BOILER TUBE FAILURE

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- **Boiler tube failures**
- **Case study on boiler tube failures**

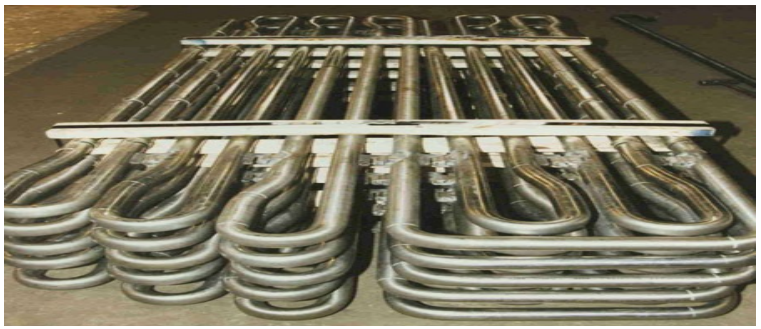
BOILER

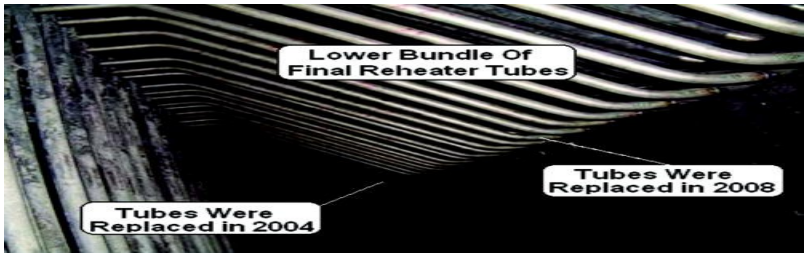
- **Boiler is the main part in the power generation.**
- **Boiler is a sealed vessel in which water is converted into steam.**
- **Boiler acts as a medium in which water is converted into steam by using the heat released in the process of combustion of coal in the presence of oxygen.**
- **Before combustion process the coal is collected from bunkers into millers.**
- **This coal is converted as powder (pulverized) in the millers**
- **During this process if their is any wet coal ,it is converted into dry coal.**
- **And finally It sent to the boiler by using the air.**

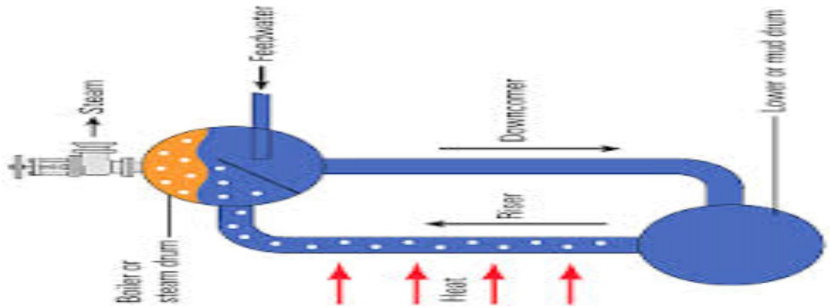
Boiler accessories

- Boiler Drum
- Down comers tubes.
- Water walls.
- Super heater tubes.
- Re-heater tubes.
- Economizer.
- Burners.

