Boiler Tube Failure, Prevention and Control

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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

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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

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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

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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

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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

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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

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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

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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

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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

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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

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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

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Stress Rupture

- Short-Term Overheating
- High Temperature Creep
- Dissimilar Metal Welds

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Water-Side Corrosion

- Caustic Corrosion
- Hydrogen Damage
- Pitting (Localized Corrosion)
- Stress Corrosion Cracking

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Fire-Side Corrosion

- Low temperature
- Waterwall
- Coal Ash

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Erosion

- Fly Ash
- Falling Slag
- Soot blower
- Coal Particle

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Fatigue

- Vibration
- Thermal
- Corrosion

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Lack of Quality Control

- Maintenance Cleaning Damage
- Chemical Execution Damage
- Material Defects
- Welding Defects

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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

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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

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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

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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

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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

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Causes of dissimilar metal weld cracking

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

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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

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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

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