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

UNUSUAL CORROSION FAILURES

The morphology of the corrosion damage that occurs on the water or steam side of a boiler tube depends upon several factors, among them: the local metal temperature, microstructure and state of stress, deposit thickness, the oxygen content of the boiler water, and the pH locally between the deposit and the tube metal. This latter factor can be substantially different from the bulk pH. Deposits are porous, and boiler water turns to steam within the deposit. The hydroxide that was in the water, that is now a steam bubble, is left behind within the deposit. Gradually the hydroxide concentration increases so that locally the pH can be strongly basic, pH 12 or 13 even.

Waterside deposits impede the heat transfer between the tube and the steam/water emulsion. The thermal conductivity of these deposits is much less than that of the steel; so there is much less effective cooling of the tube by the fluid. The net effect is to raise tube-metal temperatures. As the tube-metal temperature increases, so does the corrosion rate (greater wastage or wall thinning) and so does the degradation within the microstructure. These are competing mechanisms in the sense that failures can occur by both creep and corrosion wastage or hydrogen attack.

Grain boundaries are zones of weakness where, on a short-range atomic scale, the atoms are not as neatly arranged as they are within a crystal lattice of an individual grain. This short-range disorder leads to a slightly higher internal energy, and corrosion occurs more rapidly along these grain boundaries. Atoms are more easily dissolved from regions of high energy, less energy is required for solution. At elevated temperatures, deformation occurs more readily along the grain boundaries. Thus creep damage appears in the microstructure as voids and separation along grain boundaries.

What follows is a catalogue of several microstructural features that result from water- or steamside corrosion. In each case there are similarities to the microstructure in that they all contain grain-boundary corrosion or cracks.

Figure 1 shows a characteristic microstructure of hydrogen damage. Hydrogen damage occurs in waterwall tubes under thick, waterside corrosion deposits. One of the products of corrosion is atomic hydrogen which, being a small atom, diffuses into the steel. Hydrogen reacts with iron carbide to form ferrite and methane. The methane molecule is large and cannot diffuse through the steel; so collects at the ferrite grain boundaries. When the methane pressure is sufficiently great, intergranular cracks form along the ferrite grain boundaries.

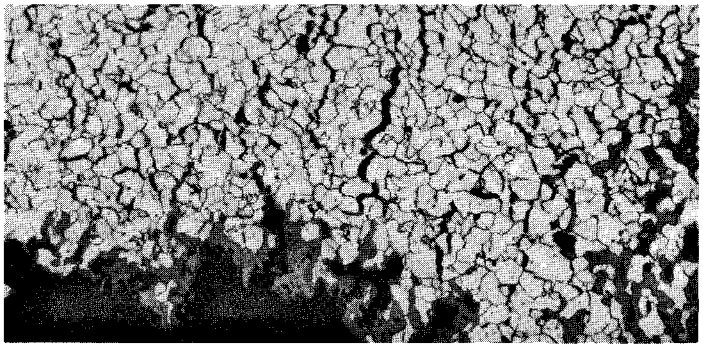

Figure 1. 200x

There are two characteristic features to hydrogen damage. 1) intergranular cracks, and 2) loss of iron carbides (decarburization). Figure 1 shows both of these characteristics. The cracks are quite long, extending over many grains and some are oxide covered with corrosion products.

