UDC 691

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EXPERIENCE AND POSSIBILITIES OF ST COMPLEX TECHNOLOGIES ON FLY ASH BENEFICIATION IN VIEW OF THE IMPLEMENTED PROJECT AT JANIKOSODA POWER PLANT IN POLAND

ABSTRACT

ST Equipment & Technology LLC (STET) has been operating commercial fly ash beneficiation systems since 1995. STET's electrostatic beneficiation technology reduces the carbon content of coal fly ash, producing a consistent, low carbon ash for use as a substitute for cement. Fly ash with carbon levels > 25% have been used to produce ash with a controlled carbon level of $2 \pm 0.5\%$. A carbon rich product is simultaneously produced to recover the fuel value of the carbon.

STET's newest project in Poland which includes a wet-to-dry ash collection conversion and an STET carbon separator was successfully commissioned in May 2010.

1. QUALITY LIMITING AVAILABLE CONCRETE GRADE FLY ASH

Of the approximately 70 million tons of fly ash generated each year at US coal-fired power plants, only about 14 million tons is used as a cement substitute in concrete production. Much of this rejected fly ash fails to meet chemical and physical specifications for use in concrete. A similar situation occurs in Europe. While some of this off-quality ash is utilized as structural fill material or for other low-value uses, much of it is simply disposed of in landfills or waste ponds.

An excessive amount of unburned carbon in fly ash is the most common problem. The American Association of State Highway and Transportation Officials (AASHTO) and European Standards (EN 450 Category A) require that the amount of unburned carbon in fly ash, measured by loss on ignition (LOI) not exceed 5% by weight. However, starting in the mid-1990's, installation of mandated NOx control equipment at coal-fired power plants increased the carbon (LOI) content of much of the previously marketable fly ash. Further requirements to reduce NOx and other power plant emissions have resulted in the contamination of fly ash with ammonia. As a consequence, while understanding of the benefits of using fly ash in concrete continues to increase, the availability of suitable quality fly ash is decreasing. Processes to economically beneficiate off-quality fly ash are thus also of increasing interest to the power and concrete industries. Separation Technologies has pioneered such processes for both carbon and ammonia removal from fly ash.

2. ST EQUIPMENT & TECHNOLOGY LLC TECHNOLOGY OVERVIEW

2.1. Fly Ash Carbon Separation

In the STET 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 40 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 STET separator. By controlling various process parameters, such as belt speed, feed point, and feed rate, the STET process produces low LOI fly ash at carbon contents of less than 3.5% from feed fly ashes ranging in LOI from 5% to over 25%.

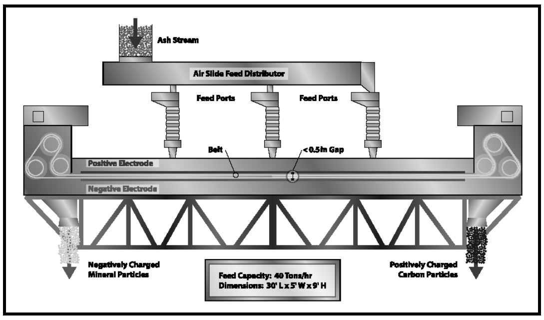


Fig. 1. ST Separator

The separator design is relatively simple and compact. A machine designed to process 40 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 plastic material. The belt is made of plastic. The separator's power consumption is below 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.

2.2. Recovered fuel value of high-carbon fly ash

In addition to the low carbon product, brand named ProAsh®, for use in concrete, the STET 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 STET EcoTherm™ Return system to reduce the coal used 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 STETs' 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.

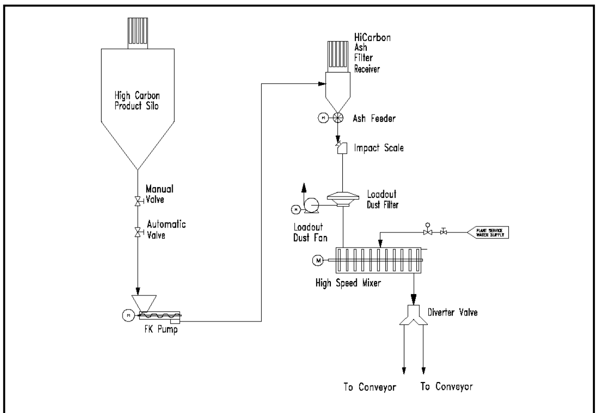


Fig. 2. EcoTherm™ Return system

STET's Constellation Power Source Generation Brandon Shores, SMEPA R.D. Morrow, NBP Belledune, RWEnpower Didcot, EDF Energy West Burton, and RWEnpower Aberthaw plants, all include EcoTherm™ Return systems (Figure 2). The newest installation of an STET carbon separator in Poland will also include an EcoTherm™ Return system. The essential components of the system are presented in Figure 2. EcoTherm™ is conveyed dry to a filter receiver over the coal belts. To prevent dusting about 7-10 wt% water is added to the EcoTherm™ in a high speed pin mixer before dropping onto the coal on the belt as the coal is conveyed to mills.