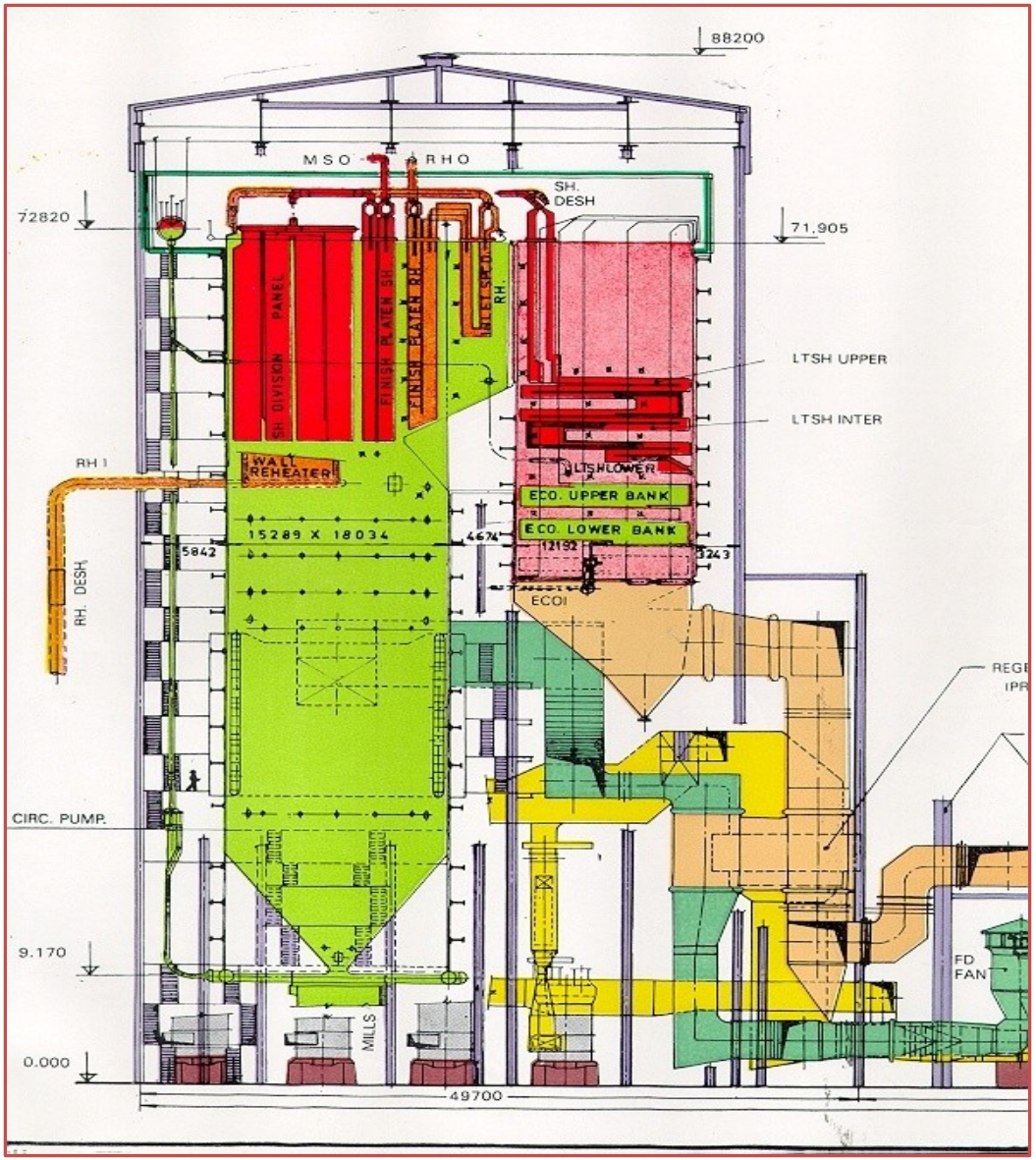
Boiler accessories image







BOILER TUBE FAILURE



Boiler Tube Failures

Overview:

- Boiler tube failures are the leading cause of forced outages of fossil-fired power plants.
- Boiler Tube Failures - main cause of forced outages and availability in steam generating boilers.

- Boiler tubes are subjected to various failure mechanisms driven by temperature, stress and environmental hazard, depending on their designs and functions.

- Super heater tubes, re heater tubes & furnace water wall tubes always experienced high temperature ductile failures such as stress-rupture failure, initiated by creep process or sudden overheating due to steam starvation or flue gas disruption.
-
- Suspended tubes with a lack of support or exposed to vibration / cyclic loading would bear a risk of mechanical fatigue.

