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PREVENTION OF CATASTROPHIC FAILURES AND BEST MAINTENANCE OF BOILERS BY RLA & NDT

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ABSTRACT
The Non Destructive Testing plays a key role in Boiler and critical Pressure parts maintenance and in prevention of catastrophic failures. The safe life of Power Station Boilers and Industrial Boilers depends on the best maintenance of boiler utilizing effective NDT Techniques during RLA Study. The effective RLA Study by able NDT Experts really prevents catastrophic failure by giving indication in the concerned NDT in advance prior to catastrophic failure and extends the Life of Boiler and Pressure parts. For effective RLA Study, the RLA Team must be guided and led by Team leader with long experience and knowledge in Boiler fabrication, welding, metallurgy, design of boiler pressure parts and expertise in NDT. And it is advisable that Team leader may be certified as ASNT / ISNT NDT – Level III and experienced since he has to take critical decision on NDT findings. The RLA Team Engineers shall be NDT specialists. Concluding the false or non-relevant indication as crack indications by inexperienced and not properly trained persons happens in some of the cases damaging the healthy Boiler Pressure Parts. Scanning by inexperienced persons results in missing the possible dangerous defects in ageing Boilers. Some Catastrophic Failures can be analyzed. The Failure analysis proves that it is due to improper NDT Evaluation. This paper explains some of such failures and how to prevent it.

INTRODUCTION
For best maintenance of boilers, Remaining Life Assessment Study plays a key role utilizing Non Destructive Testing. This paper discusses how to use NDT during Fabrication, Erection and RLA Study more effectively by NDT Techniques as health check up of boilers, best maintenance of boilers, to extend the life of boilers and to prevent catastrophic failure achieving safety and continuous boiler availability.

Non Destructive Testing provides many solutions to check for the condition monitoring of pressure parts to predict the service induced damages if any and to check for any missed dangerous defect during manufacturing or fabrication of critical pressure parts. Non Destructive Testing of pressure parts during shut down can detect the defects due to ageing, before Catastrophic Failure - preventing forced outages of boilers by utilizing effective Non Destructive Testing if carried out by able experienced and trained operators,

CATASTROPHIC FAILURES

Boiler Explosion
One Boiler explosion was analyzed after Catastrophic Failure. Surprisingly it was found that the tight side wall lack of fusion missed in Radiography Evaluation was the culprit to cause such a catastrophic failure as earth quake happened. It can be seen in the photographs. Even the concrete structures which accommodated the Boiler were damaged similar to damages due to earth quake. The tight side wall lack of fusion was not revealed during Radiographic inspection due to limitation of Radiography. Hence, the manufacturers should have done Ultrasonic Testing also in addition to Radiography. In this Catastrophic Failure the side wall lack of fusion in the butt joint was oriented from the outer surface. Hence, at least the surface NDT, Magnetic Testing should have been carried out to detect and rectify this tight side wall lack of fusion before cleared for Radiography.

This system of NDT – that is carrying out MT before clearing for Radiography is being followed in Boiler Industry NDT. In addition to Side Wall Lack of Fusion, it was found on analyzing the ruptured cross section, the area below the lack of fusion is having severe lamination also of about 300mm length where as the ASME code permits only 75mm lamination in the procedure and acceptance standard of UT. It is obvious that the particular company has not used UT quality plate for boiler fabrication.

MAIN STEAM LINE EXPLOSION

Material Mix Up
We have to follow the fool proof procedure regarding the identification of material during manufacturing, erection and
replacement of boiler critical pressure parts. If the carbon steel is placed in the place of high temperature zone of alloy steel, the carbon steel cannot withstand the temperature above 400 degree centigrade. The carbon steel will initially bulge and result in catastrophic failure. One such failure happened in the Main Steam Line is given in the Figure.

