CONDITION ASSESSMENT OF BOILER AND IT'S COMPONENTS

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ABSTRACT

Condition assessment is carried out to arrive the present state of the condition of components property degradation using non – destructive and destructive methods. Condition assessment plays a vital role in running plant without any interruption and meets increasingly stringent environmental regulations, planned outages, proper maintenance and data collection in new as well as old plants. It is an ongoing procedure rather than one time activity. This paper enunciates salient features of condition assessment of boiler from the experience gained over the period of years in this arena to arrive the scope including metallographic spots, selection of non – destructive and destructive tests, planning, execution (bar charts) and reporting.

INTRODUCTION

The boiler and it's components are built with assumed nominal design and reasonable life of operation about two to three decades (one or two hundred thousand hours). These units are generally replaced or life is extended at the end of this period. Under normal operating conditions after initial period of teething troubles, the reliability of these units remain fairly constant up to about two decades of normal operation. The failure rate is then increases as a result of their time dependent material damage. Further running of these units may become un-economical and dangerous in some cases. But it has been practiced by initiating timely preventive measures and by way of proper maintenance refurbishment actions it is possible to retain these units, in service safely, reliably and economically for many more years. A life extension program comes handy here. One of the most important steps involved in life extension strategies is the assessment of remaining life of the existing components so that required timely refurbishment steps could be introduced to extend the plant life. So remaining life assessment (RLA) becomes a necessary evil.

The main purpose of this study is to analyze the property degradation of components using non – destructive evaluation) NDE and destructive methods to arrive at the present state of condition of the components. The purpose of 'life extension' through this study is not to continue taxing the boiler and its auxiliaries beyond its useful life, but only to ensure complete utilization up to its measurable useful life. The service life can be extended through proper inspection and condition assessment followed by proper maintenance.

There are three levels involved in life assessment of components. Data from fracture, failure history, dimension condition, temperature and pressure, stress, material properties and material samples are used in three level approaches. If the Level I assessment indicates that the calculated remaining life is greater than or equal to desired life extension, then regular inspection and periodic review program should be proceeded. Otherwise Level II assessment should be followed. In the Level II assessment information from an initial inspection, simple stress analysis, measured dimensions or operating parameters are used. If the residual life arrived in the Level II is less than projected / expected extended life, then more precise evaluation Level III can be used, provided the values of the component exceeds the cost of detailed evaluation.

APROACH AND METHODOLOGY:

The methodology adopted for life assessment can be categorized into:

a) Operational data, standard material based on properties.
b) Methods based on past service examinations or past service tests on the actual components.

The RLA program may be carried out as follows:

(i) Site study, collection of data and assessment of actual conditions.
(ii) Finalization of action plan for carrying out detailed study and tests.
(iii) Various NDE and Destructive tests on components and equipments of the boiler to meet the scope.
(iv) Analysis of results & report.

Hot survey is carried out by visiting the site 3 to 4 weeks prior to shutdown of the unit and collect boiler data on operating parameters, failure and replacement history and drawings etc. Necessary photographs may be taken at this stage. Cold survey may be carried out after the unit is shut down, walk through the boiler plant and carrying out visual inspection which is the fore-runner for further inspection. Necessary photographs may be taken at this stage. Based on hot and cold surveys, the actual scope of the work will be frozen in consultation with customer. Approach and Methodology will meet the typical scope as given in the table 1.

TABLE: 1 NDE &DESTRUCTIVE TESTS: SCOPE OF CONDITION ASSESSMENT OF BOILER - TYPICAL

	FIELD WORK-NDT												LABORATORY			
COMPONENT	VT	FOB	DIM	PT	MT	UTG	UFD	IRIS	HB	IMG	ICA	OSM	OS/DA	MA	ACR	REM
1. SUPER HEATER HEADER	✔	✔	✔	✔	✔	✔	✔		✔	3 ✔	✔					
2. SUPER HEATER TUBES	✔	✔	✔	✔		✔	✔		✔	3 ✔		✔	✔	1 ✔	1 ✔	6ACR test samples from 1.5m long tube
3 FURNACE TUBES	✔	✔	✔	✔		✔	✔	✔	✔	3 ✔		✔	✔	1 ✔	1 ✔	6 ACR test samples from 1.5m long tubes
4. BOILER BANK TUBES	✔		✔	✔		✔	✔	✔	✔	2 ✔						

