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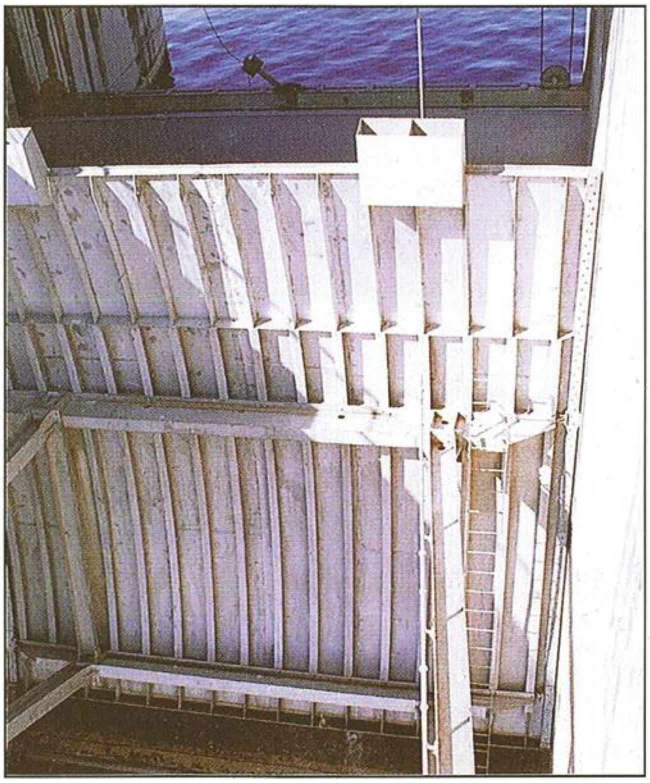
A guide to the use of 3CR12 in water – 2nd edition

Target audience

This guide is intended for use by material specifiers and end-users who wish to know if 3CR12 will be capable of satisfying their needs in a specific aqueous application.

Environment of interest

The environment of interest is water, and the guide relates to applications involving exposure to and/or immersion in waters. This includes:
Pipes
Tanks
X-GRID packing
Settlers
Immersed plate.



3CR12 Radial gates installed at Morgenstond dam

Introduction

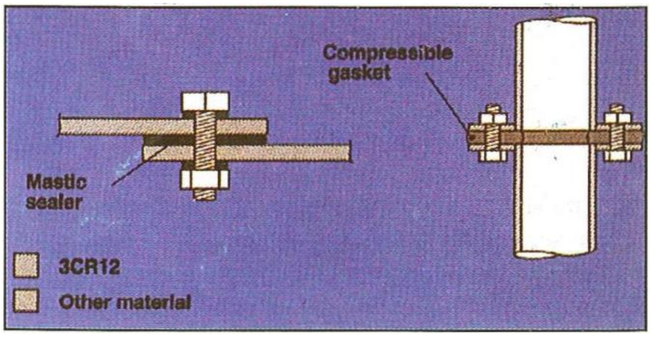
3CR12 is a Chromium-Containing Corrosion-Resistant steel which conforms to the EURONORM specifications - EN 10088 and EN 10028, DIN type 1.4003 as well as ASTM A240/A240M UNS S41003. 3CR12 has proven useful in applications where the corrosion resistance of carbon steel or even galvanized steel is considered to be insufficient. Since its introduction in 1979, 3CR12 has been used extensively in aqueous environments. Its resistance to general corrosion has often been good, but as with any material relying on the formation of a passive film for corrosion resistance; its localized corrosion resistance depends upon many factors. These will be considered in this guide.
Early recommendations for aqueous applications were based upon intuition and case-by-case study. This guide is a compilation based upon successes and failures, and draws together all the quantitative research work by various academic institutions and R&D organizations throughout South Africa. From this work, important aspects such as localized corrosion behaviour of 3CR12 can be predicted.
Factors to be considered when selecting 3CR12 for aqueous service are:

- Design
- Fabrication
- Aeration and flow rates
- Suspended solids, scaling, and fouling
- Water quality and temperature
  - * pH value
  - * alkalinity
  - * microbial activity
  - * chloride
  - * sulphate and nitrate.

