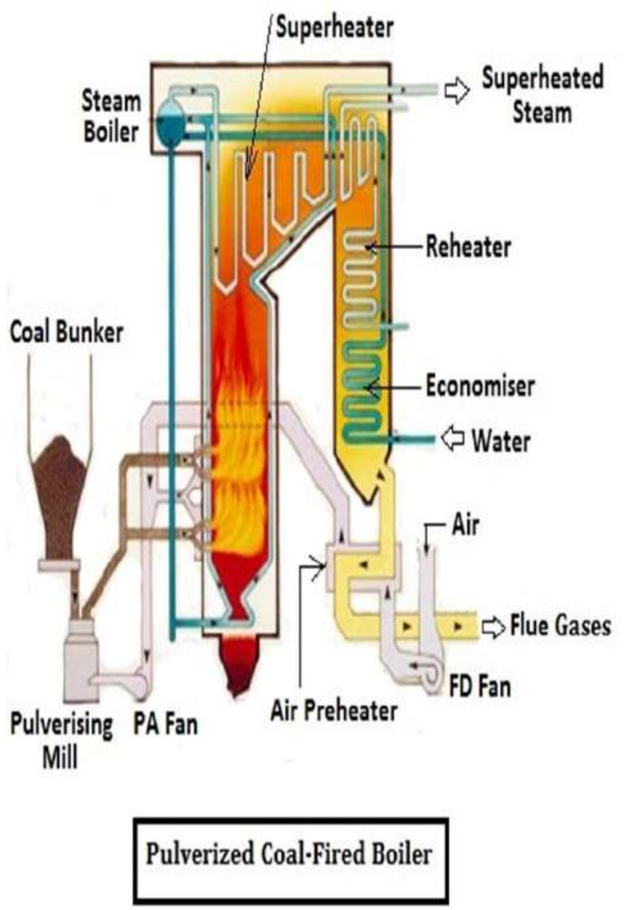

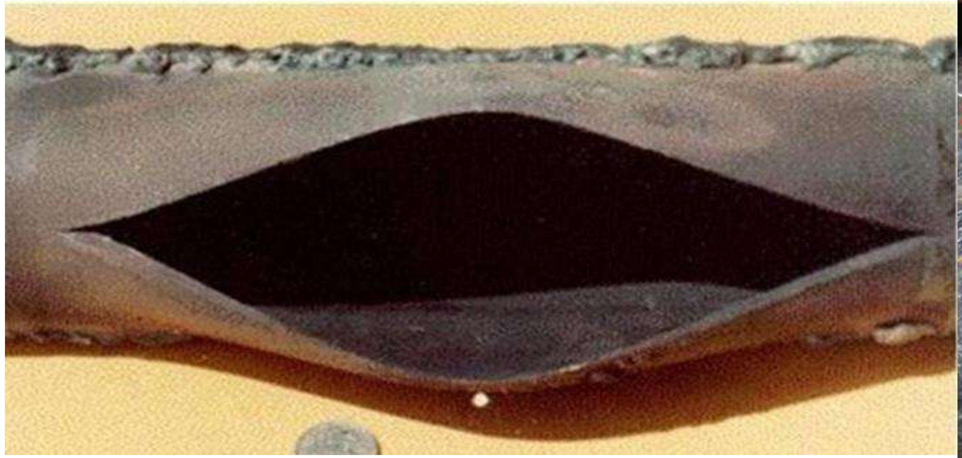

Boiler Tube Leakages : Proactive Mitigation Measures

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Contents

- ✓ Introduction
- ✓ Understanding Boiler tube failure mechanisms
- ✓ Case studies of Boiler tube failure mechanisms & their proactive mitigation measures
- ✓ Best guidelines & O&M practices for proactively mitigating Boiler tube leakages
- ✓ Conclusion

Importance of Boiler Tube Failure

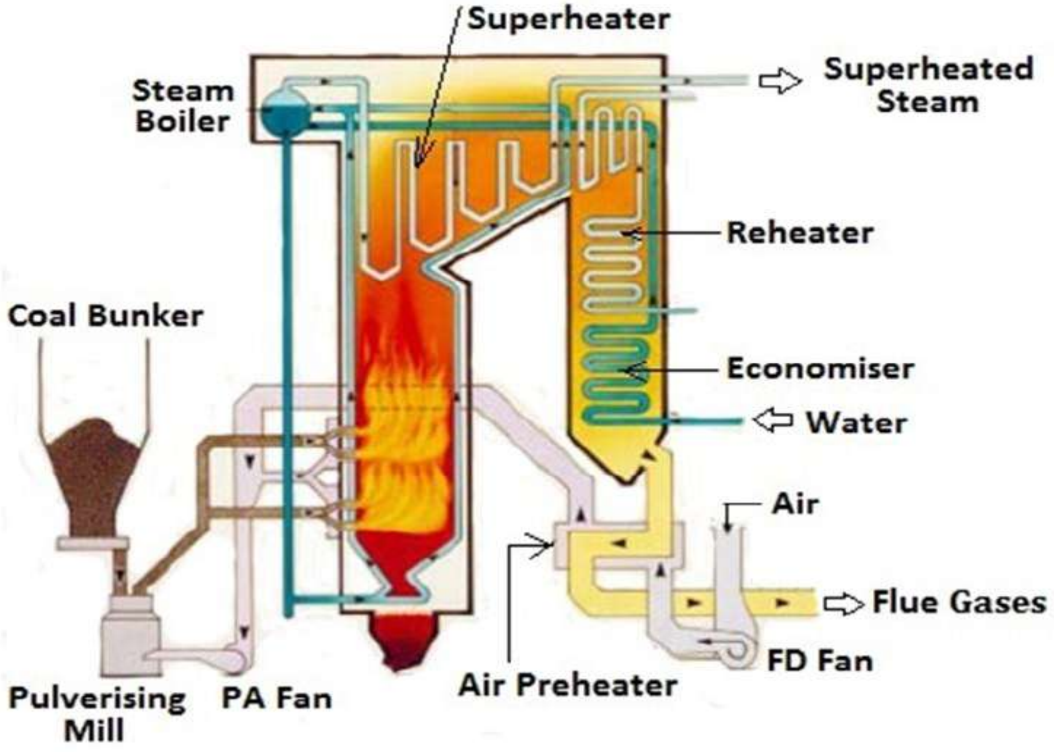
- Boiler's operating environment is extremely harsh and dynamic.
- .Boiler pressure parts:

  - Faces high pressure, temperature & cyclic loading
  - Faces mechanical, chemical, thermal / thermodynamic, micro-structural & others action/reactions

- Leading cause of Boiler forced outage: Study suggest = > 60 % boiler outage due to Boiler tube leakages.
- As per Electric Power Research Institute (EPRI) :

"Boiler tube failures have been number one availability problem for fossil plants utilities"

Boiler tube leakages are "No1" Boiler performance spoiler



Pulverized Coal-Fired Boiler

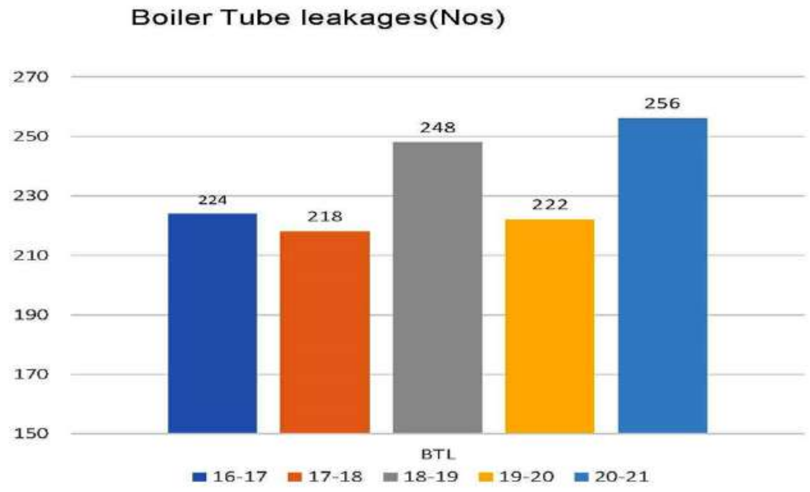
Importance of Boiler Tube Failure : Financial Impact

Commercial impact for 660 MW Plant Boiler tube failure as example

Cost of Boiler tube failure: 03 main components

- **Boiler tube repair cost:** Rs 2-3 Lakh /day of outage +cost of spares
- **Start up cost** : Start up oil + Aux. power consumption
  - Start up oil costs for 65-80 KL cons (48-60 Hour S/D) + Cost of Aux. power
- **Loss of profit margin on lost generation**
  - Loss of profit margin Rs 39.6 Lacs for 60 hour S/D @ 10 Indian Paise/unit
- Cost of total nos. of BTL in year for your station ?

  How many crores ?



Boiler tube leakages has very high financial implication leading to crores

Boiler Tube Leakage Mitigation : Proactive & Systematic Approach

Systematic proactive approach for Boiler tube leakage mitigation

- We need to understand in-depth different Boiler tube leakage mechanism, which causes tube leakages
- Best to understand each Boiler tube failure mechanism by case study
- Each Boiler tube failure mechanism case study shall contain :
  - Pictorial view / physical appearance of each Boiler tube leakage mechanism
  - How each Boiler tube failure mechanism lead to BTL ?
  - Symptom for identifying particular tube failure mechanism
  - Typical Boiler components affected by each failure mechanism

Understanding BTL mechanism is first step in mitigation

- Comprehensive proactive measures for each failure mechanism

Pictorial view of Boiler tube failure

Identification of BTL mechanism & comprehensive Systematic & proactive approach required for Boiler tube leakage mitigation as applicable to your plant is key measure

Understanding Boiler Tube Failure Mechanisms

- Boiler tube failure mechanism : Mechanical , chemical ,thermal / thermodynamic, metallurgical or other processes that result in Boiler tube failure

Broad Classification of Boiler tube failures mechanism

- Water side failure mechanism
- Fireside failure mechanism
- General failure mechanism

Each broad classification can be further sub-divided in >30

Most frequent occurring "17 no Boiler tube failure mechanism" are taken as case studies

Pictorial view of Boiler tube failure

Waterside Failure Mechanisms : Important Role of Boiler Chemistry

Waterside failure mechanisms: Role of Boiler chemistry

- Water/steam chemistry play important role in waterside tube failure
- **Formation & preservation of thin passive oxide film form during Boiler commissioning** : key to corrosion prevention

  Breakdown of "protective magnetite layer" result in BTF
- Chemicals fed to boiler may get concentrated on tubes pockets locally
- Accumulation of scale formation depends on :
  - Combustion Heat flux & Boiler water chemistry.

