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# BOILER CONDITION ASSESSMENT PROGRAM AT RIVERBAY CORPORATION CO-OP CITY UNIT NO. 4

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# Boiler Condition Assessment Program At Riverbay Corporation Co-op City Unit No. 4

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## INTRODUCTION

Riley Stoker is one of the major U.S. manufacturers of steam generators and fuel burning equipment. Riley has provided quality products and services to the power industry in both the utility and industrial markets for over seventy years, supplying steam generators and fuel burning equipment from 40,000 #/hr to over 4,650,000 #/hr steam capacity. Riley's fuel burning experience includes oil, gas, coal, bagasse, wood, refuse, coffee grounds, naphtha, phenols and tar oil.

The Riley Condition Assessment Program is an outgrowth of the Boiler Availability Improvement Program and the Team Inspection Service. These Programs have been ongoing for the past twelve years on industrial and utility boilers. To date, over one hundred inspections and over two thousand failure analyses and metallurgical reports have been completed.

Riverbay Corporation is responsible, among other things, for the thermal and electrical utility services for the world's largest housing cooperative. Co-op City as it is called, consists of 15,372 apartments, three shopping centers and two school complexes. In order to meet the heating, cooling and electrical needs of Co-op City's residents, a central plant was constructed which today consists of three oil fired steam generators.

In 1984, Riverbay Corporation began a refurbishing program to restore the utility system to good operating condition and to upgrade inefficient systems. As part of this program, Riverbay contracted with the Power Services Division of Riley Stoker Corporation to provide a condition assessment of their Number 4 boiler. Riverbay Corporation is using the findings and recommendations con tained in the final report of the program to repair and upgrade the unit. Riley's practical approach to industrial boiler condition assessment provided Riverbay Corporation the expertise and experience of a major boiler manufacturer in a cost effective manner.

# BACKGROUND

## BOILER

Boiler No. 4 is a field erected water tube boiler which was first placed into service in 1968. The boiler has a maximum continuous rating of 305,000 lbs/hr at superheater outlet conditions of 520 psig and 600°F. The boiler has four burners and its primary fuel is No. 6 fuel oil, with 0.3% sulfur content.

