LIFE MANAGEMENT OF HIGH TEMPERATURE SUPERHEATER AND REHEATER BOILER TUBES

Awadhesh Kumar

(GM COS –Boiler NTPC)

Ajay Sharma

(AGM COS-Boiler NTPC)

ABSTRACT

High temperature Superheater and Reheter boiler tubes operate under most strenuous steam and metal temperature conditions in thermal power plants. To control maximum metal temperature, sometimes rated steam temperature is reduced which affects the Unit efficiency and Unit Capacity margins. On the other hand maintaining high metal temperature affects tube useful life adversely. Sharp variation and excursion in tube metal temperatures during unit start up, mill change over and during load ramp up are also causing incremental damage to SH and RH tubes and attachments. Control of boiler tube life under these challenging conditions requires use of modern tools and techniques to precisely monitor the operating conditions during normal running and collection of tube health assessment data during unit overhaul. On the basis of information collected online and off line during overhaul, effective tube life management programme is formulated to maintain high unit reliability and efficiency.

Superheater and reheater Boiler tube life management has to start with the initial stage of boiler technical specification itself. Earlier concept of design by rule has been quite effective till the use of alloy steels but with the wide spread use of creep resistance ferritic steels and higher steam parameters, material properties, operational aspects and structural considerations have become important particularly during cyclic loading. This has shifted design approach to'" Design by analysis". Now , SH and RH reliability is governed by each step from design concept to material selection , manufacturing, site erection, unit operating parameters, cyclic loading, water chemistry and maintenance interventions.

This paper will heighlight the steps of boiler tube data collection, causes of failures in reheater and superheater tubes in boiler at different stages of plant life . Further, specific measure to address these failures will be elaborated.

On the basis of the learnings from the paper stations would be able to formulate their life management strategy of high temperature superheater and reheater tubes.

INTRODUCTION:

Strong wave of transformation has set in electricity sector in India. From power deficit market controlled by state and central power sector utilities , market has become power surplus with lot of new IPPs. In this buyers market, efficiency and reliability of power generated has become important for utilities to remain high in merit order rating of the beneficiaries. Thrust toward renewables and exponential growth in solar power has thrown new challenge of cyclic loading and efficient operation for thermal power plants at part load. Implementation of new environmental norms is going to make situation even more challenging as thermal units may be asked to close down or remain in reserve shut down or part load due to environmental reasons.

Reduction in generation and maintenance cost in this scenario is the need of the hour. Achieving rated steam parameters of SH and RH, without compromising boiler tube reliability has become essential to reduce fuel bill and maintain unit capacity margins.

To maintain design efficiency and capacity, boiler tube reliability is still one of the major causes of concern. Utilities have embarked upon intensive programmes for boiler tube life management with a good amount of success. NTPC has also working aggressively on this front and improved boiler tube reliability by successfully bringing down the losses on account of boiler tube failures steadily in past few years despite some challenges from new units.

Dividend of making and implementing good strategy in high temperature SH and reheater is very high as preventing each leakage saves around 36-48 hours of generation loss and avoids one cold start-up of the boiler.

Superheater and reheater Boiler tube life management has to start with the initial stage of boiler technical specification itself. Earlier concept of design by rule has been quite effective till the use of alloy steels but with the wide spread use of creep resistance ferritic steels and higher steam parameters, material properties, operational aspects and structural considerations have become important particularly during cyclic loading. This has shifted design approach to'" Design by analysis". Now, SH and RH reliability is governed by each step from design concept to material selection , manufacturing at works, site erection, unit operating parameters, cyclic loading, water chemistry and maintenance interventions.

HIGH IMPACT OF SUPERHEATER AND REHEATER :

Generation losses per Boiler tube failure in superheater and reheater area are invariably very high. The reason is primarily due to following:

1. High Secondary damage if Accostic Steam Leak Dtection (**ASLD)** is not available particularly in RH where tube wall thickness is less than half of SH.
2. Difficult approach and unsafe locations. High time to provide safe scaffolding.
3. Identification / locating difficulty particularly in reheater
4. In new units CRFS tube repair invariably requires preheat and post weld heat treatment.
5. Sometimes inspection of header and loop sponge ball test is also needed.
6. **Air pressurisation** test is requires in reheater to rule out any minor leakages

STEPS FOR LIFE MANAGEMENT IN SUPERHEATER AND REHEATER:

Life management in high temperature SH and RH has to start from specification stage itself. Strategy has to be made for step by step elimination of the each causes for reduction in life of SH and RH component.