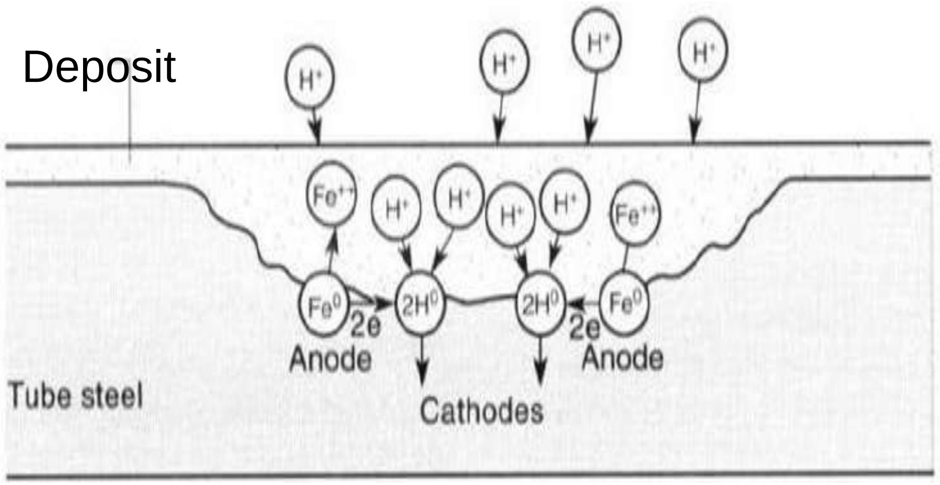
Boiler chemistry problems : Damage normally not localized but potential to cause widespread damage in boiler covering large areas

Control of boiler chemistry : Fundamental to BTL mitigation

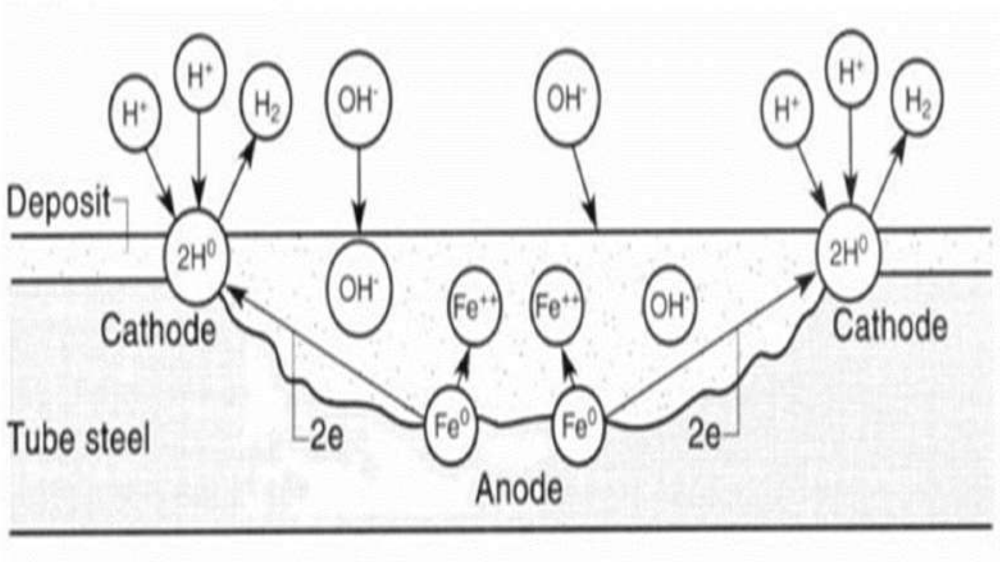
Pictorial view of Boiler tube failure

Acidic/Caustic Attack Mechanism

Low PH Condition : Acid Attack



High PH Condition : Caustic Attack



Anode: $Fe^0 - 2e \rightarrow Fe^{++}$
Cathode: $2H^+ + 2e \rightarrow 2H^0$

H^0 = Hydrogen atom
H^+ = Hydrogen ion

Fe^0 = Iron atom
Fe^{++} = Iron ion
e = Electron

Acidic upset : Concentration of H2 ions
Boiler chemistry : Acidic localized chemicals concentration cause BTF

Caustic upset: Concentration of hydroxide ions
Boiler chemistry: Caustic localized chemicals concentration cause BTF

Waterside Boiler Tube Failure Mechanisms

Waterside failure mechanisms

- **BTF corrosion mechanism :** 05 very predominant
  - Hydrogen Damage
  - Caustic Gouging
  - Oxygen pitting mechanism
  - Stress corrosion crack mechanism
  - Corrosion fatigue failure mechanism

Pictorial view of Boiler tube failure

Case Study 01 : Hydrogen Damage Failure Mechanism

How Hydrogen damage failure mechanism work?

- Cause : **Concentration of acidic content (low pH) & deposits**
- Corrosion reaction evolves H_2^{+} ,which reacts with C in tube metal & form CH4
- Intergranular micro cracking & decarburization lead to **thick edge fracture**

Reasons :

- Aggravated by upset like **condenser leaks,** predominant with sea water condenser cooling
- Other reasons :

✓ Poor process control during boiler chemical cleaning

✓ Inadequate cleaning of residual acid /passivation

Hydrogen Damage - Thick edged window opening failure

In some plants WW panels need to be replaced due to repeated BTL failure on Hydrogen damage

Case Study 01 : Hydrogen Damage Mechanism

Symptom/appearance

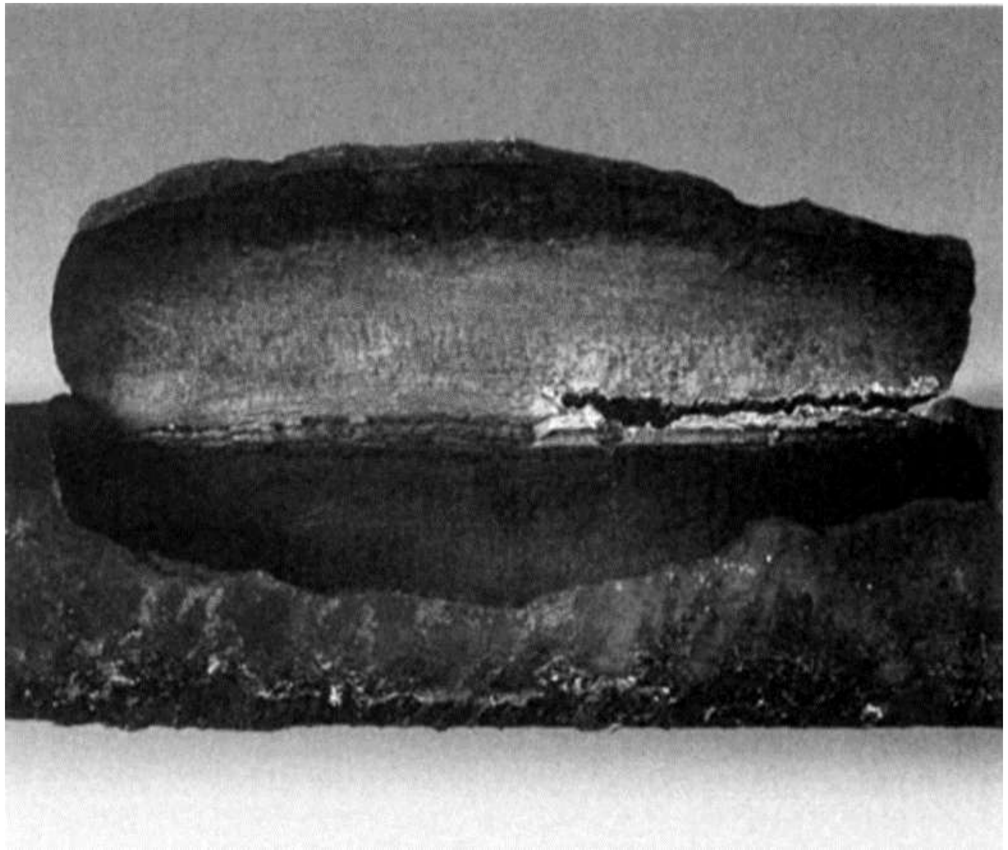
- **Thick edged window opening**
- Failure mostly with heavy scale on tube internal surface

Boiler components typically affected

- High heat flux area
- Confine to water wall tubes

Proactive measures

- Tight water chemistry control regime for scale prevention
- Watch for chemical hideout,
- Do not run Boiler with Condenser tube leakages
  Condensate ACC <= 0.2 μS/cm.
- Need based Boiler chemical cleaning
- Maintain controls during boiler chemical cleaning.
- Need based water wall tubes replacement



Hydrogen Damage - Thick edged window opening failure

Case Study 02 : Caustic Gouging Failure Mechanism

How Caustic gouging failure mechanism work ?

- **Concentration of NaOH (high pH) & deposits**
  - Dissolving oxide /metal with high PH boiler water cause caustic concentration:
    - ~ Corrosive attacks lead to protective magnetite breaks down
    - ~ Localized wall loss on inside surface of tube, result in increased stress & strain in tube wall & failure

Symptom/appearance:

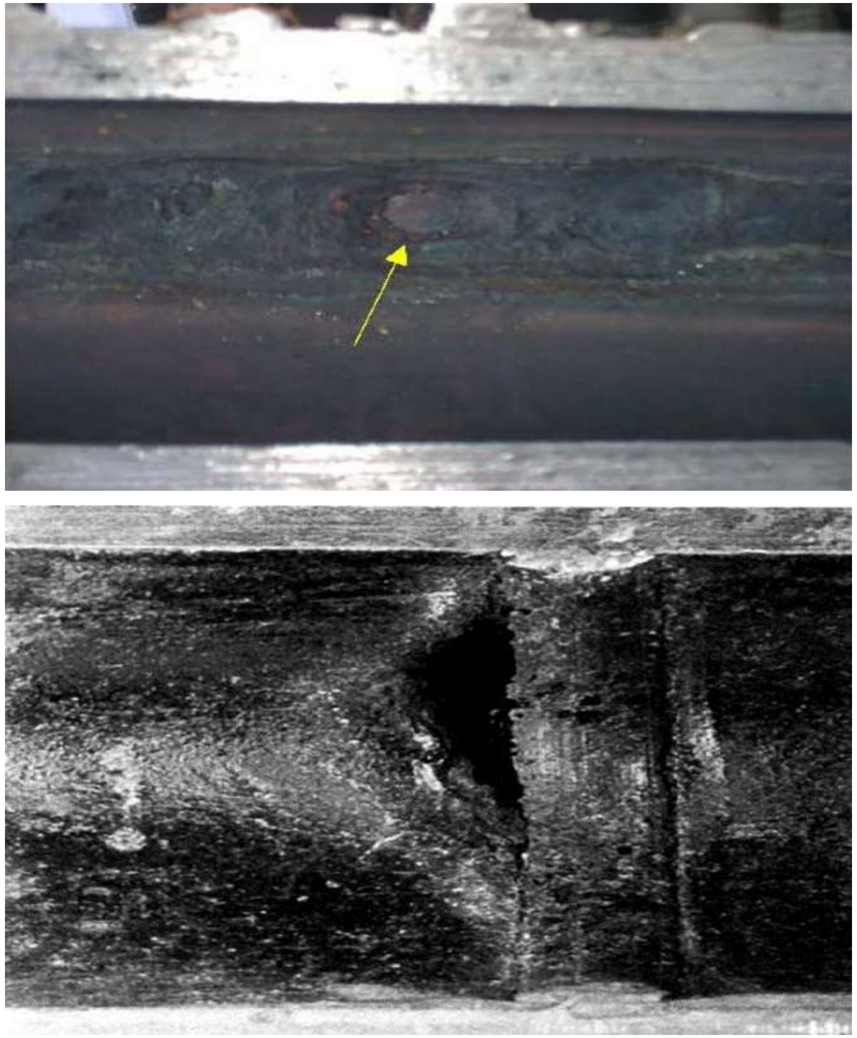
- **Failure : Ductile in nature, thin edged or pin hole leakage**
- No microstructure degradation

