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BOILER REBUILD AND UPGRADED DESIGN FOR PINELLAS COUNTY MSW

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ABSTRACT

This paper discusses the Boiler Rebuild and Upgraded design features of the Pinellas County Solid Waste Recovery Plant located in Pinellas County, Florida. The Pinellas County Solid Waste Recovery plant consists of three 1000 tons/day bulk refuse fired boilers each designed to generate a nominal 250,000 lbs. of steam per hour (pph), at 750°F/615 psig. The boilers have been in operation since the early 1980s and had come to the end of their reliability life. Based on the previous years of operating experience, specific areas of improvement were established. Desired improvements included reducing tube bundle fouling, increasing the length of time between the off-line cleaning cycles, reducing economizer exit gas temperature, and increasing steam capacity while achieving unit design steam conditions.

Design options were evaluated using a computerized heat transfer mathematical model calibrated to the current level of boiler performance. The model enabled design modifications to be evaluated and optimized with respect to performance, maintenance, and cost. Considering both the performance and maintainability allowed the design team to make a final evaluation and design selection that provided the greatest value over a long-term period.

The unit was designed, fabricated, and erected within an 18-month schedule. Performance and optimization testing was accomplished 8 weeks after start-up. The unit has met all of its performance guarantees and is fully operational.

INTRODUCTION

The Pinellas refuse recovery facility is located in Pinellas County, Florida. The facility consists of three plants which process municipal solid waste. As designed, Units 1, 2 and 3 are rated for 244,000 pph maximum continuous rating (MCR) (Figures 1 and 2). In total, the facility generates in excess of 75 megawatts (MW) of power. This paper details the modifications made to the three units.

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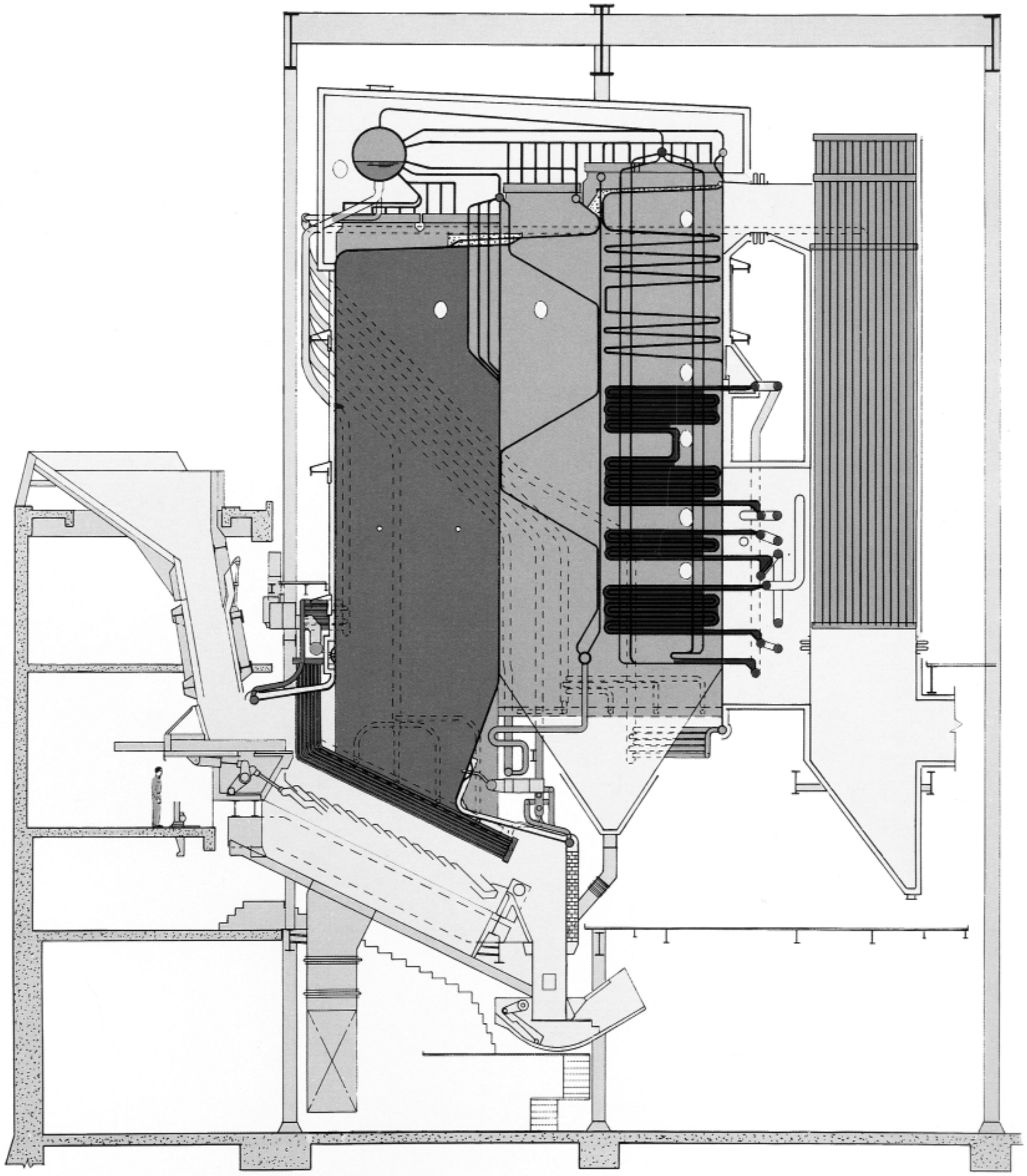

