Separation Technologies' Automated Fly Ash Beneficiation Process selected for New Korean Power Plant

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Abstract

The Separation Technologies, LLC (ST) electrostatic beneficiation technology is well established as the most extensively used technology to reduce the carbon content of coal fly ash, The low energy consuming / high efficiency process operates at high capacity – up to 40 tonnes per hour by a compact machine. Fly ash with carbon levels greater than 20% have been used to produce a concrete grade ash with a controlled carbon content of $2 \pm 0.5\%$. A carbon rich product is simultaneously produced and returned to the utility boiler to recover the fuel value of the carbon. Currently, eighteen fly ash separators are in place with over 130 machine-years of operation at locations in North America and Europe. Over 12 million tons of low carbon content ProAsh® fly ash have been sold to concrete and cement producers.. Recent improvements to the ST process include on-line LOI measurement of the ProAsh® product and automatic control of the separator by a proprietary algorithm.

ST has also developed a process that removes ammonia from fly ash. The process, currently operating at three power plants, can reduce the ammonia concentration on contaminated ash containing up to 3,000 mg NH_3 / kg (ppm) to less than 75 mg / kg.

ST's technology has been selected for the Korean Southeast Power (KOSEP) Yeongheungdo Units 5 & 6 project. These two new 870 MW units are scheduled for commercial operation in 2014. This is the first ST separator to be included in the design of a new power plant and ST's first in Asia.

Introduction

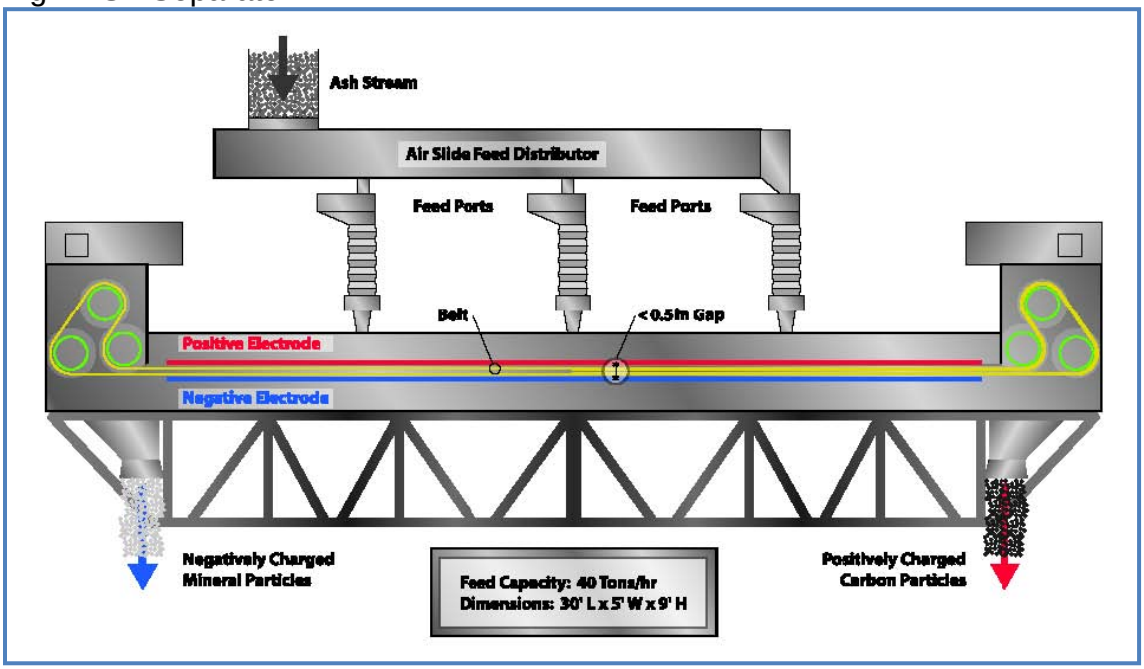
Since its commercialization in 1995, the fly ash beneficiation process supplied by Separation Technologies, LLC (ST) has become the world-dominant technology for producing controlled-LOI fly ash as a supplementary cementitious material. As air emission requirements become more rigorous for coal-fired electric power generators, resulting in greater levels of unburned carbon in the resulting fly ash, the demand for the ST technology continuous to increase.