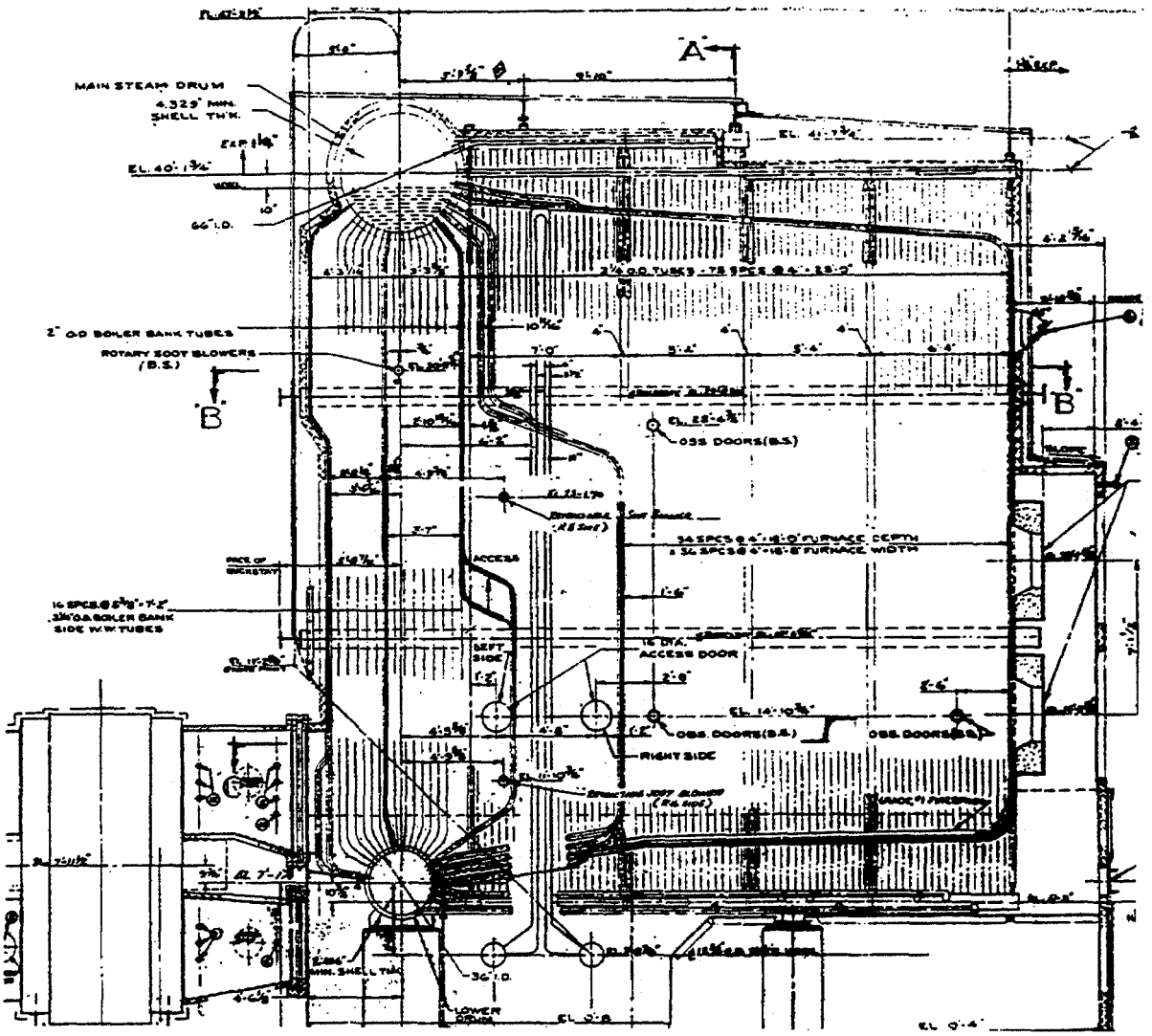


**FIGURE 1.**

## Facility

Boiler No. 4 is one of three boilers of the Co-op City Power Plant. Plant steam load is highly cyclic, varying both daily and seasonally. The plant maximum load can be as high as 580,000 lbs/hr whereas the minimum load is 30,000 Ibs/hr. The plant serves the needs of 60,000 people, involving a total of approximately 24 million square feet of floor space comprising Co-op City. The plant generates approximately 1.5 billion pounds of steam per year.

The boilers provide steam for the entire thermal needs of the facility including space heating, domestic hot water and air conditioning. Air conditioning is provided by four steam turbine driven chillers, each rated at 6,250 tons. A portion of the facility's power needs are met with a 6 MW single automatic extraction steam turbine generator.

Two thermal distribution systems service the facility. A high temperature hot water system satisfies the residential domestic hot water and all non-residential requirements and a warm/chilled water system provides space heating and cooling to the residential buildings.

The nature of the steam load makes boiler reliability of paramount importance.

## Historical

Boiler No. 4 has been quite reliable over the years. Several operating problems have existed, but they have had little impact on reliability.

A great deal of work has been devoted to restoring Boiler No. 4 to proper condition by eliminating existing problems. Over the past few years burner refractory, burner registers, air heater baskets and seals and oil guns have been replaced.

Superheater tube bowing has been a problem over the years, though tube failures have been few. Flame impingement on the lower sidewalls of the furnace has also been a problem and has resulted in tube failures in the last year. Drum water level has also been problematic during boiler transient events.

Boiler excess air levels have historically been higher than design with excess air levels increasing significantly at reduced loads. Originally believed to be related to register and trim system problems, testing has shown that conditions were not significantly improved after rebuilding the burner registers and resetting of the trim system.

The makeup water requirements have also caused problems. Boiler feedwater was originally design ed to be the source of makeup water for the thermal distribution systems. With the need of the distribution system being small, impact on the boiler would be negligible. Currently, with thermal distribution system leaks causing a high need for makeup water, solids loading into the boiler is much higher than originally anticipated in the design.

## Background for Inspection

A comprehensive inspection and evaluation was planned for this boiler because the unit is twenty years old. The primary intent of the inspection was to assess boiler condition for continued operation at present rating. It was also intended to address several operating problems since the multi-discipline background of the evaluation team was ideal for addressing those operational problems that had not been resolved to date.

This work was a portion of an overall refurbishment program for the entire utility system to restore it to proper operating condition. The inspection on Boiler No. 4 was one part of the plan. Inspection of Boiler Nos. 1 and 2 are scheduled for later this year.

Assessment of the boiler condition for increased operating condition was also performed. Uprating to 875 psig and 825°F superheater outlet conditions, if feasible, would approximately double the power output from the turbine generator and would reduce the cost of generated power.

Such uprating could only be considered if the inspection revealed the boiler to be in good condition. The boiler inspection is a key element in the evaluation of uprated service. Uprating a twenty year old boiler is a difficult decision to make without current, accurate data on the physical condition of the boiler.

