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CLEAN COAL TECHNOLOGY

The JEA Large-Scale CFB Combustion Demonstration Project

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A report on a project conducted jointly under
a Cooperative Agreement between:
The U.S. Department of Energy and JEA

Cover Picture:

Three views of JEA Northside Station, Jacksonville, Florida

CLEAN COAL TECHNOLOGY

The JEA Large-Scale CFB Combustion Demonstration Project

Executive Summary

The Clean Coal Technology (CCT) Demonstration Program is a government and industry co-funded effort to demonstrate a new generation of innovative coal utilization processes in a series of facilities built across the country. These projects are carried out on a commercial scale to prove technical feasibility and provide the information required for future applications.

The goal of the CCT Program is to furnish the marketplace with a number of advanced, more efficient coal-based technologies that meet strict environmental standards. Use of these technologies is intended to minimize the economic and environmental barriers that limit the full utilization of coal.

To achieve this goal, beginning in 1985, a multi-phased effort consisting of five separate solicitations was administered by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL). Projects selected through these solicitations have demonstrated technology options with the potential to meet the needs of energy markets while satisfying relevant environmental requirements.

Part of this Program is the demonstration of advanced electric power generation technologies, including circulating fluidized bed combustion (CFB). This report discusses the JEA Large-Scale CFB Combustion Demonstration Project which is testing the CFB concept using inexpensive feedstocks such as high sulfur coal and coal fuel blends.

The project is being conducted at the Northside Generating Station of JEA (formerly Jacksonville Electric Authority) in Jacksonville, Florida, and JEA is the project Participant. Foster Wheeler Energy Corporation, the technology supplier, is an additional team member.

To date, the JEA Project has operated CFBs to generate electricity at a scale larger than previously demonstrated. The boilers at the Northside Station are the largest CFBs in the world. Power production on coal feed meets the target goal of 297.5 MWe gross (265 MWe net). Emissions of atmospheric pollutants are below the stringent limits set for this project. A two-year demonstration test program is planned to evaluate the operational and environmental performance of the CFB system.

JEA plant with CFB boilers in center and fuel storage domes in background

The JEA Large-Scale CFB Combustion Demonstration Project

Background

The Clean Coal Technology (CCT) Demonstration Program, sponsored by the U.S. Department of Energy (DOE) and administered by the National Energy Technology Laboratory (NETL), has been conducted since 1985 to develop innovative, environmentally friendly coal utilization processes for the world energy marketplace.

The CCT Program, which is co-funded by industry and government, involves a series of demonstration projects that provide data for design, construction, operation, and technical/economic evaluation of full-scale applications. The goal of the CCT Program is to enhance the utilization of coal as a major energy source.

Fluidized Bed Combustion

Among the technologies being demonstrated in the CCT Program is fluidized bed combustion (FBC). FBC is an advanced electric power generation process that minimizes the formation of gaseous pollutants by controlling coal combustion parameters and by injecting a sorbent (such as crushed limestone) into the combustion chamber along with the fuel. In the JEA project described in this report, the fuel is coal or a blend of coal and petroleum coke. Crushed fuel mixed with the sorbent is fluidized on jets of air in the combustion chamber. Sulfur released from the fuel as sulfur dioxide (SO_2) is captured by the sorbent in the bed to form a solid compound that is removed with the ash. The resultant by-product is a dry, benign solid that can be disposed of easily or used in agricultural and construction applications. More than 90% of the sulfur in the fuel is captured in this process.

An additional environmental benefit of FBC power plants results from their relatively low operating temperature, which significantly reduces formation of nitrogen oxides (NOx).

Five FBC demonstration projects are included in the CCT Program under Advanced Electric Power Generation: (1) the JEA Large-Scale CFB Combustion Demonstration Project, (2) the Nucla CFB Demonstration Project, (3) the Tidd PFBC Demonstration Project, (4) the McIntosh Unit 4A PCFB Demonstration Project, and (5) the McIntosh Unit 4B Topped PCFB Demonstration Project. This Topical Report describes the JEA project.

Panoramic view of JEA site

Project Description

The JEA Large-Scale CFB Combustion Demonstration Project consists of installing a new 300-MWe (297.5-MWe nameplate) atmospheric circulating fluidized bed (ACFB) boiler in conjunction with an existing turbine generator at JEA's Northside Generating Station (Unit 2) in Jacksonville, Florida. In parallel with this project, JEA replaced the Unit 1 oil/gas fired boiler with an identical ACFB unit. Unit 1 continues to use its existing turbine generator.

These boilers are designed to burn fuel blends consisting of coal and petroleum coke, thereby greatly reducing plant fuel costs and maintaining fuel flexibility while meeting stringent emissions limits. These units are the world's largest ACFB boilers.

In this project, the existing Unit 2 turbine generator was upgraded, and other existing balance-of-plant (BOP) equipment and systems were either upgraded or replaced. The existing turbine building and some piping systems were re-utilized.

Steam from the combustor is used in an existing General Electric 297.5-MWe (nameplate) turbine to produce electric power. With parasitic power consuming 32.5 MWe, net power output is 265 MWe.

JEA Large-Scale CFB Combustion Demonstration Project

Project Participants and Responsibilities

JEA

- Overall project and construction management
- Funding ($234 million)
- Environmental permitting

U.S. DOE

- Funding ($75 million)
- Technology support/dissemination

Foster Wheeler Energy Corporation (Clinton, NJ)

- Design and supply of CFBs
- Engineering/procurement/construction for the extended boiler island, including CFBs, scrubbers, fabric filters, stack, and fuel and limestone preparation facilities

Black & Veatch (Kansas City, MO)

- Design of BOP and materials handling systems

Zachry Construction Corporation (San Antonio, TX)

- Procurement and construction of BOP system upgrades and replacements, including condensate, feedwater, and circulating water systems; water and wastewater treatment systems; distributed control system; station electric distribution system; and substation equipment

Fluor Global Services (Irvine, CA)

- Upgrade/uprate of turbine/generators
- Procurement and construction of materials handling systems, including continuous ship unloader (purchased by JEA), pier, conveyors, fuel storage domes, and fuel and limestone reclaim equipment

Project Participant

The Participant is JEA, who provided the host site. An additional team member is Foster Wheeler Energy Corporation (FWEC), who supplied the ACFB technology.

Fuel Supply

Coal feed is an Eastern bituminous coal having a sulfur content of 3.39 wt%. Petroleum coke having a sulfur content as high as 8% also serves as feed, either alone or in combination with coal.

Project Scale

The JEA project represents a scale-up of previous ACFB installations. The Nucla project, completed in 1992, had a capacity of 100 MWe (net) and the Tidd project, completed in 1995, had a capacity of 70 MWe (net). The McIntosh Unit 4A project (currently on hold) is designed for a capacity of 137 MWe (net), and the McIntosh Unit 4B project (also on hold) has a design capacity of an additional 103 MWe (net). At a nominal design capacity of 300 MWe gross (265 MWe net), the JEA project is the largest scale demonstration of FBC technology to date.

Jacksonville

A half century after Ponce de Leon claimed Florida for Spain, Frenchman Jean Ribault sailed into the St. Johns River to establish Fort Caroline for French Huguenot settlers. Within several years, Spanish forces from the military garrison at St. Augustine would destroy this small settlement.

In 1821, Spain ceded Florida to the United States, and one year later Isaiah D. Hart surveyed the village. He named it Jacksonville for General Andrew Jackson, the territory's first military governor.

Today, located at the crossroads of two transcontinental highways, Jacksonville is one of the Nation's largest cities in land area (841 square miles), a major port, site of Navy bases, and home of the NFL Jacksonville Jaguars, a Mayo Clinic medical center, and the Jacksonville Zoological Gardens. The area boasts beautiful beaches and numerous waterways for over 700,000 residents.

