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ANATOMY OF A WTE RETROFIT: START TO FINISH

Donald J. Castro, P.E.
HDR Engineering, Inc.
128 S. Tryon Street
Charlotte, North Carolina 28202-5001
(704) 338-1800
Fax: (704) 338-6760

John S. Hadfield, P.E.
Southeastern Public Service Authority of Virginia
723 Woodlake Drive
Chesapeake, Virginia 23320
(804) 420-4700
Fax: (804) 424-4133

ABSTRACT

This paper describes the retrofit of scrubber/baghouse air pollution control systems at an existing coal and refuse-derived fuel fired power plant located in Portsmouth, Virginia. The paper will describe the reason for the retrofit, the initial planning process, financing of the project, engineering and procurement decisions and their rationale, key construction issues, initial performance test results, and lessons learned. The initially projected and actual costs for project implementation will also be described.

INTRODUCTION

Southeastern Public Service Authority of Virginia (SPSA) is an integrated solid waste management authority serving the residential and commercial sectors for eight communities in southeastern Virginia's Tidewater area. A key element of the integrated solid waste management strategy is the preparation of Refuse-Derived Fuel (RDF), which is burned to produce steam and electricity for the US Navy's Norfolk Naval Shipyard. SPSA owns and operates the RDF production facility, and operates the coal and RDF-fired power plant for the US Navy.

Refuse-Derived Fuel Production

The RDF production facility consists of three parallel lines of production capacity, with total processing capability of 2,000 tons (1814.3 Mg) per day on a two-shift basis. Municipal solid waste (MSW) is delivered to the facility by transfer trailers from SPSA's eight transfer stations, and by packer trucks from the local communities and commercial haulers.

Mixed MSW is converted to RDF in a two-stage tromelling process, which includes several stages of magnetic separation of ferrous materials, as well as handpicking of aluminum beverage cans. The oversized materials are shredded in a vertical hammer mill, and the undersized materials are diverted to the landfill. The process produces minus 4-inch (10.2 mm) size fuel with an average heat content of 5,400 Btu/lb. (12,552J/g).

RDF is transported to the Norfolk Naval Shipyard Steam Plant by a belt conveyor consisting of underground and overhead sections. At the power plant, the fuel is either fed directly to the boilers or stored in a pit for later recovery with a grapple crane.

Power Plant Description

The power plant consists of four stoker-fired boilers, each rated for 550 tons per day of RDF (498.9 MG per day) or 133 tons per day of low sulfur stoker coal (120.7 MG/day). The boilers produce superheated steam at 700 psig (48.3 bar) and 750F (398.9 C). Steam is used to drive condensing steam turbine generators, and turbine extraction steam is transported to the shipyard for use in process and heating systems. The primary fuel at the power plant is RDF, supplemented by coal during periods of RDF feed interruption or shortage.

The original power plant air pollution control equipment consisted of a cyclone separator located upstream of a hot precipitator (ESP), followed by a regenerative air heater, induced fan, and stack discharge. The cyclone was used to remove large particles and "sparklers" from the flue gas stream before entering the ESP. The ESP was configured in eight electrical fields and equipped with eight hoppers for ash discharge. The extensive modifications to the original air pollution control system are described below.

THE RETROFIT UNFOLDS

Stage One - Dioxins and Furans

During stack tests conducted in late 1991, the level of stack emissions of dioxins and furans was found to be considerably higher than permitted levels. The plant's permit with the Virginia Department of Environmental Quality, Air Board, stipulated a maximum allowed level of dioxin and furan emissions at 1.0 Ng/dscm, based on the toxic equivalent method. Measured levels on one of the boilers firing RDF were orders-of-magnitude higher than permitted. SPSA immediately shut down RDF firing and switched over to coal. Consultations with the Air Board led to a health risk assessment to determine if continued RDF firing would cause adverse health risks to the public or plant workers. The health risk assessment demonstrated that the risk of continuing to operate was acceptable and the plant resumed RDF firing. At the same time, a task force was formed to investigate the cause of the elevated dioxin and furan levels, and to come up with a plan for bringing the plant into compliance with permitted levels.

