Stainless steel in swimming pool buildings

Selecting and using stainless steel to cope with changes in swimming pool design

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A guide to selection and use

Introduction

Stainless steels are well established as corrosion-resistant materials for many items used in building and equipping swimming pools. For decades, stainless steels have had an excellent track record - typically specified for equipment in the pool water (ladders, wave machine grilles, etc), in the pool superstructure (lintels, diving board and slide assemblies) and in environmental engineering plant (control boxes, air handling equipment, fire dampers etc

The very few reports of stainless steel corrosion in pools were usually related to poor design or workmanship. Over the last decade or so, however, staining and pining corrosion seem to have increased. More seriously, the collapse in 1985 of the suspended concrete ceiling of a pool in Switzerland highlighted the problem of stress corrosion cracking of some stainless steels. Subsequently, further examples of such corrosion have been found in pool buildings, but without serious consequences.

Investigations suggested a previously unknown link between corrosion and changing environmental conditions - higher water and air temperatures, and higher atmospheric concentrations of some chemical by-products from pool water treatment. Such environmental conditions also increase the risk of deterioration in other materials commonly used in swimming pool buildings, such as galvanized steel, high strength steels, conventional painted constructional steels, brass, aluminium, nylon, masonry and timber. The latest research confirms that appropriate grades of stainless steel are still excellent materials for both existing arid new swimming pools. But the changed atmospheric conditions do demand renewed attention to material selection, design, maintenance and pool operation.

This guide explains the background to these issues and gives practical advice on the successful use of stainless steel. It is aimed at architects, designers, builders and pool managers.

Contents

Pool environments

Swimming pool environments have changed significantly in recent years, most markedly in leisure pools. Some of these changes result in conditions that are more aggressive toward the materials used, including stainless steel.

How things have changed

Since the early 1970s swimming as a leisure activity has seen a small revolution. Traditionally customers swam in simple, rectangular pools. The water could be relatively cold, as people did not spend long in it. As the industry built pools of different shapes and styles, with features that added to the fun, customers were expected - and came to expect - to stay longer in the pool hall, and to be warmer. So temperatures crept up, attracted customers, and became a selling point. And pools did need to sell: changes in local government management of pools put considerable commercial pressures on operators. So bather numbers sometimes exceeded those with which the water treatment system could cope.

By and large, higher water temperatures, and more bathers, mean higher levels of chemical disinfection. More fun features and splashing in leisure pools mean more atmospheric moisture. All these factors are relevant to the use of stainless steel.

A crowded leisure pool

Pool chemicals

To prevent cross-infection, it is necessary to use disinfecting agents which can kill bacteria and viruses introduced into the water by bathers. Chlorine-based chemicals are the norm, maintained at a concentration which will keep the pool effectively sterile. It is not the chlorine itself which most affects bather comfort and corrodes pool materials, but products formed by its reaction with contaminants introduced by bathers. Specifically, chlorine reacts with nitrogenous substances like urea from sweat and urine to produce chloramines. These are responsible for “swimming pool smell” and cause most eye and nose irritation for pool users.

Pool water chemistry is a complicated science, affected by pH and other factors [Reference 1]. Very many chemicals, including traditionally corrosive agents like chlorides, are produced as by-products of disinfection. Chloramines, though, are very volatile, pass into the atmosphere and can be absorbed into condensate. Here the chloramines decompose and form a corrosive solution which may attack the underlying surfaces of buildings, fixtures, fittings arid furniture.

The presence of chloramines is thought to be the most important environmental factor in the corrosion of stainless steel [2]. Routine pool water monitoring of combined chlorines gives a picture of chloramine levels in the water. Work is underway in an attempt to establish a reliable method of measuring chloramine concentration in pool atmospheres.

