

CORROSION: Origin and prevention (2)

Eng. N.W. Buijs
Van Leeuwen Stainless B.V.

The origin of corrosion was described in MK6. Corrosion can only be prevented when there is enough knowledge about its causes. For this reason the measures which can be taken in order to fight corrosion in the best of ways will now be described.

Corrosion can be fought against both in a passive and in an active way. Passive means that the system itself will have a braking effect on the corrosion like for example polarisation. The active way means that mechanisms are created with the modern corrosion theory which should fight against corrosion or even have to completely prevent it.

It will be clear that most forms of corrosion have their 'roots' in the difference of local potentials whereby the less precious little spots react with the medium. Another word which can be used for this is that the little spots become active. In fact, every system which wants to go back to its old status has an active potential. This is, for example, evident with iron, once it has come in contact with moisture (electrolyte) it will immediately react so that rust formation will start. If there is a chance of changing this active behaviour in a passive behaviour than the matter is basically solved.

A very known method is to alloy it with a minimum of 12% of chrome, whereby a tough solid hide which has the same capacity as the mother material will spontaneously originate at the air and the metal is locked up by a hide of chromedioxide. It is as if it were

wrapped up and the mother material cannot react with the environment anymore because the potential rises from negative to positive (pict 8). When such an oxidehide is damaged this is automatically mended, as long as oxygen is present. Amongst other things, this means that the needed caution has to be used in reduced environments. In similar circumstances the urge to take up oxygen can be so big that the bonded oxygen can even be 'stolen' from the chrome, whereby the oxydehide is broken off. Naturally, this cannot be restored if there is no oxygen in the environment. This breaking of the chemical bond is also called dissociation.

Not only stainless steel knows the mechanism of the perfectly connecting oxide hide but also metals like aluminium and titanium. If the oxidehide does not fit the mothermaterial because of its volume it bounces off the subsurface and the oxidation can continue unlimited like for example rusting of iron and unalloyed steel. Passivity can thus only be reached when an isolated oxidized hide protects the (active) metal firmly connected so that there is no chance for 'intruders' (pict 5).

There are also special ways to thicken the oxide hide by means of the passivating process. This basically means that an object which can build a closed oxide hide is immersed for a certain time in a strong oxidizing acid like for example saltpetre acid. Stainless steel which is for example stripped of its oxide hide by means of the staining process is often passivated in a similar acid in order to quickly and adequately build a thick oxide hide.

It is also a fact that the passive oxide hides have their limitations with heavy corrosive load whereby the material choice or the process have to be adjusted.

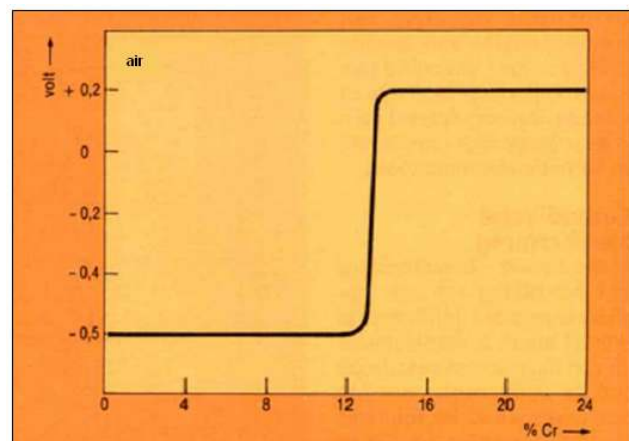
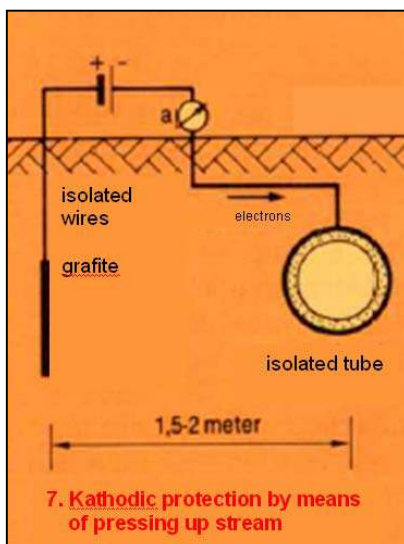
Many bonds on iron and nickel basis have been developed in order to resist corrosion in most production processes. If similar bonds cannot satisfy the set corrosion resistance requirements anymore, than also metals like titanium, zirconium, tantalum, niobium and even highly precious metals like silver, platinum and gold are available.