Figure 1 Unit 1 & 2 Original Configuration
Solid Waste Resource Recovery Project
Pinellas County, Florida
Two 244,000 lbs/hr—615 psig operating—750°F
Fired by Bulk Refuse, 1000 tons/day capacity each

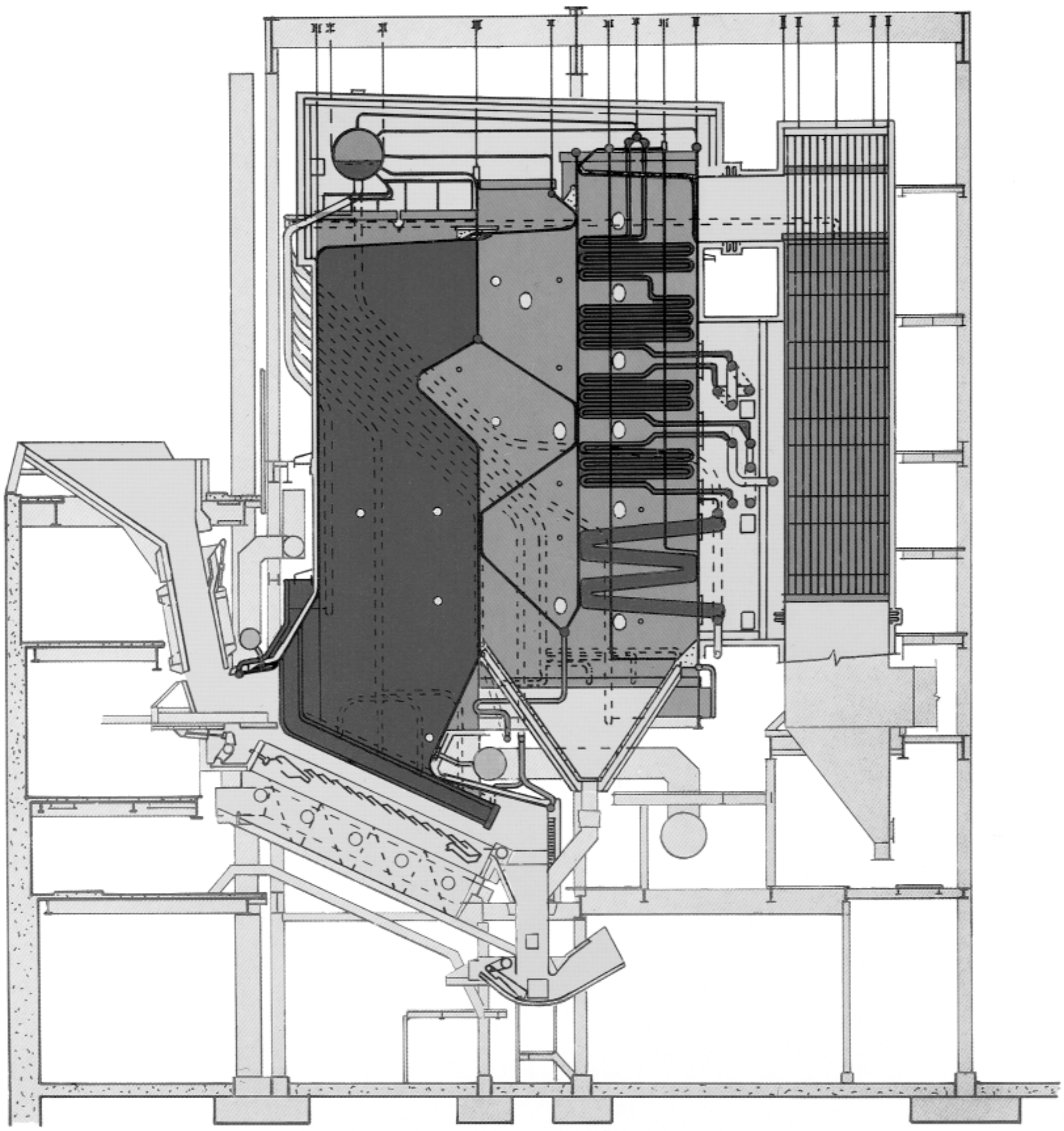

Figure 2 Unit 3 Original Configuration
Solid Waste Resource Recovery Project
Pinellas County, Florida
244,000 lbs/hr—611 psig operating—752°F
Fired by Bulk Refuse, 1000 tons/day
269,880 lbs/hr peak—1050 tons/day

The units are balanced draft boilers equipped with a reciprocating grate. A single flow, three-pass, backend carries the flue gas through evaporative (first pass), superheat (second pass), and economizer (third pass) surfaces. This paper discusses the redesign of the first and second passes of the boilers. The original furnace design of Unit 3 was slightly different than Units 1 and 2. Unit 3 contained a nose arch at the top rear wall of the furnace. Additionally, the second pass of Unit 3 had different superheat and evaporative configurations than those for Units 1 and 2, reference Figures 1 and 2. Other than these differences, the units were identical and the same design approach was used for all the units. Original design conditions based on a nominally fouled state are shown in Table 1.

The fuel source for the Facility is collected from twelve surrounding communities as far away as Georgia. The fuel is characterized by a high percentage of nitrogen waste in the form of vegetative waste products, with moisture levels of 30% as shown in Table 2.

Table 1 Pinellas Resource Facilty Design Conditions

	Unit No.		
	1	2	3
Steam Flow, pph	244,000	244,000	244,000
