BOILER TUBE FAILURE ANALYSIS IN

210MW SUBCRITICAL BOILER

AT MTPS 1

A PROJECT REPORT

Submitted by

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METTUR THERMAL POWER STATION-1

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With the blessing of our founder ayya **Thiru .R.P.SARATHY,**

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LIST OF ABBREVATION

SH	- Super Heater
LTSH	- Low Temperature Super Heater
MTPS	- Mettur Thermal Power System
MW	- Megawatt
NaOH	- Sodium Hydroxide
NOx	- Nitrous Oxide
Ni	- Nickel
Cr	- Chromium
Al	- Aluminium
Si	- Silicon
C	- Carbon
P	- Phosphorus
Fe	- Ferrous
Mn	- Manganese
S	- Sulphur
Mo	- Molybdenum

ABSTRACT

Boiler tube failure continues to be leading cause for forced outages in fossil fired boilers. The tube failure may be a simple problem unless it causes damage to the power plant and affects safety of the human being. The problem due to tube failure is realized only when the cost due to failure is estimated. The main objective of our project is to reduce the number of tube failure occurring in boiler accessories at thermal power plant station by analyzing the reason behind the tube failure and provide suitable remedies for it. Tube failure in boiler accessories occur due to various reasons and the major reasons for failure are flue gas erosion, long term overheating and steam erosion.

The major failure reasons are taken from the tube failure data, collected from Mettur thermal power station. Major causes can be controlled by using following remedies such as optimization of flue gas velocity, using tube material with better creep strength and by providing coatings along the wall of the tube. The boiler tube material is selected based on cost, creep strength and corrosion resistance, the coating for boiler tube is selected based on operating conditions and coasting feasibility. The above remedies if implemented in the power plant can reduce the tube the tube failure to a major extent.

CHAPTER 1

OVERVIEW OF MTPS

1.1. Plant Description

1. Location	:	Mettur (11° 58') North latitude And (77° 48') East latitude Evaluation 213 meters above MSL
2. Area of The Plant	:	Main Plant 362 acres Total 1733 Acres Including railway, Raw Water storage, Ash dyke, etc.
3. Installed Capacity	:	4 units-(840 MW) 1st stage: 210mw*2 units 2nd stage: 210mw*2 units
4. Requirement of Coal	:	14000 Tone/day for 4 units
5. Requirement of Coal	:	70 cubic meter/sec

6. Chimney Height	:	1st stage: 130 meters
		2nd stage: 220 meters
7. Station Transformer	:	4*31.5 MVA
8. Ambient air temperature	:	Maximum dry bulb 40°
		Minimum dry bulb 17°

CHAPTER 2

THERMAL POWER PLANT

Thermal power plants are one of the main sources of electricity in both industrialized and industrialized and developing countries. These plants have drawn flak on consumption of non-renewable sources of energy at a rapid rate and also since they release huge amounts of greenhouse gases into the atmosphere. The anti-greenhouse gas activities are calling for thermal power to be replaced by other cleaner sources of energy.

2.1 Detailed Power Generation Process in a Thermal Power Plant

2.1.1 Water Intake

Firstly, water is taken into the boiler through a water source. If plenty of water is available in the region, then source is an open pond or river. If water is scarce, then it is recycled and the same water is used over and over again.

2.1.2 Boiler Heating

The boiler is heated with the help of oil, coal or natural gas. A furnace is used to heat the fuel and supply the heat produced to the boiler. The increase in temperature helps in the transformation of water into steam.

2.1.3 Steam Turbine

The steam generated in the boiler is send through a steam turbine. The turbine has blades that rotate when high velocity steam flows across them. This rotation of turbine blades is used to convert kinetic energy to mechanical energy.

2.1.4 Generator

A generator is coupled with the steam turbine. When the turbine rotates, the generator produces electricity which is then passed to distribution systems.

2.1.5 Special mountings

There is some other equipment like the economizer and pre-heater. An economizer used the heat from the exhaust based to heat the feed water. An air pre-heater heats the air send into the combustion chamber to improve the efficiency of the combustion process.

2.1.6 Ash collection System

There is separate residue and ash collection systems in place to collect all the waste materials from the combustion process and prevent them from escaping into the atmosphere.

Apart from this, there are various other monitoring systems and instruments in the place to keep track of all the devices. This prevents any hazards from taking place in the plant.

2.2 Circuits in Thermal Power Plant

Thermal power plant consists of mainly four circuits. They are

- Coal and ash circuit
- Air and flue gas circuit
- Feed water and steam flow circuit
- Raw water and cooling water circuit

2.2.1 Coal and ash Circuit

Coal arrives at storage yard and after necessary handling it passes on the furnace through fuel feeding systems. In case of pulverizing system, In case of pulverizing system, coal is pulverized and the goes to the fuel burners. Ash resulting from combination of coal gets collected at the ash pit and is removed to ash storage yard by ash handling equipment.

2.2.2 Air and flue Gas Circuit

Air taken in from atmosphere through forced draught and passes to the furnace through air pre-heater, where it has been heated of the flue gas which pass to the chimney via pre-heater. The hot gases of combustion first flow through boiler tubes in furnace then through economizer and then finally through air pre-heater and then discharges through chimney to the atmosphere.

2.2.3 Feed Water and Steam Flow Circuit

The condensate leaving the condenser is first heated in a closed water heater; the bleeder steam from the turbine is used to heat water in the heaters. In boilers drum and tubes, water circulates due to natural circulation wet steam from drum further is heated up in the super heater. Steam then expand in turbine and produces power. From there it is exhausted in to condensate is collected in hot well.

2.2.4 Raw Water and Cooling Water Circuit

The condenser requires cooling water to condense the exhaust steam, water cooled in cooling tower or in cooling ponds and reused again and again, make up cooling water is added in the circuit. Figure 2.1 shown the over view of thermal power plant.