Temperature and humidity

Nowadays, water temperatures range from 26^{0}C in competition pools to around 30^{0}C in leisure pools. Spas and similar pools may have water temperatures above 37^{0}C. High water temperatures increase the evaporation of water and volatile chemicals which influence corrosion. The temperature of the air in pool halls is generally held at about 1 degree C above water temperature. High air temperatures significantly accelerate corrosion (see page 7). Atmospheric moisture in pool buildings comes from evaporation of pool water, and as droplets and vapour from the turbulent water features that have become increasingly common in leisure pools. Water slides, fountains, jets, wave machines, water cannons and wild water channels all increase the amount of moisture being added to the air, and thus humidity.

The design target for relative humidity is generally 50-70%. Higher levels can lead to condensation in cooler parts of the building and during the cool of the night. This in turn can cause corrosion. On the other hand humidities significantly below the target (which can increase pool evaporation) have been shown to lead to a risk of stress corrosion cracking in some grades of stainless steel [5,6,7]. Re-circulation of pool hall air (a common method of reducing energy costs) can increase humidity, as well as adding to the build up of contaminants in the atmosphere.

Managing the environment

Good design (page 8) can minimize corrosion effects, as can good pool management. Management and maintenance (page 12) has information on controlling pool management parameters, including temperature, humidity and water chemistry.

Water features contribute to atmospheric moisture

Corrosion resistance of stainless steel

Stainless steels are iron-based alloys with at least 11% chromium. There are many different types, with differing proportions of other elements such as nickel and molybdenum. But in every case the corrosion resistance derives from a thin surface layer of chromium-rich oxide. This so called passive film is normally impermeable and, if broken, self-healing by re-oxidation. In general, stainless steel items which are immersed or frequently handled in indoor pools are protected by the passive film; they do not suffer corrosion.

The passive film can, however, be damaged in various ways, including attack by acidic and chloride atmospheres, and different forms of localised corrosion can result.

Staining, pitting and crevice corrosion

The brown staining that can appear on stainless steel in indoor pools is caused by superficial pitting corrosion which generally does not impair the structural integrity of sheet, plate and tube. Wires, however, because of their smaller cross section, are more likely to be weakened if pitted.

More severe pitting corrosion can attack areas which are occasionally splashed by pool water but are difficult to clean, so that corrosive salt deposits build up. Crevices - for example, under-fasteners and coatings, within lapped and clamped joints and between the strands in wire ropes - are also vulnerable to localised attack (crevice corrosion).

Staining on ventilation trunking

Corrosion attacking the bolts of a flume

Stress corrosion cracking (SCC)

SCC is a type of localized corrosion characterized by fine cracks which can propagate quite rapidly, leading to failure of the component and possibly also of the associated structure. Often there is very little other visible corrosion associated with the cracking. Some grades of stainless steel have long been recognized as susceptible to SCC, but generally only at temperatures above about 55°C. However, the incidents of SCC mentioned in the introduction to this guide were at temperatures around 30°C, in highly stressed components which had not been frequently washed by pool water or, because of location, routinely cleaned.

SCC is difficult to detect in its early stages; and certainly cannot be detected simply by casual visual inspection. Inspection is dealt with on page 13.

Extensive research studies [2-8] indicate that SCC in swimming pools appears only under a very specific combination of three conditions:

Δ the use of susceptible grades of stainless steel

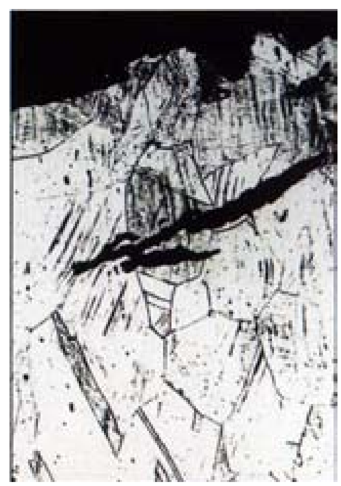
Δ tensile stress, either from structural loading or from a forming or welding operation (residual stress)

