CONSIDERATIONS IN THE DESIGN OF HIGH TEMPERATURE AND PRESSURE REFUSE-FIRED POWER BOILERS

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ABSTRACT

This paper outlines current efforts to advance existing technology of high temperature and pressure mass-refuse-fired boilers by gaining an in-depth understanding of design and operating requirements. To accomplish this, computer software was written to obtain long-term data collection and performance analysis, as well as special metallurgical and ultrasonic evaluations. These programs have resulted in the opportunity to increase design limits on steam temperatures and pressures in this type of refuse-fired boiler.

INTRODUCTION

The combustion of refuse in waterwall mass-fired boilers has been done successfully for over 30 years. The practice that became commonplace in Europe and Japan is now used worldwide as the major alternative to land disposal of solid waste. Refuse-to-energy facilities are designed to provide reliable refuse disposal, state of the art environmental control, efficient energy recovery, and reduction of landfill requirements.

For systems designed to generate electricity, steam conditions are selected to provide good energy recovery and minimum boiler downtime. The combustion of refuse in mass burning applications presents both the designer and operator with problems of tube corrosion from the products of combustion, tube erosion from ash laden gases, and tube fouling and slagging from the high ash fuel. However, by carefully studying the operation and performance of mass-fired boilers, methods can be employed to prevent unscheduled downtime resulting from tube fouling, wastage and erosion. In an attempt to achieve this goal, Babcock & Wilcox, in cooperation with Signal Environmental Systems, Inc. (SES), embarked on a data acquisition and product development program. Some of the results of that program are given in this paper.

BACKGROUND

Signal Environmental Systems, Inc. entered the refuse-to-energy business with the completion of its Saugus RESCO facility in 1975. Steam conditions for that facility were designed for 690 psig (4757 kPa) and 850°F (454°C) in order to match the conditions of the existing equipment at the General Electric Company in neighboring Lynn, Massachusetts. Since these steam conditions were not viewed as severe by the system design engineers, serious problems with tube corrosion were not anticipated. However, in just 2000 hr of operation, the SA-T13-T22 tubes in the high temperature superheater (SH) began to experience random failures.

Laboratory examination of the failures indicated that high temperature corrosion was the predominant failure mechanism. A task force was established to analyze the boiler design and operation in order to resolve the problem of SH failures. The resultant changes, most notably the use of high nickel alloy tubes (Inconel 825) in the high temperature superheater, have enabled Saugus RESCO to reliably produce high temperature steam for power generation.

In 1981, construction commenced on a new 2250 tons/day (TPD) (2036 tpd) facility in Peekskill, New York in Westchester County. Armed with the Saugus experience, SES selected B&W to build three 750 TPD (679 tpd) boilers operating at 900 psig (6205 kPa) and 830°F (443°C).

In addition, construction of a sister plant in Baltimore, Maryland, utilizing three 750 TPD (679 tpd) B&W boilers of the same design was completed in 1984.

As shown in Table 1, the ability to increase electrical output is a driving force to depart from the traditional steam conditions of 600 psig (4137 kPa) and 752°F (400°C). The Westchester facility provided the opportunity to fully analyze the design and operation of a modern high temperature and pressure mass-fired refuse boiler.

The testing programs described below provide an accurate assessment of boiler performance through the automatic acquisition of operating data, metallurgical analyses of a variety of alloy materials for corrosion protection, and periodic analysis of tube thicknesses through ultrasonic testing.

DATA ACQUISITION SYSTEM

Considerable effort was expended on the design of these units to ensure a state of the art, low maintenance mass-burning refuse boiler. In order to provide the project with continuous performance analysis capability, while simultaneously providing an "early warning" system for performance abnormalities, it was decided to install a remote, unattended data acquisition system (DAS) to automatically collect and transmit operating data. This system was installed by B&W at the Westchester facility in May of 1984 and at the Baltimore facility in October of 1985. Both systems have been providing performance data since installation.