Tube failure indications

1. Sudden or abnormal loud noise
2. Continuous hissing noise
3. Steam / Water leakage
4. Furnace draft fluctuations / pressurization
5. Flame out
6. Falling in drum level
7. Increase in quantum of make-up water
8. Uncontrolled Boiler Feed Regulation / Feed Pump Trip

Failure Mechanisms which cause Boiler Tube Failure

1. Stress rupture
2. Water-side corrosion
3. Fire-side corrosion
4. Erosion
5. Fatigue
6. Lack of quality control

Stress Rupture

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

Fatigue

- Vibration
- Thermal
- Corrosion

Water-side Corrosion

- Caustic Corrosion
- Hydrogen Damage
- Pitting
- Stress Corrosion Cracking

Erosion

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

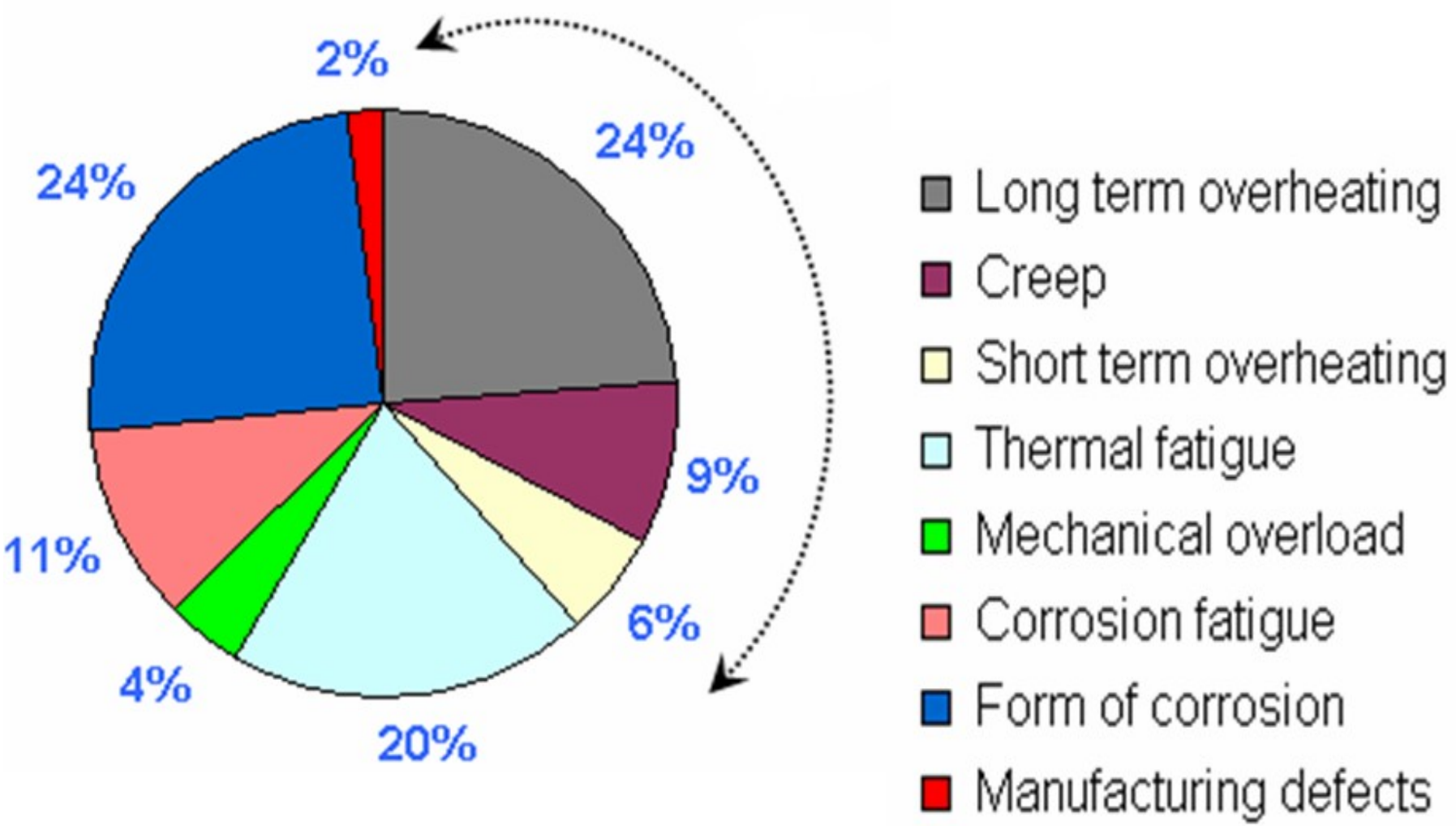
Fire-side Corrosion

- Low Temperature
- Waterwall -$
- Coal Ash - $
- Oil Ash

Lack of Quality Control

- Maintenance cleaning damage
- Chemical excursion damage
- Material Defects
- Welding Defects

$ - indicates that such problems have not been reported in India


2%
24%
24%
9%
6%
20%
4%
11%
Long term overheating
Creep
Short term overheating
Thermal fatigue
Mechanical overload
Corrosion fatigue
Form of corrosion
Manufacturing defects

Methods of Overheating

1. **Oxide build-up**
2. **Deposits**
3. **Film Boiling**
4. **Over-firing**

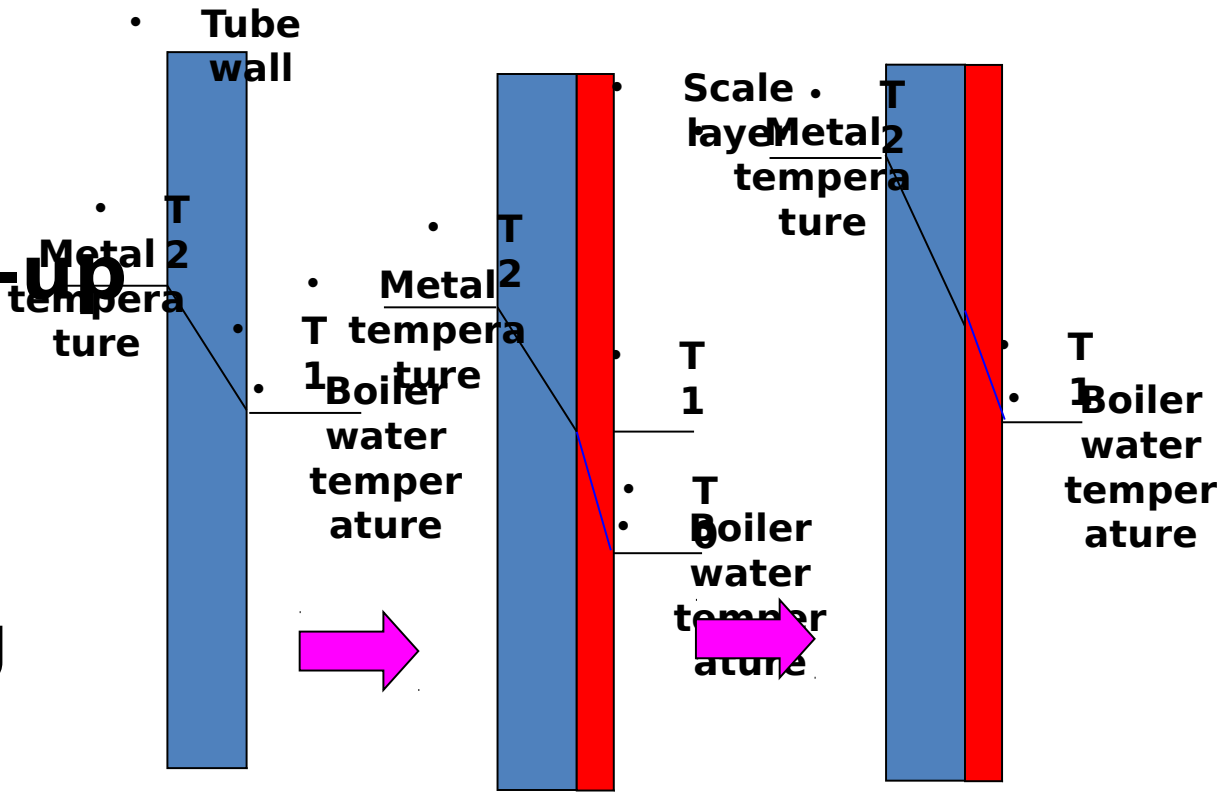


Fig. Schematic representation of temp increase in tube metal

Major reasons contributing for boiler tube failures are :

