FLY ASH
CARBON BURN-OUT
FOR COMPETITIVE ADVANTAGE

By:
James G. Keppeler
Progress Materials, Inc.

ABSTRACT

Ash remaining from the combustion of coal presents a significant challenge to today's power plant manager, who must be able to compete in an increasingly deregulated market, as well as be environmentally proactive. Carbon Burn-Out (CBO) technology makes this often unmarketable byproduct highly attractive while recovering heat to make the power plant more efficient.

BACKGROUND

The ability to use, rather than dispose of, ash left over from the combustion of coal has long been a considerable challenge to the electric power industry. This has been exacerbated in recent years by the addition of Low NOx burners to comply with ever tightening air emissions regulations. Resultant high carbon levels in fly ash severely restrict the ability to market it and usually mean that it must be disposed at some expense. Moreover, tail end pollution control equipment used to further restrict NOx emissions generally employs ammonia, which may contaminate the ash and render it unmarketable.

CBO combusts residual carbon in fly ash, producing a very consistent, low carbon, high-quality pozzolan, which is considered as a premium for replacement for Portland Cement in concrete. The process is continuous and is fueled solely by the residual carbon. In addition, heat is recovered and sent back to the power plant that originally produced the high-carbon fly ash, thereby providing a second significant benefit. In addition, the process drives off any ammonia the ash particles may have been contaminated with from pollution control techniques such as Selective Catalytic Reduction (SCR), Selective Non Catalytic Reduction (SNCR) or ammonia injection to enhance electrostatic precipitator performance.

Progress Materials, Inc. developed this technology with support from EPRI and its members. A one-tph CBO pilot plant was constructed in 1992 and continues to operate on a wide variety of ash sources. Data gathered at this plant during test programs provides design parameters for full-scale CBO plants. Extensive concrete testing has been and continues to be undertaken in

order to demonstrate the superior characteristics of very low-carbon Class F fly ash from Carbon Burn-Out.

Commercial operation of the first full-scale Carbon Burn-Out facility began in early 1999 at the Wateree Station of South Carolina Electric and Gas Corporation, which was designed to process 180,000 tpy of ash with an average 12.47% LOI ("Loss on Ignition"; essentially carbon content).

This paper presents a case study of how South Carolina Electric and Gas is using Carbon Burn-Out technology as one way to enhance their competitive advantage. Details are provided on the design, construction and operation of the Wateree Carbon Burn-Out plant, which has produced and shipped over 130,000 tons of premium fly ash as of the end of 1999, as well as recovered heat the equivalent of over 11,000 tons of coal.

HISTORY

South Carolina Electric & Gas (SCE&G) and Southeastern Fly Ash Co. (SEFA) have for many years operated an aggressive coal combustion products (CCP) utilization program in a successful effort to reduce operating costs and costs to customers. As part of this CCP program, a significant marketing effort was devoted to promote widespread use of SCE&G fly ash in concrete. By the early 90's, this marketing effort, coupled with a reasonable supply of ash, led to a market that would willingly accept essentially all concrete-quality fly ash that the several SCE&G coal-fired stations produced. However, the sources' ash carbon content was often marginal at best and non-saleable to the concrete market at worst. In addition, SCE&G and SEFA recognized that changes in combustion conditions designed to meet Low NO_x regulations would lead to a further diminishment in fly ash quality. As quality was already marginal at several stations, further diminishment would essentially shut this fly ash out of the local concrete market, which was strong and growing. SCE&G determined to avoid that outcome, and undertook an extensive review of ash beneficiation technologies. Carbon Burn-Out was subsequently selected for installation at the Wateree Station, a two-unit, 772 MW plant southeast of Columbia, SC.

PILOT TESTING

Full-scale design parameters were established through combustion of fifty tons of high-carbon ash from Wateree Station at the PMI one tph pilot plant.