ST continues to innovate and has identified a variety of means to further improve the efficiency, reliability and operational costs of applying its triboelectric belt separator to fly ash and other materials.

Technology Overview - Fly Ash Carbon Separation

In the ST carbon 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 high belt speed also enables very high throughputs, up to 36 tonnes 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%.

Fig. 1 ST Separator



The separator design is relatively simple and compact. A machine designed to process 36 tonnes per hour is approximately 9 m (30 ft.) long, 1.5 m (5 ft.) wide, and 2.75 m (9 ft.) high. 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. The separator's power consumption is about 1 kilowatt-hour per tonne of material processed with most of the power consumed by two motors driving the belt.

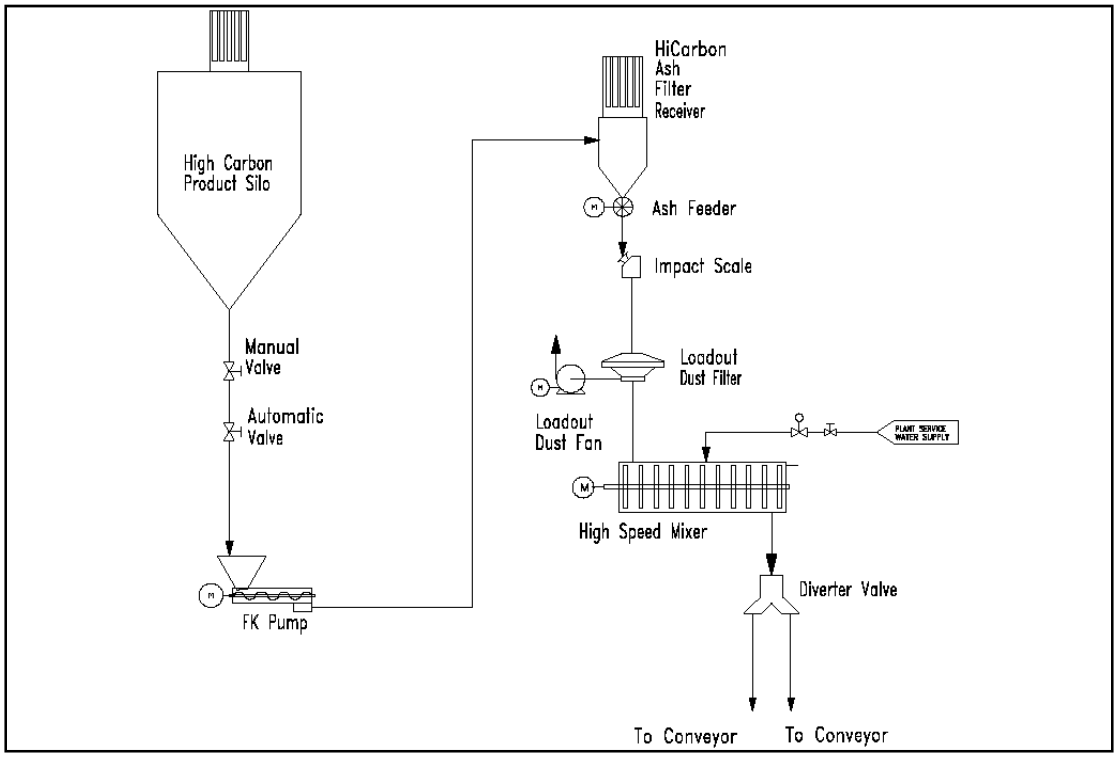
The process is entirely dry, requires no additional materials other than the fly ash and produces no waste water or air emissions. The recovered materials consist of fly ash reduced in carbon content to levels suitable for use as a pozzolanic admixture in concrete, and a high carbon fraction useful as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

Recovered Fuel Value of High-Carbon Fly Ash

In addition to the low carbon product for use in concrete, brand named ProAsh®, the ST separation process also recovers otherwise wasted unburned carbon in the form of carbon-rich fly ash, branded EcoTherm™. EcoTherm™ has significant fuel value and can easily be returned to the electric power plant using the ST EcoTherm™ Return system to reduce the coal use at the plant. When EcoTherm™ is burned in the utility boiler, the energy from combustion is converted to high pressure / high temperature steam and then to electricity at the same efficiency as coal, typically 35%. The conversion of the recovered thermal energy to electricity in Separation Technologies EcoTherm™ Return system is two to three times higher than that of the competitive technology where the energy is recovered as low-grade heat in the form of hot water which is circulated to the boiler feed water system. EcoTherm™ is also used as a source of alumina in cement kilns, displacing the more expensive bauxite which is usually transported long distances. Utilizing the high carbon EcoTherm™ ash either at a power plant or a cement kiln, maximizes the energy recovery from the delivered coal, reducing the need to mine and transport additional fuel to the facilities.