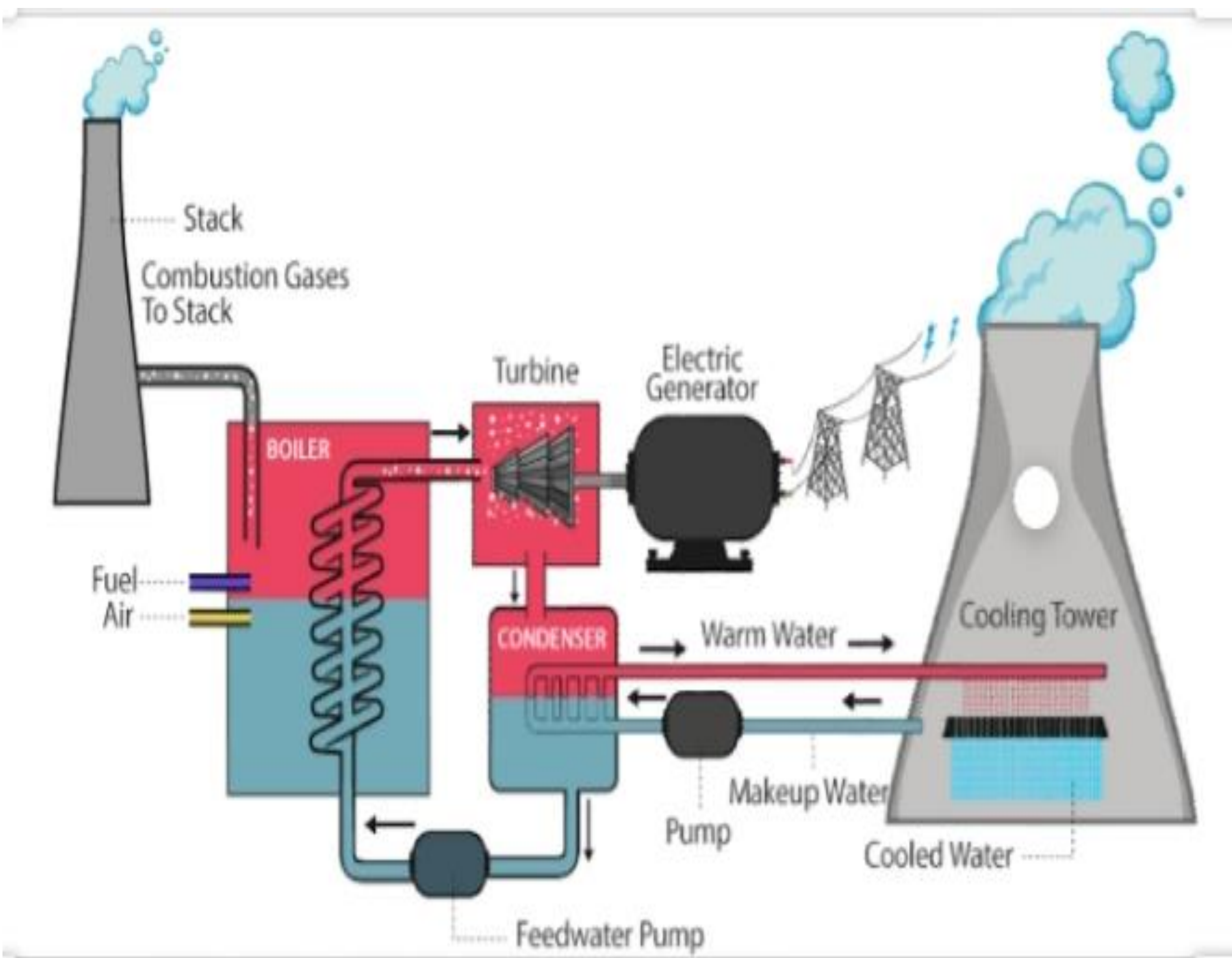

Figure 2.1 Schematic diagram of thermal power plant

CHAPTER 3

INTRODUCTION

In his chapter we are going to discuss about working of water tube boiler and about tubes used in boiler. The first step in boiler tubes failure analysis by AIS is to perform a visual inspection of the failed tube. Then make preliminary observation exchanger tube failure that fits your budget. Finding boiler tube failure mechanism cracking corrosion or boiler tube corrosion stress cracking as well as (casting cracking or embrittlement corrosion) caustic embrittlement in boiler causing replacing boiler tubes is steam boiler.

3.1 BOILER

A boiler or steam generator is a device used to create steam by applying heat energy to water. Figure 3.1 shown the process inside the boiler. A boiler or steam generator is used wherever a source of steam is required. The form and size depended on the application; mobile steam engines such as steam locomotive, portable engines and steam-powder road vehicle typically use a smaller boiler the forms an integral part of vehicle; stationary steam engines, Industrial installation and powder station will usually have a large separate steam generator facility connected to the point-of-use by piping. A notable exception is the steam-powder fireless locomotive, where separately steam is transferred to a receive (tank) on the locomotive.

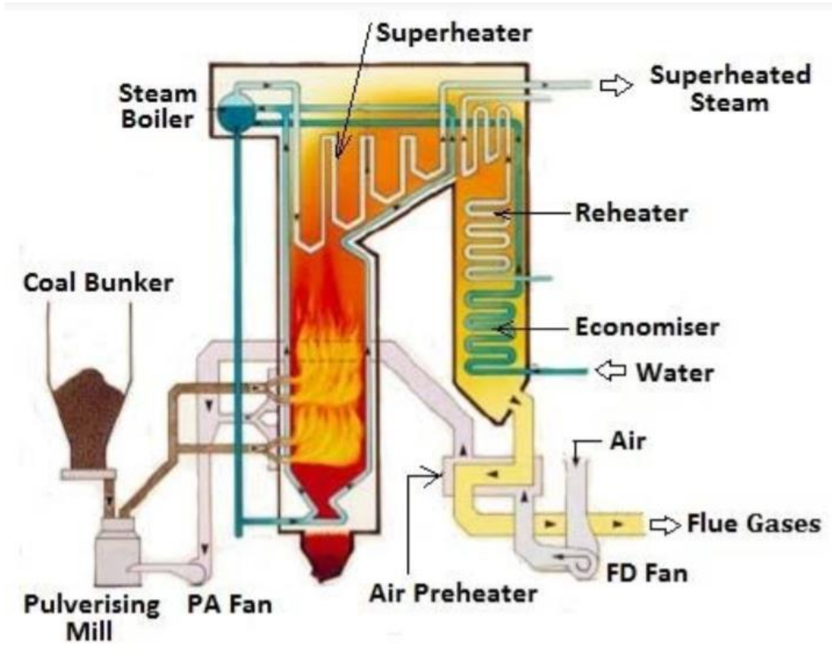

Figure. 3.1. Process inside the boiler

3.2. BOILER TUBE

Boiler tube are set of long tube several folds inside the furnace sometimes their total length may be several kilometer mainly in the cause of power plant boiler, these tubes transfer heat from flue gas to water or steam. Figure 3.2 shown the boiler tube.

Table 3.1. Tubes in water tube boiler of Mettur thermal power station

Tube material	SA210 Gr Al(C=0.27%)
Tube diameter	44.5 mm
Tube thickness	4.5 mm
Tube length	32km
No of bend	4004 (economizer)
Tube arrangement	Horizontal
Tube bend diameter	130 mm

Figure. 3.2. Boiler tube

3.3. Boiler Accessories

Boiler accessories are those components which are installed either inside or outside the boiler to increase the efficiency of the plant and o help in the power working of the plant.

Various boiler accessories are

1. Economizer
2. Super heater
3. Re-heater
4. Boiler drum
5. Air Pre heater
6. Electrostatic precipitators

3.3.1 Economizer

The economizers are placed just before the air pre heaters to recover the heat available in the flue gas, that leaves the boiler and transfer the same to the incoming feed water to raise its sensible heat. In conventional two pass boilers, the economizer coils are located at the bottom of the second pass. The feed water flow is in the counter flow direction with respect to the flue gas, giving higher heat transfer rate. Economizer recirculation line is provided to prevent the steaming in the economizer coil, during the startup of the boiler. Through the recirculation line flow is created during start-up, when there may not be any feed water flow through the economizer from BFP. Through the temperature of the flue gas in the zone will be only around 450°C; the coils are subject to heavy erosion by the fly ash in the flue gas. Refer figure 3.3. Economizer

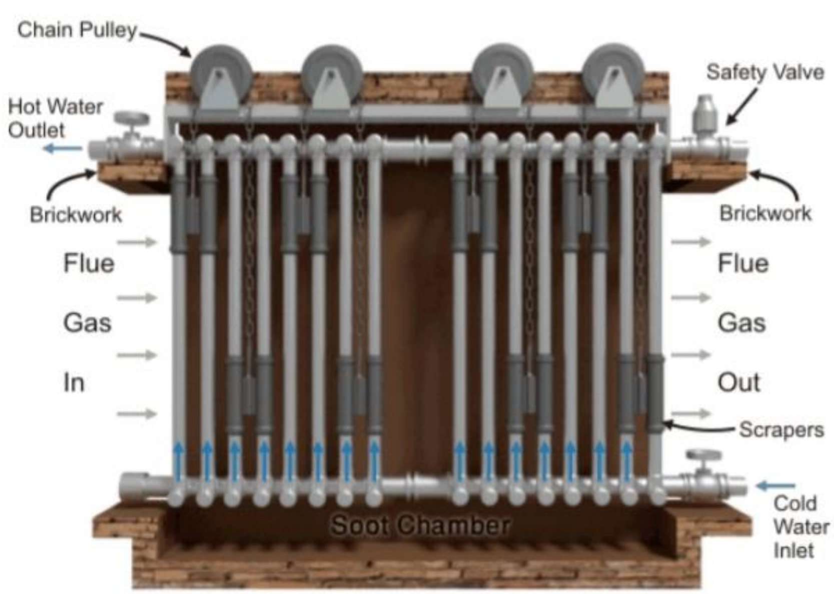

Figure 3.3 Economizer

3.3.2 Super Heater

Super heaters are to raise the steam temperature above the saturation temperature by absorbing heat from the flue gas. The super heater is composed of four sections viz. Steam cooled wall and roof sections, Low temperature SH. The dry saturated steam flows first through the roof and steam cooled wall and then enter the LTSH located in the rear vertical gas path above the economizers. From the LTSH steam flows through the Radiant/Platen super heaters which is placed above the furnace zone. The heat transfer in this SH is by radiation. The last stage super heater known as Pendant Super heater is placed in the second pass of the boiler either horizontally or allowed to hang vertically. Here the heat transfer is by convection. Superheated steam from Pendant SH outlet header goes to the turbine through the main steam lines.

Operating parameters of boiler

Load	: 210MW
Coal flow	: 126 tons/hrs.
Main stream pressure	: 133 kg/cm^2 : 147 kg/cm^2
Drum pressure	: 147 kg/cm^2
Final super heater temperature	: 538°C
Re-heater temperature	: 536°C
Economizer temperature	: 330°C
Air pre-heater inlet	: 424°C
Air pre-heater outlet	: 160°C

3.3.3 Re-heater

Re-heaters are used to raise the temperature of the steam, which is exhausted, from the HP turbine after doing work. The re heater is composed of two stags viz. the front pendant and rear pendant sections. The re heater coils are placed in between the platen and final SH. The main causes of re heater tube failure are overheating, stress corrosion and weld defects. The following Table 3.2 shows the temperatures at different areas of the boiler.