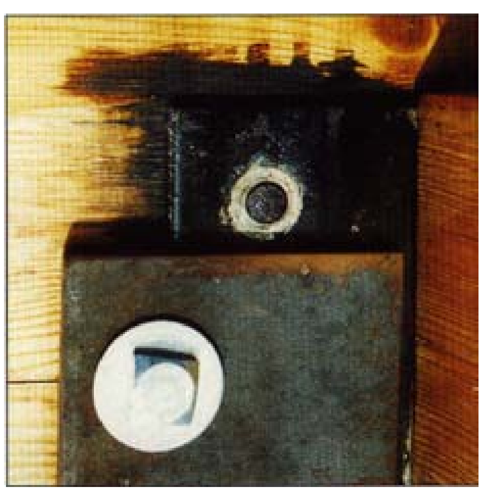
Δ the presence of a specific aggressive environment. Chlorine-containing compounds (by-products of disinfection) may transfer via the pool atmosphere to surfaces remote from the pool itself. These compounds can produce a highly concentrated and corrosive film which, on the surface of some stainless steels,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

Controlling corrosion

Corrosion can be effectively controlled by a combination of good design (page 8), careful selection of corrosion-resistant grades of stainless steel (page 11) and effective management, including maintenance and inspection (page 12).

Suspended ceiling support wire (SCC ringed)





Above left: Fractured bolt head from a pool's roof area, after cleaning
Above right: Optical micrograph of the same bolt, showing a typical SCC fracture path at the shank-head junction
Left: Another failed bolt, at the end of a tie beam

Design

Indoor swimming pools are complicated buildings, making serious demands in terms of design and construction. Their detailed design and planned operating conditions must be carefully considered by water treatment experts, as well as architects, designers and builders. That detail should extend to issues like reducing pool water pollution by providing pre-swim showers. The attractions of turbulent water features (wave machines, water slides etc) must be set against their potential to contribute to the dissemination of corrosive contaminants. This section outlines the main design issues that affect the performance of stainless steel. Because pools have a potentially aggressive atmosphere, access for inspection, cleaning and maintenance (see Section 5, pages 12-14) must be included at the design stage.

Ventilation

Ventilation systems should be designed in conjunction with the internal spatial design of the building to optimize air flow and air quality [1, 23]. The ventilation strategy must take into account contaminants and humidity. In general, air should be well circulated over the whole area. A figure of 10 litres of ventilation air per second per square metre of total pool hall floor area is usually acceptable. This can mean about six air changes per hour, depending on the height of the pool hall, but may need to be as many as ten for leisure pools with extensive water features.

The recirculation of pool hall air, in order to conserve energy, tends to encourage the build-up of contaminants from the pool water, so 100% fresh air should be available as necessary to cope with high bather loads and high external temperatures. There should always be a minimum of 12 litres per second of fresh air provided for each occupant of the pool hall - bathers, staff etc. Other energy efficiency devices - heat reclaim, combined heat and power, etc. - should be considered.

Temperature and humidity

Temperature and relative humidity are important factors which should be considered as part of the design. The maximum pool water temperatures recommended by the Pool Water Treatment Advisory Group [1] are:

27^{0}C	competitive swimming and diving, fitness swimming, training
28^{0}0	recreational, adult teaching, conventional main pools
29^{0}C	children's teaching, leisure pools
30^{0}0	babies, young children, disabled

The temperature of the pool hall air is normally maintained at approximately 1 degree C above pool water temperature, but air temperatures of above 29°C should generally be avoided if possible

Relative humidities above 70% and below 50% should also be avoided.

Stainless steel items

The risk of corrosion should be minimized right from the design stage.

Δ Choosing an appropriate grade of stainless steel is the first step. The risk of stress corrosion cracking should be eliminated by choosing a stainless steel according to the information in the next section of this guide.

Δ Surface finish must be carefully specified [9], also taking into account the overall design, detailing, and planned fabrication techniques. BS1449 number 5 finish should be the minimum standard.

Δ Designing items with smooth, flowing lines which avoid crevices will help with cleaning and other maintenance, as well as reduce the risk of corrosion.

Δ Specifying stainless steel fasteners should take into account that the corrosion resistance of the free machining grades (eg Type 303) is inferior to that of the related standard grades (eg Type 304) [10].

Δ The design of any safety-critical structure which involves stainless steel load-bearing components should be fail-safe, so that progressive collapse of the structure will not follow SCC and there is some built-in indication of a failure.

