

Demonstration of Innovative Applications of Technology for the CT-121 FGD Process

Project completed

Participant

Southern Company Services, Inc.

Additional Team Members

Georgia Power Company—host

Electric Power Research Institute—cofounder

Radian Corporation—environmental and analytical consultant

Ershigs, Inc.—fiberglass fabricator

Composite Construction and Equipment—fiberglass sustainment consultant

Acentech—flow modeling consultant

Ardaman—gypsum stacking consultant

University of Georgia Research Foundation—by-product utilization studies consultant

Location

Newnan, Coweta County, GA (Georgia Power Company's Plant Yates, Unit No. 1)

Technology

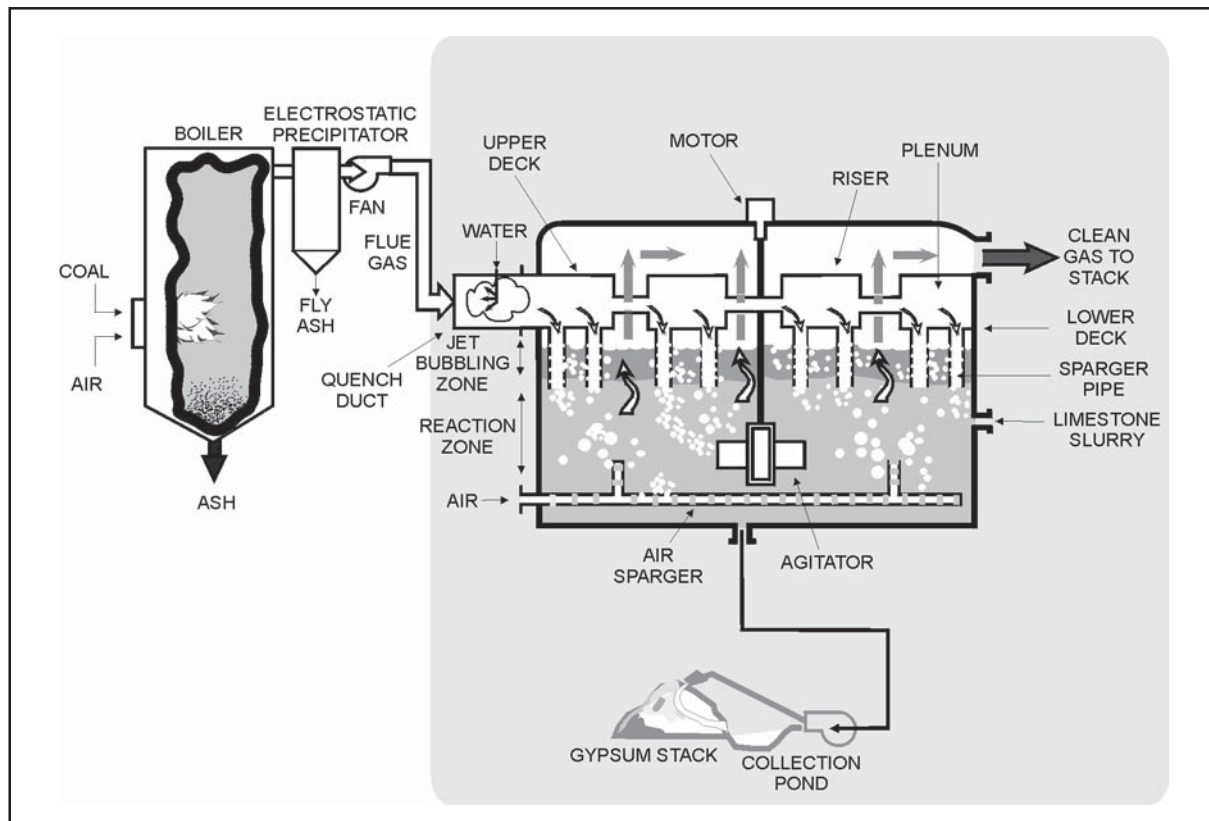
Chiyoda Corporation's Chiyoda Thoroughbred-121 (CT-121) advanced flue gas desulfurization (AFGD) process using the Jet Bubbling Reactor®

