Prevention and Correction of degrading Effects of Corrosion and its Related Processes on High Pressure Water Tubes in Fossil Fired Boilers – A Case History

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BADARPUR THERMAL POWER STATION
Present Scenario-AGRA CANAL
Location of Badarpur Plant in Delhi

705 MW, 3x 95 MW & 2x 210MW
DM consumption=1500 MT/Day
CW water= 108000 MT/Hr
BTPS- Intake raw water quality

Organic loads
*(Higher values indicate High Organic load)*

- **BOD** = 40-72 ppm
- **COD** = 60-180 ppm
- **TOC** = 25-43 ppm
- **TKN** = 15-45 ppm

- **Suspended solid**
  Turbidity = 60-950NTU

- **High Ionic Load**
  Conductivity = 1000-2500us/cm
**BTPS-WTP Infrastructure details**

**Conventional way**

**PRE-TREATMENT PLANT**
- Conventional clarifiers
- Capacity: 2 X 3200 M3/Hr

**DM PLANT**
- Conventional
- 4x 35 M3/Hr Ion Exchange Technique
- Circulation flow: 1,08,000 m3/hr
- Condenser tube metallurgy: 90:10 Cupro-Nickel

**CW SYSTEM**
- Once through Open Cycle Circulating System
**BTPS-WTP Conventional infrastructure Way**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Desired DM Water Quality</th>
<th>Present DM water Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.8-7.2</td>
<td>6.5-7.5</td>
</tr>
<tr>
<td>Cond, us/cm</td>
<td>0.2</td>
<td>0.5-1.5</td>
</tr>
<tr>
<td>TOC, ppb</td>
<td>300</td>
<td>1500-5400</td>
</tr>
<tr>
<td>Silica, ppb</td>
<td>10</td>
<td>20-25</td>
</tr>
</tbody>
</table>
Main problems

- Poor steam water parameters
  - High ACC (0.5 to 1.0 us/cm)
  - High TOC (250-1000ppb)

- Microbiological fouling &
  High Ammonical (TKN) content in CW System
- Frequent condenser tube leakages
Corrosion related process

Hydrogen damage is caused due to low pH water chemistry, as a result of ingress of acidic salts through condenser seepage and the higher TOC in make up and cooling water, which get converted to organic acids at high temperature and pressure.

Caustic Gauging- occurs when boiler water caustic concentrates to high pH within tube deposits.
History of tube failures

BTL due to Corrosion since 1996

Series1
Corrosion Mapping by Low Frequency Electromagnetic Technique (LFET)
Advantages and Design Features

• Dry non-contact method. No couplant necessary.
• Uniform rust, scale, and coatings have no impact on testing process.
• Variety of contoured scanners to fit any tube/pipe diameter.
• Scanning speed up to 10 to 15 ft. (3 to 4.5m) per minute.
• Light weight, modular, PC operated.
• Real time data display with advanced signal processing.
• High resolution color graphics with 3D display.
• 8 or 16 sensors to achieve up to 170 degrees of coverage in a single scan.

Detection Capabilities/Limitation

Using a standard size O.D. scanner on material of 0.250” (6mm) or less, pitting of 0.125” (3mm) diameter at 30% depth is detected.
# Report

<table>
<thead>
<tr>
<th>PHASE SCALE</th>
<th>9.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side View (Phase)</td>
<td>Max Phase = 7.62</td>
</tr>
<tr>
<td>Top View (Phase)</td>
<td>8 CHANNELS</td>
</tr>
</tbody>
</table>

**Testex Multi-Channel Data Viewer**

- File: WY-11-11-11.TS2
- Dir: C:\BDP-Lev 3A
## NDT-Application & findings

<table>
<thead>
<tr>
<th>Period</th>
<th>Area of application</th>
<th>Defect observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul, 2006</td>
<td>All four sides WW from 15 to 37 mt &amp; 5 mts water platen</td>
<td>13 tubes defects</td>
</tr>
<tr>
<td>Mar, 2008</td>
<td>All four sides WW from 21 to 34 mts, all burner tubes and S panel tubes 1m above &amp; below of top bend</td>
<td>5 tubes defects</td>
</tr>
<tr>
<td>Apr, 2009</td>
<td>-do-</td>
<td>No defect</td>
</tr>
<tr>
<td>Jul- Aug, 2010</td>
<td>Rear side tubes from 15 to 35 mts and S panel from 8 to 15 mts</td>
<td>No defect</td>
</tr>
<tr>
<td>Nov, 2010</td>
<td>Rear wall, S panel, Goose neck and water platen</td>
<td>50 tube defects</td>
</tr>
<tr>
<td>Nov, 2011</td>
<td>Corrosion mapping</td>
<td>A few tube defect</td>
</tr>
</tbody>
</table>
Radiography

Radiography is an effective tool in finding thickness losses in corrosion effected tubes. With this technique an accurate estimation of losses can be made and based on that replacement decisions can be taken.

