Improving Boiler Reliability and Availability

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ABSTRACT

Boilers can have efficient long life or they become useless and uneconomical to operate. How well the equipment operated and maintained, the fuel being fired, and the type of service experienced, all determine the life of the equipment and the need for carrying out major Reliability And Availability extension programs. To determine the extent of work necessary for regaining new boiler life, the actual performance and reliability of the equipment must be assessed; the existing mechanical condition of boiler components defined; and the history of problems-causes for unreliability and performance deterioration should be known.

This paper deals with the various techniques used to evaluate the condition of the boilers, boiler components and thereby provides guidance for carrying out Reliability And Availability extension programs. The power plant boilers and industrial boilers are designed conservatively with lot of safety factor in the design stage. By carefully assessing the present condition of the boiler with the help of various NDT methods and metallurgical studies, the boiler can be operated even after 25 years. These studies can help in planning for the replacements of the boiler components in phased manner.

Some of these techniques, data have been developed by Babcock & Wilcox, USA. Thermax Babcock & Wilcox Limited uses these patented techniques for remaining life assessment studies, carried out over last 15 years worldwide.

INTRODUCTION

Need For Condition Assessment and Remaining Life Analysis.

A large percentage of power, petroleum, and chemical plants all over the world have been in operation for such long duration that the critical components of these plants have been used beyond the design life of 30 to 40 years. This percentage is likely to become even more significant during the next decade because of this hiatus in new plant construction over the last several years. There is a strong desire on the part of many plant owners to continue to operate for their plants for another 20 to 40 years.

Several studies have shown that the cost of life extension of a typical power plant may be only 20 to 30% of the cost of constructing a new plant and thus cost saving can be done.

The purpose of life extension activities i.e. condition assessment and remaining life analysis is not to continue the operation of the plant beyond its useful life, but merely to ensure full utilization up to its useful life. The idea is to avoid premature retirement of plants and plant components, on the basis of the so-called design life, because the actual useful lives often are well in excess of the design life.

THERMAX BABCOCK & WILCOX
(A division of Thermax Limited), PUNE. INDIA.

CA & RLA study prior to retrofit is definitely the best tool available to justify the plant improvement projects and an opportunity to identify the problems associated with boiler components. Refer Figure No. 1

Condition assessment studies which includes NDT, Metallurgical studies helps in knowing :

1. To plan for replacements and refurbishment's of boiler components.
2. To set up proper inspection schedules, maintenance procedures, and operating procedures.
3. To optimize the start up and shut down procedures for boilers and thus resulting in increased efficiency.

Life extension thus is really a predictive maintenance knowing when to take action to prevent unreliable operation by undertaking preventive maintenance.

This paper deals with the methodology used for the CA & RLA of Utility boilers, Power boilers, and Industrial boilers. This paper explains the different techniques used to evaluate the Remaining life of the boiler components based on the Central boiler board norms and Babcock & Wilcox patented techniques.

Indian Boiler Regulations for Boiler Testing.

The component wise testing to be carried out is given in table 1 & 2.

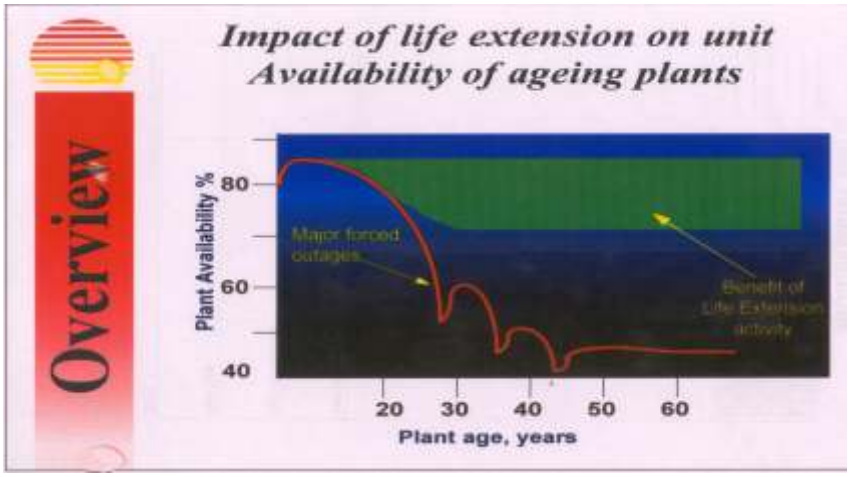

Figure 1 : Plant age V/S Plant availability.

