Triboelectrostatic Fly Ash Beneficiation: An Update on Separation Technologies' International Operations

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ABSTRACT

Separation Technologies, LLC (ST) continues to install fly ash beneficiation systems to supply high quality fly ash to the concrete industry. In May 2005, ST will have commissioned 12 carbon separation systems at 8 utility company power plants in the U.S., Canada, and Europe and one ammonia removal system. Over 3.2 million tons of ProAsh® brand processed ash have shipped since 1995.

ST's technology reduces the carbon content of fly ash, producing a consistent, low LOI ash for use as a cement substitute in concrete. Simultaneously a carbon rich product is produced that can be returned to the utility for recovery of the fuel value. In 2005, ST installed two continuously operating reburn systems to store, convey, and dedust the carbon-rich product prior to addition to the utility coal belt conveyor.

Additionally, two Separation Technologies plants are successfully beneficiating and marketing fly ash derived from a fuel mix of petroleum coke with bituminous coal with an initial LOI content of 15% to 30%. Based on extensive concrete testing using ST processed ash from coal/petcoke blends, the Florida Department of Transportation and the Canadian Standards Association have modified material specifications to permit fly ash from co-combustion of petroleum coke and coal for use in concrete.

Power plants are increasing utilization of ammonia injection to mitigate NOx and SO_3 emissions. However, residual ammonia deposits on fly ash in typical cold-side ash collection systems, requiring removal of the ammonia to prevent its release during concrete production and placement. Separation Technologies' ammonia removal process preserves the marketability of the ash.

History of Separation Technologies, Inc.

ST was founded in 1989 to develop commercial applications for a proprietary electrostatic separation process invented by one of the company's founders. By 1994, ST was focusing on applying its separation technology to processing fly ash that could be used in high value commercial applications rather than being placed in landfills. Installation of mandated NOx control equipment at coal-fired power plants which increased the carbon (LOI) content of previously marketable fly ash created this opportunity to apply the ST separation process to fly ash beneficiation.

ST began operation of the first commercial fly ash processing plant to control the LOI content of fly ash at Brayton Point Station, Somerset MA in 1995. Since that time, ST has experienced rapid growth in fly ash sales, marketing its processed ash as the first differentiated, high-value fly ash brand, ProAsh®. ST's technical and marketing expertise drove our strong growth rate, as measured by the number of commercial sites in operation and tons of ash sold. In ST's 9+ years of commercial operation, over three million tons of ProAsh® have been shipped to concrete producers.

ST responded to a further threat to fly ash utilization by developing a commercial viable ammonia removal process. Ammonia contamination of ash results from NO_x reduction processes such as SCR and SNCR methods as well as ammonia injection to enhance electrostatic precipitator performance. ST's ammonia removal process, based on chemical induced out gassing of ammonia from the ash at ambient temperatures, is designed to minimize capital and operating costs. Extensive pilot plant work was conducted on this process in 2000, and a full scale system began operation in Jacksonville, Florida in 2003.

In 2002 ST became part of the Titan America family of businesses. Titan America is one of the premier cement and building materials producers in the Eastern United States. Titan America is best known by its brand and business names: Essex Cement, Roanoke Cement, Tarmac and now ST and ProAsh®. Titan America operations include cement plants, ready-mix concrete plants, concrete block plants, quarries, import and rail terminals, as well as fly ash production facilities.