**Limitations of radiography** are:

- This is a time consuming process and requires lot of time in getting results.
- Process can be applied only on identified or suspicious location, in bare tube, long lengths application is not practical.
- For application of this in water wall, outside insulation and corrugated sheets are to be removed.
- This has hazardous effects on human being, therefore cannot be used in any quantity.
- Process is very expensive than other NDT processes.

**Application and findings**

- The process is mainly used at a large scale in 1999, 2006, 2010 and 2011 to find out defective tubes near joints.
- The process is highly effective and lot of tube more than 70-80 were find out in all these instances.
Ultrasonic Testing

Corrosion mapping and Radiography is more effective in case of under deposit corrosion or caustic gauging.

in cases of severe hydrogen damage, grain boundaries become weak and material failed with sufficient remaining thickness also.

Ultrasonic testing can help in these cases, if done with accurate and sensitive instrument and by an expert then process can be helpful in finding out hydrogen damage also.

Limitation of system:
Inspection is very slow and contact type. For detecting hydrogen damage, it takes longer time and in a big circuit like water wall, this much surface preparation and shut down time is not practical.

Application and findings
Technique is used at available opportunities and especially in Nov 2010 at large scale, but findings are mainly related to tubes where sufficient thickness loss was there.
Long length (30 m) fibro scope

Visual inspection (if possible) is best.
Limitation is that in this case a small length of tube is required to be cut for making access to fibro scope.
The process is widely used in 2010-11 and 2011-12, by using 30 meter length fibro scope.
A joint cut or a window cut can give visual inspection of full tube.

**Application and findings**
Method is used in Nov 2010 (7.5 m length) and not less than 100 tubes were identified through this process
Fibro scope inspection with 30 meter length used in Nov-Dec 2011 and damaged tubes identified even in the area where corrosion mapping already done.
Fibroscopy continue.....
Hydraulic test at elevated pressures

• In cases of hydrogen damage, caustic gauging, erosion etc. hydraulic test is a proven technique to control the imminent failures. In case of hydrogen damage, hydraulic test at 1.5 times of working pressure gives reasonable accuracy in detecting damage tubes and can provide considerable reliability (as per EPRI).

• Process is used at various opportunities and helped in detection of tubes, which were already affected but not failed and due to which several failures contained.
Chemical cleaning

Internal deposit quantity limits as per BIS 10391(1982) for Post operational Chemical cleaning-

Deposit $> 40 \text{ mg/cm}^2$.

It also helps in events of failure due to any under deposit mechanism confirming thick deposit inside tubes.

Due to thick deposit and failure due to caustic gauging, Chemical cleaning of water wall was done in Aug, 2006.
Efficiency Improvement due to Post-operational chemical cleaning, 210 MW, Unit no.4, Badarpur,

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Design Value</th>
<th>Before O/H</th>
<th>After O/H</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flue Gas Temp.</td>
<td>ºC</td>
<td>143</td>
<td>169</td>
<td>142</td>
<td>27 ºC</td>
</tr>
<tr>
<td>Boiler Efficiency</td>
<td>%</td>
<td>86.7</td>
<td>84.47</td>
<td>85.73</td>
<td>1.26 %</td>
</tr>
<tr>
<td>Unit Heat Rate</td>
<td>Kcal/KWH</td>
<td>2378</td>
<td>2676.4</td>
<td>2456.3</td>
<td>220.1</td>
</tr>
</tbody>
</table>

AUG. 2006
Chemical cleaning of water wall (2010)
Three side of water wall replaced to remove corrosion affected tubes up to 44 m elevation and chemical cleaning was done
Correction activities

Reporting of failure
R&D analysis for establishing the root cause.
Trend preparation and depiction on boiler diagram
Formalization of short term/long term strategy.
Major Replacements/correction

Major works done in 1999
Majority of failures were at or near weld joints

Corrosion at weld joints
Comprehensive hydrogen damage mapping through UT was carried out through M/s BHEL to identify the probable locations.
Major works done in 1999 continue....