Plant Capacity/Production

100 MWe

Coal

Illinois No. 5 & No. 6 blend, 2.5% sulfur (baseline)
 Range of test coals 1.2–4.3% sulfur



Project Funding

Total	\$43,074,996	100%
DOE	21,085,211	49
Participant	21,989,785	51

Project Objective

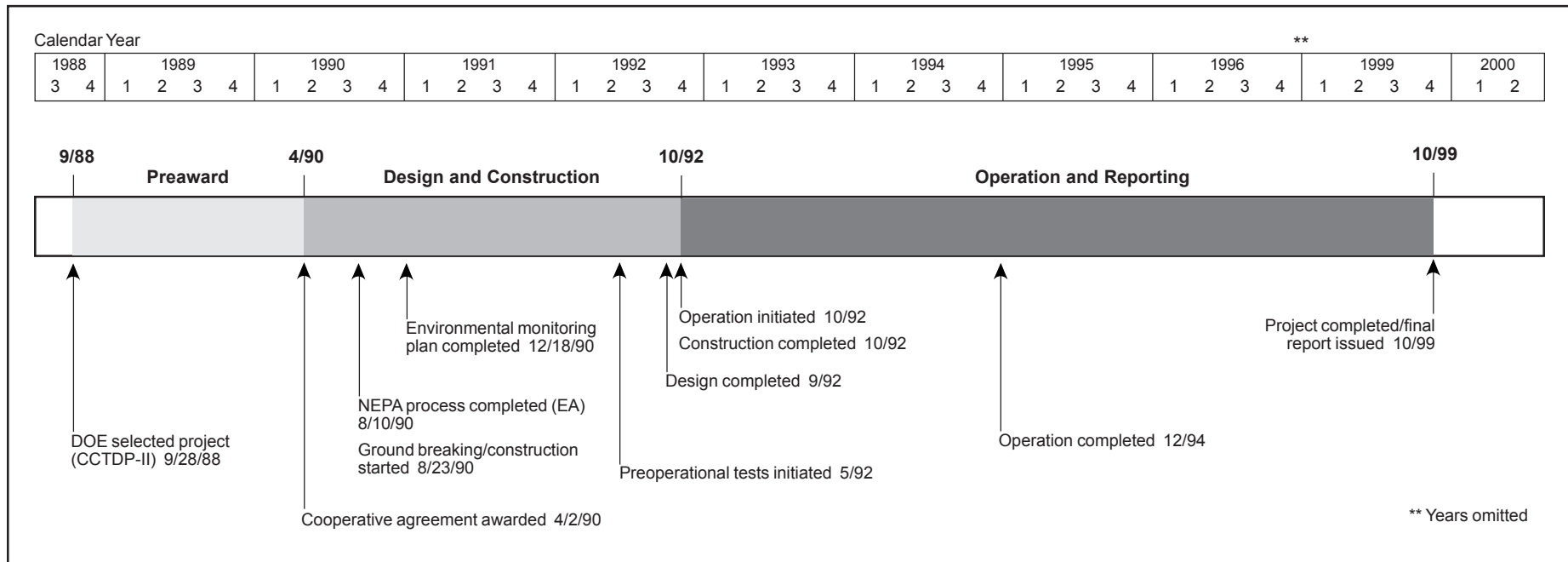
To demonstrate 90% SO₂ control at high reliability with and without simultaneous particulate control; to demonstrate reliable operation while eliminating spare absorber modules; to evaluate use of fiberglass-reinforced plastic (FRP) vessels to eliminate flue gas prescrubbing and re-heat, and to enhance reliability; and to evaluate use of gypsum to reduce waste management costs.

Technology/Project Description

The project demonstrated the CT-121 AFGD process, which uses a unique absorber design known as the Jet

Bubbling Reactor® (JBR). The process combines limestone AFGD reaction, forced oxidation, and gypsum crystallization in one process vessel. The process is mechanically and chemically simpler than conventional AFGD processes and can be expected to exhibit lower cost characteristics.