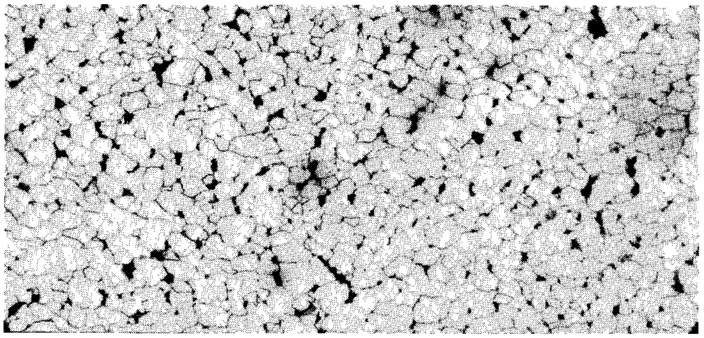

Figure 2. 200x

Figure 2, from the same boiler, shows the second effect of thick waterside deposits, that is, elevated temperatures and creep damage. The microstructure shows intergranular creep damage, or creep voids, not hydrogen damage. Here the voids appear to be no longer than a single crystal boundary and are more hole than extended crack. The microstructure along the ID surface of the tube at this location shows no intergranular cracking to the ferrite grains. For waterwall tubes, creep failures usually start at the OD surface as the metal temperature is 75°-100°F hotter than at the ID. Thus, this particular failure is an elevated-temperature stress rupture caused by the waterside deposits.

That these two microstructures came from the same boiler indicates the variability of waterside corrosion, depending on the local heat flux (metal temperature), pH (which governs the corrosion rate), and deposit thickness as it affects tube-metal temperature.

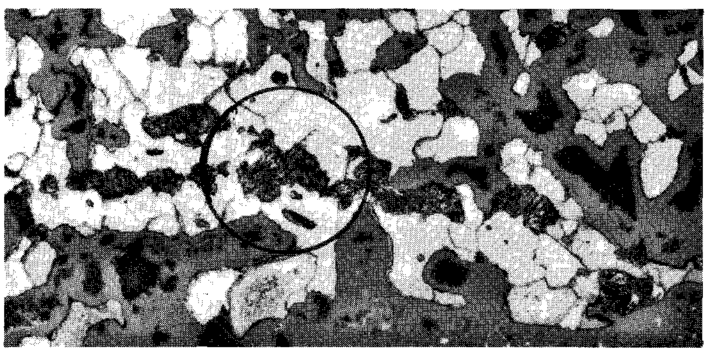

Figure 3. 500x

Figure 3 shows intergranular corrosion of a carbon steel waterwall tube. Here the corrosion attack has proceeded selectively along the ferrite grain boundaries. That this is not hydrogen damage may be seen from the fact that pearlite colonies are still intact within the region of intergranular corrosion (note encircled zone). Since this damage was noted at the bottom of a fairly large pit suggests the corrosion is by oxygen attack, rather than by a pH excursion.

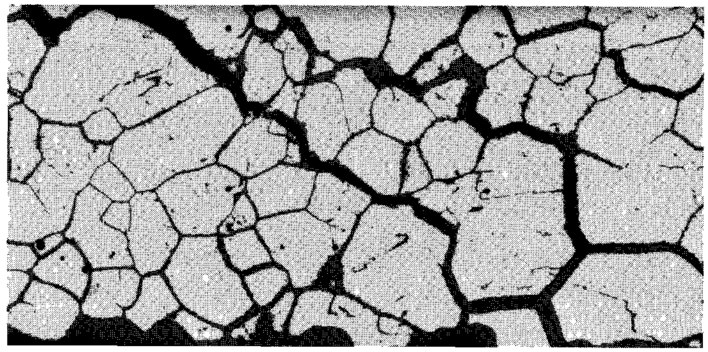

Figure 4. 100x

Figure 4 shows grain-boundary corrosion of a 304 stainless superheater tube. At temperatures above about 1050°F, chromium carbides form along the austenite grain boundaries. The formation of these carbides depletes the austenite grains of chromium adjacent to the grain boundaries. As the chromium content decreases below about 12%, the corrosion resistance is severely impaired. This structure is said to be "sensitized." In effect, the austenite grain boundaries are no longer stainless steel, and corrosion proceeds rapidly. The net effect is the attack along the austenite grain boundaries, as shown in Figure 4.

In summary, the localized corrosion and metallographic circumstances dictate the corrosion morphology. Grain boundaries being a zone of higher internal energy may be more readily corroded, referred to as intergranular attack (IGA). At elevated temperatures the grain boundaries slip past one another, a process known as "creep", and the damage collects along grain boundaries, seen in the microstructure as "creep damage." The details of the corrosion vary from location to location within the boiler depending on the local temperature and corrosion conditions.

(508) 393-3635 for metallurgical help!!!!!!!!

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