The processed ash LOI was less than 2%. This material was subjected to extensive laboratory tests and ready-mix field trials. Results demonstrated that concrete mixes made with CBO fly ash replacing varying percentages of Portland cement had nearly identical plastic and hardened characteristics to control mixes containing only cement. In short, the CBO fly ash provided significant benefits to the concrete mixes without undesirable 'side effects'. Determining the air entraining characteristics of the CBO fly ashes was given special emphasis. Laboratory concrete testing showed that CBO fly ash from all the stations had consistently superior air entraining characteristics at below 2% LOI. Field-testing confirmed the laboratory results. Very few CBO fly ash samples were analyzed with LOI values above 2%.

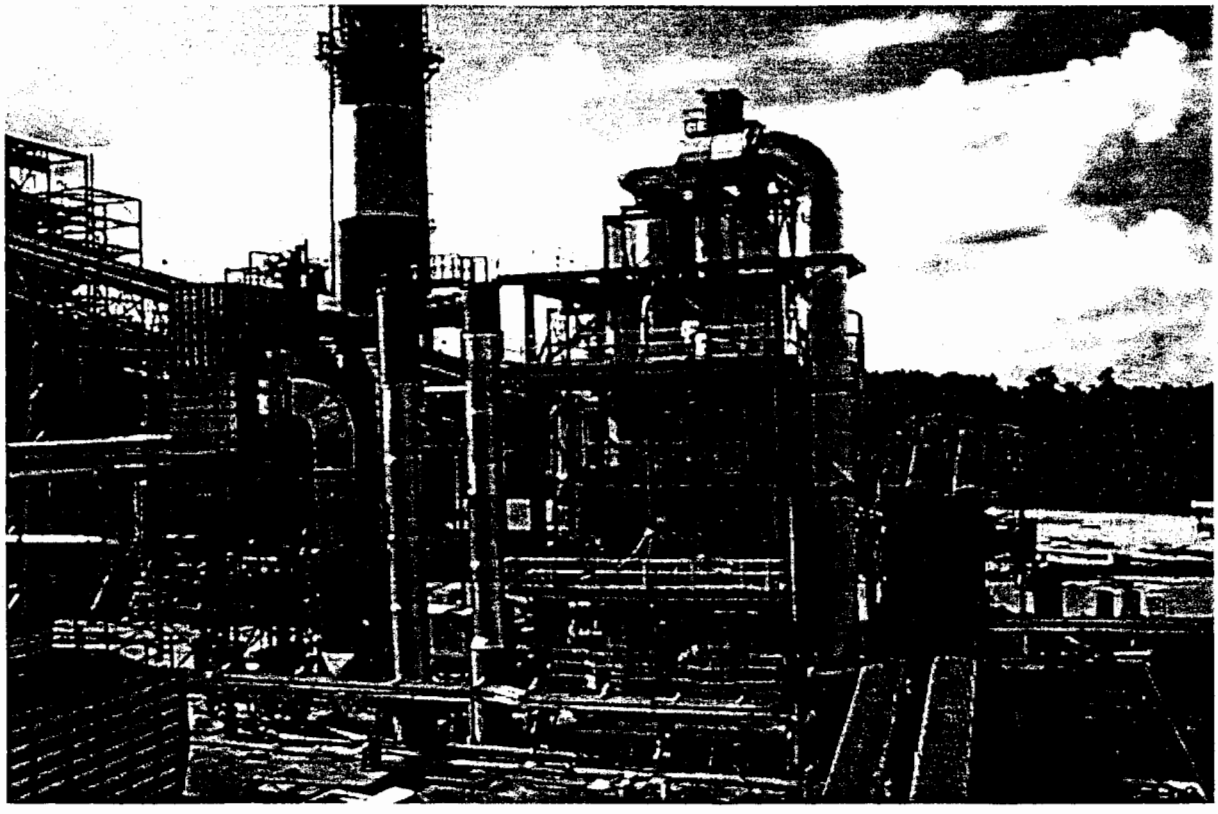
CBO PLANT DESIGN

The philosophy governing the Wateree CBO plant design includes several important elements:

