JEA NORTHSIDE UNIT 2

ASH PROCESSING SYSTEM

The JEA Large Scale CFB

Combustion Demonstration Project

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Executive Summary

As part of a major repowering and combustion demonstration project undertaken at the Northside Generating Station, JEA found it necessary to devise a new system for handling bed ash and fly ash from Circulating Fluidized Bed (CFB) boilers. Several alternative methods were considered prior to the decision to use the arrangement selected.

This report describes the application of developed technologies to the specific challenges presented at this plant. The system that has been successfully implemented involves the use of a vacuum (negative pressure) system to handle fly ash; a mechanical drag chain and pressure system to handle bed ash; and a dense phase slurry system to transport the combined materials to a byproduct storage area.

The following discusses the rationale for the design of the system and the characteristics of the material to be conveyed and stored in an environmentally acceptable fashion. Each element of the system and its actual operation is also explained. Initial results of the first year of the use of the system are reported as well.

Background

The JEA Large Scale CFB Combustion Demonstration Project consists of installing two new 300-MWe atmospheric CFB boilers. These boilers are designed to burn fuel blends consisting of coal and petroleum coke and are the world's largest CFB boilers. Each of these boilers consumes approximately 2300 tons of fuel per day, of which up to 15% is non-combustible, or ash, and must be removed from the process. Additionally, limestone is added to the boiler along with the fuel to remove up to 90% of the SO2 generated in the combustion process. The limestone quickly captures the SO2, forming gypsum, which presents itself as a solid and is removed from the process along with the ash. In addition, recycled combustion products and lime are used in the spray dryer absorber (SDA) air quality control system (AQCS) to bring the total SO2 removal of the CFB boiler and SDA up to 98.4%. The combination of ash, gypsum, and other minor constituents is termed by-products.

This topical report describes the system and equipment in place at the JEA Northside Station to remove and store the by-products generated during the combustion process.

Project Participants and Responsibilities

JEA
- Overall project and construction management

DOE
- Provides partial funding as a clean coal demonstration project designed to demonstrate the viability of CFB technology in a utility-scale application.

United Conveyor Corporation (Waukegan, IL)
- Engineering and supply of bed ash, fly ash, and high density slurry by-product handling systems.

Foster Wheeler Energy Corporation (Clinton, NJ)
- Procurement, design and construction of CFB boilers and support equipment and installation of bed ash and fly ash systems.

Wheelabrator Air Pollution Control (Pittsburgh, PA)
- Procurement, design and construction of the AQCS system

Black & Veatch (Kansas City, MO)
- Engineering of Concrete Ash Storage Silos and BOP for high density slurry system

Zachry Construction Corporation (San Antonio, TX)
- Procurement and construction of high density slurry system

By-Products Removal and Storage System Overview

Two distinct types of ash are removed from CFB boilers -- bed ash and fly ash. Bed ash consists of larger particles that exit the bottom of the boiler. Fly Ash consists of finer particles that exit the boiler with the flue gas.

Bed Ash flows out of the bottom of the boiler into a Stripper/cooler where it is stripped of fine particles that are re-injected into the boiler. The remaining heavier particles are cooled with air to around 500° F. Bed Ash is continuously removed from the Stripper/cooler through a rotary valve and is conveyed by a series of mechanical drag chains that collect the bed ash into a small transfer hopper. Beneath this hopper is a pneumatic conveying pressure system which conveys the bed ash to one of two concrete storage silos.

Fly ash leaves the top of the boiler and travels through the Economizer and Air Heater ducting. At each ducting change in direction collection hoppers collect any fly ash that falls out of the moving gas stream. The fly ash and flue gas next enter a polishing scrubber or Spray Dryer Absorber (SDA). In the SDA lime/ash slurry is sprayed into the flue gas. The high temperature of the flue gas dries the slurry and the dried solids react with any remaining sulfur compounds in the flue gas to form gypsum, an inert solid material. After leaving the SDA, the flue gas travels into a large fabric filter where all fly ash is removed along with the newly formed gypsum. This combined material is collected in hoppers located under the fabric filter. A pneumatic vacuum conveying systems conveys the material out of all of the hoppers. The vacuum system can convey the fly ash to either the SDA building where it is recycled into the lime/ash slurry, or to one of two storage silos.