ST's Constellation Power Source Brandon Shores, SMEPA R.D. Morrow, NBP Belledune, RWEnpower Didcot, EDF Energy West Burton, and RWEnpower Aberthaw plants, all include EcoTherm™ Return systems. The essential components of the system are presented in Figure 2.

Fig. 2 EcoTherm™ Return system



ST Ammonia Removal Process

Power plants are increasing utilization of ammonia injection to mitigate NOx and SO3 emissions. NOx in the flue gas is reduced by reaction with ammonia under certain conditions through Selective Catalytic (SCR) or Selective Non-Catalytic (SNCR) systems. While ammonia is consumed in these processes, some excess ammonia is required for proper control of the NOx. Any residual ammonia deposits on fly ash in typical cold-side electrostatic precipitator ash collection systems. To reduce particulate or SO_3 aerosol emissions, ammonia is injected into the flue gas just prior to the precipitators resulting in ammonium sulfates depositing on the fly ash. 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 potentially endangering workers.

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. Liberation of ammonia from fly ash requires that the ammonium ion - molecular ammonia equilibrium be shifted in favor of ammonia by the presence of alkali. Fly ashes with naturally high alkalinity need no additional alkali. For less alkaline ashes, any strong alkali will serve. The cheapest source of alkali is lime (CaO). The reaction of ammonium salts with lime liberating ammonia is strongly favored by chemical equilibrium. The chemical reaction occurs rapidly once the compounds are dissolved.

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 oxidized to molecular nitrogen in a catalytic oxidizer.

The deammoniated ash is dried by conveying the material through a flash drier to remove excess water. Final ash temperatures of approximately 65ºC (150^{o}F) are adequate to produce a completely free-flowing dry product.

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. This modular approach offers the lowest cost solution for treating otherwise unusable fly ash.

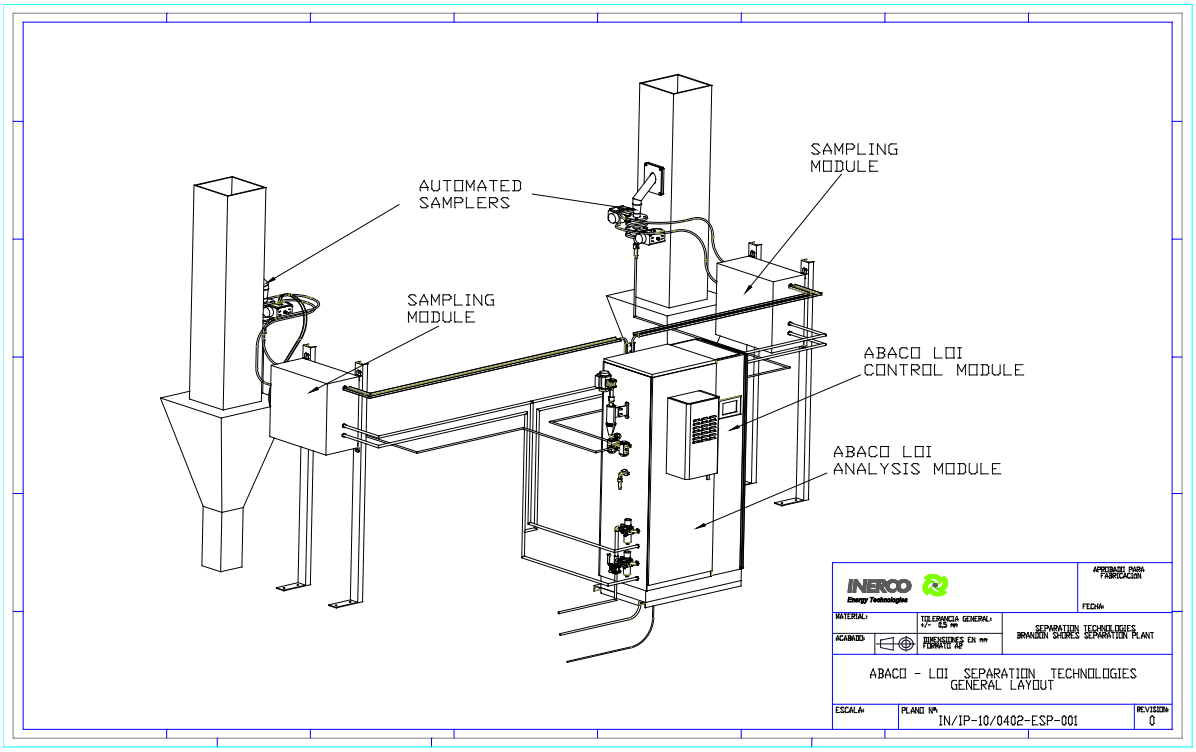
This commercial scale operation can handle up to 47 tonnes per hour of contaminated ash, reducing the ammonia content to less than 75 mg/kg. Full-scale ST ammonia removal systems are now operating at Jacksonville Electric Authority SJRPP, TEC Big Bend, and RWE npower Aberthaw ash processing facilities.