- maximize recovered heat to the power plant
- include provisions for receiving high-carbon ash from other sources
- minimize Operating and Maintenance (O&M) costs
  - 'utility-grade' equipment
  - inclusive instrumentation
  - sophisticated control system
  - open plant layout for easy access
  - automated ash truck loading system
- maximize market value of Carbon Burn-Out product ash
  - high quality product, consistent quality
    - CBO process control keys off product ash quality, not feed ash LOI
    - Design provides for precise control of variables, immediate feedback
    - Long FBC residence time plus temperature control via cooled product ash provides 'smoothing' effect.
  - Product always available, accessible, traffic not interfering with plant operations
    - Re-route ash truck traffic away from power plant
    - Provide round-the-clock product loading without silo/scale-house attendant
    - Two loading stations, both on scales
    - 15,000 product ash storage to maintain product availability during outages

The process flow at CBO Wateree may be easily summarized:

- high-carbon ash is pneumatically conveyed from silos to the CBO plant
- FD fan provides fluidization and combustion air to CBO fluid bed combustor
- feed ash is metered into the combustor
- carbon combusts on a continuous basis
- material exits CBO combustor at 1350° F
  - product fly ash
  - flue gas
- heat exchange occurs between hot product ash + hot flue gas and condensate from the power plant
  - product ash and flue gas exits at < 300° F
  - heated condensate returns to power plant's feedwater heater system
- product ash is separated from flue gas via cyclone and baghouse
- ID fan maintains entire CBO system at a slight negative pressure, transports product ash through the heat exchanger, and transports cooled, particulate-free flue gas to power plant stack.
- product ash is pneumatically conveyed to the Storage and Load-Out Area



CBO plant with Wateree stack in background

Referring to the above photo, the Fluid Bed Combustor is within the tower at right-center. The heat exchanger is the inverted "U" in the center, and the product ash/flue gas separation takes place in the tower at left-center. FD and ID fans are behind the heat exchanger, as is the condensate pump and piping system. The CBO Control Room is just off the right border.

The CBO site at Wateree Station was selected for offering minimal duct runs while maintaining open access to all existing power plant systems. The ash product storage and load-out system is ~ 400' behind the photographer.