Components typically affected:

- Furnace wall tubes or any inclined tube

Proactive measures :

- Tight water chemistry control regime,
- In case of sloped tube with steam-water separation, use of ribbed tubes



Caustic gouging - Thin edged failure

Case Study 03 : Oxygen Pitting Failure Mechanism

How Oxygen pitting failure mechanism work ?

- **Oxygen pitting occurs with excessive oxygen in boiler water**
- Localized tube corrosion + loss of tube wall
- Pits can act as initiation points for stress-related corrosion mechanisms
- Normal operation : Air leakage at pumps or failure in water treatment
- During shut down : Proper preservation procedure not followed
- During start up /shut down : Poorly de-aerated water used

Oxygen pitting failure

Case Study 03 : Oxygen Pitting Failure Mechanism

Components Typically Affected

- Non-drainable surfaces : SH loops/Sagging horizontal SH & RH tubes & supply lines
- On operating boilers : Near economizer

Proactive measures for Oxygen Pitting

- Follow proper **Boiler preservation** during shutdown period
- Improve oxygen control during boiler start ups & operation
- Arrest air ingress in system e.g. CEP glands

Oxygen pitting failure in Boiler tube

O2 control during Boiler start up, operation & preservation is key to avoid Oxygen pitting failure

Case Study 04 : Stress Corrosion Crack Mechanism

How Stress corrosion failure mechanism work?

- High-tensile stresses + corrosive fluid
- Cracks propagating from the tube ID
- Source of corrosive fluid :
  - ✓ Carry over in SH from Boiler drum
  - ✓ Contamination during boiler acid cleaning if SH poorly protected

Symptoms

- Appearance : Thick wall, brittle-type crack
- Can lead to trans granular / intergranular crack propagation
- Typically branched with numerous small secondary cracks associated with main fracture area.

Stress corrosion crack failure

Case Study 04 : Stress Corrosion Crack Failure Mechanism

Components typically affected

- Higher external stresses location near attachments
- Stainless steel SH and RH tubes

Proactive measures

- Avoid water carryover to SH
- Precaution during hydro-test
- Proper flushing after acid cleaning

Stress corrosion crack failure

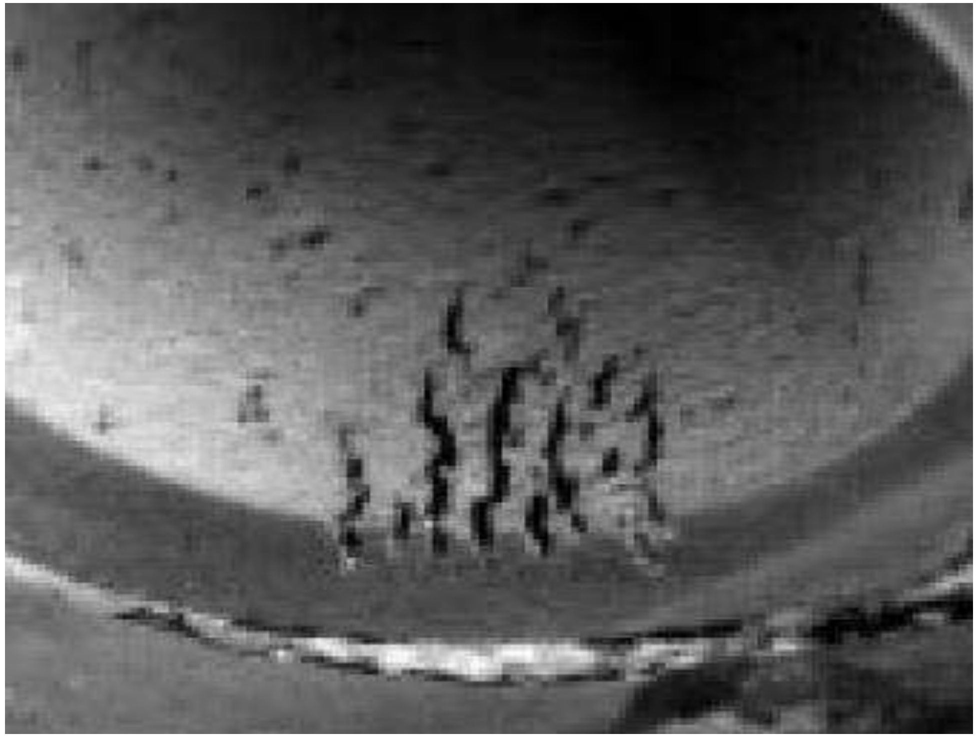
Case Study 05 : Waterside Corrosion-Fatigue Failure Mechanism

How waterside “Corrosion- Fatigue” mechanism work ?

- Cause: Thermal fatigue + corrosion
- Loss of ID protective scale exposes the tube to corrosion
- Likely to progress during boiler start-up cycles

Symptoms:

- ID initiated, wide trans granular cracks which typically occur adjacent to external attachments
- Thick-lipped failures that initiate from ID cracks that are oriented _|_ to direction of the stress



Corrosion-Fatigue failure

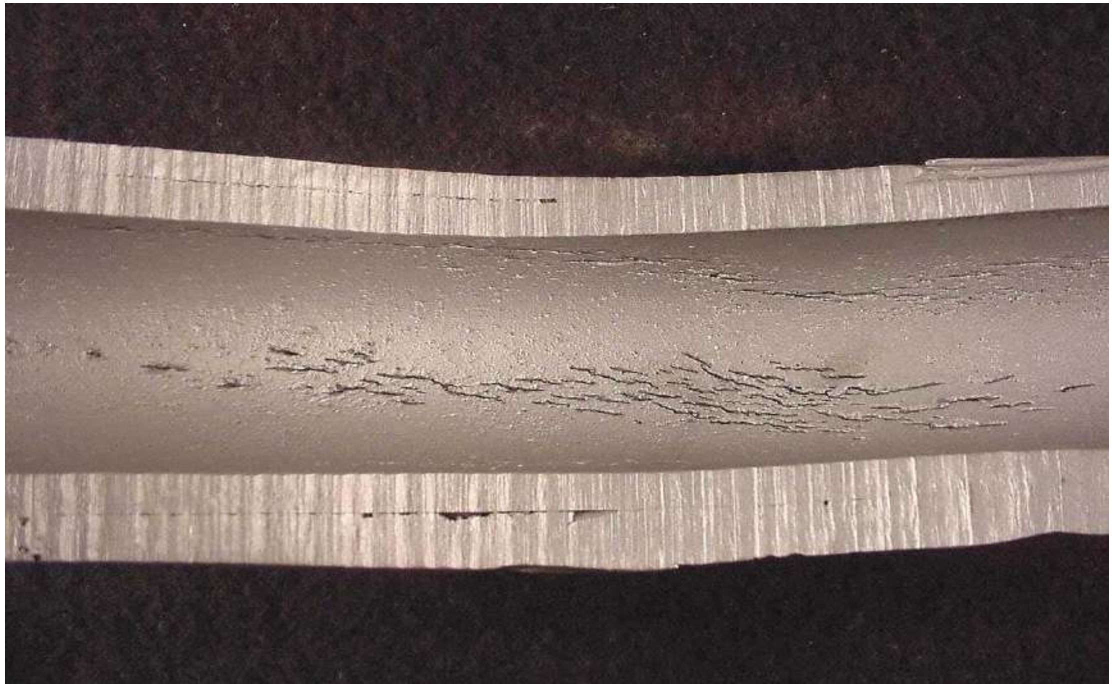
Case Study 05 : Waterside Corrosion-Fatigue Failure Mechanism

Components typically affected

- Attachment & external weldments such as buck-stay attachments, seal plates and scallop bars

Proactive measures: waterside corrosion fatigue

- Minimize cyclic operation
- Minimize tubes constraints
- Lower dissolve oxygen on unit start-up



Corrosion fatigue Boiler tube failure

Fireside Failure Mechanism

Fireside Boiler tube failure mechanism

- Boiler tube erosion
- Fuel ash corrosion
- Waterwall fireside corrosion
- Corrosion fatigue

Pictorial view of Boiler tube failure due to erosion

Fireside Failure Mechanism : Boiler Tube Erosion Failure

Boiler tube erosion

- Erosion : Metal removal caused by particles striking metal's surface

Erosion failure mechanisms :06 nos.

- Fly ash erosion
- Coal particle erosion
- Soot blowing erosion
- Falling slag erosion
- Coal burner secondary air erosion :Less frequent
- Air ingress erosion :Less frequent

Boiler tube erosion particularly "Fly ash erosion "is prominent cause of failure

Fly ash erosion in LTSH

Case Study 06 : Fly Ash Erosion Mechanism

How Fly ash erosion mechanism work?

