

# Metallurgy for Industries

Power | Petrochemical | Fertilizer | Chemical | Refinery | Engineering | Automobile

A Monthly News Letter

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## Boiler tube failure Investigation

*Damage mechanisms and mitigation*

The process environment of fossil fuel fired boilers and HRSGs, compounded by operation errors during engineering, fabrication, erection, operation, and maintenance will often result in boiler tube failures. The goal is to reduce the forced outage with zero chemistry related failures. The frequency of these failures depends on the corrective actions taken to prevent or reduce boiler tube damage. Recurrences of failures, besides forced outages do pose huge cost implication for tube replacement with direct and indirect economic losses.

Metallurgical root cause investigation helps to narrow down the reason of failure and provides inputs to initiate proper corrective action.

Common Damage mechanisms causing premature failures in boiler tubes are listed below.

### Caustic gauging



Localized corrosion due to the concentration of caustic or alkaline salts usually occurs under evaporative or high heat transfer conditions. It can be mitigated by water chemistry control and design.

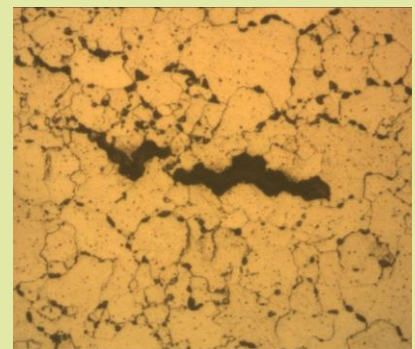
### Flow accelerated corrosion (FAC)



FAC involves the formation and removal of the protective oxide layer. It can occur in carbon or low alloy steel piping systems under flowing water at elevated temperature. Flow rate, pH, oxygen content, temperature and geometry affect the mechanism.

### Erosion, erosion & corrosion

## Microstructure of the Month



**Magnification:**250x

**MOC:** Grade 14MoV6-3

**Component:**HRH turbine inlet pipe line

**Observation:**Presence of tertiary creep fissures and aligned creep cavities are observed at the grain boundaries. Microstructure shows degradation of bainite to carbides in ferrite matrix.

**Useful hints:**Optical Metallography is a useful tool in identifying material degradation; especially under advanced stage of creep damage.

Erosion is the accelerated mechanical removal of metal due to relative movement of liquid, vapor or solid particles or their mixture. When corrosion contributes to erosion by removing protective films or scales, the combined action is erosion & corrosion.

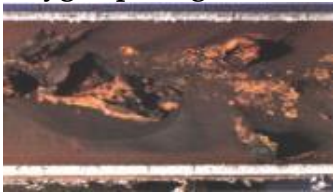
### **Stress assisted corrosion (SAC)**

Both mechanical stress and corrosive environment are necessary to initiate SAC. Dissolved oxygen, pH excursion are the major water chemistry variables. SCC cracks are frequently found where attachment exists. Stress on the tube surface can break the magnetite film formed.

### **Water corrosion**

Dissolved oxygen, low pH and the scale depositions are the main reasons of water side corrosion. Maintaining the water chemistry with respect to operating pressure and boiler type is necessary to avoid the water corrosion.

### **Oxygen pitting**



Localized corrosion occurs in form of severe pitting- especially at the locations where the water is not easily drained out during shut down, which comes contact with air.

### **Fire side corrosion**

Sodium and Vanadium in fuel and boiler operation under oxidizing atmosphere would lead to formation of low melting (995F) oxides of Sodium ( $\text{Na}_2\text{O}$ ) and Vanadium ( $\text{V}_2\text{O}_5$ ), Formation Pyrosulfates of Sodium and Vanadium and release of Sulphur and Chloride compounds by unburnt coal particles due to incomplete combustion, can eat away the tube surface, leading to thinning or puncture.

### **Stress corrosion cracking**



Highly stressed (Austenitic SS), Sodium salts concentration and deposition as surface hide out in dense steam and sudden release of superheated steam under constant pressure would promote SCC. Solution annealing of SS and optimum sodium level can prevent SCC. During shutdown care is necessary to avoid Polythionic Acid stress corrosion cracking(PASCC) of sensitized Austenitic SS.

### **Thermal fatigue**



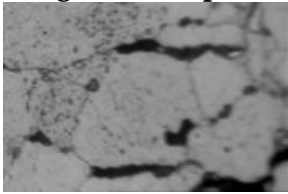
Thermal fatigue can occur due to cyclic stresses caused by temperature fluctuations. Damage is in the form of cracking may occur due to repeated thermal cycling. The cracks are observed with blunted tips, filled with scales.

**Fatigue**

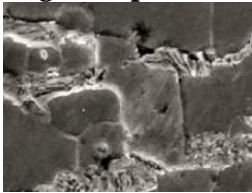
Mechanical fatigue can occur when the repetitive stresses are due to vibration, pressure fluctuation that can arise especially during start ups. The failure has typical signature of having fatigue striations on the fractured/crack surface.

**Stress rupture**

Short term over heating appears with bulging. It occurs, under operating stresses, due to localized overheating. It can also be due to design, secondary combustion in the boiler, shifting of combustion zone, starvation or obstacles to steam flow.

**Long term creep failures**

Creep failures occur due to high temperature exposure of the boiler tube that slowly and continuously deform under load below yield stress. Several factors like basic metallurgical condition, internal scale deposition and operating factors can contribute to creep failure.

**High temperature hydrogen attack (HTHA)**

Hydrogen damage of boiler evaporator tube, also called hydrogen attack, results in serious and irreparable damage to the tube steel, and it should not be confused with "hydrogen embrittlement" which is sometimes reversible as it is because of adsorption of hydrogen into steel. It occurs due to acidic condition and deposition on the hot surfaces due to poor water chemistry.

TCR has team of experts to investigate the boiler tube failures. The approach is unique with regard to correlation of operational parameters and deep understanding of damage mechanism.

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