# Optimum corrosion control with intelligent anodes

The use of cathodic protection is described for controlling metal corrosion. A well-known example being the attachment of zinc anodes to ships' hulls to protect their steel from seawater. Similar practices are also used with steels underground where corrosion can occur from moisture and groundwater. The procedure of corrosion protection of the cathode (the object to be protected) by using either a sacrificial anode or an impressed current one is outlined and it is shown that protection currents can be calculated in this way according to the Norsok RP B401 standard. This sort of protection can be used for corrosion protection of offshore constructions and quay walls.

*N.W. Buijs*
*Metallurgist at Innomet b.v.*

Cathodic protection is a familiar technique for controlling the corrosion of metals. It has been used successfully for more than 100 years. It does, however, require the presence of a conductive fluid, such as water, known as an electrolyte. A well-known example of this type of protection is the attachment of zinc anodes to a ship's hull in order to protect the steel from seawater. The anodes sacrifice themselves for the benefit of the steel as the electric potential of zinc is lower than that of carbon steel. This is in fact a desirable form of galvanic corrosion. This method is also used frequently underground as corrosion occurs here due to the presence of moisture and groundwater. In the Netherlands, for example, this method has already been used to protect several thousand kilometres of underground pipes.

The object to be protected is known as the cathode and the anode supplies the required protection current. The anode can be either a sacrificial anode or an impressed current one connected to a power supply that is also known as an impressed current cathodic protection system. The design principles for both systems are the same. If the voltage or potential and resistance of the system are known, the protection current can then be calculated using Ohm's law. With sacrificial anodes, the potential is measured by inserting a voltmeter between the cathode and a reference electrode. The most commonly known standard for calculating the resistance and the design for cathodic protection is the Norsok RP B401. The calculated protection current can vary from a few dozen milliamperes for small anodes to several amperes for large anodes. The latter are used, for example, to protect offshore constructions or quay walls. The service life of an anode can be

*Fig. 1. Installation of an intelligent cathodic protection system in a stainless sand bed filter (photo by Innomet B.V.).*

*Fig. 2. The rod-shaped magnesium anode is clearly visible iin the filter unit of a stainless steel ozone reaction tank (photo by Innomet B.V.).*

calculated on the basis of the capacity of the anode and the protection current. A sacrificial anode usually has a design life of between 10 and 30 years.

## Intelligent anodes

In addition to the above known anodes, intelligent or self-switching anodes have been developed that are able to deliver an exceptional, controlled performance. Although these anodes are classified as sacrificial anodes, electronic circuits and semiconductors enable them to do precisely what is expected of them. This means that no over protection or under protection can occur as in the case of ordinary anodes. This makes it possible, for example, to apply cathodic protection to the systems of ships which sometimes sail in fresh water and sometimes in brackish water or seawater. This would be impossible using conventional methods. Another advantage is the absence of malfunctions or broken wiring which are regular occurrences with impressed current systems. It is also considerably cheaper than impressed current systems and also requires no maintenance.

At present, thousands of intelligent anodes have already been successfully used in the protection of duplex stainless steel as well as to protect austenitic, ferritic and martensitic stainless steel. As there is no risk of over protection, hydrogen embrittlement cannot occur, which is often the case with conventional methods. Even when cathodic protection methods are used on steel constructions at sea, such as steel caissons with seawater lift pumps made of bronze or stainless steel, care must be taken to avoid over protection as undesirable hydrogen development can ultimately cause nearby duplex welds to crack. The same applies to undersea duplex pipes which can be subject to excessive negative polarisation due to the protection system of the steel platform. All these problems are completely eliminated if intelligent or self-switching anodes are used.

In addition, there is no risk of under protection, which in turn can also lead to undesirable corrosion.

## Control of fouling

Allowing the current of the intelligent anodes to pulsate causes the pH value (degree of acidity) to fluctuate. This helps prevent micro-organisms from settling on metal surfaces. In this way, fouling can be controlled and microbiological corrosion prevented. This method is already being used

*Fig. 3. Stainless steel sand bed filters used for cleaning swimming pool water are also protected using intelligent cathodic protection (photo by Innomet B.V.).*

*Fig. 4. Corrodium anodes with a stainless steel flange, used for seawater coolers etc. The electronic circuits are built in, eliminating the need for a separate housing or cables (photo by Corrodium B.V.).*

successfully with impressed currents on underground pipelines. The effectiveness of using pulsating anodes in seawater coolers in order to control fouling is currently being studied. The results that have already been obtained are more than encouraging. It has already been proven that pulsating anodes perform well when it comes to corrosion protection.
As stated earlier, these intelligent anodes have also been shown to work well with less conductive types of water. A system has been developed for river water and swimming pool water to protect appliances manufactured from AISI 316L stainless steel. Examples include sand bed filters and ozone reaction tanks which need to be protected from microbially induced corrosion (MIC) and pitting. It is also extremely convenient with these types of applications to eliminate the need for high-maintenance wiring, which also means no maintenance. Apart from an annual check, the sacrificial anodes only need to be replaced once every so many years. Intelligent sacrificial anodes can also play an important part in providing protection where water conductivity levels vary, which is the case in most sea ports.
Studies are currently being conducted into whether pulsating anodes could also save on costs. Quay walls and tubular poles often involve projects that can sometimes require investments amounting to millions of Euros. As a consequence, doubling the service life or halving the weight of the anode could work out particularly advantageous in terms of price. In principle, these aspects can be achieved with the use of intelligent anodes. This method of cathodic protection is patented and is registered in the name of Corrodium b.v. For the sake of convenience, the anodes are also known as Corrodium anodes.
To sum up, it can be said that these types of anodes offer tailor-made protection. As a result, there is no over or under protection, which both have significant disadvantages. A good example is a seawater lift pump with a conventional protection system which is subject to over protection when idle and under protection as soon as it is put into operation. This is not the case with intelligent anodes as the correct current density is constantly supplied for optimum protection against corrosion. The system also adapts itself to variable conductivity levels of the water type which may vary from fresh water to seawater without causing problems such as hydrogen blistering under the coating. This is often the case with ships which frequently sail in coastal waters.