- Fly ash containing ash mineral travels with flue gas at ~ 11m /sec & erode tube metal continuously
- Reaches critical limit where tube fail to stand internal tube pressure

Factors influencing fly ash erosion :

- FG velocity, change in FG direction, ash build up causing gas laning
- Coal mineral content, ash quartz hardness
- Operation above maximum design conditions (Coal , Air , Load)
- Distortion / misalignment of tubing rows

Failure appearance

- Smooth polished surface on outer face
- Ovality & formation of edges
- Metallurgically little evidence of microstructure changes

Affected areas

- Economizer, primary SH & RH inlet section tubes

Fly ash erosion Boiler tube failure

Proactive approach to prevent BT Erosion : Action Plan

- Avoid Boiler operation above maximum design conditions (Coal ,Air ,Load)
- Analyze reason of high flue gas velocity & take corrective measures
- Corrective action for flue gas flow distortion : Cold air velocity test (CAVT)
- Inspection & thickness survey of venerable area in O/H & opportunity maintenance
- Inspection & restoration of alignment of tubes / coils / hangers during overhaul
- Removal of foreign material between coils
- Provide Chicken wire mesh in erosion prone areas
- Erosion failures area mapping in different region for trending & corrective actions

Tube replacement criterion based on % thickness reduction : May vary from plant to plant

- Economizer / LTSH: End coils-20%, remaining coils-40%
- Extended SCW/S-Panel/Soot Blower/Burner panel-30%
- SCW/WW Hangers/WW Screens-40%
- SH Screen-25%
- SH/RH tubes near roof-30%

Main emphasis : Venerable area thickness survey in O/H & opportunity maintenance & corrective actions

Case Study 07 : Coal Particle Erosion Mechanism

Coal particle erosion mechanism

-- Erosion by pulverized abrasive coal particle

Affected location

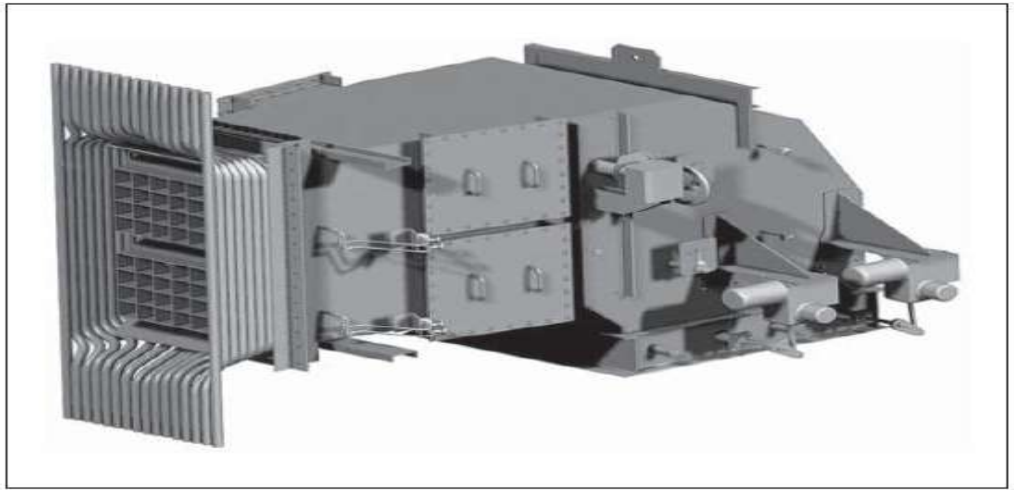
- Fine abrasive coal particle direct impact area near burners

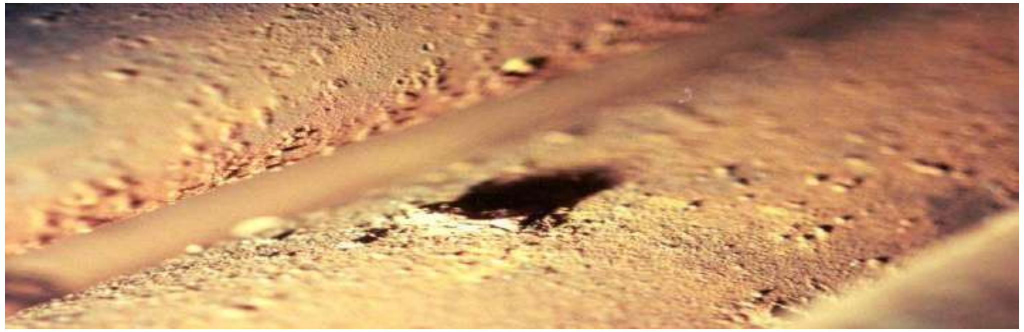
Failure appearance

- Similar to other erosion failure like wall thinning

Proactive measures for coal particle erosion

- Periodic burner inspection & need based replacement
- Burner & air damper alignment **to correct air flow pattern**
- Providing wear bar on burner wall sides
- Refractory / lining on burner bends





Coal particle erosion

Case Study 08 : Soot Blower Erosion Mechanism

How Soot blower erosion failure mechanism work ?

- Malfunction / mis-alignment of soot blowers
- Excessive soot blowing
- Incorrect steam blow temp. & pressure :Improper drainage

Symptom of soot blower erosion failure

- Wall thinning & external surface loss
- Clean surface / no visible ash deposit
- Erosion pattern : Angled from SB steam flow direction

Proactive measures

- Visual examination for maintenance shortcomings
- Optimize soot blowing periodicity
- Setting optimum soot blowing parameters
- Periodic checking of SB line steam s/v & drains

WW erosion due to Soot blower electric control failure

Optimum soot blower operation & upkeeping is key

Case Study 9 : Falling Slag Erosion Mechanism

Falling slag failure mechanism

- Ash build up detach from furnace walls ,SH pendants & falls on lower tube
- Distribution of falling ash is uneven
- Tube fracture will be **thin edged and ductile**

Proactive measures

- Boiler combustion optimization to eliminate slag formation
- Visual examination & Ultrasonic survey of affected areas
- Erosion prone tube shielding as short term measure
- Installing sacrificial materials on affected tubes.
- Providing sacrificial bars on tubes
- Replacing existing at-risk tubes with thick walled

Falling ash erosion in S-Panel

First aim : Operation measures to reduce/eliminate slag formation

Case Study 10 : Fire Side Fuel Ash Corrosion Mechanism

Fuel ash corrosion failure mechanism

- Corrosive **coal ash constituents remain in molten state** on SH/RH tube
- Failure : Function of coal ash characteristics & boiler design

Symptoms

- External tube wall loss & increasing tube strain
- **Pock-marked appearance** after corrosion products removal

Components typically affected : SH & RH tubes

Proactive measures to avoid fuel ash corrosion

- By using materials with **higher chromium concentrations** > 2% Cr
- Austenitic stainless steel tube shields in prone locations

Fire side fuel ash corrosion failure

Case Study 11 : Water Wall Fire Side Corrosion Mechanism

How water wall fireside corrosion mechanism work

- If **combustion process produces a reducing atmosphere** external surfaces of WW affected
- Mal-adjusted burners or staged firing : Produce more H_2S, instead of SO_2 or SO_3 that promotes increase in corrosion

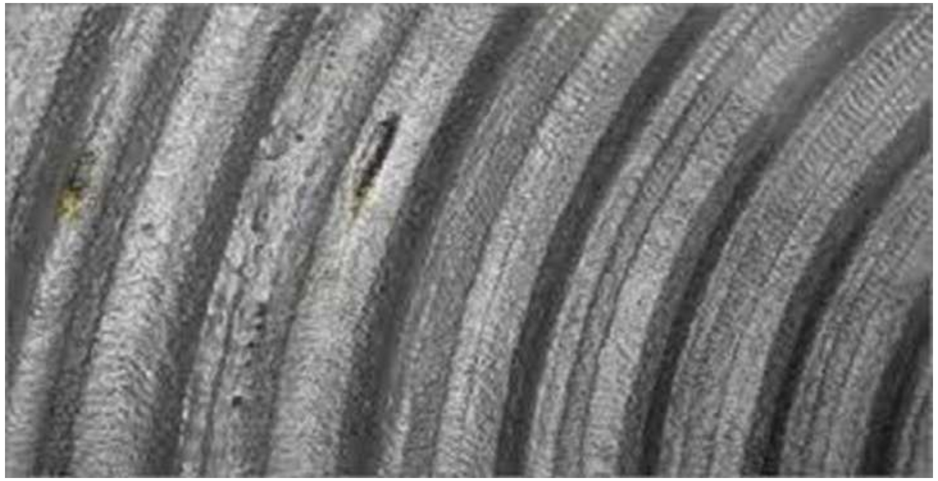
Symptoms :

- External tube metal loss, thinning & increasing tube strain

Components typically affected : Water wall tubes

Proactive measures

- Combustion optimization to prevent reducing atmosphere
- High Ni/Cr weld overlays on corrosion prone areas
- Corrosion-resistant thermal sprays



First aim : Operation measures to prevent reducing atmosphere in boiler

Weld overlay coatings

Case Study 12 : Fireside Corrosion Fatigue Mechanism

How fireside corrosion fatigue mechanism work ?

- Failure : Corrosion + thermal fatigue stress
- Thermal fatigue stress cycles : Slag shedding, soot blowing or cyclic operation
- Thermal cycling stress cause : cracking of external tube scales & expose tube material to corrosion & failure

Symptoms

- Tubes develop series of cracks initiated on the OD surface & propagate in tube wall
- Damage develop over longer period

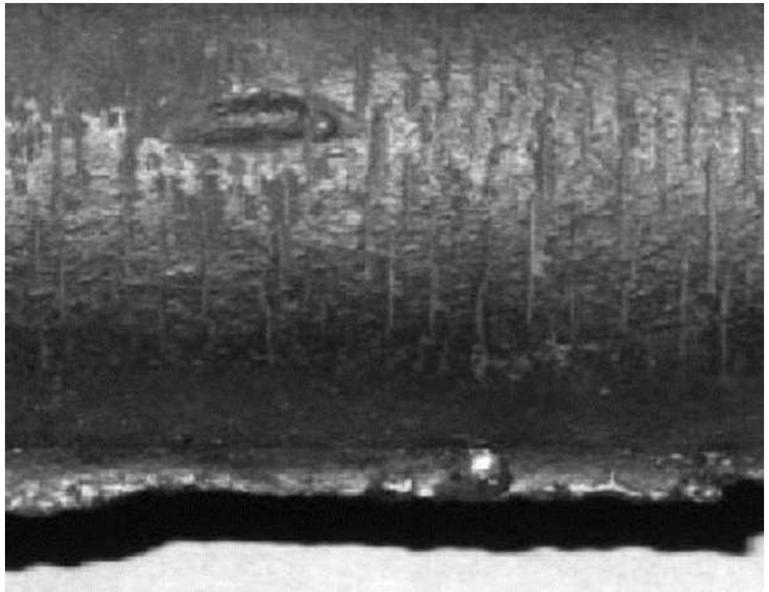
Failure Appearance

- Abnormal thickening, crocodile skin like or cracks by shrinkage
- Series of circumferential cracks

Components typically affected : Furnace wall tubes

Proactive measures

- Avoid sharp ramp rates during start-up & shut-down
- Optimize soot blowing operation