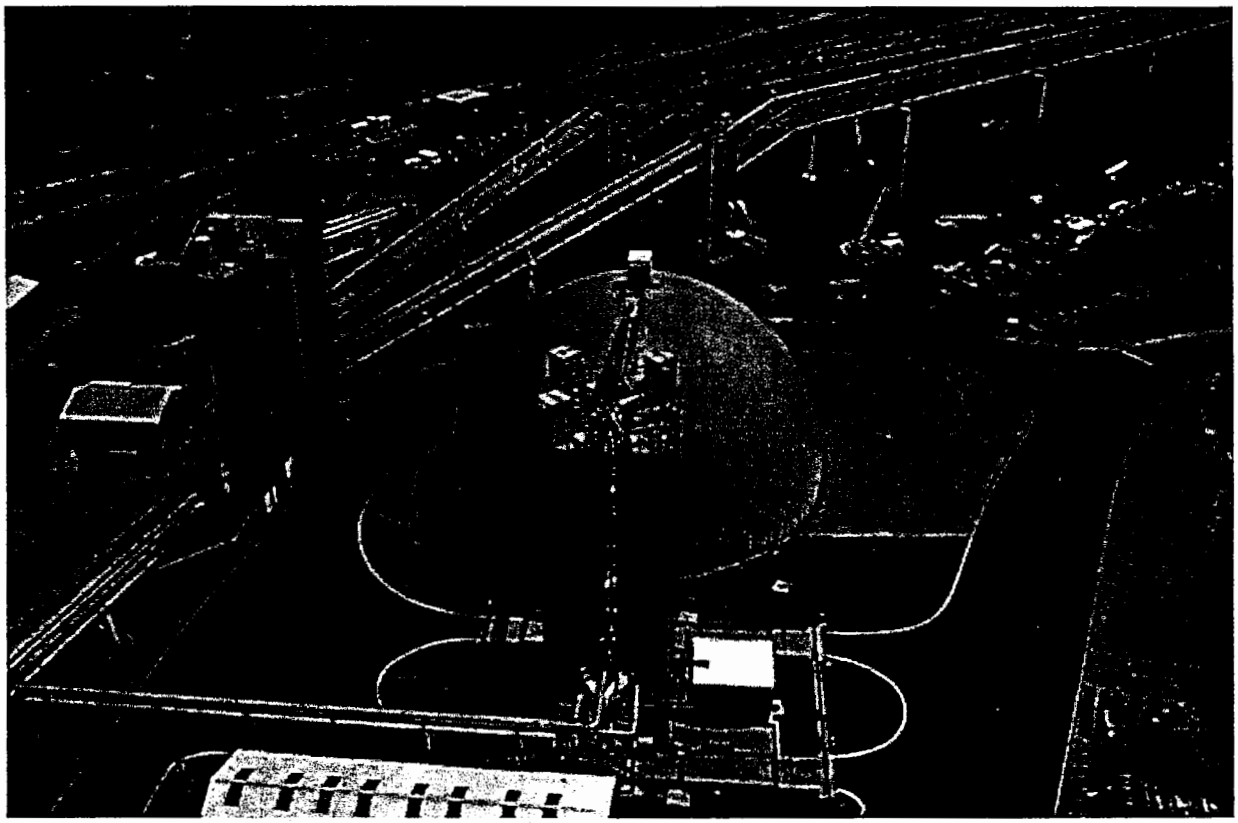
The CBO Fluid Bed Combustor (FBC) was designed and fabricated by DB Riley, using PMI's process design parameters. The combustor is a refractory-lined steel box divided into two cells to allow precise process control. The bed consists of only fly ash. For ease of maintenance, nearly all penetrations are through the roof. A start-up burner, fired by No. 2 oil, is in the air plenum below the bed. This burner is ramped down and then shut off once the bed reaches the residual carbon auto-ignition temperature of ~ 860° F.

CBO fluid bed temperature is precisely and automatically controlled by a 'recycle' system metering cooled product ash back to the FBC, where the returning product ash acts as a thermal load. The rate at which this ash is metered into the FBC is determined by the temperature profile in the fluid bed at any point in time -- increasing temperatures signal for more cool ash, declining temperatures signal for less. Pilot plant work first demonstrated this to be a very

effective temperature control technique. It has the added benefit of 'smoothing out' minor variations in ash product LOI. In addition, an Exhaust Gas Recirculation (EGR) system has been added since initial operations commenced and provides significant additional control, especially for enhancing turndown capability.

Environmental permitting for the Wateree CBO project proved quite straightforward. There is no solid or liquid waste stream from the CBO process -- all incoming high-carbon ash exits as a combination of product ash and flue gas. Wateree's heat rate is materially improved, resulting in less coal combusted for a given amount of electricity produced. Therefore overall site emissions are less. Fly ash disposal at Wateree is minimized.

FEED ASH STORAGE, PRODUCT ASH STORAGE AND LOADOUT



The left side of the photograph above shows two 250 ton silos that receive high-carbon fly ash from other power stations to be processed in CBO Wateree. To date, these have been used to receive ash from SCE&G's McMeekin and Williams Stations, although ash from other stations has been received and processed as well. Ash from these silos is transported pneumatically to the CBO feed silo located directly above the fluid bed. Ash from the two Wateree units is pneumatically fed from an existing silo on the site in the same manner. Note that the ash receiving and load-out areas were located on the site so as to avoid interference with normal power plant and coal handling operations.

In the photo's foreground are four 250 ton product ash load-out silos, which receive ash pneumatically transported directly from the CBO plant, or from the storage dome, or from both simultaneously. Ash loading and weighing is automated using an entry card system operated by the truck driver. Access is 24 hours per day, seven days a week. This system eliminates the need for operators, and to date has functioned as designed.

