeline, the process water line, and a steam supply line are all on the pipe bridge leading from the power station to the Process Building.

Continuous operation of the extruder was first achieved in July 2004. The CV was first charged with green extrudates in October 2004 and again in December 2004. A number of design, construction, and feed problems were encountered during the course of the project, which will be described in greater detail in Section III of this report.

D. Technology Description

The demonstration technology is designed to produce a lightweight aggregate using the waste stream from a spray dryer absorber as the main feedstock. The demonstration facility is designed to produce 167,000 tons per year of lightweight aggregate from 115,000 tons of SDA. In addition to water, two proprietary additives (which will be referred to as "additive #1" and "additive #2") are mixed with the SDA, which is a mixture of fly ash, unreacted hydrated lime, and hydrated lime that has reacted with the sulfur oxides in flue gas to form calcium sulfite and/or calcium sulfate.

Unconditioned SDA is received from the power plant and initially stored in the SDA silo from which it is pneumatically transferred to the SDA day bin. The SDA day bin discharges material to two separate conveyors. The first stream is discharged to a weigh feeder that feeds the material to a conveyor that feeds a pugmill. Recycle material from product screening is also fed to this SDA recycle conveyor and is discharged from the recycle day bin through a weigh feeder. The second stream from the SDA day bin is fed through a weigh feeder to the embedding material conveyor where it is mixed with additive #1 that is fed from a storage silo through a weigh feeder to the embedding material conveyor.

The SDA recycle material conveyor discharges the dry material to a pugmill. Water and additive #2 are added and thoroughly mixed with the dry material. The material leaving the pugmill is a wet, loose, granular material that is discharged to the pugsealer, which operates under a vacuum and discharges to an extruder. The extruder further mixes the material then forces it through a die, which is a metal plate that has been drilled with one or more holes. The wet (green) extrudates drop onto a belt conveyor, which transfers the material to the tumbler. Embedding material is also fed to the tumbler by the embedding material conveyor. The tumbler slowly rotates to coat the extrudates and fills the void spaces between the extrudates. The purpose of the embedding material is to cushion the soft, wet extrudates and prevent agglomeration during the curing process.

The green extrudates and embedding material discharge from the tumbler to a belt conveyor that feeds the CV. The CV is a specially designed retention bin that operates under a slight vacuum and allows the solids to slowly flow downward without channeling or bridging. The vessel is heat traced and insulated to minimize system heat losses. The heat tracing is not used to raise the solids temperature, but provides only enough heat to assure that the CV operates at a constant temperature. The small amount of vent gas from the CV was originally scrubbed to remove particulate matter; however, the scrubber was replaced with cartridge filters during the project.

The pellets cure (harden) as they slowly move down through the vessel. Cementitious reactions occur in the green extrudates during the curing process, and SDA contains the essential components for these reactions. The formation of ettringite is believed to be responsible for some of the pellet hardening. This mineral has the following formula: $Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$, or $Ca_6A1_2(SO_3)_3(OH)_{12}\cdot 26H_2O$.
Other cementitious reactions include formation of calcium silicate and aluminates. After curing, the hardened extrudates are conveyed to the screening operation.

All of the material discharged from the CV is fed to the primary screen that separates the cured extrudates from the embedding material. The embedding material drops onto the recycle fines screw conveyor, which transfers the fines to the bucket elevator where they are then sent to the recycle day bin for use in the production of extrudates. Once largely free of fines, the cured extrudates are moved to a crusher and are reduced to pellets of appropriate size for use in the production of concrete blocks. Lastly, the crushed material is transferred to the secondary screen that splits the crushed aggregate into three streams: oversize material, product, and fines.

The oversize material (i. e., +3/8”) is recycled through a bucket elevator back to the crusher. The middle screen product, which is predominately 3/8" x 18 mesh, is the desired product size and it is conveyed (via a belt conveyor/stacker) to the product stockpile. The –18 mesh fines go to an inertial separator that uses air classification to strip most of the -100 mesh fines from the coarser fines. The -100 mesh fines from the inertial separator are collected in the baghouse and are transferred to the recycle day bin by the same equipment that recycles the embedding material. The remaining material is transferred to the product stockpile. The crushing system is designed to minimize the production of fines and the need to recycle them. The Process Flow Diagram is shown in Figure 1.

