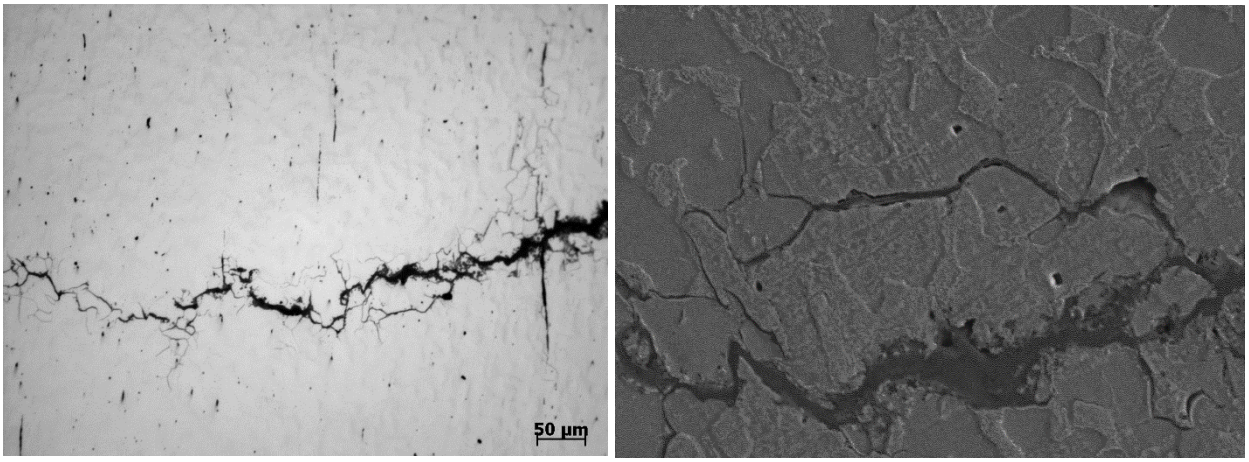
Nitrate Stress Corrosion Cracking of a Furnace Shell

Background: Extensive cracking was detected in a plain carbon steel furnace shell. The refractory of the furnace was approximately 10 inches thick and, for the first 30 years of the furnace's operation, the furnace did not have any NOx control measures in place. The cracks on the furnace shell all seemed to be near locations where thermal stresses during start up and shutdown would be maximized, and the furnace had been cycled several times per year for its entire operational life. The client contracted KnightHawk Materials Lab to conduct a metallurgical failure analysis of a section of the furnace wall, and stated that they suspected that the failures might be related to thermal fatigue.

Figure 1: Optical Micrograph (Left) and SEM Micrograph (Right) of Intergranular Cracking and Corrosion in a Polished Cross Section of the Furnace Shell



Summary: The failure of the furnace shell was caused by nitrate stress corrosion cracking, and not by thermal fatigue. The presence of stress corrosion is clear from the crack branching (left image in Figure 1) and the intergranular nature of the cracking (right image in Figure 1). There are relatively few mechanisms that result in intergranular failure of low strength plain carbon steel, and of those mechanisms, the only one likely to take place in a furnace shell is nitrate SCC. However, for nitrate SCC to occur there has to be a source of nitrates, and that is where the lack of NOx control measures is important.

The NOx that was produced by the burners for the first 30 years of operation had partially condensed on the I.D. of the furnace shell and reacted with the insulation to form magnesium and sodium nitrate salts. Then, when the furnace was cycled and cooled to below the dew point, the surface of the metal was wetted and the nitrate salts entered into solution, resulting in the formation of a stress corrosive environment. Upon startup, the areas of maximum stress were the areas where thermal stress was at a maximum, and so the stress corrosion cracking occurred most prominently in these areas.

Take Away: Nitrous oxide deposits on carbon steel surfaces can lead to intergranular SCC of the metal, especially when the metal is routinely cycled through the dewpoint. Despite the initial appearance of the failures (thermal fatigue) a detailed metallurgical analysis was able to determine that the actual cause of the cracking was corrosion related.