Process Description

Coal fuel blends, along with primary air and a solid sorbent such as limestone, are introduced into the lower part of the combustor, where initial combustion occurs. As the fuel particles decrease in size due to combustion, they are carried higher in the combustor where secondary air is introduced. As the particles continue to be reduced in size the fuel, along with some of the sorbent, is carried out of the combustor, collected in a cyclone separator, and recycled to the lower portion of the combustor. Primary removal of sulfur is achieved by reaction with the sorbent in the bed. Additional SO_2 removal is achieved through the use of a downstream polishing scrubber using a spray dryer absorber (SDA). Fabric filters are used for particulate control.

Furnace temperature is maintained in the range of 1500 to 1700°F by efficient heat transfer between the fluid bed and the water walls in the boiler. This relatively low operating temperature inherently results in appreciably lower NOx emissions compared with PC-fired power plants. However, the project also includes a new selective non-catalytic reduction (SNCR) system, using reaction with ammonia to further reduce NOx emissions to very low levels as required by the stringent environmental regulations for the JEA project.

Steam is generated in tubes placed along the walls of the combustor and superheated in tube bundles placed downstream of the particulate separator to protect against erosion. The system produces approximately 2 million lb/hr of main steam at 2,500 psig and 1,000°F, and 1.73 million lb/hr of reheat steam at 548 psig and 1,000°F. The steam flows to the turbine/generator, where electric power is produced. The design heat rate is 9,950 Btu/kWh (34% overall thermal efficiency, higher heating value basis).

The JEA CCT project incorporates several advanced features including a patented integrated recycle heat exchanger (INTREX™) in the furnace.

Two 400-foot diameter by 140-foot high aluminum geodesic domes for fuel storage

Limestone conveyors

Details of the JEA Project Systems

Limestone Preparation System

The limestone preparation system grinds and dries raw limestone and pneumatically transports it to the limestone storage silo for each Unit. The limestone grinding system consists of three rod mills with accessories. The mills are sized for grinding limestone at a maximum feed size of 1 inch to a product size of -2000 microns (approximately 1/16 inch), meeting the CFB desired product distribution curve, with a residual moisture content of 1% maximum.

Three pneumatic transfer systems are provided to convey the prepared limestone from the preparation building to the unit's silo. Each silo has a bin vent filter to control dust emissions. Each system is sized for 50 tons per hour (tph) capacity and is capable of transferring limestone to either Unit 1 or 2.

The control system for the limestone preparation system uses a programmable logic controller (PLC) with a cathode ray tube (CRT)-based operator interface located in the material handling control room. A digital communication interface is furnished to tie this local control system into the plant's distributed control system (DCS).

Air Quality Control System

To optimize overall plant performance, a polishing SO_2 scrubber was included in the design. The polishing scrubber is an SDA/baghouse combination. The SDA utilizes a dual fluid nozzle atomized with air, and the baghouse is a pulse-jet design. A key feature of the polishing scrubber is a recycle system which adds fly ash to the reagent feed, thus utilizing the unreacted lime in the fly ash from the CFB boiler and reducing the amount of fresh lime required.

The polishing scrubber for each unit, provided by Wheelabrator Air Pollution Control, consists of:

- A two-fluid nozzle SDA
- A medium-pressure pulse jet fabric filter (FF)
- A feed slurry preparation system
- A common sorbent preparation system, consisting of a lime storage silo, redundant vertical ball mill slaking systems, and redundant transfer/storage tanks and pumps
- A common air compressor system to provide atomizing air for the SDA, dried pulse air for the FF, and instrument air. The compressors are provided with a closed loop cooling system. Waste heat from the compressor is used to preheat the reuse water feed to the SDA feed slurry system.

Turbine Generator and Balance of Plant Systems

The Units 1 and 2 turbine generators were upgraded to maximize output and improve turbine heat rate as much as practical. The high pressure/intermediate pressure rotor, diaphragms, and inner casing were replaced with a GE Dense Pack design, which added four stages to the turbine and increased turbine efficiency. The normal operating throttle pressure was also increased from 2400 psig to 2500 psig. In addition, the original mechanical linkage type turbine control system was replaced with a state-of-the-art Mark VI electrohydraulic control system to allow better response to load changes and for complete integrated control, protection, and monitoring of the turbine generator and accessories. A new brushless excitation system was also installed on each generator, and a new turbine lube-oil conditioner was installed (Unit 2 only).

Unit 2 was originally designed to provide power to the JEA grid at 138 kV. However, to better interface with present and future grid capabilities, the output from Unit 2 was increased to 230 kV. This required replacement of the generator step-up transformer and associated substation upgrades.

The once-through circulating water system was upgraded by replacing the original 90% copper/10% nickel heat-transfer surfaces in the condenser damaged by erosion/corrosion with modular bundles consisting of titanium tubes welded to solid titanium tubesheets. The existing circulating water pumps were replaced with larger capacity pumps. The traveling screens were replaced with those that have man-made basket material to increase their life. Debris filters were added to minimize condenser tube pluggage and possible damage. A sodium hypochlorite shock-treatment system was installed to prevent sea life from adhering to the titanium components of the condenser.

Upgrades to the condensate system in Units 1 and 2 included upgrading the condensate pumps and condensate booster pumps, replacement of the steam packing exhausters, replacement of the LP feedwater heaters, including replacement of the tube bundle in the lowest pressure heater (located in the condenser neck), replacement of the deaerator and storage tank, installation of a new con-

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Environmental Considerations

The JEA project site is located in North Jacksonville, an environmentally sensitive area surrounded by wetlands. A major goal of the project is to minimize emissions of solid, liquid and gaseous wastes. JEA is committed to making Jacksonville "the premier city in the Southeast in which to live and do business." Through consultation with community and environmental groups including the Sierra Club Northeast Florida Group, JEA agreed to emissions limits that are significantly lower than those specified by current EPA regulations.

Sierra Club Agreement

As part of the agreement with the Sierra Club, baseline stack emission rates at JEA for Units 1, 2, and 3 in 1994-1995, in tons/yr of certain substances, were identified. Target annual emissions rates representing a 10% reduction in each of these components were calculated, and a penalty of $1000/ton was established for any emissions exceeding these rates regardless of whether such emissions are allowable under any permit or authorization. Payments are to be made to the Jacksonville Environmental Protection Board, earmarked for public environmental education. The stack emissions involved in this agreement are NOx, SO_2, particulate matter, CO, and volatile organic compounds (VOCs). In addition, the utility negotiated limits for trace metals.

JEA also agreed to reduce groundwater consumption by at least 10%, and a penalty of $1000/million gallons was established for any groundwater usage at JEA exceeding the agreed upon rate of 208.4 million gallons/yr, regardless of whether such usage is allowable under any permit or authorization.

These reductions in stack emissions and groundwater consumption are especially significant in light of the fact that total power production at JEA after repowering is about 2.7 times as great as the baseline level.

Wetlands adjoining the JEA Plant site

Timucuan Ecological and Historic Preserve

Designated February 16, 1988

The 46,000 acre Timucuan Ecological and Historic Preserve was established in 1988 to protect one of the last unspoiled coastal wetlands on the Atlantic Coast and to preserve historic and prehistoric sites within the area. The estuarine ecosystem includes salt marsh, coastal dunes, and hardwood hammock as well as salt, fresh, and brackish waters. All of these are rich in native vegetation and animal life.

The Preserve was inhabited by the native Timucuan people for over 4,000 years before the arrival of the first Europeans. The Timucuan Preserve has within its boundaries federal, state, and city park lands and over 300 private landowners.

densate polisher (Unit 2 only), and installation of new chemical feed systems (Unit 2 only). The new feedwater heaters included Type 304 N stainless steel tubes (welded to tubesheets), instead of the aluminum brass tubes rolled into the tubesheets of the original heaters.

Upgrades to the feedwater system in Unit 2 included replacement of the HP feedwater heaters, upgrading of boiler feed pumps and fluid drives, and replacement of the boiler feed pump drive motor. Again, the new feedwater heaters included Type 304 N stainless steel tubes (welded to tubesheets), instead of the aluminum brass tubes rolled into the tubesheets of the original heaters.

The capability of existing piping systems and components was reviewed to confirm adequacy for the new operating and design conditions, and where necessary they were upgraded or replaced. Existing 2-inch and larger valves in Unit 2 were either refurbished or replaced. Nearly all 2-inch and smaller piping and valves in Unit 2 were replaced. Essentially all instrumentation in Unit 2 was replaced.

