TECHNICAL PUBLICATION

REFURBISHMENT OF AN EXISTING 1000 TPD MSW FACILITY USING MODERN STATE-OF-THE-ART EQUIPMENT

by
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ABSTRACT

This paper discusses the design, startup and operation of four rebuilt and redesigned 250 TPD MSW combustion trains located at the McKay Bay Waste to Energy Facility in Tampa Florida. Each independent MSW train consists of a new steam generator, reciprocating grate stoker, ash handling, and air pollution control system.

The new steam generators are built on the footprint of the original units, which were removed in their entirety leaving only the lower foundation steel. The refurbishment was accomplished in two stages to permit the facility to remain in operation.

The new steam generators are designed to minimize fouling, maximize the amount of operating time between cleaning cycles and maintain steam temperature. Evaluation of startup and operating data demonstrates that the units exceed their planned operating time between cleaning cycles and will provide consistent, reliable performance over the service life of the facility.

BACKGROUND

The McKay Bay Waste to Energy Facility in Tampa, Florida processes a total of 1000 TPD of MSW through four separate trains. Steam from the four boilers is supplied to a common turbine generator rated at 22.7 MW.

The original facility had four boilers furnished with rotary kiln combustors. Over the years, unit reliability deteriorated to unacceptable levels. The boiler experienced excessive fouling of the convective surfaces. This led to short operating cycles with the boilers taken down frequently for cleaning. The boilers also began to experience frequent forced outages due to superheater tube failures. There were problems with the combustion system as well. Clinkers would form in the rotary kiln combustor. To clear the clinkers from the combustion chamber, boiler load often had to be reduced.

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In 1997 the City of Tampa requested bids for the replacement of the four individual waste combustion streams. The retrofit design for each waste processing train (grate, furnace, boiler, air pollution control equipment, and ash handling system) is based on the following specifications:

- Nominal Throughput: 250 TPD
- Maximum Continuous Rating (MCR) heat input: 100 MBtu/hr
  Basis 250TPD 4800 Btu/lbm
- Peak Operating Capacity: 110% Nominal Throughput
  Basis 4800 Btu/lbm fuel
- MSW HHV Range: 3800-6000 Btu/lbm
- Turndown: 75% of Nominal Throughput

Analysis of the design 4800 Btu/lbm fuel specified for the project is shown in Table 1 and the boiler design conditions are shown in Table 2.

Table 1 Design 4800 Btu/lbm Fuel Analysis

Element	% by weight
Carbon	27.30
Hydrogen	3.67
Oxygen	20.52
Nitrogen	0.33
Sulfur	0.10
Chlorine	0.02
Moisture	30.00
Ash	18.06
Total	100.00

Table 2 Boiler Design Conditions

	Design
Throughput, Tons/day	250
Design HHV, Btu/lbm	4800
Steam Flow, lbm/hr	60265
Main Steam Pressure, psig	650
Final Steam Temperature , °F	725±10
Excess Air, %	80 range 70-100
Economizer Gas Outlet Temperature , °F	430 clean 490 fouled

Refurbished Design

The refurbishment project had several notable design constraints.

- The new boilers were to be constructed on the footprints of the old units.
- The existing structural steel foundations below the 35 foot elevation were to be reused.
- The overall height of the boiler penthouse was limited to 91 feet above grade. This height was dictated by the height of the tipping floor roof.
- The existing refuse pit with refurbished feed chutes was being reused.
- The project was to proceed in two stages. Units 3 & 4 were to be modified first. The facility was to remain in operation throughout the demolition, construction, and startup of the first two units. After the first two units were placed in commercial operation, the remaining two units would be replaced.

Combustion System

The combustion system consists of a new reciprocating grate. The grate consists of 5 equal area modules of chrome alloy steel construction. Each module has an independent air supply. MSW fuel is fed with a variable speed hydraulic ram. Varying the speed of the ram controls the grate capacity. Combustion takes place with excess air levels between 70% and 100 %. To insure proper combustion of the MSW, three levels of overfire air nozzles are furnished. Two rows are located on the furnace front wall and one row is located on the furnace rear wall.