Steam Temp., °F	750	750	752
Steam Pressure, psig	615	615	611
Feedwater Temp., °F	250	250	250
Bulk Refuse, T/day	1000	1000	1000

Table 2 Pinellas Fuel Analysis

Component	Percent Wt
Carbon	27.30
Hydrogen	3.67
Oxygen	20.52
Nitrogen	0.33
Sulfur	0.10
Chlorine	0.02
H_2O	30.00
Ash	18.06
Total	100.00
HHV	4,800 BTU/lb

EXISTING CONDITIONS

Excessive fouling in the backend leading to a high economizer exit gas temperature has plagued all the three units. This temperature rose steadily to 600°F then rapidly accelerated to levels that exceeded the design conditions of several downstream components and limited the ability of the units to operate for extended periods of time. The units were operated at a maximum load of 220,000 pph consistently. Increasing the load beyond this point resulted in rapid fouling and the need to go offline for backpass cleaning. Fouling increased significantly when the units were operated above 80% MCR. Therefore, operation was limited to less than 80% MCR. The fouled conditions in the superheater surface also resulted in reduced superheater temperatures. Frequent outages occurred at approximately one-month intervals to accommodate the required cleaning cycle. Additionally, steam temperature was limited to approximately 720°F.

The units had a design capability of processing 1000 T/day of municipal solid waste (MSW). The reduction in steam capacity also reduced the MSW processing capability. In order for the plant to meet its MSW processing requirements, it became imperative to increase the steam capacity to allow for the throughput of 1000 T/day of MSW.