Table 3.2: Flue gas temperatures at different location in the boiler

Location in the boiler	Flue gas temperature in °C
Leaving furnace	1124
Before re-heater	1011
After re-heater	789
Before LTSH	689
Before economizer	462
Before air pre-heater	370
After air pre-heater	148

3.3.4. Boiler Drum

The boiler drum serves the purpose of storing feed water for conversion of stem through the water wall connection and separate steam from water and steam mixture entering the drum through the riser tubes. The feed water from economizer outlet header at a temperature of around 275°C is discharged into the drum. The water from boiler drum takes a path through the down comers to the bottom ring header and rises through the water wall tubes, absorbing heat from the furnace. Steam and water mixture generated in the furnace wall tubes enter the corresponding out let header located in the roof and are connected to the drum by means of riser tubes. Inside the drum turbo separators with screen driers are placed for separating the saturated steam from water.

Figure 3.4. Boiler Drum

A typical 210 MW boiler drum is of about 1.8 meter diameter and 15 meters length and the shell thickness is around 135mm. The drum material is subjected to high thermal stress because of the temperature difference existing between the steam and feed water. Fig 3.4 shows the overview of boiler working which is a Multi pass boiler.

3.3.4. Air Heater

Air heaters are to be designed considering a fuel moisture variation of 6-20%. The air temperature from air heater should be adequate to dry the maximum moisture coal. This is the last heat recovery surface. To achieve maximum efficiency, heat has to be extracted from outgoing gas to the extent possible. Important factor the decides the tail end temperature is the acid dew point below which if the temperature is reduced would lead to cold end corrosion which would damage the equipment (air heater) calling for frequent replacement of air heater elements.

3.3.5 Electrostatic Precipitator

The combustion dust particles are ionized when passing the flue gas in between the electrode (Emitter & collector) and attracted them to the electrode of opposite charge. Finally the dust particles are removed from collector plated by hammering with rapping motors.

3.4 Boiler Mounting

Boiler Mountings are the components generally mounted on the surface of the boiler to have safety during operation. These are the essential parts of the boiler, without which the boiler operation is not possible. The following are the important mountings of the boiler.

- Water level indicator
- Safety valve
- Pressure gauge
- Steam stop valve
- Feed check valve
- Main hole

3.4.1 Water level indicator

This device indicates the exact level of water in the boiler tube.

3.4.2 Safety valve

It is a mechanical device used to safeguard the boiler, in case the pressure inside the boiler rises above its normal working atmosphere.

3.4.3 Pressure gauge

The pressure gauge commonly used is the bourdon pressure gauge mounted on the front of the boiler shell.

3.4.4 Steam stop valve

The function of the steam stop valve is to stop or open the steam supply from the boiler to the point of application.

3.3.5 Feed check valve

A valve placed at the boiler end to regulate the flow of water.

3.3.6 Main hole

It is the opening provided of cleaning or inspection.

CHAPTER 4

LITERTURE REVIEW

4.1 Failure analysis of boiler cold and hot re-heater tubes

Khalil ranjberetal (2006) illustrates the area of the tube failure and affected parameters where studied and corrosion mechanisms were identified. An analysis was made on the failure and shut down of boiler coil and hot re-heater tubes by chemical analysis of sediments, metallographic examination and XRD,SEM and EXD studies it is concluded the dad maintenance and feed water chemistry are which are identified and discussed in the study.

Boiler tubes are generally exposed to high pressure and temperature of steam internally and high temperature of combustion externally. Corrosion elements in both of them may cause severe damage to the inside and outside of the tubes. Under normal operation condition of the boiler, a protective oxidized layer of fe_3O_4 is being formed inside the tubes accumulation of deteriorates the oxide layer, so that fresh surface of material I continuously oxidized and thinning goes on till a pin hole like damage appears. The leakage of steam with high velocity removes the deposits. In other words, these tubes were drilled and thinned from inside. Small rounded yellow colonies over the deposits are also visible, and are arrowed. Analysis of these spot by SEM-EDX confirmed the presence of sodium and silisium as the main constituents in decreasing order.

Conclusion from the journal

The most corrosion mechanism in tube was pitting, caustic corrosion and stress corrosion cracking. No micro structure and hardness change, and no overheating were noticed. The control of feed water chemistry, operation and maintenance condition should be followed as per recommended specification of the power plants.

4.2 Analysis of failures in boiler tubes due to fireside corrosion in a waste heat recovery boiler.

S.Srikanth (2020) illustrates the effects of waste heat recovery on tube failure and also tells about nature of deposits in economizer and super heater tubes.

The failures of boiler tubes due to fireside carrion in a waste heat recovery boiler utilizing the exhaust gas of a gas turbine fired with high-speed diesel has been analyzed. Thermodynamic modeling studies were carried out to study the interaction of the flue gas with the various compounds of the boiler. The waste heat recovery boiler had undergone an approximate service of 50l000 h.

It has reported that there repeated economizer tube failures as also intermittent failures at the condensate pre-heater, low pressure economizer and high-pressure economizer portions. Tube failures generally occurred in between fins and at bends and joints where the tube penetrates the support plate.

The chemical composition of the deposits in the deposits in the high-pressure evaporator and economizer sections are mainly hydrated irons sulfates and iron hydroxide sulfate. In other words, formation of ferrite oxide is favored in the super heater section and formations of ferric sulfate deposits are favored in the evaporator and economizer.

Conclusion from the journal

The nature of deposits in the boiler were in studied and examined by using various techniques. From the studies the deposits in the super heater sections mainly comprise of ferric oxide (Fe_2O_3) whereas the deposits in the HP evaporator and economizer comprise predominantly of hydrated iron sulfates and iron hydro sulfates.

4.3 Phosphate included stress corrosion cracking in a water wall tube from a coal fired boiler

K. Gopalakrishnan (2003) illustrate the failure of a water tube in coal-fired boiler from a thermal power station was analyzed.

Mild whitish deposits formation in the water side of the tube with multiple fine cracks on the internal surface (water side) of the water side of the tube was observed in the failure zone. The failure zone was studied using stereo and optical microscopy, micro-hardness measurements and scanning electron microscopy in the secondary electron imaging mode. The failure occurred because of localized caustic corrosion cracking. The corrosion products at the grain boundaries were found to be mainly iron and sodium phosphates.

The hardness is higher in the failed region in comparison to the region away from the failure. The results indicate that the overall deposit present over the heated part of the internal surface of the tubes consists of predominately iron oxides and a minor amount of sodium. The deposit showed the presence of only amount of phosphorus in the deposit.

Conclusion from the journal

The failure of water wall in a coal-fired the boiler from thermal power station was analyzed. It has been shown that the failure in the water wall tube initiated locally at the water surface because of caustic corrosion. The corrosive environment appears to be related to the presence of excess of sodium phosphates in the feed water. The subsequent failure of the tube has occurred by phosphate included inter-angular stress corrosion cracking.

4.4 CFD modeling of boiler's rupture

MasoudRahimi (2006) illustrates the result of study on the reason for tube damage in the heater.

The boiler has three type of superheated and the damage occur in a series elbow belong to the long tubes. A three-dimension modeling was performed using an in-house computational fluid dynamics (CFD) code in order to explore the reason. The code has ability of simultaneous solving of the continuity, the Reynold-averaged nervier-stokes (RANS) equation and employing the turbulence, combustion and radiation models. The whole boiler including, walls, burners, air channels, three types of tubes, etc., was modified in the real scale. The boiler was meshed into almost 2000000 tetrahedral control volumes and the standard turbulence model and the rose land radiation model were used in the model. The theoretical result showed that the inlet 18.9MPa saturated steam becomes superheated inside the tubes and exit at a pressure of 17.8MPa.

Conclusion from the journal

The steam was flow rates in the longer tube are lower than shorter ones and it is residence times are higher. Therefore this steam in the longer tube takes more energy and becomes warmer as goes out the boiler. The CFD prediction shows that working at temperature higher then design temperature is the main reason of long tube failure: the structure fatigue tension on the last elbow of the long tube has significant effect on rate of the metal microstructure. This is the reason that the tube was happened only the elbow's section.

CHAPTER 5

PROBLEM DEFINITION

The chapter explains about problem in boiler tubes and the factors the cause major damage to the boiler tubes. This helped use to identify the major reason for tube failure and suggest suitable remedies for the failure caused due to the problems.

5.1 Types of failure

Failure in boiler occurs at various places corresponding to the parameter causing the defect. Below listed are such failure could be seen in boiler tubes.

a) Fish mouth open

b) Window opening

c) Burst open puncture

d) Pinhole puncture

e) Crack formation

5.1.1 Area of failure

Most of the failure is happen at repeated places. Places at which tubes failure seen most are economizer, extended steam cooled tubes, water wall, LTSH, pre heater tubes, plate super and final super heater. These entire paces require very good maintenance for longer life and to reduce the failure rate occurring in it.