At the time that these events were unfolding, the US Environmental Protection Agency was in the process of issuing proposed rules applicable to large municipal waste combustors. For existing plants, the early drafts of this document were known as "Emissions Guidelines." The draft available in late 1991 contained limits for particulates, hydrogen chloride, sulfur dioxide, and carbon monoxide emissions. The proposed levels for all parameters except dioxins and furans were considerably more stringent than those contained in the existing state permit for the facility. Faced with forthcoming federal regulations, the task force formed by SPSA had an additional challenge: to come up with an integrated plan to meet the intent of the proposed federal regulations for dioxins and furans on an accelerated basis, and to bring the plant into compliance with the remaining parameters at minimum cost.

The first step was to understand the reasons for the elevated dioxin emissions. Two parallel studies were initiated. One part focused on improvements to the combustion process itself, with the aim of lowering furnace emissions of dioxins and furans thought to be created by incomplete combustion of chlorine containing waste products. This effort included several rounds of tests aimed at lowering emissions and stratification of carbon monoxide in the boiler, on the basis that CO was a good measure of the degree of completeness of the combustion process, and that elevated CO levels would correspond to elevated dioxin/furan levels. Suffice it to say that, while these tests did lead to some improvement in CO levels, the impact on stack emissions of dioxins and furans was either minimal or adverse. However, during one set of tests, a crude water spray system was used to lower the flue gas temperature at the economizer outlet. This test run significantly reduced dioxin emissions, and was consistent with the results of previous studies conducted at other facilities showing a strong dioxin-temperature relationship.[1]

Stage Two - Detailed Retrofit Planning

The second study focused on the long-term solution to the overall compliance plan, including HCl and SO_2 control measures required to meet the draft Emission Guidelines. The study examined available air pollution control technology approaches which would be capable of meeting all of the required emission limits, while being constructable on one boiler at a time. Alternatives examined included both wet and dry scrubbers for HCl and SO_2 removal, as well as systems with and without the existing ESPs. The acid gas removal requirement using a semi-dry scrubber ahead of the particulate collection device fits well with the need to lower the flue gas temperature to minimize dioxin and furan formation. After examining all of the feasible arrangements, the selected configuration consisted of a new tubular air heater located downstream of the economizer, followed by a semi-dry scrubber, a baghouse in place of the existing ESP, and a new induced draft fan for each unit. The existing cyclone separators and regenerative air heaters were to be demolished.

A major decision had to be made with respect to the reuse of the existing ESP, or the more costly alternative of a baghouse. This is a decision that many other facilities are facing today, in light of the now promulgated requirements of 40CFR 60, Part Cb[2]. Keep in mind that this decision had to be made in early 1992, prior to knowing what the final federal requirements would be. At that time, it was known that the 1990 Clean Air Act Amendments required additional limits to be promulgated for heavy metals emissions (mercury, cadmium, and lead), and that the basis for the final requirements would be Maximum Achievable Control Technology (MACT). Although the existing ESPs were large enough to meet, on paper, the proposed particulate emission limits, the decision to implement a baghouse was made for two primary reasons. First, the implementation of the aforementioned scrubber and air heater components would be a major construction project in and of themselves. SPSA only wanted to undertake such a large investment once, and the thought of a subsequent baghouse addition required to meet heavy metal or dioxin limits would not be acceptable. Second, the MACT basis seemed to favor baghouses as the most effective in controlling very fine particulates.

The retrofit planning process consisted of a very detailed conceptual design of the selected alternative, along with cost estimates and an implementation schedule for constructing one unit at a time, while keeping the rest of the plant in

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[1] "Control of PCDD/PDCF Emissions from Refuse-Derived Fuel Combustors", J.D. Kilgroe and T.G. Brna, US EPA Air and Energy Engineering Research Laboratory; A. Finkelstein and R. Klicius, Environment Canada, Urban Activities Division; Chemosphere, Vol 20, Nos 10-12, 1990

[2] 40 CFR Part 60, Standards of Performance for Municipal Waste Combustors and Emission Guidelines; Final Rules, Subpart CB.

service. The plan was reviewed by SPSA and the Navy, and then presented to the Virginia Department of Environmental Quality, Air Board. The implementation plan called for the retrofit to be completed by February 1996, which was the compliance date specified in the draft federal Emissions Guidelines. The plan was accepted by the Air Board, and its implementation was mandated by a consent agreement entered into in mid 1992.