- **Short Term Overheating**
- **Long term overheating**
- **Dissimilar Metal Welds**
- **Hydrogen Damage**
- **Pitting**
- **Falling Slag Erosion**
- **Soot Blower**
- **Material Defects**
- **Welding Defects**

Short term overheating

- STOH occurs when the tube temperature rises above the design limits for a brief period. Short term overheating in water cooled tubes occurs because of abnormal coolant flow are excessive combustion gas temperature. As a result, the tubes are subjected to excessively high temperature often hundreds of degrees which results in rapid failure. A considerable increase (> 5%) in the inside or outside diameter of affected tubes. Depending on the temperature, the failure might occur in a very short time.

- STOH – mostly due to an upset over a short period.

- Operating procedures or parameters are to be analysed to find out the reason for the failure.

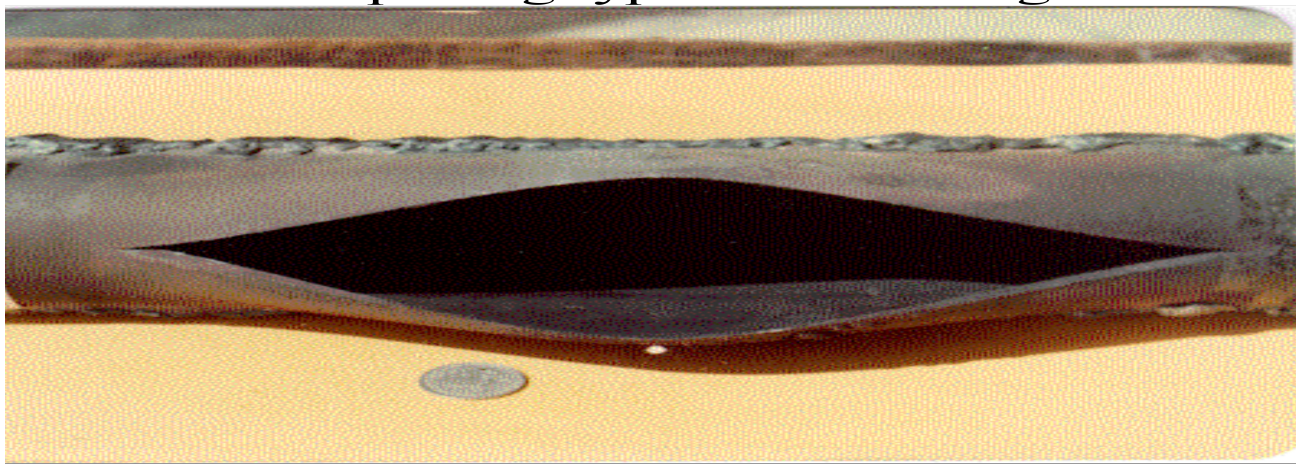
Identification:

- **Mostly a fish mouth opening with gradual reduction in thickness**
- **Uniform tube expansion.**
- **Absence of large amount of thermally formed magnetite**
- **No significant internal deposit**

Metallographic examination will reveal the reason.