Ash storage silos, two fly ash silos on the left, two bed ash silos on the right

Beneath the Fly Ash Storage Silos are high density slurry mixing tanks. In these tanks, the fly ash is mixed with water creating slurry. This slurry is then pumped to a mixing tank located under the Bed Ash Storage Silos where bed ash is added. The resultant dense phase slurry is now at 60% solids by weight concentration. This dense phase slurry is pumped to the By-Products Storage Area (BSA) by a high pressure piston diaphragm pump. Some of the water used to slurry the ash in the mixing tanks is absorbed into the solids through a continuing hydration reaction. The small amount of free water left after pumping quickly evaporates or is used in hydration, resulting in an environmentally stable landfill placement of the wet by-products.

Ash Properties. Samples taken in June 2002, 70 % pet coke/ 30% Pittsburgh #8 coal blend

Property	**Typical Values**		**Comments**
	Bed Ash	Fly Ash	
Bulk Density *The density of the ash given as weight/total volume*	87-77 lb/cu.ft.	43-33 lb/cu.ft.	
Particle Specific Gravity *The density of individual particles in the material; usually much higher than bulk density.*	2.9.	2.5	Specific gravity is a comparative figure; distilled water has a specific gravity of 1.0.
Particle Size Distribution *The relative fraction of various sizes of particles in the ash.*	Less than 50% under 350 μm	Less than 50% under 45 μm	Fly ash from sub-bituminous coal typically has a large quantity of Calcium compounds. Particles of these compounds are small in size; hence such ash will have significant amounts of fines.
Particle Shape *The shape of the particle, generally based on microscopic evaluation.*	Majority irregular with rounded edges, moderate agglomeration	Majority irregular with jagged edges, significant agglomeration	The calcium compounds in this ash have irregular shapes and tend to lock together easily.
Fluidizability *The ease with which a given ash will accept air and become aerated, thereby behaving as a fluid or is fluidized.*	Poor	Excellent	The entrained air lowers particle-particle friction and allows ash to flow easily. While typical fly ash is generally easily fluidizable, bed ash is hard to fluidize. The larger bed ash particles tend to pass air easily rather than the finer fly ash particles which entrain the air.

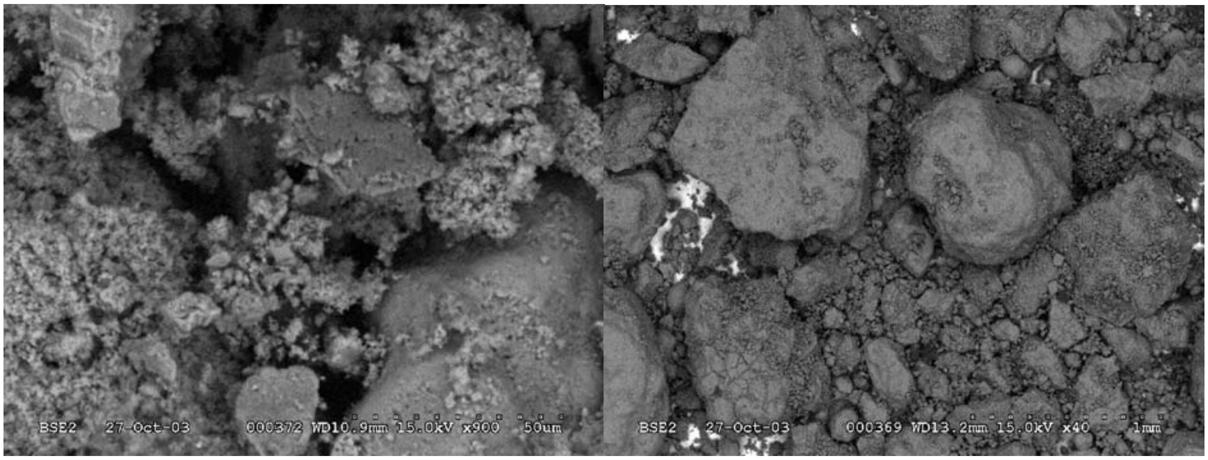
Property	**Typical Values**		**Comments**
	Bed Ash	Fly Ash	
Arching/Rat holing index *These properties are a measure of the shear stress in ash* *Arching index (AI) is defined as the minimum diameter of the outlet of a 10-ft diameter mass-flow hopper; for any opening smaller than the index, arching will occur.* *Rat holing index (RI) is defined as the minimum diameter of the outlet of the funnel-flow portion of a 10-ft diameter hopper; for any opening smaller than the index, rat holing will occur.*	0.2 ft 0.3 ft	0.3 ft 2.9 ft	Particle shape and particle size are two main parameters that affect these indices. Irregular shaped/fine sized fly ash particles tend to lock together and do not separate easily, leading to high RI values. Bed ash particles exhibit low shear stress and low AI/RI.
Pickup velocity *The velocity required to pickup ash at the feed point and convey it in a pneumatic conveying system.*	5100 fpm	3800 fpm	The heavier coarser Bed Ash particles require more acceleration energy which translates to higher velocities. Once in motion, the heavier particles tend to stay in motion. The finer Fly Ash particles require little acceleration energy but will have a tendency to fall out of suspension even in dilute phase systems, but rather in sliding bed form, the shear stress of ash becomes important here, too.