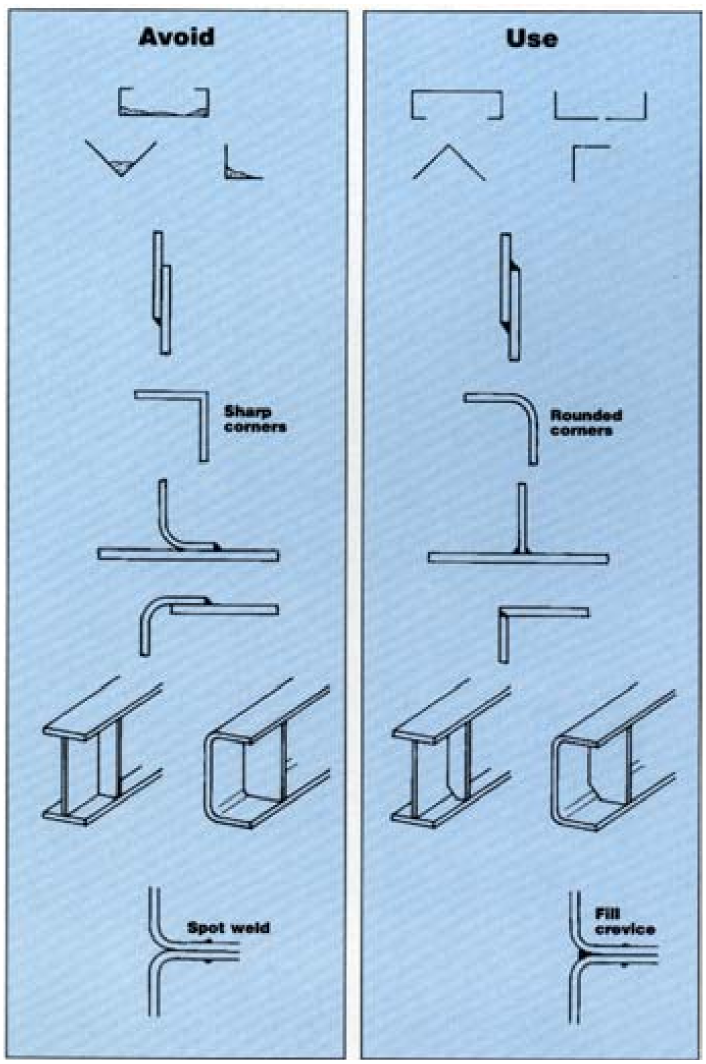
Δ Stainless steels can be formed and joined readily using standard techniques. Correct welding and post-weld cleaning procedures will produce corrosion resistance as good as the parent materials [11-15]. Poor fabrication practices can, however, lead to a loss of corrosion resistance.

Δ It is essential to choose a manufacturer with the necessary fabrication skills for the chosen grade of stainless steel; preferably one experienced in the design and construction of products for indoor pools.

Δ Access for inspection and maintenance must be provided (page 13).

Life-cycle costs

Life-cycle costs are the sum of the initial capital outlay and total operating costs of energy, maintenance, refurbishments, repairs and replacements over a specified period of time [16]. To these must be added the loss of revenue resulting from shutdowns. For swimming pools the total of operating costs and lost revenue are likely to be much greater than the initial capital outlay. So the use of higher-price materials, such as corrosion-resistant stainless steel grades, will frequently result in considerable cost savings over the lifetime of the project.



Design features to avoid, and to use, to minimize corrosion
(By permission, Avesta Sheffield)

Specifying a stainless steel

The metallurgical structure of stainless steels allows a classification into four types - ferritic, martensitic, austenitic and duplex.

The Table opposite details some of the stainless steel grades used in swimming pools. [References 10, 11, 17, 18 give further details about. the properties and application of these materials.] In choosing a grade of stainless steel for a particular pool application, the specifier must consider the corrosive nature of the environment, the consequences of corrosion, how the component will be fabricated and the level of stress to be applied. The balance of these factors will determine whether the potential for SCC has to be considered.