Location: **Steam & water cooled sections**

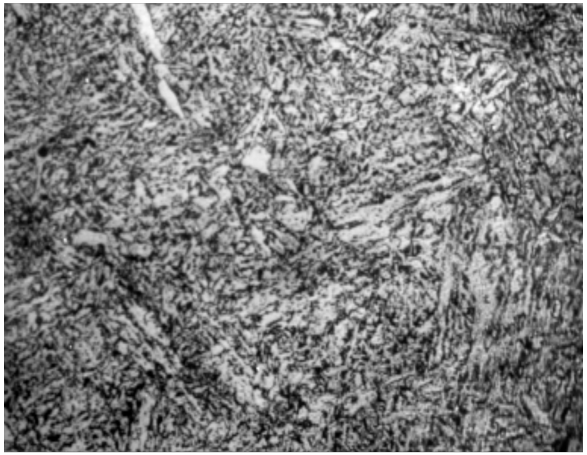
Fish mouth opening type over heating



1. STOH - ORIGINAL STRUCTURE
2. STOH - TRANSFORMED MARTENSITE

1

2



Reasons:

- Plugged by debris, scale etc.
- Poor control of Drum level
- High Heat Transfer / Improper firing
- Low water/steam flow due to poor circulation /upstream leak
- Partial blockage caused by maintenance activities.

Corrective Action:

- **The deposits can be blown off which is very time consuming, or**
- **The unit can be chemically cleaned.**
- **Prevent Blockage**
- **Maintain Drum level**
- **Assure Coolant flow**
- **Reduce over firing**
- **Redesign tubing to promote flow**
- **Relocation of horiz. / inclined tubes to avoid film boiling**

LONG TERM OVER HEATING

- Long term overheating can caused by deposits attached on inner surface of tubes.
- Long term overheating can occurs in all of pressure part in steam boiler such as water wall tubes, header, super heater, re heater, economizer, steam drum, water drum
- Almost 90% failure can occurs in super heater
- Definition of long term overheating is a condition in which pressure parts have metal temperature higher than temperature design in long term
- **<u>CORRECTIVE ACTIONS:</u>**
- **Temporary pad welds should not be used because of the uncertainty associated with base metal condition.**
- **Tube shielding.**

DISSIMILAR WELD JOINTS

- As the elevation of the boiler is very much higher we have to join the different tubes to that much of higher elevation according to the temperatures inside the boiler.
- Quality control needs to be applied to assure sound weld.
- Results from application of high temperature and stress beyond design value

CORRECTIVE ACTIONS:

- **Replacement**
- **Frequent inspection.**

HYDROGEN DAMAGE

- Hydrogen damage in boiler tubes is caused by a corrosive reaction between steam and steel

  $Fe + H_2O = Fe_3O_4 + H_2$

- The hydrogen that is released reacts with carbides to decarburize the steel and forms methane gas at the boundaries.

- Results in wall loss due to corrosion and decreases the strength in material attacked by hydrogen.

- The damage occurs in areas of high heat flux and flow disturbances includes tubes opposite to burners and tube bends

Corrective Action:

- **Control Boiler Water Chemistry**
- **Check corrosion products, Chemical cleaning**
- **Replace affected tubes**

PITTING

- The formation of small pits in a surface as a consequence of corrosion.
- Pitting corrosion may takes place in the environment of stagnant, oxygenated water formed during shutdown.
- Most familiar form of oxygen attack in boiler and condensate system.
- Dissolved oxygen is essential to corrosion of copper alloy tubes.
- At higher temperatures oxygen weakens steel.

CORRECTIVE ACTIONS:

- If D.O in feed water is >10ppb,its source needs to be identified and arrested may be mechanically or chemically.
- Proper operation of
- dearator L.P. Feed water Heater.