PROJECT OBJECTIVES

With the above stated existing conditions, the objectives were to modify the units to:

a. Reduce fouling and extend the time interval between cleaning cycles

b. Reduce exit gas temperature

c. Increase steam capacity

d. Achieve a superheater steam temperature of 750°F

e. Increase refuse throughput capability to the design value of 1000 tons/day at 100% MCR.

In addition, modifications had to be contained within the boundaries of the boiler and the unit needed to be easily maintained. Working in close association with Wheelabrator Technologies, Inc. (WTI), Babcock Borsig Power, Inc. (BBPI) was able to outline a number of unit modifications that met the objectives of the project and were feasible from a design, installation, and economic point of view.

DESIGN CONSIDERATIONS

As mentioned above, the unit consisted of a single flow three-pass backend. The first pass consisted of evaporative surface while the second pass contained both evaporative and superheater surfaces. Gas flow then channeled through to the economizer.

The existing evaporative surface in the first pass was not an effective arrangement for heat absorption. Additional surface was required that would reduce the gas temperature leading into the second pass to approximately 1100°F. This value was established based upon the observation over time that the fouling leading into the second pass increased rapidly above 1100°F. This surface addition also required that the surface would be easily maintained.

Additional superheater surface was required to enable the unit to meet the steam conditions in a nominally fouled state. Again, the surface addition needed to be easily maintained.

The units currently have operational sootblowers (SB) in the backpass. In order to minimize the need for off-line cleaning a rigorous SB schedule was proposed. The use of sootblowers on a regular and consistent basis was to be enhanced by the strategic placement of additional blowers in the backpass. Additionally, the use of rappers was to be evaluated for their effectiveness in maintaining a clean surface.

EVALUATION PROCESS AND DESIGN CRITERIA

The process of evaluating the design options consisted of a detailed analysis for performance, maintenance, and economic criteria.

In accordance with Wheelabrator's request, it was assumed that the furnace portion of the boiler was operating as designed and did not require modifications. The existing first pass of the backpass contained a widely spaced pendant that absorbed very little heat. The second pass of the convective section contained both superheat and evaporative surface. This pass currently fouled excessively. The steam capacity of the unit was below its design capability due to the excessive fouling that resulted at high capacity. In order to increase the unit capacity and unit steam conditions, the addition of heating surfaces to evaporator and superheater were required. Since the operation of the unit varied from clean state to a maximum fouled state, surface addition needed to be added in such a manner as to keep fouling at low levels and to enable on-line cleaning.

Four fouling states for the unit were identified:

a. Clean – new unit condition

b. Clean-Seasoned – the condition of a unit that has been operational for a period of time and has just undergone unit cleaning.

c. Nominally Fouled – The existing fouled condition after 4 to 5 weeks of operation after a cleaning cycle.

d. Maximum Fouled – The condition of the unit just prior to unit shutdown for cleaning purposes.

Unit performance was to be evaluated at a clean-seasoned, nominally fouled, and maximum fouled state to provide a sound basis for comparing the various surface additions.

Unit maintenance consisted of maintenance in the furnace as well as each pass in the backpass. Fouling in the unit was especially heavy in the second pass leading into the superheater. This condition deteriorated with increasing load. In order to reduce the degree of fouling in the second pass to acceptable levels, additional heat absorption that could be easily maintained was required in the first pass. It was generally believed by the Customer that by keeping the gas temperature into the second pass less than 1100°F, a significant reduction in fouling would result.

Unit shutdown on a monthly basis was having a dramatic impact to the bottom line of the facility. The addition of boiler surface modifications would represent a significant investment of time, material, and labor. Thus, any such modification had to provide a dramatic increase to the ability of the unit to remain on line for significantly longer periods of time.

