

# Corrosion of 316L stainless steel in seawater

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## 1. Generalities:

### 1.1. Seawater:

Seawater is very often described as a 3.5% NaCl solution, and a lot of simulations of corrosion of stainless steel in seawater are carried out in a solution of 35 g/l NaCl in distilled water.

However, seawater is much more complex than just a simple kitchen salt solution. Not only does the composition of seawater differ from location to location, but also the temperature, the movement in the tidal zone, salinity, oxygen concentration, etc. are parameters that are endemic and each of these have an effect on the corrosion behavior of metals in seawater.

One of the most important parameters having a very important influence on the corrosion behavior of stainless steel in seawater is the biological activity occurring in the seawater. This effect is double. First, the microbiological activity has an important influence on the electrochemical potential of stainless steel and therefore influences the sensitivity for crevice and pitting corrosion. Secondly, all kinds of macroscopic creatures may attach onto the metal surface (e.g. barnacles) which may create an ideal situation for crevice corrosion.

It is therefore useless to determine the resistance of stainless steel against corrosion in seawater by means of a simple NaCl solution.

### 1.2. Stainless steel:

The family of stainless steels is very extensive. In addition to a classification according to the metallographic structure with austenitic, ferritic, martensitic and duplex stainless steels, there also exists within each of these structures an important difference in chemical composition.

With regard to the resistance against localized corrosion, such as crevice and pitting corrosion, the elements chromium, molybdenum and nitrogen are particularly important. In view of the influence these elements have on corrosion behaviour, a so-called PRE value (Pitting Resistance Equivalent) is defined as:

$$\text{PRE} = \% \text{Cr} + 3.3\% \text{Mo} + 16\% \text{N}$$

at which the resistance against crevice and pitting corrosion increases along with increasing PRE value.

## 2. Corrosion of stainless steel in seawater:

The most obvious forms of corrosion of stainless steel in seawater are crevice and pitting corrosion.

Crevice corrosion occurs at locations where there is a contact between two identical materials (wires of metal sieve) or between a metal and a non-metal (washers, O-rings, deposits, macroscopic biological material, etc.) and hence is generally constructively determined.

Pitting occurs without any contact with another material.

Both forms of corrosion can be caused by the presence of (usually) chloride ions in a solution, and are also influenced by temperature and oxidation strength of the solution (e.g. chlorination).

A typical electrochemical phenomenon in pitting corrosion, the existence of a so-called pitting potential. If, due to external factors, the corrosion potential of the stainless steel increases above the pitting potential, pitting corrosion will occur. If the corrosion potential remains below this value, the metal remains unaffected. Also crevice corrosion requires a sufficiently high potential in the passive region.

The potential of stainless steel in synthetic seawater may slightly increase over time from a value between -100 to 0 mV to a value of + 100 mV SCE. In natural sea water however, this potential increases up to values of + 300 mV SCE and more, as a consequence of the bacteriological activity on the surface of the alloy, which results in a depolarization of the oxygen reduction reaction.

This increase in potential as a function of time (which is a general behaviour for all kinds of austenitic stainless steels) is illustrated in the following figure.

