STI's Six Years of Commercial Experience in Electrostatic Benefication of Fly Ash

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Separation Technologies, Inc. (STI) has been operating commercial fly ash beneficiation systems for over five years. STI's electrostatic beneficiation technology reduces the carbon content of coal fly ash, producing a consistent, low loss-on-ignition (LOI) ash for use as a substitute for cement in concrete applications. The STI process generates uniform quality fly ash (±0.5 % LOI) from highly variable LOI ash. Presently, five STI electrostatic separators are operating at three electric utilities to produce concrete-grade fly ash: U.S. Generating Co. Brayton Point Station (two separators), Carolina Power and Light (CP&L) Roxboro Station (two separators), and Constellation Power Source Generation (formerly Baltimore Gas and Electric) Brandon Shores Station (one separator).

STI TECHNOLOGY OVERVIEW

In the STI 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. By controlling various process parameters, such as belt speed, feed point, and feed rate, the STI process produces low carbon fly ash at LOI contents of 2 % ± 0.5% from feed fly ashes ranging in LOI from 4% to over 25%.

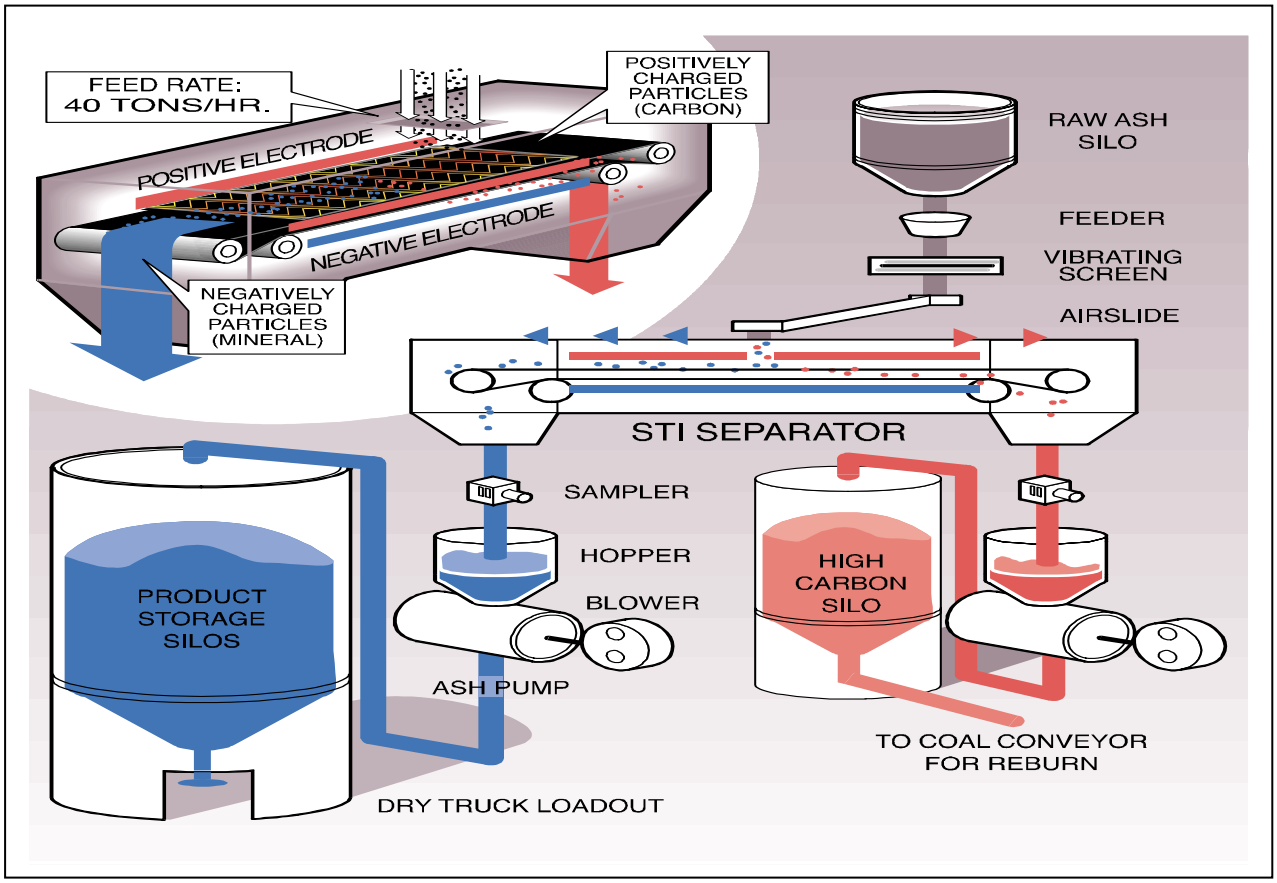
The separator design is relatively simple. The belt and associated rollers are the only moving parts. The electrodes are stationary and composed of an appropriately durable material. The belt is made of plastic belting material. The separator electrode length is approximately 20 feet and the width is dependent on the capacity desired. The 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 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 STI separator.