Design

It is important in a design process to take advantage of the corrosion resistance and mechanical properties of 3CR12 as compared to mild steel. Designing with 3CR12 can be done in accordance to the following design specifications; PED/2014/68/EU certificate and the EURONORM design specifications. 3CR12 has been included in part 4 of the SANS 10162 "Code of Practice for the structural use of steel". This code of practice is based on "Limit State Design" principles and has extensive tables and formula for all aspects of structural design. In this guide, design refers to maximizing the corrosion performance. The following guidelines apply.

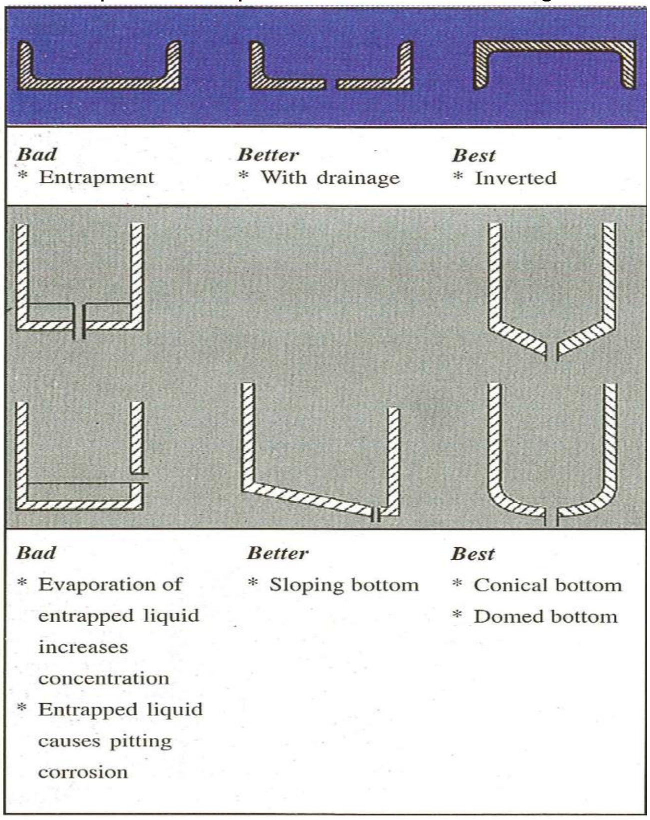
- **3CR12 is noble to most other materials.** A non-porous insulator should be used between 3CR12 and other materials. Washers should always be used on bolted systems. Consideration can also be given to coating the joint area to avoid galvanic attack.



Use impervious mastic sealer or a compressible gasket for sealing the crevice in bolted joints

- **Crevices should be designed out of the system.** In addition to the use of gaskets, water retention, which would permit the build-up of silt and salts, must be avoided. Angles therefore should point downward, and not upward.

- **Free drainage must be provided for.** Where possible, corners should be avoided at the bottom of tanks. Piping should be sized to ensure adequate flow to prevent suspended solids from settling out.



Provide free drainage at the bottom of the tank

- **3CR12 may discolour in aqueous media.** However, there is usually no contamination of the water or loss of material thickness.

- **Design should permit access to the structure** for initial fabrication and possible repair to the required standard when using 3CR12. Inevitably, assessment of an entire system will lead to the conclusion that one area may be more vulnerable to localized corrosion than others. The guide should be used to determine the performance of 3CR12 in the most vulnerable area, as this will determine the performance of the whole system.

- **Care should be taken at times when the plant is *not* under normal operating conditions,** for example during commissioning, stoppages, and mothballing. Changes to the environment such as aeration, settling of solids, etc., may result in conditions that could be detrimental to the material.

- **Closed 3CR12 water conveyance systems should be coated.** Experience has shown that epoxy coated 3CR12 outperforms epoxy coated carbon steel piping even in aggressive conditions. Holidays which are inevitably in coating systems would cause corrosion of the substrate steel. 3CR12 is more forgiving than carbon steel in this situation, as the extent of corrosion product formed does not cause blistering of the coating as is the case with carbon steel. The choice between coated and uncoated 3CR12 should be based on a thorough water quality analysis, including microbial count.