## Goals of Inspection

The goals of the inspection were:

- A comprehensive assessment of the boiler's physical condition for continued safe operation. Recommendations for correction of operating problems would be provided. A punch list of items requiring corrective action would be generated;
- To provide data based on the recommedations, for annual budget and long term financial planning;
- A comprehensive assessment of condition for future uprating to original design conditions, including identification of repairs required to achieve boiler reliability at the higher rating.

Findings have been prioritized and budgetary costs have been established for each item. This is of great

importance since repairs and upgrade work to the utility system are conducted using annual operating funds rather than with borrowed money.

### Condition Assessment Program

The Condition Assessment Program began well before any on-site inspections were undertaken. A thorough review of design documentation and drawings was conducted in Riley's Worcester Office. This review was supplimented by correspondence between Riverbay Corporation and the Riley Team Leader. Early cooperation between Riverbay Corporation and Riley Stoker provided the inspection team with information on areas of special concern to Riverbay Corporation before the team arrived on-site. The major problem areas identified:

- Flame impingement and resulting furnace water-wall tube blistering and failures
- Superheater element distortion and failure of tube guides
- Deposits found in superheater and turbine generator
- High excess air

In order to address each of the problem areas and make an accurate assessment of the current condition of the boiler, a week long inspection of the unit was conducted by members of Riley Power System's Boiler Evaluation Group. The major areas inspected were:

- Boiler pressure parts
- Boiler setting
- Fuel systems
- Air and flue gas systems

The major portion of the condition assessment program consisted of a thorough visual inspection by experienced engineers. Still photography was utiliz ed to provide a permanent record of the condition of the boiler and components during the inspection. Each of the four areas of the boiler were checked for the following:

#### Boiler Pressure Parts

- Alignment, bowing, distortion of tubes or headers
- Intergrity of hangers, attachments, clamps and supports
- Signs of external erosion, corrosion, swelling or overheating
- Presence of external deposits
- Condition of the drum internals

#### Boiler Setting

- Integrity of main support pedestals
- Condition of casing, insulation and lagging
- Adequacy of furnace roof seals
- Integrity of supports, braces and attachments in penthouse
- Condition of buckstays

#### Fuel Systems

- General condition of windbox structure and attachments
- Integrity of burner throat refractory, with dimensions
- Condition of oil guns, piping and burner nozzles
- General condition of dampers and registers

#### Air and Fuel Gas Systems

- Overall condition of air heater, including baskets, seals, expansion joints, inlet and outlet ducts and dampers.
- Integrity of forced draft fan and intake screen.
- Condition of air and gas ducts and turning vanes.

The external visual inspection of the boiler pressure parts was supplemented by an internal inspection of the superheater and lower waterwall headers. This inspection was performed using a six foot flexible fiberscope and was used to check for internal cracking and the presence of deposits.

Additional testing and examination of the boiler pressure parts included ultrasonic (UT) thickness surveys of the boiler tubing and metallurgical examinations of tube samples removed from the boiler. The data obtained from the UT survey helped to determine the extent and severity of the waterwall tube blistering and also located an area of minor tube thinning which had not been previously detected, see Figures 2 and 3. In addition, the UT thickness data provided a basis for evaluating the possibility of uprating the unit operation.

Furnace UT thickness readings were supplemented by the removal and metallurgical evalua tion of a small tube sample from one of the side waterwall tubes, see Figure 4. The evaluation provided the answers to the cause of the blistering and insights into the origin of the white deposits found in the superheater and turbine generator. Similar, but less extensive, UT surveys were conducted in the superheater and boiler bank areas.

The next step in the program was to use the data obtained from the inspection in calculations to determine the remaining life of various boiler components. Inputs to the stress calculations consisted