ST Triboelectrostatic Separation Technology Overview

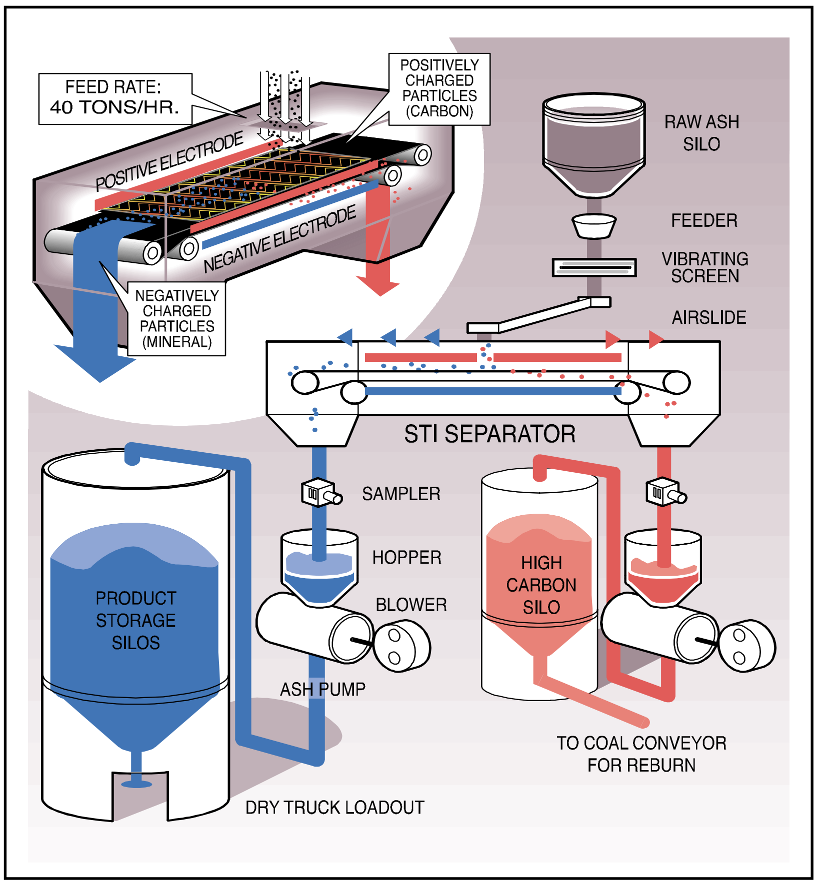
ST utilizes a unique, patented process for separating unburned carbon from the mineral constituents of coal combustion fly ash. In the ST separator (Figure 1), material is fed into the thin gap between two parallel planar electrodes. The particles are triboelectrically charged by interparticle contact. The positively charged carbon and the negatively charged mineral are attracted to opposite electrodes. The particles are then swept up by a continuous moving belt and conveyed in opposite directions. The belt moves the particles adjacent to each electrode toward opposite ends of the separator. The counter current flow of the separating particles and continual triboelectric charging by carbon-mineral collisions provides for a multi-stage separation and results in excellent purity and recovery in a single-pass unit. The high belt speed also enables very high throughputs, up to 40 tons per hour on a single separator. The small gap, high voltage field, counter current flow, vigorous particle-particle agitation and self-cleaning action of the belt on the electrodes are the critical features of the ST separator. By controlling various process parameters, such as belt speed, feed point, and feed rate, the ST process produces low LOI fly ash at carbon contents of less than 3.5% from feed fly ashes ranging in LOI from 4% to over 25%.

The separator design is relatively simple. The belt and associated rollers are the only moving parts. The electrodes are stationary and composed of an appropriately durable material. The belt is made of plastic belting material. The separator's power consumption is about 1 kilowatt-hour per ton of material processed with most of the power consumed by two motors driving the belt.

The process is entirely dry, requires no additional materials other than the fly ash and produces no waste water or air emissions. The recovered materials consist of fly ash reduced in carbon content (LOI) to levels suitable for use as a pozzolanic admixture in concrete, and a high carbon fraction useful as fuel. Utilization of both product streams provides a 100% solution to fly ash disposal problems.

The ST separator is relatively compact. A machine designed to process 40 tons per hour is approximately 30 ft. long, 5 ft. wide, and 9 ft. high. The required balance of plant consists of systems to convey dry fly ash to and from the separator. The compactness of the system allows for flexibility in installation designs: two ST separators with a combined processing capacity of 450,000 tons/year have been installed in a truck loading bay of an existing 44 ft. diameter fly ash silo. A diagram of the ST separator and essential balance of plant components is found in figure 1.