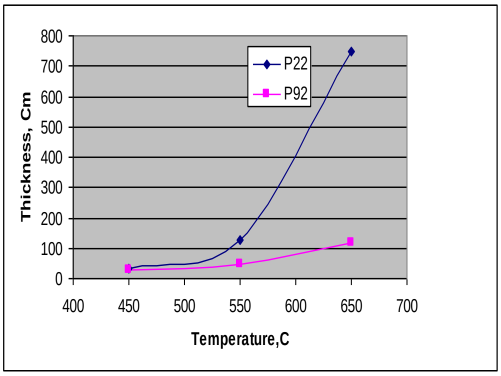
STEP 1

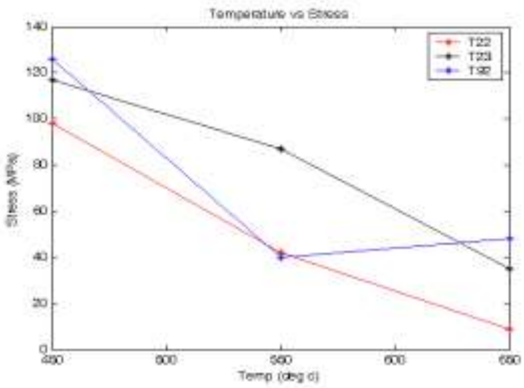
BOILER SPECIFICATION STAGE:

Specification must clearly specify not only the steam parameters, material metal temperature limits, erosion allowance, steam temperature adder but also specify

- The metal temperature measurement point in flue gas path

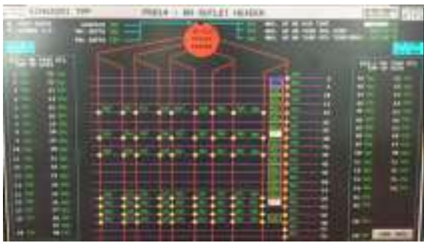
- Maximum metal temperature limits in operation with respect to acromat temperature and pent house thermocouple temperature
- Rate of change of metal temperature to have intended design life.
- Ramp rate to avoid any exfoliation of scale during start up, load ramp up, ramp down and shut down.
- Cyclic loading of the unit in the regime of must run renewables should be factored in design specification.



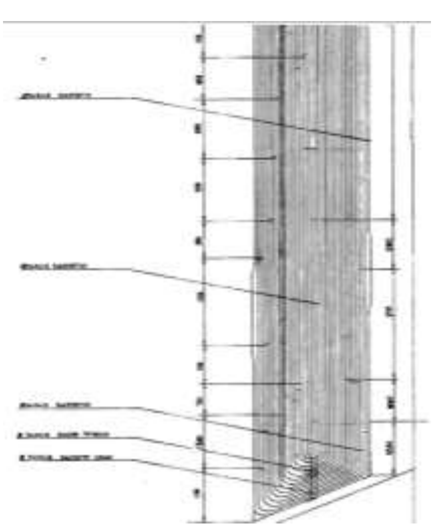


Design by analysis concept to be followed instead of conventional Design by rule concept. NTPC has made some changes on the basis of past experience like avoiding DMW in flue gas path, doing away with girdling loop, provision of acromat in gas path in reheater, provision of ASLD etc.