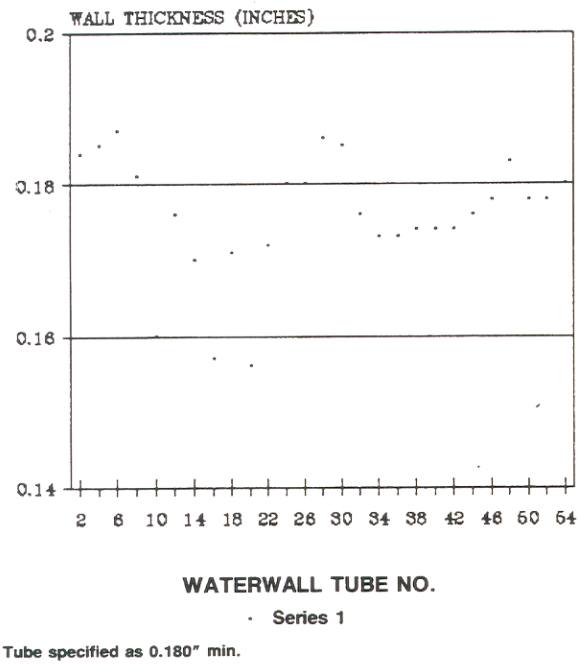


FIGURE 2. Riverbay Corp. Front Wall UT Survey

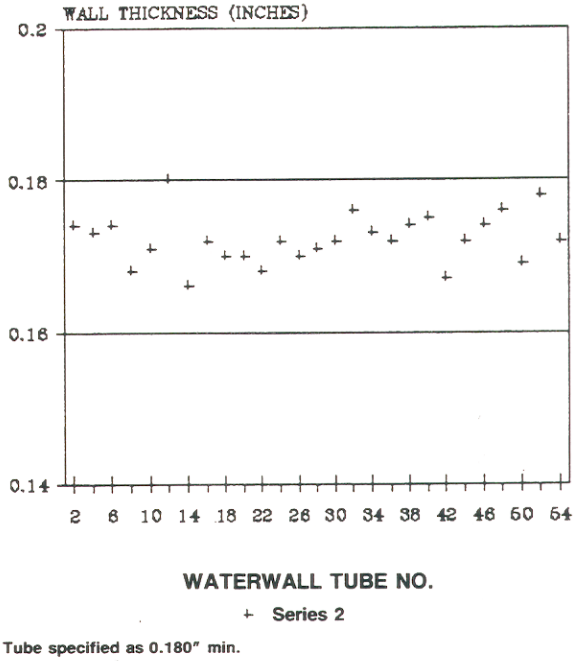


FIGURE 3. Riverbay Corp. Screen Tube UT Survey

FIGURE 4. Blistered Tube Sample

of the tube outside diameter and representative thickness values, based on the UT survey and the specified maximum working pressure, which is conservative. A steady state pressure stress value was obtained using the equations of PG-27.2.1 of ASME Code, Section I.

The Larson-Miller parameter was used to calculate a time to rupture for each tube sample based on the steady state pressure stress and temperature exposure. The effects of internal scale were accounted for in the temperature inputs.
It was concluded that the subject tubes would not fail from creep rupture effects in the current or proposed future operation of the unit, provided that there is no significant future increase in internal scale or decrease in wall thickness.

The final step in the condition assessment program was to bring all of the inspection and testing findings together with the analytical results in a clear and concise final report. All pertinent information and photographs were presented and used as the basis for the final set of conclusions and recommendations. A brief summary of the findings and conclusions taken from the final report are:

- The boiler and equipment are in good condition considering the 20 years of duty to date.
- The results of the UT survey indicated that minor tube thinning has occurred throughout the furnace waterwalls. The thinning of the tubes would not adversely affect the short term operation of the boiler. The vast majority of UT readings were above the minimum required for uprated service. However, the few readings below the minimum indicated that the uprating of the boiler would virtually eliminate any tube wall thickness margin. The presentation of this information stresses the importance of monitoring the tube wall thickness to ensure continued reliable operation of the boiler in any future uprated operating mode.
- Replace furnace sidewalls in the flame impinged area.
- Prior to replacing any waterwall tubes, the poor burner performance must be corrected and methods to improve water treatment are required. The top priority should be given to returning the burners to original specifications, most importantly the installation of burner shrouds. After modifications, a full combustion test should be run. Improved methods to help turndown can be developed during the tests.
- In an effort to prevent future superheater tube misalignment, two recommendations were presented. First adding thermocouples to the tubes and the superheater inlet header will provide information regarding improper or insufficient steam flow through the tubes. The second recommendation was an additional design feature which would restrain the upper portion of superheater elements. These two recommendations will provide information on the cause of the problem and help eliminate the misalignment of the superheater.