NOMENCLATURE

Field work: Non-Destructive Test

VT	Visual Testing
FOB	Fiber Optic Boroscope
DIM	Dimension Measurement
MT	Magnetic particle testing
PT	Dye penetrant
UTG	Ultrasonic thickness testing
UFD	Ultrasonic Flaw Detection
IRIS/ UT	Internal Rotary Inspection System / Submerged UT
HB	Insitu Hardness Measurement

IMG Insitu Metallography –
ICA Insitu Chemical Analysis (PMI)
OSM Oxide Scale Measurement

LABORATORY: Destructive Test:
DA- Deposit Analysis- deposits collected from Steam drum and other tubes
OS - Oxide Scale: Inside tube - thickness, amount, qualitative
Replica evaluation: LIFE ASSESSMENT NDT&CCS, Material Testing Laboratory, Dammam
MA - Metallurgical Analysis at NDT&CCS Material Testing Laboratory, Dammam
Chemical Analysis, Macro & Micro-structures; Macro Hardness(BHN), Tensile (RT), Dimension of cut tubes.
ACR - Accelerated Creep Rupture Test – From a reputed Laboratory.
100 tubes will be selected for IRIS based on visual Test.
MT/PT on all cirseam of the headers and 20% of the tube and Header joints in the ligament area within this scope.

REMAINING CREEP LIFE BY REPLICA EVALUATION

Replication is carried out to arrive at microstructure degradation of the components, as this method has an advantage over other methods in terms of reliability, accuracy and it does not require any information with regard to operational history. This technique is especially suitable for those components whose complex load cannot be described by stress analysis and have complex metallurgical structure. As creep damage is concentrated in narrowly limited zones, replication is most suitable method of detecting this narrow zone. Replica spots may be selected (1) based on metallic thickness and oxide scale measurement. Highly sophisticated techniques like Barkausen Noise Analysis (BNA) and insitue stress analysis may be considered depending upon requirement and commercial viability. In general creep failures initiate mostly at surface of the component's weldments (girth, longitudinal seam, and stub tube) and regions of complex component geometry associated with major branch connections selected for replica spots as these are vulnerable for creep damage. Localized over heating may be due to build up of an internal scale in the tubes. This over heating temperature can be arrived from microstructure and may be verified with the records (data) available if any. Remaining life estimation will mislead without this verification phase of the program as the variation in temperature of the line joining in the points in the stress vs Larsen Miller Parameter graph changes substantially the remaining life. The insitu metallographic spots should be selected and remaining life may be obtained wherever high internal oxide scale thickness, low metal wall thickness , high insitu stress and low Barkausen noise signal (high BNA number) are observed,. The replica (light microscope microstructure) evaluation is based on Neubauer, B et al (ASME 195, 51, PSU) and Pathy P.U. (2) .

ACCELERATED CREEP RUPTURE TEST (ACR):

Accelerated creep rupture test is conducted at higher temperature with constant stress and quantitative remaining creep life is obtained using software based on Larsen Miller Parameters.

Method :

1. Tube sample 1.5 m is cut from the super heater and furnace tubes as desired.
2. Test pieces are made according the drawing.
3. Accelerated creep rupture test is performed with required temperature and stress which may run into 16 to 20 weeks.
4. Arrival of quantitative remaining life using software.
5. Presentation of the remaining life.

NON-DESTRUCTIVE OXIDE SCALE THICKNESS MEASUREMENT OF THE TUBES.