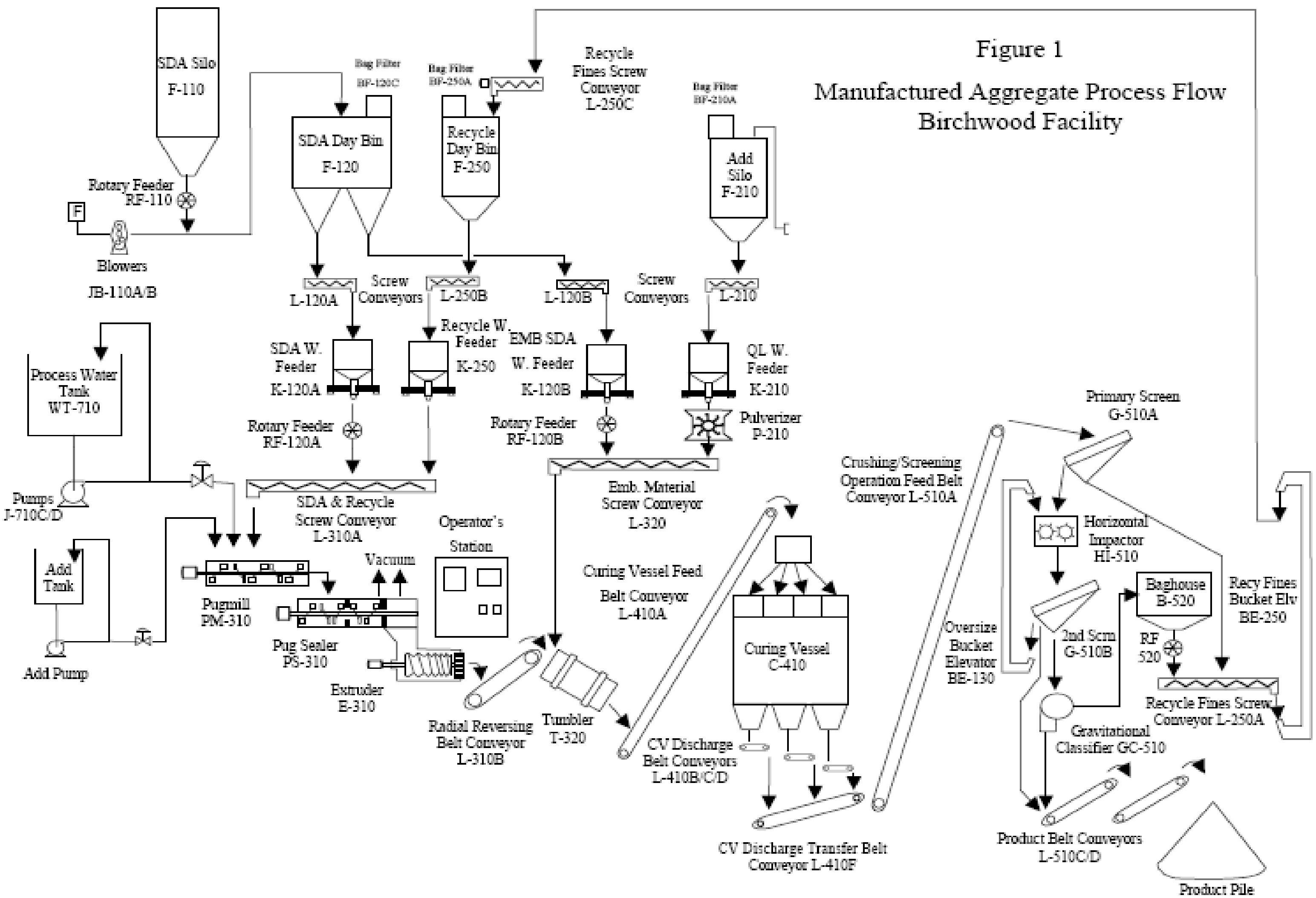

Figure 1. Process Flow Diagram for Manufactured Aggregate Plant

The only potential for emissions is the dust that can be generated at various solids transfer points, from the curing vessel, and the crushing and screening operations. These potential emission sources are now all equipped with filters. Dust emissions from the storage pile are controlled with a water spray (on an as-needed basis).

III. REVIEW OF TECHNICAL AND ENVIRONMENTAL PERFORMANCE

A. Technical Performance

When initial startup took place in April of 2004, operational problems occurred almost immediately. (It must be noted that the demonstration plant was subjecting SDA to unique operations and the CV was a first-of-a-kind design.) The extruder acquired was designed to operate on clay, not SDA. A further challenge was that the SDA exhibits unusual flow properties. The length of time over which problems were encountered was largely due to problems in a piece of equipment that would frequently not be discovered until problems in upstream equipment were at least partially overcome. For example, problems with the pugmill would not occur before problems with the feeder were at least partially solved. Operating problems were addressed for each subsystem comprising the plant.