The combustion system also includes a new siftings conveyor, ash discharger, steam coil air preheater, forced draft fan and overfire air fan.

The forced draft fan draws air from the refuse receiving pit through the cold air intake duct, which was reused. The overfire air fan also takes air from the cold air intake duct.

A new gas-fired auxiliary burner is located a nominal 20 feet above the grate in the boiler sidewall. Each burner is equipped with a centrifugal fan mounted on the windbox. The burner is used for startup and shutdown operation. The burner can provide a maximum heat input of 10 MBtu/hr for each unit and is capable of a 10:1 turndown.

Boiler

The boilers are a balanced draft, naturally circulating design. A gas-tight setting is formed by welded water wall construction. The boilers are nominally rated at 250 TPD each with a maximum continuous rating of 62,186 pounds of steam per hour per unit when burning the specified 4,800 Btu/lbm MSW. Figure 1 shows a side elevation of the boiler.

Each boiler is bottom supported by the structural steel framework. The main steam drum is supported at each end by an 18-inch diameter main downcomer trunk line.

The boiler is a five-pass design. The five passes are:

- Furnace
- 1st dropout pass
- 2nd dropout pass
- 4th pass
- 5th pass

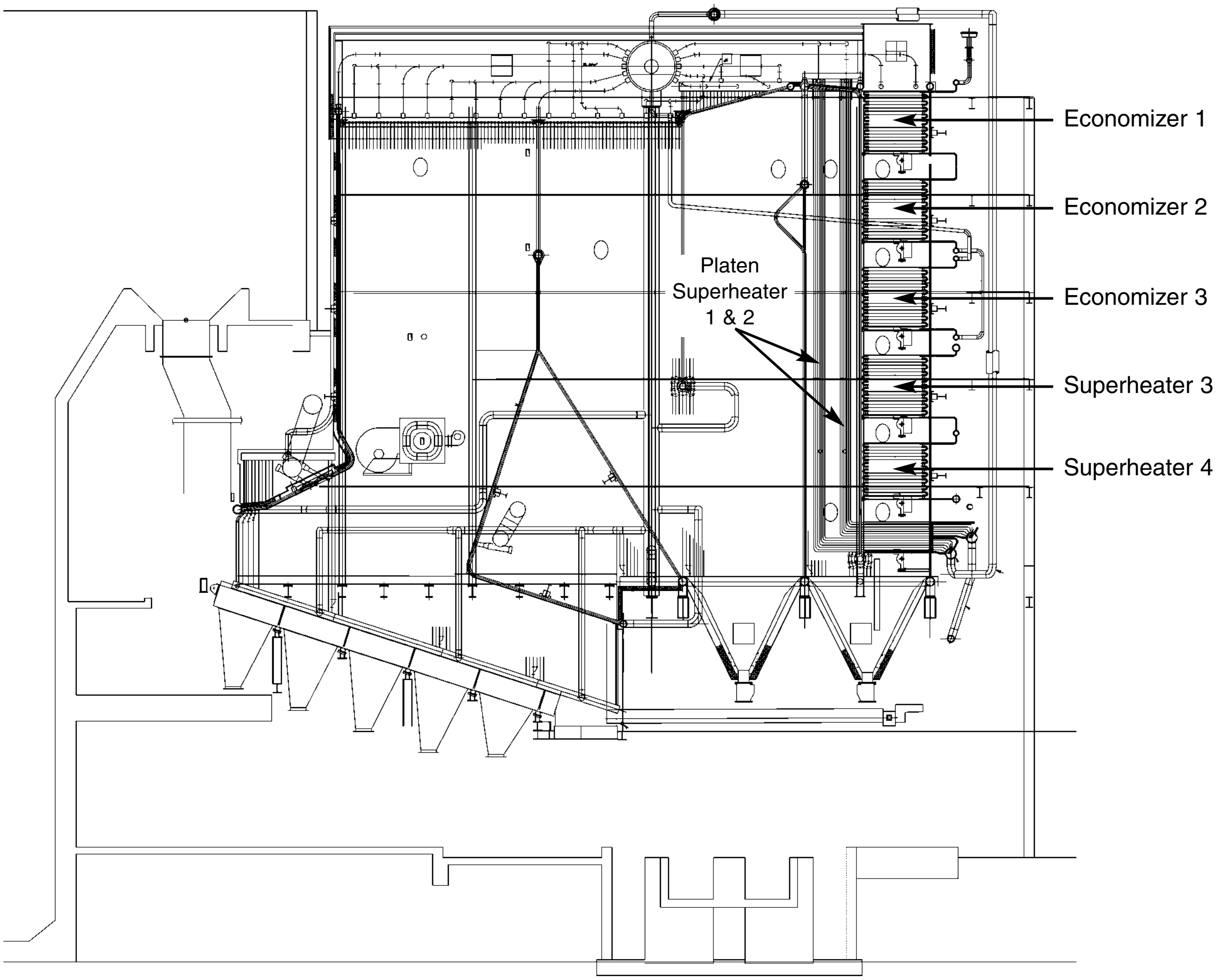

Figure 1 McKay Bay Side Elevation

The furnace dimensions accommodate several different design constraints. The lower furnace had to match the stoker dimensions. The design of the front wall nose arch was based on the recommendation of the stoker manufacturer but it had to fit within the confines dictated by the location of the existing feed chute and the refuse pit retaining wall. The overall height of the furnace was limited by the restriction on boiler penthouse height imposed by the tipping floor roof. In order to provide enough furnace radiant surface area to keep the furnace heat release rate and furnace exit gas temperature within accepted design guidelines, furnace depth had to be increased. The end result is a short, squat furnace configuration.