Fabrication[1]

- 3CR12 should be handled in the same way as stainless steel, with every effort being made to ensure cleanliness both in the workshop and on-site. **Contamination from mild steel can cause significant discolouration and potential loss of corrosion resistance.**

Mild steel contamination on 3CR12

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[1] Refer to 3CR12 fabrications guide for more detailed information

- **3CR12 can be formed, machined, and welded by commonly used industrial process.** In all these operations, it should be treated as a stainless steel. Poor fit-up must be avoided, and competent welding practices should be followed to ensure smooth joints free of craters, spatter, and arc strikes.

- **Post-fabrication cleaning and subsequent chemical passivation is essential for 3CR12 when it is to be used in aqueous environments.** All welding processes give rise to a zone of discolouration in the weld area. This can provide a site for corrosion, and must be removed.

Municipal water tank manufactured from 3CR12 instead of concrete; the manufacturer won an award from SASSDA

Aeration and flow rates

Aeration is beneficial to the overall performance of 3CR12. The presence of oxygen is essential to the formation and maintenance of the protective passive film. Flow rates should therefore be sufficient to maintain high oxygen levels in the aqueous stream. Stagnant conditions should be avoided, as localized attack of the material may then occur.

Suspended Solids, Scaling and Fouling

- **Suspended solids** should be considered in combination with flow rate. This is an area where experience has shown the performance of the material to be quite complex. Sufficient flow should be maintained in order to prevent any suspended solids from settling out. Moving mineral solids should not present a corrosion risk. Should settling occur, localized corrosion may well result.

- **Scaling tendency** is described by the Langelier Index, (LI). In the unlikely event of water containing only calcium hardness, a LI value between 0 and 2 may be considered protective. However, at values higher than this, the chance of a ruptured scale forming becomes greater, and therefore crevice corrosion is possible. Negative LI values are not considered to be detrimental to 3CR12.

- **Fouling** is difficult to quantify. Microbial induced corrosion (MIC) is a problem which could be considered specific to each and every application. Consequently the possibility should be kept in mind when conducting material selection. In sewerage applications (weirs, baffle plates, etc.) 3CR12 has performed admirably in the presence of high bacterial counts. Bacteria in this application have shown not to result in microbial induced corrosion, provided that observable bio fouling is minimized.

Water Quality and Temperature

- **pH value**

In general, a pH value between 3 and 9 has no apparent effect on the pitting performance in deaerated environments.

- **Alkalinity**

Increasing alkalinity inhibits the initiation and propagation of pitting. However, in real situations, high alkalinity may lead to the precipitation of an insoluble carbonate, which may promote under-deposit attack on the surface of the metal.

- **Microbial activity**

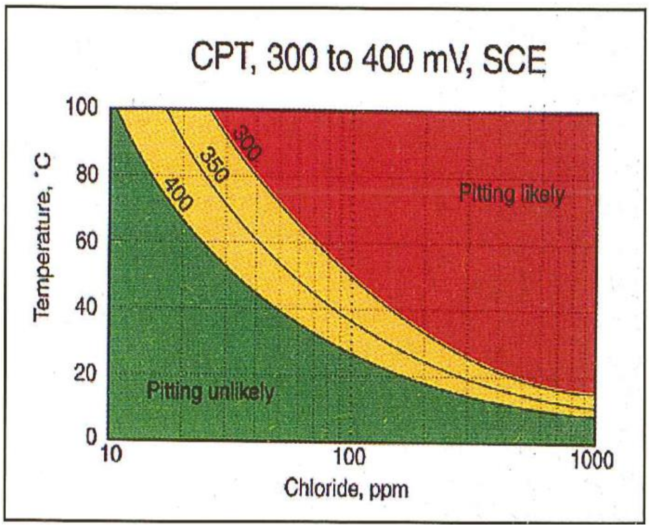
Sulphate reducing bacteria (SRB), and iron oxidising bacteria have been cited as the most common causes of MIC in 3CR12. SRB associated corrosion occurs in anaerobic conditions in the presence of water, and is affected by flow rates - beyond a certain flow rate bio fouling ceases. The mode of attack is pitting rather than general corrosion. MIC caused by SRB therefore perforate a pipeline rather than disintegrating the line.