Shortly after startup, problems were encountered with the SDA feed. As the SDA is pneumatically conveyed to the SDA day bin, the SDA becomes aerated, which can cause free-flowing conditions and a loss of mass flow control through the weigh feeders. The day bin vent baghouse size was increased to help maintain a controlled feed rate. This increase enabled the operators, by the end of April, 2004, to operate at 10,000 pounds per hour SDA (about 13 percent of capacity) into the pugmill and pugsealer, and finally to attempt to feed the extruder.

Throughout the demonstration project, occasional problems were also encountered with various material transfer equipment items. These problems included failed or damaged belts and rotary feeders, the recycle chute, and the product oversize chute. These items were repaired, replaced, or modified as appropriate. In addition to the day bin vent baghouse, the CV vent wet scrubber experienced problems throughout the demonstration and was ultimately replaced with a dry cartridge filter.

Problems were also encountered with the quality of the feedstock. An analysis of extruder difficulties led to the tentative conclusion that the high hydrated lime content of the SDA feedstock resulted in a material that was too "sticky." A study was conducted to determine how the BPF could modify the operation of the spray dryer to reduce the hydrated lime content of the SDA. Once results were implemented to lower the hydrated lime content of the SDA, this potential variable in SDA composition was reduced, the operation of the extruder improved, and the operating cost of the spray dryer at BPF was reduced as well. Some equipment damage resulted from tramp metals and other foreign material in the SDA received from the BPF. These difficulties were eliminated by the installation of a magnetic separator and cage-type strainer between the BPF and the SDA day bin.

The pugmill experienced intermittent problems during the demonstration period. The first modification was made to improve mixing. The water spray nozzles were replaced for better wetting, and a dam was installed to increase retention time. Water addition was increased and a high dam was installed near the pugmill outlet to increase densification of the wetted SDA. Other changes to the pugmill included the following: the addition of high-pressure water spray pumps, changing blade positions, and adding a bridge in the center. Over the course of the project, it was necessary to add new knives and to shut the unit down for multiple cleanings. It was ultimately determined that the original pugmill did not have sufficient capacity to meet design production rates, and a new double-shaft pugmill was designed during the project and installed shortly after the project ended. UA has reported that it is functioning well.

Like the pugmill, the initial operation of the pugsealer was less than ideal and also required several cleanings to remove material. A number of modifications were required to improve contact of the wetted solids and increase densification of the charge at lower moisture levels. These included:

- Tested an auger with a design volume reduction ratio of 2.5:1 as compared to the original auger with a design ratio of 1.5:1.
- Modified shell liners to improve axial flow and prevent plugging.
- Modified shear plates to improve axial flow and improve vacuum efficiency.
- Installed new knives and dam.
- Altered the sealing auger interface distance.

- Installed a new 400 horsepower variable speed motor.

Initial attempts at extrusion were unsuccessful, due to inaccurate SDA and water-feed controls, lack of mixing and extrusion consistency, and frequent extruder backup. Modifications of the pugmill were required to increase mixing time and throughput. Modifications of the pugsealer were necessary to enhance mixing for extrusion, introduce adequate vacuum, and control feedrate to the extruder. Replacement of the auger with a porcelain-enameled auger and modification of the liner and die geometry resulted in satisfactory extrusion operation.

The CV, which is fed through four pant legs and loading cans, exhibited problems almost immediately after startup due to unequal flow distribution and plugging. Initially mass flow distribution was accomplished by passive control through an equally divided hopper. In addition to the plugging, bridging in the pant legs prevented proper distribution of the material being fed to the CV. These problems were overcome by installing a mechanical rotary distribution chute, which was coordinated with the level indicators in the CV cans. Belt scales were added to confirm CV balance and discharge rates, and a hopper and vibrating feeder were added to the CV recirculation circuit as well.

Throughout the project, UA continually worked to evaluate the operational parameters of the plant to achieve optimal performance. This included not only the best way to operate the equipment but an evaluation of SDA properties, process water quantities, and additives. The end result was greatly improved performance and reliability, although not to expected levels.

The demonstration project formally ended on December 31, 2006. The new double-shaft pugmill and filters for the CV were installed after the demonstration project ended. UA reported that the plant was operating at 50–60 percent capacity. Contact with UA after the project ended indicates that the company continues to make significant progress and most of the plant’s components are now performing satisfactorily.