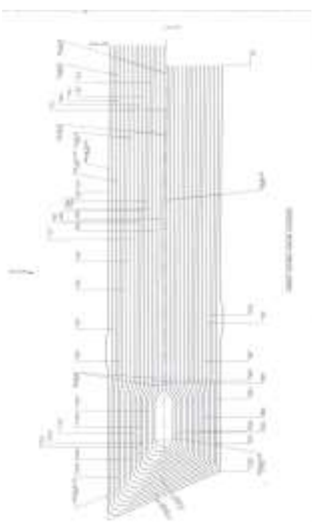
SIMHADRI WITH ACROMAT



RIHAND WITHOUT ACROMAT



Unmodified



Modified

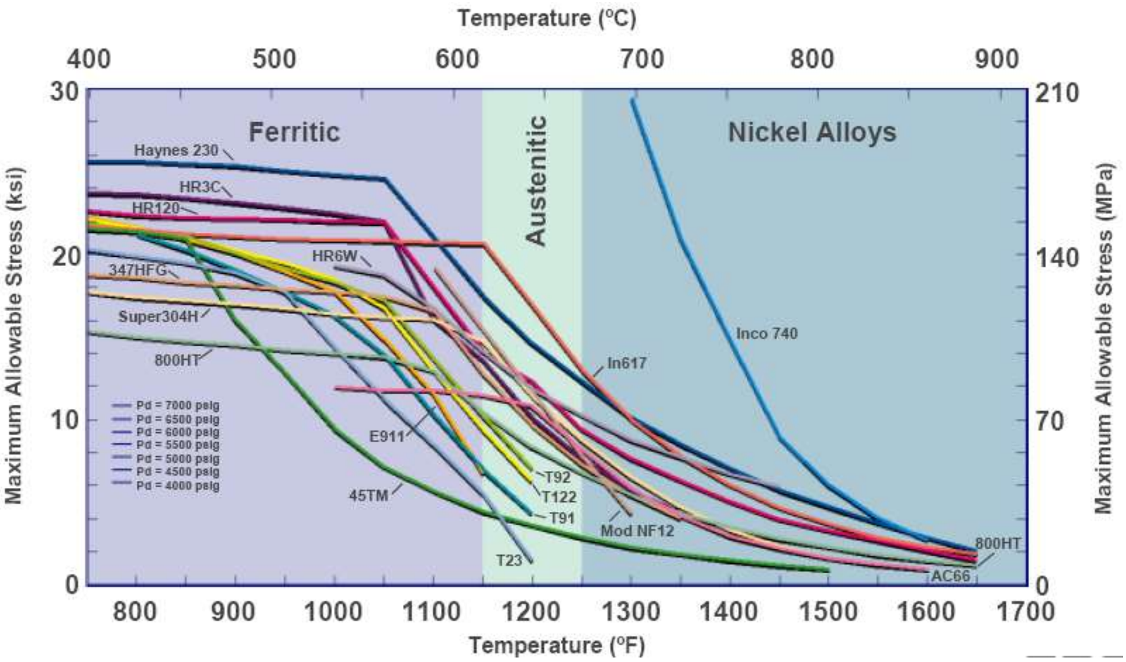
Knowledge gathered on Creep resistance ferritic steels , stainless steel without shot peening and behaviour of their oxides under cyclic loading should be taken care in the design stage itself. Boiler geometry and local onsite welding requirement in material requiring Pre and PWHT should be factored in during selection of material.

Ramp rate and cyclic loading of the unit has be in synchronous with design of support, connectors and structures. **A complete design audit needs to be done for old as well as new boilers in the new regime of cyclic loading and behaviour of new materials in operating conditions.**

During R&M in reheater in 1st generation boiler, NTPC has incorporated T91 in place of T22 and done away with girdling loop.

In 2nd generation boiler T91 has been replaced with SS 347 H to maintain rated steam parameters and in latest boiler for higher steam parameters SS 347HFG and Super 304H is being widely used.

In SS it is important that we specify shot peening and specify SP grade material only. As some of the utilities are already facing problem of exfoliation and had to replace those panels.



- ✓ **Life management Action Plan 1**

Each Boiler design information should be collected and design audit to be done.

STEP 2

MANUFACTURING STAGE:

Use of seamless tubes is the norm and DMW are to be made only at works.

SS tubes to be used should be of SP grade to prevent exfoliation. As understood some boiler Manufacturer are using only SP grade in their new boilers. EPRI also recommends use of SP grade SS in high temperature SH and RH.

Extremely tight U bends in divisional Superheater and Reheater inlet are prone to water and debris accumulation which makes these bends vulnerable for failure. Where such tight bends are to be avoided at design stage itself on the other hand in existing boilers Life management plan of these bends should include radiograpy of inner most bend during every overhaul for any chocking of these U bends.

Any cemferring on lower grade material should not be allowed while making weld joints of different grade material. In these cases HAZ of lower grade material becomes the most weak link .**These joints needs to be replaced as per opportunity.**

- ✓ **Life Management Action Plan 2**

Each Tube failure history with specific analysis report to be collected to make plan to mitigate any manufacturing defects

STEP 3

ERECTION STAGE :

Storage and transportation of material: Coil tubes must be kept in capped condition and free from any entry of dust and water. This has become very important in view of choking by foreign material or presence of chloride in case of stainless steel (transportation through Sea).

Here, it is important to note that any pitting inside bends and chloride attack will remain even after steam blowing.

In Indian condition it is preferable to reduce the number of site weld and weld with Preheat and PWHT.