TABLE - 1

COMPONENTS (1)	VISUAL (2)	ULTRA-SONIC TESTING (3)	MAGNETIC PARTI-CLE INSPN. (4)	LIQUID/ DYE PENE-TRANT INSPN. (5)	REPLI-CATION (6)	SAMP-LING (7)	DEPO-SIT ANALY SIS (8)	OUTSIDE DIA-MTR & THK MEASUR-EMENT (9)	FIBRE-OPTIC INSPEC-TION. (10)	HARD NESS (11)	OTHERS (12)
Drum (Steam)	Yes	Yes	No (★)	Yes	Yes	No	Yes	Yes	No	Yes	
Water Drum	Yes	Yes	No (★)	Yes	Yes	No	Yes	Yes	No	Yes	
LowTemp Hdr	Yes	No (★)	No (★)	Yes	No	No	No (★)	Yes	Yes	Yes	
Attemp. Header	Yes	Yes	No (★)	Yes	Yes	No	No	Yes	Yes	Yes	Swell Mea-surement
High temp. Eco tubes	Yes	No	No	No	No	Yes	No (★)	Yes	No (★)	No	
Low temp. Eco tubes	Yes	No	No	No	No	Yes	No (★)	Yes	No (★)	No	
Conv. SH coils	Yes	No	No	No	No	Yes	Yes	Yes	No (★)	Yes	NOTIS
Primary SH coils	Yes	No	No	No	No	Yes	No	Yes	No (★)	Yes	Non-destr-ctive oxide thickness.
Pre-final SH coils	Yes	No	No	No	No	Yes	No	Yes	No (★)	Yes	NOTIS
Final SH coils	Yes	No	No	No	No	Yes	No	Yes	No (★)	Yes	NOTIS
Reheater Coils	Yes	No	No	No	No	Yes	No	Yes	No (★)	Yes	NOTIS
High temp headers	Yes	Yes	No (★)	Yes	Yes	No	No	Yes	Yes	Yes	Swell Mea-surement
Final SH header	Yes	Yes	No (★)	Yes	Yes	No	No	Yes	Yes	Yes	Swell Mea-surement
Reheater Header	Yes	Yes	No (★)	Yes	Yes	No	No	Yes	Yes	Yes	Swell Mea-surement
Main steam ppg	Yes	No (★)	No (★)	No (★)	Yes	No	No	Yes	No (★)	Yes	Swell Mea-surement
Platen SH header	Yes	Yes	No (★)	Yes	Yes	No	No	Yes	Yes	Yes	Swell Mea-surement
Primary SH header	Yes	Yes	No (★)	Yes	Yes	No	No	Yes	Yes	Yes	Swell Mea-surement
Eco. Header	Yes	No (★)	No (★)	Yes	No	No	No (★)	Yes	No (★)	No	
Auxiliaries	Yes	No	No	No	No	No	No	Yes	No	No	
Blr Bank tubes	Yes	No	No	No	No	No (★)	No (★)	Yes	No (★)	No	
Water wall	Yes	No	No	No	No	Yes	No (★)	Yes	No (★)	No	FHyNES
Furnace water wall	Yes	No	No	No	No	Yes	No (★)	Yes	No (★)	No	FHyNES

Note : Yes / No As per Central Boiler Boards regulations
(★)Test performed by TBW in addition to Central Boiler Boards requirement

The boilers which are operating at a temperature of 400 Deg C and above including utility or industrial boilers and all boiler parts operating in the creep range of the boiler shall be No-destructively tested as per the Table 1, after they are in operation for 1,00,000 hours for assessment of the remnant life of parts.