Stage Three - Financing

The estimated cost of the project, including engineering, design, procurement, installation, construction administration, and testing was estimated to be $31.4 million in 1993 dollars. Table 1 shows the breakdown of this estimate as originally planned and the actual funds expended for each item. The funds were obtained by a long term revenue bond offering, which was closed in the spring of 1993. The impact of the project's cost on the system-wide tipping fee was estimated to be about $3 per ton of MSW.

Table 1
SDA/Fabric Filter Retrofit
Project Budget
(January 1996)

Item	Budget	Actual*
SDAs, Fabric Filters, Supply & Erection	$16,300,000	$15,993,000
Fabric Filter & Ductwork Erection	---	1,330,000
ESP & Ductwork Remedi ation & Demolition	---	1,545,000
ID Fans, Mat'l. & Shipment	760,000	424,000
ID Fan Motors - 2-speed, Mat'l. & Shipment	350,000	332,000
Tubular Air Heaters & Field Tube Installation	600,000	525,000
Mechanical/Electrical Provisions, Mat'l. & Labor	460,000	558,000
Piling, Foundations, Site Civil Work, Mat'l. & Labor	1,350,000	1,068,000
NO_x Control System Supply & Installation	2,400,000	N/R
Carbon Injection System, Supply & Installation	750,000	N/R
Engineering, Design & Procurement	2,500,000	2,800,000
Construction Coordination & Start-up Support	1,000,000	1,042,000
Stack Tests & System Acceptance Tests	600,000	600,000
Subtotal	$27,070,000	$26,217,000
Contingency	4,060,000	--
Total Installed Cost	$31,130,000	$26,217,000

* Actual contracted costs or current projections to complete, rounded to nearest $1,000.

Stage Four - Engineering & Procurement

Detailed engineering and procurement was initiated in mid 1992. The implementation plan's approach was to break the project into several procurement and construction phases. Procurement packages were developed for the air heaters and induced draft fans. The scrubber/fabric filter contract was configured as a design/build contract with installation responsibilities for the air heaters and induced draft fans, as well as supply and erection of the scrubbers, fabric filters, and lime preparation building and systems. This contract included performance responsibilities for air emissions, as well as schedule requirements with substantial Liquidated Damages.

Additional packages were issued as fully-engineered, construction-only contracts, which were issued only after selection of the scrubber/baghouse vendor and integration of plant-specific design configurations into the overall site plan. The major construction packages were developed for piling, foundations, and mechanical/electrical tie-ins to existing plant systems.

The specifications for the scrubber/fabric filter/lime preparation facilities were very detailed, with prescriptive requirements for the layout, configuration, sizing, and materials of construction to be used. The development of the configuration and the equipment-related specifications was done after visiting several existing plants with scrubber/ baghouse equipment; interviewing plant operations and maintenance personnel about equipment performance and layout considerations; and identifying strengths and weaknesses of the installed systems. These trips were done by a team of SPSA and HDR personnel, and were very beneficial in developing the detailed plant specifications.

The scrubber/baghouse specifications were issued for bid in December 1992, and a contract was awarded in May 1993. Soon thereafter, releases for fabrication were issued for the air heaters and the new induced draft fans and drives, which were timed for site delivery no sooner than one month prior to planned installation dates. This was because the site did not have an abundance of available laydown space. In addition, as soon as loads were confirmed with the scrubber/baghouse contractor, the piling was designed, and the piling contractor was mobilized to the job site in the fall of 1993.

The selected configuration for the new air pollution control equipment consisted of four rotary atomizer type spray dryer absorbers (scrubbers). Each is a 27-foot (8.2m) diameter vessel, with 32-foot (9.8m) high straight sections, and a conical bottom hopper. The scrubbers were elevated such that the existing fly ash conveyors could be reused. Each scrubber has a full height walk-in weather enclosure at the upper operating level. Reuse of existing stairways and access platforms was maximized.

The fabric filter is configured with pulse jet cleaning systems, and consists of eight isolatable compartments. Bags are 16 feet (4.8m) long by 6-inch (15.2 mm) diameter P84[3] polyimide fiber material. The net-net air to cloth ratio is

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[3] Trademark of Lenzing USA Corp.