5.1.2 Failure occurring at MTPS

At MTPS (Mettur Thermal Power Station) the failure records of boiler tubes over a period of time 2014-2019 and the details of failure are displayed below. The data displayed are failure data of MTPS Unit-1 boiler during the period 28.03.2014 to 26.02.2019. Records show that around 12 failures occur regularly over a period of time a power station. The following table 5.1 shows the failure occurs in MTPS unit-1 for last 5 years and figure 5.1&5.2 shows the pie chart of failure.

Table 5.1. show the failure occur in MTPS Unit-1 for last 5 years

28.03.2014	Fly ash erosion
24.05.2014	Steam erosion
11.06.2014	Falling slag erosion
19.09.2014	Flue gas erosion
06.10.2014	Flue gas erosion
25.10.2014	Fly gas erosion
06.08.2014	Flue gas erosion
19.08.2015	Flue gas erosion
01.11.2015	Flue gas erosion
17.05.2016	Flue gas erosion
25.05.2017	Flue gas erosion
26.02.2019	Flue gas erosion

CHAPTER 6

CAUSES OF THE TUBE FAILURE

There are numerous that accounts of failure of boiler tube in water tube boilers. These are twenty-two primary reasons for tube failure in a boiler. Knowledge and maintenance practice reduce tube failure in boiler increases the availability of boiler. A single tube failure in 210MW oiler may cause loss of millions of rupees apart from power generation loss. They are four major groups into which all tube failure can be classified and can be grouped under four major causes:

- Erosion
- Stress rupture
- Corrosion
- Loss of quality

6.1 Erosion

These are various reasons behind the erosion of boiler like fly ash, coal particles etc. The factors that which causes erosion in boiler tubes are listed below

- Fly ash
- Coal particles
- Falling slag
- Air erosion

6.1.1 Fly ash

Fly ash travels with flue gas at the same speed around 11m/s when it continuously travels at this speed it world erode the metal in constant manner and finally it word reaches the critical limit at which the tube no more with stand the pressure. The amount of ash in coal and its velocity are major factors in the rate of fly ash erosion is experienced in the economizer, primary SH, and inlet section of steam re-heater tubes. When non-uniform flues gas flow distribution occurs increases, the rate of erosion increases multifold.

- The velocity of flue gas
- The temperature of the gas
- The change in direction of flue gas
- The arrangement of pressure parts
- The operation above the maximum condition design rating or with excess airflow above design rate

6.1.2 Coal particles

Coal particles erosion is similar to fly ash erosion in which un burnt coal particles flow with the flue gas and erodes the boiler material, it may also deposit on the tube surface and causes reduced heat transfer and corrosion the following are the areas in the boiler where the coal particles erosion in normally experienced. Economizer bens and tubes, screen tube, goose portion at furnace top, soot blower openings in the water walls, wind box opening in the furnace, bottom hopper tubes.

6.1.3 Slag formation

Slag is formed by the reaction of deposited ash particles with the boiler tube material, prolonged travelling of ash particles around boiler tube cause deposition of ash, and at high temperature these ash deposit tube particle reacts and forms molten slag, this slag on the lower tube and erodes those tubes.

6.1.4 Air erosion

Continuous flow of hot air in the flue gas also causes considerable erosion. But when compared to other factors which is causing the erosion it is bit lower.

6.2 Stress rupture

Stress rupture is another important cause to failure of boiler tube in water tube boiler. Some reasons for stress rupture of boiler are given below.

- Short term overheating
- Long term overheating
- Dissimilar metal welding

6.2.1 Short term overheating

Short term overheating can occur if temperature of pressure part (tube, drum, pipe and header) increases rapidly in short period exceeding limitation of design temperature. If can occur at the pressure part which has high operating temperature such as superheated, water wall, roof wall, boiler bank, screen tubes and down comes and rarely occur in low operating temperature of pressure part such as air heater and economizer. When the tubes has insufficient cooling from inside and recessive heat input from combustion process will lead to short team overheating. Figure 6.1 show the failure of boilers due to short term overheating.

Fig 6.1 short term over heating

6.2.2 Long term over heating

Long term overheating tube failures are due to operating metal temperature of the boiler tubes going above the allowable limit. These types of failure are soon in steam cooled tubes like super heater and re-heater and in water tubes of water wall. While selecting the tube there is requirement to select the correct material for withstanding the metal temperature. Normally the water cooled areas likes economizer and water walls are made of carbon steel of boiler quality. Super heaters and re-heater will have combination of low alloy tubes to stainless steel tubes selected to withstand the metal temperature. Figure 6.2 show the failure of boilers tube due to long term overheating.

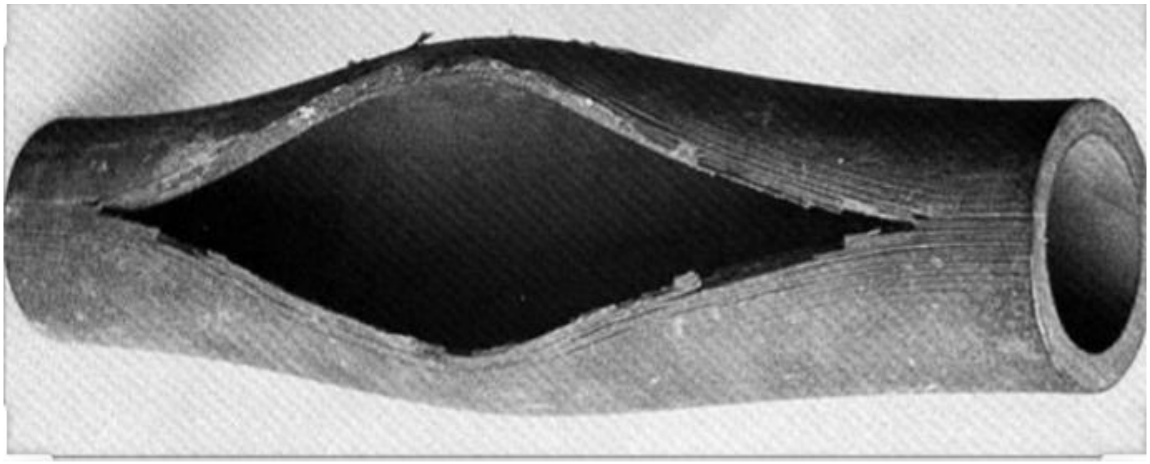

Figure 6.2 long term over heating

6.2.3 Dissimilar metal welding

In the mettur thermal plant station, dissimilar metals welds (DMWS) are used join ferrite low-alloy steels to austenitic stainless steel. Unfortunately, these welds can fail prematurely from austenitic steel to ferrite could replace the one dissimilar weld with two similar welds. Figure 6.3 show the dissimilar welding metals.

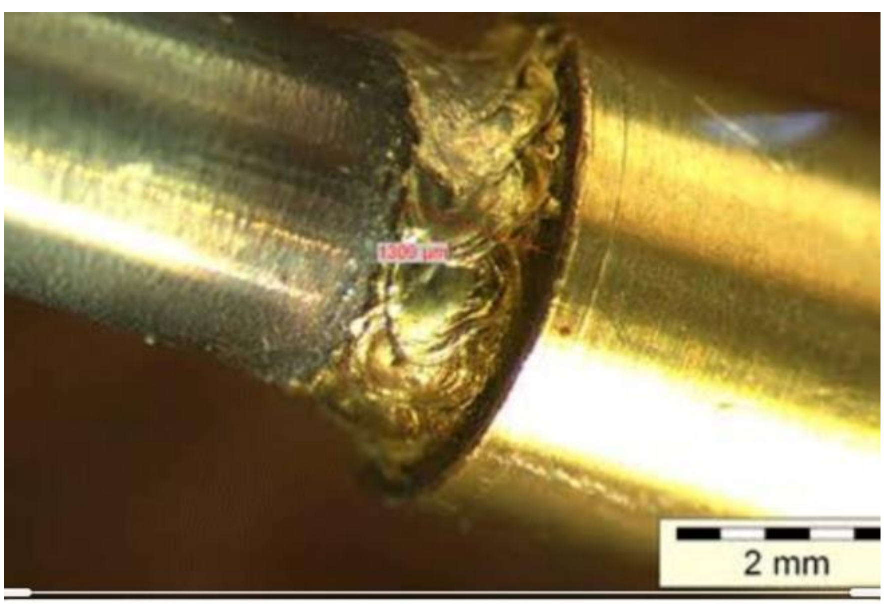

Figure 6.3 Dissimilar metal welding

6.3 Corrosion

In corrosion boiler tube materials are taken away by chemical around it.