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 which can be reburned at the generating plant. Utilization of both product streams provides a 100% solution to fly ash disposal problems.

The STI 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 STI 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 STI separator and essential balance of plant components is found in Figure 1.

Figure 1: Separator and Balance of Plant



COMMERCIAL HISTORY

New England Power (now U.S. Generating) Salem Harbor Station

STI installed the first commercial separator at the then New England Power Salem Harbor Station in 1994. This project enabled STI to demonstrate the process technology on a commercial scale. However, while low carbon fly ash was generated at this facility for sale to the New England ready-mixed concrete market, the balance of plant to allow continuous production from this location was not installed. With the startup of SNCR NOx control at Salem Harbor, the fly ash from that plant became heavily contaminated with ammonia, Although ammonia did not affect the separation process, the ammoniated ash was no longer marketable. On the basis of the successful demonstration at Salem Harbor, New England Power and STI installed two STI separators to beneficiate all fly ash at the larger Brayton Point Station where ammonia was not an issue.

U.S. Generating Co. (USGEN) Brayton Point Station (formerly New England Power)

The first fully configured system designed for 7 day per week, 24 hour per day operation to produce fly ash was started up at the NEP Brayton Point Station in July, 1995 and operations continue to the present. This power plant burns bituminous coal from up to twenty different sources in three units producing 1100 megawatts of power. Approximately 240,000 tons of fly ash are produced at Brayton Point station annually. Before NOx conversion in 1995, the power plant produced relatively low (3 to 5%) LOI fly ash. All three coal fired generating units were converted to low NOx burners to comply with the mandate of Phase I, Title IV of the Clean Air Act of 1990. These conversions resulted in an increase of the fly ash LOI from 6% to 25%, and made the ash unacceptable for use in ready-mixed concrete. STI produces fly ash with an LOI below 2.5% from this raw material.

The combined processing capacity of the two separators installed at Brayton Point exceeds 300,000 tons annually. The STI fly ash has gained wide acceptability in the New England market as well as New York state. The STI process has provided a reliable source of consistent quality fly ash which in turn has allowed ready-mixed concrete producers to optimize the utilization of this material.