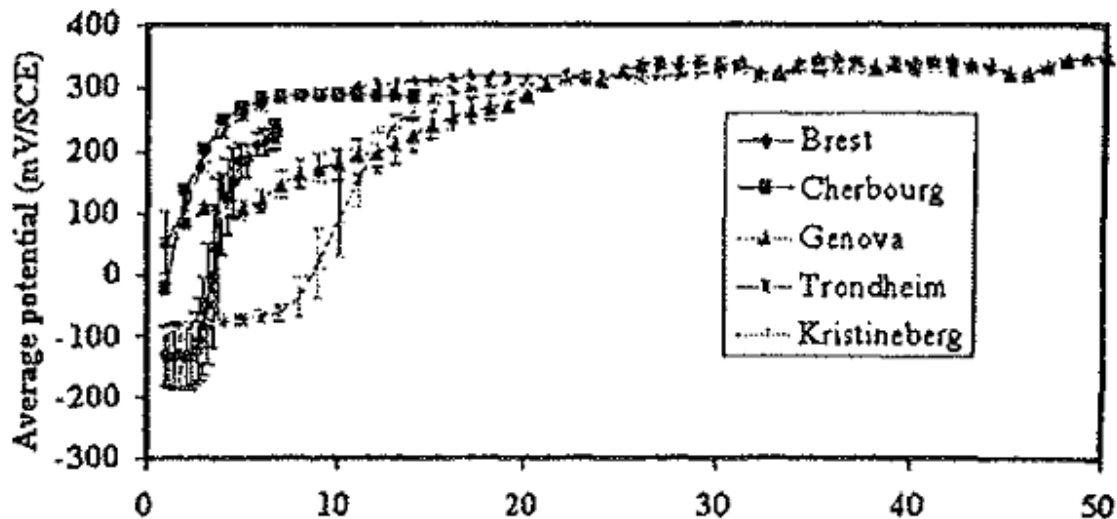


Figure 1\*

Because of this the stainless steel reacts in a totally different way compared with a synthetic NaCl solution. The corrosion potential may increase above the crevice corrosion potential resulting in the initiation of crevice corrosion, as pointed out for stainless steel AISI 316 in seawater, in the following figure (2). At the start, the potential increases due to biological activity, increases above the crevice potential, thus initiating crevice corrosion, after which the potential decreases again due to the presence of an active crevice.

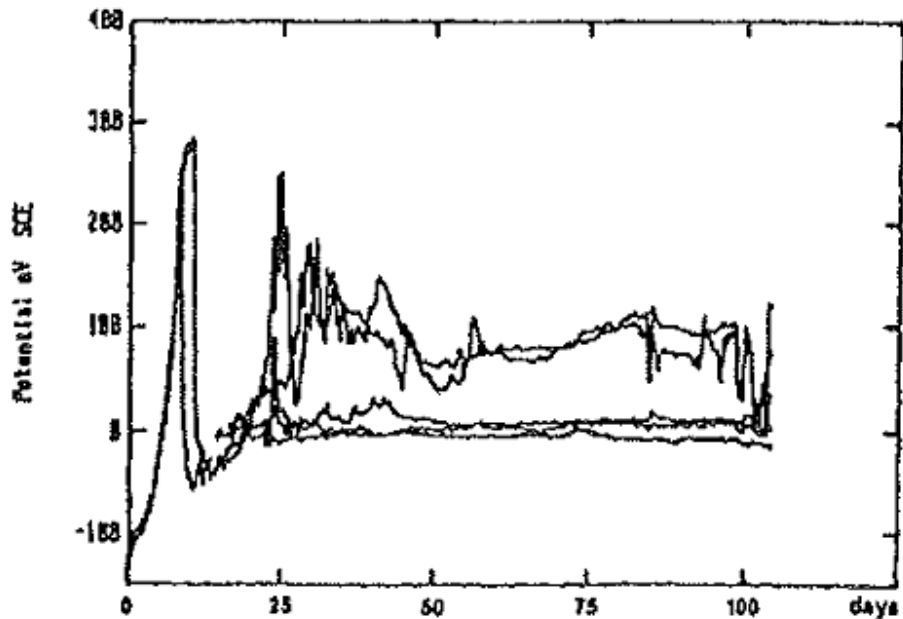


Figure 2\*

Since the relationship between the PRE value and the resistance to crevice and pitting corrosion is determined in a synthetic chloride solution, a direct comparison with seawater is not possible. Therefore, based on empirical data a so-called "seaworthy" PRE value equal to 40 is introduced for stainless steels.

Stainless steel AISI 316 has a PRE value of about 28 and is certainly not "seaworthy".

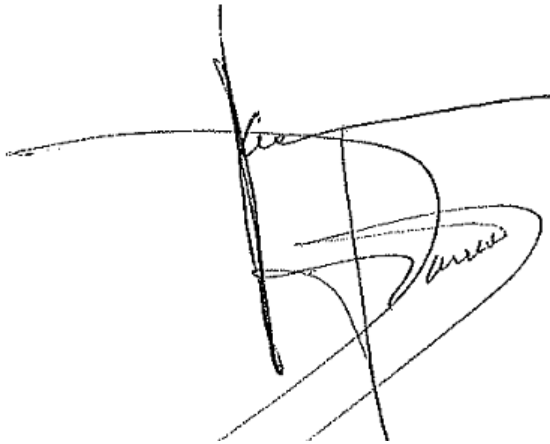
One also has to take into account that the stainless steel may also be fully or partially covered by sand, silt, macro biological and other material on the seabed, creating all the necessary conditions for crevice corrosion.

(\*) Fig. 1& 2; Corrosion behaviour of stainless steels in natural seawater: Results of an European Collaborative Project 31/12/1996 NTis.

**3. Conclusion:**

It is not recommended to use stainless steel of the type AISI 316 or AISI 316L in stagnant seawater.

Merelbeke, January 30<sup>th</sup> 2013.

A handwritten signature in black ink, consisting of several overlapping loops and lines, positioned over a horizontal line.

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