



FIRE-SIDE PROBLEMS IN SUPERHEATERS AND REHEATERS

The principle problem in superheater and reheater components may be tabulated as follows:

(1) Fuel-ash Corrosion (2) Carburization and Sulfidation (3) Soot Blower and Fly-ash Erosion (4) Thermal and Corrosion Fatigue (5) Rubbing and Fretting Damage

All steels develop oxidation and corrosion resistance by the formation of stable, tightly adherent oxide scales. The reaction of a steel tube with oxygen in the flue gas forms the iron oxide. The addition of chromium to steel, eg. T-11, T-22, T-9, and 304H austenitic stainless steel, also adds chromium to the oxide and improves the corrosion resistance. In general, the more chromium in the steel, the better the corrosion resistance; as the more chromium there is then in the oxide. Iron-chromium oxide is more adherent and more difficult to remove, hence, more protective.

Any removal of these protective oxides will increase the wastage rate. Fuel-ash corrosion occurs by the formation of low-melting-point constituents within the ash. These constituents form liquids at the operating temperature of the superheater and reheater, dissolve the protective oxide scale, and thus lead to rapid corrosion.

The mechanism is similar for refuse-, coal-, and oil-fired units. However, the liquid species are quite different. In refuse-fired boilers, chlorine (mainly from PVC plastics) creates mixtures of chlorides of many metals, principally sodium, potassium, calcium, lead, zinc, and, of course, iron, as a corrosion product. Melting points can be quite low, less than 600°F, depending on the mix. In coal-fired boilers, mixtures of sodium- and potassium- iron trisulfates are the liquid species. Depending on the sodium-potassium ratio, the melting points vary from about 1030°F to 1130°F, well within the operating temperature range of the high-temperature superheater and reheater. In oil-fired units, mixtures of sodium oxide and vanadium pentoxide or sodium sulfate and vanadium pentoxide are the culprits. Again, depending on the precise composition, the melting points in these systems may be as low as 950°F.

Reducing conditions within the convection pass exacerbate these corrosion problems. Under reducing conditions, the scales that form are not pure oxides, but mixtures of oxides and sulfides; and the oxides that do form may be less dense or more porous. In either case, the scales are less protective than the pure oxides that develop under oxidizing conditions.

The ash deposits form in a characteristic double layer; a dark (nearly black) inner layer that is tenaciously bonded to the steel, and an outer, friable layer that is a lighter color. At operating temperatures, the chlorides, trisulfates, and vanadium-pentoxide species are liquid. The strength of this liquid layer is poor. The ash will build up to the point where the weight of the ash deposit is too great, and the mixture falls off. The temperature of the now bare steel rises sharply due to improved heat transfer since there is no insulating layer of ash; and the "alligator-hide" morphology associated with fuel ash corrosion develops as a result of thermal, or more accurately, corrosion fatigue.

Under reducing atmosphere conditions, the liquid salts also promote the transfer of both carbon (from carbon monoxide or unburned fuel) and sulfur to the surface of the steel leading to carburization and sulfidation. In stainless steels, the addition of carbon to the surface reduces the corrosion resistance by the formation of chromium carbides. A similar reduction in corrosion resistance occurs in ferritic steels for the same reason, but the effects are less dramatic. In stainless steel, the addition of sulfur to the surface forms a nickel sulfide. In any event, corrosion or wastage rates rise, and failures occur sooner than expected. The use of low-Nox burners that may promote reducing conditions (low or no oxygen) within the flue gas exacerbates these conditions. The deliberate off-stoichiometric firing is designed to lower the flame temperature and thus reduce nitrogen-oxide formation. However, excessive amounts of carbon monoxide and perhaps unburned fuel will lead to both carburization and sulfidation.

Sootblower and fly-ash erosion lead to premature failures by the mechanical abrasion of the oxide on the tube surfaces. As the wall thickness is reduced, failures occur when the strength of the material becomes inadequate to contain the internal steam pressure. For steam operated sootblowers, thermal fatigue may be a component of the damage, especially as the initial soot-blowing medium may be liquid. The condensate thermally shocks the steel tubes and promotes the formation of thermal-fatigue cracks. Thermal fatigue is also associated with alignment clips and attachments. Differential expansion between neighboring tubes applies a local strain at the attachment. Slip spacers that are plugged with fuel ash and do not slip are particularly suspect. The boiler designer has acknowledged the differential expansion by the use of these slip spacers. When they do not slip, cracks form. Unexpectedly high differences in steam temperature between neighboring tubes can develop greater strains than anticipated; and even though slip spacers function properly, they may bottom out and lead to the formation of thermal-fatigue damage.

Relative motion between neighboring tubes, due to vibration for example, leads to rubbing and fretting damage. Localized wastage occurs as the protective oxides are removed mechanically; and the tube re-forms the oxide scale at the expense of tube metal. In general, the metallographic features of the failures associated with all of these root causes may be similar - that is, a creep or stress-rupture type. As the wall thickness is reduced by whatever means, the hoop stress due to internal steam pressure increases. Failures occur by high temperature creep; and thus the microstructural features would be similar, grain-boundary voids and cracks.