Carolina Power and Light (CP&L) Roxboro Station

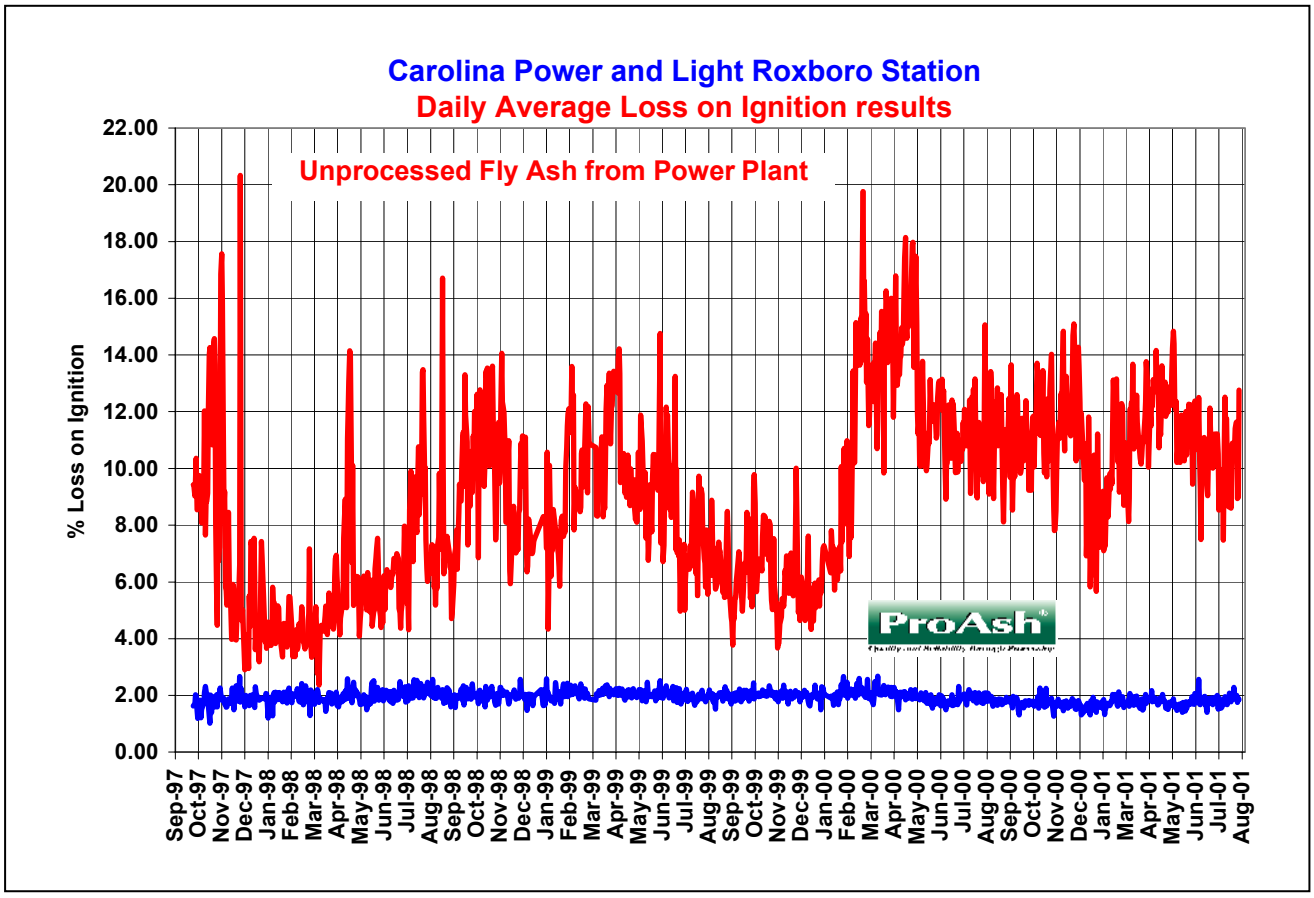
STI started a processing operation at the Carolina Power and Light Roxboro Generating Station, North Carolina in September, 1997. ProAsh LLC, a wholly owned subsidiary of STI, owns and operates the fly ash separation facility and is also responsible for processing and landfilling of both fly ash and bottom ash from the Roxboro plant.

The installation at Roxboro utilizes the existing four 3000 ton storage silos on site. STI engineers designed a system which houses two STI separators, the balance-of-plant

systems, and two product loadout stations within these 44-foot diameter silos. Wet truck loadout stations from two of the silos and the full storage volume of 12,000 tons of material were preserved. The capital investment for installing the systems was minimized by this method: the first separator and necessary conveying equipment and a loadout station was installed for $3.1 million. A second separator was added along with a second truck loading bay in 1998 for an additional $2 million. The processing capacity of the CP&L Roxboro facility is over 450,000 tons annually.

The low LOI fly ash (marketed as *ProAsh*® by Roanoke Cement Company) is supplied to ready-mixed concrete operations in Virginia, North Carolina, and South Carolina where it is used extensively to mitigate alkali silica reaction in concrete due to the use of reactive aggregate and unavailability of low alkali cement. The LOI of processed ash has been extremely consistent at Roxboro (See Figure 2): processed ash shipments have averaged 1.95 % with a standard deviation of 0.25 %. Customers have reported complete elimination of air entraining problems due to ash variability. With the high reliability of quality and supply provided by ProAsh, customers have expanded their utilization of fly ash.

Figure 2: LOI Control at CP&L Roxboro Station.