The original control systems in Units 1 and 2 were replaced with a new DCS provided by ABB Inc, to provide control, monitoring, and protection of the boiler, turbine interfaces, and BOP systems. Foster Wheeler provided the logic design for the CFB boiler, and Black & Veatch provided the logic design for the BOP systems, including provisions for turbine water induction prevention. ABB provided the programming to implement the logic design for the boiler and BOP systems.

The Units 1 and 2 auxiliary electric systems (switchgear and motor control centers) were replaced because of equipment obsolescence. All power and control wiring was replaced due to the age of the wiring and because the existing control wiring was not segregated from the power wiring, thus not meeting the requirements of the new DCS.

Other miscellaneous modifications included the installation of additional air dryers and screw-type air compressors as well as the installation of titanium plate-type heat exchangers for the Unit 2 closed cooling water system, similar to those previously installed in Unit 1.

Fuel Handling System

The function of the fuel handling system is to receive petroleum coke, coal, and limestone and convey it to stock-out and storage areas. The materials are reclaimed and conveyed to the in-plant fuel silos and to the limestone preparation system for limestone sorbent.

Receiving System

Solid fuels and limestone are received at the Northside river terminal. A new 800-ft dock and over 2 miles of new belt conveyors were installed as part of the project. Fuels are delivered in 60,000-ton capacity ships and limestone in 40,000-ton ships. The fuel ships are unloaded by a state-of-the-art continuous bucket type unloader rated at 1,666 tph for coal and 1,500 tph for petroleum coke. The unloader is guided by a sophisticated electronic control system. Limestone is unloaded at a rate of 2,800 tph.

Solid fuels are stored in two 400-ft diameter by 140-ft high geodesic domes, made of aluminum, having a capacity of 60,000 tons. These domes serve to keep the fuel dry and to reduce fugitive dust emissions as well as storm water runoff. They are built with only outside support structures to eliminate pyramiding of coal dust in the interior.

Reclaim Systems

The reclaim systems used for moving feed materials from storage to the boilers are redundant. Each storage facility can provide sufficient reclaim rate for the two operating units. With two storage domes and two stacker/reclaimers, the coal and petroleum coke can be blended. Each reclaim system can deliver coal or petroleum coke at a rate of up to 600 tph.

Common Equipment

Dust suppression systems are provided at all material transfer points. The systems are of the foam type and directly control dust emissions at all transfer areas except the crusher building and the area adjacent to and above the in-plant storage silos, which have dust collectors. Reuse water is used for the foam type dust suppression system.

Dust collection systems collect and return the dust to the surge bins, or downstream of the collection points in the case of the collection points in the crusher building. The dust collected in the in-plant storage silo area is returned to one of two in-plant fuel storage silos.

A PLC based control system controls the fuel handling system and is provided with remote control for belt conveyors and associated equipment and necessary interlock control for the conveyors and machines (ship unloader and stacker/reclaimers).

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Emissions Targets

Design emission rate for NOx is 0.09 lb/million Btu, which is achieved by the use of relatively low operating temperatures in the CFB coupled with post-combustion reduction of NOx via SNCR.

For SO_2, the design emission rate is 0.15 lb/million Btu, which is achieved through the use of a sorbent for sulfur capture in the combustor, coupled with scrubbing of the flue gas.

For particulate matter having a diameter of 10 microns (µm) or less (PM_{10}), the design emission rate is 0.011 lb/million Btu. Fabric filters are used to achieve this low level of particulate emissions.

Fugitive emissions are controlled by minimizing the number of bulk material transfer points, enclosing conveyors and drop points, enclosing the fuel storage area, and using wet suppression for particulates.

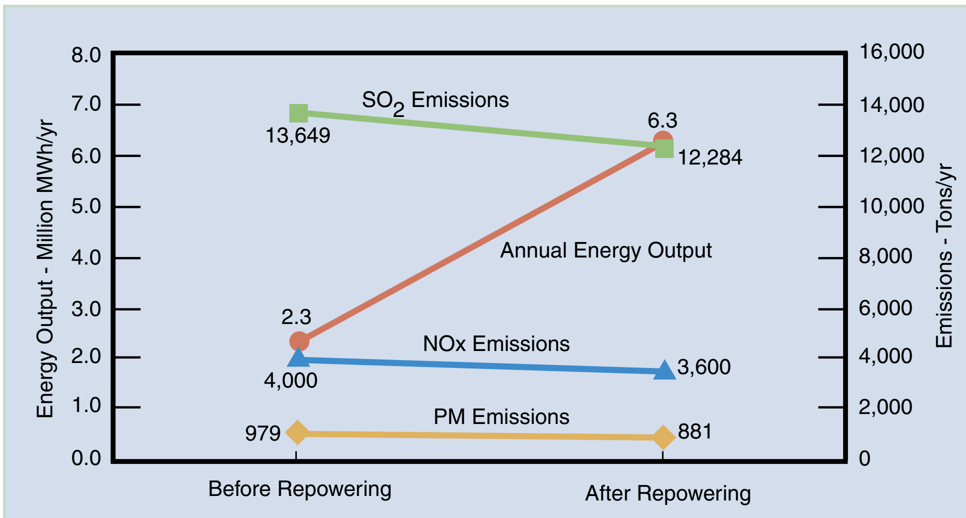
The reduction in groundwater consumption is achieved by using treated wastewater from a nearby municipal facility for certain plant applications.

Project Cost

The estimated cost of the JEA Large-Scale CFB Combustion Demonstration Project is $309 million, of which the Participant provided $234 million (76%) and DOE provided $75 million (24%). The repowering of Unit 1, which is not cost shared by DOE, is not included in this cost figure.

Stack Emission Rates in Sierra Club Agreement

Parameter	Existing Facility Units 1 and 3, tons/yr	Reductions from 1994/1995 Baseline, tons/yr (10% reduction)	Proposed Facility Units 1, 2, and 3, tons/yr
NOx	4,000	400	3,600
SO_2	13,649	1,365	12,284
Particulate Matter	979	98	881
CO	--	--	3,066
VOC (computed as 4% of CO)	--	--	123



Comparison of anticipated annual energy output and emissions before and after repowering

Fuel storage dome under construction

Ash Handling System

The ash handling system transports bed ash from the outlets of the stripper coolers to the bed ash silos, and fly ash from the economizer, air heater hoppers, and baghouse hoppers to the fly ash silos. Two sets of ash handling systems and associated equipment are provided, one for Unit 1 and the other for Unit 2. The bed ash mechanical conveying system and fly ash vacuum conveying system in turn consist of two fully independent parallel lines. Normally any one line is in operation and the other is an installed spare; however, in an emergency upset condition, both lines can be operated simultaneously.

The bed ash and fly ash from the ash silos is slurried using reclaimed water, mixed together, and pumped as a dense slurry to the by-product storage area.

Reuse Water System

Reuse water is domestic wastewater that has been treated and disinfected to a high degree and reused for beneficial purposes. The reuse water used at Northside Generating Station is obtained from the District II Water Reclamation Facility, transported via an eight-mile pipeline. The wastewater is treated through primary, secondary and advanced treatment. During primary treatment, large solids are removed. Secondary treatment uses microorganisms to remove the remaining solids and organic material.

After secondary treatment, the wastewater travels through cloth membrane filters, with a pore size of approximately 10 microns, to remove virtually all remaining solids. During advanced or final treatment, the wastewater is disinfected using chlorine or ultraviolet light to destroy bacteria, viruses and other pathogens.

Consumption of reuse water is expected to be more than 1 million gallons/day when all three units are operating. The reuse water is used for circulating water pump seals, boiler/precipitation area drains, polishing scrubbers, ash slurry preparation, and fuel handling dust suppression and wash down. Future uses may include irrigation.

Limestone preparation system

Project History

DOE selected the Large-Scale CFB Combustion Demonstration Project in June 1989 as part of Round I of the CCT Program. After a number of host sites were considered, the project was resited in August 1997 to Jacksonville, Florida. The Cooperative Agreement was signed in September 1997.