As a means of verifying the furnace design prior to construction, an outside consultant was hired to construct a one-sixth scale flow model of the furnace and boiler[1]. The flow modeling objectives included:

- Establishing and confirming optimum air flow distribution
- Examining combustion gas flow and mixing patterns
- Demonstrating that the furnace size and geometry provides the required residence time at elevated temperatures
- Reviewing and optimizing the proposed secondary air nozzle arrangement

All combustion takes place in the furnace pass. Upon leaving the furnace, the flue gas flows down through the empty second pass and the up through the empty third pass. In the middle of the third pass, the boiler width increases from 11 feet to 19 feet. After exiting the third pass, the flue gas flows down the fourth pass over superheaters 1 and 2. These are a platen design and are arranged side by side in the 4th pass. There are a total of 14 platen superheaters. Seven platen superheaters on the left hand side of the 4th pass comprise superheater 1. Superheater 2 consists of the remaining seven platens located on the right hand side of the boiler. After leaving the 4th pass, the gas flows over the horizontal section of superheaters 1 and 2 and then flows over superheater 4, superheater 3, and finally the economizer tube bundles.

On the steam side, saturated steam leaves the drum and travels through the feed pipe to platen superheater 1 located in the left hand side of the 4th gas path. The steam leaves platen superheater 1, passes through a spray attemperator, and enters platen superheater 2 located in the right hand side of the 4th gas path. After passing through platen superheater 2, the steam flows through a spray attemperator and into superheater 3 located in the 5th pass between superheater 4 and economizer 3. Steam from superheater 3 collects in a header and then flows through superheater 4. From superheater 4 the steam travels to the turbine.