Figure 1: Separator and Balance of Plant



ST Ash Processing Facilities

ST continues to produce controlled LOI fly ash at its previously constructed facilities in Massachusetts, North Carolina, Maryland, Florida, and Scotland. The processed fly ash is marketed under the trademark ProAsh® throughout the east coast of the United States. ProAsh® has been approved for use by fifteen state highway authorities, as well as many other specification agencies. In August of 2003, the ST installation in Roxboro reached the milestone of 1 million tons of ProAsh® shipped from a single processing location. In aggregate, ST has shipped over 3.2 million tons of ash to concrete producers. Currently operating ST facilities are listed in table 1.

Table 1: ST Commercial Operations

ST Commercial Operations			
Utility / Power Station	**Location**	**Start of Commercial operations**	**Facility Details**
U.S. Generating Co. - Brayton Point Station	Massachusetts	July 1995	2 Separators
Progress Energy – Roxboro Station	North Carolina	Sept. 1997	2 Separators
Constellation Power Source Generation - Brandon Shores Station,	Maryland	April 1999	2 Separators 35,000 ton storage dome
WPS Power Development - Sunbury Station	Pennsylvania	Nov. 2000	Unprocessed Ash
ScotAsh (LaFarge / Scottish Power Joint Venture) - Longannet Station	Scotland	Oct. 2002	1 Separator, Classification
Jacksonville Electric Authority - St. John's River Power Park, FL	Florida	May 2003	2 Separators Coal/Petcoke blends Ammonia Removal
South Mississippi Electric Power Cooperative R.D. Morrow Station	Mississippi	Jan, 2005	1 Separator High Carbon Reburn
New Brunswick Power Company Belledune Station	New Brunswick, Canada	April 2005	1 Separator Coal/Petcoke Blends High Carbon Reburn
RWE Innogy Didcot Station	United Kingdom	Scheduled May 2005	1 Separator

During 2004 – 2005, Separation Technologies considerably expanded its operations both by upgrading existing installations and constructing new facilities. Additional separators have been installed at ST's facilities at CGPS Brandon Shores Station, Baltimore, Maryland, and JEA St. Johns River Power Park in Jacksonville, Florida. Additionally, a 35 thousand ton storage dome was constructed at the Brandon Shores Station to enable continuous processing of material during periods of low demand in the winter months. These additions will allow 100% capture of fly ash produced from the power units at these two power plants.

ST also commissioned new fly ash beneficiation facilities in Mississippi and New Brunswick, Canada, two areas where little concrete-quality fly ash was available. Construction is also currently nearing completion at our second facility in the United Kingdom, located at the RWE Innogy Didcot Power Station. This facility will provide high quality fly ash for the production of aerated autoclaved concrete (AAC) blocks and ready-mix concrete in the south-central region of the UK and greater London area.

