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Boiler Tubes Failure: Causes and Remedies a Case Study of a Fertilizer Plant

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ABSTRACT: The boiler tube failure is occurring frequently in fertilizer plants, power plants, sugar manufacturing plants, paper manufacturing plants and all industries using boilers. The present study is related to the boiler tube failure analysis of three Boilers which are under operation at National Fertilizers Limited Naya Nangal. Frequently occurring boiler tube failure gave the reason to diagnose the reasons responsible for failure and to provide the solutions in the interest of Nation. In this research the coal samples were taken and tested in the laboratory then the combustion process of boiler was analyzed. The various boiler parts materials characteristics were analyzed. The previous job history cards were reviewed for identification of frequent boiler tubes failure problems. The nondestructive testing images were reviewed for detecting internal failure and their propagation. The mechanical properties of boiler tube material have been tested at the section of failure, which gave significant clue for preventive maintenance. The remedial measures and precautions were taken in the method of coal firing, quality of water and operation of plant.

Keywords: Fuel ash corrosion, Fluidized Bed Combustion, Non Destructive Testing,

I. INTRODUCTION

Unexpected boiler tube failure is the major factor causing unreliability in utility boilers. Boiler tube failure is the major cause of unscheduled shutdowns in the coal fired boiler plants, which is responsible for production loss. There are many factors responsible for boiler tube failure like, short time overheating, long time overheating, creep, thermal fatigue, mechanical overload, corrosive fatigue[1,2], Solid particle erosion of metals and alloys at elevated temperature is a loss of materials during repetitive impacts of solid particles, and is one of the primary reasons for the damage of components used in the energy production and utilization industries such as coal gasifiers, fluidized bed combustors, steam turbine, gas turbine and compressor blades[3]. To estimate the remaining life of power plant boilers which have been in use from long time is highly demanded for economy and safety reasons. In India there is a great demand as some power sector boilers are older than twenty years. In real life both premature retirement and life extension (in relation to design life) can be encountered. The decision for retiring a component is not purely technical but also one of economics and safety [4]. The present study is related to the boiler tube failure analysis of three Boilers which are under operation at National Fertilizers Limited Naya Nangal. The stem generation plant consists of three boilers, which are in operation since 1970.

Frequently occurring boiler tube failure gave the reason to diagnose the reasons responsible for failure and to provide the solutions. The attempt has been made to diagnose the responsible causes.

II. OPERATING CONDITIONS

The environmental conditions and other parameters are:
1. Ambient temperature is 50˚C
2. Temperature of operation 1000˚C
3. Height of Tube 36 meters
4. Time period in use 32 years
5. Speed of fly ash 20 to 25 m/s
6. Make: BHEL

III. BOILER PARTS MATERIAL

The boiler parts material presently in use at NFL Naya Nangal is as:

Sr No.	Name of Part	Material	Dimensions (Out Side Diameter X Wall Thickness) in mm
1	Super Heater Tubes	SA 213 T-22	54.0×9.0 mm
2	Economizer Tubes	SA 210 GR-AI	31.8×4.5 mm
3	Import Steam Super Heater Tubes	SA 213 T-11	44.5×4.0 mm
4	Bank Tubes	SA 192	50.0×4.5 mm

IV. CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES

Sr No.	Material	Composition	Mechanical Properties	Method of Manufacturing
1	SA 210 GR-AI	C-0.20%, Si-0.17%,Mn-0.63%, P-0.014%, S=0.022,	Yield Stress 26.0 Kg/mm^2, Tensile Strength 42.2 Kg/mm^2, % elongations 30% BHN-143	Seamless steel tubes, cold drawn, Heat treated
2	SA 213 T-11	C-0.12%, Si-0.33%,Mn-0.49%, P-0.007%, S=0.004, Cr-2.23%, Mo-1.00%,	Yield Stress 49,500 Psi, Tensile Strength 76,800 Psi % elongations 30% BHN-156	Seamless steel tubes, hot finished, Normalized at 910°c and tempered at 710°c (54.0×6.0) mm
3	SA 192	C-0.10%, Si-0.17%, Mn-0.43%, P-0.016%, S=0.012, N-0.0050%,	Yield Stress 38,120 Psi, Tensile Strength 56,470 Psi % elongations 65% BHN-108	Seamless steel tubes cold drawn, Annealed (65.5×5.6) mm