4.0:1, with one compartment isolated for maintenance and one in cleaning. A unique aspect of this project is that the baghouse is constructed within the existing envelope formed by the ESP's outer casing and hoppers. All internals of the ESPs were removed, and the gutted casing turned into an eight-compartment baghouse. This led to some interesting environmental and construction issues, which are further described below.

The lime preparation facilities are common to all four units, and housed in a new building. The pebble lime silo is sized for 7-day capacity, and feeds dual rotary feeders and paste type slakers. Two lime slurry tanks, each sized for 8-hour storage capacity, are provided. Each train of slakers, slurry tanks and slurry pumps serves two boilers. A dilution water tank and two dilution water pumps are also housed in the lime preparation building. The building is generously sized, provided with washdown and drainage features, adequate heating, ventilation and lighting, and with maintenance access provisions for all key equipment. The building is configured with a separate section for the compressed air system, electrical and PLC equipment areas, which are separated from the lime-handling areas by a full height wall.

Stage Five - Construction

Construction began in the fall of 1993, with the mobilization to the site of the piling contractor. The new scrubbers and lime preparation facilities required the installation of 170 new piles, all of which were installed while the plant remained operational. Immediately following pile installation, the foundation contractor poured pile caps and grade beams. This work progressed relatively smoothly and was completed on schedule in early 1994. In addition, the electrical, water, and drainage tie-ins to pre-established points were made ready for later completion by the scrubber/fabric filter contractor.

The scrubber/fabric filter erection began in January 1994. A large 300-ton (272 Mg) capacity hydraulic crawler crane was erected, and structural steel for scrubber erection began in February. The implementation plan was designed to perform all of the scrubber and lime preparation facility erection prior to taking the boilers off line for ESP, cyclone and ductwork demolition, and subsequent fabric filter erection. The demolition and fabric filter erection phase was to be implemented on one boiler at a time, with the remainder of the plant remaining in operation. The scrubber and lime preparation erection proceeded on or ahead of the planned schedule.

While this work was underway, a detailed plan for the demolition and fabric filter erection phases was being formulated with the scrubber/fabric filter contractor. The plan concerned the environmental and personnel protection means and methods to be employed to work within the confines of the ESPs, ductwork, and other areas known to contain high levels of lead, cadmium, arsenic, and other potentially hazardous materials. While the presence of these materials was known at the time the contract was negotiated, the OSHA regulations governing such work were evolving, and the need to proceed with other phases of the project necessitated that the plans be finalized at a later date. Ultimately, these negotiations failed to produce a workable plan acceptable to both parties, and a new course of action was formulated.

Stage Six - Demolition/Remediation

The chosen course of action was to separate the remediation/demolition work from the scrubber/fabric filter contractor's scope of work, and to hire a specialty contractor to perform this work. This was done in late 1994, and the remediation/demolition on the first boiler commenced in early 1995. The work was governed primarily by OSHA regulations regarding lead exposure to workers. The specialty contractor's personnel were provided with forced air respiratory equipment, full tyvex suits, and closely supervised by an on-site Certified Industrial Hygienist. Following demolition of the ESP internals and ductwork, the ESP's remaining surfaces were extensively pressure washed, with the objective of reducing the surface contamination to levels which would enable the remaining erection work to be done by normally clothed industrial workers. However, there was no practical degree of cleanliness which would enable the work to proceed in that fashion, and the decision was made to continue using the specialty contractor's workers for erection in potentially contaminated areas.

The process of contracting for and mobilizing the specialty contractor, along with slower than expected progress, caused the first schedule delay on this project. The demolition/erection phase on the first unit was planned to take 115 days; the actual completion took 179 days. Subsequent units were completed in 127 days, 105 days, and, as of the date of this paper, the last unit is under construction, with completion expected in late March, 1996.

Stage Seven - Startup & Operation

Startup of the units progressed without major problems. Operator and maintenance training was conducted prior to the first unit startup, and personnel quickly adapted to the new equipment. There were no unusual events, and, to date, no forced outages caused by the new air pollution control equipment.