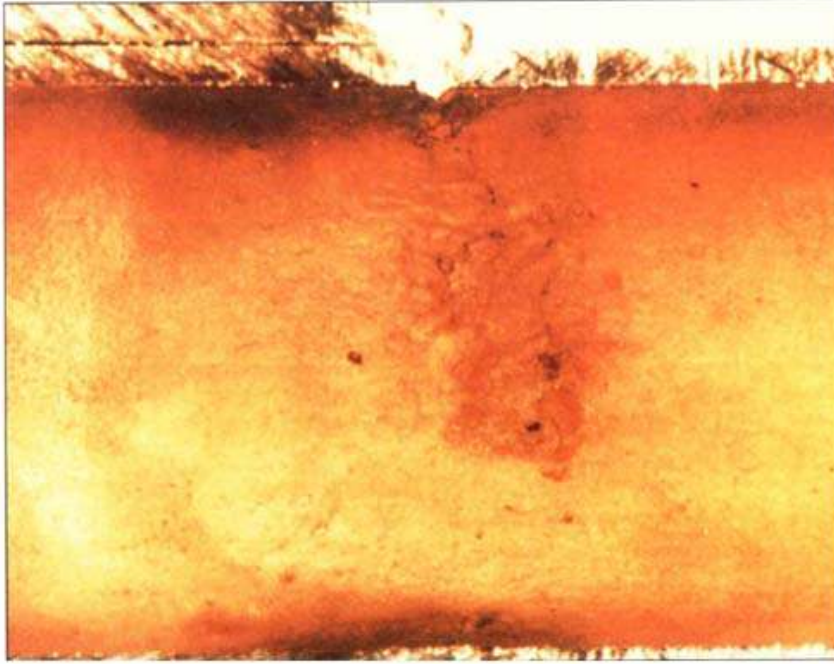
Inhibitors

Fighting corrosion by means of inhibitors aims to contain a corrosion reaction or even to completely prevent it by means of an 'inhibitor' which is added to the corrosive medium. In fact, this is an extremely simple method to fight corrosion; however, it is important to determine the right 'braking material'. Empirically a lot is decided in practice like organic amines which decrease the aggressiveness of muriatic acid with regard to steel. The braking mechanism can be explained by adsorption (cover layer formation) on the anode or cathode. Therefore in practice it is spoken about anodic and cathodic inhibitors.

Cathodic protection

Cathodic protection regarding a sacrifice anode, for example zinc with





Inter-crystalline corrosion of a welding connection 316 in seawater

steel, has already been described in a detailed way. In practice it is proved that it is not practical to continuously replace sacrifice anodes on time and therefore there is also a way to press up the stream whereby the replacement of anodes is basically not anymore needed. In this case, of course, a source of power is needed and also help-electrodes like for example graphite or platinized titanium (pict 7).

In fact, the protection mechanism is the same as with the case of the sacrifice anodes, however the anodes do not or hardly dissolve. By means of measuring poles it can always be determined how much stream has to be pressed on the system in order to discourage corrosion. In this way big objects can be protected against galvanic- and wander stream corrosion. Hydrogen develops on the cathode ($2H + 2e \rightarrow 2H$) in straight proportion to the quantity of pressed up stream. Therefore it is important that power is not pressed up unlimited so that the production of hydrogen would increase in such a way that it would push off the isolation of the object to be protected.

Protective coating

If a metal cannot passivate itself by forming a tough closed oxide hide this can also be applied artificially by means of a protective layer which is also called coating.

In practice we distinguish various protective covers like:

- metallic protective layers
- claddings
- painting, bituming and plastics;
- anodising.

Examples of metallic protective layers are: coppering, chroming, zincing,

nickeling, tinning, etc. Covering layers can also be applied with the help of cadmium and lead but these quickly loose terrain because of the environmental pollution. Most metals described above are applied with the help of the galvanotechnic even if tin and zinc are also applied in their fluid status also by means of immersion.

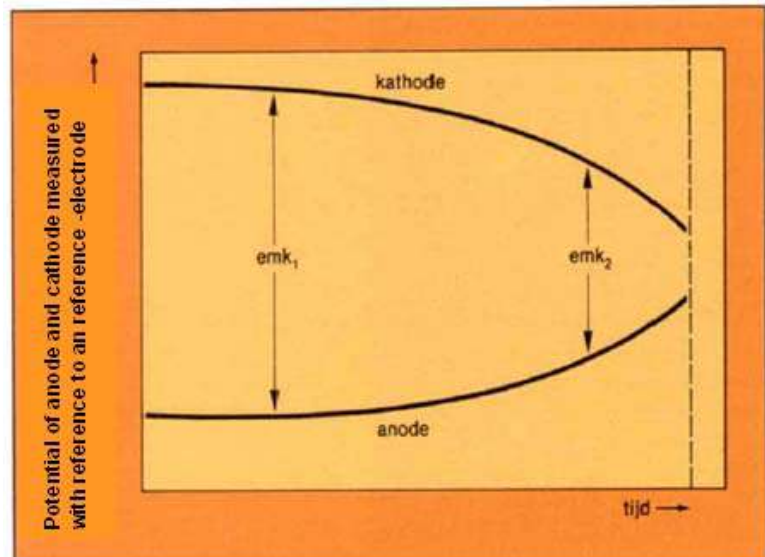
A good example is thermal galvanising. The thickness of the layers is very much dependent on the type of process and therefore can fluctuate between 4 and circa 200 um. Thick layers originate mainly by thermal appliance of a protective coating. Thin layers originate mainly through galvanizing where by means of electric power a metal from a solution of one of its salts precipitates on the substrate. Furthermore also metal powders

