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British Stainless Steel Association



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Corrosion of Stainless Steels in Supply (Drinking) and Waste (Sewage) Water Systems

Introduction

In pure water at normal (ambient) temperatures, stainless steels can be considered "inert". Except for chemically purified waters there are various levels of anions, including chlorides, which can be aggressive to stainless steels under certain circumstances.

General corrosion over large areas of the surface is not usually encountered on stainless steels, due to formation and maintenance of an inert "passive" surface layer, but localised corrosion can occur due to the breakdown of the passive layer by chlorides at discrete sites.

There are three main types of localised corrosion mechanisms that can affect stainless steels : -

Pitting corrosion

Crevice corrosion

Stress corrosion cracking

- Pitting corrosion tends to be associated with free surfaces of stainless steel. This form of localised attack can be severe and lead to rapid perforation of thin sheets or tubes. Attack is concentrated at microscopic defects in the protective passive oxide film (for example at the site of inclusions at the surface of the steel).
- Crevice corrosion is a form of attack based on "engineering" sites rather than the "metallurgical" sites responsible for pitting. It tends to occur more readily at sharp changes in section or shielded areas and so is potentially more hazardous.
- Stress corrosion cracking normally occurs at temperatures over 60°C This condition must be accompanied by tensile stresses and chlorides to enable this form of attack.

The main factors that promote corrosion in waters are: -

Chloride level
Temperature
Oxygen level
Water flow rates
Presence of bacterial oxidants

Chloride levels

A limit of 200 ppm (mg/litre) maximum has been set for chlorides in drinking (potable) waters by the EU.

Levels in the UK tend to be below 100ppm and at "ambient" UK water supply storage and distribution temperatures these chloride levels should not be a crevice or pitting corrosion hazard to stainless steel types 304 (1.4301 / 1.4307) or 316 (1.4401 / 1.4404), which are commonly used in these applications.

The accepted view is that crevice corrosion is rare below: -

200 ppm for 304 (1.4301 / 1.4307)
1000 ppm for 316 (1.4401 / 1.4404)

In situations where exposure times are short and there is some "rinsing", as in the case of coastal sewage outfall installations, where high tide chloride levels can reach 1000-2000ppm levels for short periods of time, the 316 (1.4401 / 1.4404) types can be a satisfactory and economic choice. Well maintained water flow rates and oxygen levels will help these steels maintain their corrosion resistance in these applications.

Care must be taken in design however to ensure that chloride levels do not increase by evaporation at liquid surfaces or in splash zones.

Chloride concentration under water scales can also be a corrosion hazard.

Between 1000 and 3600ppm duplex grade 1.4462 (2205) can be considered.

Above these levels "super duplex" grades, such as 1.4410 (SAF2507) or 1.4501 (Zeron 100) or super-austenitics, such as 1.4547(254SMO) or 1.4529(1925hMo) are appropriate.

These can also be used in seawater applications, where chloride levels are of the order of 26,000ppm.

Temperature

The risk of crevice & pitting corrosion attack increases with temperature. At the temperatures and chloride levels normally encountered in water supply & treatment applications, these forms of attack are not usually relevant.

These corrosion mechanisms, along with stress corrosion cracking, are only usually of concern in applications such as water boilers and heating systems, particularly in situations where chlorides can concentrate. Lower temperature environments such as swimming pool building atmospheres, which are particularly aggressive to stainless steels, can also be a SCC hazard concern.

Oxygen Levels & Flow Rates

Oxygen is an essential ingredient in maintaining the naturally occurring protective "passive" layer on stainless steels.

The levels of oxygen normally found in waters are sufficient to maintain the corrosion resistance of stainless steels. It is very localised reductions in oxygen at the surface of the metal, as may occur in a crevice, which can lead to corrosion.

Good water flow rates (above 1 metre / second) help maintain corrosion resistance in stainless steels, whereas stagnant conditions can promote attack by crevice or pitting attack. Low flow rates allow the build up of chloride as localised corrosion product in pits and crevices and so promote the development of localised corrosion cells.

Bacterial Oxidants (Chlorine)

Oxidants based on chlorine (as a gas or more normally as a solution product of hypochlorites) or chlorides (ferric chloride) can promote localised attack.

Levels normally encountered in natural and treated waters are below 1ppm but this can be increased at the chlorination points or due to inadequate mixing in water treatment systems, where attack on stainless steels can then be a potential hazard.

Grades 304 (1.4301 / 1.4307) and 316 (1.4401 / 1.4404) may become vulnerable to free or residual chlorine levels above 2ppm and 5ppm, respectively.

Short- term disinfection and cleaning cycles using high levels of chlorine up to 25ppm for short periods of up to 24 hours can be tolerated safely by the 316 (1.4401 / 1.4404) types, provided there is a thorough post cleaning treatment rinse, using water with the "residual" chlorine level maxima, already mentioned.

Oxidants such as chlorine dioxide and ozone are normally considered safe in most waters.

Other Considerations

Sulphates may reduce the tendency for waters to corrode but where calcareous deposits (i.e. scale) form crevice corrosion can be a hazard.

Aerobic bacteria do not normally present a corrosion risk in potable (supply) waters.

Guide to Selection of Stainless Steels in Water

Water type	Chloride level ppm	Steel type	Common grade names	Nearest EN 10088 Grades
Supply and ground waters	<200	austenitic	304	1.4301/1.4307
	<1000	austenitic	316	1.4401/1.4404
Brackish waters	1000-3600	duplex	2205	1.4462
Brackish & seawaters	3600-26000	super-austenitic	254SMO/1925hMo	1.4547/1.4529
		super-duplex	SAF2507/Zeron100	1.4410/1.4501

These levels assume that the conditions described have been considered.

Acknowledgements

SAF2507 is a trade name of Sandvik AB
Zeron100 is a trade name of Weir Materials Ltd
254SMO is a trade name of AvestaPolarit AB
1925hMo is a trade name of Krupp Hoesch Steel Ltd

References

Further reading on Applications for Stainless Steel in the Water Industry can be found in the Water Industry Information & Guidance Note No. IGN 4-25-02, which is available from the WRc

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