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Stress Corrosion Cracking of Stainless Steels in Swimming Pool Buildings	

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To
Divisional Directors
Heads of Operations
Food and Entertainment PIs

STRESS CORROSION CRACKING OF STAINLESS STEELS IN SWIMMING POOL BUILDINGS

This SIM alerts inspectors to potential failures in swimming pool buildings due to stress corrosion cracking in stainless steels induced by the atmospheric conditions.

BACKGROUND

1 In 1985, 12 people were killed in Uster, Switzerland when the concrete roof of a swimming pool collapsed. The roof was supported by stainless steel rods in tension, which failed due to stress corrosion cracking. Last year, the suspended ceiling of a municipal swimming pool in the Netherlands collapsed due to a similar cause. There have been other incidents associated with the use of stainless steel in safety-critical load-bearing applications in the environment created by modern indoor swimming pools and leisure centres.

2 Swimming pool environments have changed significantly in recent years, most markedly in leisure pools. Higher water temperatures combined with an increase in the number of bathers, has led to higher levels of chemical disinfection. Chlorine-based disinfectants are the norm, which together with contaminants introduced by bathers, produce chloramines. These are thought to be the most important factor in the corrosion of stainless steel in a swimming pool environment.

3 The temperature of the air in pool halls is generally held about 1^{o}C above water temperature. High air temperatures significantly accelerate corrosion.

4 Atmospheric moisture in pool buildings comes from evaporation of pool water and as droplets from the turbulent water features that have become increasingly common in leisure pools. Higher levels of humidity can lead to condensation in cooler parts of the building and during the cool of the night. Recirculation of pool air (a common method of reducing energy costs) can

increase humidity, as well as adding to the build up of contaminants in the atmosphere.

5 Consequently the atmosphere of indoor swimming pools is one of the most aggressive to be found in a building environment. Under the specific temperature conditions near the ceiling, chlorine containing chemical species in vapours from the pool water can condense onto the stainless steel components and dry out. As this can be a repeated cycle, very aggressive concentrations of chlorine-containing species may build up. The situation is aggravated by the fact that components may not be easily accessible for regular cleaning.

STRESS CORROSION CRACKING (SCC)

6 SCC is a type of localised corrosion characterised by fine cracks which can propagate quite rapidly leading to failure of the component and potentially the associated structure.

7 Extensive research studies indicate that SCC in swimming pools appears only under a very specific combination of three conditions:

1) the use of susceptible grades of stainless steel;

2) tensile stress, either from structural loading or present as residual stresses from forming or welding operations during manufacture and installation; and

3) the presence of a specific aggressive environment. Chlorine containing compounds (by-products of disinfection) may transfer via the pool atmosphere to surfaces remote from the pool itself. These compounds can produce a highly corrosive film, which can lead to SCC.

8 Some grades of stainless steel, including the most familiar 1.4301(304) and 1.4401 (316)Types often specified for swimming pool environments, have long been recognised as susceptible to SCC, but generally only above 55^{o}C. However, the examples of failure given in para 1 occurred around 30^{o}C, in highly stressed components which had not been washed by pool water or frequently cleaned.

9 Consequently the standard stainless steel grades that perform perfectly well in pool water or poolside equipment may not be suitable for safety-critical items, ie those mainly load-bearing components where fracture could result in a risk of injury - for example, structural components in ceilings or roofs - where they are faced with a combination of mechanical stress and a highly corrosive environment.

10 Components in the pool hall atmosphere, which are safety-critical, but are not washed or cleaned frequently, are also potentially vulnerable to SCC. These include components such as:

1) brackets for suspended light fittings and loudspeakers, pipework, conduits, etc;

2) rod/bar supports for ventilation trunking, water slides and other design features;

3) wire rope supports for water slides, etc;

4) fasteners.

Components, such as ceiling wire, fasteners, cable strapping and hose clips, which are heavily cold-worked are the most vulnerable. Some component configurations, such as twisted wires and some forms of bolt, nut and washer combinations, create a crevice region, which increases the risk of localised corrosion attack.

PREVENTATIVE MEASURES

11 Corrosion can be effectively controlled by a combination of good design, careful selection of stress corrosion-resistant grades of stainless steel and effective management, including maintenance and inspection.

12 Specific steps can be taken to prevent the onset of SCC and minimise its consequences when it does occur by:

1) careful consideration of the potential for SCC during the design and fabrication of the swimming pool building and components;

2) careful selection of appropriate stainless steel grades - some are much more suitable for safety critical use than others;

3) carefully maintaining the chemical balance of the pool water by regular monitoring and dosing;

4) ensuring that the bathing load of the pool is not exceeded and that the potential for organic contamination is minimised by the provision of good pre-shower facilities, toilets, and instructions to bathers;

5) maintaining air quality by the correct operation of ventilation and heating plants;

6) regular inspection by a competent third party of safety-critical components for signs of corrosion and SCC.

INSPECTION PROCEDURES

13 The inspection of safety-critical stainless steel components for SCC and loss of section by pitting should be viewed as a priority. The following inspection procedures are recommended:

1) compile an inventory of all stainless steel components within the pool building, identifying their grade, location and function;

2) specifically inspect all stainless steel components at least twice a year for any evidence of staining or corrosion. During inspection special attention should be given to components which are load bearing and/or safety-critical. Findings should be logged;

3) SCC may be difficult to detect in its early stages and, although normally accompanied by visual signs of other types of corrosion, such as pitting corrosion, reliance should not be placed on visual means alone. Although not definitive, a normal tell-tale sign is brown staining, varying from a pale, dry discolouration to wet pustules;

4) where staining or corrosion is found, the corrosion products should be removed and the loss of cross-section and integrity assessed;

5) where the component is load-bearing and/or safety-critical, samples of the component should be tested for SCC. Where tests reveal the presence of SCC the services of a qualified engineer should be employed to undertake a full risk assessment of the affected components and to recommend a suitable course of action; and

6) if necessary, components should be replaced with a suitable more corrosion resistant stainless steel grade.

ACTION BY HSE INSPECTORS

14 Inspectors should raise the issue of SCC when they make contact with swimming pool operators and satisfy themselves that the organisation and arrangements within the management system of the pool adequately address the issues surrounding SCC.

15 As well as the operational measures which dutyholders can take to reduce SCC, they should have a structured system for inspecting safety critical stainless steel components.

16 Further information can be obtained from the NDI publication *Stainless steel in swimming pool buildings* or from the British Stainless Steel Association (telephone 0114 290 0888).

17 All enquiries regarding this SIM should be addressed to the Food and Entertainment Sector, Entertainment Section, FOD Scotland, VPN 521 3045.

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