Recovered fuel value of high-carbon fly-ash

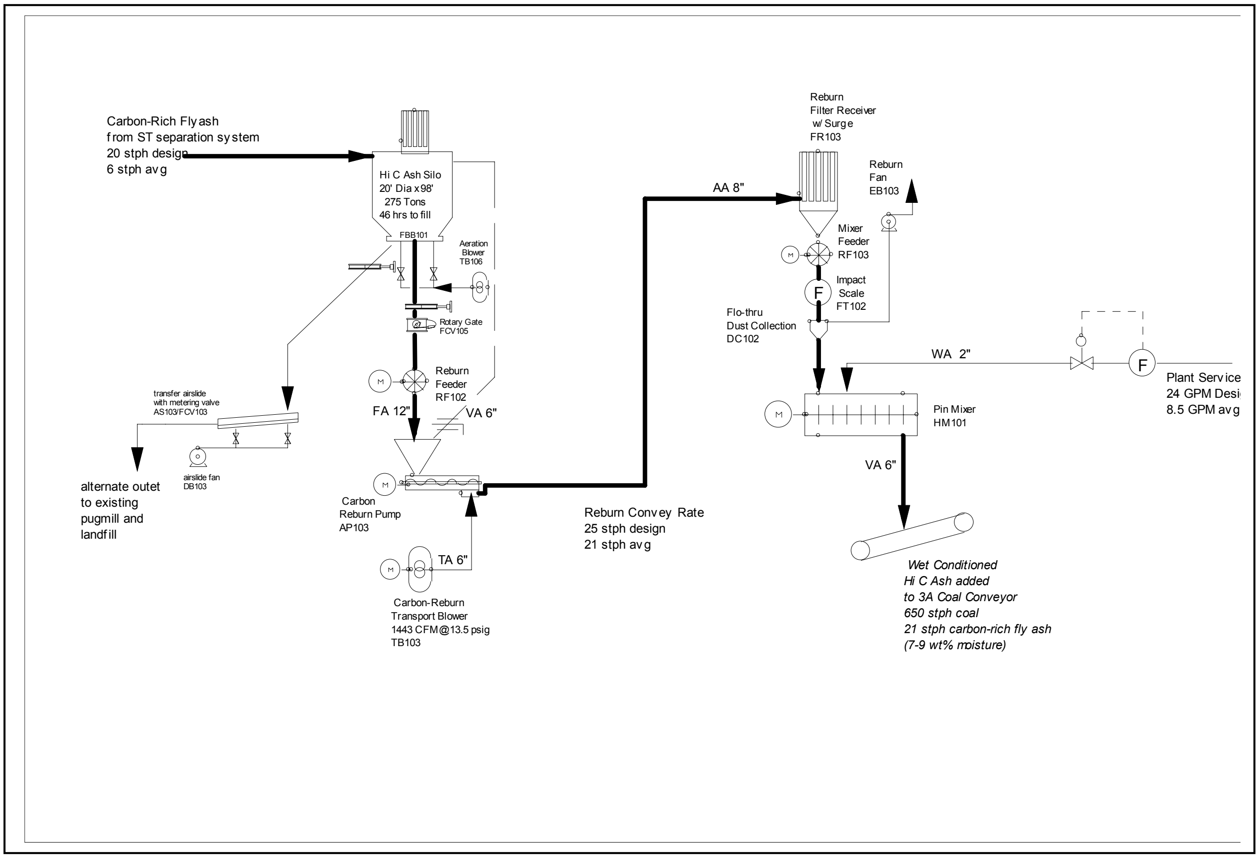
In addition to the production of a controlled-LOI fly ash for use in ready-mixed concrete, the ST process recovers an stream enriched in carbon. The reburning of high-LOI fly ash in utility boilers is a relatively simple method of utilizing this concentrated unburned carbon (UBC). Furthermore, recovery of the residual energy contained in the high-carbon fly ash increases the value of the beneficiation process directly to the power plant operation in the form of reduced fuel costs.

New England Power (NEP) and Salem Harbor Station demonstrated the combustibility of high carbon ash from the STI process and its use as a fuel in 1995.[1] To assess the combustion properties of high-carbon ash, drop-tube furnace combustion tests and full-scale field trials injecting ash into a commercial boiler were conducted. Trials at the Salem Harbor station proved the viability of burning the high-carbon ash as a supplemental fuel. Energy recovery was similar to coal at greater than 85%. Flame shape and stability were unaffected. Particle and gas emissions and opacity all remained acceptable.

Subsequent to the test at Salem Harbor, Baltimore Gas and Electric (now Constellation Power) performed a full-scale reburn trial of ST generated carbon-rich fly ash[2]. This test was conducted by adding the carbon-rich fly ash as a wet conditioned material directly to the plant coal conveyor. The dedusted material was then co-conveyed with coal into the utility boiler for reburn. The utility concluded that the energy recovery was equivalent to coal: heat rate was improved. Further, they observed that precipitator performance and air emissions were not significantly effected. Based on these trials, ST concluded that addition of wet conditioned high carbon product directly to the coal belt conveyor is the preferred method of reburn.

ST's two recently commissioned plants, SMEPA R.D. Morrow and NBP Belledune, both include systems to return high carbon concentrates to the fuel system. ST designed, constructed, and operates the carbon-reburn systems for these plants. The SMEPA system conveys carbon-rich ash from an existing storage silo to a filter-receiver located above the primary coal feed belt conveyor. The carbon-rich material is first mixed with water in a pin mixer for dust control. The dust-free carbon-rich ash then drops directly onto the coal feed belt conveyor. The system includes process instrumentation and PLC controls to allow remote operation by the ST separator operators. A hardwired control interface with the utility coal yard control system provides interlock to permit reburn system operation only when coal is on the belt conveyor . A simplified flow diagram for the SMEPA system is shown below (Figure 2). The NBP system is similar.