Microbial induced corrosion on the internal surface of a water tanker lead to concentration of deleterious chlorides causing pitting corrosion due to poor water chemistry

- **Chloride**

Chloride ions have a detrimental effect on the localized corrosion of stainless steels by enhancing the localized dissolution of the thin passive layer. Increasing chloride ion concentration and temperature reduce the localized corrosion resistance of the material. Critical pitting temperature diagrams (CPT) are often produced in order to ascertain the propensity of the material to pitting attack. These diagrams are produced for waters containing chlorides only. The CPT diagram for 3CR12 is shown. In waters where other ionic species are present, caution should be exercised in taking a particular numerical value for pitting potential.

Chlorination of water to normally accepted levels will not affect the corrosion behaviour of 3CR12. It is important to note, however, that the chloride level in such waters may increase with time as a result of the breakdown of chlorine.

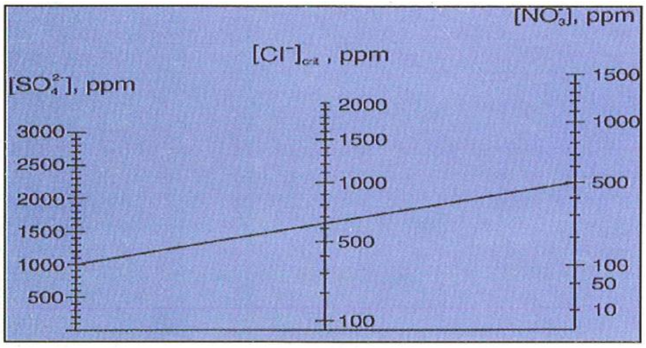


CPT diagram for 3CR12

- **Sulphate and Nitrate**

Both sulphate and nitrate ions have a marked inhibiting effect on localized corrosion. Nitrate is a more efficient inhibitor than sulphate. For a given content of inhibiting anions, there is a chloride level, defined as the critical chloride concentration, below which pitting is completely inhibited. A linear relationship exists between the critical chloride concentration and sulphate and nitrate, both in isolation and in combination.

A model has been designed to predict the maximum concentration of chloride that can be permitted in water containing sulphate and nitrate ions before localized corrosion of 3CR12 takes place. This model was derived for ideal waters at ambient temperature, and with non-scaling and non-fouling characteristics. The monogram has three vertical axes showing the sulphate, chloride, and nitrate concentrations. A straight line drawn between the concentrations of sulphate and nitrate will intersect the chloride axis at the maximum permitted chloride concentration for this water. An example is shown for water containing 1000 ppm sulphate and 500 ppm nitrate, with a critical chloride concentration of approximately 640 ppm. The model has been checked against several actual case studies, and no real anomalies were obtained. The model tends to err on the conservative side.



Model for predicting $(Cl^-)_{crit}$, from known sulphate and nitrate contents

Application 1

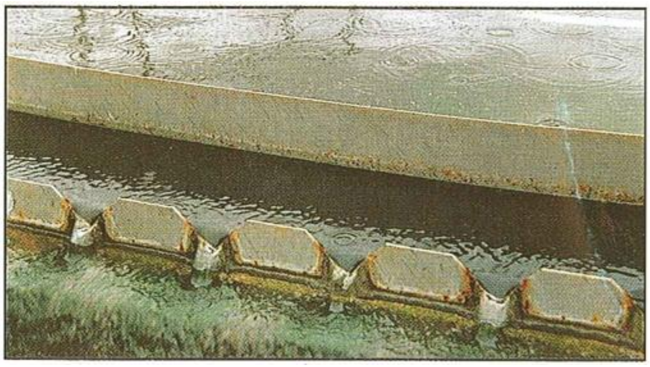
X-GRID, an expanded metal mesh manufactured from 3CR12, has been installed in several cooling towers over the past few years. The longest service installation has been in use since December 1986. During that time these towers have been in full operation, with the exception of periods in which electricity demand was low and the station may have taken a tower off-line. The power station is still in operation, hence a service life of about 30 years for the X-GRID installation. The X-GRID is exposed to circulating purified sewage effluent. Typical water-quality values of the circulating water are: pH 7.3- 9.3, chloride 90-160 ppm, sulphate 100-150 ppm, and nitrate 40-70 ppm. Circulating water is distributed above the cooling pack below. Droplets of water impinge on the splash bars of the X-GRID, causing smaller droplets to fall to the next layer below. Therefore, although the X- GRID is not immersed in water, its surface is totally wetted at all times during operation. The incoming and outgoing water temperatures vary with the ambient conditions, but are of the order of 35-40°C and 25-30°C respectively.