The Environmental Impact Statement for the Jacksonville site, as required by the National Environmental Policy Act, was completed in December 2001.

JEA Background

JEA is the largest municipal power company in Florida and the eighth largest municipal utility in the United States. JEA currently serves nearly 350,000 customers and is experiencing a load growth rate of more than 3% per year. Most municipal utilities in the United States do not generate their own power. Those that do so are relatively small, generating 25 MWe or less. Many of these small utilities use diesel engines for power generation. JEA is one of very few municipal utilities having an installed capacity of greater than 300 MWe.

Prior to the Large-Scale CFB Demonstration Project, JEA's Northside Station consisted of three oil/gas fired steam electric generating units. Units 1 and 2 were each nominally rated at 275 MWe and Unit 3 at 518 MWe. Units 1 & 3 had been in service since 1966 and 1977 respectively. Unit 2 was completed in 1972, but had been inoperable since about 1983 due to major boiler problems.

As part of its Integrated Resource Planning Study in 1996, JEA concluded that additional base load capacity was needed to support Jacksonville's growing need for energy. With demand growing, JEA executives saw that the utility's ability to generate all of the electricity required by its customers—something JEA had done for 100 years—would be compromised early in the 21st century unless it soon began planning new facilities.

The optimum source for that additional capacity was determined to be repowering Unit 2 with a state-of-the-art ACFB boiler fueled by coal fuel blends. To provide the project with an overall environmental benefit, increase the economies of scale, and further diversify JEA's fuel mix, a decision was made to repower Unit 1 with an identical ACFB boiler as well. The DOE cost sharing does not cover the Unit 1 repowering.

The environmental benefits include a reduction in emissions of NOx, SO_2, and particulate matter by at least 10% compared to 1994/1995 levels. As a result of increased generating capacity and improved capacity factor, total power production was planned to increase from about 2.3 million MWh/yr to about 6.3 million MWh/yr, an increase of about 170%. An additional economic benefit results from the fact that, prior to the repowering project, Units 1 and 3 fired relatively high cost fuels, resulting in limited dispatch of these units. As a result of the repowering, both Unit 1 and Unit 2 are now capable of firing relatively low cost solid fuels. The use of these fuels, which can be delivered by ship, takes full advantage of JEA's existing strategic assets including access to the St. Johns River.

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Process Flowsheet

Coal or coal fuel blends are crushed to about ¼ inch diameter and mixed with limestone crushed to the size of sand. The fuel is gravimetrically metered and swept with heated combustion air into the base of the combustor. Limestone is injected into the same area of the combustor by the use of positive displacement blowers.

As the solid mixture rises, it ignites and begins a controlled “slow burn.” The slow burn process maintains temperatures below 1600°F across a large area, minimizing the production of pollutants. At temperatures above 1600°F, production of NOx increases significantly.

As the fuel particles burn, they become lighter and, with the help of additional air that constantly turns the particles over in a fluid-like motion, they are carried higher in the combustor. The limestone absorbs about 90% of the sulfur in the fuel (as SO_2).

At the cyclone inlet located at the top of the combustor, aqueous ammonia is injected into the flue gas to further reduce NOx produced in the furnace, converting it to molecular N_2. The cyclones provide for efficient mixing of the flue gas and ammonia as well as sufficient residence time at the optimum operating temperature for effective NOx reduction.

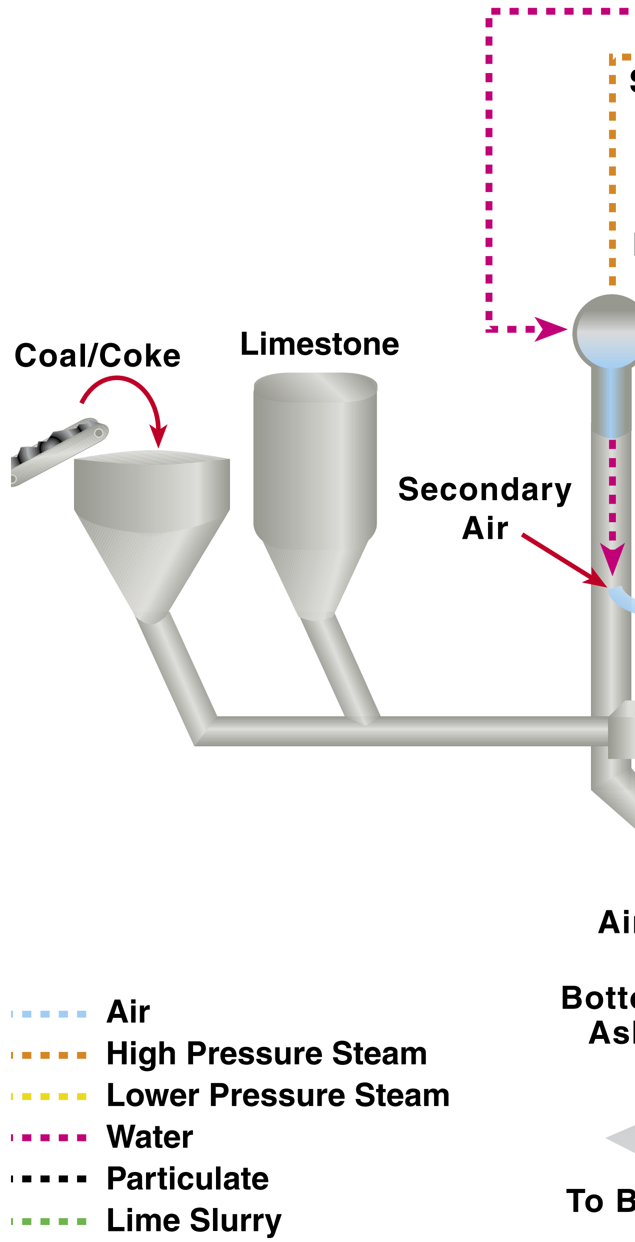
The hot ash and limestone pass through the INTREX™ exchanger before being recycled to the bottom of the combustor. In the INTREX™ exchanger, superheated steam is produced in tubes over which the hot ash returning to the combustor flows.

The steam flows into the cyclone inlet panels, through the cyclone walls, into the convection cage wall, through the primary superheater, and into the intermediate and finishing superheaters which reside within the INTREX™ exchanger. Solid material, consisting primarily of ash and $CaSO_4$, is removed from the bottom of the combustor and sent to by-product storage.

The hot gases leaving the top of the cyclone enter additional reheater/superheater tubes that also generate steam for the turbines. The still hot flue gas is used to preheat the main combustion air before it is introduced to the bottom of the furnace.

After the reheater/superheater, the flue gas enters an air quality control system, where it travels downward through a polishing scrubber that applies a lime slurry to absorb SO_2. Following the scrubber, the flue gas passes through a baghouse containing fabric filters to further clean the gas before it is sent up the stack. The collected particulates, which are sent to by-product storage, include trace metals captured in the fabric filters.