The parts of a boiler when it completes a life of twenty-five years are to be tested as per Table 2, for assessment of the remnant life of such parts.

Steps Followed in Remaining Life Analysis

Introduction

Boiler parameter study, drawing and design data study, Preoutage meeting, Outage site testing, Destructive testing of tube samples, Remaining life calculations of boiler components based on all the results and data of the boiler.

Boiler Operating History And Data Collection.

As further explained in the paper the life analysis methodology; mainly based on corrosion, creep and thermal fatigue principals, is structured in a multi-level approach where the final scientific approach is a mix of design, operation & maintenance history in combination with quantified material characteristics.

Following points gives a specific plant history input so we complete design data with operating & maintenance events which are :

- For the operating part :
  - The operating parameters like pressure & temperature
  - Incidents, events of failure & repair statistics
  - Condition of the plant facility by n° of starts/stops & service hours
- For the maintenance part :

TABLE 2

COMPONENTS (1)	VISUAL (2)	ULTRA-SONIC TEST-ING (3)	MAGNETIC PARTI-CLE INSPN. (4)	LIQUID/ DYE PENE-TRANT INSPN. (5)	REPLI-CATION (6)	SAMP-LING (7)	DEPO-SIT ANALY SIS (8)	OUTSIDE DIA-MTR & THK MEASUR-EMENT (9)	FIBRE-OPTIC INSPEC-TION. (10)	HARD NESS (11)	OTHERS (12)
Drum (Steam)	Yes	No (★)	No (★)	Yes	No (★)	No	No (★)	Yes	No	No (★)	
Water drum	Yes	No (★)	No (★)	Yes	No	No	No (★)	Yes	No	No	
Econom-iser tubes	Yes	No	No	No	No	Yes	No (★)	Yes	No (★)	No	
Conv. SH coils	Yes	No	No	No	No	Yes	No	Yes	No (★)	No	NOTIS
Primary SH coils	Yes	No	No	No	No	Yes	No	Yes	No (★)	No	NOTIS
Final SH coils	Yes	No	No	No	No	Yes	No	Yes	No (★)	No	NOTIS
High temp headers	Yes	No (★)	No (★)	Yes	Yes	No	No	Yes	Yes	No (★)	
Final SH header	Yes	No (★)	No (★)	Yes	Yes	No	No	Yes	Yes	No (★)	
Eco. Header	Yes	No (★)	No (★)	No	No	No	No (★)	Yes	No (★)	No	
Auxiliaries	Yes	No	No	No	No	No	No	No	Yes	No	
Blr. Bank tubes	Yes	No	No	No	No	No	No (★)	Yes	No (★)	No	
Water wall	Yes	No	No	No	No	Yes	No (★)	Yes	No (★)	No	FHyNES
Main steam ppg	Yes	No (★)	No (★)	No	No (★)	Yes	No	Yes	No (★)	No (★)	

Note : Yes / No As per Central Boiler Boards regulations
(★)Test performed by TBW in addition to Central Boiler Boards requirement

- Review of componet replacement & repair
- Review of component geometry

- For the inspection part :
  - Non destructive testing results where the most important are :
    - Wall & internal oxide thickness measurement by ultrasonic.
    - Metallographci examionation by replication
  - Destructive material testing.

The results of the NDE & DE provide one essential input for the component integrity evaluation and life assessment.

Non-Destructive Testing.

Non destructive examinations (NDE) are essential constituents of any residual life assessment programme. The objective of such assessment is to compare the current condition of the material of a given component with its original condition to define the amount of deterioration of the component.
Three major questions have to be answered before starting NDE :

- When ?
- Where ?
- How ?