System Configuration and Operation

The DAS not only collects and stores boiler operating data, but when requested, transmits these data for remote analysis.

TABLE 1 ELECTRICAL OUTPUT COMPARISON

	STEAM PRESSURE	STEAM TEMP.	FEEDWATER TEMP.	POWER SOLD
°	600 PSIG (4137 kPa)	752 F (400 C)	250 F (121 C)	450 kWh/ton (497 kWh/tonne)
°	900 PSIG (6205 kPa)	830 F (443 C)	300 F (149C)	525 kWh/ton (580 kWh/tonne)

ABOVE BASED ON:

° Turbine back pressure 2.5" Hg (63.5mm Hg)

° Refuse Calorific 4500 Btu/LB HHV (2170 kCal/kg LHV)

° In-Plant Power 65 kWh/ton (72 kWh/tonne)

The system draws upon two sources for data. Interfaced with the plant computer, the system acquires flow rates, pressures and temperatures from permanent plant instrumentation. Additional data is collected with the aid of a voltmeter internal to the DAS. The two sources jointly provide about 250 data points including gas temperature thermocouples (TC's), SH outlet tube metal temperatures, chordal TC temperatures, numerous steam temperatures, excess oxygen, and draft indications.

System Equipment/Peripherals (Fig. 1)

The heart of the DAS is a small Hewlett-Packard desktop computer (model HP85). This computer receives hourly portions of its data from the plant computer control system via an RS-232 connection to an unused printer port. The HP85 collects additional data with the aid of an HP 3497/3498 digital voltmeter system.

Data is collected hourly by the test computer and is stored on floppy disks. When requested, the HP85 communicates with B&W's engineering facilities through a telephone modem.

System Operation

Stand-By-Mode. The DAS system normally is in a stand-by mode, monitoring action on the printer port and "listening" for incoming calls. A request in this mode will send the test computer into either a data collection or data transmission mode.

Data Collection Mode. Incoming data from the plant computer will send the DAS computer into the data collection mode. The test computer carefully monitors the incoming logs for an initialization command. Detection of this command starts the transfer of appro-

