Boiler Tube Failure, Prevention and Control

Mike Rogers
Alberta Technology & Science Inc
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Introduction

• The content of this short presentation is expected to give you the ability to:
  – Explain four reasons why large number of repeat boiler tube failures, i.e. same failure mechanism, same root-cause, same tube, etc., occur in fossil-fired boilers
  – Describe the six requirements for a formalized boiler tube failure prevention program
  – Discuss twenty-two common tube failure mechanisms in terms of typical locations, appearances, root-causes, corrective action, etc

Definitions

• A boiler tube is considered to have a failure when
  – Its pressure boundary is broken by a leak or rupture, or prone to be broken due to wall thinning before the next scheduled boiler inspection
Repeat failures are defined as multiple failures in a single boiler having the same failure mechanism and root-cause

- Repeat boiler tube failures occur for the following reasons:
  - Not following state-of-the-art practices
  - Lack of proper tube failure analysis
  - Wrong choice of corrective/preventive action
  - Lack of tube failure reporting and monitoring

Not following state-of-the-art practices

- State-of-the-art practices are defined as operation, maintenance and engineering practices demonstrated by experience to be necessary in the prevention of repeat boiler tube failures and fall into the following categories:
  - Operating practices
  - Maintenance practices
  - Engineering practices

State-of-the-Art Operating Practice

- Major operating practices influencing boiler tube failure are:
  - Cycle water chemistry
  - Boiler, superheater and reheater temperature control
  - Combustion control
  - Waterside and fireside layup
EXAMPLE (operating)

• These costly repeat failure problems can be eliminated by the establishment and use of plant action-oriented operating procedures; where these procedures define not only normal limits for boiler water chemical parameters, but also proper corrective action to be taken when parameter limits are exceeded.

EXAMPLE (Maintenance)

• Establish and use of plant repair procedure; where these procedures clearly define not only the repair method and materials to be used, but also proper quality-control action to be taken to ensure against boiler tube-repair repeat failures.

EXAMPLE (Engineering)

• Establish and use of plant boiler tube inspection procedures; where the procedures clearly define not only the method for verifying the integrity of the tube repair, such as radiography and/or hydrostatic test, but also proper residual life preventive action to be taken to ensure against loss-of-life-damage repeat tube failures.
Lack of proper failure analysis

• Analysis of a tube failure incident should include:
  – Inspections to determine the extent of primary and secondary tube damage
  – Identification of the failure mechanism
  – Determination of the root-cause
  – Determination of residual life/predictive maintenance

Formalized Boiler Tube Failure Prevention Program

• Every boiler tube failure will be reported and documented by responsible personnel in a comprehensive format describing:
  – Specific boiler and tube locations
  – Failure mechanism
  – Root-cause and verification basis
  – Type of repair and name of repairee
  – Type and extent of prerepair-inspection and name of inspector
  – Future preventive and control action taken or recommended

Failure mechanisms

• Primary Failure Mechanisms
  – A mechanism is defined as the process by which something comes into being. There are six broad classifications
    • Stress rupture
    • Water-side corrosion
    • Fire-side corrosion
    • Erosion
    • Fatigue
    • Lack of quality control
Stress Rupture
• Short-Term Overheating
• High Temperature Creep
• Dissimilar Metal Welds

Water-Side Corrosion
• Caustic Corrosion
• Hydrogen Damage
• Pitting (Localized Corrosion)
• Stress Corrosion Cracking

Fire-Side Corrosion
• Low temperature
• Waterwall
• Coal Ash
Erosion
• Fly Ash
• Falling Slag
• Soot blower
• Coal Particle

Fatigue
• Vibration
• Thermal
• Corrosion

Lack of Quality Control
• Maintenance Cleaning Damage
• Chemical Execution Damage
• Material Defects
• Welding Defects
Root-Cause Analysis an Verification Methods

- Tube metal temperature
- Tube metal stress
- Tube metal thickness
- Tube metal microstructure
- Tube metal material properties
- Boiler water and feedwater chemistry
- Boiler water flow
- Fuel constituents
- Fuel fouling and slagging characteristics
- Flue gas flow pattern and velocity
- Flue gas temperature
- Tube deposit constituents and thickness

Six steps in boiler tube failure investigation

- Isolate the probable failure mechanism by the tube failure location and position
- Select the actual failure mechanism by assessing other relevant failure characteristics
- Select the probable root-cause of the failure
- Verify the most probable root-cause of failure
- Assess the need for, and selection of the residual life methodology
- Select corrective/preventive actions directed towards permanent solutions

Short-Term Overheating

- Blockage of tube internally
- Loss of boiler coolant circulation or low water level
- Loss of coolant due to an upstream tube failure
- Overfiring or uneven firing of boiler fuel burners
High Temperature Creep

- Partial blockage by debris, scale, or deposits
- Exposure to radiant heat
- Before the change to a higher grade material
- Just above the final outlet header
- Exposure to high gas temperature due to blockage of gas passages or laning
- Have incorrect grade of steel material
- Have higher stresses due to welded attachments

Causes of high temperature creep

- Restriction of the tube's coolant flow internally by scale, debris, or condensate
- Reduction of heat transfer capability due to internal (steam-side) surface oxide scales or chemical deposits
- Periodic Overfiring or uneven firing of fuel burners
- Blockage or laning of boiler gas passages
- Operation of a tube material at temperatures higher than allowable
- Increases in stress due to wall thinning

Causes of dissimilar metal weld cracking

- Application of high temperatures and stresses that exceed the expected design values
Causes of caustic corrosion

- Selective deposition of feedwater system or preboiler corrosion products at locations of high heat flux
- Concentration of sodium hydroxide from boiler water chemicals or from upsets in the water chemistry

Pitting (Localized corrosion)

- Exposure of the tube to water with high acidic or oxygen concentrations
- Existence of close-fitting surfaces and deposits where differences in oxygen concentration can be produced