V. COAL SAMPLES

Coal samples have been tested in the laboratory, following observations were made:

IM% w/w	1.04
Volatile Matter %w/w	16.02
Ash %w/w	47.95
Fixed Carbon %w/w	34.99
Gross Calorific Value cals/gm	3844
Net Calorific Value cals/gm	3699

Case-I: Plant SGP (Mech), Section: Boiler-I Date: 15.09.2005

Observations of Import Steam Super Heater Tube Leakage

On 15.09.2005 coil no 1 from south side of ISSH reported leakage [5] on the bottom tube just above the economizer of this coil in segment-B. During analysis, it was found that failure occurred because of erosion caused by ash passing between this tube & skin casing. Around one meter length of the tube had severe thinning because of this erosion. Also the tube just above this tube in the same coil had severe thinning. Then the coil was plugged with alloy steel taper plugs on both the headers using E-8018 electrodes.

Cause

Superheater Fireside Ash Corrosion resulted in external tube wall loss and increasing tube strain. Tubes commonly have a pock-marked appearance when scale and corrosion products are removed. Fireside ash corrosion is a function of the ash characteristics of the fuel and boiler design. It usually is associated with coal firing, but also can occur for certain types of oil firing. Ash characteristics are considered in the boiler design when establishing the size, geometry and materials used in the boiler. Combustion gas and metal temperatures in the convection passes are important considerations. Damage occurs when certain coal ash constituents remain in a molten state on the superheater tube surfaces. This molten ash can be highly corrosive

Fig. 1. Import Steam Super Heater Tubes of Boiler-I SGP NFL Naya Nangal.

Case-II: Plant SGP (Mech), Section: Boiler-I Date: 10.11.2005

Failure Observation of Economizer

On 10.11.2005 water leakage was detected in the economizer tubes in the south east side of the coils [5]. The boiler was shut down for maintenance. After opening the manhole & entering the economizer top following observations were recorded: 25^{th} coil, 2^{nd} loop top SN between segment C&D is having 3mm diameter hole and also eroded 3 inch in length. Due to the impingement of the above leaky coil on coil No 24.first loop bottom length all around & 4 inch in length was found heavy reduction in thickness. NDT testing of surrounding tubes was done and reduction in thickness was observed.

Cause. Aggressive localized corrosion and loss of tube wall, most prevalent near economizer feed water inlet on operating boilers. Flooded or non-drainable surfaces are most susceptible during outage periods. Oxygen pitting occurs with the presence of excessive oxygen in boiler water. Non-drainable locations of boiler circuits, such as super heater loops, sagging horizontal super heater and reheater tubes, and supply lines, are especially susceptible. More generalized oxidation of tubes during idle periods is sometimes referred to as out-of-service corrosion. Wetted surfaces are subject to oxidation as the water reacts with the iron to form iron oxide. When corrosive ash is present, moisture on tube surfaces from condensation or water washing can react with elements in the ash to form acids that lead to a much more aggressive attack on metal surfaces.

Fig. 2. Economizer Tubes of Boiler-I SGP NFL Naya Nangal.

Case-III: Plant SGP (Mech), Section: Boiler-I Date: 22.07.2008

Failure Observation of Bank tubes

Bank tubes of Boiler-I were observed to be leakage near stem drum. 3 no (2 side wall and 1 bank tube) leaked [5] in succession one after the other. When pressure testing was carried out initially side wall tube 4th in North cluster on west side of drum was found leaking. In pressure testing side wall tube 5th in the same cluster was found leaking. When again pressure testing was done 18-1 bank tube was found leaking. All these were plugged in both steam drum and the mud drum of the boiler no I and DPT of the root of each tube was done. Adjoining tubes in the same areas were also scanned for pinhole by grinding, DPT and then welding. Welding electrode used was 7018 2.5 mm, plug size 41.0×44.0×60.0mm

Cause. Fireside ash corrosion is a function of the ash characteristics of the fuel and boiler design. It usually is associated with coal firing, but also can occur for certain types of oil firing. Ash characteristics are considered in the boiler design when establishing the size, geometry and materials used in the boiler. Combustion gas and metal temperatures in the convection passes are important considerations. Damage occurs when certain coal ash constituents remain in a molten state on the water tubes and super heater tube surfaces. This molten ash can be highly corrosive.

Fig. 3. Bank Tubes of Boiler-I SGP NFL Naya Nangal.