- Caustic corrosion
- Pitting corrosion
- High temperature corrosion
- Low temperature corrosion

6.3.1. Caustic corrosion

Caustic corrosion, a specific form of stress corrosion, results in the inter crystalline cracking of steel. Inter crystalline cracking result only when all of them following are present: specific condition stress, a mechanism for concentration such as leakage, and free NaOH(sodium hydroxide) in the boiler water. There, boiler tubes usually fail, from caustic embrittlement at point where tubes are into sheets, drum or header. Figure 6.4 refers the caustic corrosion in boiler tube.

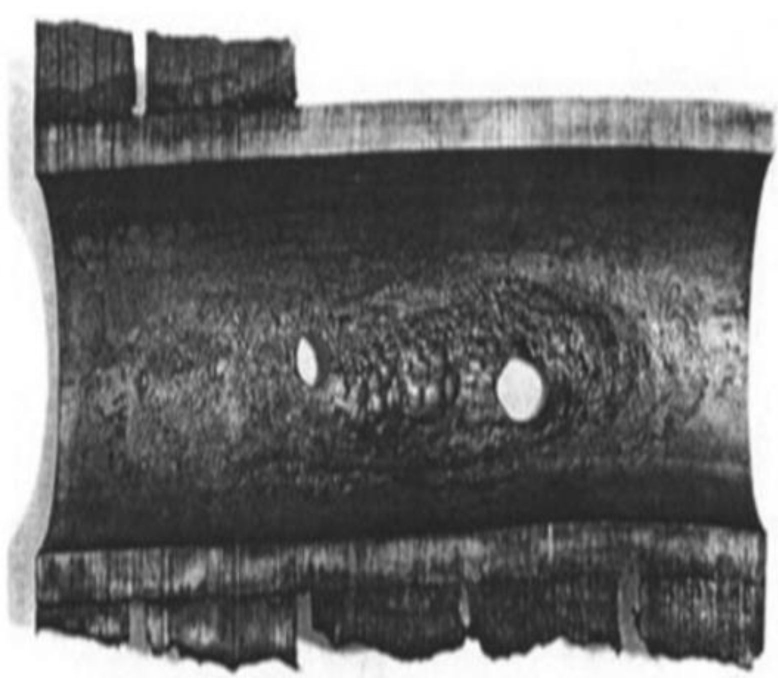

Figure 6.4 Caustic corrosion

6.3.2 Pitting corrosion

Pitting corrosion is a form of extremely localized corrosion that leads to the creation of small holes in the metal. The driving power for pitting corrosion is the depassivation of a small area, which becomes anodic while an unknown but potentially vast area becomes cathode; leading to very localized galvanic corrosion. The corrosion penetrates of the metal, with limited diffusion of ions. Figure 6.5 refers the pitting corrosion made in boiler tubes.

Figure 6.5 Pitting corrosion

6.3.3 High temperature corrosion

High temperature corrosion is a mechanism of corrosion taking place in boiler tube coming in contact with hot gas containing contaminations. Flue contains sometime vanadium compounds or sulfur which can from compounds during combustion having a low melting point.

These liquid melted salt are strongly corrosive for stainless steel and other normally inert against the corrosion and high temperature. Other high temperature corrosion includes high temperature oxidation, and carbonization. Figure 6.6 refers the high temperature corrosion.

Fig 6.6 High temperature corrosion

6.3.4 Low temperature corrosion

Mettur thermal power station uses coal as a fuel this fuel contains sulfur to differing percentage. The higher the percentage of sulfur, the will be the risk of cold end corrosion in boiler. The sulfur in the fuel during combustion gets converted to sulfur dioxide some portion of the sulfur dioxide gets converted to sulfur dioxide. The presence of moisture in the fuel gas to moisture in the fuel and air, sulfur dioxide, and trioxide, combines with moisture and forms sulfuric acid. These acids condense from around 115° centigrade to slightly higher than 160°, depending upon the metal wastage and boiler tube failure, air-preheated corrosion and fuel gas dust corrosion.

6.4 Deaerator Cracking

In numerous desecrators, cracks have developed at welds and heat-affected zones near the welds. The cracking most commonly occurs at the heat-to-shell below the water level in the storage compartment. However, it may also occur above the water level and at longitudinal welds. Because cracks can develop to the point of equipment failure, they represent a potential safety hazard requiring periodic equipment inspection and, when warranted, repair or replacement. Wet fluorescent management particle testing is recommended for identification of cracks.

The mechanism of most deaerating cracking has been identified as environmentally assisted fatigue cracking. Although the exact causes are not known, steps can be taken to minimize the potential for cracking (e.g., stress-relieving of welds and minimization of thermal and mechanical stress during operation). In addition, water chemistry should be designed to minimize corrosion.

6.5 Feed Water Line Erosion

High tube economizer is often subjected to the serious damage of oxygen pitting. The most server damage occurs at the economizer inlet and, when present, at the tube welds seams. Where economizers are installed, effective deaerating heater operating is absolutely essential. The application of a fast-acting oxygen scavenger, such as catalyzed sodium sulfite, also helps protect this vital part of the boiler.

While oxygen pitting is the most common form of waterside that causes economizer tube failure, caustic soda has occasionally accumulated under deposited and caused casting gouging.

6.6 Fatigue and Corrosion Fatigue

Tran granular cracking primarily due to cyclic stress is the most common form of cracking encountered in industrial boiler. In order to determine the cause of a Trans granular failure, it is necessary to study both the design and operating condition of the boiler. Straight tube, shell-tube waste heat boiler frequently develops tube and tube sheet failure due to the imposition of unequal stresses. A primary cause of this is the uneven distribution of hot gasses across the face of the tube sheet. The tube involved tends to come loose, creating leakage problems. Even when the tubes are securely welded, imposed stresses can cause transverse cracking of the tubes.

Any design feature that allows steam pockets to form within a unit can cause cyclic overheating and quenching. This can lead to transverse cracking of tubes and, occasionally, shells. Such cracking always appears in the area of greatest stress and results in cracks that are primarily trans granular.

Some inter crystalline cracking may develop in this type of failure whether or not free NaOH is present. However, the predominant type of cracking of cracking is across the grain structure of the metal. Because it is mechanically induced, the cracking occurs irrespective of boiler water chemical concentration. The cracks are often accompanied by a number of pits adjacent to or in line with the cracking-another specific indictor of the mechanical stresses imposed. Any corrosives present contribute to the formation of the pits. The normal reaction between iron and water is sufficient to cause pitting at breaks in the thin oxide film formed on freshly exposed surfaces under stress.

6.7 Stress-Induced corrosion

Certain portions of the boilers can be very susceptible to corrosion as a result of stress from mechanical forces applied during the manufacturing and fabrication processes. Damage is commonly visible in stressed components, such as rolled tube ends, threaded bolts, and cyclone separators. Tefular inspection for evidence of corrosion, particularly in the wind box area of Kraft recovery boilers, is recommended because of the potential for an explosion caused by a tube leak.

The potential for stress-induced corrosion can be reduced if the following factors are minimized: Stresses developed in the boiler components, the number of thermal cycles, and the number of boiler chemical cleanings. In addition, it is necessary to maintain proper water chemistry control during operation and to provide from corrosion during shutdowns,

6.8 Dissolved Oxygen

Dissolved oxygen corrosion is a constant threat to feed water heater, economizer, and boiler tube integrity. As deposit control treatment methods have improved, the need for effective control of oxygen has become increasingly important.

The first serious emphasis on oxygen control began when phosphate-based treatments were introduced to replace the soda ash treatments common before that time. The dense, hard calcium carbonate scale which developed with the soda ash treatments protected tubes and drums from surfaces oxygen corrosion. With the application of phosphate treatment, the tube and drum surfaces were cleaner. Therefore, more of the surface area was exposed to corrosives in the water.

6.9 Steam blanketing

A number of conditions permit stratified flow of steam and water in a given tube, which usually occurs in a low heat input zone of the boiler. This problem is I influenced by the angle of the affected tubes, along with the actual load maintained on the boiler. Stratification occur when, for any reason, velocity is not sufficient to maintain turbulence or through mixing of water and steam during passage through the tubes. Located away from the radiant heat zone of the boiler, where heat input low and positive circulation in the tubes may be lacking.

Examination of the affected tubes usually reveals a prominent water line with general thinning in the top area of the tube or crown, hi rare instance, the bottom of the tube is thinned.