Figure 2: Flow diagram of High Carbon return system.



The SMEPA reburn system started operation in January 2005. Initial testing showed excellent control of dusting with only 7 – 9% added moisture when using the installed pin mixer. The resulting wet conditioned high carbon material consists of fairly uniformed size agglomerates which are dropped onto the moving coal conveyor with no visible dusting. High carbon reburn rates of 20 – 23 stph were accepted by the power plant with no observed detrimental effects on the combustion systems, precipitator performance, or emissions. The system now operates routinely at SMEPA. The NBP system will start operation in April.

Removal of Ammonia from Fly Ash

Power plants are increasing utilization of ammonia injection to mitigate NOx and SO_3 emissions. However, when SCR, and SNCR for NO_x control, and ESP ammonia injection for SO_3 control systems are installed, residual ammonia deposits on fly ash in typical cold-side ash collection systems. While ammoniated ash is not detrimental to concrete performance, when the ammoniated ash is mixed with the alkaline cement in production of concrete, the ammonia is volatilized. The released ammonia presents a hazard to workers both at the concrete plant and during placement and finishing of the concrete. Ammonia can also be released from cured concrete at low levels upon repeated wetting of the concrete, causing an unpleasant, though non-hazardous condition. Generally, fly ash containing greater than 100 ppm is considered unacceptable for production of concrete.

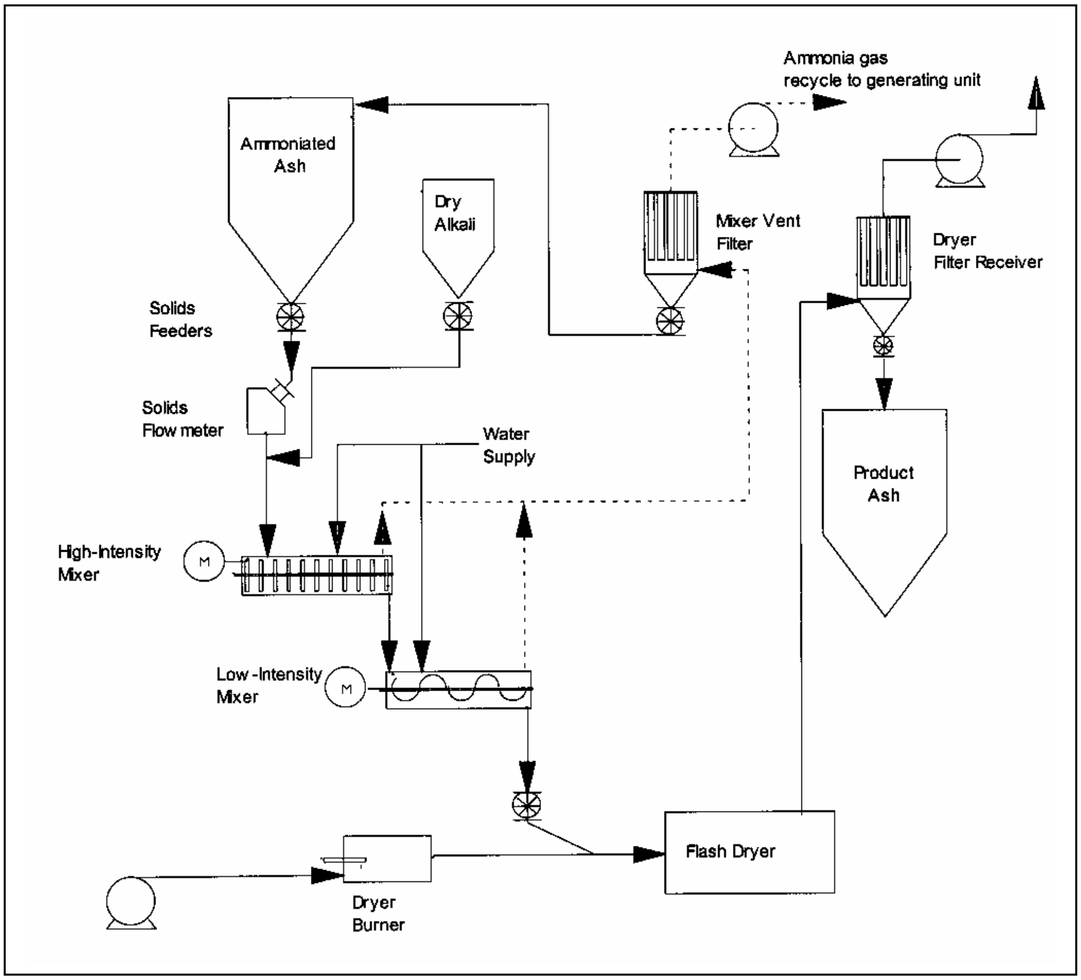
Due to environmental controls at the Jacksonville Electric Authority St. Johns River Power Park (SJRPP), the fly ash can be contaminated with appreciable amounts of ammonia. SJRPP injects ammonia into the unit ESP hoppers to control SO_3 aerosol emission, resulting in an ammonia content of up to 1000 mg NH_3/ kg (ppm) on the fly ash. While the fly ash ammonia does not affect the ST separation process for LOI reduction, ammonia can limit the use of fly ash in concrete production due to worker exposure issues.