Even at site, making joints at ground floor should be preferred to ensure the proper monitoring as per the WPS

One quality engineer must be exclusively kept for preheat and PWHT.

- ✓ **Life Management Action Plan 3**

Quality audit/ Observation reports made during erection stage highlighting difficulties in assemblies and aberrations in Pre and Post weld heat treatment, radiography defects should be preserved for any subsequent failure analysis.

STEP 4

COMMISSIONING OF BOILER

In newly commissioned boiler tube life reduction are mainly on following account:

4A WELD JOINT FAILURE:

It is observed that there are many failures of weld joints during Hydro Test and Commissioning stage.

- ✓ **Life Management Action Plan 4 A**
    - Record to be kept of each weld joint failure.
    - Weld joint failure must be analysed for the root cause and corrective action plan to be put in place as per the findings.

Where failure due to weld defect may be identified by additional radiography in that area but failure due to wrong preheat or post heat are difficult to identify. Quality audit report during erection are good input for these defects. Action plan is to be made on basis of information gathered and time available.

Hardness of the joint and MCF values can prove a handy tool.

However, it is essential that no exception to preheat should be allowed and PWHT must be done before Hydro.

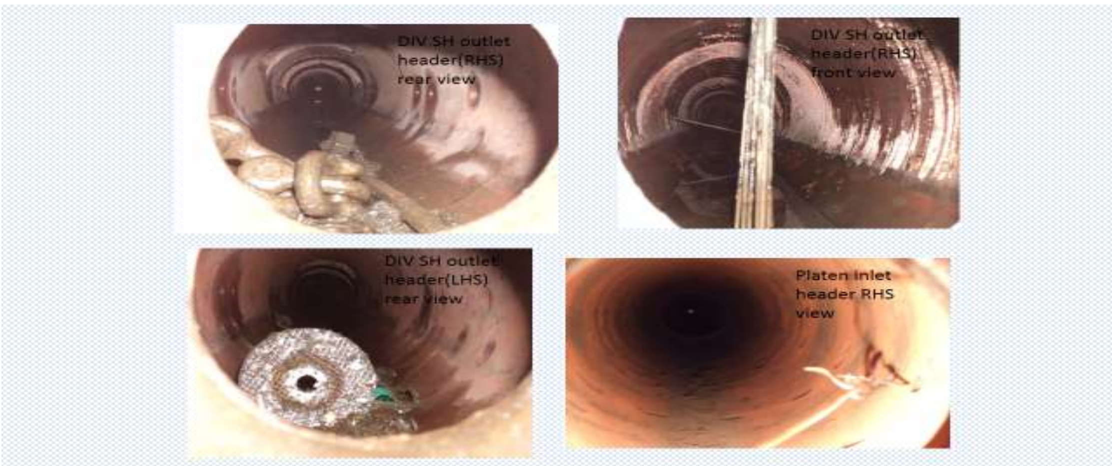
4B Short term overheating of Boiler tubes in SH and RH

Number of boiler tube damage and failures in coil due to short term overheating have been faced in utilities just after commissioning. These failures are primarily due to foreign material inside coil tube or foreign material inside headers or material mix up.

4Bi Foreign material Inside at Header/Tube

✓ **Life Management Action Plan 4 Bi**

- Action plan to prevent short term overheating is to ensure header internal clearance before final Box up .
- In case of any short term overheating failure in coil tube, a cross check by **video imagescope** should be planned
- Bends in the failed loop to be checked by **radiograph for any blockage**.
- Boiler start up and subsequent operation, it is to be checked if there is any evidence of excessive spray and steam saturation after spray**. (PI data alerts and analysis)**
- Failed Tube **Pent house thermocouple metal temperature or acromat** to be checked for any excursion.



4Bii Material Mix Up Failure

In some cases use of lower grade material mix up at works or at site causes premature failure of tubes.

- ✓ **Life Management Action Plan 4 Bii**
  - Tube material particularly spools used at site to be checked by **metal alloy analyser.**
  - Tubes to be colour coded at every one meter length.

4C SCC FAILURE

SS grade material in particularly high stress locations are highly susceptible for chloride attack. The source of which could be any, varying from hydro water, transportation through sea route, uncapped storage or poor quality feed water.

- ✓ **Life Management Action Plan 4 C**
  - If failure analysis proves SCC, it is essential that failure location is checked for extra stress, material grade and any contact with poor quality water having chloride .
  - Next action should be planned on basis of cause of SCC.