DESIGN CONSIDERATIONS

The redesign effort required the establishment of a computerized heat transfer performance model to understand the impact of the proposed modifications. The model was based upon an iterative heat balance and heat transfer model using thermal and fluid performance factors that were gathered in the field. Model development consisted of the following:

- Current operation data from the unit control room was used as the baseline data for the evaluation process. Although this database was extensive in quantity, the completeness of the data was somewhat limited. Subjective values of degree of fouling had to be made by the operators and were somewhat variable. A series of data points for clean-seasoned, nominally fouled, and maximum fouled conditions were extracted from the database for use in the modeling process.
- A model was established using the surface area of the current boiler configuration. Respective effectiveness factors were assigned to each bundle that enabled each surface bundle to generate the same temperature profiles as were collected in the baseline tests. Surface effectiveness factors were generated based upon both BBPI design criteria and the respective consideration of the particular environment. Once the model was refined to the degree necessary to generate the baseline data, surface modifications were added. As additional surfaces were added, their effectiveness was designated with respect to the established effectiveness of the adjacent surfaces and BBPI design experience.
- All surface conditions were analyzed for metal temperatures and the appropriate materials were specified. The maximum allowable metal temperature for carbon steel was limited to 800°F. Above this temperature, alloy materials were utilized.

Several conditions existed at the plant that aggravated the operation of the unit and provided for an unstable design basis. These included:

a. A variable fuel supply. In order to address this issue, the proposed design modifications clearly identified the pertinent fuel analysis. Deviations from this analysis would need to be addressed separately.

b. Undocumented sootblower operation. A regular sootblower sequence was specified, as well as the potential use of rappers where appropriate.

Of the numerous design modifications available for unit redesign, there were two primary design alternatives that were evaluated:

a. Adding evaporative surface in the first convection pass. Surface addition in the form of vertical evaporative platens in the first pass offered the ability for accumulations on the tube surfaces to shed easily. The vertical platens also provided increased heat surface for evaporative heat absorption, although the vertical surface provided less than optimal orientation to the gas flow for convective heat absorption.

b. Replacing evaporative surface with superheater surface in the second convection pass, and adding additional superheater surface in the second pass.

FINAL SELECTION

Addressing each of the design considerations in the previous section, the following surface modifications were specified. Refer to Figure 3.

In the first pass of the backend, the use of vertical platens provided for additional evaporative surface as well as enabling the surface to be easily maintained. Since the gas flow in this pass runs parallel to the added platens, the additional surface does not provide as great a surface effectiveness as would a horizontal surface. However, the vertical design is more easily maintained in an optimal operation state. The original evaporator surfaces were spaced 6 inches apart. The replacement vertical platens were spaced 20 inches apart. This platen design readily accepts the use of tube rappers, Figure 4, to provide for on-line cleaning and easy maintenance of the bundle. Carbon steel tubing was used for these vertical platens.

