Paper Number:
DOE/PC/01386-98/C0944

Title:
Cofiring Wood and Coal to Stoker Boilers in Pittsburgh

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Contract Number:
DE-AP22-96PC01386

Conference:
Advanced Coal-Based Power and Environmental Systems ‘97 Conference

Conference Location:
Pittsburgh, Pennsylvania

Conference Dates:
July 22 - 24, 1997

Conference Sponsor:
Federal Energy Technology Center - Morgantown and Pittsburgh

Disclaimer

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Introduction

National interest in the combustion of wood and wood/coal mixtures is growing rapidly in response to the world-wide concern for global warming, the U.S. concern for SO_2 and NO_x emissions, and regional interest in expanding the utilization of forest products and byproducts.

Throughout the forest product sector, combustion of wood and wood byproducts is widely practiced. Numerous small combustors for use by the homeowner to burn seasoned firewood are on the market. Lumber and paper mills produce large amounts of raw wood wastes, which many of them combust in industrial boilers to provide process heat and mechanical energy for their operations. In the case of both small and large combustors, the feed systems, burners, thermal recovery systems and flues have been specially designed for 100% wood use.

Within the industrial and utility coal-fired boiler sector, furnaces are designed for 100% coal combustion and there is very little experience with wood/coal cofiring in these systems. Moreover, what experience is out there has not been documented in the open literature. Thus, it is proving very difficult for operators of coal-fired boilers to join quickly the national effort to increase wood firing.

To provide assistance in this direction, the Federal Energy Technology Center (FETC) is initiating a joint, nationwide program with the Electric Power Research Institute (EPRI) to test and thoroughly document the cofiring of biomass and coal into ten boilers of various configurations. Nine of the boilers use pulverized coal in the combustor. One uses stoker coal. With support from the U.S. Department of Energy (DOE), the University of Pittsburgh has developed a detailed plan for conducting the stoker parametric test at the Bellefield Boiler Plant in the Oakland District of Pittsburgh. The university also is currently participating in a demonstration of wood/coal cofiring into a stoker boiler at the Pittsburgh Brewing Company. This demonstration is being conducted with support from the Forest Service of the U.S. Department of Agriculture.

Objective

The prime objective of the University of Pittsburgh's overall wood/coal cofiring program is the successful introduction of commercial cofiring of urban wood wastes into the stoker boilers of western Pennsylvania. Central to this objective is the demonstration test at the Pittsburgh

Brewing Company. In this test the project team is working to show that two commercially-available clean wood wastes — tub-ground pallet waste and chipped clearance wood — can be included in the fuel fed daily to an industrial stoker boiler.

Irrespective of its economic outcome, the technical success of the demonstration at the brewery will allow the local air quality regulation agency to permit a parametric test at the Bellefield Boiler Plant. The objective of this test is to obtain comprehensive data on all key parameters of this operational boiler while firing wood with coal. The data would then be used for thorough generic technical and economic analyses. The technical analysis would be added to the open literature for the general planning and operational guidance for boiler owners and operators. The economic analysis would gage the potential for providing this stoker fuel commercially in an urban setting and for purchasing it regularly for combustion in an urban stoker boiler.

Approach

As the university's overall program began to take shape, the project which initiated it was a feasibility study during 1996 of the parametric test and ultimate commercial operation of urban wood/coal cofiring at the Bellefield Boiler Plant. The feasibility study was conducted with the sponsorship of the DOE's Pittsburgh Energy Technology Center under Purchase Order No. DE-AP22-96PC01386. The COR was Dr. Perry Bergman (bergman@fetc.doe.gov; 412-892-4890). The study laid out the details for conducting the parametric test in one of the traveling grate stokers at the boiler plant. It also defined the steps needed to initiate commercial wood/coal cofiring at the plant and what the cost structure for cofiring there would be.

At the conclusion of the feasibility study in late 1996, it became clear that the parametric test could not begin immediately. Two factors delayed it. First, the Bellefield Boiler Plant's application for a new Title V air permit was still under review at that time. Second, the Allegheny County Health Department (ACHD), which has primacy for air quality assurance at the boiler plant, expressed an interest in seeing the results of the demonstration at the brewery before approving the test at the Bellefield Boiler Plant.