Oxide scale thickness plays a vital role in remaining life of the tubes since the temperature of the tube raises where the considerable oxide thickness exists. Conventionally oxide thickness is measured by destructive method, but ultrasonic method is used non – destructively and remaining life is arrived using software. It is possible to measure the inside oxide scale more than 0.1mm. But outside tube should be cleaned for UT.

LOSS OF TUBE THICKNESS MEASUREMENT BY IRIS / SUBMERGED UT

IRIS is conducted to detect the loss of wall thickness from internal of the tube with pure water filling. Conventional thickness measurement is carried out in selected spots only by UT thickness gauge which is the limitation of this technique. But IRIS / submerged UT over comes this limitation and thickness is scanned continuously. This technique may be used in tubes connected between steam and mud drum and other locations.

1. Visual Inspection and selective Ultrasonic thickness measurement will decide the selection of tubes for IRIS.
2. Inner scale deposit should be removed with water jet cleaning.
3. Rubber or nylon plugs should be plugged in the tube end at mud drum side and pure water is injected from the steam drum.
4. UT probe is inserted from steam drum to mud drum connected tubes and inspection is carried out. The results are recordable in the instrument.
5. The report can be submitted using software.

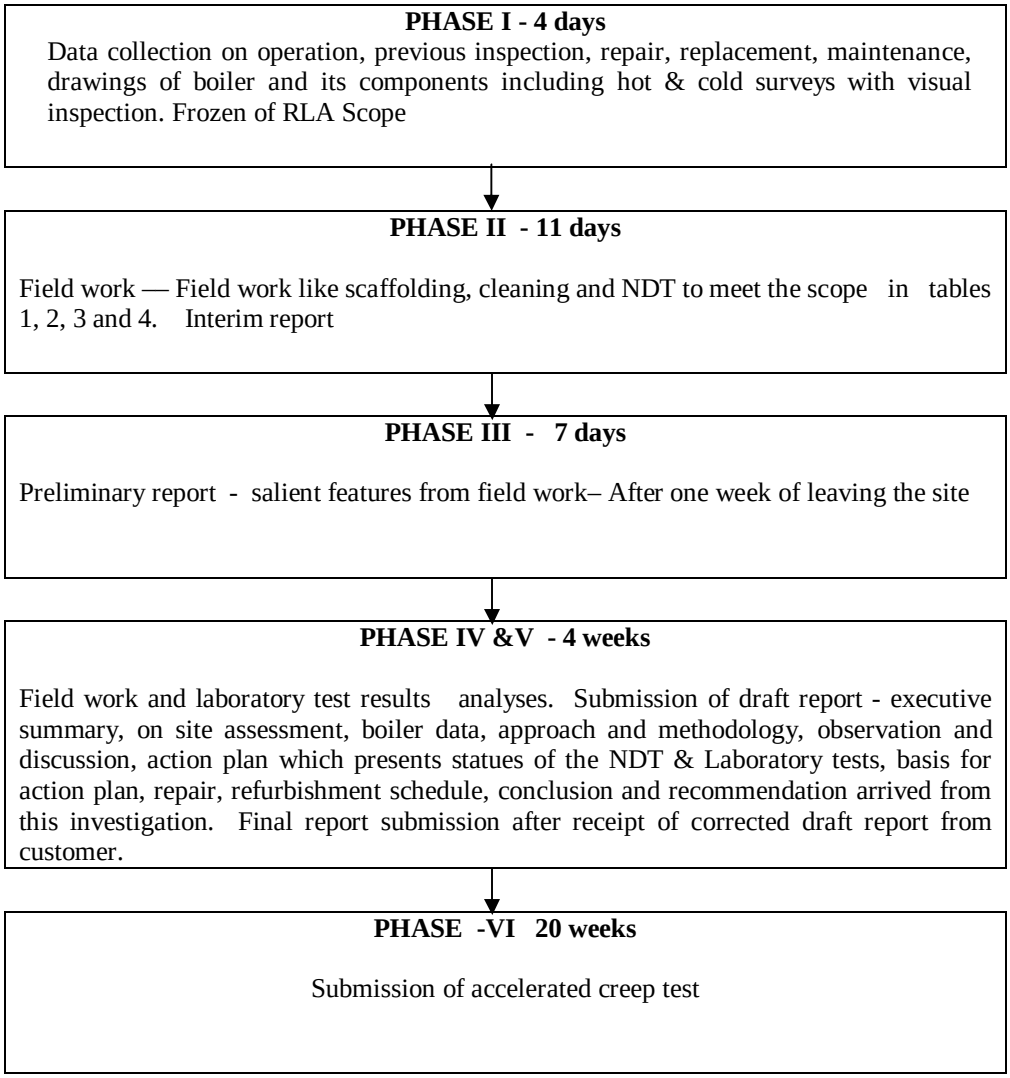
Table 2 shows typical man power distribution:

TABLE 2: **TYPICAL MAN POWER DISTRIBUTION – RLA**

SL. #	METHOD / OPERATOR	QUANTITY	SHIFT / DAY	DAYS
1	RLA SPECIALIST	1	-	-
2	SHIFT INCHARGE	2	2	11
	VT „	„	5	5
3	IRIS OPERATOR	2 +4 HELPERS	2	7
4	UFD OPERATOR	1 OPERATOR	1	2
5	UTG (THICKNESS) OPERATOR	2 + 2 HELPERS	2	6
6	REPLICATION	1 + 1	2	4
7	MT& PT (FLUORESCENT PT……	2 + 2 HELPERS	2	6
8	FOB OPERATOR	1 + 2 HELPERS	1	2
9	INSITU HARDNESS & PMI	1 OPERATOR	1	2
10	OXIDE SCALE MEASUREMENT	2 + 2 HELPERS	2	6
		1+13+14	17	
	SCAFFOLDING+CLEANING		6+10	

The typical activities flow chart is shown as below:

ACTIVITIES - FLOW CHART



FIELD WORK AND LABORATORY PROGRAMME:

The table 3 and 4 show the schedule of the programs to be carried out in the field and laboratory. Visual test is carried out in all the components. Since visual test results form the basis to carryout majority of other tests. In general surface imperfection, discoloration, misalignment, crack, sagging, hogging, erosion and corrosion, structure imperfection etc., Visual test capability is enhanced further by fibre optics boroscope

NDT TECHNIQUES:

During surface preparation oxide or corrosion deposits or any other foreign material should be removed ether by wire brushing / buffing or surface grinding. MT and PT is carried out on the surface of the weld and parent metal where surface is cleaned in the range 25 to 50mm on either side of the parent metal. Ultrasonic flaw detection / oxide scale measurement / thickness measurement are carried out depends on the accessibility of areas. Tubes are cleaned by water jet for IRIS / submerged UT inspection.

TABLE - 3 SCHEDULE RLA OF BOILER - FIELD WORK

ACTIVITIES DAYS →	1	2	3	4	5	6	7	8	9	10	11	REM
VT												
SCAFFOLD												
CLEAN												
UTG												
OSM												
IRIS												
PT & MT												
IMG												
UFD												
FOB												
HB & PMI												
DIM												
SAMPLE TUBE CUTTING												

TABLE - 4 SCHEDULE RLA OF BOILER - LABORATORY

ACTIVITIES WEEKs →	1	2	3	4	5	6	7~20
REPLICA EVALUATION							
DEPOSIT ANALYSIS							
SPECIMEN CUTTING							
TUBE SAMPLE MOUNTING							
POLISHING, OSM, THICKNESS ETC.,							
MACHINING CREEP SAMPLE							
MACHINING T.S.							
CHEMICAL & MICRO							
ACCELERATED CREEP TEST							

METALLURGICAL EXAMINATION AND INVESIGATION:

NDT &CCS insitu metallography procedure (SOP -091 -19) will be followed during replication and evaluation. Differential etching is carried out by dividing 120degrees apart in 30mm spot with 2 % Nital or other suitable etchants to ensure optimum results. The replica is evaluated under light microscope for remaining life assessment of the component based on carbide transformation and cavity formation. Hardness values are taken on the replica spots and other required spots using portable hardness tester. Portable metal analyzer is used to check the chemical composition and correlate the specification. Test specimens are made from cut test tubes and

accelerated creep tests are carried out under constant stress and temperature till the specimen fractures or breaks. Remaining creep life is determined using Larsen Miller Parameter.