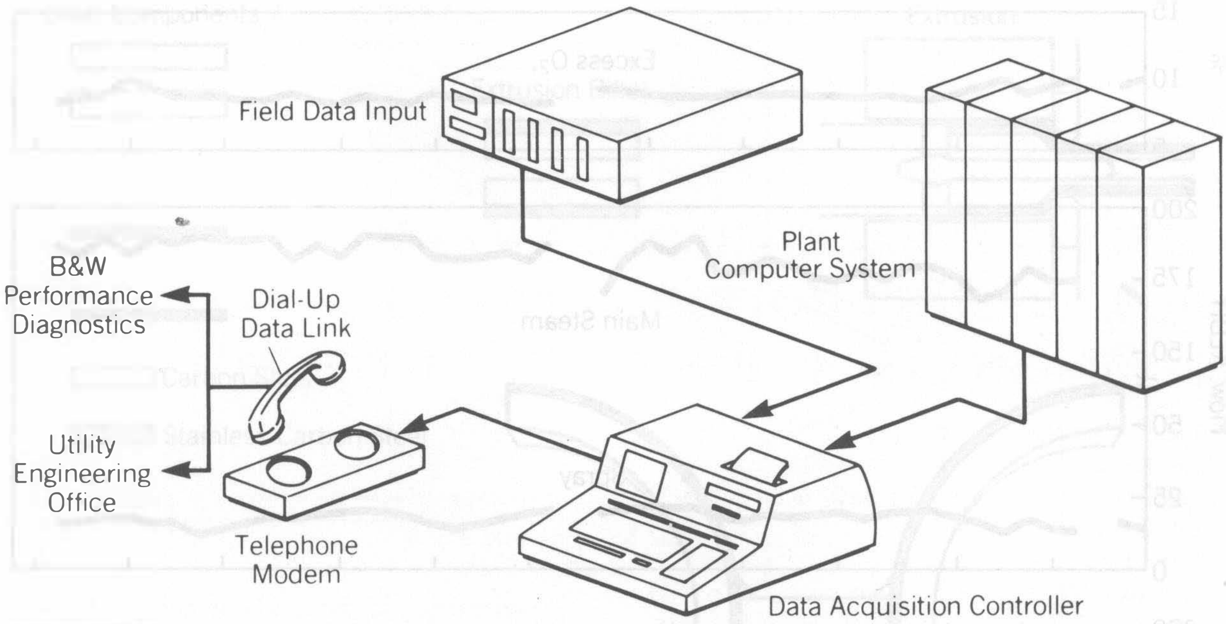

FIG. 1 SYSTEM EQUIPMENT

priate incoming data into the test computer's memory. This transfer ceases when a termination code is received.

Once required information is received from the plant computer, all remaining data is taken from the test system voltmeter. This mode is now complete and the collected data is stored, after which the test computer returns to the stand-by mode.

Data Transmission Mode. A call from B&W's engineering office will shift the test computer into the data transmission mode. The on-site test computer will then automatically receive instructions remotely regarding data transmission and resumption of data collection. This mode is automatically terminated in the event of telephone system abnormalities.

Performance Evaluation (Fig. 2)

Performance calculations include boiler efficiency, convection bank absorptions, flue gas weights and air weights. Key items are then averaged and plotted as both daily and weekly averages. These long-term trends provide a major tool for overall performance evaluation. They are generated monthly and distributed to appropriate personnel within SES and B&W.

METALLURGICAL EVALUATIONS

Higher temperature pressure cycles can improve project economics and the likelihood that a given project will go forward. Material selection is one of the most critical design criteria for refuse-fired boilers. Because gas-side corrosion is more aggressive at higher temperature pressure cycles, arrangements were made to carry out metallurgical evaluations of SH tubes at the Westchester and Baltimore facilities.

Based on prior studies performed at Nashville Thermal Transfer and the City of Hamilton (Ontario, Canada), B&W designed and installed a superheater test loop at the Baltimore facility and a composite tube test wall panel at the Westchester facility for the purpose of observing corrosion rates of different materials in the refuse-fired environment.

Composite Tube Panel Test

The boiler waterwalls at the Westchester and Baltimore facilities are a gastight membrane construction consisting of 2½ in. (63.5 mm) diameter tubing on 3 in. (76.2 mm) centers. This construction is similar to the boilers supplied to Nashville Thermal Transfer. A prior test program conducted at that plant yielded data