The plan for demonstration was an outgrowth of the feasibility study. The provider of tub-ground pallet waste had proposed the demonstration at the brewery as a result of his observations of the trends of the feasibility study. The health department (ACHD) picked up on this and saw an opportunity for careful regulatory development at another facility within its jurisdiction. The brewery saw the possibility of beneficial use of its pallet waste within its own processing system.

Thus, the stage was set for initiating a demonstration at the brewery in the spring of 1997 with the sponsorship of the USDA's Forest Service under Grant No. NA-96-0381. The COR is Lew McCreery (304-285-1538).

Both the completed feasibility study and the on-going demonstration test will be described in the next two sections of this report.

Project Description

Feasibility Study. In early 1996 the University of Pittsburgh approached the operators of the Bellefield Boiler Plant about the availability of its facility as host for the DOE/EPRI stoker parametric test. The boiler plant provides steam for a district heating system that serves the majority of the institutional buildings in the Oakland District of Pittsburgh, which includes the University of Pittsburgh, Carnegie-Mellon University, several major hospitals and other public structures. The plant is operated by a consortium composed of all of its steam users.

The plant contains three chain grate stokers, two underfed retorts and two gas-fired boilers. The three chain grate stokers are: Boiler #1 — Babcock and Wilcox Two-Drum Stirling Water Tube Boiler; Boiler #3 — Zurn Industries Two-Drum Water Tube Boiler; Boiler #5 — Erie City Iron Works Two-Drum Water Tube Boiler. All three boilers are rated at 100,000 pounds of steam per hour. Stoker coal is brought into the plant in 70-ton rail cars which originate about ten miles south of the plant at MonValley Transport Company (MVTC), a barge/rail transfer station. Once in the plant, coal discharges from the bottom of the cars into a unique bucket conveying system for both horizontal and vertical transfer into the bunkers above the furnaces. A set of chutes, each furnace having one of individual design, lead down to the grate hoppers.

An extended search through the urban wood sector of the Pittsburgh area led the project team to Allegheny Recycled Products (ARP) and J. A. Rutter Company (JRC). ARP is a pallet recycler, one of whose customers is Pittsburgh Brewing Company. ARP currently supplies broken pallet pieces to JRC, which processes urban wood wastes for several markets. For the landscape mulch market, JRC regularly tub-grinds broken pallet pieces and double screens the ground material to a 1¼ by ½ inch intermediate product.

The project team obtained an expression of interest in participating in the stoker parametric test from the Bellefield Boiler Plant, MVTC, ARP and JRC. It then discussed the expected characteristics of a test within the DOE/EPRI biomass cofiring program with the DOE COR for the feasibility study. From all of this field work, the project team constructed a plan for conducting the stoker parametric test at the Bellefield Boiler Plant. The plan was presented to FETC-Pittsburgh in December 1996.

Demonstration Test. As the university was completing the feasibility study, discussions began with the Pittsburgh Brewing Company and ARP about conducting a demonstration of cofiring of the screened tub-ground pallet pieces at the brewery. The brewery is located four miles east of downtown Pittsburgh near the boundary between the Strip District and Lawrenceville.

Steam for brewing, bottling and space heating is produced at the brewery's boilerhouse, which contains a gas-fired boiler and two traveling-grate stokers. The stokers are Sterling Water Tube Models manufactured by Babcock and Wilcox. They are rated at 42,000 pounds of steam per hour. Stoker coal is brought to the plant by truck from a transfer station twenty miles west of the plant. Deliveries are made directly to a pit at the base of a bucket elevator which conveys the coal to a day bin above the stoker in operation at the moment. Two straight chutes lead down from the day bin to the stoker operating below.

The first wood obtained for the demonstration test has been the screened tub-ground pallet pieces from ARP and JRC. Currently (early July 1997 as this paper is being written) the test is being expanded to include a second urban wood waste — 1 inch by zero chipped clearance wood provided by North Suburban Tree Service (NSTS) located ten miles outside of Pittsburgh.