The used inspection techniques depend on the given component, the location on the component, the damage modes to be looked at and the material used. Some of the regularly used methods to establish the material condition provide data which can be quantified in analyses whereas others can only indicate whether a defect is present or not.

NDE techniques adopted in the residual life assessment of power plant components can be broadly classified as conventional techniques and specialised techniques. Conventional techniques include Visual examination & Dimensional measurement using appropriate tools, Ultrasonic thickness gauging, Penetrant testing, Magnetic particle inspection using wet flourescent method.
Specialised NDE techniques include video probing using fibreoptics to assess the damage on the internal surfaces especially for corrosion, erosion, cracks and the presence of foreign materials, in-situ replica technique to study the material degradation and the presence of microcracks. Ultrasonic testing using high frequency pulse and transducer for measurement of oxide scale on the steam side, ultrasonic method detect hydrogen damage, boroscopic inspection. The specialised NDE techniques are discussed in D. 2.

Destructive Testing.

The scatter band of material properties (creep strength) is an important source of uncertainty for the calculation of the life expenditure. It may therefore be necessary to determine mechanical property values from specimens of material taken from the actual components. Sampling may however not in any way degrade the integrity of the component. Various sampling methods are used.
Destructive testing can have following objectives

- verification of non-destructive examinations results (if no defects are found)
- direct (quantitative) assessment of the degree of damage (structural & mechanical)
- determination of component material mechanical properties (to reduce the scatter band) :
- Post failure search for the damage mechanisms and propagation depth.

Remaining life Calculations of the components based on testing results.

The testing results and overall study of boiler data used to calculate the remaining life of components.

The In-situ Metallography gives the microstructure condition from which the degradation level of material is decided. The Non-destructive testing methods put together give an overall condition of the boiler.

D 1. List of Testing and short Description.

Testing.	Short Description.
1. Visual Inspection.	To check the condition of the pressure parts. The corrosion, erosion, physical deformation, other abnormalities can be identified.
2. Ultrasonic Thickness Gauging.	For all the pressure part tubes, headers and drums. To check the thinning pattern.
3. Ultrasonic Flaw Detection.	To detect the flaws, defects in the material which cannot be detected by Dye penetrant/ Magnetic particle testing.
4. Dye Penetrant Testing.	To find the surface flaws.
5. Magnetic Particle Testing.	To find the surface flaws/sub surface flaws.
6 Non-destructive Oxide Thickness Inspection Service. (NOTIS®)	This is ultrasonic specialized method for measuring internal oxide scale thickness of SH tubes and calculating its life with the help of boiler data and software. **This is Patented technique by B&W.**
7. Furnace Wall Hydrogen Damage Non-destructive Examination System. (FHyNES ™)	An ultrasonic testing technique used to detect the Hydrogen damage in the furnace wall where the heat flux is high. **This is Patented technique by B&W.**
8. Hone & Glow.	For examination of cracks at the ligament locations in headers. **This is Patented technique.**
9. Replication.	To detect creep damage, microstructural degradation and micro cracks in pressure parts, especially operating in the creep range i.e. above 425 Deg C. Electropolishing method is used for replication, the **new VAPINE** technique developed by Mr. G. Venkataraman, which got international ASM award.
10. Fiberscopy.	To inspect the internal condition of all the pressure part locations which are inaccessible.
11. Hardness Testing.	Field Hardness testing at the Replica locations and on the drum ligament from drum inside.
12. Destructive Testing of tubes. a) Visual Inspection. b) Chemical Analysis c) Physical Testing d) Microstructure Examination e) Hardness Testing f) Internal scale Analysis g) Percentage Weight loss	These overall results compilation and engineering data, boiler operating history data is being used for deciding the Life of furnace, Economiser and Superheater tubes.

Please correlate IBR Table no. 1 & 2 and above table for detailed plan of testing.

Tests Conducted during RLA

Specialized tests carried out by TBW. (Patented Techniques By B&W, USA).