can be applied by spurting of melted metal powders, which is more and more suppressed by plasmablows. The latter is mainly used to apply layers which also have to be wear-resistant.

Relatively thin layers of metal which behaves in a precious or passive way, are applied on a metal which has to be protected with a rolling mill process or an explosive weld process. These are the so called claddings. These processes are mainly practised when building apparatuses for respectively trunks for (reactor-)drums and pipeplates for heat exchangers. Painting, bituming and plastics are non-metallic cover layers which can be applied by means of immersion, surfacing or squirting. Plastics can also be limed as foil on the subsurface. It is a requirement that the layers are hermetically closed otherwise a small damage will comport a fast deterioration. Similar layers can also be applied thermally like for example enamelling, vulcanizing of rubber, epoxying etc. Nowadays, very good

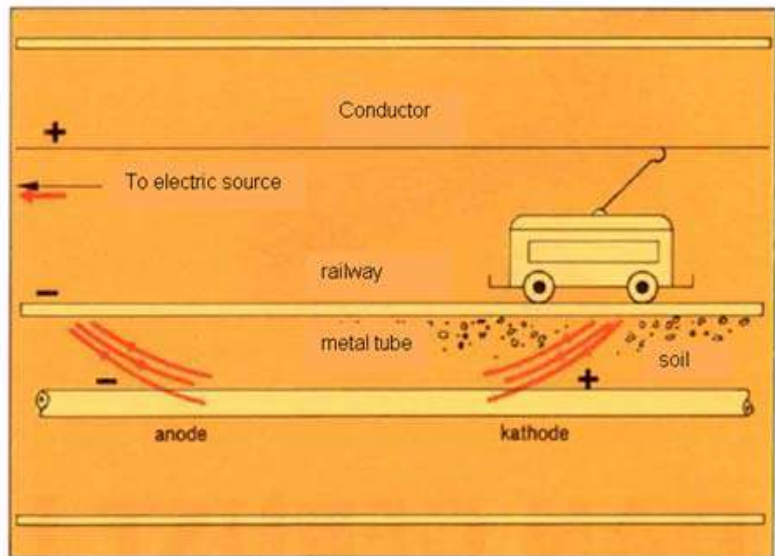
painting systems have been developed to protect metals from corrosion. Anodizing is a process to replace the natural oxidefilm of certain aluminium bonds with a much thicker oxidehide which is obtained by means of an electrochemical process. This oxidehide, which will be porous after the treatment, can be coloured with cooking water before being sealed. It is also possible to colour electrochemically. In this way arise various aluminium objects which have acquired a much higher resistance to corrosion. A well-known application is the commercial and industrial building industry where many anodized aluminium profiles are used.