The economizer consists of three bundles located in the top of the 5th pass. Water enters economizer 1 and flows down through the bundle in a counterflow arrangement into economizer 2, which is also a counterflow arrangement. After leaving economizer 2, the feedwater flows through a transfer pipe into economizer bundle 3. Economizer bundle 3 is a parallel flow arrangement. Economizer bundle 3 was made a parallel flow arrangement to have the water flow in an upward direction. This was done to insure proper water flow distribution in case the economizer began to steam during boiler operation under heavily fouled conditions.

A notable feature of the 5th pass is that it was designed for easy removal and replacement of the tube elements. The 5th pass rear wall tubes are 2.25" OD on 5-inch centers. Starting at the elevation of superheater 4, the membrane fins have been removed. This allows the convective superheater and economizer elements to be easily inserted and removed without having to cut out any of the rear wall tubes. To replace an element, the buckstay is unbolted and the casing is removed. The element can then be cut out and a new one slipped in between the rear wall tubes.

To further facilitate replacement of the convective surface, the tube elements comprising economizer bundles 1, 2, and 3 and superheater 3 are identical. This minimizes the number of different elements that must be kept as spares.

Boiler Design Considerations

The refurbished design had to solve the following original operating problems:

- Excessive fouling
- Short operating time between outages
- Frequent outages due to tube failures
- Corrosion/Erosion

Several measures were taken to prevent excessive fouling and to provide for increased operating time between outages. A primary means to limit fouling is to control gas temperatures entering the convective sections. High flue gas temperatures lead to increased fouling and corrosion rates. Gas temperatures entering platen superheaters 1 and 2 were limited to 1250°F by the use of the two empty dropout passes. Gas temperatures entering the serpentine bundles were designed to be even lower.

Maintaining wide tube spacing in the hottest gas zones also controls fouling. Tube spacing is 12" in the platen superheaters and 8" in the high temperature superheater.

Adequate provision for cleaning the heating surfaces was provided. In the 5th pass, rotary sootblowers were supplied to clean the horizontal section of the platen superheaters, the convective superheaters, and the economizer. In the case of the vertical platens, experience has shown that this type of surface configuration naturally tends to shed slag. However, to further insure the cleanliness of the platens, pneumatic rappers were provided. The rappers are located on the sidewall of the 4th pass approximately 25% of the way up from the bottom of the platen. A tie bar transmits the rapping force from the rappers to the individual platens. The end result has been some of the best cleaning cycles in the industry.

To prevent frequent outages due to tube failures, design measures were taken to address potential corrosion/erosion issues. On the material side, the entire furnace above the refractory and the top section of the second pass were clad with Inconel. Superheater 4, the high temperature superheater, was constructed with stainless steel.

Limiting the flue gas temperature entering the convective surface, discussed above as a means of reducing the fouling rate also serves to reduce the corrosion rate. In addition, platen superheaters 1 and 2, located in the hottest flue gas path have the lowest temperature steam. This insures metal temperatures are kept as low as possible, further reducing the corrosion potential.

To prevent erosion, the design specification limited flue gas velocities to 20 ft/s. It is possible, due to flow stratification to have local flue gas velocities in excess of the 20 ft/s requirement. The 1/6 scale flow model of the furnace and boiler previously noted above was also used to:

- Confirm even flue gas flow distribution throughout the unit
- Insure that flue gas velocities were maintained below 20 ft/s.

As a result of this modeling, a nose arch was added at the outlet of the third pass and baffles were added in the bottom of the 4th and 5th pass to establish even flow distribution over the convective surface.

After 18 months of operation, (Units 3 and 4), there has been no noticeable erosion or corrosion in the boiler.

Startup and Operations

Unit 3 went into operation in late August 2000. Unit 4 followed three weeks later. Units 1 & 2 went into operation a year later.

