Subject: Eight Forms of Corrosion

This is the last of eight primers which introduce the forms of corrosion likely to be encountered in the petrochemical, refining, fertilizer, and other industries. The eight forms have been used for decades to describe, by appearance, the common degradation mechanisms in metals and alloys.

8. Stress Corrosion Cracking

Stress corrosion cracking (SCC) results when a material, which is susceptible to SCC, is stressed in tension to an environment which causes SCC. The tensile stresses can be residual, applied, or both, and must be above a certain threshold but that threshold is often low. Research has found that dealloying plays a role in SCC generation and propagation. Macroscopically, SCC failures appear brittle though uncracked material retains its original ductility. For owner-operators which experience SCC, damaged piping and equipment is typically unrepairable by welding.

SCC can generate intergranular, transgranular, or mixed-mode cracking with varied amounts of branching. SCC is normally accompanied by limited general corrosion but can be spawned by pitting and crevices which produce environments more conducive to crack generation. Like pitting, SCC can have an incubation time of months or years. Due to the possibility of an extended incubation time, testing for SCC in a specific environment must utilize highly stressed coupons over an extended time. At the completion of testing the conclusion should be resistance for the test period but not immunity.

Due to the ubiquitous nature of chlorides, chloride SCC is perhaps the most common type experienced by owner-operators. Other halogens can cause SCC but are far less common. Chloride SCC occurs externally and internally and only requires part per million (ppm) levels to crack 300 series stainless steels. Cracking is usually transgranular and highly branched but can be intergranular on sensitized material. Most chloride SCC occurs above ~60°C (~140°F) on 300 series stainless steels and above ~120°C (~250°F) on 2205 duplex stainless steel and a liquid water film is required. Higher tensile stresses increase susceptibility, which makes weld zones, cold worked components, and fasteners especially prone.

Caustic SCC of steels is typically related to sodium hydroxide but can also occur in potassium hydroxide/caustic potash. Cracking is typically intergranular, oxide filled or rimmed, and branched. A minimum of 2-5% sodium hydroxide is required even though the NACE Caustic Soda service chart implies otherwise. Above the 2-5% threshold level, stress relieving increases steel resistance though the use of an alloy is eventually required based on the temperature and concentration. The caustic soda service chart for 300 series stainless steels is like the chart for steel so stainless steels are not typically regarded as an upgrade to steel.

Polythionic acid SCC affects sensitized 300 series stainless steels, alloy 600/600H, and alloy 800/800H/800HT. The sulfur acids ($H_2S_xO_y$) form when water and oxygen combine with metal sulfides. Intergranular cracking occurs in minutes to hours, especially in weld zones, during shutdowns, start-ups, or maintenance if the guidelines found in NACE SP017-2018-SG are not followed. Even L-grade and stabilized (321 & 347) grades of stainless steels can experience cracking after high temperature service or if carburized. Thermal stabilization at 900°C (1,650°F) at the mill and after welding will help to control in-service sensitization of susceptible materials.

Compilations of alloy-environment combinations which can result in SCC can be found online and in reference material on corrosion.

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