JEA Large-



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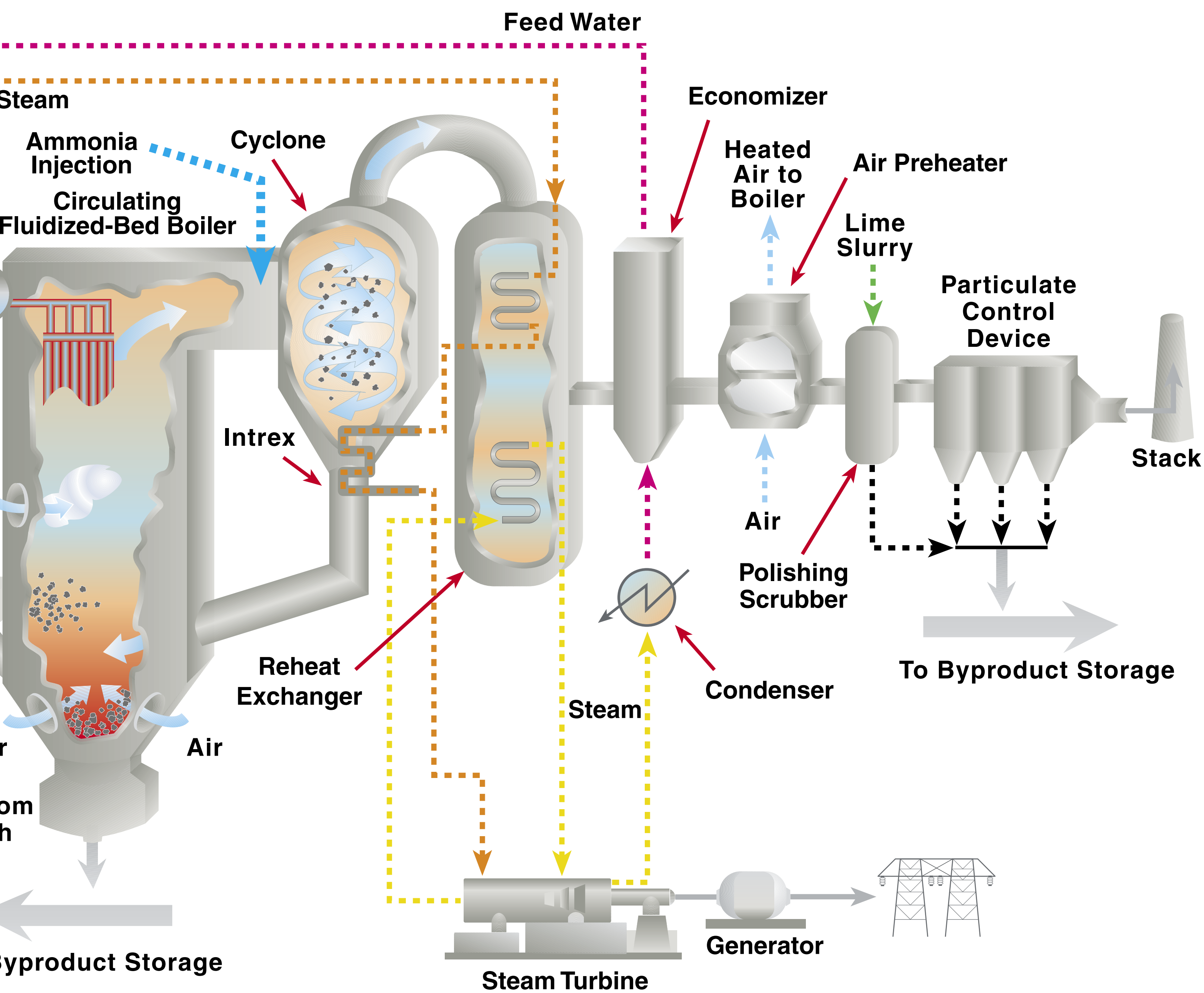


Fluidized Bed Combustion

Fluidized bed combustion (FBC) is one of the major technologies being developed under Advanced Electric Power Generation in DOE's CCT Program. FBC reduces emissions of SO_2 and NOx by controlling combustion parameters and by injecting a sorbent, such as crushed limestone, into the combustion chamber along with the coal.

Pulverized coal mixed with the limestone is fluidized on jets of air in the combustion chamber. Sulfur released from the coal as SO_2 is captured by the sorbent in the bed to form a solid calcium compound that is removed with the ash. The resultant by-product is a dry, benign solid that can be disposed of easily or used in agricultural and construction applications. More than 90% of the SO_2 can be captured in this manner.

At combustion temperatures of 1,400 to 1600°F, the fluidized mixing of the fuel and sorbent enhances both combustion and sulfur capture. The operating temperature range is much lower than that of a conventional pulverized-coal boiler and below the temperature at which thermal NOx is formed. In fact, NOx emissions from FBC units are about 70 to 80% lower than those for conventional boilers. Thus, FBC units substantially reduce both SO_2 and NOx emissions. Also, FBC has the capability of using high-ash coal, whereas conventional pulverized-coal units must limit ash content in the coal to relatively low levels.

Two parallel paths have been pursued in FBC development—bubbling and circulating beds. Bubbling FBCs use a dense fluid bed and low fluidization velocity to effect good heat transfer and mitigate erosion of an in-bed heat exchanger. Circulating FBCs use a relatively high fluidization velocity that entrains the bed material, in conjunction with hot cyclones, to separate and recirculate the bed material from the flue gas before it passes to a heat exchanger. Hybrid systems have evolved from these two basic approaches.

Fluidized bed combustion can be either atmospheric (AFBC) or pressurized (PFBC). As implied by the name, AFBC operates at atmospheric pressure. PFBCs, which operate at pressures 6 to 16 times higher, offer higher efficiency by expanding the hot combustion products through a gas turbine and utilizing the steam generated within the combustor to operate a steam turbine. Consequently, operating costs and waste are reduced relative to AFBC, as well as boiler size per unit of power output.

Second-generation PFBC integrates the combustor with a pyrolyzer (coal gasifier) to fuel a gas turbine (topping cycle), and the waste heat is used to generate steam for a steam turbine (bottoming cycle). The inherent efficiency of the gas turbine and waste heat recovery in this combined-cycle mode significantly increases overall efficiency. Such advanced PFBC systems have the potential for overall thermal efficiencies approaching 50%.

Since PFBCs have not yet been demonstrated on a commercial scale, AFBCs were chosen for the JEA project.

Natural gas was rejected as an option because northeastern Florida was served by only one pipeline at that time. Orimulsion was not considered seriously because it was not held in high regard by regulatory authorities and it did not offer a cost advantage.

In early 1997, detailed condition assessments of Unit 1 and Unit 2 BOP equipment and systems were conducted by JEA and Black & Veatch. The results of that study indicated that both Unit 1 and Unit 2 were good candidates for repowering and were capable of operating for many more years, provided various equipment and system upgrades were made.

In April 1997, JEA approved the project and authorized staff to begin working with Foster Wheeler (FW) on contract negotiations and environmental permitting.

Project Organization

JEA contracted with Foster Wheeler Energy Corporation (FWEC) to provide the design and supply of the ACFB boilers. Foster Wheeler USA (FWUSA) provided engineering, procurement, and construction management services for installation of the boilers and for furnishing and erecting the air pollution control systems, stack, limestone preparation system, and ash handling system. Foster Wheeler Environmental Corporation, a subsidiary of FWUSA, was also contracted to provide environmental permitting services.

The remaining portions of the project were implemented by JEA staff, supplemented by Black & Veatch through a pre-existing alliance with JEA for engineering services. Procurement, construction and related services were provided through other pre-existing alliances between JEA and Zachry Construction Corporation, Fluor Global Services, W.W. Gay Mechanical Contractor, Inc., and Williams Industrial Services Inc. This work included upgrades of the existing turbine island equipment, construction of the receiving and handling facilities for the fuel and reagent required for solid fuel firing, upgrading of the electrical switchyard facilities, and construction of an ash management system.

Project Status

Environmental permitting work was initiated by FW in the latter part of 1997. This work and associated preliminary engineering proceeded through 1998 and into early 1999. FW began detailed engineering for the boiler island, including the air quality control system, stack, and limestone preparation system, in December 1998. Black & Veatch began detailed engineering for BOP systems, including the fuel handling system, in February 1999. Permits necessary to begin construction were issued in July 1999, with site clearing and construction beginning in August 1999.

Initial synchronization was achieved for Unit 2 on February 19, 2002, and for Unit 1 on May 29, 2002. The JEA project will include two years of demonstration test runs, during which a variety of coal fuel blends will be fired.

Design Parameters

Fuel Specifications	Coal	Petroleum Coke
Heating Value, Btu/lb	>11,600	>13,000
Sulfur, %	0.5-4.5	3.0-8.0
Ash, %	7-15	<3
Volatile Matter, %	30-60	>7
Steam Flow and Conditions	**Reheat**	**Main**
Flow, 1000 lb/hr	1994	1773
Pressure, psi	2,500	548
Temperature, °F	1,000	1,000

JEA plant view from by-product storage area

Project Objectives

The JEA project objectives are (1) to demonstrate ACFB technology at 297.5 MWe gross (265 MWe net), representing a scale-up from previously constructed facilities; (2) to verify expectations of the technology's economic, environmental, and technical performance to provide potential users with the data necessary for evaluating large-scale ACFBs as a commercial alternative; (3) to accomplish greater than 90% SO_2 removal; and (4) to reduce NOx emissions by 60% compared with conventional pulverized-coal (PC) fired boilers not equipped with post-combustion NOx removal.