Chemical Analysis of 70% Pet Coke 30% Coal Ash

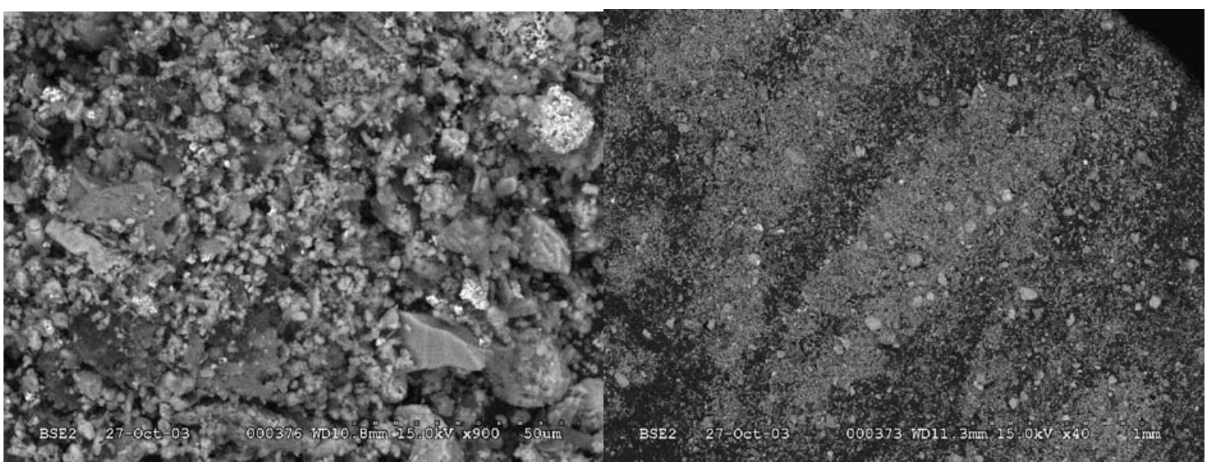
	Bed Ash	Fly Ash
SiO2	1.95	13.14
Al2O3	0.8	6.78
Fe2O3	0.49	7.02
CaO	48.76	47.16
MgO	0.73	0.64
SO3	42.74	18.83
Na2O3	0.13	0.33
K2O	0.04	0.35
TiO2	0.07	0.28
P2O5	0.04	0.10
Mn2O3	0.02	0.02
SrO	0.07	0.08
Cr2O3	0.04	0.02
ZnO	<0.01	<0.01
L.O.I	3.49	16.71
Moisture	0.04	0.60

The high values of CaO and SO3 are indicative of large amounts of Calcium Sulfate or Gypsum

The ash consists primarily of sorbent and reacted sorbent materials from the limestone injected into the boiler and the lime/fly ash slurry injected into the SDA.