In early 1997 the project team assisted the Pittsburgh Brewing Company in preparing a request to ACHD for approval of the demonstration. In the request, the team stated the benefits of cofiring wood with coal, identified the participants, stated the goals of the test, and described how it would be conducted.

Three goals were listed — to determine

- whether it is possible to convey a wood/coal fuel blend from the mixing point through the conveying system (vehicles, intake pit, bucket elevator, day bin and chutes) onto the grate without flow stoppage or fuel segregation;

- once on the grate, whether the rate of combustion for the fuel mixture can be controlled to produce the required heat output from the boiler without the flame propagating back into the fuel across the gate, or unburned or still-burning fuel from passing forward into the ash pit;

- whether the wood/coal blend has a deleterious effect on opacity.

A two-month test schedule was proposed. Five 40-ton batches of wood-coal blend would be prepared on site — (1) 5% wood by volume, (2) 10% wood by volume, (3) 20% wood by volume, (4) 30% wood by volume and (5) 40% wood by volume. This corresponds roughly to blends of 3%, 6%, 12%, 18% and 24% wood by weight and 2%, 3½%, 7%, 10% and 15% wood by heat content (seasoned dry wood basis). For each of the five test mixtures prepared, there would be three test runs for a total of fifteen test runs. During the 60-day testing period no more than one test run would be conducted on any given day. The actual days of testing would be determined by weather and the availability of personnel and fuel. Testing would begin with a 5% wood by volume mixture and would progress, assuming no difficulties, by increasing wood percentage to the 40% blend. For each blend ratio, the first test run would utilize five or six tons of fuel blend and would last between three and four hours. This test's primary purpose would be to determine the blend's flow/handling characteristics. The second test run for a given blend would utilize 12 to 13 tons of blended fuel and would last between ten and twelve hours. The run would test the boiler at both high and low fire. The third run would be a repetition of the second one.

A test log would be maintained, which would include a record of

- the times that each test run started, that each test run ended, and that the boiler experienced any significant operational change during a test;

- the exact nature of the fuel mixture used during each test;

- any occurrence of fuel bridging, fuel segregation, burn-back across the gate, incomplete combustion along the grate, or changes in slagging or fouling;

- fuel feed rate, opacity meter output, and steam production during each test run.

The health department responded with its approval of the demonstration.

Accomplishments

Feasibility Study. The completed feasibility study provided details of the parametric test at the Bellefield Boiler Plant.

For the test burns, ARP would convey pallet waste to JRC. There it would be tub ground, double screened and trucked to MVTC. MVTC would modify its standard procedures to blend the wood/coal mixture for the test. Coal and wood would be dumped into the 70-ton rail cars by a front-end loader in alternating layers. The buckets per layer would be adjusted to provide the desired wood/coal ratios. CSX would deliver the rail cars with the wood/coal fuel blends to the boiler plant as part of a regular coal shipment. Wood/coal fuel would be unloaded from the rail cars, sampled and stored separately in an empty fuel bunker. Test burns would be conducted under the supervision of and follow the DOE/EPRI protocols developed by Foster Wheeler Environmental Corporation, taking into account the permitting requirements of the plant. During the test the following parameters would be monitored: (1) furnace temperature; (2) particle sizing and particulate loading; and (3) gaseous NO_x, CO_2, O_2, CO and SO_2. Two four-hour tests would be conducted each day.

The test would be scheduled in late March or early November. During these two periods the following conditions are expected: (1) both of the underfed retorts are off line and (2) only one of the chain-grate stokers needs to be on line because (3) steam demand is moderate. Given these conditions, it should be possible to (1) monitor stack emissions from the test boiler without interference from non-test coal-fired boilers, (2) store the wood/coal fuel in its own separate bunker, and (3) meet the plant's steam demand (without wasting steam) by adjusting the operation of the on-line, gas-fired non-test boilers.

Two test scenarios were constructed. The first carries an estimated cost of $140K while the second is a scaled-down version, carrying an estimated cost of $90K.

Scenario #1: This scenario includes the minimum number of test burns required to optimize and permit all three chain-grate stokers for cofiring. Test burns in Boiler #3 would be used to ramp up the wood content in the fuel mixture from 10% to the 20% expected to be used on a long term commercial basis. Boilers #1 and #5 would be test fired at 20% wood only. Each fuel mixture (including the 100% coal base case) would be tested at both high and low fire. There would be a total of 16 test burns conducted over eight working days.