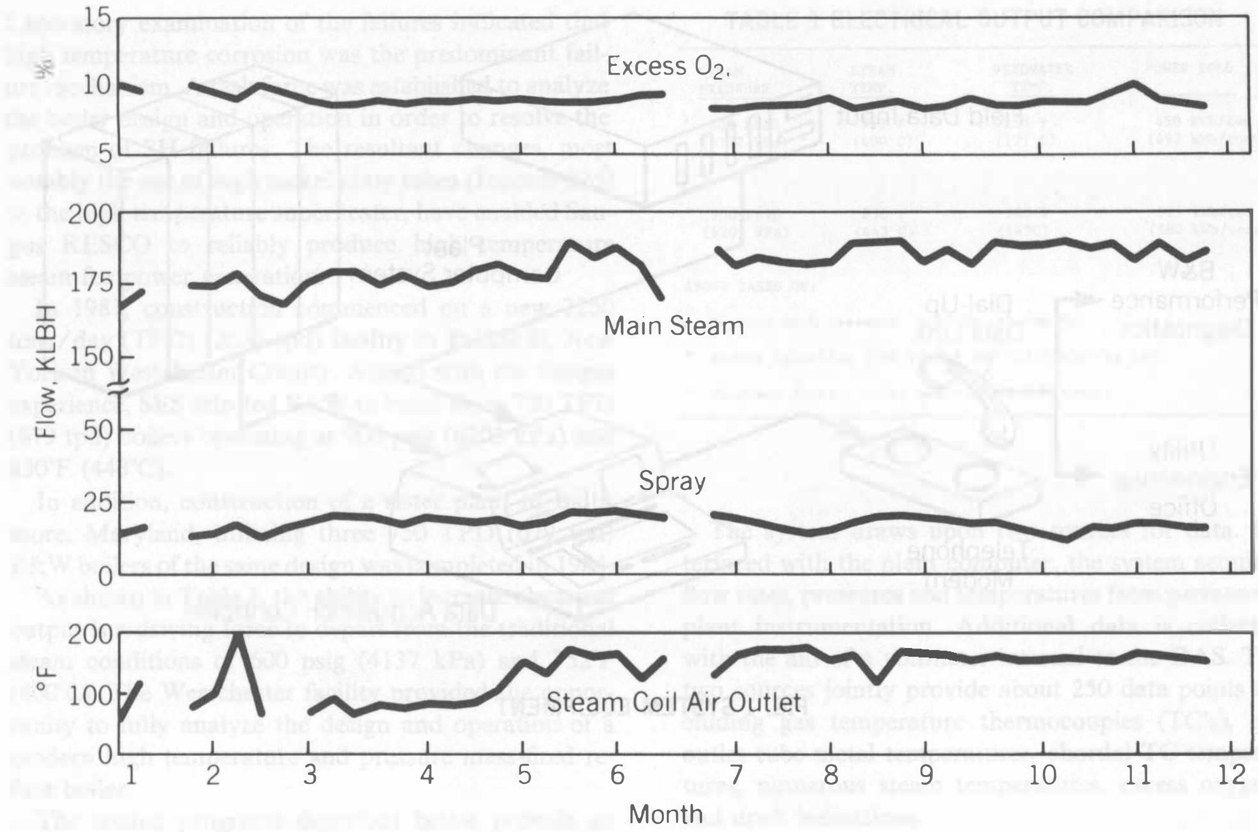

FIG. 2 TRANSMITTED DATA 1985

suggesting a cost-performance advantage for co-extruded stainless-carbon steel tubing over carbon steel. During fabrication of the sidewall panel for one of the Signal boilers, a 10 ft. (3 m) long, ten-tube wide panel insert constructed from tubing jacketed with 304 stainless steel (Fig. 3) was installed. A chordal thermocouple tube section was installed in the middle of this insert, in a position of strategic value relative to the location of the furnace arches and overfire air ports.

Base ultrasonic testing of the composite tube panel was completed in January 1984, after installation but prior to initial operation. Follow-up ultrasonic testing was done during periodic outages in order to track corrosion progress. Within the first 6 months, it was visually apparent that the stainless steel was corroding at a rate in excess of the Nashville experience. Since exposed carbon steel tubing in the vicinity of the panel insert was not suffering measurable corrosion, it was decided to leave the insert in place and observe the corrosion phenomenon after the base carbon steel tubing became exposed. Chordal thermocouple data were charted to track heat input to the panel.

Corrosion of stainless steel continued in a pattern approximating the gas flow leaving the lower frontwall furnace arch. Corrosion was not arrested nor diminished when the stainless steel jacket had completely corroded. On May 1985, a tube failure occurred in the panel insert and the entire test panel was removed for metallurgical studies. All other furnace tubing remains in satisfactory condition.

Superheater Test Loop

A long-term superheater corrosion study had been completed previously on the boilers of the City of Hamilton, Ontario. These boilers burn refuse-derived, semisuspension fuel. The results of the study were helpful in formulating test strategies for a similar study at the 2250 TPD (2036 tpd) mass-fired facility in Baltimore. A special single-flow superheater loop, constructed of nine different materials placed in various locations, was fabricated and installed subsequent to plant commissioning (Fig. 4). Steam flow to the loop in the Baltimore plant is controlled separately. Tem-