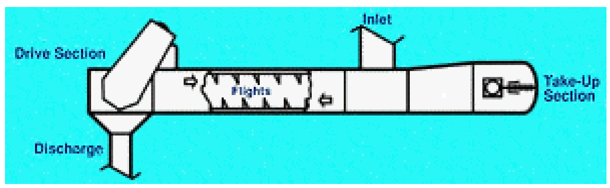
Scanning Electron Microscope photo of Bed Ash, 900x magnification on the left, 40x magnification on the right. The agglomerated particles visible in the left hand photo are typical of gypsum (calcium sulfate)



Scanning Electron Microscope photo of Fly Ash, 900x magnification on the left, 40x magnification on the right. The smaller size distribution of the fly ash particles is clearly evident in when comparing the 40x bed ash and fly ash photos.

Bed Ash System Description

Each unit has four Stripper/cooler drains. Two drains are located near the center of the boiler and two are at opposite ends of the boiler. Since this is the largest CFB boiler in the world (the boiler footprint is approximately 115 feet by 125 feet), the distance between bed drains is quite substantial -- from end drain to end drain is more than 120 ft. Additionally, the removal rate at each drain varies, and since these drains are underneath the boiler, the head room or storage volume available at the drain point is limited. The solution to this material handling problem was to use mechanical drag chain conveyors to remove bed ash from the drains continuously, and deposit the bed ash in a small transfer hopper located to the side of the boiler where head room is not a limitation.



Typical arrangement of drag chain conveyors.
Bed Ash is conveyed via chains and flights along the bottom of the unit.
The chain and flights return along the top.

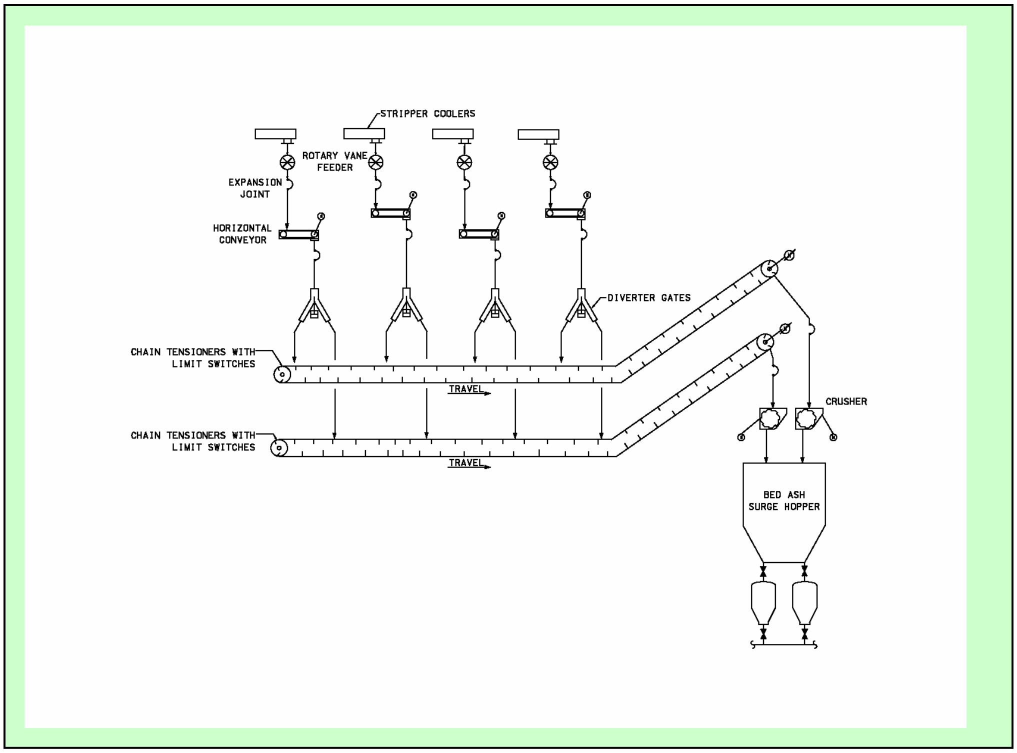
The drag chain conveyor is a chain and flight conveyor system that conveys dry ash by continuously transporting it through the entire length of the conveyor trough. The chain transmits the pull of the drive unit and the flights fitted to the chain move the material.