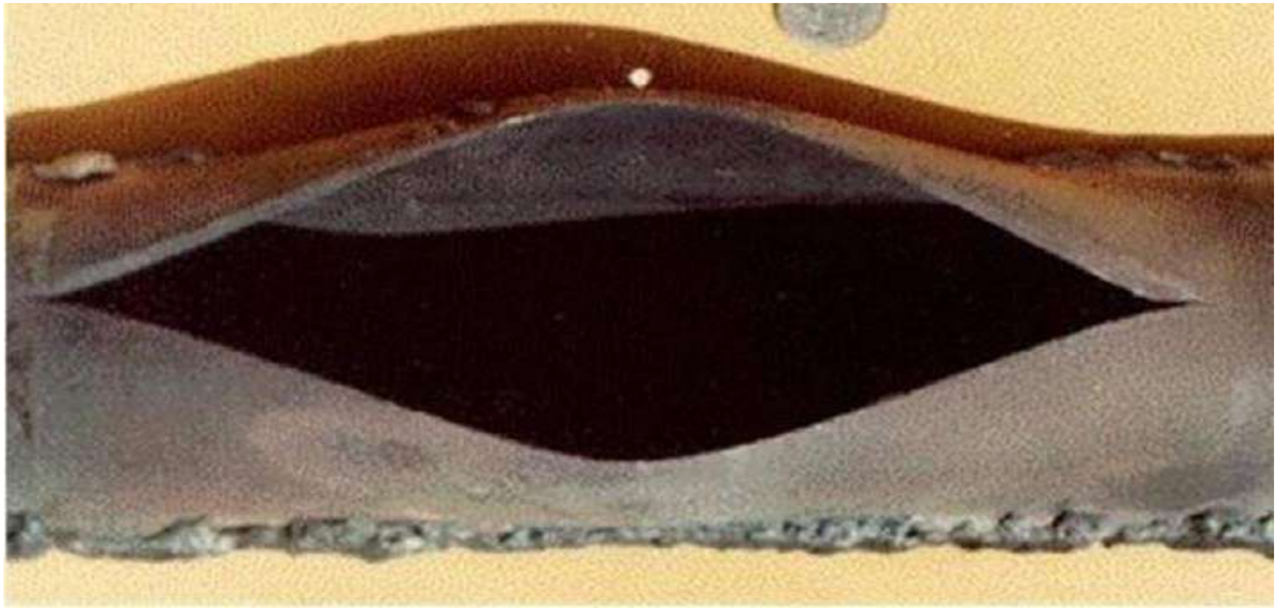
General Boiler Tube Failure Mechanism

General Boiler tube failure mechanism:

- Boiler tube overheating failure
- Weld joint failure
- Dissimilar metal weld failure
- Mechanical fretting failure

Boiler tube overheating can be :

- Short term overheating
- Long term overheating



Case Study 13 : Short Term Overheating Failure Mechanism

How short term overheating failure mechanism work ?

Root causes of failures : Low flow &/or Excessive heat flux

- Blockage by separated oxide scale / debris / foreign material
- High heat release / improper firing
- Improper Boiler tube maintenance
- Improper chemical cleaning leaving deposits in bends
- Improper startup /shutdown (Condensate in SH/RH bends)

Symptom of short term overheating failures

- **Swelling** / increase in tube diameter
- Ductile, **thin-edged** final failure
- **Fish mouth opening appearance**
- Oriented **longitudinally**
- Little evidence of oxide layer
- Not depend on tube age

Fish mouth opening appearance is typical of short term overheating

Pictorial view of short term overheating failure

Case Study 13 : Short Term Overheating Failure Mechanism

Typical locations of failure

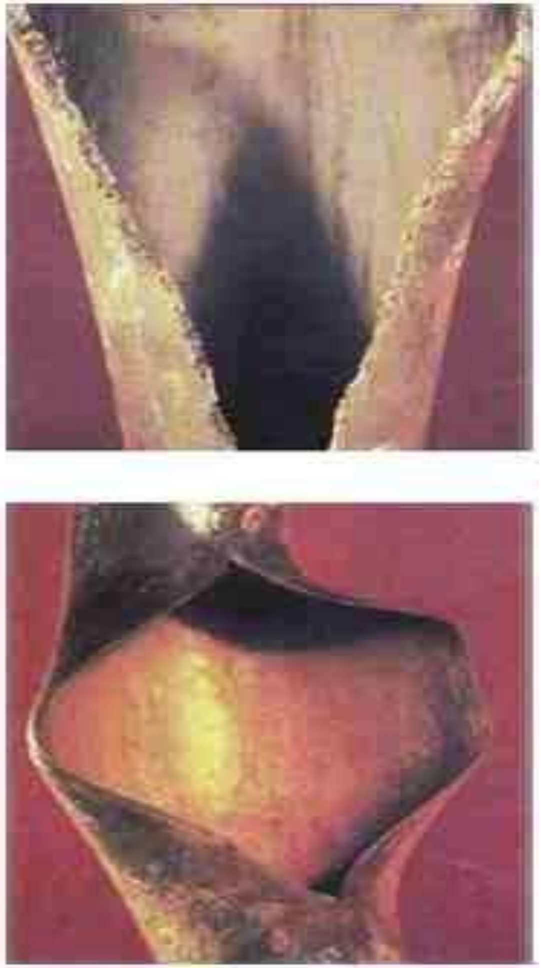
- High heat flux zone
- Tubes repair left over
- Water walls orifices blockage or deposition of corrosion products

Components typically affected

- Furnace wall tubes, superheaters, reheaters.

Care during Boiler start up to avoid ST overheating :

- If superheater tubes have not drained of condensate during boiler start-up, it obstruct steam flow. Tube metal temperatures reaches flue gas temp. of 870 degree C or greater which lead to tube failure.
- Proper drum level control in sub-critical boiler & feed flow control in Super-critical boiler must to avoid short term overheating



Pictorial view of short term overheating

Case Study 13 : Corrective & Proactive Action for ST Overheating

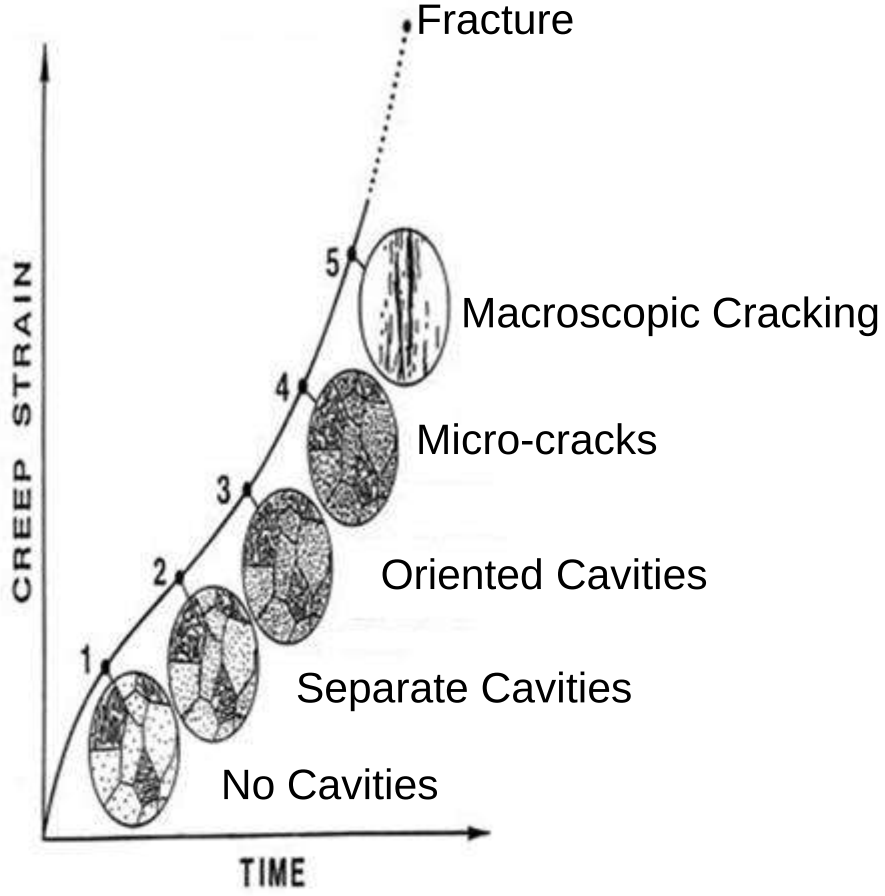
Proactive Corrective actions during maintenance

- Cap tube with metallic caps after cutting
- Alignment of coils, restoration of connectors
- Check bends below failed locations for any foreign material
- Check new tubes/bends for thruness before fixing
- Check thruness of entire circuit before welding
- Affected area inlet & outlet header inspection for foreign material
- Relocation of horizontal/ inclined tubes to avoid film boiling

Case Study 14 : Long Term Overheating Failure Mechanism

How Long term overheating failure mechanism work ?

- Long-term overheat occurs over months /years
- SH & RH tubes fail after years of service as a result of creep
- Alloy SH/RH tubes experience temperature & strain over life **until the creep life expended**
- Furnace WW tubes also fail from long-term overheat due to partial deposits, scale, or restricted flow



Long term overheating mechanism

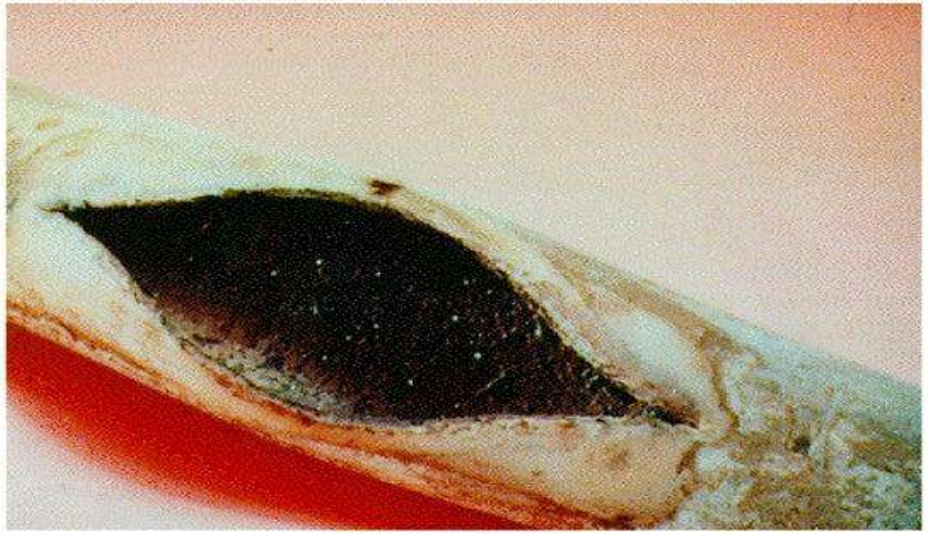
Creep is time dependent deformation that take place at elevated temperatures under mechanical stresses

Case Study 14 : Long Term Overheating Failure Mechanism

Symptom of Long term overheating failure :

- **Bulging or blisters in tube**
- **Thick-edged fractures with very little ductility**
- **Longitudinal "stress cracks"** in either/ both ID & OD oxide scales
- Intergranular voids & cracks in micro-structure
- Failure at highest temperature locations
- **Extensive signs of overheating on failed area**
- In reheater tubes, failures will be thinner due to thin walls.