Under these conditions 3CR12 exhibits generally good corrosion resistance, with no definite signs of general or localized corrosion. Minor discolouration was caused by mild steel contamination during the manufacture of X-GRID.


View of the X-GRID layers inside the cooling tower after 20 years' service. Diameter is approx. 52 metres. Picture courtesy of SASSDA.

Application 2

Weir plates are commonly used in settler systems at sewage works. 3CR12 weir plates have been installed at the Waterval Sewage Works at Klipriver. Inspection of one of the modules (Module 3) six months after installation of 3CR12 weir plates revealed the presence of very light pitting and discolouration in the splash zones of the plates. The pitting was not fabrication or weld related. However, at the time of inspection another module in operation for approximately four years revealed pitting to the same extent as was observed on the weir plates of Module 3.



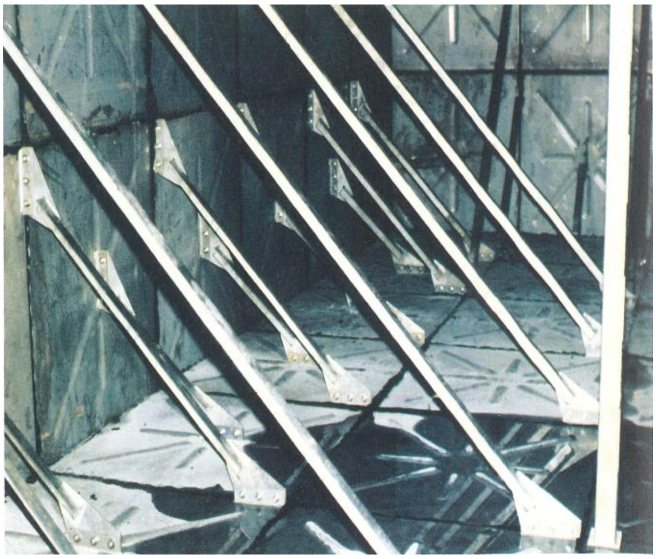
3CR12 weir plates at Klipriver after approximately two and a half years in operation

Both these modules, Module 2 and 3 were re-inspected two years later. Module 2 was then in operation for approximately six and a half years and Module 3 for approximately two and a half years. In both instances the severity of the pitting and the extent of discolouration had not increased as compared to the first inspection. In other words the severity of the pitting corrosion did not increase over time. In this specific case the initial corrosion mechanism was the formation of shallow pits. The mechanism progressed by coalescence of the pits forming a "patina". The source of the chloride ions was the ferric chloride used as a flocculation. The amount of corrosion was minimal with no effect on the effectiveness of the weir plates.

Application 3

3CR12 found application in construction of a water storage tank for demineralized water (boiler feed water) at a power station as pictured below. It was constructed of rectangular panels, screwed together. This invariably means that a crevice is created between the mating surfaces of the panels; however this was overcome by sealing the crevices as shown in the second photograph. The water tank was installed in 1984, although the power station operates at lower than design output currently.

Boiler feed water storage tank installed at Rooiwal Power Station



Sealing of crevices in boiler feed water storage tank – Rooiwal Power Station

Application 4

The most recent application of 3CR12 was in the fabrication of municipal water storage tanks. Traditionally these water storage tanks were fabricated from concrete, which necessitated extensive cleaning operations to ensure adequate water quality for human consumption due to settling of silt in the water. The manufacturer provided a tender submission which recommended 3CR12 as the basis for a new water storage tank design, as well as proper drainage design to lower the maintenance requirements on the water storage tank. The tender was awarded to the manufacturer, where after SASSDA awarded them with a prize for their innovative design. The manufacturer was nominated as a contestant in the International Stainless Steel Federation awards.

Photograph shown earlier in the document as an example of proper tank design.