INSPECTION OF SELECTED BOILER COMPONENTS:

Steam and Mud Drums:
VT will be carried out on all accessible locations externally and internally including dish ends. Especially just above at the water stagnation level inside drum to assess the corrosion. Dimension may be taken to find out the ovality or expansion if any. PT is carried out on all accessible weld joints preferably inside drum. Ultrasonic thickness is taken selective locations and flaw detection is carried out on all accessible weld joints. PMI, IMG and hardness are carried out on selective locations. Deposits are collected for analysis and reported. .

High And Low Temperature Headers:
Visual inspection is carried out wherever insulation is removed including hangers and support structures. Fibre optics boroscope enhances visual inspection internally to check cracks if any due to fatigue, corrosion and their effects around and in between stubs (tubes joints). This observation is the basis for further tests like UFD and thickness measurement. Dimension will be taken to assess the ovality MT carried out on the butt-weld joints of headers and end caps etc. , PT may be carried out 20% of the stub joints and replica on selected butt weld joints and stub joints based on VT and thickness measurements. UFD may be carried out on all major butt joints and end cap joints of the headers. UTG is taken on the headers and 20% of the tubes. ICA (PMI) may be taken on selected locations of headers and tubes.

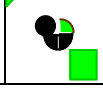
Tubes:
IRIS may be carried out on 100 tubes and oxide scale thickness on 50 tubes and other tests as per scope in the table 1. Thickness is measured on 20% of the respective tubes. ACR will be carried out on the tubes cut from furnace and super heater tubes. Metallurgical analysis will be carried out on 1.0m meter cut tubes as per the scope in the table.1 Deposits / scales are collected from these cut tubes and chemical analysis is carried out .

REPORTING:
Report may be presented either conventional or novel method and reference (3) may be referred for further information on reporting.

TABLE : 5. **SCOPE OF THE WORK (CONVENTIONAL)**

S.No	Boiler Pressure Parts	VT	DIM	MT	PT	UFD	UTG	IMG	HB	HD	DA	FOB	OSM	ICA	ACR/MA
1	STEAM DRUM	✔	✔	✔	✔	✔	✔	✔	✔	-	-	-	-	✔	-

TABLE : 6. A NOVEL METHOD OF PRESENTATION (TOP LEVEL)

S.No	Boiler Pressure Parts	VT 1	DIM 2	MT 3	PT 4	UFD 5	UTG 6	IMG 7	HB 8	HD 9	DA 10	FOB 11	OSM 12	ICA 13	ACR /MA 14
1	STEAM DRUM									-	-		-		




CONCLUSION:

In a nutshell scope of the condition assessment , criteria for selection of metallographic spots ,man power distribution, field work and laboratory schedule and activities flow chart are presented with novel method presentation table.

GENERAL REFERENCE:

1. Indian Boiler Regulations ISBN 81 – 7111 -046 - 0
2. Neubauer, B et al (ASME 195, 51, PSU)
3. Experience gained from RLA / CA activities over the period.

REFERENCE :

1. Pathy, P.U. " Selection of Insitu Metallography Spots in in-service inspection of boiler and its accessories" 'NDT Voyager – 2000s' ISNT – Baroda Chapter, India 17 – 19th December, 1999, pp 124 -126
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AUTHOR'S PROFILE

Dr.P.U.PATHY (docpathy @yahoo.com) secured University (Madras) first in M.E., (Industrial Metallurgy) and received PhD in Metallurgy from Indian Institute of Technology, Madras(Chennai) , India.. He has gained more than two decades of experience from many mother industries in India as well as abroad.

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