AMBIENT-TEMPERATURE STRESS-CORROSION CRACKING OF AUSTENITIC STAINLESS STEEL IN SWIMMING POOLS

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Ambient-Temperature Stress Corrosion Cracking of Austenitic Stainless Steel in Swimming Pools

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Chloride stress corrosion cracking failures of type 304 and 316 components in the atmosphere of indoor swimming pools are discussed. No failures under immersed conditions have been reported, nor in the atmosphere associated with outdoor pools. Changes in pool operations over the last few years are listed.

The 60°C (140°F) limit, below which chloride stress corrosion cracking (Cl^-SCC) of austenitic stainless steels does not occur, is widely accepted and used by corrosion engineers.

Recently, there has been a spate of SCC failures of type 304 (UNS S30400) and 316 (UNS S31600) components in the atmosphere of indoor swimming pools that has stimulated research into conditions that give rise to room-temperature Cl^-SCC. The seriousness of the problem can be gauged by the first-reported failure that involved the collapse of a concrete ceiling at Uster, Switzerland, in May 1987, resulting in 13 deaths. The ceiling was suspended from the main structure by type 304 rods.

Since then, failures have been reported in swimming pools in the United Kingdom, West Germany, Denmark, and Sweden. Fortunately, these later failures did not result in any fatalities. The German failures resulted in a survey of 71 pools in Bavaria that revealed SCC in eight pools—four in type 304 and four in titanium-stabilized type 316 (German designation DIN 1.4571, UNS S31635). *All were in the atmosphere of indoor pools and no failures under immersed conditions have been reported, nor in the atmosphere associated with outdoor pools.*

Room-temperature SCC of stainless steels can be produced in the laboratory at very low pH and high chloride levels. It is pertinent to note that the pH levels required for cracking with chloride levels up to 5 N are below, i.e., more acid than, those that occur in pits on these alloys in immersed chloride environments. This would explain why exposure to chloride-containing solutions at ambient temperatures does not result in cracking. It does not, however, explain how conditions for cracking develop in swimming pools and not in other atmospheric exposures.

The Nickel Development Institute (NiDI) has been investigating this phenomenon and has reproduced room-temperature SCC in the laboratory at about pH −0.3 and 5 N chloride. The appearance of the laboratory cracks is very similar to that of service failures (Figures 1 and 2).

Until the mechanisms of attack are clarified, use of type 304 and 316 stainless steel for stressed components exposed to swimming pool atmospheres cannot be recommended.

Assuming that low pH–high chlorides are responsible for cracking, it is necessary to explain how these are generated and why they seem to be confined to indoor swimming pool atmospheric environments.

A NiDI survey of pool operations in the United Kingdom revealed that conditions have changed over the last few years. Notable changes are as follows:

- Generally higher operating temperatures, 85°F (approximately 30°C) compared to 70°F (approximately 21°C);
- As a result of higher operating temperatures, pool usage is greater, resulting in more dispersal of pool water to the atmosphere;
- Pools with features such as fountains, wave machines, flumes, which also increase atmospheric dispersion;
- Recirculation of pool waters and atmospheres to conserve fuel. This results in higher dissolved solids in the water and contaminants in the atmosphere; and
- Adoption of ceilings suspended by stainless steel wire and rod to improve acoustics. SCC failures are often associated with these ceiling supports.

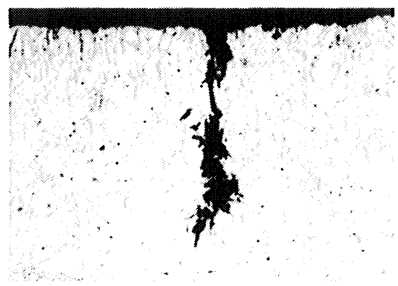

FIGURE 1
Cracked type 304 stainless steel wire from a suspended ceiling structure in an indoor swimming pool in the United Kingdom. The wire had been in service for about six years. (Original magnification 200X.)

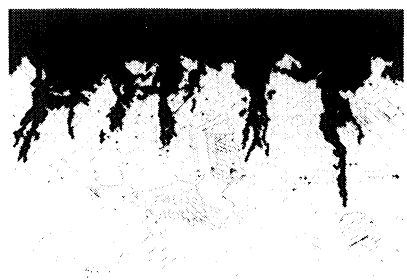

FIGURE 2
Cracked type 304 stainless steel wire stressed at ambient temperature for one week at 100 percent of the 0.2 percent proof stress in 4.3 N NaCl, 0.7 N HCl (pH minus 0.37). (Original magnification 200X.)

It is clear that pool conditions have changed in the United Kingdom and possibly elsewhere. Also, these changes have generally led to more aggressive corrosive conditions for stainless steels. However, as yet, no agreed mechanism for the development of atmospheric Cl^-SCC conditions has been established.

Current work in Europe (United Kingdom, West Germany, and Switzerland) is aimed at clarifying the mechanism by which SCC conditions can develop. NiDI tests on materials such as UNS N08904, MONEL† (alloy 400 [UNS N04400]), and alloy 825 (UNS N08825) have shown these alloys resist cracking under low-pH and high-chloride laboratory conditions where types 304 and 316 cracked. Similar tests on duplex 2205 stainless steel (UNS S31803) revealed preferential attack on the ferrite phase, leaving the austenite phase, which had suffered SCC. This behavior was considered unsatisfactory.

Until the mechanisms of attack are clarified, use of type 304 and 316 stainless steel for stressed components exposed to swimming pool atmospheres cannot be recommended. All existing installations should be inspected regularly and any cracking reported to a competent authority.

Technical Editor's Note: Additional information on the Swiss swimming pool incident can be found in

- Federal Institute for Material Testing, Technical Group 1.3, "Assessment of the Corrosion Behavior of Metals and of Corrosion Protection Measures in Indoor Swimming Pools," 4.3.86;
- S. Manleiter, W. Stichel, "Corrosion of Stainless Steel Building Components in Swimming Pool Atmospheres," Mitt. Inst. f. Bautechnik 17, 5 (1986): p. 145; and
- C.I. Page, R.D. Anchor, "Stress Corrosion Cracking of Stainless Steel Swimming Pools," Structural Engineer 66, 24 (20 December 1988): p. 416.

†Trade name.