Initial Performance Results

Emissions	Guarantee Value	100% Coal Test	100% Coke Test
SO_2, lb/10^6 Btu	<0.15	0.00-0.04	0.03-0.13
NOx, lb/10^6 Btu	<0.09	0.04-0.06	0.02
CO, lb/10^6 Btu	<0.22	0.044-0.054	0.013-0.015
Particulates, lb/10^6 Btu	<0.011	0.004	0.007
PM_{10}, lb/10^6 Btu	<0.011	0.006	0.0044
SO_3, lb/hr	1.1	0.43	0.00
Fluoride, lb/hr	0.43	0.29	0.261
Lead, lb/hr	0.070	0.015	0.016
Mercury, lb/hr	0.03	0.0027	0.0008
VOC, lb/hr	14.0	<0.1	<0.1
Opacity, %	<10	0.36-1.12	0.21-2.64
Ammonia Slip, ppm	40	0.9	n/a
Boiler Parameters			
Steam Flow, 1000 lb/hr	>1794	1950	1937
Main Steam Temperature, °F	>980	996	992
Reheat Steam Temperature, °F	>980	1001	993
Main Steam - Reheat Steam Temperature, °F	<30	6	5
Boiler Efficiency, %	81.8	88.2	92.0

Project Scope

The JEA project involves the construction and operation of a new 300-MWe ACFB boiler fired with coal fuel blends to repower an existing steam turbine. ACFB boilers are capable of removing about 90% of the SO_2 generated, using limestone at a design Ca/S ratio of < 2/1. Greater percentage removal can be achieved by increasing the Ca/S ratio, but the added cost for limestone sorbent becomes prohibitive. To optimize the overall economics and to meet environmental requirements, a polishing scrubber was included in the JEA project. This added feature is required when firing higher sulfur fuels, including petroleum coke containing up to 8.0% sulfur.

A key feature of the polishing scrubber is a recycle system which adds fly ash to the lime sorbent, thereby taking advantage of the unreacted lime in the fly ash to reduce the amount of fresh lime required. The resulting savings in sorbent and ash disposal costs offset the added capital and operating costs for the scrubber. In addition, the scrubber offers reductions in emissions of trace elements. The JEA installation represents the first use of a polishing scrubber in conjunction with a CFB in the United States.

As indicated previously, the project includes an SNCR system to reduce NOx emissions to the very low levels required. A new baghouse was installed to achieve over 99.8% reduction in particulate emissions.

In addition to the ACFB combustor itself and the air pollution control systems, new equipment for the project includes an approximately 500-ft high stack as well as handling systems for fuel, limestone, and ash. This includes facilities for delivery of solid fuel to the site by ship. The project also required overhaul and/or modifications of existing systems such as the steam turbines, condensate and feedwater systems, circulating water systems, water treatment systems, plant electrical distribution systems, the switchyard, and the plant control systems.

JEA plant with ship unloading dock in foreground

A significant aspect of the JEA project design is that many of the boiler components are at the leading edge of technology, but have been applied successfully in commercial service at least once before. Integrating all these components while significantly scaling up boiler size is a major project accomplishment.

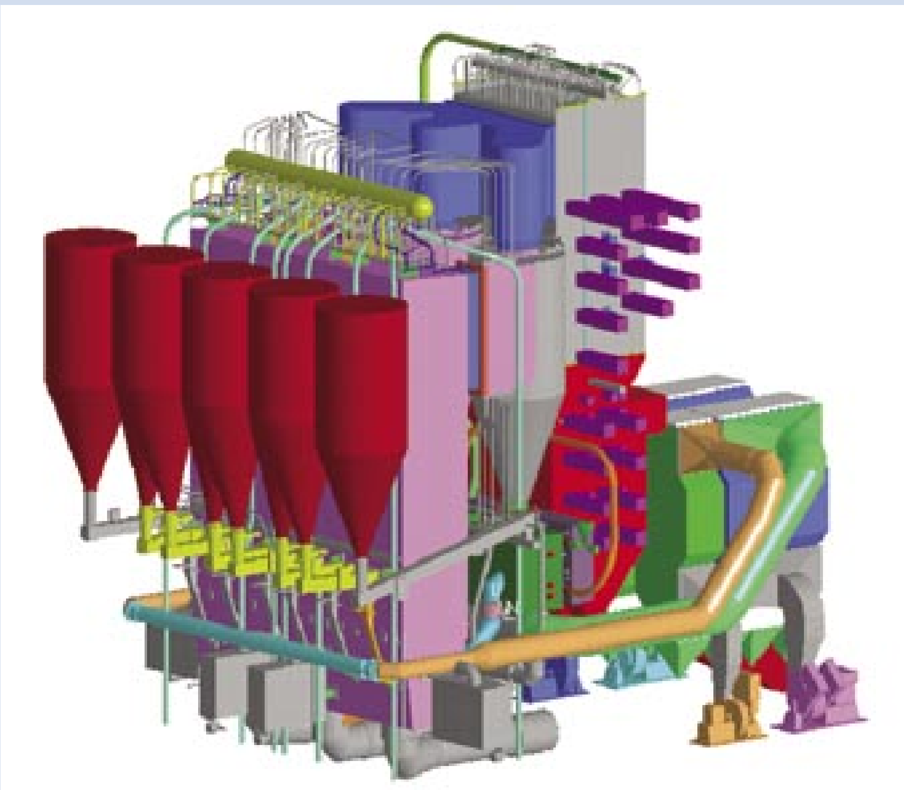
Wherever possible, existing facilities and infrastructure were used. These include the intake and discharge system for cooling water, the wastewater treatment system, and the electric transmission lines and towers.

Project activities include engineering and design, permitting, procurement, construction, startup, and a twenty-four month demonstration of the commercial feasibility of the technology. During the demonstration test program, Unit 2 will be operated on several different types of coal fuel blends to enhance the viability of the technology. Upon completion of the demonstration test program, Unit 2 will continue in commercial operation. As long as petroleum coke is less expensive than coal, it will continue to be the preferred fuel for the JEA plant.

Fuel unloader at dock

Advantages of CFB Boilers

Combustion efficiency is improved in circulating fluidized bed (CFB) boilers compared to bubbling bed boilers. This is primarily because the elutriated particles are separated from the flue gas in cyclone collectors (hot cyclones with vortex finders) and returned to the furnace for further exposure to combustion temperature and high turbulence. This fact results in an increase of up to 4% in overall combustion efficiency. The particles captured in the cyclone collectors make up the circulating bed material within the "hot loop." The hot loop is a term given for the circulating path of bed material inside the boiler.



Schematic diagram of CFB boiler at JEA

Other advantages of CFB boilers over conventional PC-fired boilers are:

- Lower capital cost
- Ability to burn a wide range of low- to high-grade fuels
- Increased sulfur capture with less limestone consumption and low SO_2 emissions
- Lower operating temperatures compared with other types of boilers, thereby reducing slag formation and excess stack emissions
- Improved heat transfer with the increase in residence time for fuel and limestone
- Lower NOx emissions because of low operating temperatures

Lower operating temperatures mean fewer pollutants and less equipment needed to clean up the combustion process while burning a variety of fuels. The ratios between operating gas velocity and minimum solids entrainment velocity allow turndown ratios as high as four to one. Operation over a wide range of boiler loads is possible without starting and stopping burners and auxiliary equipment.

Fluidized Bed Combustion Systems

The ACFB boiler technology selected for the JEA project is an advanced method for utilizing coal and other solid fuels in an environmentally acceptable manner. The low combustion temperature allows SO_2 capture via limestone injection while minimizing NOx emissions. The technology provides the capability to burn a wide range of coal fuel blends. Presently, there are two types of fluidized bed boilers in commercial operation: bubbling bed and circulating bed.