The flue gas enters underneath the scrubbing solution in the JBR. The SO₂ in the flue gas is absorbed and forms calcium sulfite (CaSO₃). Air is bubbled into the bottom of the solution to oxidize the calcium sulfite to form gypsum. The slurry is dewatered in a gypsum stack, which involves filling a diked area with gypsum slurry. Gypsum solids settle in the diked area by gravity, and clear water flows to a retention pond. The clear water from the pond is returned to the process.



Results Summary

Environmental

- Over 90% SO₂ removal efficiency was achieved at SO₂ inlet concentrations of 1,000–3,500 ppm with limestone utilization over 97%.
- JBR achieved particulate removal efficiencies of 97.7–99.3% for inlet mass loadings of 0.303–1.392 lb/10⁶ Btu over a load range of 50–100 MWe.
- Capture efficiency was a function of particle size:
 - >10 microns—99% capture
 - 1–10 microns—90% capture
 - 0.5–1 micron—negligible capture
 - <0.5 micron—90% capture
- Hazardous air pollutant (HAP) testing showed greater than 95% capture of hydrogen chloride (HCl) and hydrogen fluoride (HF) gases, 80–98% capture of most trace metals, less than 50% capture of mercury and cadmium, and less than 70% capture of selenium.
- Gypsum stacking proved effective for producing wall-board/cement-grade gypsum.

Operational

- FRP-fabricated equipment proved durable both structurally and chemically, eliminating the need for a flue gas prescrubber and reheat.
- FRP construction combined with simplicity of design resulted in 97% availability at low ash loadings and 95% at high ash loadings, eliminating the need for a spare reactor module.
- Simultaneous SO₂ and particulate control were achieved at fly ash loadings similar to those of an electrostatic precipitator (ESP) that has marginal performance.

Economic

- Capital costs for project equipment, process, and startup were \$29 million, or \$293/kW at Plant Yates.
- Fixed O&M costs were \$354,000/yr (1994\$), and variable operating costs were \$34–64/ton of SO₂ removed, depending on specific test conditions.

- Generic plant costs were not estimated; however, elimination of the need for flue gas prescrubbing, reheat, and a spare module should result in capital requirements far below those of contemporary conventional flue gas desulfurization (FGD) systems.

Project Summary

The CT-121 AFGD process differs from the more common spray tower type of flue gas desulfurization systems in that a single process vessel is used in place of the usual spray tower/reaction tank/thickener arrangement. Pumping of reacted slurry to a gypsum transfer tank is intermittent. This allows crystal growth to proceed essentially uninterrupted, resulting in large, easily dewatered gypsum crystals (conventional systems employ large centrifugal pumps to move reacted slurry causing crystal attrition and secondary nucleation).

The demonstration spanned 27 months, including startup and shakedown, during which approximately 19,000 hours were logged. Exhibit 3-16 summarizes operating statistics. Elevated particulate loading included a short test with the electrostatic precipitator (ESP) completely deenergized, but the long-term testing was conducted with the ESP partially deenergized to simulate a more realistic scenario, *i.e.*, a CT-121 retrofit to a boiler with a marginally performing particulate collection device. The SO₂ removal efficiency was measured under five different inlet concentrations with coals averaging 2.5% sulfur and ranging from 1.2– 4.3% sulfur (as burned).