Automation Controls – the ABACO LOI Analyzer

At its Brandon Shores fly ash processing plant outside Baltimore, MD, ST has installed an ABACO LOI analyzer manufactured by INERCO Ingenieria, Technologia y Consultoria, S.A. of Seville, Spain. The ABACO LOI instrument provides real time LOI data for the product streams discharged from both ST electrostatic separators at this plant. ABACO LOI performs a rapid, true loss-on-ignition gravimetric analysis, and does not show the random offsets characteristic of other techniques such as microwave absorption.

A sketch of the ABACO LOI installation is shown in Figure 3. Automated samplers are installed in the product discharge chutes from each separator. At the beginning of each sampling cycle, one sampler and its sample lines are cleared using compressed air. The sampler then collects a constant volume of solids from the flowing product stream, which is transported pneumatically to the analyzer module. Inside the analyzer module, a specified mass of sample is delivered to a crucible and heated to a temperature of 750º C within an electric furnace. Calcination proceeds to a constant sample mass, and the LOI result is reported electronically. Duration of a measurement cycle is about 7 minutes, after which the cycle repeats for the other sampler. Statistical studies have shown excellent agreement between ABACO LOI data and the manual ST sample and test results normally used for quality control.

Figure 3. ABACO LOI analyzer installation.



The rapid frequency of data reporting from the on-line analyzer greatly reduces the manual testing load of the separator operator. This frequency is also sufficiently rapid to permit feedback control of the separator operation. ST developed a control algorithm to adjust separator operating conditions in response to variations in product LOI, maintaining product quality within strict limits. Known as the Limited Interaction Mode of separator control, the algorithm standardizes responses to product quality excursions while operating the separator more economically. The chart in Figure 4 shows a day's operation of the B Separator at Brandon Shores.

Figure 4: Separator Operation with ABACO analyzer

At the beginning of the chart, the separator starts at a conservative operating condition, as shown by the gray trace, “Control Action”. ABACO LOI provides LOI values for the product stream about every 7 minutes, as shown by the red triangles. About every two hours, normal production samples are taken and tested (black circles) to illustrate the level of agreement between on-line and manual quality control checks. Product quality improves rapidly after startup, allowing the control algorithm to move the separator to a more aggressive operating condition. Stepwise adjustments are made over the first two hours of the run, causing the product LOI to increase from its low of about 1%, approaching the 2% level. During this time, the yield, or percentage of the feed stream converted to product, improves as the operation becomes more aggressive. Late in the day, the product LOI begins to increase, in this case due to increasing LOI of the feed ash. The algorithm applies control changes to center the product stream about the 2% LOI level. A corresponding dip appears in the yield trace, as the separator operation becomes more conservative.