Long Term Overheating



LT overheating : Thick edged longitudinal failure with micro structure crack

Case Study 14 : Long Term Overheating Failure Mechanism

Root causes of LT overheating failure :

- External / internal oxide-scale build up
- Inadequacy of tube metallurgy for Boiler operating conditions
- Poor combustion conditions/Local gas temperatures higher than design
- Blocking or laning of flue gas passage
- Partial blockage of tube
- Boiler operation beyond design life

Typical locations for LT overheating failure :

- Partially choked Radiant Heat Zone
- Incorrect Material/Material Transition
- Higher stress due to weld attachment

Pictorial view of Long term overheating

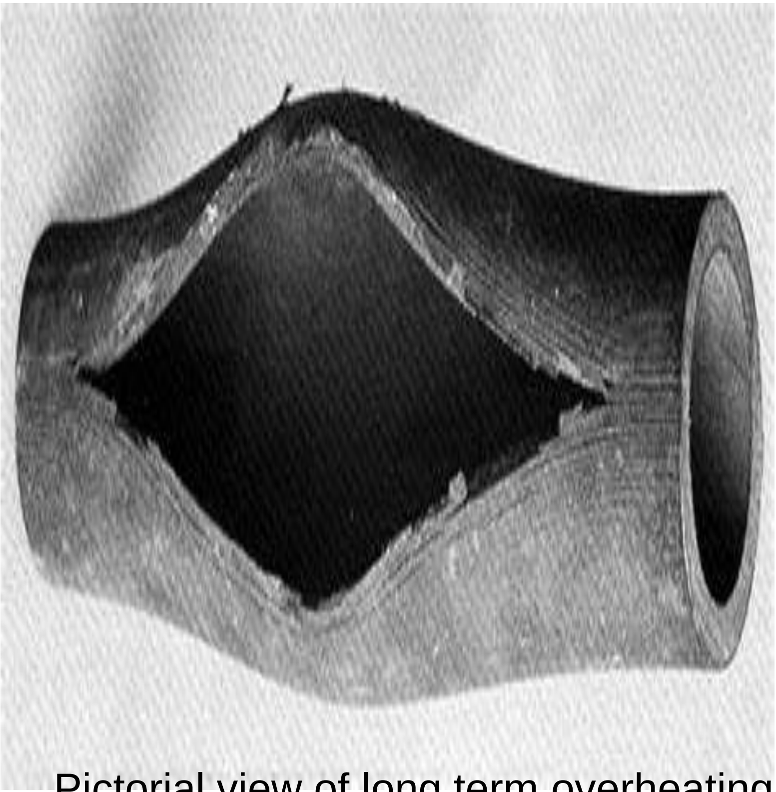
Case Study 14 : Long Term Overheating Failure Mechanism

Proactive operational measures to avoid LT overheating failure

- Correct flame impingement on WW tubes
- Correct water/steam circulation mal-distribution
- Balance furnace/flue gas temp to reduce tube temperature
- Ensure max. metal temp limit as per OEM guideline. Analyze & correct reason of temp excursion
- Ensure RH spray down stream superheat >10°C

Proactive measures for Boiler overhaul

- Measure steam side oxide scale thickness non-destructively
- Perform metallographic analysis of tube samples
- Provision of additional direct temp. measurement points
- Chemically clean boiler tubes to improve heat transfer if required



Pictorial view of long term overheating

Preventive measures : Oxide scale measurement & metallographic analysis

Case Study 14 : LT Overheating Proactive Action Plan Based on Experience

- With first symptom of overheat, affected area sample to be tested at reputed lab & trended
- Inspect surrounding tubes affected by long term overheating
- Ensure 100% tube capping during repair
- New tubes /bends checking for thruness before fixing
- Thru-ness of entire circuit to be checked before welding. Sponge ball test of loops having high metal temperature
- Ensure alignment of coil tubes
- Identification of all spools during O/H & material cross check
- Radiograph of differential thickness weld joint
- Tube shielding as per requirement as short term measure
- Plan tube replacement based on NDT oxide thickness measurements
- Additional thermo-couples installation to assess the metal temperature

Case Study 14 : LT Overheating Proactive Action Plan Based on Experience

- Affected area inlet & outlet header inspection for foreign material
- Radiograph of inner most bends in PSH & FSH extreme coil bends
- Criteria for tube replacement: Based on experience
  - 25% reduction in net effective thickness
  - Microstructure shows micro cracks at the grain boundaries
  - Creep test showing life less than 20000 hours
- Residual Life Assessment (RLA)
- Replacement of Coils, if design limitation

Case Study 15 : Weld Joint Failure Mechanism

Weld joint failures

Poor welding practices leads to weld joint failure

- Porosity, lag inclusions,Undercut,Lack of fusion, lack of penetration improper joint preparation , misalignment, poor cleaning of the joint, inadequate preheat, improper choice of filler metals, improper stress relief

Proactive Action plan to prevent weld joint failure

- Thorough inspection during unit O/H
- DPT/ MPI of attachment welds of vulnerable areas
- 100% radiography of Erection welds in phases
- Edge preparation inspection before weld
- Experienced & tested IBR certified H.P. Welder
- Follow guidelines for Boiler Light-Up & ramp rate

Attachment weld failure in SCW

Case Study 16 : Dissimilar Metal Weld Failure (DMW) Mechanism

Features of Dissimilar metal weld failure

- Dissimilar metal welds: Butt weld where an austenitic (stainless steel) material joins ferritic alloy (such as SA213T22).

How DMW failure mechanism work ?

- High stresses at austenitic-to-ferritic interface due to:

  -- Differences in expansion properties of two materials,

  -- Excessive external loading stresses and thermal cycling &

  -- Creep of the ferritic material
- Improper tube supports /restraint
- Partial tube blockages

DMW Failures are function of operating temperatures & design

Dissimilar metal weld failure

Case Study 16 : Dissimilar Metal Weld (DMW) Failure Mechanism

Symptoms of DMW failure

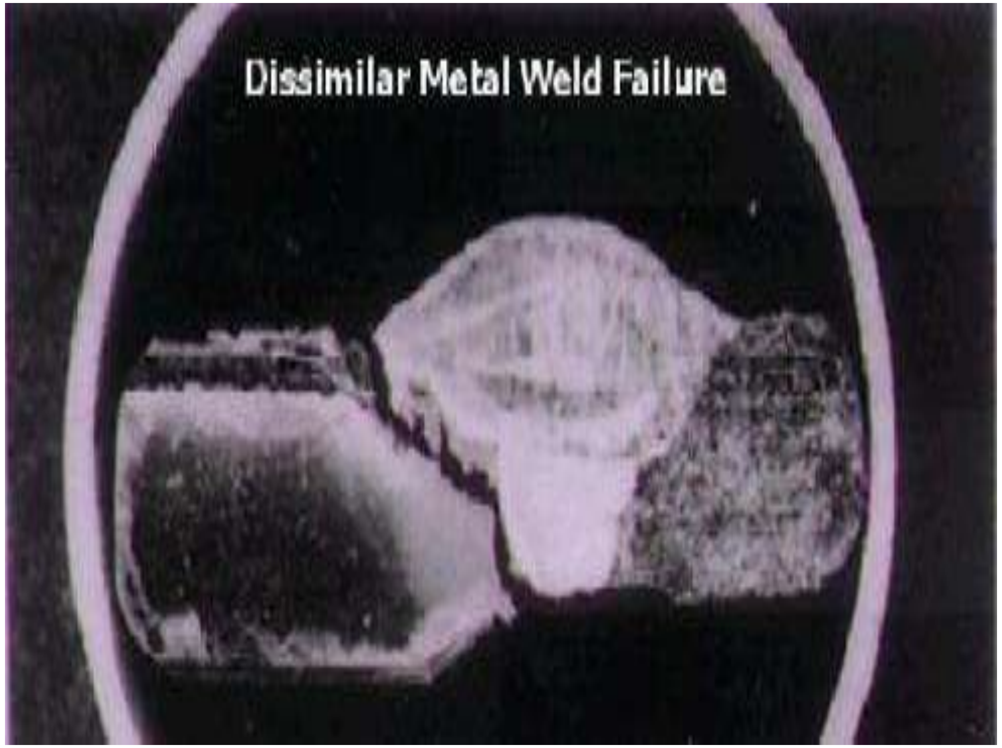
- Failure is preceded by little or no warning of tube degradation.
- Material fails at ferritic side along weld fusion line.
- Catastrophic failure as entire tube fail across circumference of the tube section.