## Applications

Applications of this unique method of protection are mainly to be found in the offshore industry and in other maritime situations. They are frequently encountered on platforms for oil and gas extraction. Typical examples include the protection of heat exchangers, pumps, valves, tanks, vessels and also pipeline systems. This method of protection has been used to stop corrosion mechanisms in the cooling systems of fishing vessels and in seawater-cooled ammonia coolers to

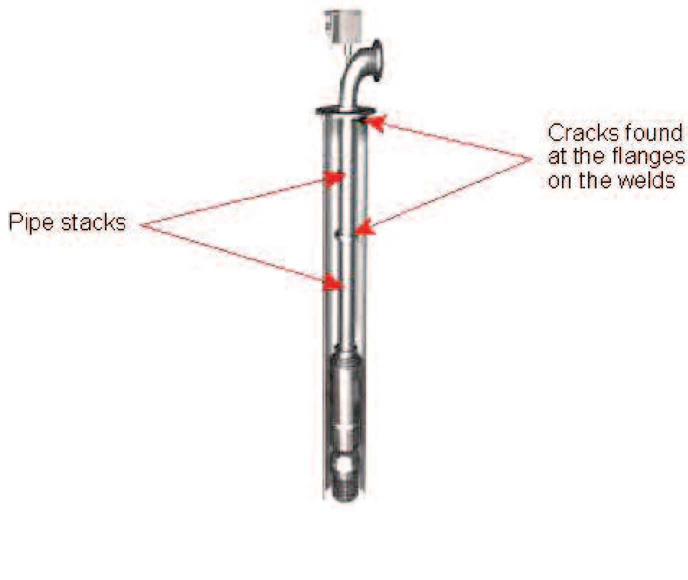


*Fig. 5. A duplex seawater lift pump fitted with a riser.*

cool the casings of blast furnaces. These applications also take advantage of pulsating currents to counteract the formation of dreaded biofilms. Other applications can mainly be found in systems cooled with fresh water, swimming pools and in sewage purification installations. Due to the lower conductivity level of the water, switched magnesium anodes are usually used in these cases.
Fig. 5 shows a seawater lift pump manufactured from duplex stainless steel. The pump is fitted with a riser and the whole ensemble hangs in a steel tube. Aluminium anodes were attached to protect the entire system but it was subject to over protection when idle causing the development of an excessive amount of hydrogen at the cathode. This resulted in the formation of cracks in the duplex welded joints. Intelligent anodes do not cause these problems at all. In other words, galvanic corrosion is also controlled here, since there is a relatively large potential difference between carbon steel and duplex stainless steel. Moreover, this type of protection system also uses a so-called reference electrode. When this electrode acts as a sensor, the electronics maintain the potential at an ideal level under all conditions, without loss of power or capacity of the anode. If a variable system needs to be protected, such as a ship that sails in both freshwater and seawater, magnesium anodes are chosen as the conductivity of river water is relatively low. Normally, this type of anode would get out of control in seawater as magnesium is such a base metal. This would then lead to significant hydrogen formation at the cathode, resulting in the development of blisters under the coatings. This phenomenon is known as 'hydrogen blistering'. As intelligent anodes are smart, the electronic circuit will cut off the current, allowing the magnesium anode to continue functioning normally in seawater. In other words, as soon as the resistance changes, the electronics regulate a constant current. This is why these types of anode are so multifunctional.
Fig. 6 shows duplex (1.4462) risers fitted with anodes.

*Fig. 6. Over protected duplex stainless steel (1.4462) risers protected by conventional cathodic protection with cracks in the weld*

A particularly special application that is new is the attachment of intelligent anodes to a large yacht currently being constructed from duplex stainless steel as shown in Figure 7. Because of the high-quality type of stainless steel being used, these anodes have been chosen in order to prevent galvanic corrosion in those areas in particular which involve metals with a great potential difference in relation to duplex steel. The anodes also protect against corrosion in the event of damage to the coating, as it is known that even duplex stainless steel can be subject to pitting corrosion caused by MIC in seawater. At the same time, the system ensures that no over protection can occur. Over protection leads to excessive hydrogen development which significantly undermines the quality of the coating. In a nutshell, it can be said that all cathodic protection systems developed up until now are static while the intelligent anodes are dynamic since they are self-adjustable. A bright future is therefore expected for these types of protection systems. More information can be obtained from info@innomet.nl

## Acknowledgement

Thanks must go to the company Corrodium B.V., The Netherlands, for providing relevant information.

*Fig. 7. The hull of this yacht is made from duplex stainless steel 1.4462 and fitted with intelligent anodes.*