During the startup of Units 3 & 4, there were two performance related concerns. The first concern was that the boilers were not meeting the 725°F steam temperature guarantee. It took about three and one half weeks for the steam temperature to reach its design value once the boiler properly seasoned from new conditions. Operating and special test data collected during this period showed that the cause of the low steam temperature was low gas temperatures entering the convective section. One of the design objectives was to limit the gas temperatures entering the convective surfaces. In order to accomplish this, a large amount of surface area, the 2nd and 3rd dropout passes, were located in front of the convective section. These dropout passes took longer then expected to season. After seasoning, however, steam temperature reached its guarantee value and the boiler began to spray. Figure 2 plots steam temperature, spray flow, and the superheater platen gas inlet temperature variations from startup. Now that the boilers are seasoned, it only takes one to two days for steam temperatures to recover after the unit has been shutdown for a cleaning outage.

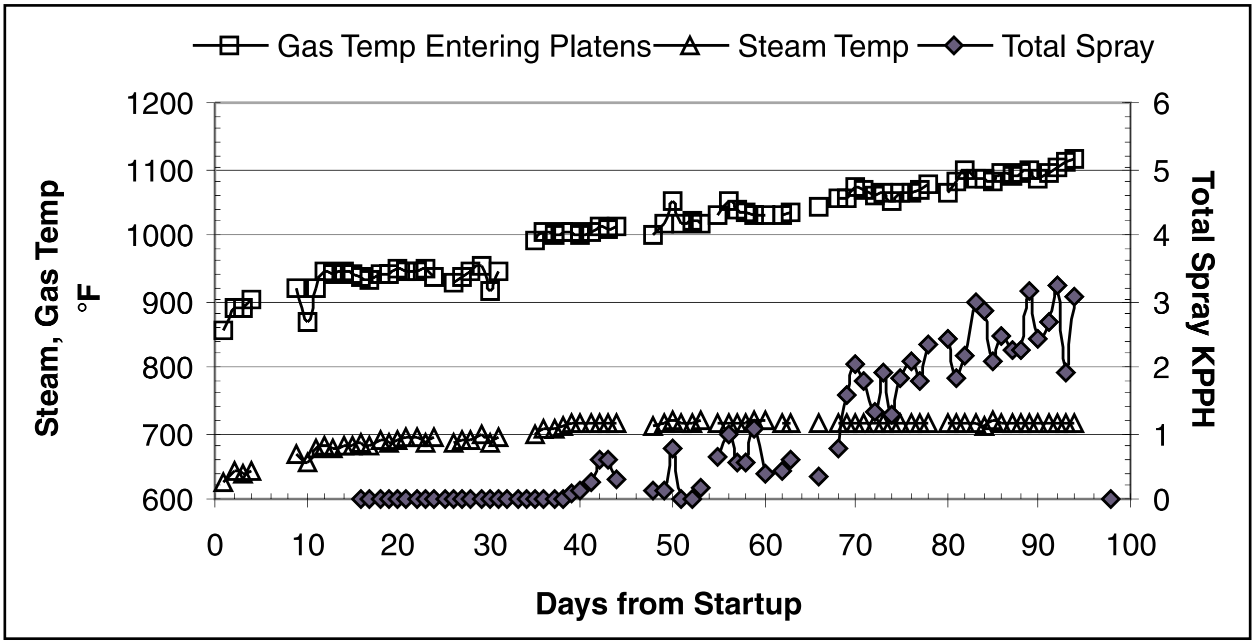

Figure 2 Spray Flow, Steam Temperature, and Platen SH Gas Inlet Temperature From Startup McKay Bay Unit 4

Performance Data

Design and performance data for the refurbished design is shown below in Tables 3-6. The data reflects Unit 3 & 4 performance data recorded during the acceptance tests conducted October 15-22, 2000[2]. The facility met all its performance guarantees.

