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

THERMAL FATIGUE

The operation of sootblowers may lead to both erosion wastage of neighboring tubes and the development of thermal-fatigue cracks. The latter are particularly likely when the first fluid is liquid condensate from a steam system. The cold water quenches, or thermally shocks, the steel. Rapid cooling over many soot-blowing cycles results in circumferential cracks and leaks.

Thermal-fatigue occurs under conditions that combine a variable stress and elevated temperatures; those temperatures where the reaction of oxygen and steel forms iron oxide. Variable stress, or more accurately variable strain, leads to the thermal-fatigue crack formation. The sequence of events is something like: a dense, tightly bonded iron oxide forms at the operating temperature. These scales are necessary for oxidation resistance and protect the steel from further wastage, are brittle and exhibit virtually no ductility prior to crack formation. The strain fractures the protective oxide scale. This crack or fracture "short-circuits" the path between the air and the bare steel. As the scale re-forms at the root of the crack, a small cusp forms as the break in the scale is "healed" by the formation of new oxide. Continued cyclic strain will then re-crack the new scale, and the cycle continues. The resultant crack is transgranular, dagger-shaped, and oxide-filled, with a central crack down the oxide wedge; see for example Figure 1. When there are reducing conditions or unburned coal particles within the ash deposit, these scales may also contain iron sulfide. The presence of metallic sulfides is easily determined with a sulfur print.

The most common locations for thermal-fatigue crack formation are at superheater header connections and refractory-retaining lugs.

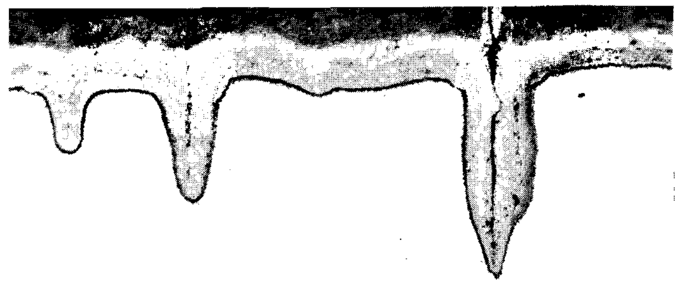

Figure 1

The differences in expansion between the roof tubes, for example, and the superheater outlet header cause a bending of the superheater tubes which, in turn, leads to thermal-fatigue cracks at the socket-weld connections. The operating temperature of the superheater outlet header is, for example, 1005°F; and the saturation steam temperature within the waterwall or roof tubes is 650°F. This 350°F temperature difference means the superheater outlet header will expand more than the waterwall tubes, the difference in expansion "bends" the tube connectors and leads to cracking.

Refractory-retaining lugs are alternately heated and cooled as the ash or refractory forms and erodes. Regardless of the location, these thermal-fatigue cracks are transgranular and dagger-like in appearance.

SOOTBLOWER EROSION

The frequency of operation of soot-blowers is somewhat variable, obviously, depending on the particular conditions within an individual boiler. Whether the soot-blowing cycle is once per shift or once per day, the real problem develops when condensate rather than steam is the first soot-blowing medium to strike the tubes. The quenching action of water on the superheater tubes will quickly lead to the formation of circumferential, thermal-fatigue cracks, as shown in Figure 2.

Figure 2

The shape of the cracks is similar, but the frequency (that is, the number of cracks per linear inch of tube) differs. This frequency is a function of the severity of the thermal strain developed by the quenching of the hot superheater or reheater tube by the liquid condensate.

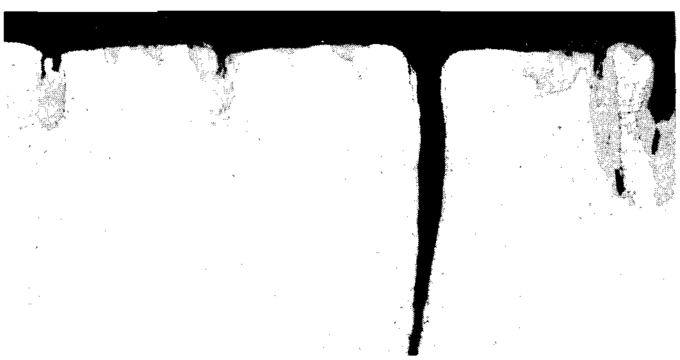

Figure 3

Figure 3 shows a cross section through the circumferential cracking shown in Figure 2, and the general shape or appearance is similar to that shown in Figure 1.

The wastage on the superheater or reheater tube as a result of sootblower use, again, is somewhat variable. The wastage on the tube shown in Figure 2 was about 10% of the wall thickness. If there is liquid coal- or oil-ash corrosion present, the molten ash constituents will be easily removed; and any soot-blower erosion will be exacerbated by the presence of rapid coal/oil-ash corrosion. Figure 4 is one such example.

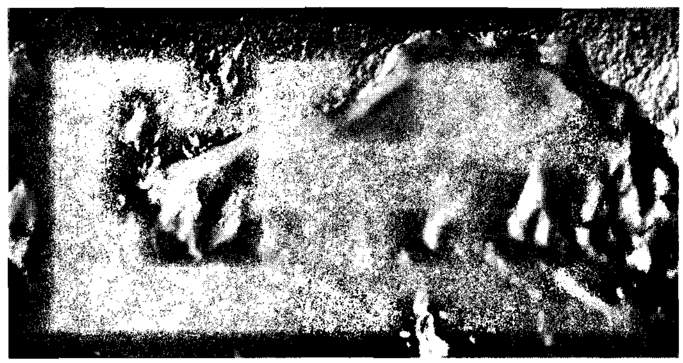

Figure 4

In this case, any thermal-fatigue cracks that would form were removed by the rapid coal-ash corrosion.

In summary, the morphology of all thermal-fatigue cracks is similar, regardless of the root cause. These cracks are dagger-shaped, transgranular, oxide- (or perhaps a mixture of oxide and sulfide) filled, and lead to thick-lipped, limited-ductility, or brittle-appearing failures. Well-developed cracks are easily identified by either ultra-sonic techniques or liquid-penetrant examination.

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