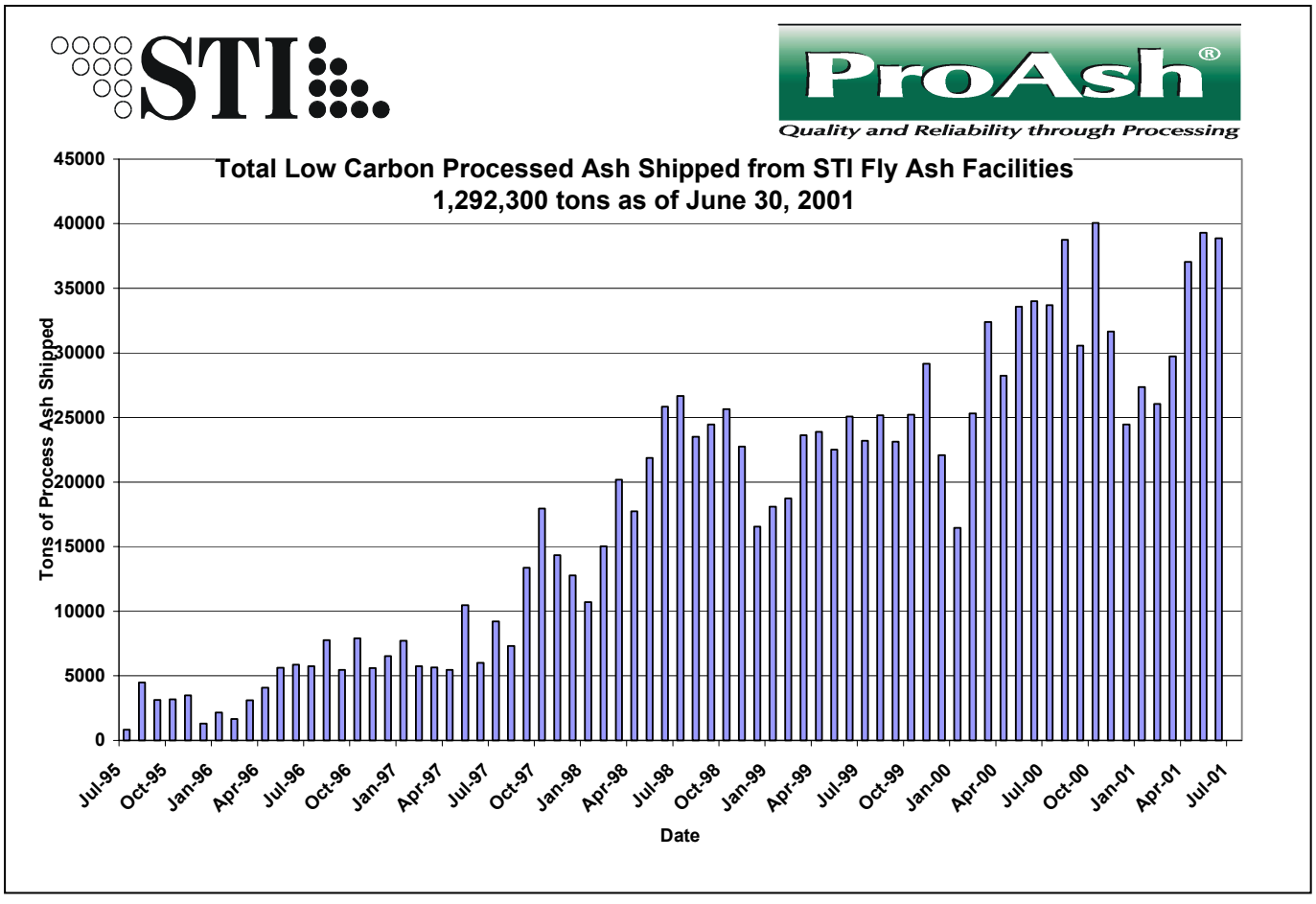
Constellation Power Source Generation - Brandon Shores Station

STI's latest plant startup occurred at the Constellation Power Source Generation (formerly Baltimore Gas and Electric) Brandon Shores Station in April 1999. STI owns and operates this fly ash processing facility. Master Builders Technologies, Inc. of Cleveland, Ohio, a leading producer of admixtures for the concrete industry, markets processed ash from this facility for STI.

The Brandon Shores processing facility required the construction of a building to house the separator and balance of plant components as well as a new 3300 ton product silo with a truck loading station. A 42' X 60' two-story building was designed to eventually house two separators as well as much of the balance of plant equipment for the operation. STI engineers developed the preliminary design package and supervised the detailed engineering and construction of the project. From the initiation of detailed engineering activities to startup of the separation system required nine months. Using the experience gained from previous installations, the separator was in full production shortly after start-up.