The colour coding system of identification of material belonging to carbon steel and alloy steel of critical Pressure Parts shall be successful if painted lengthwise throughout the length of pipe and tube material. In addition to the colour coding system by raw material suppliers, Boiler manufacturing industry uses material analyzer during fabrication of critical Pressure Parts. Some companies follow the system of colour coding only at the end of the pipe and tubes. If this system is followed, when the tube or pipe is cut at the ends, the balance material of tube or pipe cannot be identified whether belonging to carbon steel and alloy steel. This system of colour coding followed in pipe material resulted in catastrophic failure of Main Steam Line. This catastrophic failure is given in the figures. Two spool pieces of Main Steam Line, cut and removed from the MSL line since they have bulging. The bulged spool pipes were doubted to be carbon steel on analyzing by measuring hardness and by material analyzer it was confirmed they are carbon steel instead of P22.

**BOILER OPERATION AND MAINTENANCE**

**Water Chemistry**

**Pitting Corrosion**

If the DM water has dissolved oxygen, the severe pitting corrosion shall be formed at water side of the Boiler Pressure Parts. Photo of such severe Pitting Corrosion, formed inside the Boiler Steam Drum is given in the Figure. Improper chemical dosing results in heavy thick coating of water deposits on boiler pressure parts water side, affecting heat transfer. The Pitting Corrosion is formed at outer surface of Boiler Drum also in some of the Sites, if the drum is not properly covered by insulation and protected from water entering the insulation.

**Hydrogen damage in furnace tubes**

\[ \text{Hydrogen} + \text{Carbon} = \text{Methane} \]

The boiler water pH value has to be in the range of 9 to 10 to prevent Hydrogen Damage in water wall panel tubes. If boiler water pH value is less than 7 and acidic, the acidic deposit gets collected at the ID of the water wall tube. The nascent Hydrogen of atomic number one enters the ID of the water wall tube through grain boundary. The nascent Hydrogen entered inside the water wall tube material forms Methane combining with carbon from carbon steel of water wall tubes. Methane being gas exerts enormous pressure with-in the wall thickness of the water wall tube resulting in micro fissures. These hydrogen damaged water wall tubes will start bursting by window opening type tube failure.

This hydrogen damage can be scanned and predicted before tube failure by Special Ultrasonic Technique by well experienced and trained ASNT – Level –II certified personnel guided by ASNT – UT - Level III certified RLA Team Leader since Ultrasonic Testing depends highly on operator whether analog UT unit is used or digital UT unit is utilized for scanning. SH tube ID oxide deposit also leads to creep failure of high temperature SH tubes. The SH Boiler tube ID oxide scale thickness can be measured and surveyed by using high frequency special Ultrasonic instrument containing soft ware for critical measurement.

**Ligament Crack / Thermal Fatigue Crack**

Ligament Cracks occurs at the ID of the high temperature headers. The Super Header Headers and Re-heater Headers which are at above the creep temperature 400 degree centigrade, develop Thermal Fatigue cracks originating from the inner surface of the Header pipe material. The presence of this type of cracks are initially detected by visual inspection inside the Header pipe using video fiberscope and sized by shear wave Ultrasonic Testing.

And a still photo from UK is given depicting catastrophic failure due to ligament cracks in a SH Header. This catastrophic failure could have been prevented if proper NDT / RLA were carried out as per IBR norms. The Thermal Fatigue crack which develop due to high temperature fluctuations and ageing, forms in high temperature pressure parts. The mechanism of Ligament crack formation at the ID of high temperature headers also is Thermal Fatigue. The De-Super Heater Header is prone for Thermal Fatigue crack. Thermal Fatigue crack detected by Magnetic Crack Detection Testing is shown in Figure. This belongs to one Main Steam line butt joint of 210 MW.

**Boiler Water Level Maintenance**

Most of the catastrophic failure in Package Boiler has happened due to low water inside the Boiler. The water level maintenance being critical should be maintained properly and continuous monitoring should be followed for all type of boilers. The boiler water level maintenance is very much essential to prevent catastrophic failure. Water Wall furnace tube failure due to water starvation results in fish mouth opening of water wall tube and distortion of water wall panel.

**IBR Act 391a / Requirement of RLA Study**

For the boilers which operate at more than the creep temperature 400 degree centigrade, as per the Indian boiler Regulation, carrying out RLA Study is mandatory after 1,00,000 hours operation. [After about 11.4 years of operation]. For the boilers which operate at less than the creep temperature 400 degree centigrade the RLA Study is mandatory after 25 years.