Taking into account also the latest research on SCC resistance [2-8], it is possible to be quite specific about the grades that pool designers should consider.

Types of stainless steel

Δ The corrosion resistance of both ferritic and martensitic steels is based mainly on chromium - up to 30% in the super ferritics. Although ferritic steels are generally recognised as having good resistance to SCC, the balance of characteristics of both ferritic and martensitic steels is such that, they have not been widely used in swimming pools.

Δ Austenitic steels have chromium, with nickel to make them more workable and often molybdenum for extra corrosion resistance. As a result, austenitic is the type most widely used in pool applications. But standard grades have low resistance to SCC; highly alloyed grades, with extra chromium, nickel, molybderrum and nitrogen, have therefore been developed to give increased SCC resistance.

Δ Duplex steels - 50:50 austenitic: ferritic structure - combine good SCC resistance and strength. But the pitting corrosion found under laboratory tests in aggressive environments may limit their use in pools.

When SCC is not an issue

The factors linked with SCC (see page 7) are very specific. So it is possible to be confident about specifying austenitic stainless steels for components which are:

Δ fully immersed or thoroughly drenched every session - eg pool ladders, pool-side rails, some diving board structures

Δ only splashed with pool water but neither safety-critical nor load-bearing - eg changing room fittings, lockers, etc

Δ in the pool hall atmosphere but neither safety-critical nor load-bearing - eg decorative panelling

Δ remote from the influence of the pool hall atmosphere - eg café and entrance lobby fittings.

Types 201, 304. 316 and 321 are widely used in such applications, and give excellent service when properly maintained. Type 316 is preferred for its greater resistance to staining, pitting and crevice corrosion.

When SCC is an issue

Components which are in the pool hall atmosphere, which are safety-critical and load-bearing, but are not washed or cleaned frequently, are potentially vulnerable to SCC. This means such components as:

Δ brackets for suspended light fittings and loudspeakers, pipework, conduits, etc

Δ supports for suspended ceilings

Δ rod/bar supports for ventilation trunking, water slides and other design features

Δ wire rope supports for water slides etc

Δ fasteners.

Laboratory tests [2-8] have determined the SCC resistance of stainless steels in highly aggressive chloride environments. Types 304 and 316 were found to fail, and they have also been affected by SCC in some swimming pools. Accordingly, the, recommendation is that Types 304 and 316 (and the related Types 201 and 321) must not be used for components vulnerable to SCC if failure could result in personal injury. More highly alloyed grades of austenitic stainless steel have a much greater degree of SCC resistance. Two grades have been tested and found to be resistant to SCC under laboratory conditions – 3171 MN and 904L. [5-7].

6%Mo austenitic grades have been shown to have better SCC resistance than 904L in tests above 55°C [19]. However, their performance is still to be confirmed at ambient temperatures.

Duplex stainless steels, eg 2205, have better SCC resistance than standard austenitic steels. But they suffer from pitting corrosion in highly acidic, high chloride laboratory conditions and so cannot currently be recommended where resistance to both SCC and pitting corrosion is needed.

Where SCC is a potential issue, the advice is to use alloys 317LMN or 904L - rather than Types 201, 304, 316 or 321. Other highly-alloyed austenitic stainless steels, for example 6%Mo grades, may also be appropriate.

In any case, because the aggressiveness of a particular pool atmosphere cannot be predicted the components should be inspected regularly and replaced if necessary (see page 13).

Highly aggressive conditions can be found in some areas of ventilation and water treatment plant. Specific advice on suitable materials should be sought from the literature or a source of technical advice such as NiDI, BRE or the Stainless Steel Advisory Centre.