Performance tests were conducted after each unit had a minimum of 30 days run time on RDF. Results of the first two units' stack tests confirmed that they were operating well within guaranteed levels, and well below the levels required under the newly issued 40CFR 60, Part Cb limits for particulates, dioxins and furans, lead, cadmium, mercury, hydrogen chlorides, and sulfur dioxides. Table 2 shows the average performance levels achieved compared to the Part Cb limits. Of particular note is the low level of dioxin and furan emissions, which are less than 5 ng/dscm, and representing more than 99.9% removal in the scrubber/baghouse. Particulate emissions are also more than an order-of-magnitude below the new Part Cb standard.

Table 2
Stack Test Summary
Unit 3 & 4 Averages

		Limit*
Stack Concentration, gr/dscf		
@ 7% O_2:	-	
- Particulates	0.00070	0.012
Stack Concentration, mg/dscm		
@ 7% O_2:		
- Cadmium	0.0008	0.04
- Lead	0.026	0.49
- Mercury	0.009	0.080
Stack Concentration, ng/dscm		
@ 7% O_2:		
- Total PCDD/PCDF	3.72	30
Stack Concentration, ppmdv		
@ 7% O_2:		
- Hydrogen Chloride	18.1	315
- Sulfur Dioxide	28.8	35

* 40CFR60, Part Cb Emission Limit

Stage Eight - the EPA Steps In

In March 1994, with site erection work progressing on schedule, and in accordance with all of the agreements with the Virginia Department of Environmental Quality, SPSA and the US Navy received Administrative Orders from the US EPA concerning dioxin and furan emissions from the facility. The EPA Orders required a series of interim control measures to be taken while the retrofit was in progress, in order to immediately reduce dioxin emissions. The EPA Order cited broad authority under the Resource Conservation and Recovery Act (RCRA) statutes, and required rapid response. There were 28 separate items in the Work Plan mandated by EPA, and progress on each is reported monthly.

The key element of the Work Plan, and the most difficult to accomplish, was the experimental installation and operation of a temporary water spray system to reduce flue gas temperatures entering the ESPs, and thereby reduce dioxins and furan emissions. A water spray system was designed and installed on one of the operating units, and dioxin readings taken with and without the water sprays in use. Not surprisingly, reductions in the 90% range were achieved by lowering the gas temperatures about 100F (37.8 C). This quickly led to implementation on the remaining operational units.

While the water sprays achieved substantial dioxin reductions, they were very difficult to operate and maintain. The sprays used steam atomization, which produced the necessary small droplet sizes required to quickly evaporate the water. However, the slightest system upset resulted in substantial operational difficulties, along with concerns about long-term corrosion. The principal operational problems occurred with the ash handling equipment, which became subject to pluggage. In addition, the ductwork in the vicinity of the spray nozzles was subject to ash buildup, and the creation of hard, crusty, and difficult to remove deposits.

CONCLUSIONS

The retrofit of scrubber/baghouse technology at this plant has been an unqualified success. The project is nearing completion, with three of the four boilers operational, and with no unusual operating or maintenance problems. The project will be completed well within its original budget of $31.1 Million, and will be completed within the originally planned schedule. The plant operators have quickly adapted to the new equipment, and have been relieved of concerns with opacity excursions. Stack test results have been excellent to date, and continued performance at these levels will enable the plant to easily qualify for the reduced testing frequencies allowed under 40 CFR 60, Part Cb.

While the project has not been without unexpected problems, they have been manageable and solvable without major cost or schedule impacts. The use of a multiple contract implementation scheme has enabled us to select the best available equipment at minimum cost. While this method entails more risk for the Owner than "turnkey Contracting", the risk has been manageable and economical compared to other similar projects.

Key to the success of this type of project is very detailed planning in the pre-implementation and equipment selection phases. This level of planning is expensive only when viewed in dollar terms; in context of the entire project cost, it represented less than 1% of project costs.

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- HDR Engineering, Inc.; Engineering, Planning, Procurement Assistance, Construction Administration
- Industrial Alloy Fabricators, Inc.; Remediation, Demolition, Baghouse & Ductwork Erection
- Prepact, Inc.; Piling
- Process Mechanical, Inc.; Air Heater Tube Installation
- Zurn, Inc.; Tubular Air Heaters