Production figures are presented in Table 2.

Table 2. Aggregate Production During the Demonstration Project

Date	SDA to Pugmill, lb/hr	SDA to Tumbler, lb/hr	Recycle, lb/hr	Aggregate Production, tons
December 2004	12,000	3,980 – 7470	4,000 –11,820	580
January to March 2005	8,000 –10,000	2,000 – 3,685	700 – 3,670	450
September 2005	15,000 – 22,000	5,500 – 8,500	2,500 –12,000	1,500
December 2005	13,500 – 22,000	6,100 – 9,150	8,100 –13,500	800
January 2006	19,000 – 29,000	8,178	4,000 –14,000	700
February 2006	27,000 – 29,000	8,178 – 8,216	4,000 – 9,000	965
March 2006	26,000 – 29,000	8,178 – 8,716	4,000 – 9,000	627
July 2006	29,000	7,126	0	900
August 2006	22,000 – 29,000	7,126 – 7,880	2,000 – 7,000	3,036
September 2006	11,000 – 26,000	4,325 – 8,182	2,000 – 7,000	1,732
December 2006	12,000 –26,000	3,645 – 7,591	3,000 – 5,000	1,276

B. Environmental Performance

The UA process is inherently environmentally friendly. The process turns a solid waste into a useful product. Processed SDA and bottom ash not used to manufacture aggregate will continue to be beneficially utilized as “alternate daily cover” in local landfill operations. Off-spec aggregate is recycled back through the process. Storm water and sanitary waste are the only liquid effluents from the plant and are handled in the host facility systems.

The only potential atmospheric emissions are “fugitive dust” from the various solids transfer points, crushing and screening operations, and the product storage pile. There is also some potential for particulate emissions from the vent systems used for equipment that operates under a slight vacuum. All systems are enclosed and vented through fabric filters. During the project, some upgrades to the particulate removal systems were required, including the replacement of a wet scrubber on the CV with a system of cartridge filters. By the conclusion of the project, risks to the environment were effectively mitigated.

IV. DISCUSSION OF RESULTS

During the 33 months from initial start-up attempts until the project was completed, the UA plant produced approximately 26,000 tons of product, equal to about 2 months of operation at design conditions. In a few cases, production was limited by power outages or reduced operations at the BPF; however, a large majority of the problems that limited or prevented operation were due to equipment problems in the UA plant as described in Section III of this report.

The pugmill/extruder train was originally designed for use with clay, rather than the materials it was required to process. Since the UA plant was a first-of-a-kind commercial plant, it is reasonable to assume that no commercially-proven equipment was available for this particular application. Under such circumstances, significant problems were not unexpected. Similarly, the CV was an innovative design used in a first-of-a-kind application, and the need for considerable changes was not unanticipated.

Numerous problems were also encountered in the rest of the facility with such basic items as conveying/material handling equipment, fabric filters, pumps, spray systems, crushers, and screen systems. Although the engineering firms and manufacturers of the plant equipment were well experienced in their respective businesses, the likelihood of numerous equipment problems and failures always increases when processing a new feedstock in a new type of facility. In this case, an innovative piece of equipment, the CV, was also added, further increasing the risks.

UA continued to address the problems by replacing or modifying equipment and operating procedures, and reported that the plant was able to operate at 50–60 percent of design capacity by the end of the project. UA’s final report, which covers the period from the start of the project through the end of 2006, indicates that the company continues to work on upgrading the plant with the goal of achieving reliable operation at design capacity.

While only 26,000 tons of aggregate products were produced during the project demonstration, it all found a ready market with the exception of some small quantities that were used for evaluation tests. The end product consistently met the appropriate specifications of the customers who used the manufactured aggregate. In 2007, over 41,000 tons of lightweight aggregate were produced and sold after improvements to mixing and extrusion were introduced.

V. MARKET ANALYSIS

A. Potential Market

The immediate market area for the Birchwood manufacturing plant covers over 11,000 square miles. Fifteen concrete masonry production plants operate within the immediate market area and the annual consumption of lightweight aggregates is relatively steady at 400,000 tons. A strong, steady construction market exists from the greater Baltimore, Md./Washington, D.C., corridor to south through Richmond, Va., and on towards Chesapeake, Va. The demand for all basic construction materials (including lightweight aggregate) is estimated to remain steady, if not increase slightly for the foreseeable future. Residential and commercial development are expected to remain strong in the foreseeable future. The resulting demand for concrete masonry products consumes much of the lightweight aggregate market share. Extended market areas exist west and north of the Birchwood plant. With the possibility of rail transportation, this extended market area provides access to an additional thirteen concrete masonry production plants and up to 200,000 tons of lightweight aggregate consumption annually.