Some stainless steels used in swimming pools

Common designation	UNS number	British Standard designation	Werkstoff number	Nominal composition[1] %			
				Cr	Ni	Mo	Other[1]
Austenitic							
201	S20100		1.4371	17	4.5		Mn, N
304	S30400	304S15[2]	1.4301	19	9.5		
321	S32100	321S31[2]	1.4541	18	10.5		Ti
316	S31600	316S31[2]	1.4401	17	12	2.5	
317LMN	S31726		1.4439	17.5	13.5	4.5	N
904L	N08904	904S13[3]	1.4539	21	26	4.5	Cu
6%Mo	Various[4]			20-28	18-35	6-7	Cu, N
Duplex							
2205	S31803	318S13[3]	1.4462	22	5	3	

The balance of the composition is iron in all cases. Carbon is also present, but may be controlled to low levels when an L is added to the common desination, eg 316L. NiDI publications 9014, 10032, 10044, and D-002 have more details
2 BS 1449: Steel plate, sheer and strip
3 BS 1501: Steels for pressure purposes
4 A number of different 6%Mo grades are available, eg UNS S31254, N08031, N08367, N08925, N08926
Note Steel identification numbers are also covered in the new European Standarrd EN 10088-1, to be published in 1995

Management and maintenance

A well-managed swimming pool will provide an environment where stainless steel corrosion is minimized. Managing a pool benefits from the input of a team of professionals - owner, operators, engineers etc. Professional experience and training of the sort provided by the Institute of Sport & Recreation Management is also important. Successful management must be built on a rigorous design that includes a treatment system specified to provide good water quality for the anticipated bathing load. The principles and practice behind this can be found in the *Pool Water Guide [1]*.

Water and air quality and maintenance are important for the whole building, and are also critical for minimising corrosion. Inspection of stainless steel components, given the concern about stress corrosion cracking, is a safety issue that management must take seriously.

Water and air quality

It seems clear that those conditions which maximize the comfort of pool users are generally those which also minimize stainless steel corrosion. In order to ensure good water quality, the chemical balance of the pool water must be maintained within recommended limits. The same applies to microbiological control. *The Pool Water Guide* [1] contains the appropriate guidance for disinfectant and combined chlorine levels, pH, alkalinity, water balance, turnover, backwashing, filtration, etc. It also contains details of the checks on water chemistry and microbiology needed to ensure that the chemical balance is maintained. Automatic monitoring and dosing of chemical levels is recommended; such equipment should itself be checked regularly, but over-ridden only if it goes wrong.

In order to control pollution of the water, the bathing load for which the pool has been designed must not be exceeded. And bathers should be encouraged to shower before they swim, and not to urinate in the pool. Good showers (ideally, pre-swim separate from post-swim) and toilets will help. To the same end, it is worth educating bathers about the links between their behaviour and the quality of their swim.

Air quality should also be maintained within the acceptable limits by correct operation of the ventilation and heating plants.

Maintenance of stainless steel

The function of maintenance is to preserve the installation, and to ensure that it remains capable of being operated correctly, safely and efficiently.

Good design (page 8) will minimize the burden of maintenance. Nevertheless, the entire installation including general fabric, plant, services, structures, special features and surface conditions should be regularly cleaned and inspected as an essential part of maintenance schedules.

All stainless steel items around the pool should be washed down daily. Other stainless steel items should be cleaned by wiping once a week, although clearly this presents problems with inaccessible items like suspension wires. As long as the environmental conditions are maintained within recommended limits, this cleaning will keep the steel clean and lustrous. Conversely, if the steel starts to discolour, either the cleaning regime is inadequate or the pool hall environment has been allowed to deteriorate. The pool management can then identify the problem and take appropriate action. If the first signs of corrosion persist, the management must carefully inspect its extent. Carbon steel brushes or carbon steel wire wool should never be used on stainless steel. Chemical cleaners used must be compatible with stainless steel. Detailed advice about cleaning stainless steel is readily available [20, 21].

Inspection of stainless steel

The inspection of load-bearing stainless steel components for SCC and loss of section by pitting must clearly be a priority. This applies particularly to components installed without the benefit of recent advances in the understanding of SCC-resistant grades. Inspection procedures (below) similar to those for wire hangers in suspended ceilings [22] can be applied to water slide supports (some manufacturers also issue advice) and supports for air handling ducts, pipework, cable trays etc.

