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

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

STRESS ENHANCED CORROSION

Corrosion may be defined as the attack of a metal by its environment by a chemical or electrochemical process. Stress-enhanced corrosion increases the expected environmental attack at regions of higher stress. Metallic corrosion can be understood with reference to a dry cell. A dry cell has a central carbon rod called a "cathode" and a zinc can called an "anode". Within the can surrounding the cathode is an ammonium-chloride solution called an "electrolyte". The electrode at which chemical reduction occurs is called a cathode, for example,

$$2H^{+}+2e^{-}=H_2$$

The electrode in which chemical oxidation occurs is called the "anode". In the case of a dry cell:

$$Zn=Zn^{+2}+2e^{-}$$

The dry cell works because the flow of the electrons between the anode and the cathode can do useful work, for example, light a flashlight. Thus corrosion of metals usually will occur at the anode.

There are three cells that lead to corrosion reactions:

1) A dissimilar-electrode cell. This is illustrated by the dry cell just discussed. Other examples would be: a cold-worked metal in contact with the same metal fully annealed, and a grain boundary in contact with a grain. (This tendency of grain boundaries to corrode more rapidly than the grains allows for the etching of steels to bring out the detailed microstructures.)

2) Concentration cells. These have electrodes of the same metal in contact with solutions of differing composition. A differential aeration cell is most common and accounts for the rusting of steel. Under a scab of rust, there is a low oxygen concentration and the area becomes anodic. The edge of the blister of rust has a higher oxygen level and is cathodic. Anodic areas dissolve and the cathodic areas are protected.

3) Differential temperature cells have electrodes of the same metal at different temperatures. The high-temperature corrosion of a superheater or a reheater tube in liquid coal ash, for example, may be an example.

Stress-enhanced corrosion is a special circumstance of a dissimilar-electrode cell. Corrosion of these cells may be thought of as the highly stressed regions contain slightly higher internal energy due to the strain. The higher internal energy makes it easier for the deformed crystal to dissolve in the electrolyte. Cold-worked metals will behave in a similar fashion and corrode more rapidly than the surrounding annealed material. Attachment welds that support systems loads increase the stress locally which reacts as the cold-worked/annealed-metal cell.

In order for the corrosion to occur, there needs to be a corrodant; and in a boiler the most common is dissolved oxygen in the water. This will lead to oxygen pitting, and in those areas of high local stress, there will be localized stress-enhanced corrosion.

Figure 1 shows the ID surface of a waterwall tube in the vicinity of a buckstay weld.

Figure 1.

The corrosion is greatest in the general vicinity of the buckstay weld. A cross section through this area shows a localized deeper pit. See Figure 2.

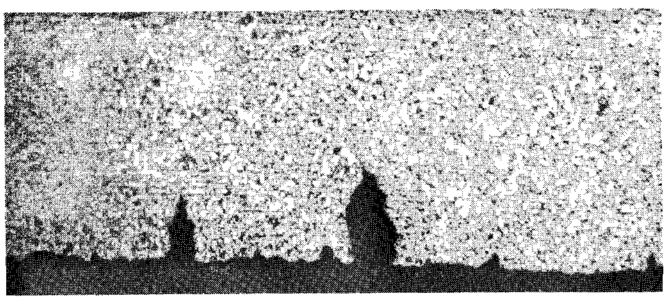

Figure 2.

Another example of this kind of stress-enhanced corrosion associated with weld attachments is presented in Figure 3.

Figure 3.

Again, the longitudinal cracks are concentrated between the waterwall tube membrane and an attachment. Those regions remote from this stress concentration show much less corrosion attack.

One final example of stress-enhanced corrosion is at a dissimilar-metal weld in a liquid-ash corrosion environment. Figure 4 shows the oxide-wedge formation along the heat-affected zone of a dissimilar-metal weld.

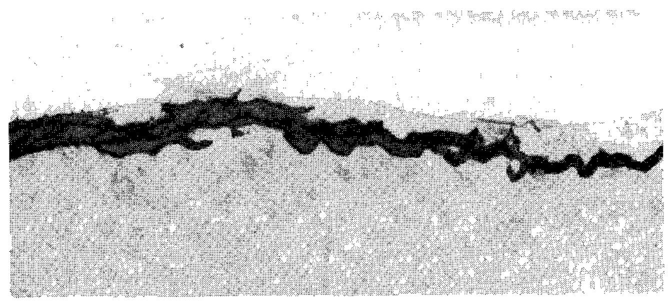

Figure 4.

The weld attaches a stainless-steel support clip to a T-11 tube. The operating tube temperature is estimated to be 980°F. The tube suffers from coal-ash corrosion, and the oxide wedge has nearly separated the lug weld from the tube. There is no evidence of any creep damage along the heat-affected zone and at a metal temperature of 980°F creep is not likely. The ash corrosion is accentuated in the high stress area caused by the differences in the expansion coefficients of stainless steel and T-11. The high stress in the heat-affected zone promotes more rapid corrosion than elsewhere on the T-11 tube.

In summary, the galvanic nature of most corrosion processes gives an explanation for the localized stress-enhanced corrosion. Those areas under high applied stress from the attachment of support clips can enhance the corrosion rate in a localized fashion and lead to boiler tube failures.

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