Additional lightweight aggregate market potential exists for lightweight structural concrete in applications such as structural embankments. The demand within these markets varies annually between 50,000 tons and 150,000 tons due to annual fluctuations in the demand for high-rise, multi-level building construction, bridge construction and rehabilitation, and highway construction activities.

UA reports that its market research located many potential sources of raw feedstock materials; however, not all potential sources of raw feedstock materials fit the business model. Since basic supply/demand economics prevail, an end product market must be reasonably accessible, and the aggregate competitively priced. In addition, a minimum supply of quality feedstock materials must be available to justify the financial investment with the required rate of return. Where the appropriate market conditions exist, UA states that it will perform the necessary due diligence to expand the commercial deployment of the manufactured aggregate technology.

B. Capital, Operating, and Maintenance Costs

UA conducted a cost analysis based on projected performance of the Birchwood facility; the analysis forecast an actual operating budget for calendar year 2007, using the 2006 year-end production rate of 72,000 tons of lightweight aggregate produced and sold. (This level of production was not maintained and only 41,000 tons were produced in 2007.) The projected performance was based primarily upon estimated annual production at approximately 50 percent of the design operating capacity and the corresponding lightweight aggregate sales from that production. UA performed a sensitivity analysis for cost-based performance at three annual production forecast cases using the current staffing requirement of twenty hourly and salary employees at the Birchwood manufacturing plant. The company concluded that the demonstration project must operate at, or very near, full production capacity to experience a positive net cash flow.

Due to the extensive start-up problems and modifications, the costs that were and are being incurred at Birchwood cannot be used as a reliable estimate for future facilities. (These costs are included in the appendix for general information.) However, given the post-project plant refinements and continued operation at increased capacity, UA is currently gaining valuable operation and maintenance experience. This experience will allow the organization to realistically budget annual operating costs and estimate costs for future implementation of this technology.

VI. CONCLUSIONS

The manufactured aggregate plant has experienced nearly continuous operating problems and equipment failures since its initial startup in April 2004. During the course of the project, UA continued to modify or replace equipment and operational procedures, which resulted in approximately 50 percent operational plant capacity at the end of the project.

Given the inability of the demonstration plant to achieve the design production rate in the course of the project, the project cannot be considered to be fully successful, especially since UA analysis determined that the plant must operate at or near full design capacity to generate a positive cash flow. It must also be noted, however, that UA was able to sell the entire product and that the manufactured aggregate does meet the needs of its customers. Manufactured aggregate has several advantages over competing materials (primarily expanded clay and shale). The manufactured aggregate uses a waste stream as the primary feed thereby avoiding landfill disposal costs, eliminates the need to mine raw materials, and unlike clay and shale, it does not require the fuel needed to fire a kiln.

Communication with the participant in December 2007 confirmed that UA has continued to address the problems that limit production. The front end of the plant was operating at or near design capacity and the CV problems have been largely overcome. This was accomplished in large part due to the lessons learned during the demonstration project. The only major impediment to full production is in the crushing/screening of the cured extrudates. While issues such as these still exist, UA's success in addressing the many problems that have occurred indicates that there is a reasonable probability the plant will meet its goals, albeit at a later date than initially planned.

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R. T. Patterson Company, Inc., "Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash – Topical Report #1-Public Design Report," April 2003.

Wu, Milton and Paul Yuran, "Commercial Demonstration of the Manufactured Aggregate Processing Technology Utilizing Spray Dryer Ash - Final Technical Report," September 26, 2007.

Appendix
Project Costs

Universal Aggregates, LLC Total Project Recap
1020 Lebanon Road
West Mifflin, PA 15122

DOE Cooperative Agreement # DE-FC26- 02NT41421

Period of performance covered by this billing 1/1/2002 to 12/31/06

Cost description	Claimed for this billing Period	Cumulative claimed Life to date
Wages		$ 4,609,870.00
Benefits & Taxes		$ 982,544.00
Travel		$ 221,800.00
Consultants		$ 5,126,402.00
Other		$ 7,252,528.00
Insurance		$ 54,981.00
Equipment		$ 7,431,238.00
Total Direct Cost		$ 25,679,363.00
G & A		$ 4,647,748.00
Total Cost		$ 30,327,111.00
Universal Aggregates		$ 23,103,111.00
Department of Energy		$ 7,224,000.00