Assessing the corrosion risk

Pools with a history of corrosion problems need specific examinations to supplement the normally recommended twice-annual visual inspections of fabric and equipment. The same applies if there are indications of an aggressive pool atmosphere. A tell-tale sign is brown staining, varying from a pale, dry discolouration to wet pustules:

Δ on stainless steel surfaces, including the undersides of components whose tops are regularly washed and inspected

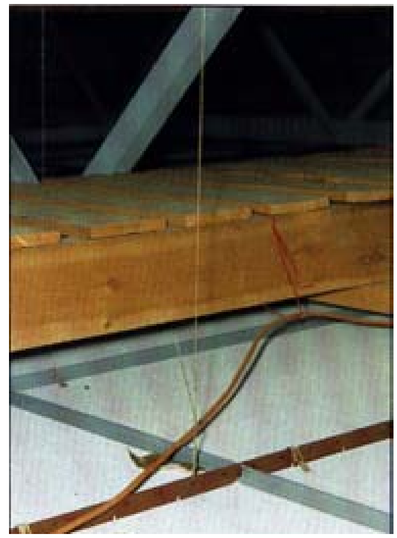
Δ in some cases distant from the pool, but where ventilation has introduced some recirculated pool air.

Such signs should dictate the extent of cleaning and inspection regimes, as well as efforts to improve operating conditions.

Inspection for SCC

Safety-critical, load-bearing components should be tested specifically, at least as often as the general inspections - whose frequency is determined by an assessment of the chance of corrosion in the pool building. The following guidelines cover routine inspection, but should be supplemented by detailed information [22] and competent professional advice.

Δ Small components such as ceiling wire, fasteners, cable strapping and hose clips - heavily cold-worked, creviced and made from leaner alloy (Types 201, 304, 316 and 321) - are the most vulnerable.



The inspection of roof spaces is critical

Inspection of the underside of this air ducting revealed corrosion

Management and maintenance

Δ Ideally, such components should be removed, cleaned and examined by eyeglass at x10 magnification or more, to reveal well-established cracks. Simple visual examination for SCC cannot be relied on. But there are other in situ tests, depending on the components involved:

ceiling wires - with pliers on the end of the wire, shake, bend and rotate the termination. Any SCC will allow the wire to bend easily or break. Bends or kinks in the wire should be inspected particularly closely

strapping and hose clips – gently lever with a small screwdriver against the bend of folds or crimps

wire ropes - full inspection demands an expert; but brown discolouration between strands suggests that there may be internal corrosion. There may be SCC in the steel lining of rope eyes

fasteners - tightening and loosening of fastener beads and nuts will propagate cracks like those in the optical micrograph (page 7). Whether or not corrosion products are visible, sample fasteners should be removed and inspected at x10 magnification; SCC can start immediately under bolt heads or nuts.

Inspection procedures

To summarise what is clearly a complicated issue, there are four basic procedures that should be followed.

Δ All stainless steel components should be examined visually at least twice a year.

Δ Safety-critical, load-bearing components subject to corrosion should be tested specifically for SCC; failures, and all similar components, should be replaced with a more resistant grade.

Δ Heavily cold-worked, safety-critical, load-bearing components made from Types 201, 304, 316 and 321 steel should be replaced with more resistant grades - unless inspection procedures are such that the safety of the structure can be guaranteed.

Δ The corrosion products of any pitting should be removed and the loss of cross section and integrity assessed. If necessary the components should be replaced - again, with a more resistant grade.

Conclusions

Stainless steel has a long and successful history of use in swimming pool buildings. Despite recognition of the problem of corrosion, it is clear that. properly specified stainless steel remains an excellent material for a wide variety of pool applications. Changes in swimming and leisure, however, demand a more rigorous discipline in the design and management of pools. Appropriate grades of steel must be used, and maintenance and inspection closely controlled.

Recent research has established that certain highly-alloyed grades of stainless steel have unproved resistance to stress corrosion cracking where a combination of temperature, humidity and disinfection by-products produce aggressive environments. Where used for safety-critical, load-bearing applications, such grades should still be inspected periodically. Other grades should be reserved for areas where stress corrosion cracking is not a potential problem.