Scenario #2: This scenario includes the minimum number of test burns required to optimize and permit *only* Boiler #3 for cofiring. The test burns in Boiler #3 would be the same as in Scenario #1. There would be eight test burns conducted over four working days.

Demonstration Test. At the date of this writing (early July 1997) seven six-hour tests of up to 38% ground pallet wood/62% coal by volume have been made in the traveling-grate stoker at the Pittsburgh Brewing Company.

Each test begins by preparing the wood/coal mixture. Wood and coal are stored in two open piles on the ground near the boilerhouse. A laborer uses a small front-loader bucket to draw the appropriate amounts of coal and wood from the two piles, place them together in a separate pile on the ground, and blend them by lifting and dropping portions of the pile several times. The mixture is loaded onto a small truck, driven to the boilerhouse, and dumped into the feed pit. The feed pit is covered by a grizzly (approximately 7-inch square openings) to remove large trash. The mixture is conveyed to the day bin, which has been pretty well run out, so that the wood/coal mixture reaches the grate within an hour or so of being transferred to the bin. An opening at the top of the day bin permits observation of the movement of fuel into and out of it.

The day bin is approximately 30 feet high with a V-shaped bottom. It has a rectangular cross-section — about 16 feet long (parallel to the front of the stoker below) and 14 feet wide. The lower apex of the V at the bottom of the bin is also parallel to the front of the stoker below. Two chutes about two feet square lead down at a steep angle from the bottom of the day bin to a point about two feet above the grate. Each chute discharges at the center of that half of the grate which it feeds. The movement of the grate carries the feed through an adjustable gate into the firebox. A chute, perpendicular to the stoker below, leads down at about a 45-degree angle from the top of the bucket elevator (which is located on the other side of the day bin from the boiler) to the middle of the top of the day bin, but off-center — just above the lower chute which leads to the left-hand side of the grate (facing the boiler). Fuel is ejected from the chute at about the center of the bin. It freely moves to the far wall of the bin (the one closest to the boiler) and impacts that wall about 10 feet below the top of the bin — with vigor!

Test #1: A 10% wood/90% coal by volume mixture was tested on Monday, May 19, 1997. There was no apparent change in conveying to the boiler or in boiler operation.

Test #2: A 20% wood/80% coal by volume mixture was tested on Tuesday, May 20, 1997. There was no apparent change in conveying to the boiler or in boiler operation.

Test #3: A 30% wood/70% coal by volume mixture was tested on Wednesday, May 21, 1997. Occasional mild clumping at the grizzly and in the chamber underneath was observed, but they were easily broken up. The rest of the conveying process appeared normal. The bed depth was increased and the fireman biased the electronic controller to a higher grate speed in comparison to normal operation. Otherwise the boiler operation was nearly normal. However, on the day following the test, a buildup of feed material was found in the day bin just below the point where feed impacts the wall upon filling. When this material slumped, some surging was experienced

through the chute below and that half of the boiler burned as if more fines were on the grate. The material coming down the chute contained many fines, interlaced with long, stringy wood pieces.

Test #4: A 25% wood/75% coal by volume mixture was tested on Tuesday, June 3, 1997. Occasional mild clumping at the grizzly was observed. The angle of repose of standing coal appeared to be about 45 degrees, that of flowing coal about 40 degrees and that of the wood/coal mixture about 50 degrees. The slope of the sides of the chamber underneath the grizzly appears to be about 45 degrees. The last portion of the wood/coal mixture leaving the chamber had to be poked for complete flow.

The filling of the day bin was observed from the opening at its top. The mixture leaving the chute from the top of the bucket elevators moves very fast and is very dilute. Individual particles are relatively far from each other as they emerge from the chute. Very little of the cross-section of the chute is filled. It appeared that fine material segregated below the point of impact and larger particles, especially coal, bounced to the side and across the bin. A sloping mass with a high point below the point of impact and sloping downward to the other side of the bin was established. The wood/coal material otherwise seemed to be very well mixed in general.