Stripper/Cooler outlet feeding drag chain

Each bed drain has a rotary vane feeder providing an airlock between the Stripper/cooler and a short drag chain located under the drain. This drag chain collects the ash and deposits it into a larger gathering drag chain conveyor. The gathering conveyors discharge into a crusher located on top of the transfer hopper. The crusher will reduce the size of any large particle to 1” or less. The transfer hopper has a storage capacity of two hours with worst case fuel.

Bifurcated outlet of Stripper/Cooler drag chain feeding Gathering drag chain conveyors

The drag chain system is fully redundant. If necessary, only two of the four bed drains can handle the bed ash discharging requirements. Each collection drag chain is capable of feeding either of the gathering drag chains through the use of diverter valves located at the inlet of the feeding drag chains.



Schematic of mechanical portion of the bed ash system for one unit

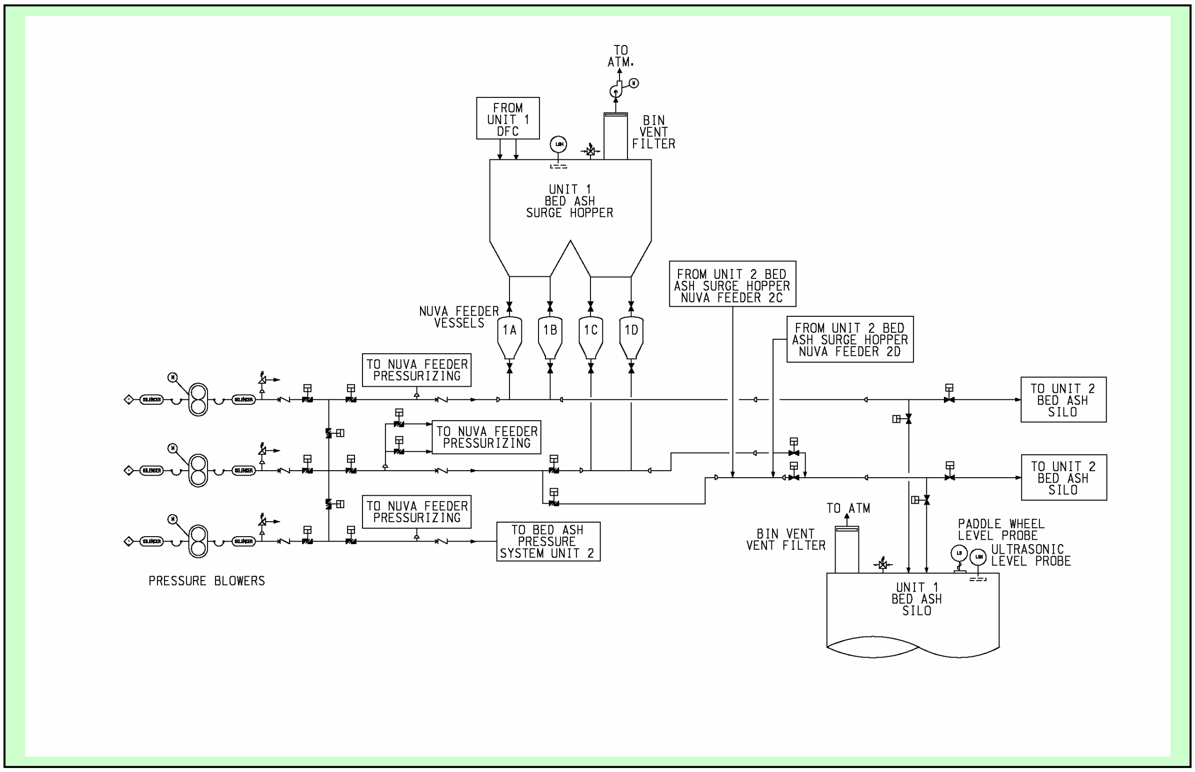
Bed Ash Collection and Conveying Capacity Data for Mechanical Conveyors