ST has developed and patented a process that removes ammonia from fly ash[3]. To remove ammonia as a gas from the fly ash, the ST process utilizes the same fundamental chemical reaction that results in ammonia release in concrete. However, the ST process uses only minimal quantities of a calcium based alkali and water.

The process flow diagram for the continuous operation of the STI process is presented in Figure 3. Ash, water and lime in controlled proportions are metered to a mixer. To assure rapid mixing and uniform dispersion of the added water and alkali, a high intensity mixer is used. A low intensity device such as a pug mill is used as a secondary mixer to provide good air contact to permit transport of ammonia from the bulk of the ash. Since the moisture content of the ash is very low, the material flows through this mixer as a highly agitated dry powder. Ammonia gas collected in both the high and low speed mixers is recycled to the generating unit flue. Recycling the collected ammonia gas reduces ammonia addition to the flue and minimizes ammonia emission to the environment.

The deammoniated ash is dried by conveying the material through a flash drier to remove excess water. Due to the minimal amount of water added, water consumed in the formation of hydrated calcium sulfate upon reaction with soluble sulfate in the ash, and loss of water during the low intensity mixing stage, only a small amount of water needs to be removed by the drier. This minimizes the energy demand of the drying stage. Final ash temperatures of approximately 150^{o}F are adequate to produce a completely free-flowing, product fly ash with moisture contents well below the ASTM C 618 specification of 3 wt. %.[3]

Figure 3: ST Ammonia Removal Process



Key features of the ST process are the use of a minimum quantity of water (1 to 4%, typically 2%) and minimal quantities of alkali (< 2%). The deammoniated ash is dried by conveying the material through a flash drier to remove excess water. Drying requires relatively little energy due to the minimal moisture addition required by the process. Final ash temperatures of approximately 150^{o}F are adequate to produce a completely free-flowing, product fly ash with moisture contents well below the ASTM C 618 specification of 3 wt. %.[4]

The process recovers 100% of the fly ash treated and the resulting ash meets all specifications for use in concrete. ST's ammonia removal process can be used alone or in combination with the company's carbon separation technology. The carbon separation process is not affected by the presence of ammonia. This modular approach offers the lowest cost solution for treating otherwise unusable fly ash.

The first full-scale application of ST's ammonia removal process is operating at ST's SJRPP ash processing facility. This commercial scale operation handles up to 40 tons per hour of contaminated ash, reducing the ammonia content to less than 30 ppm. Ammonia levels in the incoming fly ash varies from ~200 to 900 ppm.. Effective ammonia removal was observed at somewhat lower levels of lime injection than indicated by preliminary lab work.