Polarisation

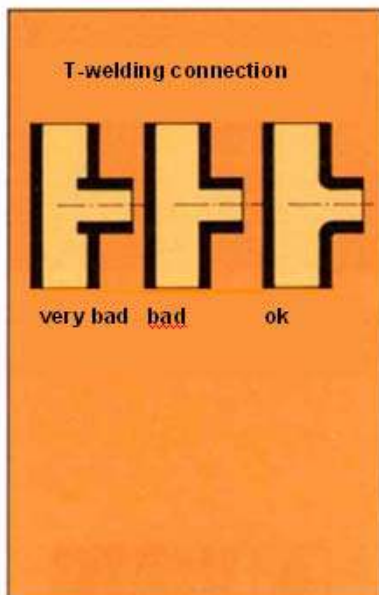


9. Polarisation Emk_2, Emk_1, E

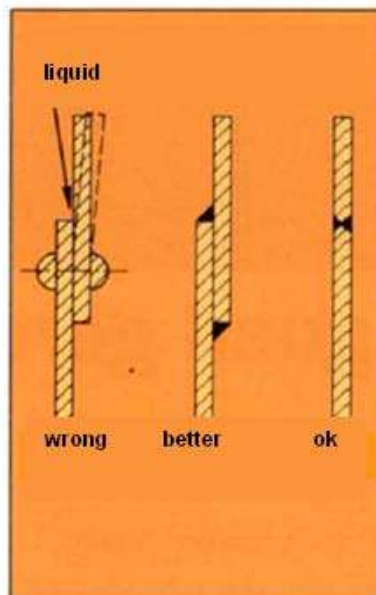
Finally, also the understanding 'polarisation' deserves some attention. Polarisation is a passive way of fighting against corrosion because this happens without intercession of human actions. When in a galvanic system corrosion products settle on the anodic surface it will be clear that this not electric-conducting layer can give metal ions to an electrolyte with a lot of difficulty. For example, on the zinc anode layer of an iron-zinc element originates $Zn(OH)_2$ because of the reaction $Zn^{++} + 2OH^-$. This zinc hydroxide forms an isolated layer whereby the corrosion comes completely to a standstill. This is called the polarisation of the corrosion-element. Besides anodic polarisation there is also the cathodic polarisation which serves the same aim, i.e. building



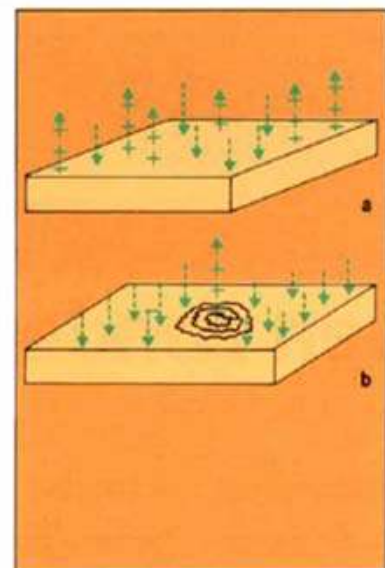
13. Schematic impression of stray-current-corrosion of a tube caused by an electrical railway



10. Avoid turbulence



11. Avoid capillarity

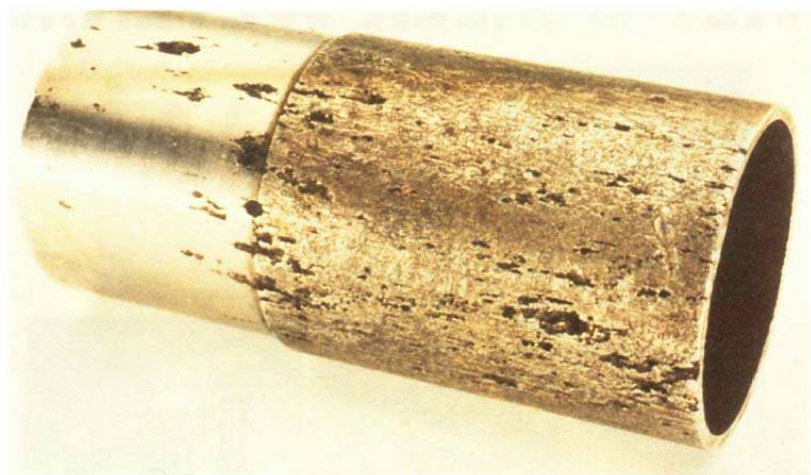


12. Schematic impression of the difference between uniform a) and local b) corrosion

up a resistance in order to have the electric stream to drop off having as limit that the stream is completely blocked. In any case polarisation thus achieves the electromotor power of a corrosion element to decrease (see picture 9). When this decreases, than naturally also the corrosion speed decreases in connection with the decreasing concentration of ions. The measure of polarisation also depends on the flowing pattern of the electrolyte which, for example through turbulence, can decrease the origin of this phenomenon.

Conclusion

It can be left unsaid that a lot can be told about the discussed



Pitcorrosion of stainless (17% Cr)

subject. There are many other methods to fight corrosion like chloring, phosphating, **scoping**, sherardising, aluminizing, anodic protection, control of the oxygen content and similar; however, in general it can be said that also in the metal world it counts that: 'prevention is better than cure', in other words: take preventive actions in order to precede corrosion. Therefore during the planning phase it is of big importance that constructors concentrate on constructions which are insensible to corrosion. Often it turns out that due to ignorance and nescience all kinds of unnecessary splits and dead corners are taken up in a system which later lead to corrosion. Also the combination of assorted metal bonds are sometimes chosen rashly. In conclusion, in pictures 10 and 11 some examples are given which demonstrate illustratively what should and what should not be done while constructing. Furthermore, it will be clear that with the aid of knowledge, logic, empiricism and the required consultation one will come to the decisions which at last will lead to the results which had been set as objective.