The ABACO LOI analyzer became operational at Brandon Shores in 2011, with the Limited Interaction Mode of control proven on both separators during the year. The positive effect of this development is shown in Table 1:

Table 1. Brandon Shores Station LOI control annual data

	Shipments			
Control Mode	Manual		Limited Interaction	
% Average LOI	1.23		1.54	
% Std. Dev. LOI	0.30		0.26	
	Production			
Separator	A	B	A	B
% Average Mass Yield	89	79	93	87

Compared to 2010 under operator control, Limited interaction control has permitted more aggressive operations, for an increased average product LOI. At the same time, Brandon Shores enforces a maximum product LOI specification of 2.5%, so an increase in the average LOI is possible because the variability is reduced. Limited interaction control has decreased the standard deviation of product LOI by over 10%. Looking at production data for the individual separators, product yield has improved by almost 5% for Separator A by means of Limited Interaction control. Separator B shows a much larger yield benefit, but this is confounded by the improvement in feed ash quality achieved by the power plant within the same time period.

In summary, installation of the ABACO LOI on-line analyzer provides real time product LOI data for both ST electrostatic separators at ST's Brandon Shores fly ash processing plant. This real time LOI data reduces the manual testing load of the operator and also permits automated feedback control of the separator operations. The effect of the on-line analyzer with Limited Interaction separator control has been reduced variability in product quality and increased product yield. ST is actively promoting this technology for implementation in future fly ash processing projects.

ST Ash Processing Facilities

Controlled low LOI fly ash is produced with ST's technology at twelve power stations throughout the U.S., Canada, the U.K and Poland. . ProAsh® fly ash has been approved for use by over twenty state highway authorities, as well as many other specification agencies. ProAsh® has also been certified under Canadian Standards Association and EN 450:2005 quality standards in Europe. ST ash processing facilities are listed in Table 2.

Table 2. ST Commercial Operations

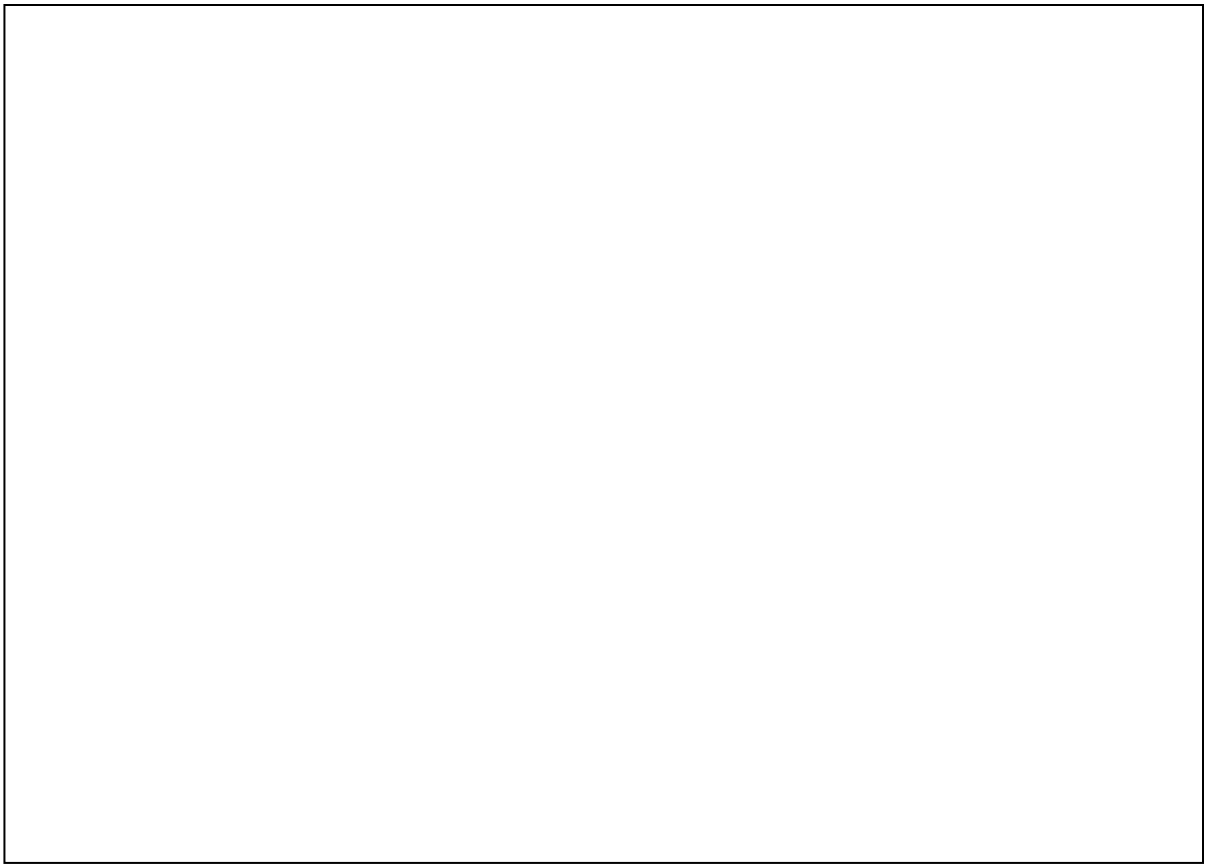
Utility / Power Station	Location	Start of Commercial operations	Facility Details
Progress Energy – Roxboro Station	North Carolina USA	Sept. 1997	2 Separators
Constellation Power Source Generation - Brandon Shores Station,	Maryland USA	April 1999	2 Separators 35,000 ton storage dome. Ecotherm™ Return 2008
ScotAsh (Lafarge / Scottish Power Joint Venture) - Longannet Station	Scotland UK	Oct. 2002	1 Separator
Jacksonville Electric Authority - St. John's River Power Park, FL	Florida USA	May 2003	2 Separators Coal/Petcoke blends Ammonia Removal
South Mississippi Electric Power Authority R.D. Morrow Station	Mississippi USA	Jan. 2005	1 Separator Ecotherm™ Return
New Brunswick Power Company Belledune Station	New Brunswick, Canada	April 2005	1 Separator Coal/Petcoke Blends Ecotherm™ Return
RWE npower Didcot Station	England UK	August 2005	1 Separator Ecotherm™ Return
PPL Brunner Island Station	Pennsylvania USA	December 2006	2 Separators 40,000 Ton storage dome
Tampa Electric Co. Big Bend Station	Florida USA	April 2008	3 Separators, double pass 25,000 Ton storage dome Ammonia Removal
RWE npower Aberthaw Station (Lafarge Cement UK)	Wales UK	September 2008	1 Separator Ammonia Removal Ecotherm™ Return
EDF Energy West Burton Station (Lafarge Cement UK, Cemex)	England UK	October 2008	1 Separator Ecotherm™ Return
ZGP (Lafarge Cement Poland / Ciech Janikosoda JV)	Poland	March 2010	1 Separator
Korea South-East Power Yeongheung Units 5&6	South Korea	To be commissioned 2013	1 Separator Ecotherm™ Return