Components typically affected

- SH/RH outlet bank connections to outlet headers

Proactive measures to avoid DMW failure

- Replace DMWs with shop-welded Dutchman or a field weld that utilizes a Ni-based weld metal
- Ensure DMWs locations not overheated

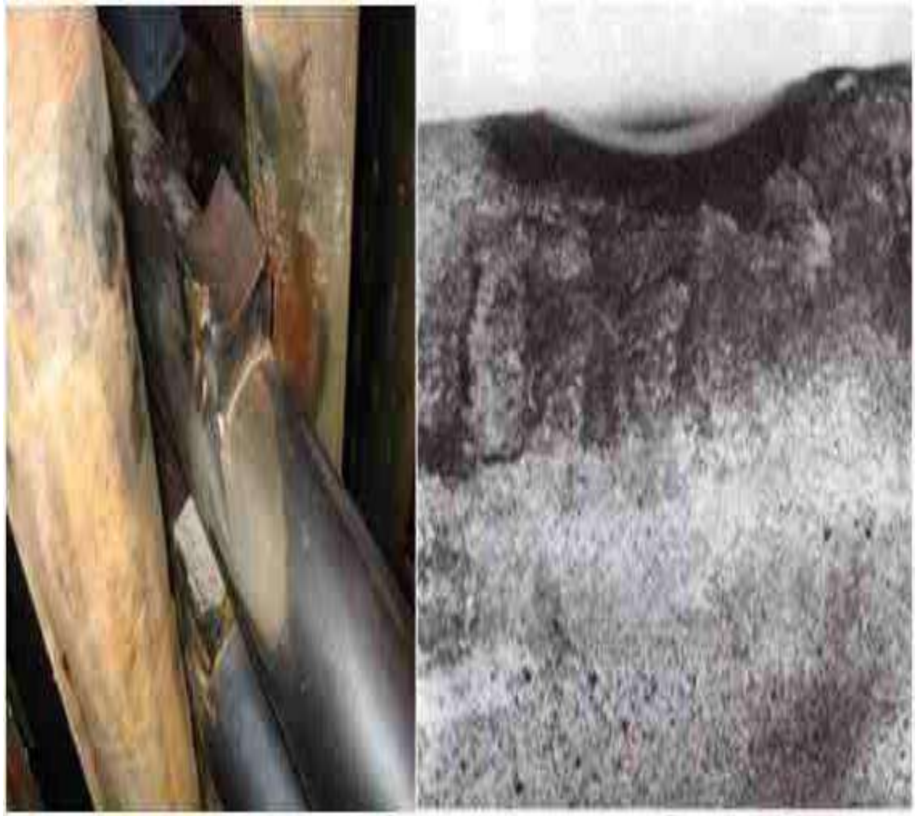


Preventive measure : DPT of all DMW joints & random (5%) radiography of DMW in Boiler overhauling

Case Study 17 : Mechanical Fretting Failure Mechanism

How mechanical fretting failure mechanism work?

- Wear caused by small movements between contacting metal surfaces



Symptom of mechanical fretting failure

- Rubbing removes protective oxides
- Occurs mostly on contact of similar metals
- Not require high contact loads
- Stainless steel more prone than low alloy steels

Location

- Vibrational contact between tubes mostly in platen SH

Proactive measures for mechanical fretting failure

•Vibrational contact points/areas between rubbing tubes to be set right by proper alignment

•Modify support as per requirement

Operational Proactive Control For Prevention of Boiler Tube Leakage

Temperature excursion monitoring

- Real time monitoring Boiler pressure parts temp excursion : trending & analysis for corrections

Core chemical parameters monitoring

- Water & steam pH , Sodium in saturated Steam, ACC in condensate water, drum phosphate.
- Dissolved oxygen in de-aerator & condenser monitoring & corrective action.

Supercritical Boiler to be stopped immediately if :

- Eco inlet PH drops < 7.0
- Eco inlet/main steam cation conductivity > 2 µmhos for 05 minutes
- Eco inlet/ main steam cation conductivity > 5 µmhos for 02 minutes

Operational Proactive Control For Prevention of Boiler Tube Leakage

Combustion optimization

- Optimize excess air with multi grid & CO monitoring
- SADC position monitoring
- Coal Mill performance optimization (Fineness, O/L temp & PA flow)
- Equal flow thru each coal pipe of Coal mill

Avoid tubes starvation

- Drum level control & protection in service (Sub-critical) / FW to coal flow ratio (Supercritical)

Care during start up

- Proper draining of SH loops
- Ensuring Adequate flow through all tubes
- Right timing of first mill in & gradual ramp up

Boiler combustion optimization, Boiler metal temperature excursion & Chemical parameter monitoring is key measures

Proactive Operation Practices for Early BTL Detection

- Early detection of Boiler Tube Leakage
  - Avoid secondary damage in Boiler
  - Saving in Maintenance cost & time
  - Early restoration of Unit & better unit availability
- Important parameters monitoring for early detection
  - Difference in steam & water flow
  - Furnace draft
  - Drum level
  - Flue gas temp . drop
  - DM consumption monitoring: shift & day
- Regular Boiler checking: twice in shift
- Acoustic Steam Leak detection system

Acoustic leak detection system

Early BTL detection & unit stoppage : SCE/Operation Head to be accordingly authorize to take decision

Best Operation Practices : Effective Boiler Preservation for BTL Mitigation

Boiler Preservation

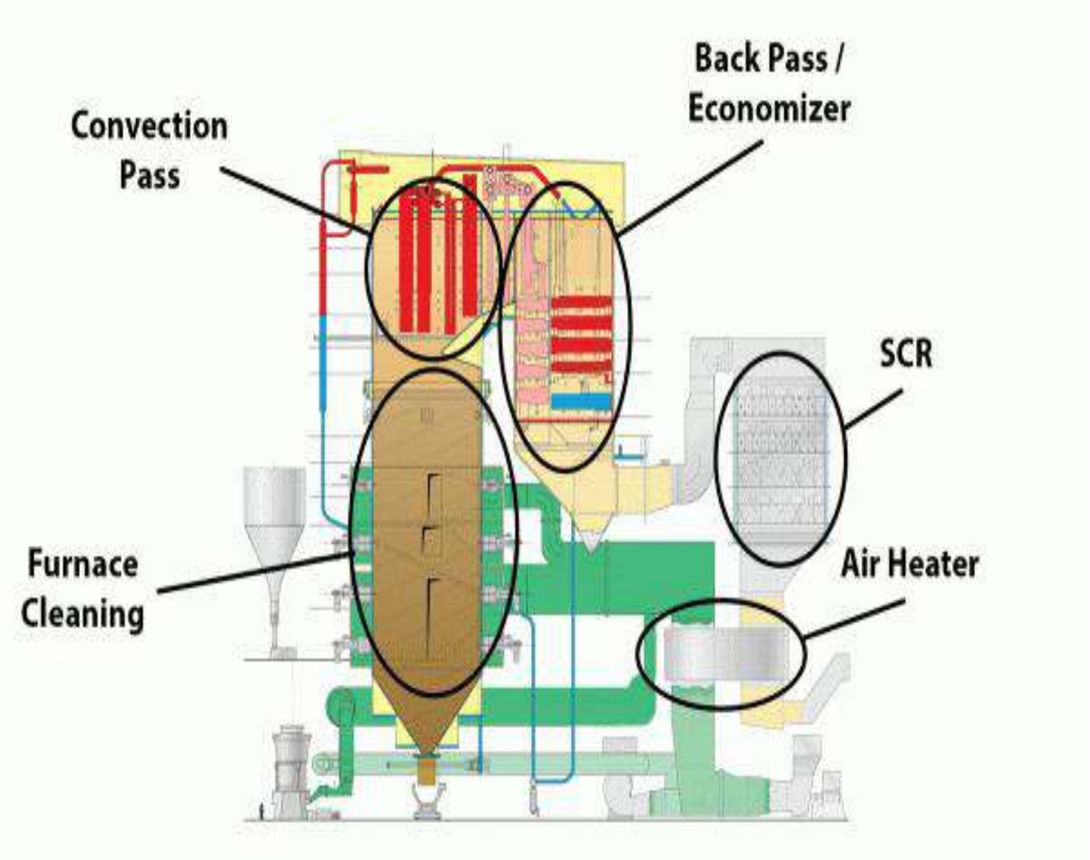
Proper preservation procedures

- Dry preservation : Completely drying the boiler to remove all water
- Wet preservation
  - If no oxygen in boiler water & nitrogen blanketing to prevent ingress of oxygen
  - If oxygen present, ensure boiler water circulation to eliminate stagnant conditions
- To prevent pitting in RH, complete drying in each long shutdown

Best Operation Practices : Soot Blower Operation Optimization for BTL Mitigation

Soot blower operation optimization

- Soot blower un-appropriate use can cause BTL due to SB steam erosion
- **Soot blowing frequency optimization: Based on coal quality & operation regime**
- Home position check in each shift
- LRSB operation frequency : Weekly/fortnightly
- Insufficient steam superheat & moisture removal :Drain valve auto operation setting
- Soot blower alignment check
- Relief valve & pressure setting: Each six monthly
- Avoid steam condensation
  - Improper drainage
  - Temperature changes
  - Insufficient steam SH



Best Maintenance Practices : Proactive NDT techniques for potential BTF identifications

NDT techniques for potential BTF identifications: Very frequently used & specialized

1.Visual inspection
2.D metering : Ultrasonic testing
3.Dye penetration testing (DPT)
4.Magnetic particle inspection (MPI)
5.Eddy current testing
6.Oxide scale measurement
7.Thermography
8.Boroscopic inspection for header
9.Remote Field Electromagnetic Technique(RFET)
10. Low Frequency Electromagnetic Technique (LFET)
11. Time of Flight Diffraction Technique

NDT Techniques play vital role in potential BTL identification

Best Maintenance Practices : Boiler Tube Failure Analysis

Visual Inspection: Investigate

- Primary method used before any NDT technique
- Visual inspection on tube thinning
- Sign of overheating
- Significant bulges on ruptured tubes
- Pitting/corrosion related observation
- Suspected area & surrounding area for secondary damage

Visual inspection by experiensed Boiler Engineer can reveal a lot

Visual inspection reveals a lot

Best Maintenance Practices : NDT Techniques In Boiler Overhaul for Potential BTF Identification

D-metering : Ultrasonic Testing

- Conventional method.
- Scan boiler tubes for thinning
- Provide measurement & record of tube wall thickness.
- System uses ultrasonic Electro Magnetic Acoustic Transducer technique providing accurate thickness (with accuracy of +/- 0.127mm) readings with none or minimal tube surface preparation.
- System provide alarm if tube is below a pre-programmed threshold
- Technique permits 100% inspection of boiler with up to 15 cm/s of scanning speed.