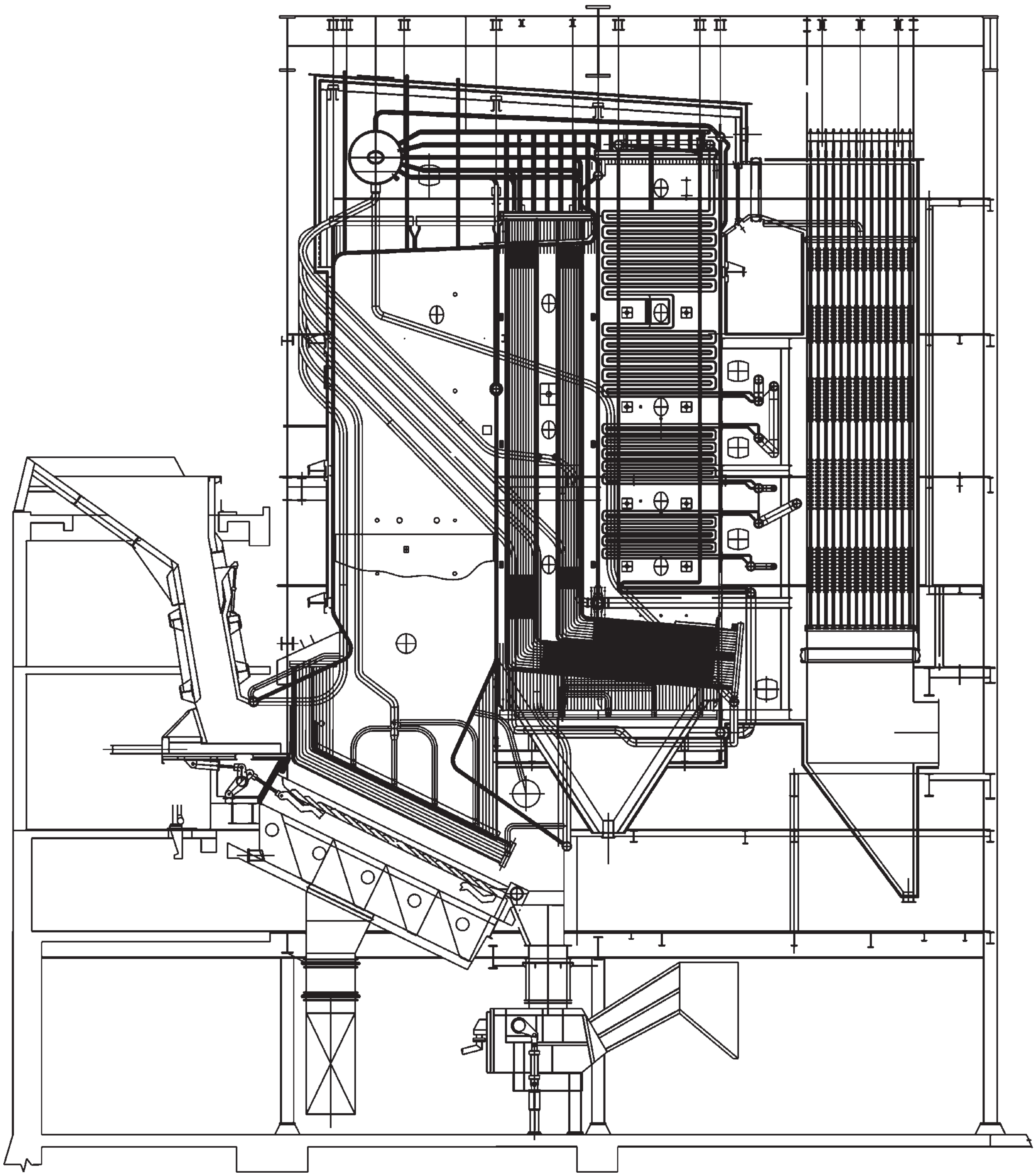

Figure 3 Units 1, 2, and 3 Redesigned Configuration

To provide for the requirement of higher superheater temperatures, the evaporative surface in the second pass was removed and additional superheat surface was added. A total of four bundles of superheater surface were included. Two sootblowers were located horizontally between each pass. Surface addition to the superheater is summarized in Table 3. All superheater surfaces were at 10 inch spacing vs. the original 6 inch spacing.

In terms of maintenance and performance, the unit economizer was determined to be acceptable as designed for Unit 3 and so was not modified. The economizer for Units 1 & 2 was of an older design that was more difficult to maintain. In order to provide a more easily maintained arrangement, the Unit 1 and 2 economizers were modified to the same configuration as Unit 3 with surface conditions as specified in Table 4.

Unit performance was calculated for both 210,000 pph and 244,000 pph, representing 85% and 100% MCR, respectively. At 85% MCR, in a nominally fouled state, a Furnace Exit Gas Temperature (FEGT) of 1535°F was determined. Gas temperature leaving the first and second passes was 1048°F and 798°F, respectively. Gas temperature leaving the economizer was 471°F.

For the design run at 100% MCR, an FEGT of 1571°F was calculated. Gas temperature leaving the first and second passes was 1102°F and 838°F, respectively. Gas temperature leaving the economizer was 505°F. Summarized guaranteed data is provided in Table 5. Additionally, a final steam temperature of 750°F was guaranteed between the operating range of 210,000 pph to 244,000 pph.