The process is very robust, resulting in 90+% ammonia removal under all trial settings, producing ash well below our target of maximum 50 ppm ammonia. Final moisture contents are <0.3%. Representative results are listed in Table 2. All control systems operate well for automatic startup and shutdown as well as fault monitoring during processing.

Table 2: Typical Full Scale ammonia system results

Feed Rate, tons/hr	Initial Ammonia, ppm	Final Ammonia, ppm	Lime rate, % of feed	Water rate, % of feed
21	910	25	1.35	1.9
25	190	9	0.88	2.6
40	350	12	0.70	2.05
18	242	20	0.82	1.52

Fly ash from coal / petcoke co-combustion

Two of the power plants with ST processing facilities routinely use a fuel blend of petroleum coke (petcoke) and bituminous coal. Jacksonville Electric Authority (JEA) St. Johns River Power Park was the first of these plants ST investigated. At the time that ST and JEA reached an agreement for the fly ash processing facility, the Florida Department of Transportation (FDOT) would not permit the use of fly ash derived from other than 100% coal. In order to gain FDOT acceptance of this fly ash, ST performed extensive concrete testing using ash derived from up to 20% petcoke. Long-term durability testing including strength development to 90 days (ASTM C 39), corrosion resistance (ASTM G 109 and FM 5-522), chloride permeability (AASHTO T-277), drying shrinkage (ASTM C 157) and sulfate expansion (ASTM C 1012) showed that the processed fly ash from SJRPP matched or exceeded the performance of fly ashes being used in the Florida market place.

Based on these results, FDOT modified their specifications in 2000 to allow the use of Class F fly ash derived from the co-combustion of coal and petroleum coke upon completion of specific durability tests[5]. ST received final approval from FDOT to supply processed ash from the ST Jacksonville facility for state work in May of 2003. This was the first approval by a state agency responsible for highway construction within the United States of fly ash derived from other than 100% coal.

The New Brunswick Power (NBP) Belledune station routinely uses a 25% petcoke / 75% bituminous coal fuel blend. Canadian Standard Association's (CSA) specifications again did not allow for use of fly ash in concrete production other than from only coal combustion. Dr. Michael D. A. Thomas conducted extensive testing and prepared a report on the use of fly ash from coal / petcoke blends for the CSA which included results from mortar and concrete tests comparing fly ash derived from coal only and coal / petcoke blends[6]. Dr. Thomas concluded that there were little if any differences expected in the use of ash from coal / petcoke blends. The only difference observed between the two types of ashes was a tendency of ash from the fuel blend to have a lower effect on air entrainment in concrete compared to ash derived from coal only. On the basis of this report and other discussions, the CSA committee on cementitious materials amended the definition of acceptable fly ash to include material derived from the coal-combustion of petroleum coke and coal. This change was incorporated into the CSA A3000 standards on cementitious materials. Dr. Thomas recently initiated a discussion within the ASTM C09.24 subcommittee to consider altering the current ASTM definition for fly ash also.

Summary

The Separation Technologies' beneficiation processes continue to be the most extensively applied methods to upgrade otherwise unusable fly ash to high value materials for cement replacement in concrete and enabling the utilities to avoid disposal costs. Twelve ST separators are in place with over 42 machine-years of operation. The ST processed ash has found wide acceptance in the concrete industry as a premium fly ash requiring far less monitoring of air entrainment requirements due to less LOI variability than other ashes. Reintroducing the high-carbon concentrate from the ST process into the fuel mix at a power plant allows recovery of the material's fuel value at an efficiency similar to coal. With the additional availability of the ammonia process, ST offers commercially economical means to recover material for high value use that would otherwise be land filled. Electrostatic carbon separation, fly ash reburn, and ammonia removal processes provide a modular solution to a utility's fly ash needs. These three processes can be implemented in phases, or as a single project.

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[2] Internal memo to John Hayden, High Carbon Ash Reinjection at Brandon Shores – Test Results – Final Report – Constellation Power Source Generation, January 27, 2000.

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