Due to the strong market for fly ash in the Northeast, Constellation Power Source Generation and STI have recently concluded an amendment to the contract under which STI will construct a 35,000 ton capacity dome for seasonal storage of fly ash to expand the deliverable capacity of the Brandon Shores facility.

Figure 3: Shipments of ash from STI's separator installations



FUEL VALUE OF UNBURNED CARBON

In addition to the production of a controlled-LOI fly ash for use in ready-mixed concrete, the STI process recovers an ash stream enriched in carbon. The reburning of high-LOI fly ash in utility boilers is a relatively simple method of utilizing this 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 have proven the viability of burning the high-carbon ash as a supplemental fuel. Burnout efficiencies were greater than 85% and flame shape and stability were unaffected. Particle and gas emissions and opacity all remained acceptable. Based on the success of these reburn trials, STI and New England Power installed a permanent system for burning the high-carbon fly ash and began commercial operations in July 1997.

CP&L Tests

In August, 1996, CP&L submitted a proposal and subsequently received a matching grant of $7,500 from the North Carolina Division of Pollution Prevention and Educational Assistance (DPPEA) Challenge Grant program[2]. The scope of work proposed included the installation of beneficiation technology with a goal of reducing fly ash sent to the landfill. The final report concluded that ash disposal could be reduced by 400,000 tons/year by 1) selling processed ash into the ready-mixed concrete market, and 2) reburning the high-LOI ash produced by the separators in the utility boilers.

As part of the emissions testing required by DPPEA, CP&L conducted a series of “test” burns using high-LOI ash produced by the ProAsh LLC facility. CP&L obtained permits to reburn a mixture of coal and high-LOI ash in Units 1, 2, and 3. The permit required particulate emission tests (PETs) within 90 days of the first firing of the carbon-rich fly ash in the boilers.

Wet conditioned high-carbon fly ash was placed on the coal conveyer using a portable conveyor with a variable speed belt. The portable conveyor was calibrated and then used to achieve a coal/ash ratio of 9.5%. The conditioned, high-LOI ash contained 25% moisture to control dusting. A 23% LOI ash with an estimated heating value of 2000 Btu/lb and a 12,000 Btu/lb coal was used for the tests. Since completion of the test burn, low-NO_x burners have been installed on Unit 3. As a result, the high-LOI ash from the ProAsh LLC facility has been as high as 45% LOI. The heating value of this ash is about 6000 BTU/lb.

During the test period, over 800 tons of high-LOI ash was added to six different mills at the plant. The tests showed that the energy from the high-carbon fly ash was

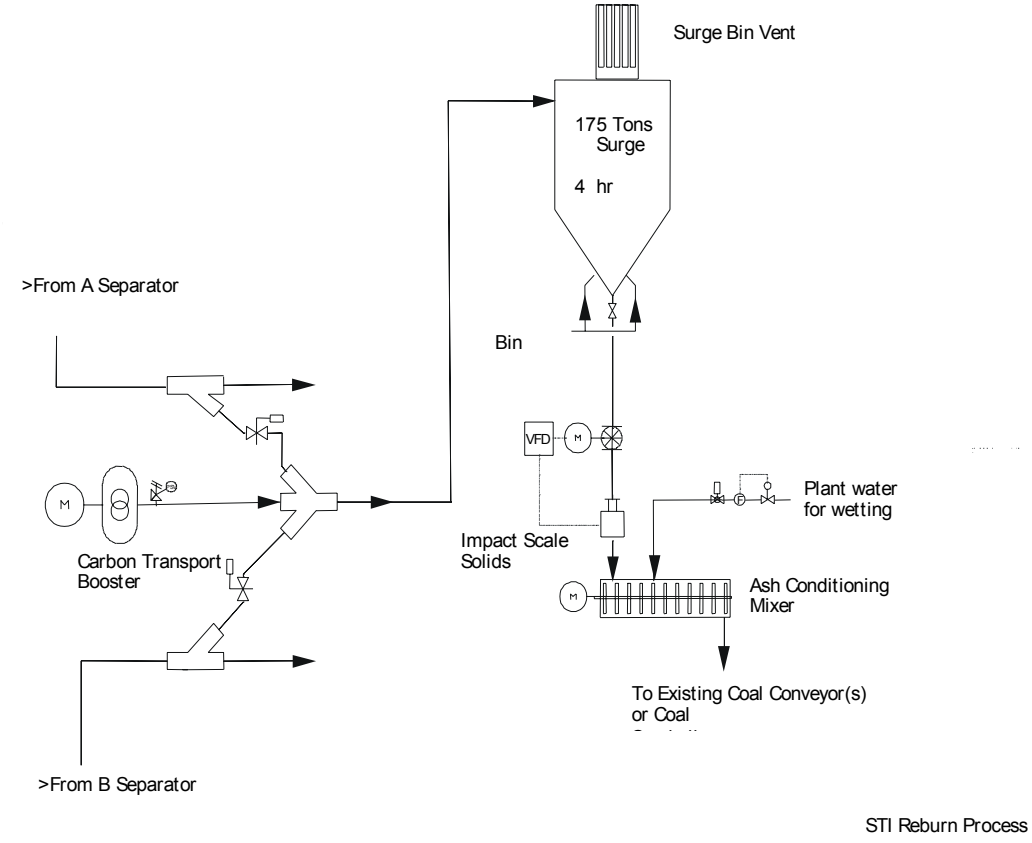
recovered. A significant change could not be detected in steam-side performance heatrate (9322 vs. 9323). Air emissions and precipitator performance was not impacted during the tests.