- Corrosion reported was there in bare tube also and at that time no proven technology to detect the inside damage, therefore rear wall from top of S’ panel to below goose neck level so that corroded tubes were replaced.
- replaced all erection joints on the front, left and right side of the water wall at high heat flux zone.
- water wall platen bottom bends for all 04 panels replaced.
- Post work, the failures due to hydrogen damage was not occurred up to 2004
- Once again, there was a similar situation in May 2006, 02 failures were occurred in the left side of water wall.
**Works done in 2006**

a) RT of welded joints at burner panels, erection joints, high heat zones, etc. This process resulted in identification of 119 corroded joints.

b) UT at near weld joints.

c) Corrosion mapping of water wall for detection of under deposit corrosion.

Post work the chemical cleaning was also carried to remove the deposits and clean the surface.

Approximate 350 tubes of water wall were identified and replaced during 2006 overhaul. Post 2006, it was found that the occasional occurrence of BTF due to hydrogen damage do happened. Suddenly in late 2009 there was a sharp increase in failures on the left, right and front side of the water wall.
Major works done in 2010

a) Since failures occurred on LHS, RHS and front wall. Station replaced water wall from ring header to 43’m elevation of LHS and RHS water wall, 13’m elevation to 44’m of front water wall. This massive work was carried out in 37 days by dividing the works in 02 parts.

b) Corrosion mapping of front and rear S’ Panel, rear water wall for detection of under deposit corrosion
Rear side and S Panel Joints replacement

All Panel joints in rear side of water wall starting from 15 meter to 34 meter were replaced.

A small length of tube, where deposits were suspected is cut from all ‘S’ Panel tubes cut and replaced. Through the opening fibro scopy was also done.

A small length of tube cut in all water platen also to assess condition of remaining tubes and based on assessment replacement were made.
Goose neck tubes bends replacement Feb. 2011
During a tube leakage in gooseneck bend, all 22 defective tubes of gooseneck bends replaced. Tubes identified by fibroscopy.

Rear Water wall, Goose neck and S Panel Replacement Nov-Dec 2011
During overhauling remaining portion of water circuit i.e. Goose neck tubes, Rear water wall (only 12 years old) and S panel both sides (Front and Rear) replaced with new ones.

Inspection of water wall during Dec-2012
During recent overhauling of 2012-13, inspection of replaced portions and remaining portions done and no abnormality in inside surface of tubes observed. After performing these corrective actions unit had not any failure due to corrosion and its related processes and running with its rated capacity.
Efforts to control corrosion -

1) To meet stringent DM water quality norms -

**Short term measure -**

a) Utilisation of NTPC-Badarpur Plant Township STP Plant water for DM Production (STP treated water has lower TOC value - 9.8 ppm than Agra canal Raw water; TOC value, 25-43 ppm)

b) Re-polishing stored DM water of high conductivity by Mix-bed, prior to its use as make up water

**Long term measure -**

Newer sewage treatment technique, MBR/ MBBR+UF & RO plant upstream of existing DM Plant
2) **To minimise deviation in steam-water cycle parameters** - better monitoring with installation of core level online instruments and coordination with operation

3) **Proper Circulating water System**
   a) Conversion from open cycle to closed cycle CW system - **R&M Package-II**, Construction of additional cooling Tower
   b) STP treated make up to CW system  
      **R&M Package-I**, for 96 MLD STP Plant

4) -addressing condenser tube leakages/ingress on priority
   **Acoustic based system** to identify the condenser leak tubes & its plugging
5) Better metallurgy for condenser tube, in view of frequent tube replacement

Super ferratic steel condenser tube for one unit, in indenting process

For arresting tube end seepage, tube sheet and condenser tube cladding under exploration

6) Post operational Chemical cleaning-

More elaborate procedure for Boiler cleanliness status-

12 nos of boiler tubes, three each from front, rear, left and right high heat flux zone are being sent to NTPC-NETRA during each annual overhaul for ascertaining boiler deposit condition and planning for its Post operational chemical cleaning.

Unit #4, # 5 & # 2 results assessed.