But, for both the above mentioned boilers the RLA Study has to be repeated after every 5 years of operation as per the IBR Act 391-A to confirm the Boiler Health and Safety.
POSSIBLE DAMAGES IN AGEING BOILER PRESSURE PARTS:

As per Electric Power Research Institute - USA

The possible damages in critical pressure parts due to ageing and various damage mechanisms are given below. The concerned effective NDT method to detect the service induced damages in boiler critical Pressure Parts also are tabulated below.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of Pressure Part</th>
<th>Damage Mechanism</th>
<th>Effective NDT Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Boiler Drum</td>
<td>Thermal Fatigue</td>
<td>MT / WFMT</td>
</tr>
<tr>
<td>02</td>
<td>High temperature Headers – S.H Headers, Re-Heater Headers – De-Super heater – [above 400°C]</td>
<td>Irreversible Creep damage due to high temperature and Pressure</td>
<td>Field Metallography to assess level of creep damage MT Critical Shear wave Ultrasonic scanning</td>
</tr>
<tr>
<td>03</td>
<td>High temperature Headers – S.H Headers, Re-Heater Headers</td>
<td>Ligament crack at ID of header pipe</td>
<td>Video Fiberscope &amp; Shear wave Ultrasonic Scanning</td>
</tr>
<tr>
<td>04</td>
<td>S.H Coils and R.H. Coils</td>
<td>Tube ID oxide deposit leads to creep damage.</td>
<td>High frequency Ultrasonic scanning and Tube sample analysis.</td>
</tr>
<tr>
<td>05</td>
<td>Main Steam Line</td>
<td>Creep damage and Thermal Fatigue due to high temperature</td>
<td>Field Metallography, above 400°C. MT Critical Shear wave Ultrasonic scanning</td>
</tr>
<tr>
<td>06</td>
<td>Furnace Water Wall Tubes</td>
<td>Hydrogen Damage</td>
<td>Special Ultrasonic Scanning</td>
</tr>
</tbody>
</table>

Magnetic Crack Detection Testing

Magnetic Crack detection Testing is more effective for examining surface cracks on Boiler Pressure Parts of ferromagnetic materials since PT can not reveal cracks which are contaminated in ageing Boiler Pressure Parts. Most of the service induced cracks originate from surface. Hence, MT using AC has more sensitivity to detect service induced surface crack since the magnetic field is more concentrated on surface. The limitation of PT is it cannot detect the defects, even open to surface with contamination. We can employ PT on non-magnetic materials to detect surface open defects and cracks after thorough cleaning and removing the contamination – a time consuming process.
**Ultrasonic Testing**

Radiographic Testing is more sensitive to reveal volumetric defects like gas holes and slag. But, the aim of RLA Study is to detect the possible service induced crack like indications – due to thermal fatigue or irreversible creep damage, etc. Ultrasonic Testing is more sensitive in detecting tight lack of fusion and cracks like fatigue crack, creep crack, Hydrogen induced Crack and any other crack like indications. The service induced cracks like Thermal Fatigue Crack and Creep Crack will be tight in nature. Since, Radiography can not reveal tight cracks, during RLA Study, Ultrasonic scanning is more effectively employed. But, UT is highly operator dependent.

**CONCLUSION**

The RLA Team shall be led by a well experienced NDT Expert, certified as NDT – Level III in the applicable methods with knowledge and experience in damage mechanisms in ageing Boiler pressure parts and effective NDT Techniques. Since Interpretation and Evaluation of NDT findings are critical and require well experienced RLA Study Team Leader and Team Members. the RLA Team leader responsibility is entrusted to ASNT – NDT – Level III certified Engineer in Electric Power Research Institute – USA. Other RLA Team Members also shall be certified as NDT - Level II and well trained and experienced.

Knowledge and experience in Boiler Design, critical Pressure Parts fabrication, welding, Boiler operation and metallurgy are essential to carry out the RLA Study effectively. Utilising quality sensitive calibrated NDT Instruments and consumables also are mandatory.

**REFERENCES**

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