Select adequate material of construction

Corrosion is recognized as one of the most serious problems in our modern societies and the resulting losses each year are in the hundreds of billions of dollars and more important are the accidents which happen due to failure or malfunction of systems due to corrosion. Selecting adequate material and to specify and correctly applying the right corrosion protection can make a huge difference. It will ultimately define safety, reliability and cost of any kind of plant, system or equipment. The following tragedy indicates the importance of specific know how when it comes to material selection!

In 1985, 12 people were killed in Uster, Switzerland when the concrete roof of a swimming pool collapsed only after thirteen years of use. The roof was supported by stainless steel rods in tension, which failed due to stress corrosion cracking. A few years later, 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. The collapse of this ceiling above a swimming pool showed how a simple structural concept could be sensitive to the loss, through corrosion, of support from one of many hangers.

The Federal Materials Testing Institute, Switzerland, and the Federal Materials Research and Testing Institute of Berlin concluded that the collapse was the result of chloride-induced stress corrosion cracking. Chloride is a major factor in corrosion of reinforced concrete, as in the case at Uster. The chloride was either already present in the concrete or came from the pool via water vapor.

Chloride can overcome the passivity of the natural oxide film on the surface of the steel. The steel, lacking its passive film, readily releases iron atoms into solution (in this case, moisture is present in the concrete due to the humid environment).
When the concrete roof of a swimming pool collapsed, concrete and steel rained on the swimmers below. The cause was the chloride in the pool; it corroded the anchor bolts which held the roof panels in place. The bolts suffered intergranular, stress-induced micro-cracks which ultimately was the cause for this tragedy.

There is a lot of information and experience available and can be drawn from various source, even the World Wide Web offers a vast amount of valuable information. But like any other topics, you have to ask the right questions and potential corrosion has to be part of an integrated risk analysis. For example: what is the use of corrosion tests if you have not mapped out the possible range of process parameters? Chloride in the swimming pool causing stainless steel roof hangers to crack and to strike dead swimmers below – a terrible failure of engineering!

In the chemical- and pharmaceutical industry corrosion protection is a key discipline as chemical processes must run under extreme conditions with regards to pH, temperature or pressure. Very often one has to accept a certain corrosion rate and it is therefore essential to monitor and determine the remaining material condition.

Corrosion and prevention of corrosion are very complex processes as it involves the full understanding of material science which includes electro chemical behaviour, erosion of material surface, induced force, environmental conditions, material impurities, welding technology, etc.

Once the process conditions are outlined and defined, it is down to material testing to identify a suitable material or adequate surface protection.

**Corrosion of stainless steels can be categorized as one of:**

- General corrosion
- Pitting corrosion
- Crevice corrosion
- Stress corrosion cracking
- Intergranular corrosion
- Galvanic corrosion
- High temperature corrosion

**General Corrosion**

General corrosion is an allover weight loss or also loss of thickness of material. Uniform corrosion (or "general corrosion") is characterized by an even, general wasting away of metal from the corroding surface. Virtually all metals are to some extent subject to this type of corrosion under certain conditions (e.g., rusting of carbon steel in the atmosphere, dissolution of steel or zinc in many acids, etc.). If unavoidable, it is sometimes said to be the most desirable form of corrosion, since it lends itself rather well to the life prediction of structures or equipment (in contrast to the localized forms of corrosion, like pitting or stress corrosion cracking).
Pitting Corrosion

Pitting corrosion (or "Pitting") can be defined as an extreme case of localized attack which results in the development of cavities or "pits" in the metal surface. The pits may range from deep cavities of small diameter to relatively shallow depressions.

Pitting corrosion forms on passive metals and alloys like stainless steel when the ultra-thin passive film (oxide film) is chemically or mechanically damaged and does not immediately re-passivate. The resulting pits can become wide and shallow or narrow and deep which can rapidly perforate the wall thickness of a metal.

Crevice Corrosion

Crevice corrosion (CC) is a particular form of localized corrosion (i.e., including phenomena somewhat related to pitting corrosion reactions) which occurs in a crevice formed between two surfaces, one at least of which is a metal. Examples of such crevices are: flanged or threaded connections, shielded areas on metal surfaces (e.g. as a result of deposit formation).

Stress Corrosion Cracking

Stress corrosion cracking (SCC) is the cracking of a material produced by the combined action of corrosion and tensile stress. This stress can either be applied (external load), or can be residual stress in the metal (e.g., due to production process or heat treatment).

Stress corrosion cracking is especially insidious. It is usually unpredictable in nature. Even after a few years of trouble free service, a metal can suddenly crack without any warning or previous deformation.
Intergranular Corrosion

Intergranular corrosion (IGC), sometimes also indicated as "IGA" (intergranular attack), is a localized attack at and adjacent to grain boundaries, with relatively little (or virtually no) corrosion of the grains.

Transgranular chloride induced attack is just through the grains.

Galvanic Corrosion

When dissimilar metals are used in contact with each other and when they are exposed to an electrically conducting solution, then - as a general rule - combinations of metals should be chosen that are as close as possible in the galvanic series.

Coupling two metals widely separated in this series will normally lead to accelerated attack of the more active metal. Often however, protective oxide films and a number of other effects will tend to reduce bimetallic corrosion.