In certain instances, stratification may occur together with input of heat to the top or crown of the tube. This creates a high degree of superheat in the steam blanket. Direct reaction of steam with the hot steel develops if the metal temperature reaches 750°F or higher. Corrosion of the steel will proceed under such circumstance whether or not caustic is present. When there is doubt about the exact cause, a metallographic analysis will show if abnormal temperature excursion contributed to the problem. Deposits usually found under such circumstances are composed primarily of magnetic iron oxide ($Fe3O4$). Hydrogen is also formed as a result of the reaction and is released with the steam.

A somewhat unusual problem related to circulation and heat problems has been encountered in roof tubes. These tubes are usually designed to pick up heat on the bottom side only. Problem generally develops when the tubes sag or break away from the roof, causing exposure of the entire surface of the tube to the hot gases.

The overheating the usually develops, along with the internal pressure, cause a gradual enlargement of the tube, sometimes quite uniformly. Failure occurs thermal stress and internal pressure.

Super heater tubes often show the same swelling or enlargement effect. In such instances, steam flow has been restricted for some reason, leading to overheating and eventually failure.

6.10 Acidic Attack

Acid attack of boilers tubes and drums is usually in the form of general thinning of all surfaces. Smooth surfaces appear at areas of flow where the attack has been intensified. In severe occurrences, other components, such as baffling, nuts and bolts, and other stressed areas, may be badly damaged or destroyed, leaving no doubt as to the source of the problem.

Severe instances of acid attack can usually be traced to either as unsatisfactory acid cleaning operation or process contamination. Some industrial plants encounter periodic returned condensate contamination, which eliminates boiler water alkalinity. Occasionally, regeneration acid from an ion exchange process is discharge accidently into the boiler feed water system.

In the case of industrial process contamination, it is possible for organic contaminants to decompose under boiler temperature and pressure to form organic acids. Sugar is an excellent example of an organic which, when returned in a large quantity, can cause rapid loss of boiler water alkalinity and reduce pH of the boiler water to 4.3 and lower. Most sugar refining plants maintain standby pumping systems, to add caustic soda to neutralize these acids as quickly as possible.

6.11 Corrosion due to Copper

Pitting of boiler drums and tube banks has been encountered due to metallic copper deposits, formed during acid cleaning procedures which do but completely compensate for the amount of the copper oxides in the original deposits. Dissolved copper may be plated out on freshly cleaned steel surfaces, eventually establishing anodic corrosion area and forming pits very similar in form and appearance to those caused by oxygen.

In such instances, metallic copper plating is quite evident. In most cases, it is localized in certain tube banks, giving rise to random pitting in those particular areas. Whenever deposits are found containing large quantities of copper or its oxide, special precautions are required to prevent the plating out of copper during cleaning operations.

Copper deposits and temperature over 1600°F can cause liquid metal embrittlement.

6.12 Hydrogen Attack or Embrittlement

In systems of this type, the alkalinity of the boiler water is maintained at values that are quite low compared to casual standards for lower-pressure operation.

When contaminants lower the boiler water pH sufficiently the acid attack of the steel generates hydrogen. If this occurs under hard, adherent, nonporous tube deposits, the hydrogen pressure within the deposit can build up to the point at which the hydrogen penetrates the steel tubing.

When atomic hydrogen permeates the metal structure, it reacts with the carbon content to form methane. Because the methane molecule is too large to diffuse through the steel, excessive pressure develops within the metal structure, causing the metal to rupture along the crystalline boundaries where methane has formed. The cracking that develops is primarily inter crystalline or inter granular in nature, the metallic area affected becoming decarburized in the process. Failure occurs when the ruptured section can no longer withstand the internal pressure. Failed sections of tubing are cracked in the inter granular mode and decarburized, but usually retain the original dimensions or thickness of the tubing material.

6.13 Super heater tubes

Super heater tube failure are caused by a number of conditions, both mechanical and chemical. In any instance of super heater tube failure, analysis of the deposits found is an important factor in solving the problem. The oxidation occurs during overheating where metal temperatures exceed the design temperature and steel enters into a direct reaction with the steam to form magnetic iron oxide with hydrogen release. When the deposits found in the area of failure are primarily iron oxide, it may be necessary to explore a number of operating conditions in order to determine the initial cause.

Oxidation may occur if the flow of steam through the tubes is restricted of if the heat input is excessive, permitting overheating. In the case of insufficient steam flow, the restriction may be due to conditions prevalent during the transition periods of boiler start-up or shut down. This occurs if adequate precautions have not been taken to protect the super heater during the transition periods. At no time should gas temperatures exceed 900°F in the area of the super heater until the boiler is up to operating pressure and all super heater tubes are clear of any water which may have accumulated during the downtime. Overheating conditions may develop during times of low-load operation when adequate distribution of saturated steam across the tube bank at the inlet heater has not been achieved.

Soluble-salt deposits may form at a super heater tube inlet as a result of excessive entrainment of boiler water solids with the steam. This can result in restricted flow. However, overheating and direct oxidation failures may occur in areas distinctly removed from the blockage, such as the bottom loops or the hottest areas of the super heater tubes.

Periodic overheating of super heaters, caused by insufficient control of firebox temperatures during start-up and shut down periods, usually results in thick-lipped fissures and blistering with all the evidence of creep failure. As in the case of water tubes, a super heater tube will fail rapidly (often violently) when flow is blocked for a short period of time and tube temperature escalates rapidly to plastic flow temperatures.

CHAPTER 7

BOILER DESIGN PROBLEMS

Certain basic design flaws can contribute to tube failures. Problems which occur as a result of a design flaws may be intensified by the boiler water chemistry. The boiler water often contains elements that become corrosive when concentrated far beyond normal values as a result of design problems.

Many industrial boilers, for example, are treated in such a manner that low concentrations of caustic soda are present in the boiler water. The caustic can become corrosive to steel when the boiler water is allowed to concentrate to abnormally high values as a result of poor design. Even in the absence of caustic, conditions which permit stratification or steam blanketing and localized elevation of metal temperatures in excess of 750°F allow direct oxidation or corrosion of the steel in contact with water or steam. This causes loss of metal and eventual rupture of the tube.

Roof tubes, nose arch tubes, and convection pass tubes with slopes of less than 30 degrees from the horizontal are more subject to deposition and stratification problems and tube failures than vertical tubes. A frequent contributor to waste heat boiler problems is the uneven distribution of gases across the inlet tubes at the hot end. This causes unequal stresses and distortion and leads to mechanical stress and fatigue problems.

The use of horizontal hairpin tube configurations with inadequate forced circulation of water through the tube often permits stratification of steam and water. This often leads to steam blanketing or caustic corrosion problem.

CHAPTER 8

RESULT AND DISCUSSION

8.1 COATING FOR BOILER TUBE

Boilers operating with low NOx burner present unusually harsh environments for power plants materials. In particulars change from normally oxidizing condition in a standard boiler to reducing in a low NOx boiler causes usually protective oxide to give way to serve wastage by suffixation corrosion and erosion.

8.2 Coating materials

There are various material used for coating the boiler tube for protection against various causes that virus causes that account for tube failure like erosion, corrosion etc., the materials used in boiler external coating are

- M-Cr-Al-y alloy
- Ni20Cr

8.2.1 M Cr Al Y (Ni Cr Al Y)

The M of M Cr Al Y stands for Either Ni or Co, or combination of both (when applied to steels, it can also be Fe), depending on the type of super alloy. Co-based appear to have superior resistance to corrosion. Al content is typically around 10-12 wt%. Since oxidation life is essentially controlled by the availability of Al, it would be tempting to increase the aluminium content. However these result I significant reduction of ductility M Cr Al Y also typically contain 1 wt% yttrium(Y), which enhance adherence of the oxide layer, pet Y bond coating and ZrO/sub 2/-6.1 wt pet Y/sub 2/O/sub 3/thermal barrier coating. Table 8.1 show the modeling and degradation of the boiler tube material resist erosion.

Table 8.1 Modelling and degradation to resist erosion

Element	Ni	Cr	Al
Wt%	35.0	5.9	0.95

8.2.2 Ni 20Cr

The high temperature creep properties of single crystals of Ni-20Cr have been investigate in temperature range of 650°C-1300°C. A single crystal tension specimens were cut from plates having a large elongated grain structure and constant stress vacuum creep tests were various stress conducted at various stress and temperature.

By including the temperature depends of the elastic modules in analysis of data the creep activation energy was found to be very nearly equal to that for self diffusion of Ni 20Cr. Stress depends upon the creep rate was observed to be large and variable, with power law exponences ranging from 9 to 70 over the temperature studied. The creep properties these disposing strength can be described accurately considering creep strength to be given by sample sum of creep strength unthoriated polycrystalline Ni 20Cr. This model describes the measured creep rates of all stress and temperatures. Table 8.2 show the modeling and degradation of the boiler tube material to resist corrosion.