2.3. 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.

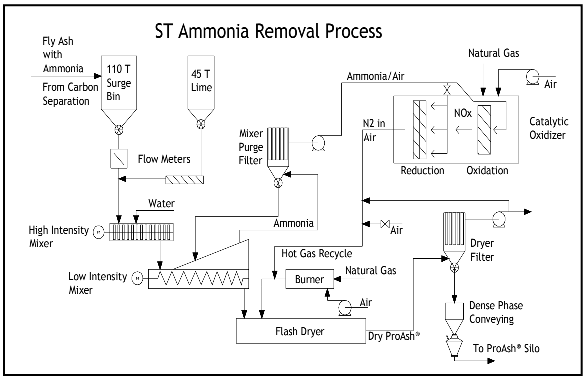


Fig. 3: STET Ammonia Removal System

A schematic diagram of the ST ammonia removal process is shown 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.

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. STET'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 STET ammonia removal systems are now operating at Jacksonville Electric Authority SJRPP, TEC Big Bend, and RWE npower Aberthaw ash processing facilities.

3. STET ASH PROCESSING FACILITIES

Controlled low LOI fly ash is produced with STET's technology at eleven power stations throughout the U.S., Canada, the U.K., Poland and Korea. The processed fly ash is marketed under the ProAsh® brand throughout these market areas. 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. STET ash processing facilities are listed in Table 1.

In 2008, STET commissioned its largest US fly ash beneficiation facility at the Tampa Electric Company Big Bend Station in Florida. Two STET separators are installed to produce low LOI ProAsh®. A first-of-its-kind third separator is used to further concentrate the carbon to maximize the fuel value of the EcoTherm™ and to maximize the amount of ProAsh® recovered. The Big Bend facility, which produces 260,000 tons per year of ProAsh®, includes a 25,000 ton dome for feed ash, a 10,000 ton silo for ProAsh® and a 6,500 ton silo for EcoTherm™.

3.1. ZGP Project, Poland

In April 2010 the first STET Separator installation in continental Europe was commissioned on the boundary of the combined steam and power plant of Soda Polska Ciech Sp z o.o. - Janikosoda and Inowrocław plants in Poland. This ash processing facility, developed jointly with STET, is owned and operated by ZGP Sp. z o.o., a joint venture company of Lafarge Polska SA and Soda Polska CIECH Sp. z o.o. The power plants produce about 180,000 tonnes per year fly ash which was transported wet to lagoons 2 km away.

The facility was built at the boundary of the power plant. The project included the conversion of the wet ash collection and transport systems for five boilers to a dry ash dense phase collection systems, an STET Separator, storage silos for the feed ash, the ProAsh® and the EcoTherm™ products, and an EcoTherm™ Return System to return the EcoTherm™ to the boilers to recover the fuel value, as well as auxiliary buildings, compressors and new roads. Because feed ash is also be processed from the nearby Inowrocław- Matwy power plant owned by Soda Polska Ciech Sp. z o.o., provisions have been made for unloading feed ash hauled to the facility in pneumatic tanker trucks. The process flow diagram for the ash beneficiation facility is shown in Figure 4 and the general facility layout in Figure 5. The low LOI ProAsh® is produced to EN450:2005 standards and is used at the nearby cement plant owned by Lafarge to produce fly ash cement. A 30,000 tonnes dry ash silo was built within the premises of the cement plant, to store ash during the winter season.

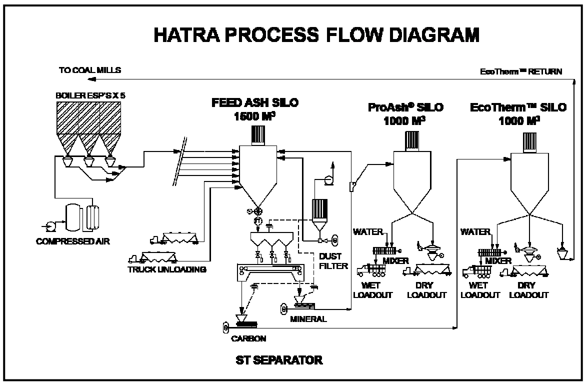


Fig. 4. ZGP Process Diagram

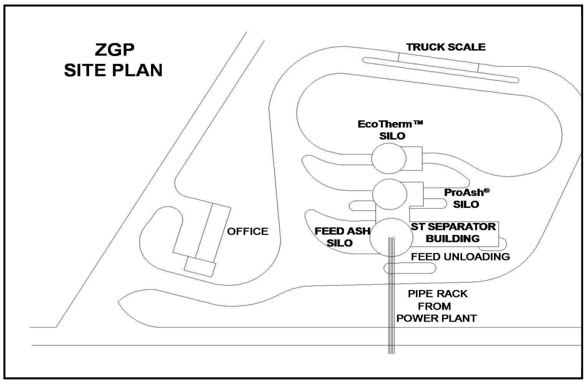


Fig. 5. ZGP Site Plan

TRUCK SCALE	Feed unloading
EcoTherm silo	Pipe rack from power plant
ProAsh® silo	Feed ash silo
ST separator building	