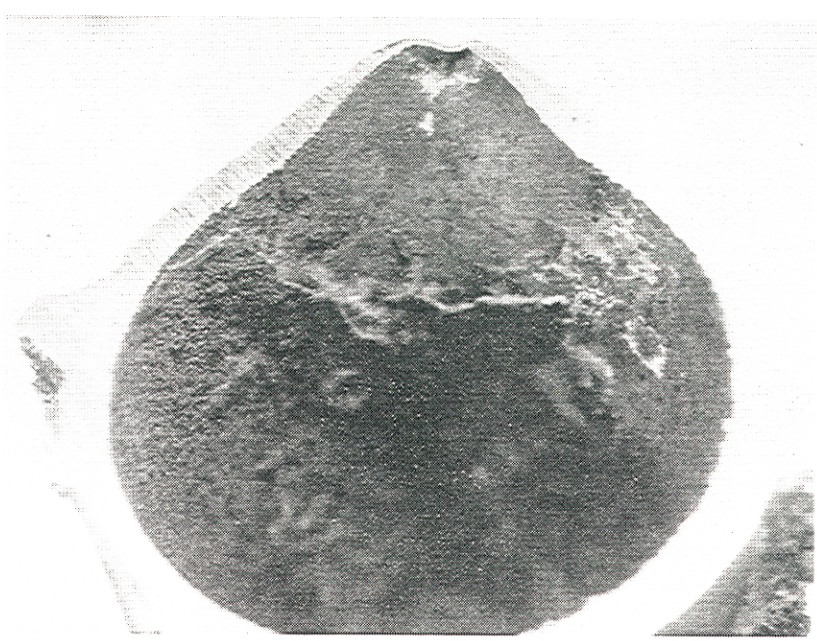

**FIGURE 5. Cross Section of Blistered Tube**

- The metallurgical analysis revealed deteriorated micro-structure in the furnace wall tubes due to excessive temperature exposure. Incomplete combustion of fuel, has led to flame impingement on the furnace side waterwall. The high heat input to the tube which resulted, caused deposits in the feedwater to plate on the hot inside surface of the tube. The combination of high heat input and inadequate heat transfer through the relatively thick scale deposits resulted in the tube overheating and blistering, see Figure 5.
- The two chemical analyses performed on the deposits found in the mud drum and the blistered tube revealed a significant amount of copper and particularly in the waterwall tube, chlorine. The chlorine is believed to be a result of inadequate rinse of softeners located upstream from the boiler. An investigation to pinpoint the origin of copper should be conducted.

## Overview of Replacement and Modification items

One of the first items repaired, as recommended in the final report, was the installation of perforated burner shrouds. The design of the shroud was provided by Riley for installation by Riverbay personnel. The function of the shrouds was to properly distribute air evenly to all the burners at a variety of loads.

The bowed and misaligned superheater is currently scheduled for replacement in the near future. **Although** the actual design modification to prevent futre bowing, presented in the final report, is not being used, other new design features are being instituted. Specificily, a new guide lug design and a tube material change.

The final step to uprated service is to conduct an engineering study to determine the new set points, flow rates, etc. A proposal for this work has been submitted and is presently under review.

## Program Costs

Inspection costs were quite modest and heavily in favor of doing the work when evaluated on a cost-benefit basis. Riverbay Corporation's cost of preparing the boiler for the inspection, supporting the inspection and restoring the boiler to operating condition was moderate. Although the cost of the evaluation was a significant portion of typical boiler annual maintenance costs, the expected operating savings are significant.

The findings of the evaluation are expected to reduce the annual operating costs by several percentage points. With each percentage point reduction being valued at $30,000 significant payback is expected.

## SUMMARY

During the refurbishment of the Co-op City utility system, Riverbay corporation recognized the need for upgrading and repairing the boiler in their power plant. They also realized that for repairs and upgrades to be effective, a detailed picture of the current condition of the boiler was necessary. To meet this need, Riverbay Corporation and Riley Stoker worked together to develop a comprehensive condition assessment program for their No. 4 boiler.

The condition assessment program consisted of four phases. First the review phase allowed team members to familiarize themselves with the design and operational history of the unit through a review of design documents and operational data. Second, the inspection phase consisted of detailed non-destructive and destructive testing and a **thorough** visual inspection of the unit. The third phase used the data obtained in the review and inspection in computations to help determine the current condition of the boiler. Finally, all of the data, analyses and recommendations which resulted from the program are presented in a detailed final report.

There are many factors which contributed to the success of the program. First, and most importantly, the cooperation and communication between Riverbay and Riley provided the team members with quality information regarding the unit operation and maintenance. The cooperation enabled the inspection team to be comprised of individuals with a diverse background which was used to attain all of the goals of the program.

The ultimate goal of any condition assessment program is to determine the current condition of the boiler. Information gathered during the assessment program is used as the basis for conducting repairs and modifications to the boiler which will ultimately result in direct operating cost savings and a higher availability factor for the owner/operator. Reducing Riverbay's annual operating costs by several percentage points, qualifies the condition assessment program as a success.