Table 8.2 Modelling and degradation to resist corrosion

Element	Ni	Cr	Si	C	P	Fe	Mn	S
Wt%	80.1	19.3	0.085	0.051	0.0039	<0.10	<0.005	<0.0005

Method of coating

The various method employed in coating are

- Thermal spray coating
- Electro deposit inter metallic coatings
- Weld overlays coating

8.3.1 Thermal Sprayed Coatings

Thermal spray is defined as applying these coatings takes place by means of special devices / systems through which melted or molten spray material is propelled at high speed onto a cleaned and prepared component surface..” This definition does sufficiently describe the thermal spray process. Figure 8.1 is a diagram showing the principle of thermal spray. The coating feedstock material is melted by a heat source. This liquid or molten material is then propelled by process gases and sprayed onto a base material, where it solidifies and forms a solid layer. The individual aspects of thermal sprayed coating follows.

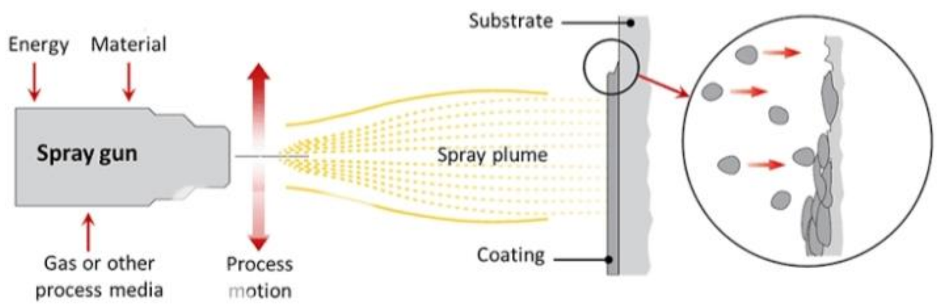

Figure 8.1 Principle of Thermal spraying

8.3.2 Electro deposited inter metallic coatings

One way to protect tubes against corrosion is to apply a thin layer of pure chromium. In an oxidizing environment, the chromium layer from a protective oxide layer which prevents deterioration underlying saved tubes. This worked to the eventual development of new type of coating inter metallic aluminized which can applied the low cast electro deposition process.

8.3.3 Weld overlay coating

The advantage welded coating is that they can be applied to the surface of the boiler tube as well as in a shop, without the usual penalties. However, selection of proper weld alloys and control of the weld overlay process condition are critical to producing coating with the desired properties.

8.4 Thermal Spray Coating Process

There are several different processes used to apply a thermal sprayed coating.

They are:

- Plasma spray
- High velocity oxy-fuel spray (HVOF)

8.4.1 Plasma Spray

The principle of plasma spraying is shown schematically in Figure 8.2. A high frequency arc is ignited between an anode and a tungsten cathode. The gas flowing through between the electrodes (i.e., He, H_2, N_2 or mixtures) is ionized such that a plasma plume several centimeters in length develops. The temperature within the plume can reach as high as 16000° K. The spray material is injected as a powder outside of the gun nozzle into the plasma plume, where it is melted, and hurled by the gas onto the substrate surface. For specialized applications, a variant of the process is to plasma spray in a controlled, low pressure atmosphere. In contrast to coating in air (atmospheric plasma spraying, or APS), the melted particles oxidize far less with vacuum plasma spraying (VPS), resulting in coatings of considerately higher quality.

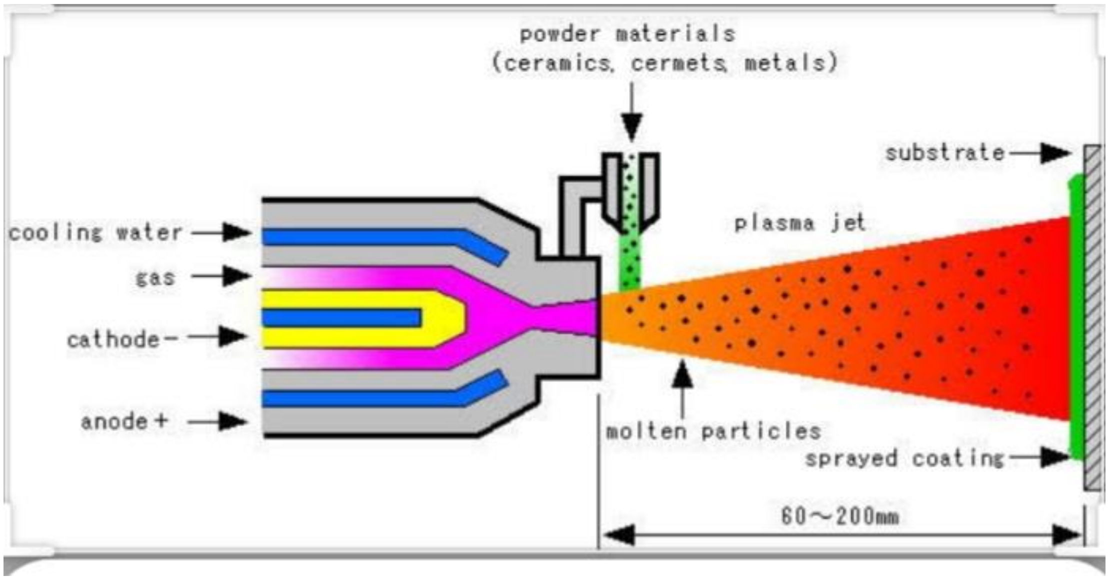

Figure 8.2 Schematic diagram of the plasma spray process

8.4.2 High Velocity Oxy-Fuel Spray (HVOF)

The high velocity oxy-fuel spray (HVOF) process is a relatively recent addition to the family of the family of thermal spray processes. As it uses^ a supersonic jet, setting it apart from conventional flame spray, the speed of particle impact on the substrate is much higher, resulting in improved coating characteristics. The mechanism differs from flame spraying by an expansion of the jet at the exit of the gun. Fuel gases of propane, propylene, acetylene, hydrogen and natural gas can be used, as well as liquid fuels such as kerosene.

8.5 Experimental Details

- Ni-20Cr coatings were obtained on the boiler tube steels through plasma spray
- Process. Ni-Cr-Al-Y was used as a bond coat before applying Ni-Cr coatings. These coating were subjected to SEM studies along the surface and across the cross-section.
- Oxidation behavior of these uncoated and coated steels has been evaluated in air at 900°C under cyclic studies. XRD, SEM/EDAX and EPMA analysis techniques have been used to characteristics the coatings and to identify the oxidation products. The coating has indicated good resistance to oxidation at 900°C in air under cyclic conditions. Oxidation resistance was more when GrAl steel was the substrate and minimum in case of T22 steel.
- The internal oxidation, cracking of scale and sometimes even cracking of coating has been observed.
- The concept of placing a protective barrier between materials and their environment is so ancient that it origin is lost in the mist of history.
- As can be expected with a concept so old, its materials, methods and qualifications are numerous and diverse.
- Advances in materials performance require the development of composite systems, of which coated materials are one form. Abrasion and corrosion resistance of components can be greatly increased by protective coatings and this is a growing industry of considerable economic importance.
- Although protective surface treatments are widely used at low temperatures.

- Yet the use of these at elevated temperature is more recent. Current high temperature applications are limited largely to the aerospace industry. An enormous challenge exists now to develop and apply these techniques to other high temperature applications, such as in process industries and diesel engines. The purpose is to provide enhanced protection over that afforded by the oxide scale formed naturally in the particular corrosive environment. Several factors influence the selection of a surface treatment, both in terms of composition of the layer and technique of application.
- Maintenance costs for replacing broken pipes in some installations are very high and can be estimated at up to 54% of the total production costs.
- One possible way to attack these problems is the use of thin anti wear and anti-oxidation coatings. With good thermal conductivity, such as plasma sprayed nickel based or iron based and chromium-nickel based alloyed coatings.
- Thermal spray coatings are used widely to protect alloy substrate against high temperature corrosion and erosion.
- Plasma spraying is gaining importance in many critical areas of application. The main advantage of plasma spray technique is that it enables a whole range of materials including metals and alloys to be plasma sprayed on to a great variety of substrate types and geometries [12-14].
- It is most widely used technique to prepare composite structural parts providing required mechanical strength properties as well as inhibition of oxidation and other corrosive degradation processes.
- The oxidation behavior of plasma sprayed coatings was studied by Higueraetal with an aim to reduce maintenance cost and down time at power generating plants. Protective coatings are being used on structural

alloys in energy conversion and utilization systems to protect their surface from oxidation and erosion.

