Boiler Tubes Overheating Failures and Actions to Control Them

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Abstract—Boiler tube failures continue to be the leading cause of forced outages in fossil-fired boilers. To get your boiler back on line and reduce or eliminate future forced outages due to tube failure, it is extremely important to determine the specific root cause. One of the main reasons for boiler forced outages is boiler tube leakage. The plan was to carry out for experimental investigation and analysis of the boiler tube failure, and then strategy is to implementation of plan with different power plants and failure techniques until it was considered effective. This paper aims to covers the major reasons of Boiler tube leakages and effective design considerations and recommended suggestions to avoid the same. Failure analysis methodology is applied to the principal mechanisms by which boiler tubes fail during service. Several important factors often associated with component failures are deficiency in design, fabrication, operating conditions and expended useful life.

Key words: Boiler Tubes Failure, Boiler Tubes Overheating Failures

I. INTRODUCTION

The operation of a boiler is a dynamic balance between heat flow from the combustion of a suitable fuel and either steam formation within the furnace or steam super heating within the superheater or reheater. In effect, the steel tube is "heated" by the flame or hot flue gas and simultaneously "cooled" by the fluid (steam, water or a mixture of steam and water) flow. When this balance is maintained within the design limits, metal temperatures are also maintained within design parameters. However, when the balance is upset, metal temperatures rise and failures occur sooner than expected. Depending on the relative temperature rise, failures can occur either very quickly, that is, in a matter of minutes; or over a much longer time period, that is, in matter of many months. For convenience these two regimes are defined as "long term" and "short-term" overheating. This article will discuss on these high-temperature failures. [1]

II. SHORT TERM OVERHEATING

The simplest explanation for all "short-term" overheating failures is: when the tube metal temperature rises so that the hoop stress from the internal steam pressure equals the tensile strength at elevated temperature, rupture occurs. For example, in a super-heater of SA192 tubes, with a designed metal temperature of 800°F, the ASME Boiler and Pressure Vessel Code gives the allowable stress at 800°F as 9,000 psi. If the tube-metal temperature should rise to a temperature of around 1300°F, the hoop stress would be equal to or slightly greater than the tensile strength at 1300°F, and failure would occur in a few minutes.[2]

In a superheater or reheater, DNB-departure from nucleate boiling cannot occur as only steam super heating takes place, no boiling. However, short-term overheating failures do occur but usually during start-up. Boiler operational problems that can lead to these short-term high-temperature failures include, among others:

- Flame impingement from misaligned or worn burners that leads to the formation of a steam blanket, as the local heat flux is too great for the fluid flow through the tube.
- Blockage of a superheater tube with condensate or foreign material that prevents steam flow. These problems are more frequent during start-up.
- Reduced flow in either a water or steam circuit that leads to inadequate cooling. Pinhole leaks, especially at poor welds or slag falls, severe dents from slag falls or ruptured tubes, and partial blockage from debris or other foreign matter are some of the more obvious causes.
- Foreign objects, broken attemperation- spray nozzles, for example, in headers that partially block a superheater or reheater tube.[3]

Regardless of the location within the boiler that these failures occur, the appearance is similar. There is a wide-open burst with the failure edge drawn to a near knife-edge condition, and the length of the opening four or five tube diameters. These failures display considerable ductility: the thinning at the failure lip may be more than 90% of the original wall at the instant of rupture. The microstructures throughout the failure will usually indicate, in the case of ferritic steel, the peak temperature at the time of failure. For ferritic steels there is a transformation from ferrite and iron carbide or pearlite, to ferrite and austenite. This temperature is referred to as the lower-critical transformation temperature and occurs at 1340°F or higher, depending on the exact alloy composition.[4]
Ductile failures can also occur at normal operating conditions but are not as high-temperature failures. Wastage of a tube from corrosion or erosion can reduce the wall thickness, which, in turn, raises the hoop stress. Such failures occur in waterwall tubes, for example, where sootblower erosion has reduced the wall thickness, or in the convection pass from fly-ash erosion. These failures can occur at normal operating temperatures if the wall thickness reduction is sufficient. While these microstructures and the estimated peak temperature at the time of failure cannot predict the sole cause of the failure, the metallurgical analysis can suggest the kind of boiler-operational problem that is likely to be the cause of the rupture.[5]

III. LONG TERM OVERHEATING

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 seen in steam cooled tubes like superheaters and reheaters and in water cooled tubes of waterwalls. These tubes are of various sizes and thicknesses depending upon the pressure and the mid-wall metal temperature. When the mid-wall metal temperature exceeds the allowable metal temperature of the tube material, overheating sets in. When the metal temperature of the tube exceeds the allowable limit the material strength reduces drastically, depending upon the material composition.

During this period of long term overheating the tube outer surface develops bulging, creeping elongate fissures along the axis of the tube. There will be little or no wall thickness reduction in the non-blistered area. These are the typical identifiable signs of long term overheating. These failures are also called as high temperature creep failures. Areas in boilers prone for long term overheating are waterwalls and superheaters.

Waterwalls normally, due to internal deposits and partial choking of the tube internally, are subjected to long term overheating. Superheaters are subjected to high desuperheating, higher radiant heat fluxes in the region, and lower grade material at transition points. Reheaters are also prone for long term overheating, but not so much like superheaters. This can happen due to many reasons like internal deposit, low flow though the tube due to partial choking of the tube internal diameter, due to sudden load raise, due to sudden fuel input, etc.[6]

Long term overheating failures can occur in tubes throughout the boiler. The following can be causes of this mechanism of failure:
- Blockage by debris, scale, or deposits restricting flow.
- Excessive magnetite on the internal surfaces has an insulating effect. This can cause over-firing of the furnace, subsequently increasing metal temperatures.
- Exposure to radiant heat or excessive gas temperature due to blockage of gas passages or are located before the final outlet header.
- Incorrect material selection relative to the design operating temperatures.
- Have higher stresses due to welded attachments or insufficient support.[7]

IV. ACTIONS TO BE TAKEN TO PREVENT & CONTROL Boiler Tube FAILURES

During overhauling of Steam Generator, Internal Washing of passes should be carried out so that proper scanning of tubes can be carried out.

Intensive 'D' metering of boiler tubes at pre-determined locations to be carried out & comparison with respect to last overhaul should be done, especially in wear prone areas.

The limit of 20% reduction in thickness due to fly ash erosion must be adhered to, for replacement of worn out portion of boiler tubes.

DPT of attachment welds should be carried out, especially in Pent House.

100% radiography of weld it’s during overhaul & also during tube failure repair is to be carried out.

Platen S/H, R/H & Final super heater Coils must be checked for overheating during over hauling. During operation of units, the metal temperature excursions in above area should be avoided and monitored by Operation Department and should be discussed in daily Planning meeting.

For determining the fire side corrosion and internal corrosion of furnace tubes, samples from each corner of furnace must be sent to R & D in each unit overhaul. [8]

V. CONCLUSION

In conclusion it may, therefore, be said that overheating is one of the major reasons responsible for the failure of boiler tubes, carbon steel tubes and final superheater tubes respectively. Analysis of large database clearly indicates that irrespective of operating temperature and pressure to which the boiler tubes are exposed as well as loss of wall thickness due to the corrosion oxidation and erosion processes in service, modified steel exhibited the longest life/resistance to creep damage. The next candidate material recommended for such operating condition is another variation of steel up to a mid wall temperature beyond which steel shows longer creep life.

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