Safety-critical, load-bearing components which fail inspection tests for stress corrosion cracking should be replaced with more resistant grades. So too should such components (even without testing) if they are heavily cold-worked and made from Types 201, 304, 316 and 321 steel, unless inspection procedures can guarantee the safety of the structure.

Pool designers and managers must constantly address the issues of water and air quality. Adherence to the guidelines in the *Pool Water Guide* should help ensure good quality. This will also minimize the sort of atmospheric conditions which may exceed the corrosion resistance of stainless steel and other materials used in pool construction.

As every other pool component, stainless steel items should be designed and incorporated in a way that is sympathetic to their maintenance requirements. Then, routine attention should safeguard their appearance and long life.

References

1 Pool Water Treatment Advisory Group. Pool Water Guide: The treatment and quality of swimming pool water 1995.£24 from Pool Water Guide, PO Box 19, Diss, Norfolk IP22 3ES.

2 Oldfield JW, Todd B. Room Temperature SCC of Stainless Steels in Indoor Swimming Pools. Br Corr J 1991; Vol 26, No 3, p173.

3 Page CL, Anchor RD. Stress corrosion cracking of stainless steels in swimming pools. The Structural Engineer 1988; 66 (24).

4 Fielder JW, Hobson BA, Pickett ML. SCC Behaviour of Stainless Steel at Temperatures below 50°C. ECSC Final Report 1991; BS Ref: FR S230-7 902.

5 Hirschfield D et al. Stress corrosion cracking behaviour of stainless steels with respect to their use in architecture. Part 1: Corrosion in the passive state. Steel Research 1993; Vol 64, No 8/9.

6 Arlt N et al. Stress corrosion cracking behaviour of stainless steels withrespect to their use in architecture. Part 2: Corrosion in the natural state. Steel Research 1993; Vol 64, No 10.

7 Arlt N et al. Corrosion behaviour of stainless steels in the atmosphere of indoor swimming pools. Innovation Stainless Steel; Florence, Oct 1993. Paper 3.99.

8 Fielder J, Lee BV, Dulieu D, 'Wilkinson J. The Corrosion of Stainless Steels in Swimming Pools. Conf on Applications of Stainless Steel, Stockholm, June 1992.

9 Stainless Steel Fabricators Association (now British Stainless Steel Association). Surface Finishes of Stainless Steel. Information Sheet No.3.

10 NiDI. Design Guidelines for the Selection and Use of Stainless Steels. NiDI publication No 9014.

11 NiDI. The Stainless Steels. NiDI data disc D-0002.

12 NiDI. Welding of Stainless Steels and other Joining Methods NiDI publication No 9002.

13 NiDl. Fabrication and Post-Fabrication Cleanup of Stainless Steels. NiDI publication No 10004.

14 NiDI. Stainless Steel in Architecture. NiDI publication No 10037.

15 Stainless Steel Fabricators Association (now British Stainless Steel Association) Welding Stainless Steel. Information Sheet No 6.

16 Eurolnox. Life Cycle Cost disc available from Eurolnox members, eg NiDI, Stainless Steel Advisory Centre.

17 NiDl. Practical Guide to using 6Mo Austenitic Stainless Steel. NiDI publication No 10032.

18 NiDI. Practical Guide to using Duplex Stainless Steels. NiDI publication No 10044.

19 Arnvig P-E, Wesielewska W Stress Corrosion Behaviour of Highly Alloyed Stainless Steels under Severe Evaporative Conditions. Proc. Danish Met. Soc. Winter meeting Jan 1993 pages 37 to 49.

20 Stainless Steel Fabricators Association (now British Stainless Steel Association) Care and Maintenance of Stainless Steel. Information Sheet No 4.

21 NiDl. Cleaning and Descaling Stainless Steel. NiDI publication No 9001.

22 Moore JFA,Cox RN. Corrosion of Metals in Swimming Pool Buildings. Building Research Establishment Report 1989; C1/SfB 541(L44).

23 Sports Council. Handbook of Sports and Recreational Building Design Vol 3. (in production).

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