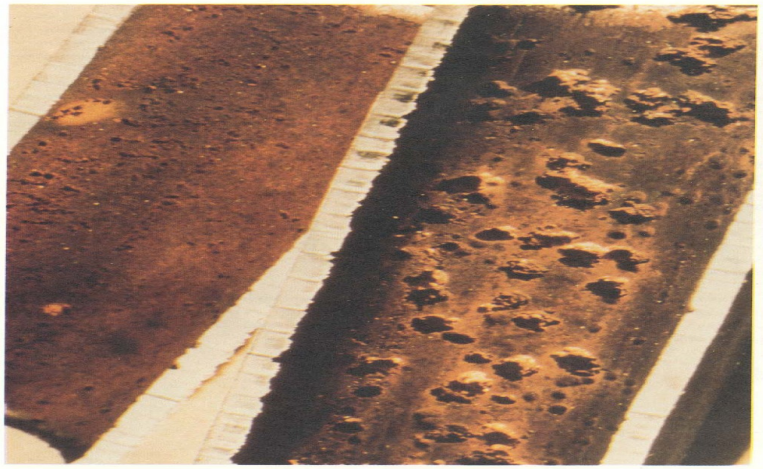


Figure 3-10. Pitting Damage from Localized Corrosion. Localized pitting results when electrochemical galvanic cells are established on the tube surface due to a difference in oxygen concentration in the boiler water and within a surface deposit or a crevice. Metal loss will occur at sites where the oxygen concentration is below that of the boiler since these locations become the anodes of the cell. Source: Metz Laboratories, Inc.

FALLING SLAG EROSION

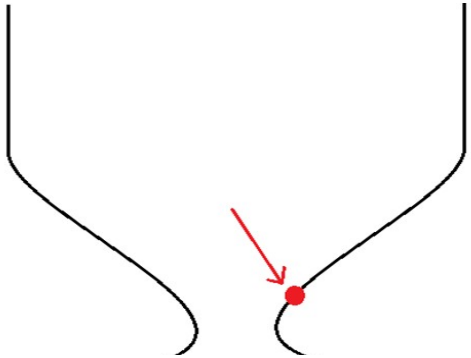
Typical Locations:

- **Lower furnace sloping wall near bottom opening**

Probable Root Cause:

- **Slagging of coal and massive clinker fall**

Coal properties and boiler design



Corrective Action:

- **Change in fuel**

SOOT BLOWER

- A soot blower is a system for removing the soot that is deposited on the furnace tubes of a blower during combustion.

- Soot deposited on the heating surfaces of a boiler acts as a heat insulator. The result is that less heat is transferred to the water to raise steam and more heat is wasted up the chimney. This leads to higher fuel consumption and/or poor steaming.

- Various types of soot blowers such as wall blowers, long retractable blowers and air heater blowers are used for cleaning.

- Steam is normally used as a medium for blowing away the soot.

PROBLEMS CAUSED BY SOOT

- Reduce efficiency


case
study

INTRODUCTION

- **NTPC, Talcher Super Thermal Power Plant is divided into 2 stages.**
- **Stage 1 has two units of 500MW each and stage 2 is 500*4 MW.**
- **In Talcher stage I boilers, the level of forced outage was around 4%.**

Talcher stage I boilers experienced tube failures mainly at the following areas:

- Waterwall bottom `S' panel
- Burner panel
- Hanger tubes
- Economizers
- Low Temperature Reheater (LTRH)
- Intermediate Temperature Superheaters (ITSH)
- High Temperature Reheater (HTRH)

- **During the year 2006-07, the average availability loss due to forced outage for 500 MW boilers in our country was around 2.2%.**

- **The reduction in unit boiler availability is mainly due to increased number of boiler tube failures.**

- **Talcher STPP / NTPC had requested BHEL to inspect the boiler and to suggest remedial measures to overcome boiler tube failure.**

Inspection carried out to address the following problems:

- **Erosion of water wall (spiral wall) tubes in corners 2 and 4 at the bottom sloped portion.**
- **Erosion of Low Temperature Reheater (LTRH) and hanger tubes.**
- **Uneven gap between water wall tubes at furnace bottom and bottom seal trough.**

EROSION OF SPIRAL WATER WALL TUBES AT BOTTOM SLOPE

PROBLEM OBSERVED :-

- **Spiral wall constructed with inclination of 13.4° and 35°.**
- **corners 1 and 3 are inclined at 13.4°, while 2 & 4 are inclined at 35°.**
- **In this configuration, the tubes with steep slope of 35° of front and rear water walls experienced more erosion .**

CAUSE :-

- **Bottom ash/slag that slides over the tubes is the main reason for the erosion of water wall tubes having 35° spiral angle.**

SUGGESTION:-

It was suggested to put refractory over the fin (between the spiral tubes) up to the top surface of the tubes; carbon steel rods are to be welded on to the fin prior to refractory for holding refractory.