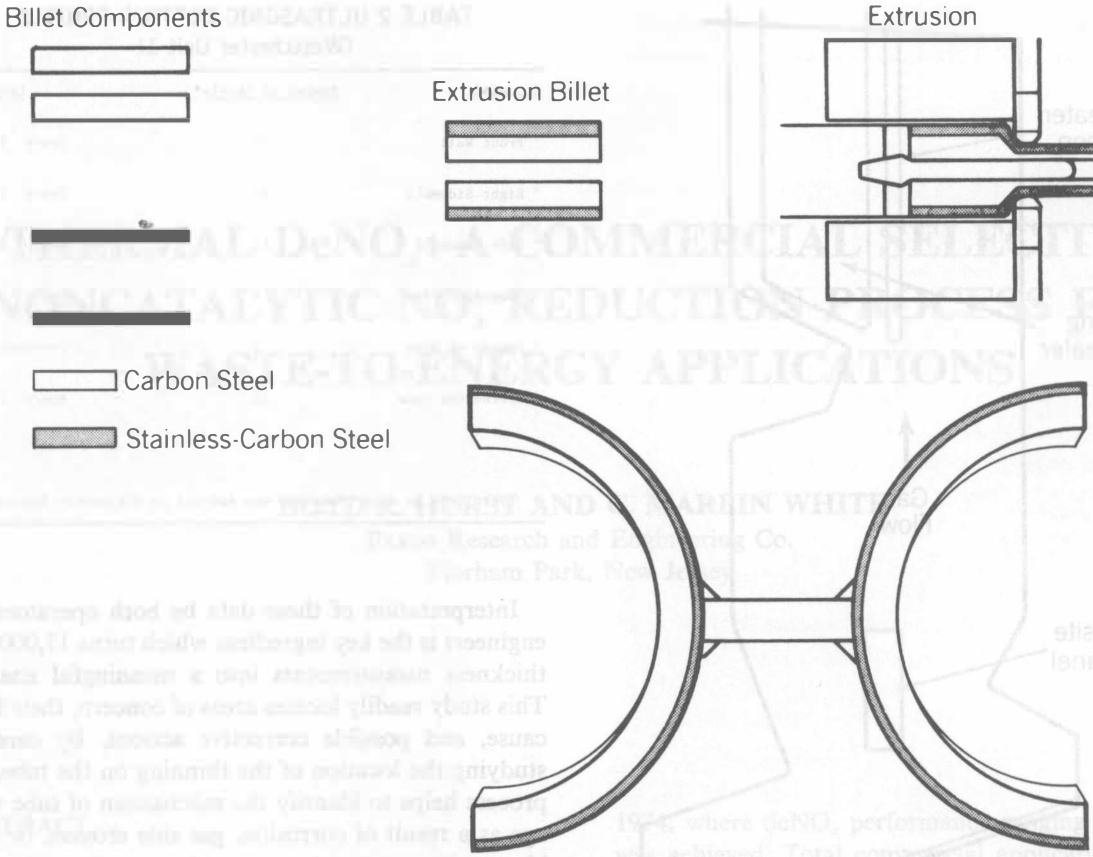

FIG. 3 COMPOSITE TUBE PANEL

peratures (gas side, steam side, and tube metal) are monitored by thermocouples embedded or pad welded to tubes in several locations. The entire test loop can be isolated in case of tube failure so that plant availability is not jeopardized by a potential tube leak. All tubing received an ultrasonic test to baseline tubing thickness. The test loop, installed since October 1985, is being operated at metal temperatures exceeding 1025°F (552°C) and at a steam temperature exceeding 925°F (496°C).

The installation of a similar data acquisition system on this boiler greatly facilitates data collection and analysis of this test loop as well as integration of its performance with other boiler data. This system also permits real time observation and analysis of operating data at B&W's engineering offices in Barberton, Ohio. The test program is continuing and preliminary data indicate good correlation with the Hamilton test data which suggest that higher alloys perform better in the refuse combustion environment. The results of this test program will enhance future superheater metal selection on a cost versus performance basis.