STEP 5

MID LIFE MANAGEMENT

As per IBR 391A boiler RLA study is required at 1 lac hours of operation and subsequent study is to be done as advised in the report or after 06 years whichever is earlier. Study covers all areas and finding of the report becomes the basis of future action plan. These studies have their own limitation due to quality of replica and tube sample selected for analysis.

5A Failure due to short term overheating

These failure can be caused by foreign material fallen due to maintenance intervension.

- ✓ **Life Management Action Plan 5A**
  - Coil tubes to be cut by only grinder and to be capped immediately after cutting.
  - Sponge ball test to be done before welding.
  - Water soluble purge paper to be used during welding.

5B. Tube can fail due to chocking from excessive spray or exfoliation of scale

- ✓ **Life Management Action Plan 5B**
  - Steam temeperature after Desuperheat spary >10^0 C above steam saturation temperature during unit start up and operation.
  - Radiograph of bends during shut down

5C.Failure due to material degradation over period of time

- Excessive high metal temperature during unit operation
- Lower grade material usage either at design stage or erection and maintenance stage

✓ **Life Management Action Plan 5C**

1. Metal temperature to be monitored on continuous basis with provision of alarms and time period of excursions using state of art DCS
2. Insitu oxide thickness measurement during overhaul
3. Sample checking for microstructure degradation

5D Tube failure due to Cracking at high stress locations

I. Fatigue failure
II. SCC failure

✓ **Life Management Action Plan 5DI**

5D I FATIGUE FAILURE:

1. Attachment failure to be checked for structure integrity
2. MPI to be done at extensive scale in cyclic loading boilers
3. Header Stubs, IPW joints and attachments MPI to be done aggressively.
4. Load ramp up and ramp down to be monitored and optimised.
5. Metal Temperature variations during start up, mill change over, and load ramp up to be captured and analysed for control initiation.

5D II STRESS CORROSSION CRACKING FAILURE:

✓ **Life Management Action Plan 5DII**

- Water chemistry to be monitored round the clock online for any increase in ACC
- Any water intake in boiler to be done thru CPU only particularly once thru boiler.
- Offline chloride to be measured in once thru boiler periodically.
- Reason of stress to be analysed in reference to supporting structure.
- Source of moisture to be found out and it could be excessive spray or water accumulation during shut down.

STEP 6

✓ **LIFE MANAGEMENT ACTION PLAN 6 (AFTER 25 YEARS OF OPERATION)**

There are boilers operating without any tube failure in reheater and superheater even after 25 years of continuous operation. This is a sufficient to believe that SH and RH life can be managed with high degree of reliability even after 25 years. To ensure health of superheater and reheater Insitu oxide thickness measurment is the best available tool , however in case of exfoliation these readings can be erroneous therefore multiple reading at high heat zone tube facing gas flow needs to be taken and **net effective thickness to be checked.**

Tube or complete Reheater replacement plan to be made on the basis of net effective thickness mesurment and on the basis of **actual microstructure test report of a tube with highest oxide thickness.**

However on short term following measures needs to be ensured

a. Limiting the maximum metal temperature limits.
b. Radiography of all bends to remove any exfoliated material.
c. Shielding of tubes in high heat pickup zone.
d. Ensuring coil tube alignment so that lower grade tube is not becoming the leading tube from gas flow side.

On a long term basis replacement plan of the affected coils or full replacement of outlet reheater should be planned with necessary upgradation of material.

NTPC has been doing such upgradation in old units viz: SSTPS, Ramagundam etc after detailed analysis on basis of online and offline data and tube sample analysis.

CONCLUSION:

High temperature SH and reheater life can be satisfactorily managed if above action plan are put in practice. Necessary precautions taken during unit start up, operation, maintenance and close monitoring through alerts of important parameters viz maximum metal temperature excursions, ACC excursions etc., offline measurement of chloride in once through boiler can ensure expected design life of the components. Load ramp and ramp down is another parameter which has become critical nowadays in times of flexible operation of units. Therefore parameter excursion and rate of change should be maintained within permissible limits. DSM also sometimes make it difficult to maintain the parameters within permissible limits and may cause exfoliation of oxide scales mainly in SS tubes . Therefore short term gain may be moderated to have long term reliability of superheater and reheater tubes, piping and headers. Further, it would be beneficial to include demonstration of cold start up, warm and hot start up curves, ramp rate and parameter deviation limits under boiler PG test. This would ensure a practical reference for future operation of the boiler without compromising on the life of boiler components.