Drag Chain	No. of Collecting Points	Temp (°F)	Maximum Conveying Rate (tph)	Conveyor Length (Feet)
Stripper/Cooler	1	550	35	18
Stripper/Cooler	1	550	18	26
Stripper/Cooler	1	550	18	26
Stripper/Cooler	1	550	35	24
Gathering	4	<550	43	190
Gathering	4	<550	43	190

Data shown for one Unit

The advantages of mechanical conveyors are continuous removal of ash, low headroom requirements, and low horsepower usage. The disadvantage is high cost per foot of conveyor. Since the bed ash ultimately needs to be conveyed another 600 feet horizontally and 100 feet vertically, using drag chain conveyors all the way to the bed ash silo was not an economical option. The solution was to use a pneumatic pressure system the rest of the way.

Two separate pneumatic pressure systems are located under each transfer hopper, each capable of conveying at 43 tons per hour (TPH). During worst case fuel burn, both systems can run simultaneously for a combined capacity of 86 TPH. Present fuel burn requirements have demonstrated only one conveyor needs to run to keep up with bed ash production.



Schematic of Bed Ash pressure system for one Unit

Each pressure system uses two airlock feeders. One feeder fills with material while the other feeds pressurized material to the conveying pipeline. The bed ash is conveyed to one of two concrete silos. On top of each silo is a fabric filter, which captures any particulate in the conveying air and vents the conveying air to atmosphere.

NUVAFEEDER Airlock vessels under Bed Ash transfer hopper

Bed Ash Conveying Data for Pneumatic Pressure Systems:

Number of Systems	Conveying Rate (TPH)	Design Point (Origin)	Disposal Point (Final)	Line Size (Inches)	Pipe Length (Feet)	Risers (Feet)	Number Of Elbows (90°)	Blower (BHP)
2	43	Bed Ash Transfer Hopper	Bed Ash Silo	8”,10”, 12”:	600	100	6	500

Fly Ash System Description

Each unit has a series of hoppers at ducting changes in direction and under the baghouse. The large number of hoppers spread throughout the plant make a negative pressure (vacuum) pneumatic system the most economical material handling solution. Two 35 ton per hour vacuum systems are supplied for each unit.

Fly Ash Conveying Data for Pneumatic Vacuum Systems:

Description	Conveying Rate (TPH)	Design Point (Origin)	Disposal Point (Final)	Line Size (Inches)	Pipe Length (Feet)	Risers (Feet)	Number Of Elbows (90°)	Exhauster (BHP)
Each line (2 per unit)	35	Recycle	Fly Ash Silo	9,10	515	133	8	83