NOTIS® (Non-Destructive Oxide Thickness Inspection Services)

Boiler tube failures are the leading cause of forced outages among utilities. One failure can impinge on adjacent tubes, causing numerous failures and increasing repair costs.

NOTIS® is a specialized technique, developed to quickly and easily, determine the remaining life of steam cooled tube operating with high temperatures and pressures. This is microprocessor controlled UT technique, which not only measures the thickness & the tube wall but also the steam side Oxide scale build up and subsequently relates the scale thickness to operating temperatures and life remaining in the tube. Measuring the oxide thickness is very important because the oxide acts as an insulating barrier, allowing the tubes to operate at increasingly high temperatures thus shortening it operating life. Measuring the thickness of the oxide layer is not only imperative for accurate remaining life calculations but it also indicates the potential for exfoliation which can be damaging to the turbine.

The data is fed into a computer program developed by B & W which considers metal loss due to erosion or corrosion along with the increase in tube metal temperature caused by the insulating properties of the steam side oxide scale build up. Temperature increases can accelerate the degradation or creep rupture failure mechanisms experienced by the tubes. The program then determines the hours of remaining life in the tube based on information in the B & W database for steam oxidation kinetics and for creep rupture of various alloy steels. The remaining life of each tube and section inspected is then tabulated in a hard copy printout.

FHyNES™ (Furnace Wall Hydrogen Damage Non Destructive Examination System)

Furnace tube failures are a leading cause of forced outages of older high-pressure boilers. Fatigue, corrosion, erosion, wastage, overheating, or hydrogen damage may cause these failures. Of these failure mechanisms, hydrogen damage is one of the largest causes of forced outages and may be one of the most difficult to detect before failure occurs.

Tube failures are usually the first indication of hydrogen damage, which generally cannot be detected by normal inspection. When hydrogen damage is detected it is frequently misreported as internal corrosion, weld leaks, or caustic corrosion.

As for the economiser, common inspection techniques also include visual inspection, UT for wall thickness, fiber-optic inspections of tubes and headers for internal deposits, scale and water side corrosion as well as the periodic tube sampling from the hottest input furnace zones for evaluating needs for chemical cleaning of the boiler.

In addition to these commonly known techniques, B & W has developed and patented a fast, non destructive examination which locates and maps regions of the furnace which have hydrogen damage before tube failure occurs. This new service PHyNES is an easy, reliable method for locating damage which was previously undetectable.

FHyNES spot-checks selected tubes in the regions of the furnace which are highly susceptible to hydrogen damage. Once any indications of hydrogen damage are found, a more thorough examination of these areas is performed by FHyNES to determine the extent of damage.

Hone & Glow

In addition, inspection of the tube hole, penetrations are required to determine if any fatigue cracking has initiated in the body of the header. To detect cracks, the oxide is carefully removed to avoid the smearing over of any shallow cracks. Then a high sensitivity dye penetrant is applied and the penetration is examined by fibroscope. If any cracks are detected knowledge of length/width ratio of these defects gives a qualitative measure of the degree of damage and projections for the remaining life of these components.

Replication

High temperature stress can leave high-pressure headers and hot steam lines in worse physical shape than you can imagine.

B & W studies indicate that, depending upon your plant's operating cycle through the years and the constant strain of expansion and contraction, the major stress points could be literally cracking open at the seams.

Field surface replication is a process that permits obtaining an image of a component surface with sufficient retention of fine structure, to permit laboratory examination and evaluation, without having to cut out a portion of the component. The evaluation of the grain size, precipitate spacing using both optical and electron microscopy can establish presence of creep damage or microstructure changes and assist in understanding service conditions.

A very thorough and accurate assessment by non destructive and metallurgical analysis, is the first step of an overall condition assessment plan.

Our total service plan encompasses proven technologies like replication, ultrasonic testing and destructive testing.

CONCLUSION

Extending the life of power plant components is the very best way to regain boiler reliability and availability quickly at a fraction of the cost of building new generating capacity.

