Guidelines for integrity evaluation and remaining life assessment of recovery boilers – CENIBRA’s experience

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ABSTRACT: The need for integrity evaluations and remaining life assessments of boilers arises from technical, economic, and legal reasons. The pulp and paper industry has less experience and tradition in using this engineering discipline when compared to other industries such as oil, petrochemical, and power generation. The pertinent Brazilian legal standard (NR-13) is concise in establishing this requirement, without providing details of applicable technical procedures. Furthermore, recovery boilers are a special type of steam generator, being very specific as to their inherent in-service degradation mechanisms and inspection needs.

In view of the above scenario, pulp and paper mill engineers often have doubts and encounter diverse interpretations of the official regulations when they need to carry out integrity evaluations of quarter-century old recovery boilers. This paper relates CENIBRA’s recent experience in evaluating its recovery boiler No. 1. Application: This paper may serve as a guide for other pulp mills and help answer questions about the process of integrity evaluation and remaining life assessment of aged recovery boilers.

Basic Requirements

The objective of a structural integrity evaluation (SIE) is to enable a safe continuation of the unit’s operating life, generally beyond the period first intended. Of course, there is not a single formula for conducting such investigations. However, some basic requirements must be taken into consideration in these procedures. Annual inspections do not fully address such requirements. An SIE differs from routine inspections in the following ways:

- It investigates time-dependant degradation mechanisms that occur in the mid- and long-term, such as fatigue, creep, metallurgical degradation, and water chemistry effects. These mechanisms must be clearly differentiated from those acting “faster” or those more related to incidents or to accidental and circumstantial factors.
- It investigates in greater depth the integrity of parts that do not usually receive such attention during periodic inspections due to lack of time and difficulty in access: headers, drums, attemperators, main steam lines, structural elements, etc. (see Figs. 1-3).
It evaluates the integrity of each boiler component individually, to determine the susceptibility of each one to the corresponding degradation mechanisms, indicating those whose useful life will expire before the others.

It evaluates metallurgical aspects, mostly in high temperature parts, to identify nonvisual damage mechanisms that may not be indicated by changes in wall thickness. Examples of microstructural degradation include spheroidizing, graphitization, precipitation of carbides, and microvoids from creep. These are illustrated in Figs. 4-7. The main concern with corrosion in recovery boilers may divert the engineers’ attention from this point.

- It focuses attention on the steam and water side, investigating the unit’s history in relation to possible waterside contamination (e.g., with liquor) and evaluating possible consequences.
- It investigates possible alterations in behavior of structural elements, such as increases in hysteresis of elastic supports of steam piping.
- It takes operations above rated capacity and excessive cycling into consideration.

SIE should encompass more than the legally required evaluation of the boiler itself. Common sense and best practices dictate that SIEs should extend to peripheral and ancillary elements closely associated with the boiler, especially those subjected to high temperatures, such as the main steam line, headers, and accumulators, up to the turbine’s inlet flange. Additionally, the mill should evaluate the integrity of the deaerator, feed water tank, feed water line, dissolving tank, and other support systems (see Figure 8).

### SIE conceptual approaches

Mills vary in their approach to conducting SIEs, their objectives, and the criteria they may use to assess in-service damages and degradation. The two main approaches are as follows:

**The “Project Code” approach**—The evaluation of used and degraded equipment, exclusively from a design codes’ point of view (American Society of Mechanical Engineers, for example) is the simplest and most traditional approach. It applies the same design and manufacturing criteria for evaluating the boiler’s condition and damages resulting from service. Through testing and repairs and replacements, this approach aims to restore the boiler’s condition and reliability to “as good as new.”

**The “Fitness-for-Service” approach**—This newer approach evaluates the equipment’s fitness-for-service, in spite of accumulated damages, in its degraded condition. Analytical techniques to establish the possibility to continue operating with existing defects are applied (taking into consideration the flaws’ dimensions, shape, localization, evolution, kinetics,
The evaluation may include stress analyses, calculations through fracture mechanics, and use of API 579 and BS:7910 standards. Among other benefits, this approach seeks to minimize repairs and replacements, without compromising reliability.

The second approach, already consolidated in the power generation, oil, and chemistry industries, has also gained increasing recognition and acceptance in other industries. Both philosophies mentioned, and others, are acceptable from the technical point of view and recognized by legislation. It is up to the boiler owner to evaluate it and other approaches in terms of cost, time, availability of technical resources, company culture, and other factors.

PROCEDURES FOR EVALUATING STRUCTURAL INTEGRITY AND REMAINING LIFE

Integrity evaluations involve complex engineering work that must be carried out by extremely specialized and qualified professionals. While specific procedures may vary, the evaluation is usually conducted in three distinct phases:

1. Phase 1: Preliminary Evaluation

**Objectives**
- Define physical limits, or the “boiler island,” within which analyses will be carried out.
- Collect information on the equipment (scrutinize the unit’s operational, maintenance, and inspection history, and its design data).
- Identify in-service degradation mechanisms taking place in the boiler.
- Identify the boiler’s critical parts or zones, and which damage mechanisms affect them.
- Analyze the collected information and determine whether available data are sufficient to establish the unit’s structural condition.
- Plan inspection and additional non-destructive testing (NDT), as needed.