Fig. 6. ZGP ST fly ash beneficiation plant

3.2 Design Basis

Ash volume to be processed annually: 180,000 T
LOI 8%
Operation time 8000 hours/year
ProAsh® LOI 4%
EcoTherm™ LOI 30% min.
EcoTherm™ combusted by the power plant 24,000 tonnes/year, the remaining volume to be used by the cement plant
Staff 15 employees
Scope of the project:

1. Disassembly of the wet transport system
2. Delivery and assembly of the new dense phase conveying system
3. Delivery and assembly of compressors
4. Construction of the ash separation facility
   Silos: Feed Ash silo 1,200T
   ProAsh® 1,000T
   EcoTherm ™1,000T
5. Construction of roads and site infrastructure

Facility start-up in May 2010

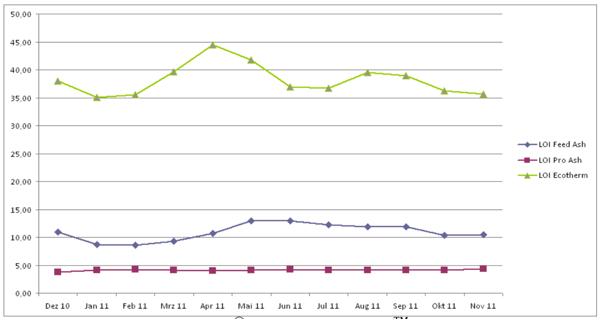
The project was implemented within the planned budget and on schedule.

3.3 Performance of the facility in 2011

Based on the positive operational experience acquired during the start-up operations, and on 2010 performance, the facility management decided to process additional ash from other power plants, with a higher carbon content in fly ash than acceptable according to the EN 450 standard.

The LOI in the delivered ash was from 8 to 20%. In the light of the above, the ash volume processed by the ZGP facility increased in 2011 to 220,000 tonnes.

<u>Brief summary of 2011 data:</u>
Processed ash volume: 220,000 tonnes
Including ash from other power plants 30,000 tonnes
Average fly ash LOI ca. 10%
Facility operation time 8200 hours
Average product LOI:
LOI ProAsh® 4%
LOI EcoTherm™ ca. 40%



LOI for fly ash, ProAsh® and EcoTherm™ in 2011

4. SUMMARY

The completed fly ash processing facility, based on the technology delivered by Separation Technologies LLC completely eliminated the need to store fly ash at Mątwy and Janikowo power plants.

The waste fly ash that had caused environmental damage for years and had been stored outside the premises at a very high cost became a marketable product called ProAsh® and is now wholly utilized by the cement industry, conforming to the EN-450 standard.

EcoTherm™ is now used as fuel by the power plant and cement plant, reducing the amount of coal burnt by those plants and thus increasing the efficiency of boilers.

The project met both its financial and environmental objectives. The facility demonstrated a high ash processing capability, in terms of quality, quantity and processing technology, and proved reliable.

Maximizing the utilization of fly ash as a cement substitute in concrete production substantially reduces the carbon dioxide emissions associated with construction activity. In order to avoid loss of this valuable resource of material for concrete production as well as reduction of green house gas emissions associated with concrete construction, processes for restoring the quality of the fly ash in an economic and environmentally viable way are needed.

The beneficiation of fly ash with Separation Technologies' processes further increases the supply of this important material. 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. 19 STET carbon separators are in place with over 100 machine-years of operation.

ProAsh® 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 STET process to the boiler at a power plant allows recovery of the recovered carbon fuel value at efficiency similar to coal.

STET offers a complex of economically efficient technologies for receiving ash of the improved quality that would otherwise be landfilled. Technologies of electrostatic carbon separation, Ecotherm™ return to the boiler, and ammonia removal provide a modular solution of problems relating to fly ash utilization and environmental protection in power sector. These three technologies can be implemented in phases, or as a single project. In Table brief data on results of implementation and commercial operation of STET coal ash beneficiation installations are presented.

Table. **STET Commercial Operations**

Utility / Power Station	**Location**	**Start of Commercial operations**	**Facility Details**
Progress Energy – Roxboro Station	North Carolina, USA	September 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	October 2002	1 Separator
Jacksonville Electric Authority - St. John's River Power Park, FL	Florida, USA	May 2003	2 Separators Coal/Pet coke blends Ammonia Removal
South Mississippi Electric Power Authority R.D. Morrow Station	Mississippi, USA	January 2005	1 Separator EcoTherm™ Return
New Brunswick Power Company Belledune Station	New Brunswick, Canada	April 2005	1 Separator Coal/ Pet coke 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)	Poland	May 2010	1 Separator
The Customer wishes to remain anonymous	Europe	2011	1 Separator
The Customer wishes to remain anonymous	Canada	2011	1 Separator
KEPCO	South Korea	2014	1 Separator EcoTherm™ Return
JV (Termika / Lafarge Cement Poland)	Poland	2016	1 Separator EcoTherm™ Return