Most Recently Scheduled Installation – KOSEP

The first ST carbon from fly ash separator installation in Asia will be commissioned in the fall of 2013 at Korea South-East Power's Yeongheung Thermal Plant on Yeongheung Island, Incheon, South Korea. The ash processing facility, developed jointly with ST, will be owned and operated by KOSEP and dedicated to beneficiation of ash from the newest Units 5 and 6. Units 5 and 6 are each designed for 870 MW generation, and together will produce up to 1000 Tpd of fly ash.

The project includes an ST Separator, storage silos for raw feed ash, classified feed Ash, and the separator products, ProAsh® and EcoTherm®. An EcoTherm® return system will also be installed to recover the fuel value of the carbon removed from Feed Ash. The separator will be equipped with an on-line ABACO LOI analyzer and automated control of ProAsh® quality. The process flow diagram for ash processing at KOSEP Yenogheung Plant is shown in Figure 5.

Figure 5: KOSEP process flow diagram.



Summary

The ST 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. Eighteen ST carbon separators are in place with over 130 machine-years of operation.

ProAsh® fly 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. Returning the high-carbon concentrate from the ST process to the boiler at a power plant allows recovery of the recovered carbon fuel value at an efficiency similar to coal. ST has also installed three ammonia removal systems at power plants. With the additional availability of the ammonia process, ST offers

commercially economical means to recover material for high value use that would otherwise be landfilled. Electrostatic carbon separation, Ecotherm™ return to the boiler, 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.

ST continues to improve the efficiency and economics of the fly ash beneficiation processes through technical improvements. Utilization of the ABACO on-line LOI analyzer has resulted in improvements in product LOI control, overall recovery of ProAsh® and reduced operator attention.

ST's technology has been selected for the Korean Southeast Power (KOSEP) Yeongheungdo Units 5 & 6 project as an integral part of the fly ash recovery systems. These two new 870 MW units are scheduled for commercial operation in 2014.