Case-IV: Plant SGP (Mech), Section: Boiler-II Date: 3.10.2005

Failure Observation of Bank tubes leakages

Leakage was observed in boiler no 2 in bank tube south side and steam leakage was observed in the north side near ISSH. Manhole cover of ISSH and economizer were opened and observations are 8th row (W-E) and tube No 4(N-S) in the north cluster were completely open [5]. Skin casing was cut and removed and observed that leakage was at the outlet of the steam drum. This leakage had also damaged the 7th tube in the same cluster due to impingement of water. After scanning the tube it was decided to plug the tubes ends.

Cause. Failure of the first tube was contributed to the leakage travel between tube outer diameter and tube sheet internal diameter. The small pinhole in the weld joint is responsible for the leakage of the other tubes. The photographs of the damaged tube are given below. Stress corrosion cracking failures were observed as in a thick wall, brittle-type crack at location of higher external stresses, such as near joints was observed. These failures are associated with austenitic super heater materials and can lead to either transgranular or intergranular crack propagation in the tube wall. It occurs where a combination of high-tensile stresses and a corrosive fluid are present. The damage results from cracks that propagate from the ID. The source of corrosive fluid may be carryover into the superheater from the steam drum or from contamination during boiler acid cleaning if the superheater is not properly protected

Fig. 4. Plugging of Bank Tubes of Boiler-II SGP NFL Naya Nangal.

Case-V: Plant SGP (Mech), Section: Boiler-II Date: 15.11.2006

Failure Observation of Bank tubes leakages

Bank tube leakage in boiler -2 was observed as water was coming out from the tubes, plant was shut down and investigation was done. After cutting skin casing of the taper portion the observation were made are: water was coming from the root of the 4^{th} tube in 6^{th} row from west side in the north cluster [5]. Cracks in the tube were observed which are irreparable and this tube as plugged from the ends. DPT after grinding was done of nearby tubes for any leakage and found satisfactory.

Cause. Tube damage was occurred due to the combination of thermal fatigue and corrosion. Corrosion fatigue was influenced by water chemistry and boiler water oxygen content in the boiler water during operation. The Combined effect leads to the breakdown of the protective magnetite on the ID surface of the boiler tube. The loss of this protective scale exposes tube to corrosion.

Fig. 5. Bank Tubes of Boiler-II SGP NFL Naya Nangal.

Case-VI: Plant SGP (Mech), Section: Boiler-III Date: 20.11.2005

Failure Observation of Economizer leakage

On 20.11.2005 when boiler no 3 was running hissing sound was noticed from Northeast side of economizer and leakage in the coils were detected and water was leaking out before E.P. duct. After cooling down the manhole cover of economizer & ISSH were opened and found the leakage in extreme north bottom. the observation are that bottom loop N-S in the segment was found leaking and having 3 mm hole, moreover the coil was totally eroded over 3 meter in length and its thickness was reduced to 2.5 mm.

Cause. Economizer tube leakage was occurred due to superheater fireside ash erosion and corrosion. Fireside ash corrosion is a function of the ash characteristics of the fuel and boiler design. It usually is associated with coal firing. Ash characteristics are considered in the boiler design when establishing the size, geometry and materials used in the boiler. Combustion gas and metal temperatures in the convection passes are important considerations. Damage occurs when certain coal ash constituents remain in a molten state on the superheater tube surfaces. This molten ash can be highly corrosive and eroded the surface of boiler tubes. The Combined effect leads to the breakdown of the protective magnetite on the ID surface of the boiler tube. The loss of this protective scale exposes tube to corrosion.

Fig. 6. Thickness Reduction due to fly ash Boiler-III SGP NFL Naya Nangal.

VI. CONCLUSIONS

There are many reasons due to which the failure of boiler tube occurs some are Caustic Attack, Oxygen Pitting, Hydrogen Damage, Acid Attack, Stress Corrosion Cracking (SCC), Waterside Corrosion Fatigue, Super heater Fireside Ash Corrosion, High-temperature Oxidation, Water wall Fireside Corrosion, Fireside Corrosion Fatigue, Short-term Overheat, Long-term Overheat, Graphitization, Dissimilar Metal Weld, Erosion and Mechanical Fatigue. There may be some other reasons depends upon the service conditions but we can diagnose the reason in advance by visual inspection and NDT techniques which can save the production loss of the industry and increase the safety of workers.

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