ULTRASONIC TESTING

Routine nondestructive examination of pressure parts is an important aspect of the preventive maintenance program for refuse-fired boiler operation. Tube thickness measurements by means of ultrasonic testing (UT) alert the operator to potential trouble spots in the boiler setting and indicate a need for more frequent examinations, changes in operating procedures, or replacement/shielding during scheduled maintenance outages.

In order to fully evaluate the performance of the 750 TPD (679 tpd) boilers at Westchester, an extensive UT program has been conducted on Unit 1. As shown in Table 2, extensive coverage of the unit provided a detailed profile of the condition of the furnace and the

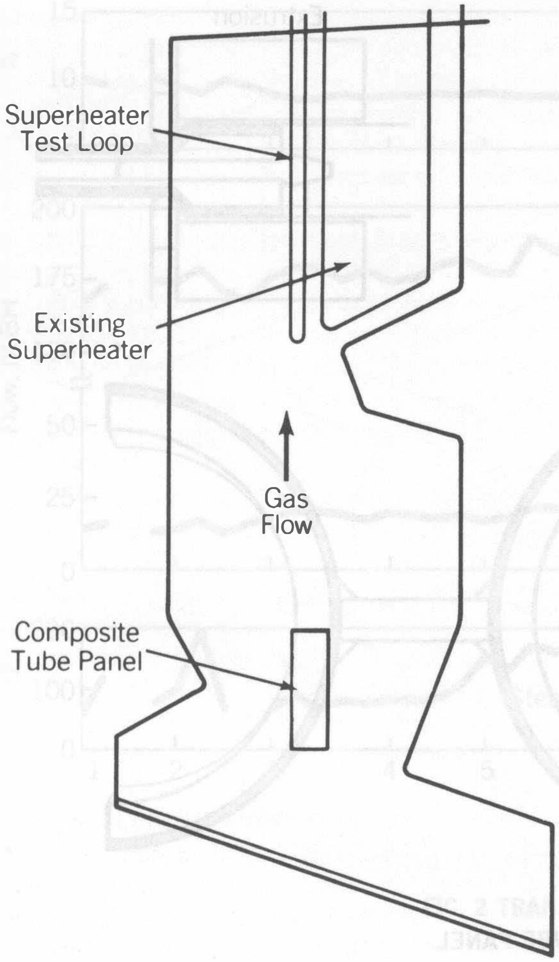

FIG. 4 TEST SECTION LOCATIONS

superheater. The complete set of readings was done prior to first firing (baseline). A second set of readings was taken at 2500 hr of operation and a third set, representing 12,500 hr of operation, was taken in February 1986. These data points are carefully recorded and color plotted to illustrate a clear picture of overall pressure part soundness. System engineers and operators carefully review the data for signs of areas with excessive metal loss so that corrective measures can be implemented.

TABLE 2 ULTRASONIC TESTING PROFILE
(Westchester Unit 1)

Location	Number of Levels*	Level
° Front Wall	11	Every 5 feet
° Right Sidewall	11	Every 5 feet
° Left Sidewall	11	Every 5 feet
° Composite Panel	8	Every 1 foot
° Center of Nose	1	-----------
°Superheater Face	12	Every 2 feet

* Every tube at each elevation was subject to Ultrasonic Testing

Interpretation of these data by both operators and engineers is the key ingredient which turns 17,000 tube thickness measurements into a meaningful analysis. This study readily locates areas of concern, their likely cause, and possible corrective actions. By carefully studying the location of the thinning on the tube, this process helps to identify the mechanism of tube wastage as a result of corrosion, gas side erosion, or sootblower impingement to provide assurance that unscheduled downtime can be minimized.

CONCLUSION

SES and B&W have developed an optimum arrangement of heat absorbing surface and air flows to achieve reliable combustion and heat recovery from unprepared refuse. An overall performance and materials test strategy (including installation of data acquisition and analysis equipment) was chosen during the design of these boilers. This process has provided an excellent understanding of boilers and materials performance, allowing system designers to make informed decisions on refuse boiler design optimization with the confidence that overall plant reliability will not be compromised.