DAVID N. FRENCH, INC., METALLURGISTS
ONE LANCASTER ROAD
NORTHBOROUGH, MASSACHUSETTS 01532
TEL: (508) 393-3635

SUMMER 1997 VOL. XIV, No. 2

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

STEAM-SIDE PROBLEMS IN SH AND RH

There are four principal problems associated with the steam path in superheaters and reheaters:

1. Exfoliation of the steam-side oxide.
2. The reaction of steam with the steel tube to form iron oxide which acts as an insulating layer to the transfer of heat. The net effect is to raise tube-metal temperatures which both exacerbates the fire-side problems and leads to early creep failures.
3. Condensate that collects in the bottom of pendants and in sagged horizontal tubes that leads to oxygen corrosion and pitting.
4. Weld backing rings or excessive root bead penetration that leads to restricted steam flow.

1. The exfoliation of steam-side scale leads to turbine-blade erosion and loss of efficiency. When pieces of oxide spall, the larger pieces collect at the bottom of pendants; and the smaller pieces become entrained in the steam. At the bottom of the circuit, tumbling and abrasion lead to more very fine particles of oxides becoming entrained within the steam. These oxide particles then lead to turbine-blade erosion and loss of turbine efficiency. The large flakes of oxide that are too big to be moved up the pendant with the steam flow collect at the bottom. When the unit is shut down, any fine oxide particles and condensate collect. When the unit re-starts, the evaporating condensate and solid particles of scale sinter to form an immovable mass. Locally, the scale thickness build-up may approach 1/8" or more, and the deposit then acts as an insulating barrier to heat transfer. The thermal conductivity of the deposit is perhaps 5% that of the steel and hence a pretty good insulator to heat flow from flue gas to steam. The net effect is to raise tube-metal temperatures, and creep failures may occur.

The formation of these local deposits is exacerbated by cycling service. More frequent starts and stops increase moisture collection within the pendant. As the condensate evaporates, any dissolved solids within the boiler water (for example sodium phosphate used to control pH or copper from the condenser) sinters the loose collection of oxide particles into a hard, rigid mass.

2. The reaction of steam with steel forms iron oxide. The rate at which the steam-side scale develops is related to both the composition of the steel and the temperature of operation. In general for the chromium-molybdenum steels similar to T-11 and T-22, the average rate is about 1 mil/year. For the austenitic stainless steels similar to 304H, 321H, and 347H, the rate is less than half that, perhaps 1 mil every 3 or 4 years.

The increase in metal temperature as a result of the steam-side scale formation depends on several factors: the heat flux, the tube diameter and wall thickness and, of course, the thickness of the steam-side scale. The temperature increase is somewhere between 1 and 4 times the scale thickness. Thus for a superheater with a fairly high heat flux, a thickness of 15 mils may raise the tube-metal temperature between 50° and perhaps as much as 75°F. For a reheater where the heat fluxes are usually much lower, the increase is somewhat less, perhaps 25° to 50°F. In any case, the increase in tube-metal temperature will exacerbate the fire-side problems of fuel-ash corrosion and will hasten the onset of creep failures. A 50°F increase in metal temperature reduces the time for the onset of creep deformation by 85%, and a hotter tube will suffer more serious fire-side corrosion.

Both the exfoliation problems associated with turbine-blade erosion and the increase in tube-metal temperature may be mitigated by chemical cleaning to remove the scale. Scale removal may prolong the life of the superheater or reheater tube by 50 and 75% as the effective or average metal temperature is cycled between lower temperature limits.

3. In cycling boilers, steam condenses and collects either in the bottom of a pendant or in the bottom of a sagged horizontal superheater or reheater tube. When the unit is open to the atmosphere, the combination of moisture and air leads to oxygen pitting and corrosion. These problems are also more prevalent in cycling units, units frequently opened to the atmosphere.

The second potential problem with condensate blockage in pendant-style superheaters and reheaters is that a rapid start-up may lead to a short-term high-temperature failure. Failures occur before the condensate is evaporated and steam flow and steam cooling are fully established within the circuit. These failures are thin-lipped, wide-open bursts; and the microstructural transformations often indicate peak temperatures well above 1500°F.

4. The fourth problem is associated with weld backing rings or excessive root penetration at tube-to-tube butt joints. These irregularities of the ID surface lead to distorted steamflow and poorer heat transfer downstream of the weld. Poor heat transfer leads to a local hot spot, and, again, creep failures occur prematurely.

Two other more uncommon problems occur when excessive attemperation-spray water enters the tubes. As the water evaporates, the hydroxide within the boiler water used for pH control may concentrate to the point where stress-corrosion cracking will occur in ferritic steels similar to T-11 or T-22. These events are almost always associated with a damaged attemperation-spray nozzle. The attemperation spray should be a fine mist that completely evaporates within the header. A broken nozzle projects a solid stream of water that does not evaporate within the header. The liquid may then run down the superheater or reheater tubes before it ultimately evaporates.

Finally, when hydrochloric-acid solutions are used for chemical cleaning of the furnace, carryover into the superheater can occur. When the superheater contains austenitic stainless steel, eg. 304H, 321H, 347H, stress-corrosion cracking failures are inevitable. While this type of damage is unusual, it is not unheard of, and care needs to be exercised to prevent back-filling the superheater with the chemical-cleaning solution prescribed for ferritic alloys within the waterwalls.

****

****

OTHERS WHO MIGHT LIKE TO RECEIVE OUR NEWSLETTER:

NAME:______________________________________COMPANY:______________________________

ADDRESS:____

IDEAS FOR FUTURE TOPICS:____