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A VIEW FROM THE PENTHOUSE: USEFUL INFORMATION FOR THE WORLD OF BOILERS

WATERWALL PROBLEMS-WATERSIDE

There are seven principal problems in waterwall tubes that originate on the waterside.

1. Oxygen pitting
2. Corrosion fatigue
3. Acid-cleaning corrosion
4. Hydrogen damage
5. Caustic gouging, and
6. Phosphate corrosion
7. Creep failures as a result of thick, waterside deposits.

The problems that occur most frequently are oxygen pitting, hydrogen damage and corrosion fatigue. The others, while serious when they occur, do not occur as often. Unfortunately, all waterwall problems are not limited to a tube location or individual circuit but are wide-spread.

All, with the exception of acid-cleaning corrosion, are related to upsets in boiler-water chemistry control. Acid-cleaning corrosion occurs at low pH, i.e., during the acid cycle of the chemical cleaning process, and leaves the ID surface roughened, or in the extreme, filled with shallow pits. To prevent corrosion of the boiler tubes during chemical cleaning, an inhibitor is added to the cleaning solution. Corrosion occurs when there is poor control of the inhibitor concentration or the inhibitor breaks down and loses its effectiveness because of too high a temperature.

The loss of control of the boiler-water chemistry can lead to the other six corrosion problems. Oxygen pitting develops only when there is a combination of moisture and oxygen. The most frequent time of attack is during shutdown periods when the boiler has been incompletely dried of condensate and then opened to the atmosphere. During operation, usually during a start-up, when oxygen levels have not stabilized within the control range, oxygen pits may form, principally within the economizer as it is, in effect, the final purification stage in the water-treatment control scheme. The iron oxide thus formed is picked up by the boiler water and transported throughout the furnace. In the high heat-release areas, where boiling is most rapid, the iron oxide precipitates and becomes part of the waterside deposit that can lead to other problems.

Corrosion fatigue occurs in those regions of the furnace where there is the highest local stress, often at the waterside of buckstay attachment clips, or at the waterside of membrane welds surrounding sootblower openings, and burner and windbox attachments. The combination of a local stress and the presence of excessive oxygen leads to the damage. It has sometimes been referred to as stress-enhanced or stress-assisted corrosion. It may also be viewed as a corrosion condition that occurs under constant stress but a variable oxygen concentration. The damage usually occurs during start-up, before the oxygen concentration has been established within the control range.

Hydrogen damage occurs under thick corrosion deposits, usually but not always under acidic or low pH boiler-water conditions. The acid reacts with the boiler steel to form iron ions and hydrogen as the corrosion products. The hydrogen atom is trapped between the thick deposit and the steel. Hydrogen being a small atom easily diffuses into the steel where it reacts with iron carbide to form methane and ferrite. The methane collects at the ferrite grain boundaries; and when the pressure is high enough, intergranular cracks develop. The microstructure of hydrogen-damaged furnace tubes will have two characteristic features, inter-granular cracks and decarburization. Hydrogen-damage fractures tend to be thick-lipped, low-ductility ruptures, sometimes without excessive tube wastage.

Caustic gouging is a problem similar to hydrogen damage in that the corrosion wastage may develop under waterside deposits. Caustic gouging is usually, but not always, associated with excessive hydroxide concentrations which allow high caustic concentrations in those regions of the furnace where boiling occurs most rapidly. As steam bubbles form, the hydroxide that was in the water that is now a steam bubble is left behind within the porous deposit, as the hydroxide is insoluable in the steam. This phenomena is sometimes called "wick boiling" and the deposit becomes a "sponge" filled with caustic. Local concentrations of hydroxide can lead to pH values that are strongly basic, 12 or 13 or more. The concentrated hydroxide dissolves the protective iron oxide and then dissolves the steel. The appearance of caustic-gouging corrosion tends to be smooth, bathtub-shaped holes that in the extreme can cover the entire ID surface of the tube where boiling occurs.

The presence of thick, waterside deposits act as a barrier to heat transfer from the flame to the boiling water, the net effect is to raise tube-metal temperatures. Phosphate corrosion is one consequence of the high metal temperature. At high concentrations of mono- or disodium phosphate, a corrosion product of sodium iron phosphate will form in high-pressure boilers. The iron comes from the steel tube and results in tube wastage.

A second consequence of these waterside deposits that raise tube-metal temperatures is the development of creep or stress-rupture failures. The normal operating temperature of a furnace tube in the highest heat-flux region is in the neighborhood of 750°F. The formation of a waterside deposit several-mils thick can raise the tube-metal temperature by 150°F, or into the creep-rupture range for carbon steels. The microstructures in these creep failures (and often seen in phosphate corrosion) will be spheroidized carbides and ferrite, and perhaps graphitized as well, proof that the operating temperature has been above about 850°F. Creep or stress-rupture failures are characterized by inter-granular creep damage and thick-lipped rupture edges.

On occasion the tube failure will contain both hydrogen damage, intergranular cracking, and decarburization along the ID, and spheroidization and intergranular creep cracking along the OD. It is a truism that the hydrogen damage occurs only along the ID surface, and creep damage occurs mainly along the OD surface.

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