A comprehensive Life Extension Program which accurately establishes the existing condition of components and projects how much life remains in those components is recommended for every plant over ten years old. Today there are numerous new non-destructive testing techniques available which allows these projections to be made accurately.

Knowing how much life remains in a component and then taking action to repair or replace it prior to failure is one very essential factor for obtaining reliable operation from the equipment and increase its availability.

TBW SERVICES JUST A CALL AWAY……

Purpose

To create awareness and to appraise customers on the various services offered by the Service Group.

Background

Analysis of interactions with customers, at various levels, revealed the need for TBW to render specialized assistance for any problem in any boiler in the customer's premises with a prime focus on achieving Customer Delight.

TBW Services started operations in 1993 with a small team. It has grown into a full-fledged Service Group with a dedicated team of trained and experienced professionals armed with the will to serve and state of the art equipment and facilities.

Services rendered

1. Services on call: Prompt response to any customer call/complaint and deputation of engineer as required, rectification / trouble-shooting, suggestions and recommendations for corrective and preventive action, data collection and analysis, updation of boiler and customer history etc.

2. Preventive/predictive service: We offer annual service contract package comprising of site visits for performance monitoring and organizing annual shutdown and emergencies. The job structure is worked out on the type and size of boiler(s) and the number of mandays offered are convertible under any of the service heads mentioned above. Further, customers entering in an ASC also have the advantage of the topmost priority for any service aspect and the cost of package is restricted to a bare minimum. Regular checks on boilers also help to control operating costs, ensure consistent availability and optimum efficiency.

3. Condition assessment and remaining life assessment studies: Review and survey is done using special testing equipment and methods of in situ examination and analysis of pressure parts to assess the present condition and remaining life. The parts needing replacement are identified and replaced. Re-designing is done, if required, followed by boiler performance checks and verification. State of the art techniques and programs, patented by Babcock & Wilcox, USA is used for the field tests, calculations and analysis.

4. Boiler performance optimization: Not all boilers run to rated conditions in terms of operating efficiency and output parameters due to a variety of reasons. Even changes in fuel with time, availability, calorific value, composition or price have a significant impact on operating cost. We provide for in-depth studies and engineering solutions to bring back the unit to optimum performance, fuel conversions, capacity enhancement and technological upgrades.

5. Test facilities : Our major in-house test facilities encompass proven technologies like:

a. Non-destructive oxide thickness inspection (NOTIS) patented by B&W, for internal oxide scales build up in superheater, re-heater tubes.

b. Furnace hydrogen damage non-destructive examination (FHyNES) patented by B&W using ultrasonic flaw detection for hydrogen embrittelment of water tubes in high temperature zones of boiler.

c. Hone and Glow technique, patented by B&W, for detection of location and characterizing ligament cracks originating from inside the headers.

d. In-situ Replication / Metallography, without cutting

specimen for detecting microstructures of high temperature headers and piping, microstructure photography for interpretation and as case history records.

e. Metascopes for in-situ material verification and to determine alloy configuration.

f. Boroscopic examination is carried out for inspection of scale / deposits, foreign objects inside headers and tubes.

g. Hardness tester (size of a fountain pen) to carry out hardness tests on base metal, HAZ and weld metal.

h. Ultrasonic Thickness Meters for thickness measurement of various tubes.

i. Metallurgical Microscopes are used for viewing prepared/ polished microstructures and replicas taken during condition assessment studies.

j. Other supplementary equipment include Micrometers/Periphery Tapes for Swell measurement, Impact Testing Machines, CO_2, O_2, CO, NO_X, SO_X analyzers, Calorimeters, Viscometers, Digital pH Meters, laptop computers for data management, calculations and report generation at field, Digital Still Cameras to have instant color images that can be readily transferred to computers for printouts.

The Central Boilers Board has granted us recognition under sub regulation (2) of regulation 4C of the Indian Boiler Regulations, 1950, as a well-known remnant life assessment organization.