D-metering is extensively used in suspected/leak prone area

Potential BTF Identification : DPT NDT Techniques In Boiler Overhaul

Dye Penetration Test (DPT)

- Simple, portable & effective NDT method, which can be used to detect fine surface flaws with high sensitivity.
- NDT technician training requirements are less compared to other NDT methods.
- Test can be carried out on any non-porous material

Disadvantage

- DPT check time is quite long.
- Regular monitoring is required to accurately locate flaw during development stage
- **DPT Test can only be effective for flaws that are open to surface**
- Tube parts must be cleaned fully before inspection

DPT is extensively used for suspected joints

Potential BTF Identification : MPI NDT Techniques In Boiler Overhaul

Magnetic particle inspection (MPI)

- Simple, easy, fast & very effective.
- Shape & size of cracks can be indicated.
- Relatively low cost technique that allow for higher sensitivity than liquid penetration testing
- Detection of flaw on or just underneath surface of ferromagnetic material using fluorescent , black or dry magnetic particles
- MPI uses magnetic fields & magnetic particles for detecting defects in ferromagnetic components.
- MPI Basic principle : Component specimen is magnetized to generate magnetic flux in material which travels from north pole to south pole. If there is any discontinuity or flaws in component, secondary magnetic poles are produced in cracked faces

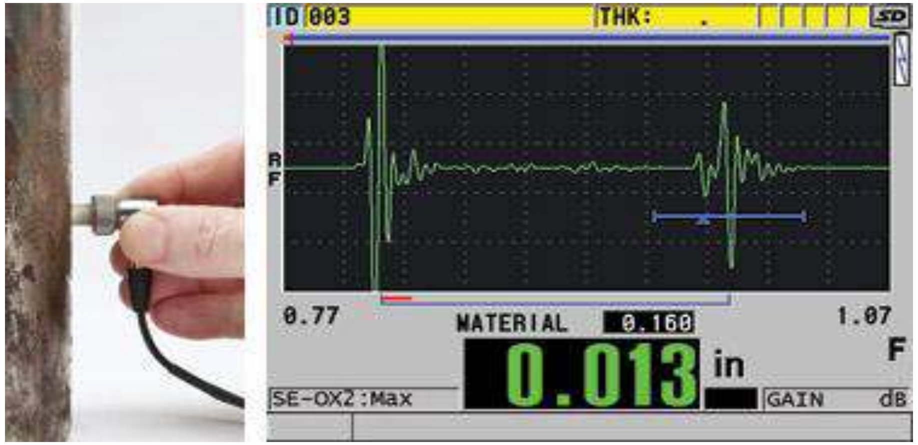
Disadvantage

- **Can only used for ferromagnetic material with clean surface**

Potential BTF Identification : NDT Techniques In Boiler Overhaul

Oxide Scale Measurement

- Oxide scale formation : Temperature phenomenon over a period
- Linear relationship between thickness of oxide scale, temp & time
- It reveals temp to which tube exposed
- Remaining life can be evaluated using LMP (Larson Miller Parameter)



Thermography of Water Wall Tubes

- Water walls of furnace can be checked by "Thermography" for any suspected chocking/blockage of tube below goose neck area after overhauling of boiler

Boroscopic inspection for header internal

- Inaccessible header internal surface inspection by Boroscope
- Useful to examine internal scaling & presence of foreign material inside header

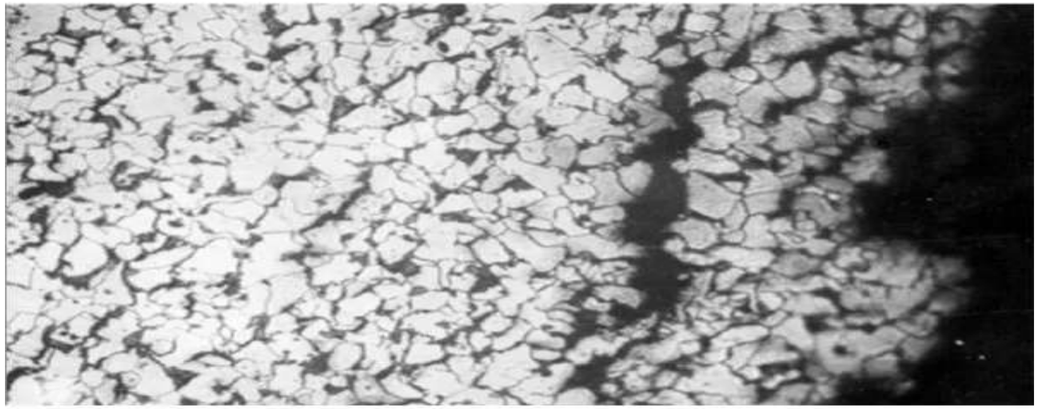

Boroscope

Any flaw in header internal can be best inspected by Boroscope

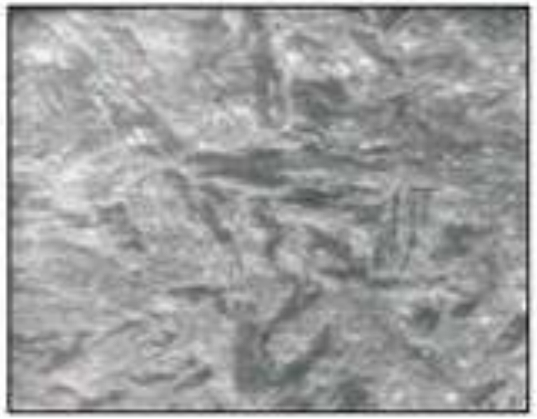
Micro-structure Study for BTF Analysis & Potential BTF Identification

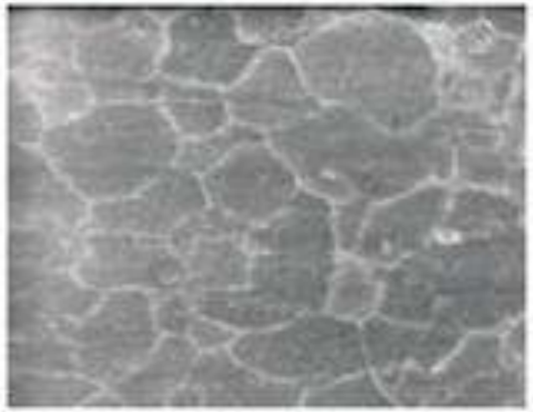
Micro-structure Analysis

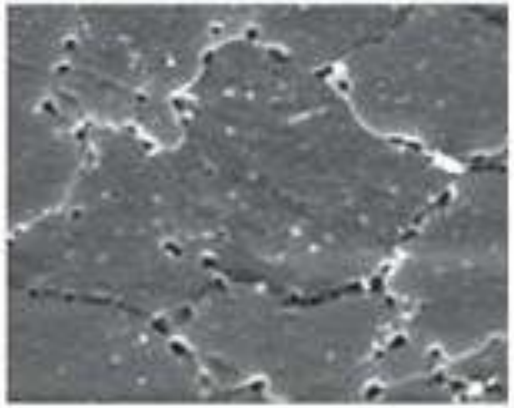
- Analysis of surface morphology of tube sample by Electron Microscope reveal corrosion pits & scale cracks
- Metallography reveal microstructure degradation or creep damage



Micro structure near water wall failure due to hydrogen embrittlement







BTL Diagnosis & Monitoring Management System At Plant Level

- **BTL Committee:**

  --Cross function team (Operation ,BMD, Chemistry, Planning Quality assurance etc.)
- Each tube failure RCA by Committee
- Standard C2 form to be used for report preparation
- Lab analysis of failed tube as per requirement
- Action plan preparation based on failure analysis
  - Short term & Long term: Preventive & corrective measures
- Maintain history of Boiler tube failures
  - Photographs
  - Data form/Lab report
  - Committee report
  - Standardized tube leakage analysis form (Form C)
- Mapping of tube failures on pressure part diagram

Each Coal power plant must have BTL diagnosis & monitoring management system

Best Guidelines/Practices for Boiler Tube Failures Prevention During Overhaul

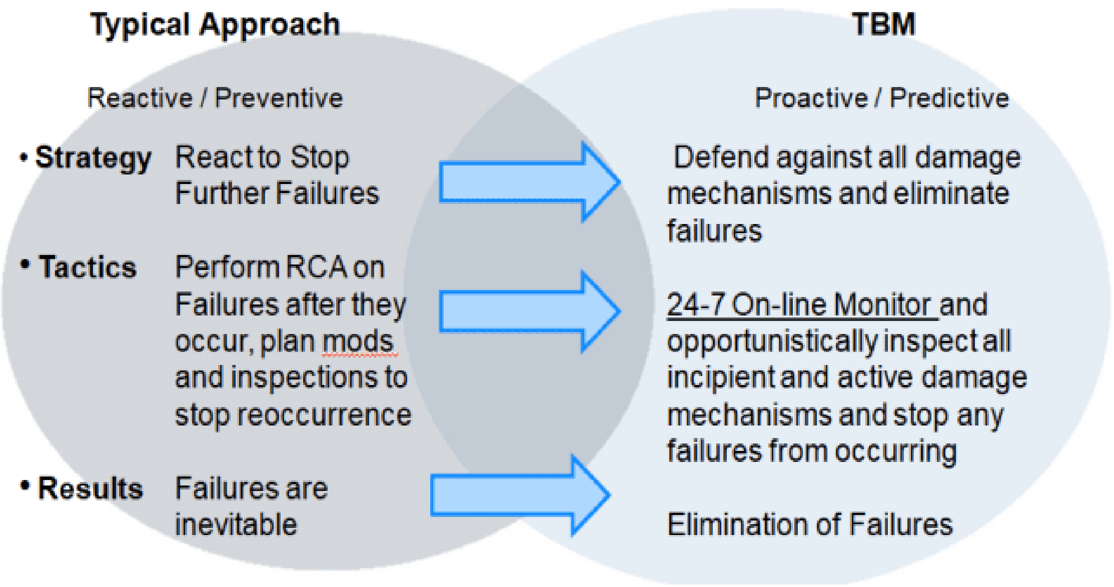
- **In each BTF mechanism, best practices for prevention of BTL was discussed in details**

  Besides these following best practices can be followed :
- Boiler internal washing 1st and 2nd pass at start of overhaul to facilitate proper inspection
- Boiler tubes 'D' metering at prone areas & comparison w.r.t. to last overhaul
- Replace tubes at pre-determined thickness reduction or as decided reduction criteria due to erosion
- DPT of attachment welds, especially in Pent house
- Inspect tube assemblies for parallel/perpendicular tube/tube or tube/attachment
- 100% radiography of all weld carried out during overhaul
- Investigate Platen S/H, R/H & Final super heater coils for overheating
- Sent tube samples to reputed R & D Lab for fire side & internal corrosion as predictive analysis measure
- DPT of all DMW joints & random (5%) radiography of DMW

Best Guidelines/Practices for Boiler Tube Failures Prevention During Overhaul

- Lowering & inspection of extreme L/R Economizer Coils, if erosion exist & feasible to lower down
- Inspection of Steam cooled side walls after lowering of Eco coils
- Inspection of LTSH coils by lifting up the extreme L/R coils, if feasible to lift
- Inspection of Economiser hanger tubes for fly ash erosion
- Inspection of extended Steam Cooled Wall (L/R) in arch area for erosion
- Wall blower area inspection for erosion
- Burner corner panel tubes inspection for erosion due to fly ash carryover in secondary air in capital overhaul

Conclusion



Proactive Approach for BTL mitigation

- ✓ Understanding BTL types & their failure mechanism
- ✓ Sensitizing commercial impact of BTL
- ✓ Understanding factors affecting BTL
- ✓ Learn preventive & predictive measures proactively
- ✓ Learning guidelines & best practices in improving O&M practices for BTL mitigation

Switch over from “Typical Reactive/Preventive approach to Proactive/ Predictive Total Boiler Maintenance” to achieve Zero BTL between 02 overhauls.

Thanks !!

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