CFB boiler under construction

Bubbling Bed Boilers

In the bubbling bed type boiler, a layer of solid particles (mostly limestone, sand, ash and calcium sulfate) is contained on a grid near the bottom of the boiler. This layer is maintained in a turbulent state as low velocity air is forced into the bed from a plenum chamber beneath the grid. Fuel is added to this bed and combustion takes place. Normally, raw fuel in the bed does not exceed 2% of the total bed inventory. Velocity of the combustion air is kept at a minimum, yet high enough to maintain turbulence in the bed. Velocity is not high enough to carry significant quantities of solid particles out of the furnace.

This turbulent mixing of air and fuel results in a residence time of up to five seconds. The combination of turbulent mixing and residence time permits bubbling bed boilers to operate at a furnace temperature below 1650°F. At this temperature, the presence of limestone mixed with fuel in the furnace achieves greater than 90% sulfur removal.

Boiler efficiency is the percentage of total energy in the fuel that is used to produce steam. Combustion efficiency is the percentage of complete combustion of carbon in the fuel. Incomplete combustion results in the formation of carbon monoxide (CO) plus unburned carbon in the solid particles leaving the furnace. In a typical bubbling bed fluidized boiler, combustion efficiency can be as high as 92%. This is a good figure, but is lower than that achieved by pulverized coal or cyclone-fired boilers. In addition, some fuels that are very low in volatile matter cannot be completely burned within the available residence time in bubbling bed-type boilers.

Circulating Fluidized Bed Boilers

The need to improve combustion efficiency (which also increases overall boiler efficiency and reduces operating costs) and the desire to burn a much wider range of fuels has led to the development and application of the CFB boiler. Through the years, boiler suppliers have been increasing the size of these high-efficiency steam generators. FW has designed (but not built) CFB boilers that are capable of producing 400 MWe of power.

continued on page 21

The Clean Coal Technology Program

The Clean Coal Technology (CCT) Program is a unique partnership between the federal government and industry that has as its primary goal the successful introduction of new clean coal utilization technologies into the energy marketplace. With its roots in the acid rain debate of the 1980s, the program has met its early objective of broadening the range of technological solutions available to eliminate environmental concerns associated with the use of coal for electric power production. As the program has evolved, it has expanded to address the need for new, high-efficiency power generating technologies that will allow coal to continue to be a fuel option well into the 21st century.

Begun in 1985 and expanded in 1987 consistent with the recommendations of the U.S. and Canadian Special Envoys on Acid Rain, the program has been implemented through a series of five nationwide competitive solicitations, or rounds. Each solicitation was associated with specific government funding and program objectives. After five rounds, the CCT Program comprises a total of 38 projects located in 18 states with a total investment value of over $5.2 billion. DOE's share of the total project costs is about $1.8 billion, or approximately 34% of the total. The projects' industrial participants (i.e., the non-DOE participants) are providing the remainder—about $3.5 billion.

Processes being demonstrated under the CCT Program have established a technology base that will enable the nation to meet more stringent energy and environmental goals. Also ready is a new generation of technologies that can produce electricity and other commodities, such as steam and synthesis gas, at high efficiencies consistent with concerns about global climate change.

Most of the CCT demonstrations are being conducted at commercial scale, in actual user environments, and under circumstances typical of commercial operations. These features allow the potential of the technologies to be evaluated in their intended commercial applications.

Each application addresses one of the following four market sectors:

- Advanced electric power generation
- Environmental control devices
- Coal processing for clean fuels
- Industrial applications

Given its programmatic success, the CCT Program serves as a model for other cooperative government/industry programs aimed at introducing new technologies into the commercial marketplace.

Two follow-on programs have been developed that build on the successes of the CCT Program. The Power Plant Improvement Initiative (PPII) is a cost shared program, patterned after the CCT Program, directed toward improved reliability and environmental performance of the nation's coal-burning power plants. Authorized by the U.S. Congress in 2001, the PPII involves eight projects having a total cost of $95 million. Private sector sponsors are expected to contribute nearly $61 million, exceeding the 50% private sector cost sharing mandated by Congress. Most of the PPII projects focus on technologies enabling coal-fired power plants to meet increasingly stringent environmental regulations at the lowest possible cost.

The second program is the Clean Coal Power Initiative (CCPI), also patterned on the CCT Program, authorized in early 2002. Valued at $330 million for the initial stage, this initiative will accelerate the commercial deployment of technology advancements that result in efficiency, environmental and economic improvement compared with available state-of-the-art alternatives. Proposals submitted under the CCPI are currently being evaluated.

CFBs offer a number of advantages:

Fuel Flexibility – The relatively low furnace temperatures are below the ash softening temperature for nearly all fuels. As a result, furnace design is independent of ash characteristics, thus allowing a given furnace to handle a wide range of fuels.

Low SO_2 Emissions – Limestone is an effective sulfur sorbent in the temperature range of 1500 to 1700°F. SO_2 removal efficiency of 90% has been demonstrated with good sorbent utilization.

Low NOx Emissions – The combination of low furnace temperatures and staging of air feed to the furnace produces very low NOx emissions.

High Combustion Efficiency – The long solids residence time in the furnace resulting from the collection/recirculation of solids via the cyclone, plus the vigorous solids/gas contact in the furnace caused by the fluidization air flow, results in high combustion efficiency, even with difficult-to-burn fuels.

Characteristics of CFB Boilers

In the furnace of a circulating fluidized bed boiler, gas velocity is increased to more than that in a bubbling bed boiler. This increase in velocity causes the dense mixture of solids (fuel, limestone and ash) to be carried up through the furnace. There is a minimum gas entrainment velocity required for the particles to lift and separate (elutriate) and flow up, through and out of the furnace.

Reaching this entrainment velocity marks the change from a bubbling bed boiler to a circulating bed boiler. At approximately 500°F bed temperature, air flows are above minimum and the entrainment velocity is reached.

Solids move up through the furnace at lower velocities than the air and gas mixture. This fact, coupled with the elongated furnace in a CFB boiler and recirculating bed material, allows particle residence times of up to several minutes in the furnace. During this long residence period, the crushed fuel particles are consumed in the combustion process.

The fuel is reduced in size during the combustion process and thoroughly mixed with limestone and the balance of the bed material. This action produces the "fines" (small particles of bed material) necessary to have circulating bed material in the "hot loop." Long residence time, coupled with small particle size and high turbulence, results in a better sulfur removal rate with less limestone than in a bubbling fluidized bed boiler. In addition, higher gas velocity produces heat transfer rates that are greater than in the bubbling bed.

In normal operation there is no defined fixed bed depth in a CFB boiler. There are different densities of circulating bed material depending on the weight of the particles. Heavy particles stay in the lower region of the furnace. As the height within the furnace increases, the smaller bed particles (less dense) enter the circulation path of the hot loop. When the particles break down enough, they are carried out of the hot loop (circulating path) with the flue gas as fly ash.

New 500-foot stack in foreground, with inset showing the stack interior

Sulfur Removal in CFB Boilers

Most of the sulfur in the fuel combines chemically with oxygen during the combustion process to form SO_2 and, to a limited extent, sulfur trioxide (SO_3). These sulfur oxides must be removed from the flue gas to comply with environmental regulations.

The mechanism for removing SO_2 with limestone is as follows:

Calcination of limestone:

$CaCO_3 + Heat \rightarrow CaO + CO_2$

Reaction with sulfur oxides (sulfation):

$CaO + O_2 + SO_2 \rightarrow CaSO_4$

The product, $CaSO_4$, is an inert substance known as gypsum. Limestone continuously reacts with the fuel at normal operating temperatures. The sulfation reaction requires that there always be an excess of limestone. The amount of excess limestone required depends on several factors, such as the amount of sulfur in the fuel, the temperature of the bed material in the furnace, and the physical and chemical characteristics of the limestone (reactivity).

The ideal reaction temperature range is 1500 to 1700°F.