Table 3 Refuse Processed Retrofitted Units 3 & 4 October 2000 Seven-Day Demonstration Test

	Unit 3 & 4 Total	Unit 3 Total	Unit 4 Total
Refuse Processed, tons	3602	1786	1816
Demonstration Standard, tons	3500	1600	1600
Test Duration, hours	168	168	168

Table 4 Facility Seven-Day Throughput Capacity
October 2000 Demonstration Test

	Before Retrofit	**After Retrofit**
Refuse Processed, tons	2046	3602
Steam Production, 10^6 lbm	8345	20857
lbm steam/lbm refuse	2.04	2.90
Residue Produced, tons	804	857
Moisture in Residue, %	-	20.10
Unburned Carbon in Residue, %	-	1.8
Average HHV of MSW, Btu/lbm	-	4829

Table 5 Summary of Emissions Test Results

	EPA Method	**Permit Limit**	**Permit Limit Achieved?**
Units 3 & 4			
Particulate (mg/dscm @ 7%O_2)	M5	27	Yes
Particulate (lbm/hr)		2.76	Yes
Particulate (lbm/10^6 Btu)		0.0230	Yes
Visual Emissions (percent)	M9	10	Yes
Hydrogen Chloride (ppmdv @7% O_2)	Mod. M26A	31	Yes
Hydrogen Chloride removal (%)		or > 95%	Yes
Fluoride (lbm/hr)	13B	1.5	Yes
Fluoride (lbm/10^6 Btu)	13B	0 – 0.0125	Yes
Nitrogen Oxides (ppmdv @7% O_2)	M19	205	Yes
Sulfur Dioxide (ppmdv @7% O_2)	M19	29	Yes
Sulfur Dioxide removal (%)	M19	75	Yes
Carbon Monoxide (ppmdv @7% O_2)	M19	100	Yes

Table 6 Data Summary 8-Hour Steam Generation Test Unit 3

	Retrofit Design	Test Average After Retrofit
Refuse Feed Rate, tons/day	250	270
Unit Steam Flow, lbm/hr	62,186	62,284
Steam Temperature ,°F	725 ± 10	715[1]
Spray Flow, lbm/hr	2,784	2,060
Steam Pressure, psig	650	642
Feedwater Flow, lbm/hr	60,438	66,593
Feedwater Temp ,°F	280	280
Steam to Airheater, lbm/hr	4,575	4,588
Drum Pressure, psig	725	717
Primary Air Flow, SCFM	17,400	15,250
Secondary Air Flow, SCFM	11,600	10,670
Primary Air Temp ,°F	250	222
Flue Gas Flow, ACFM	59735	72,270
Economizer Gas outlet, °F	432-490	483
Oxygen Concentration, % dry vol	10.59	10.07
Carbon Dioxide Concentration, % dry vol	9.45	9.27
Flue Gas Moisture, % vol	14.6	12.09

[1] Steam temperature controls are set to maintain final steam temperature at 715°F

Long Term Operation

Units 3 & 4 have been in operation for 17 months, and units 1 & 2 have operated approximately 5 months. The units are operating reliably at full capacity and maintain steam temperature with no significant slagging, corrosion, or high exit gas temperature problems. Cleaning cycles range from 5 to 6 months.

CONCLUSIONS

The McKay Bay refurbishment project demonstrates that it is possible for an existing facility with major equipment reaching the end of its service life to replace that equipment with new state-of-the-art equipment and return the facility to consistent reliable operation.

MAJOR PROJECT PARTICIPANTS

Babcock Borsig Power, Inc.

- Provided a new boiler design and 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 to oversee the plant reconstruction
- Supplied and installed new grates, new air pollution control equipment, and ash handling equipment
- Responsible for project planning and execution

City of Tampa, Florida

- Owner of the facility
- Provide overall project coordination

Malcolm Pirnie, Inc.

- Owner's engineer
- Provided technical guidance and assisted to the City of Tampa throughout the project.

REFERENCES

1. NELS Consulting Services Inc., Furnace and Boiler Air Flow Model Study Laboratory Test, Revision 1, November, 1999
2. Kelly, T. J., Preliminary Demonstration Test Report, Wheelabrator McKay Bay, 2000