Fuel Savings

Assuming 400,000 tons of ash were processed at an average LOI of 15%, ProAsh LLC could produce enough high-LOI ash to displace approximately 60,000 tons of coal. Additional savings for the utility could be realized from avoided disposal costs.

STI has designed a carbon-reburn system for the Roxboro Plant. The system will convey high-LOI ash from the storage silo to a 175-ton surge bin. The ash will be conditioned with a dust suppression additive and then placed on the coal conveyor. A simplified flow diagram is shown below (Figure 3).

Figure 3: Flow diagram of High LOI return system.



AMMONIA CONTAMINATED FLY ASH

The utilization of fly ash as a pozzolan in concrete may be severely impacted by the effects of air quality regulations on utility plant operations. Specifically, mandated reductions in NOx , particulate, and sulfur containing aerosol emission levels are expected to require the installation of control systems which will use ammonia as a reagent. Depending on the level of ammonia present in the flue gas at the unit precipitators, the collected fly ash may be heavily contaminated with ammonia. For NOx control, the flue gas ammonia level will be set by the amount of ammonia "slip", i.e. unreacted ammonia present after the SCR unit. To reduce particulate or SO_3 aerosol emissions, ammonia is injected into the flue gas prior to the precipitators and is deposited on the fly ash. The degree to which this occurs depends on the SO_3 content, fly ash sulfur content, alkalinity of the fly ash, the ammonia concentration, and ash loading in the flue gas.

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 and 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 mg NH_3/ kg (ppm) is considered unacceptable for production of concrete.

STI has patented a process that removes ammonia from fly ash. The process recovers 100% of the fly ash treated and the resulting ash meets all specifications for use in concrete. STI'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.

Pilot plant trials conducted by STI have demonstrated the process to reduce the ammonia concentration on contaminated ash containing up to 1000 mg NH_3 / kg to less than 20 mg / kg at a rate of 3000 lb / hour. Design of a commercial size operation is underway which will handle 40 tons per hour of contaminated ash.

Summary

Separation Technologies, Inc. currently has commercial carbon separation facilities at three utility plants. Five STI separators are in place with over 15 machine-years of operation. The STI operations have made it possible to utilize otherwise unusable fly ash as a high value cement replacement in concrete and enabling the utilities to avoid disposal costs. Cumulative production from the STI systems exceeded one million tons in 2000. The STI 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. Reburning the high carbon material from the STI process also allows the utility to recover the fuel value of the carbon. STI also developed a practical ammonia removal process to beneficiate fly ash contaminated

with ammonia from plant emission controls. This process recovers material that otherwise for high value use would be landfilled. STI's fly ash processing technologies provide excellent alternatives to disposal for utilities generating high volumes of coal ash products.

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[1] Coates, M. E., Sload, A. W., *Recycling Carbon-Enriched Fly Ash into a Utility Boiler,* Proceedings of the Third Conference on Unburned Carbonaceous Material in Utility Fly Ash, U.S. Department of Energy Federal Energy Technology Center, pp. 27-30, 1997.

[2] Carolina Power & Light, *Addendum to Final Report: Recycling Residual Fly Ash Derived From Coal-Burning Electric Generating Facilities*, August 1998.