Exhibit 3-16
Operation of CT-121 Scrubber

	Low Ash Phase	Elevated Ash Phase	Cumulative for Project
Total test period (hr)	11,750	7,250	19,000
Scrubber available (hr)	11,430	6,310	18,340
Scrubber operating (hr)	8,600	5,210	13,810
Scrubber called upon (hr)	8,800	5,490	14,290
Reliability ^a	0.98	0.95	0.96
Availability ^b	0.97	0.95	0.97
Utilization ^c	0.73	0.72	0.75

^a Reliability = hours scrubber operated divided by the hours called upon to operate
^b Availability = hours scrubber available divided by the total hours in the period
^c Utilization = hours scrubber operated divided by the total hours in the period

Operating Performance

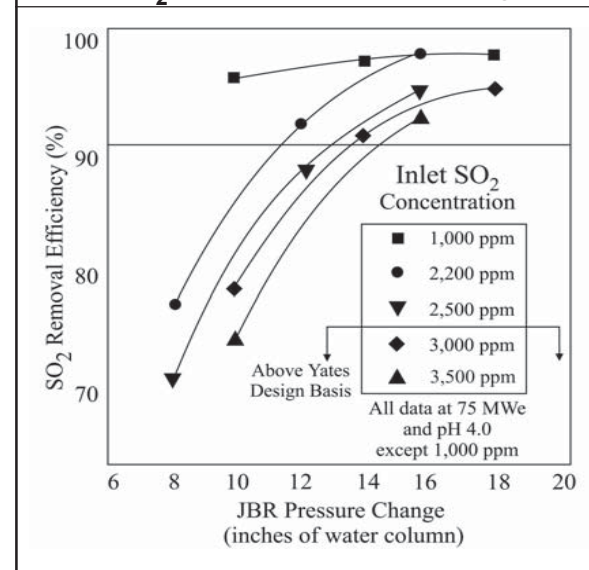
Use of FRP construction proved very successful. Because their large size precluded shipment, the JBR and limestone slurry storage tanks were constructed on site. Except for some erosion experienced at the JBR inlet transition duct, the FRP-fabricated equipment proved to be durable, both structurally and chemically. Because of the high corrosion resistance, the need for a flue gas pre-scrubber to remove chlorides was eliminated. Similarly, the FRP-constructed chimney proved resistant to the corrosive condensates in wet flue gas, eliminating the need for flue gas reheat.

Availability of the CT-121 scrubber during the low ash test phase was 97%. Availability dropped to 95% under the elevated ash loading conditions due largely to sparger tube plugging problems, precipitated by fly ash agglomeration on the sparger tube walls during high ash loading when the ESP was deenergized. The high reliability demonstrated verified that a spare JBR is not required in a commercial design offering.

Environmental Performance

Exhibit 3-17 shows SO₂ removal efficiency as a function of pressure drop across the JBR for five different inlet concentrations. The greater the pressure drop, the greater the depth of slurry traversed by the flue gas. As the SO₂ concentration increased, removal efficiency decreased, but adjustments in JBR fluid level could maintain the efficiency above 90% and, at lower SO₂ concentration levels, above 98%. Limestone utilization remained above 97% throughout the demonstration. Long-term particulate capture performance was tested with a partially deenergized ESP (approximately 90% efficiency), and is summarized in Exhibit 3-18. Analysis indicated that a large percentage of the outlet particulate matter is sulfate, likely a result of acid mist and gypsum carryover.

Exhibit 3-17
SO₂ Removal Efficiency



This reduces the estimate of ash mass loading at the outlet to approximately 70% of the measured outlet particulates.

For particulate sizes greater than 10 microns, capture efficiency was consistently greater than 99%. In the 1–10 micron range, capture efficiency was over 90%. Between 0.5 and 1 micron, the particulate removal dropped at times to negligible values, possibly due to acid mist carryover entraining particulates in this size range. Below 0.5 micron, the capture efficiency increased to over 90%. Calculated air toxics removals across the CT-121 JBR, based on the measurements taken during the demonstration, are shown in Exhibit 3-19.