NOTE : It was not advisable to weld wear bar on to the tubes as it is done for 500MW conventional two pass boilers; the wear bar will increase the quantity of ash that slides over the spiral tubes because of increase in the effective height of tubes and hence would increase erosion on tubes.

EROSION OF LTRH AND HANGER TUBES

PROBLEM OBSERVED: -

- **6 rows of hanger tubes are provided to support the SH, RH and economizer sections .**
- **Out of 6 rows 1,3,4 and 6 are located closer to the LRSB travel path.**
- **The hanger tubes in these 4 rows, especially which are facing the LRSB, are experiencing erosion.**

CAUSE :-

Erosion of tubes could be due to the blowing steam from LRSB aided by dust-laden ash.

SUGGESTION:-

- **Optimizing frequency of operation of LRSBs by reducing the frequency of use of LRSBs and subsequently checking the boiler parameters.**

- **Reducing the pressure of soot blowing steam. The blowing steam pressure of LRSBs may be reduced in steps of 1kg/sq cm from the current set value of 10 kg/sq.cm. to 7.0 - 7.5 kg/sq.cm.**

- **Blowing steam temperature :-Proper functioning of thermal drain valve in the soot blowing system is to be ensured to confirm that condensed water is not flowing through the LRSB during starting of blowing. Blowing steam temperature is to be kept at a minimum of 20°C more than the saturation temperature of the blowing steam pressure.**

UNEVEN GAP BETWEEN WATERWALL AT FURNACE BOTTOM AND BOTTOM SEAL TROUGH

PROBLEM OBSERVED:-

It was observed that at furnace bottom, the gap between water wall and bottom seal trough is not uniform at all the four sides.

OBSERVATION :-

- **The gap between waterwall at furnace bottom and bottom seal trough is gradually reducing from corner 1 to corner 2 and at rear this gap is reducing from corner 3 to corner 4.**

- **The level difference (gap X) between,**
- **corners 1 & 2 in front water wall is 68 mm.**
- **corners 3 & 4 in rear water wall is 125 mm.**
- **corners 1 & 4 in LHS water wall is 135 mm.**
- **corners 3 & 2 in RHS water wall is 58 mm.**

CAUSE:-

- **The gussets at the corners welded at the left and right ends at 9900mm elevation, which connects the buckstays of LHS and RHS water walls through corner links were not welded back to the water wall during tube replacement.**

- **The above has lowered the water wall tubes during operation and created permanent level difference between the corners because of inadequacy in support which results in reduced gap between water wall and seal trough at corners 2 & 4.**

SUGGESTION:-

- **Putting back the attachments will only retain the present condition.**
- **So, in order to get back the original gap, the water wall replacement need to be carried out .**
- **All the supporting arrangements are to be provided; the spring hangers given for water wall bottom main and branch headers are to be given pre compression to the required level**

BOILER TUBE FAILURE INSPECTION TEST

Some of the very commonly performed NDT techniques are used on boiler tube :

- The Visual Inspection
- The Liquid Penetrant Inspection
- The Magnetic Particle Inspection
- The Radiography Test Inspection
- The Ultrasonic Test Inspection
- The Eddy Current test Inspection
- Leak Testing

RADIOGRAPHY TEST

- It is a NDT Method.

1. It is a simplest weld examination technique.
2. It passes Gamma radiation through the component using photographic means.
3. Radiation is produced by using Radioactive source.
4. Presently used Isotope- Iridium-192/ Cobalt-60.

Thus we can identify the failures in the water tubes by using the radiography test

BOILER TUBE FAILURE PREVENTIVE PROTECTION

For reducing tube failure used some primary protection steps :

- **Ceramic coating on the boiler tubes surface.**
- **Used metallic tube cover on bending tube surface.**