- Almost any material can be used for plasma spraying on almost any type of substrate. This flexibility is probably one of the major reasons for the rapid expansion of this technology.
- Applications for plasma spraying include formation of corrosion, temperature and abrasion-resistant coatings. It also helps in production of monolithic and near net shape/coatings and also incorporate the advantages of the rapid solidification process.
- Alloys that are developed for heat and oxidation resistance typically form a protective layer of chromium or alumina. The more rapidly this layer is established, the better protection if offered.
- As this layer grows or as it reforms over areas from which the original layer was removed, it must withdraw chromium or aluminum from the metal in order to provide for further scale growth.
- Link et al have carried out studies exposing pure nickel, Ni-20Cr and Ni 30Cr alloys to conditions of erosion and corrosion simultaneously at 700°C and 800°C.
- The exposures were made using normal impact of an air steam loaded with 20 (am alumina. According to them under erosion corrosion, the erosive stream prevented the formation of a continuous layer of chromia by removing the oxide faster than it could spread laterally. So they have established that it would be difficult for protective scales to from in the presence of erosion and oxidation behavior of an alloy cannot be used as a guide to its resistance to erosion-corrosion.

- The oxidation behavior of Ni-20Cr foils of 100- and 200-u.m thickness was studied in air between 500 and 900°C by Calvarin et al [17]. They observed that scale formed at all temperatures was complex with an outer NiO layer having columnar grains and an inner %temperatures (500 and 600°C) the chromium content was insufficient to form a continuous Cr2O3 layer while such a continuous Cr2O3 layer could get formed at the interface at oxidation temperatures of 700 to 900°C.
- The observation of no significant differences between the oxidation behavior of thin strips and thick materials is related to the limited exposure times of the study.
- An attempt had been made to apply Ni-20Cr coating by plasma spray process on the surface of the substrate. These plasma spraying coatings have been characterized. Cyclic Oxidation behavior of these coatings has been studied at 900°C in air. X-ray diffraction analysis (XRD), SEM, EDAX and EPMA techniques are used to identify the coatings and oxidized samples.

8.6 Development of coatings

Low carbon steel ASTM-SA210-Grade Al (GrAl), ICr-0.5Mo steel ASTM SA213- T-11 (Tll) and 2.25Cr-Imo steel ASTM-SA213-T-22(T22) were used as base steels. Composition of these steels is shown in Table 8.3.These steels are used as boiler tube materials in some power plants.

Table 8.3 Chemical composition (Wt%) for various boiler steels used in present study

Types of steel	C	Mn	Si	S	P	Cr	Mo	Fe
Grade	0.27	0.93	0.1	0.058	0.048	-	-	Bal
T-11	0.15	0.3-0.6	0.5-1	0.03	0.03	1-1.5	0.44-0.65	Bal
T-22	0.15	0.3-0.6	0.5	0.03	0.03	1.9-2.6	0.87-1.13	Bal

Samples were plasma spraying 40kw Miller Thermal Plasma Spray Apparatus available with Anode Plasma Ltd. Kanpur (India) was used to apply the coatings. Argon was used as powder carrying and shielding gas. All the process parameters including the spray distance were constant throughout coating process. Ni-20Cr-10Al-iY powder was used as a bond coat around 150 µm before applying the final Ni-20Cr coating. After bond coat Ni-20Cr coating approximately 200 µm was applied and the process conditions were as reported in Table 8.4.

Table 8.4 Parameters of argon shrouded plasma spray process

Arc Current (A)	700
Arc Voltage (v)	35
Powder flow rate(rev./min)	3.2
Spraying distance(mm)	90-110
Plasma arc gas(Argon)(Psi)	59
Carrier gas (Psi)	40

8.7 Oxidation Studies in Air

The cyclic oxidation studies for coated and uncoated samples were conducted in air 900ºC for 50 cycles each cycle of I hour heating at given at temperature followed by 20 minutes cooling at ambient conditions. The base metal specimens were mirror polished before oxidation and the coated sample were also subjected to wheel cloth polishing before studies. The samples were examined critically at the end of each cycle and subjected to weight change measurements. The Electronic Balance machine Model CB-120 (Contech, India) with a sensitivity of 1mg was used to measure the weight change values. The spalled scale was also incorporated to the weight change values. Efforts were made to understand the kinetics of corrosion.

Average scale thickness (mm) and parabolic rate constants (Kp) of substrates and coatings exposed to cycle oxidation in air at 900ºC. Table 8.5 refer the coating thickness of Ni 20Cr in plasma coating.

Table 8.5 Coating thickness of Ni 20Cr in plasma coating

Environment	Scale thickness (mm)			Kp (10^{-8} g^2 $cm^{-4}s^{-1)}$		
Type of steel	Gr Al	T11	T22	Gr Al	T11	T22
Uncoated	1.667	0.879	0.700 Scale spalling	26.171	15.908	21.992
Plasma Coated	0.522	0.551	1.306	0.312	0.944	-

8.8 Calculation

Loss of coast while puncture take places rectification time 24 hours.

Loss of unit	= 210 Mw
	= 210 x 1000 kw
	= 210000 unit/hr
Approximate selling price	= Rs.5 per unit
	= 2100000 units/hr x 24 hrs x Rs.5
Total cost	= Rs.25,200,000/day

Oil consumed one light up after shutdown

Approximate	= 40kL
	= 40,000 L
Cost of 1 litre	= Rs.50/-
Approximate oil loss cost	= 40,000 x 50
	= Rs.20,00,000/shutdown

Economizer coil coating area calculation

Economizer coil length	= 8035 mm
Dia of tube	= 44.5 mm
Thickness	= 5 mm
Coil upper and lower bank coil	= 8.035 m x 0.0445 x 1.57 x 2 tubes x 2 boilers
	= 2.2456m$^{2/}$coil
	= 2.246 x 143 coils
	= 321.10 = 321 m^2

Water wall tube coating area calculation

Water wall tube coating area = 63.5 x π/2 x 1 meter x 20 tubes x 56 location

= 0.0635 x 1.57 x 1 x 20 x 56

= 111.6584 m^2 = 112m^2

Total = 321 + 112 = 432m^2

Cost of coating :

Material cost

Approximate cost Ni 20 Cr = RS. 4648/kg

1 kg metal powder can be used for = 0.43m^2 coating with thickness of 2.99

Take labor cost = 25% of metal cost

Therefore, cost for coating 0.43m^2 = 4648 + 25% of 4648

= 4648 + 1162

= Rs.5810/m^2

Approximate metal powder cost 1 kg = Rs.4648/-

Approximate metal powder requires for economizer coil

Cost of coating per m^2 = (5810/0.43) x 1

= 13511.6 = 13512/m^2

Cost involved for coating of

Economizer coil 143 number = 321 m^2 x Rs.13512 m^2

= Rs.43,37,352/-

Cost involved for coating

Water wall tube = 111.658 x 13512/m^2

= Rs.15,08,728.3008 = 15,08,729

Approximate total cost = Economizer coil cost + Water wall tube cost

= Rs.43,37,352 + Rs.15,08,729

= Rs.58,46,081/-

Conclusion :

Amount of savings = Total loss due to one shutdown – Total investment of coating

= Rs.2,52,00,000 – Rs.58,46,081

= Rs.19,35,39,199/-

Payback period

Based on previous records three shutdown/year on boiler tube failure due to erosion.

Total loss due to failure = 2,52,00,000 x 3 times

= Rs.7,567,00,000

Therefore, newly proposed expenditure= Total expenditure / Total loss

= Rs/58,46,081 / Rs.7,56,00,000

= 0.077 yrs x 12 months

= 0.93 ≈ 1 month

CHAPTER 9

CONCLUSION

Our project discuss on the major remedies which is reduce the tube failure in Mettur thermal power station. From the tube failure data we conclude that the four major reasons for the tube failure is flue gas erosion, fly ash erosion, steam erosion and falling slag erosion. Based on the result we obtained us suggested Nickel-chromium (Ni-20Cr) coatings could be obtained by plasma spray process successfully under the given parameters on boiler tube steels (Gr Al, T11 and T22). A flue gas velocity is 9 m/s which would considerably reduce the tube failure due to flue gas erosion. The usage of nickel chromium as tube material for the boiler tube provides extended tube life is better creep and strength. The loss of power generation and cost of repair for boiler tubes can be reduced. The failure due to flue gas erosion is reduced if coatings such as Ni 20Cr deposited outer metallic coating by using plasma spray coating or applied on the boiler tune surface the above remedies is implemented in power plans not only reduce the tube failure, but also reduce the repair cost of tubes and less interruption in power generation. The general suggestion to reduce the failure is to use low ash cone it will reduce the erosion rate and also reduce the major tube failure problems the future presence several challenges with expected tightening electric marking likely to increase the cost of tube failure coming at the tie when the number of failure is expected to rise.

CHAPTER 10

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