The dominant structure in the rear is the new 120' diameter concrete dome. This dome, with its 15,000-ton ash storage capacity, was primarily intended to smooth out seasonal construction fluctuations. However, the enhanced operational flexibility provided by the dome has led to almost daily use, as sales of CBO low-carbon ash has exceeded forecasts. The dome features inward-sloping concrete floor over a fly ash structural fill. Aeration slides are mounted on the floor radially from the center. Fluidized ash enters pneumatic transporters at the center of the dome's floor and is transported to the specified load-out silo. Dome fluidization is by segments, with the pattern and timing being automatically performed by the CBO control system signaling motor-operated valves on the aeration manifold. To date, the filling, storing and reclaim systems all have functioned as designed.

CBO PLANT OPERATIONS SUCCESS

Following pre-operational checkout, start-up, and de-bugging, Wateree CBO was placed into commercial operation in early January 1999. To date, the 1350° F operating temperature has proven satisfactory at CBO Wateree for all ash sources processed.

Recovery of heat from CBO Wateree and application back to the turbine cycle in the power plant has functioned fully as designed. By the end of 1999, approximately 260,000 million Btu's have been directly recovered to the Wateree units, or approximately the heating value of 11,000 tons of coal that did not need to be purchased, transported, stored, and combusted for the same amount of electricity produced.

Two people per shift perform CBO plant operations, including quality control on the product ash being shipped.

The Wateree CBO fly ash product is finer in particle size than the high-carbon feed ash, and is very similar to the fineness of low carbon fly ash produced by the Wateree units before Low NO_x burners. The CBO product fly ash shows no signs of agglomeration. The fly ash has performed very well in the concrete marketplace and is viewed as a premium product. By the end of 1999, approximately 130,000 tons of product ash has been sold.

FLY ASH QUALITY AND MARKET ACCEPTANCE

After the Wateree CBO plant began commercial operation in early 1999, SEFA produced and tested CBO fly ash with varying LOI values to determine the effect of LOI on the air entraining characteristics of Wateree CBO Plant fly ash. Strength data was also obtained.

The Wateree CBO fly ash has the same superior air entraining characteristics demonstrated by the bench model and pilot plant product ash, even at slightly higher LOIs than observed in the preliminary testing. Hardened concrete testing confirms the good strength-producing characteristics expected of Class F fly ash. There is no significant correlation between LOI and the concrete strength results obtained to date.

The Wateree CBO fly ash product is significantly finer in particle size than the high-carbon feed ash. It is very similar to the fineness of low LOI fly ash previously produced by the Wateree units before their Low NO_x conversion. The Wateree CBO product fly ash shows no signs of agglomeration.

Wateree CBO fly ash has performed very well in the concrete marketplace and is viewed as a premium product. As mentioned earlier, the production capacity of the Wateree CBO plant is 20% greater than designed. However, partly due to the excellent market acceptance of CBO fly ash, SEFA has increased their customer base to accommodate the higher production capacity.

FUTURE IMPLICATIONS

Wateree Station is now fitted with low NO_x burners and complies with current regulations. However, further reductions in NO_x emission limits may well require the application of either Selective Catalytic Reduction (SCR) or Selective Non-Catalytic Reduction (SNCR) technology. Both are known to deposit ammonia onto the fly ash. Even at relatively low levels, ammonia-on-ash presents significant marketing problems and perhaps occupational health and safety issues as well.

Progress Materials has undertaken a CBO pilot plant test program on high-carbon fly ash containing ammonia. This work has demonstrated that, even without process flow changes, product ash from the Carbon Burn-Out fluid bed is both low-carbon and ammonia-free.

SUMMARY

- Carbon Burn-Out has proven effective and efficient in producing a consistent, very high quality fly ash
- The plant has demonstrated its ability to produce a consistent 2% LOI product from a range of feedstock carbon contents and sources
- The CBO process flow was successfully enhanced so as to provide a much greater operating range than originally designed
- Plant storage and loadout features significantly enhance market flexibility
- Heat recovery back to the power plant functions fully as designed