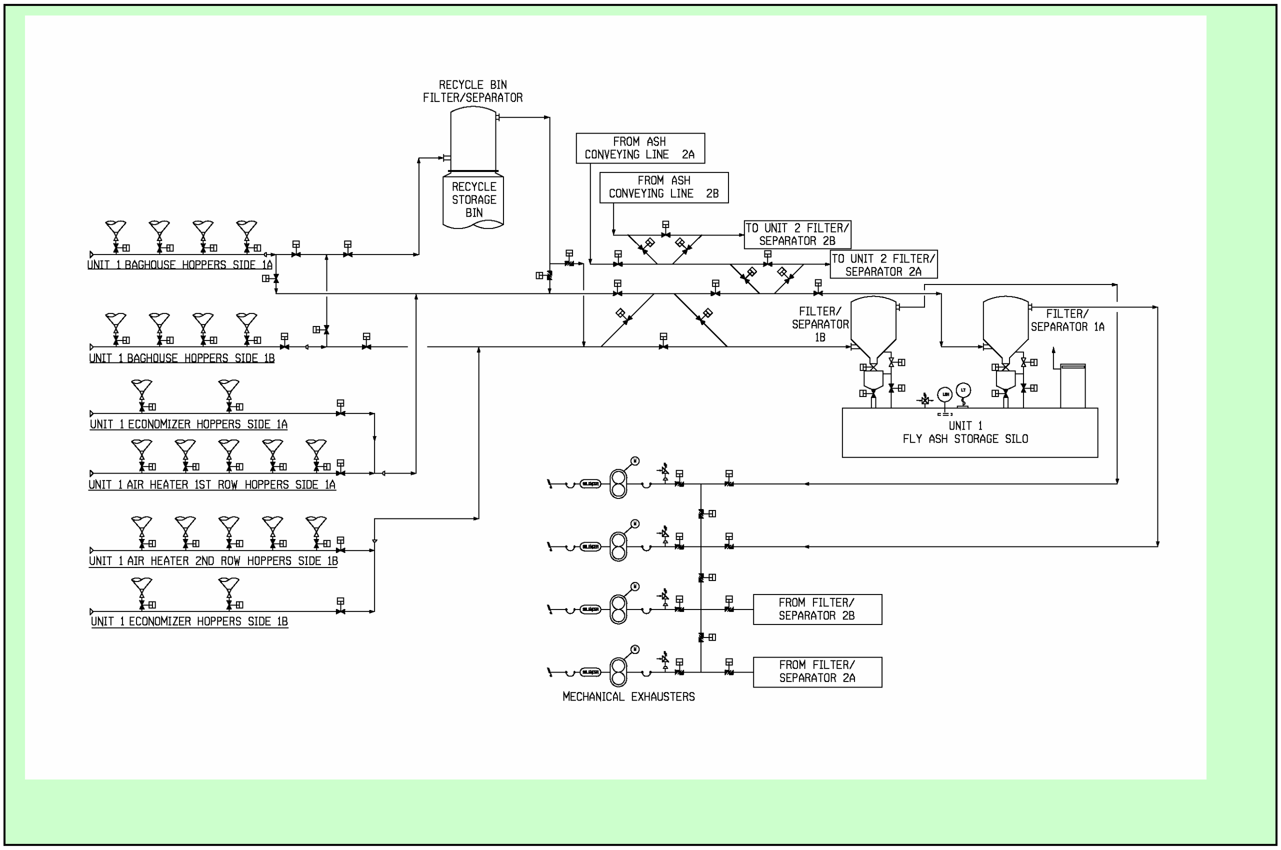
Below each hopper, an ash intake controls the flow of fly ash into a branch conveying line. The intakes are opened sequentially to permit one hopper at a time to be emptied. An air intake at the end of each branch line admits air into the line to provide a moving air stream into which the material will drop.

Fly Ash intake below baghouse hopper feeding vacuum system

Carbon steel Schedule 40 pipe was furnished for all the conveyor piping. The fittings and wear sections on the pneumatic lines are cast of DURITE® iron with a minimum 400 Brinell hardness number (BHN).

There are six branch lines per unit serving the economizer, air heater, and baghouse hoppers.

The branch lines converge to a single conveying line that carries the ash to one of two filter/separator units on top of the fly ash storage silo, or to the recycle storage bin. At the silo, a rotary positive displacement mechanical exhauster produces the vacuum required for conveying. The filter separator removes ash from the conveying air and deposits the ash into the silo.