There is little limestone reaction when the bed temperature is below 1500°F or above 1700°F. Within the optimum temperature range, about 90% of the SO_2 can be removed at an acceptable Ca/S ratio. Outside this temperature range, significant increases in limestone feed rate are required to maintain emission levels within regulated limits.

The CFB bed material typically contains limestone products as the predominant component, with smaller amounts of fuel, ash and impurities (for example, rocks or tramp iron). Calcium oxide content rises with decreasing fuel sulfur content and high removal rates. The ash content increases with higher ash fuels and those that are less friable, i.e., brittle.

Fresh limestone enters the furnace and, at the normal operating temperature, calcines by liberating CO_2. It then absorbs SO_2 from the burning fuel that sulfates the limestone, converting limestone to gypsum. In the calcining stage, limestone is physically weak and is easily decrepitated (crumbled) into dust and carried out of the bed (elutriated) by the furnace draft.

With a sulfur content in the fuel of 2.5% or more, enough SO_2 is produced during combustion that the limestone can readily sulfate (combine with the SO_2). This strengthens the limestone and reduces loss of limestone from decrepitation and elutriation. A low sulfur content can lead to loss of limestone through attrition. This loss must be compensated for by increasing limestone feed to maintain bed inventory and SO_2 capture. Gypsum and some excess limestone are carried out of the CFB furnace and trapped by the downstream flue gas cleanup equipment.

Demonstration Test Program

The demonstration test program will be conducted in accordance with the plan developed in coordination with DOE. The test program consists of the following major components.

Operational Testing will be performed to:

- Demonstrate unit functionality
- Establish initial operating, maintenance and inspection criteria
- Establish constraints related to dispatch of the unit
- Demonstrate continuous full- and part-load capability and performance

Operational testing includes a series of operability, reliability, and performance tests.

Operability involves tests of cold startups, warm startups, hot restarts, dispatch, minimum stable load, and operation at maximum continuous rating.

Reliability testing includes availability, capacity factor, and forced outage rate.

Performance testing will be conducted in conjunction with fuel flexibility testing, which involves burning four different fuels and fuel blends. The specific fuels to be tested are as follows:

- 100% Pittsburgh No. 8 high-sulfur coal
- 90% petroleum coke and 10% Pittsburgh No. 8 high-sulfur coal
- 50% petroleum coke and 50% Pittsburgh No. 8 high-sulfur coal
- 100% Illinois No. 6 high-sulfur coal

Fuel Flexibility Testing includes boiler capacity and controllability, load following capability, bed/cyclone agglomeration potential, and air quality control system performance.

Long Term Durability Testing consists of reviewing significant maintenance issues experienced with major equipment throughout the demonstration period.

Interior of fuel storage dome

Operating Results

The JEA Unit 2 CFB boiler has operated at full load, achieving rated output in May 2002. The unit can maintain operation on both coal and coal fuel blends. However, satisfactory operation on 100% petroleum coke has not yet been demonstrated. One major problem when operating on 100% petroleum coke has been plugging in the hot gas path, specifically in the cyclone and the INTREX™ heat exchanger. Steps are being taken to remedy this situation.

Initial results indicate that the JEA plant is capable of meeting emissions guarantees when operating on both coal and coal fuel blends.

JEA receives the *Power* magazine 2002 Powerplant award. On hand for the award ceremony were (left to right): Mike Hightower, JEA's Board Chairman; Joey Duncan, JEA's Project Manager; the Honorable Corrine Brown, U.S. House of Representatives; Rita Bajura, Director of U.S. DOE's National Energy Technology Laboratory; and Bob Schwieger, *Power* magazine consulting editor

Awards

The JEA project received the 2002 Powerplant Award from *Power* magazine. This award recognizes outstanding achievement in "the development of a successful repowering strategy for converting existing oil/gas-fired steam plants to solid fuels to increase efficiency while reducing both emissions and the cost of electricity."

Bob Dyr, JEA's Boiler Island Project Manager, was presented the Engineer of the Year award by the Florida Engineers Society in 2002 for outstanding technical achievement, on behalf of the project team.

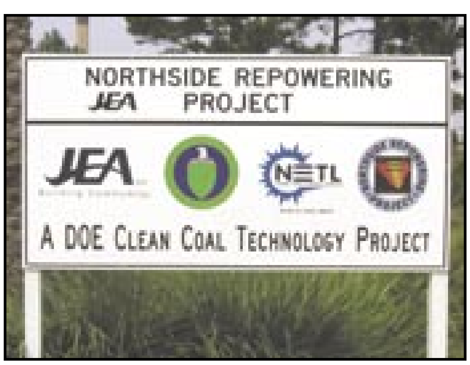
Commercial Applications

ACFB technology has potential application in both the industrial and utility sectors, for use in repowering existing plants a well as in new facilities. ACFB is attractive for both baseload and dispatchable power applications because it can be efficiently turned down to as low as 25% of full load. While the efficiency of ACFB is on a par with conventional PC-fired plants, the advantage of ACFB is that coal of any sulfur or ash content can be used, and any type or size unit can be repowered. In repowering applications, an existing plant area is used, and coal- and waste-handling equipment as well as steam turbine equipment are retained, thereby extending the life of the plant.

In its commercial configuration, ACFB technology offers several potential benefits compared with conventional PC-fired systems:

- Lower capital costs
- Reduced SO_2 and NOx emissions at lower cost
- Higher combustion efficiency
- A high degree of fuel flexibility, including use of renewable fuels
- Dry, granular solid by-product material that is easily disposed of or sold.

Recently, two other commercial scale ACFB projects in the U.S. have been announced, one at Reliant Energy's Seward Station in Pennsylvania and the other at Tractabel's Red Hills Station in Mississippi.



Conclusions

The JEA Large-Scale CFB Combustion Demonstration Project is demonstrating the commercial application of this advanced technology for generating electricity. The two boilers at the Northside Station are the largest CFBs in the world burning coal fuel blends. Despite the large furnace size, solids distribution is good, lending confidence to the CFB design.

Power production from each boiler on coal feed meets the target goal of 297.5 MWe gross (265 MWe net). Emissions of atmospheric pollutants are below the stringent requirements set for the project.

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List of Acronyms and Abbreviations

ACFB .... atmospheric circulating fluidized bed
AFBC .... atmospheric fluidized bed combustor
AQCS .... air quality control system
BOP .... balance of plant
Btu .... British thermal unit
$CaCO_3$ .... calcium carbonate
CaO .... calcium oxide
$Ca(OH)_2$........................ calcium hydroxide
$CaSO_4$........................... calcium sulfate
CAAA........................... Clean Air Act Amendments of 1990
CCPI............................. Clean Coal Power Initiative
CCT .... Clean Coal Technology
CFB .... circulating fluidized bed
CO_2............................... carbon dioxide
CRT .... cathode ray tube
DCS .... distributed control system
DOE .... U.S. Department of Energy
EPA............................... U.S. Environmental Protection Agency
FBC .... fluidized bed combustion
FF .... fabric filters

Stack shortly after 9/11/2001

kWh .... kilowatt hour
micron .... one millionth of a meter
MCR .... maximum continuous rating
$MgCO_3$ .... magnesium carbonate
$Mg(OH)_2$ .... magnesium hydroxide
MWe .... megawatts of electric power
MWh .... megawatt hours of electric power
NETL .... National Energy Technology Laboratory
NOx .... nitrogen oxides
PC .... pulverized coal
PFBC .... pressurized fluidized bed combustor
PLC .... programmable logic controller
PM .... particulate matter
PM_{10} .... particulate matter having a diameter of 10 microns (μm) or less
PPII .... Power Plant Improvement Initiative
psig .... pressure, pounds per square inch (gauge)
SDA .... spray dryer absorber
SO_2 .... sulfur dioxide
SO_3 .... sulfur trioxide
tph .... tons/hr
VOC .... volatile organic compound
wt % .... percent by weight

Sunset at JEA

To Receive Additional Information

To be placed on the Department of Energy's distribution list for future information on the Clean Coal Technology Program, the demonstration projects it is financing, or other Fossil Energy Programs, please contact:

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