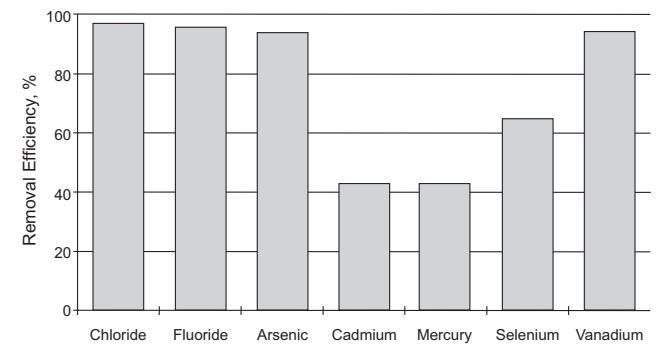
As to solids handling, the gypsum stacking method proved effective in the long term. Although chloride content was initially high in the stack due to the closed loop nature of the process (with concentrations often exceeding 35,000 ppm), a year later the chloride concentration in the gypsum dropped to less than 50 ppm, suitable for wallboard and cement applications. The reduction in chloride content was attributed to rainwater washing the stack.

Exhibit 3-18
CT-121 Particulate Capture Performance
(ESP Marginally Operating)

JBR Pressure Change (inches of water column)	Boiler Load (MWe)	Inlet Mass Loading (lb/10 ⁶ Btu)	Outlet Mass Loading* (lb/10 ⁶ Btu)	Removal Efficiency (%)
18	100	1.288	0.02	97.7
10	100	1.392	0.010	99.3
18	50	0.325	0.005	98.5
10	50	0.303	0.006	98.0

*Federal NSPS is 0.03 lb/10⁶ Btu for units constructed after September 18, 1978. Plant Yates permit limit is 0.24 lb/10⁶ Btu as an existing unit.

Exhibit 3-19
CT-121 Air Toxics Removal
(JBR Components Only)



Economic Performance

The capital cost of the Plant Yates CT-121 project was \$29,335,979, or \$293/kW, which includes equipment, process, and start-up costs. The annual fixed O&M cost was \$354,000/yr. (1994\$). Variable operating cost was \$34–64/ton of SO₂ removed (1994\$), depending on specific test conditions.

FRP construction eliminates the need for prescrubbing and reheating flue gas. High system availability eliminates the need for a spare absorber module. Particulate removal capability eliminates the need for expensive (capital-intensive) ESP upgrades to meet increasingly strict environmental regulations.

Commercial Applications

Involvement of Southern Company (which owns Southern Company Services, Inc.), with more than 20,000 MWe of coal-fired generating capacity, is expected to enhance confidence in the CT-121 process among other large high-sulfur coal boiler users. This process will be applicable to 370,000 MWe of new and existing generating capacity by the year 2010. A 90% reduction in SO₂ emissions from only the retrofit portion of this capacity represents more than 10,500,000 tons/yr of potential SO₂ control.

Plant Yates continues to operate with the CT-121 scrubber as an integral part of the site's CAAA compliance strategy.

The project received *Power* magazine's 1994 Powerplant Award. Other awards include the Georgia Chapter of the Air and Waste Management Association's 1994 Outstanding Achievement Award, the Georgia Chamber of Commerce's 1993 Air Quality Citizen of the Year Award, and the Composites Institute (Society of Plastics Industries) 1996 Design Award of Excellence.

Contacts

Steve Woodfield, (205) 992-6223
 Southern Company
 P.O. Box 2625 / bin no. B223
 Birmingham, AL 35291
 (205) 257-7161 (fax)
 swwoodfi@southernco.com

Victor K. Der, DOE/HQ, (301) 903-2700
 victor.der@hq.doe.gov

Thomas A. Sarkus, NETL, (412) 386-5981
 sarkus@netl.doe.gov

References

Demonstration of Innovative Applications of Technology for Cost Reductions to the CT-121 FGD Process. Final Report. Volumes 1-6. Southern Company Services, Inc. January 1997.

Comprehensive Report to Congress on the Clean Coal Technology Program: Demonstration of Innovative Applications of Technology for the CT-121 FGD Process. Southern Company Services, Inc. Report No. DOE/FE-0158. U.S. Department of Energy. February 1990. (Available from NTIS as DE9008110.)

Demonstration of Innovative Applications of Technology for the CT-121 FGD Process Project—Performance Summary. U.S. Department of Energy. August 2002.