High Temperature Corrosion

The development of, for example, high temperature petroleum cracking processes and the use of metals in contact with combustion products in furnaces, flues or gas turbine gas has led to an increasing interest in the problem of corrosion in high temperature environments. Under the influence of high temperature grains of steel are growing. Carburization and nitriding attack can occur in hot regions of furnace tubes where compounds containing carbon or nitrogen give rise to carbide or nitride formation on the metal surface. The formation of methane or ammonia in the carburized surface layer can lead to physical disintegration of the surface.

Material testing (both on site and in a laboratory)

Testing on site

The test steel coupons are cleaned and etched with a nitric acid/hydrofluoric acid solution. The weight of the test coupons is determined (4 places after comma) and registered. At the end of a test weight and condition is finally checked. Steels are checked for corrosion forms like pitting, stress cracking, intergranular or transgranular corrosion. The result of an on site test is much more representative than a test at laboratory, because the exact conditions during a reaction can hardly be simulated in a lab test. The on site tests are also for monitoring and so the test time is preferably longer and the result more accurate.
The coupons have to be mounted with electrical isolation to all other metal parts, in order to avoid galvanic corrosion. For this purpose on the one side to the carrier the Teflon plate is used. The bushes are used to avoid electrical contact to the screws used for fixation. (See drawing) For the holder you may use the same material as the wall and may weld or screw it to the wall.

Testing in a laboratory

Corrosion tests in Lab:

Laboratory corrosion tests are frequently the best available source of data for materials selection, if there are none available in literature or our database of tests already done.

The immersion tests are performed in glass vessels with one test coupon in the gas and one in the liquid phase. For the testing of glassed steel teflon vessels are used.

The tests are performed after German Industry Norms DIN 4761, 50900 and 50904 part 4.

Coupons for tests:

Different steel qualities:
- approx. 30 x 50 mm, without weld seam
- approx. 30 x 80 mm, with weld seam
- C-ring stress corrosion test specimens cut of welded tubes
- coated coupons
- Halar, glassed steel, rubber

Plastics (PE, PVDF, PTFE, PP, rubber qualities) for the tests of plastics we use samples for tensile strength testing.
The test steel coupons are cleaned and etched with a nitric acid/hydrofluoric acid solution. The plastics are cleaned and tried over night. The weight of the test coupons is determined (4 decimal places) and registered. The duration of a norm test is 500 h. The test solution is changed after 1 and 2 weeks in order to keep enough corrosive medium at the coupons. At the end of a test weight and condition is finally checked. Steels are checked for corrosion forms like pitting, stress cracking, intergranular or transgranular corrosion, tensile strength, elongation, hardness, content of ferrite, growing of grain size, steel analysis. Plastics are tested for growing in thickness, Shore hardness, and changes in tensile strength, elongation and surface.

**Corrosion theory and its protection methods**

Most metals used in the construction of facilities are subject to corrosion. This is due to the high energy content of the elements in metallic form. In nature, most metals are found in chemical combination with other elements. These metallic ores are refined by man and formed into metals and alloys. As the energy content of the metals and alloys is higher than that of their ores, chemical re-combination of the metals to form ore like compounds is a natural process.

There are two methods of combating corrosion which are widely used are cathodic protection and chemical inhibitors. Cathodic protection is effected by forcing the potential to a negative region where the metal is completely stable. This can be done by using a sacrificial anode made from a more reactive metal, or using an external power supply to change the amount of charge on the metal surface. Cathodic protection is well suited to steel structures in marine or underground environments. Chemical inhibitors work by removing electrons from the metal, thereby pushing the potential into a positive region where an oxide film spontaneously forms. This results in a stable, passive surface with in a very low corrosion rate. Industries apply this technology in processes where the inhibitors can be conveniently added without causing environmental or health problems. An introduction of corrosion protection methods is listed in the table below.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Industrial Process</th>
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<tr>
<td>Removal of oxidizing agent</td>
<td>Boiler water treatment</td>
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<td>Prevention of surface reaction</td>
<td>Cathodic protection - sacrificial anode</td>
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<td>- impressed current</td>
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<td></td>
<td>Anodic protection</td>
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<td>Inhibition of surface reaction</td>
<td>Chemical inhibitors</td>
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<td>Protective coatings - a. Organic</td>
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<td>Metal spraying</td>
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<td>Conversion coating</td>
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<td>- b. Metallic</td>
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<td>- c. Non-metallic</td>
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<tr>
<td>Modification of the metal</td>
<td>Alloys - stainless steel</td>
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<td>- cupronickel</td>
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<tr>
<td>Modification of surface condition</td>
<td>Maintenance to remove corrosion agents</td>
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<td>Design to avoid reactive crevices</td>
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<td>combinations</td>
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In this context, Lonza Engineering’s service could include:

- Process review
- Material selection utilizing vast amount of lab data’s
- Perform lab test
- Root cause analysis of corrosion problems
- Material evaluation and cost comparison

Pls. discuss your requirements with our experts, we would be very happy to offer our support.

An extensive service list is available on our website:

http://www.lonza.com/engineering

Lonza Engineering Ltd
Lonza Engineering is a subsidiary of Lonza Group Ltd and provides customer oriented services with a professional, experienced and highly motivated engineering team. We have more than 15 years of successful project management experience in China which makes us a perfect partner for the chemical, pharmaceutical and biopharmaceutical industry. A broad range of services with a project reference list underlining our capabilities is available upon request.

Lonza Engineering has successfully managed multiple and complex projects such as continuous operating plants for the production of food and feed additives as well as active pharmaceutical ingredient plants including waste gas and liquid waste treatment facilities. The management team of the new company consists of current Lonza employees from Switzerland and China.

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