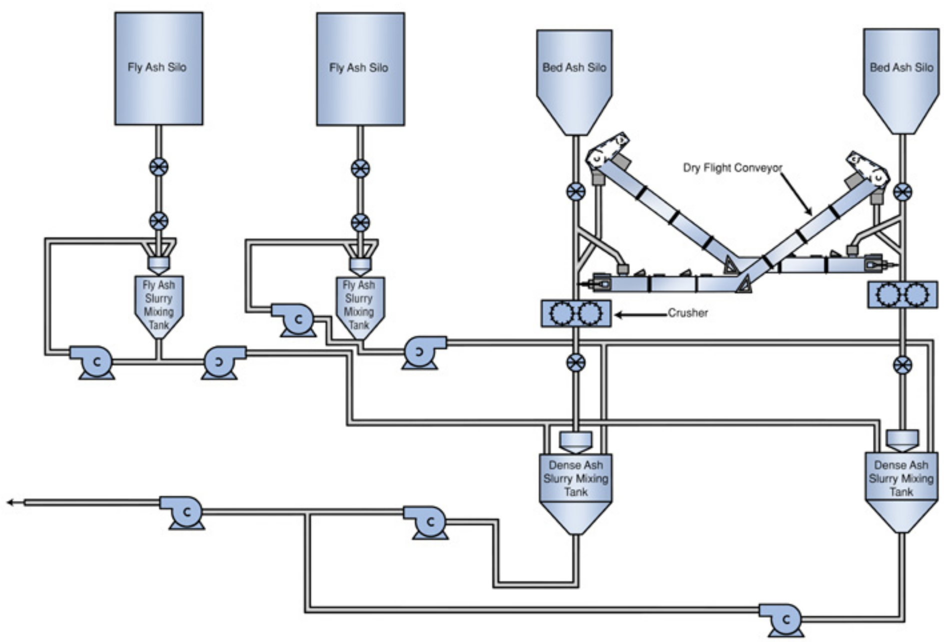
The recycle ash storage bin has a filter/separator on top of the bin to remove the ash and deposit it in the bin. The entire bin is under vacuum and a large percentage of the ash drops out of the air stream due to the low velocity of the air in the bin due to its large diameter. The system has full redundancy with respect to filter/separators, conveying lines, and mechanical exhausters.

Recycle Storage Silo (tan) with integral Filter/Separator on top (gray)

High Density Slurry System Description

The High Density Slurry System (HDSS) system consists of feeding, mixing, and pumping components. One pair of fly ash and bed ash mix tanks is designed to handle 125 TPH. Each pump train and 4" diameter discharge line is designed to handle 62.5 TPH. If worst case petroleum coke fuel is burned, the CFBC by-products make rate will be 125 TPH -- there will be redundancy on the mix tanks but both pumps and both discharge lines will be in service. This was an economical compromise, since the likelihood of burning worst case fuel in the near term is limited. Provisions to add a third pump at a later date were incorporated into the system.

Total water usage to convey 62.5 TPH of solids is 160 gallons per minute. Tertiary treated municipal effluent, or "reclaimed water" is the water source. There are no water returns lines with this technology. All conveying water is either absorbed or evaporated at the BSA.



Schematic of HDSS

The main mixing tanks are located under the bed ash silos. Fly ash slurry is conveyed into these tanks from the fly ash mix tanks which are located under the fly ash silos. Bed ash is then added to the fly ash slurry. Once the combined slurry density reaches target levels, a centrifugal slurry pump conveys the mixture to the high pressure piston diaphragm pump, which conveys the slurry out to the BSA.

High Pressure Piston Diaphragm Pump used to convey 60% solid slurry one mile to BSA

Left Photo - Fly Ash mix tank top showing inlet rotary vane feeder and premixer. Right Photo – Bed Ash mix tank showing mixing pumps.

Discharge line and BSA

One six acre cell of the BSA is being developed first. The 4" diameter schedule 80 carbon steel discharge line runs along the plant boundary line to the back side of the active cell. From grade to the top of the storage pile, High Density Polyethylene pipe is used. This pipe simply lies on the ground and discharges over a dike created by a bulldozer.

Poly pipe routed over dike on recently placed high density slurry.

The current strategy for the active cell is to work upwards first, achieving the permitted height of 100 feet. Plant personnel divided the top of the ash pile into three mini-basins. One has slurry going into it, one has just been filled up and is drying, and one is being worked with dozers to raise the pile edges. No transport water is recirculated back to the plant. All the water used to convey the solids is absorbed by the material through a hydration reaction, or is evaporated. Leachate and runoff from rainfall are collected and treated in the plant waste water treatment system.


BSA as seen from top of bed ash silo

The BSA was designed as a dry landfill. Local permitting required a liner system and rainwater drainage scheme, along with appropriate monitoring stations for leachate.


Rainwater collection canal at BSA