Table 3 Pinellas Resource Facility
Superheater Surface Summary

	Original		Re-Designed
	Units 1 & 2	Unit 3	
Low Temperature Superheater (LTSH)			
Surface Area, Sq-ft	5,183	8,208	13,328
Tube OD, in	1.25	1.25	2.0
ST (Horizontal centerline to centerline spacing across boiler width), inches	6	6	10
SL (Vertical centerline to centerline spacing within a bundle), inches	3	5	4.375 + 3.0
Intermediate Temperature Superheater (ITSH)			
Surface Area, Sq-ft	3,887	4,123	5,380
Tube OD, in	1.25	1.25	1.75
ST, in	6	6	10
SL, in	3	5	4.375 + 3.0
High Temperature Superheater (HTSH)			
Surface Area, Sq-ft	5,183	6,874	4,312
Tube OD, in	1.25	2.5	1.75
ST, in	6	12	10
SL, in	5	3 + 5	4.375 + 3.0
Stringers and Screen			
Tube OD, in			
Surface Area, Sq-ft	3,300	na	1,430
Tube OD, in	1.25	2.5	1.75
ST, in	6	6	10
SL, in	5	5	4.375
Total Surface Area, Sq-ft	17,553	19,205	24,450

Table 4 Pinellas Resource Recovery Economizer Surface Summary

	Original		Re-Designed
	Units 1 & 2	Unit 3	
Total Surface Area, Sq-ft	27,000	32,100	32,100
Tube OD, in	1.5	1.75	1.75
ST, in	4.5	4.5	4.5
SL, in	4.5	4.5	4.5

Table 5 Guaranteed Performance

	Unit No.		
	1	2	3
Steam Capacity, pph	244,000	244,000	244,000
Superheat Temperature, °F	750	750	750
Superheat Pressure, psig	615	615	615
Feedwater Temperature, °F	256	256	256
Fuel Heating Value (HHV), BTU/lbs	4800	4800	4800
Refuse Consumption, tons/day	1000	1000	1000

INSTALLATION OF MODIFICATIONS

To date, the modifications have been installed on Unit 2. Modifications to Unit 1 and 3 will follow later this year.

UNIT PERFORMANCE AND ACCEPTANCE TESTS

As mentioned above, the modifications stated in this report have been implemented in Unit 2. Testing on Unit 2 was conducted in late 2001[1]. A test matrix was developed for two load conditions, one at 84% MCR and the second at 100% MCR. The test duration was 4 hours and was conducted under the ASME test criteria.

For the 84% MCR test, the boiler was run at a nominally fouled condition of 5 weeks operational. Average steam flow was 205,000 pph. Average superheater temperature was 750°F with a feed water temperature (FWT) of 243°F. Excess air was 72% (measured locally) and exit gas temperature was 417°F.

For the 100% MCR test, the boiler was run at a nominally fouled condition of 5 weeks operational. Average steam flow was 244,000 pph. Average superheater temperature was 750°F with a FWT of 240°F. Excess air was 57% (measured locally) and exit gas temperature was 438°F.

CONCLUSIONS

The Pinellas County Solid Waste Recovery Plant, Units 1, 2, and 3, are being rebuilt and upgraded to enable longer operational periods between cleaning outages and to provide greater steam capacity. Working closely with the Operator (WTI), BBPI was able to provide a rebuild design to achieve the original steam conditions at a steam capacity of 244,000 pph. The rebuilt unit offers a pendant evaporative bank in the first convective pass that is easily maintained through the use of rappers. Additional superheat surface in the second pass provides the required surface addition needed to meet design steam conditions. Maintaining gas temperatures entering the superheater below 1100°F minimizes fouling in the convective pass.

The installation of the modification for Unit 2 has been completed and the unit has met all of the proposed guarantee conditions during the performance tests. Installation of the modifications for Units 1 and 3 are scheduled for later this year.

MAJOR PROJECT PARTICIPANTS

Babcock Borsig Power, Inc.

- Revised design of existing boilers with new performance data
- Fabricated new pressure parts
- Provided field service guidance during boiler erection and start-up

Wheelabrator Technologies, Inc.

- Operator of the facility
- General contractor overseeing the plant reconstruction
- Managed reconstruction of the existing boilers and installed new air pollution control equipment
- Responsible for project planning and execution

Pinellas County Utilities, Pinellas County, Florida

- Owner of the facility
- Provided overall project coordination

HDR Engineering, Inc.

- Owner's engineer
- Provided technical guidance and assistance to the County throughout the project.

REFERENCES

1. "Acceptance Test Report for Wheelabrator Pinellas Unit 2, Pinellas County, FL," Paul O'Brien, BBP #100136, February 13, 2002