As the wood/coal mixture emerged onto the grate, it was observed that the material coming from the right-had chute had less wood and what was there were larger pieces. The left-hand chute was discharging more wood, much of it being the fine material. This mass was more pasty than that coming from the right-hand chute. The wood and coal were very wet from much rain over the weekend and a light rain falling Tuesday morning. The mixture from the right-hand chute flowed uniformly. That from the left-hand chute surged somewhat, but the general flow was quite good. The fireman reported no major change in the flame front nor in the boiler's performance when the wood/coal mixture went onto the grate.

At this point in the test, the discharge from the day bin was observed from the opening at its top. The wood/coal mixture slowly, smoothly slumped downward toward the top of the two chutes. The slopes where the larger particles were located were relatively uniform. The swath of fines coming down from the impact point had several benches on its path toward the left-hand chute. The angles of repose appeared as noted above.

Test #5: A 33% wood/67% coal by volume mixture was tested on Monday, June 16, 1997. The mixture this day was relatively dry. After the mixture had been conveyed to the day bin, observations from the top of the bin found an oval mound of fines and stringers, about four feet wide, six feet long and a foot deep, stuck to the wall at the point where the blend hit during conveying into the bin. The blend slumped erratically downward into the chutes, creating small benches with steep slopes above them. But the material came through smoothly down the chutes all day. The combustion also went smoothly all day, even when the stoker was turned down during the afternoon.

Test #6: A 38% wood/62% coal by volume mixture was tested on Tuesday, June 17, 1997. The mixture this day was soaked. Numerous large masses hung up on the grizzly. The conveyance from the chamber below the grizzly to the day bin was acceptable, but somewhat more difficult

than normal. The stoker was running with a light steam load, so no movement of the wood/coal pile in the day bin could be observed before the day's coal load arrived and was placed on top of the wood/coal mixture in the bin. When the wood/coal mixture began to emerge from the bottom of the chutes just above the grate, it flowed smoothly onto the grate. However, the mixture coming down the left-hand chute was heavily laden with fines of both coal and wood. Later in the day, when the stoker again was turned down when the steam load dropped early, the fireman found that he could not control the fire on the left-hand side of the grate because the fines blocked what air was called for by the controller. The fireman had to stop the stoker more than once to keep the fire on the left-hand side from running into the ash pit. Once he actually lost the fire and had to restart it. The project team attributes this problem principally to the creation of extra coal fines by unnecessary over mixing by the laborer preparing the mixture that morning. In future tests, minimum mixing should be used.

Test #7: A 25% wood/75% coal by volume mixture was tested on Wednesday, June 25, 1997. The wood was a new batch of tub-ground pallet material which had received a second bottom screening, so it contained less fines than the first batch. There was no apparent change in conveying to the boiler or in boiler operation.

Benefits

The DOE and EPRI have initiated their joint program on biomass/coal cofiring as part of the national effort to reduce the U.S. emission of carbon dioxide from fossil fuels. The build-up of fossil CO_2 in the global atmosphere is one of the major factors to which global climate change is attributed. The wood in wood/coal mixtures is a renewable fuel which substitutes for a portion of the coal, a fossil fuel. Pallets and clearance wood are major sources of clean urban wood waste. Currently pallets are simply being landfilled, while clearance wood is graded into the site being cleared. There are a number of small urban coal-fired stoker boilers throughout the coal regions of the United States. Using clean urban fuel wastes in urban stoker boilers will make a small but measurable contribution to reducing greenhouse gases and landfill requirements. Wood/coal cofiring can also lead to reductions in SO_2 emissions or allow boiler operators to maintain current levels of SO_2 emissions using less expensive, higher sulfur coal.

Future Plans

The long-range plan for the stoker wood/coal cofiring program of the University of Pittsburgh includes (1) completing the Pittsburgh Brewing Company demonstration, (2) initiating commercial use of wood/coal mixtures at the brewery, (3) conducting the parametric test at the Bellefield Boiler Plant, (4) initiating commercial use of wood/coal mixtures at the boiler plant, and (5) initiating commercial use of wood/coal mixtures at other coal-fired boilers in western Pennsylvania.