**Phase 2: Non-destructive Testing**

**Objective**
- To supplement data collected in Phase 1 (which in extremely rare cases are sufficient *per se*), verify through additional inspections and NDTs the presence of accumulated in-service damage, defining its extent and responsible mechanisms.

**Phase 3: Complementary analysis**

**Goals**
- Analyze data collected in the previous phases.
Confirm the hypotheses formulated during Phase 2, using complementary tests to samples taken from the equipment, double-checks, actual stress analysis, etc.
Reach final evaluation of the structural condition and the remaining life.

A final report must then be issued, containing all the information regarding the evaluation: the current structural condition and remaining life of each boiler component; recommended procedures for future similar evaluations; possible recommendations for repairs or replacements, re-rating of components, possible process changes; calculations; and all applicable planning.

### RECOMMENDATIONS FOR NEW BOILERS
The procedures addressed in this paper are mainly intended for owners of older boilers, especially those approaching the
legally established time for starting the integrity evaluation. However, the discussion and suggestions may be useful to those dealing with new boilers, and even for projects in the early stages of specification and procurement for a future unit.

The following suggestions may be helpful to owners of newer boilers, or those specifying or procuring a future unit:

- Require that the vendor who is offering a new boiler provide recommendations or guidelines for future SIE of the equipment being supplied.
- Keep samples of all materials of construction of a newly erected boiler, as a reference for future comparison as to micro-structural degradation and creep.
- Conduct dimensional examinations of the high temperature tubes before the initial start-up as a reference for future comparison as to creep.
- Consider installing instrumentation to monitor the temperature of the hottest and most critical parts of the future boiler.
- Perform an “early start” of the SIE program, collecting data of interest and recording relevant information through the life of the boiler from the beginning of its operations.

**FINAL CONSIDERATIONS**

An integrity evaluation is not just an extensive program of inspections and testing, or life-time projections, although elements of those are markedly present. It is rather an ongoing, multi-disciplinary program that should be established from the beginning of the boiler life cycle. It must be customized for each individual plant, taking into consideration its actual status as to accumulated damage. Thus, the boiler owner should be cautious about vendors offering a predetermined, “standardized” program of inspections. The integrity evaluation also presumes a close participation and co-operation of the boiler owner and the professionals commissioned to do the evaluation.

The following are some of the benefits afforded by integrity evaluations and remaining life assessment programs:

- Establishment of a base line of the boiler’s structural condition
- Increased safety for personnel and facilities
- Increased availability of the boiler at maturity
- Economic flexibility, allowing the mill more time to explore replacement and repair options, and possibly postpone investments
- “Good will” through a positive image of the mill, associated with safety and proper engineering practices
- Training for the mill’s engineers
- Legal compliance.

**Author’s Note:** The information and recommendations contained in this paper reflect the author’s best knowledge and belief at the time of writing. However, the text should serve only as a general reference to the reader. No warranties are offered or responsibilities taken that the information provided is perfectly adequate or sufficient for the purpose in question. T.J.

**LITERATURE CITED**

3. O Papel, magazine (Vol. 88 No. 2).}

**13. CENIBRA’s recovery boiler No. 1.**

This unit had its first start-up in 1977, and underwent an integrity evaluation program in 2002, according to the guidelines described in this paper.

4. Procedimento Geral de Avaliação de Vida Restante de Componentes Estáticos Submetidos a Alta Temperatura. Instituto de Soldadura e Qualidade, Lisboa.

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Facing the need to conduct an integrity evaluation and remaining life assessment program to a recovery boiler in the mill I work for, I soon realized there was limited information available about this subject within the Brazilian pulp industry, in spite of its importance. Also, I found diverse interpretations (by previous users and inspection services suppliers) of the official requirements, and no written guidelines with a specific focus on recovery boilers. That prompted me to write this article.

Brazilian official standards require that boilers undergo an integrity evaluation at 25 years. But they give no technical guidance and do not highlight the special needs and risks associated with recovery boilers. This paper is therefore intended to help provide mill engineers with some complementary support when they carry out such programs.

The most difficult aspect of preparing for an integrity evaluation, and in writing this paper, is the lack of references and successful past experiences in Brazilian mills. I searched the procedures used in other industries, and by pulp mills abroad, then adapted them to our reality.

Through my research, I was particularly impressed by the wide array of available engineering disciplines and testing techniques that now can help engineers evaluate the conditions of a used recovery boiler, giving an excellent level of confidence in the results of such evaluations.

Some Brazilian mills are systematizing and improving their procedures in evaluating the integrity of aged recovery boilers. This paper, while not intended to be a complete or definitive guide, could be a first step towards this improvement.

With time, more recommendations and aspects pertaining specifically to recovery boiler in-service evaluations should be added to the contents of this paper, making it more and more comprehensive.

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