

## **INTERNAL CATHODIC PROTECTION FOR LARGE HOT-WATER STORAGE RESERVOIRS. INFLUENCE OF THE WATER QUALITY AND THE WALLS COATING.**

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The aim of this presentation is to comment some issues related to the internal cathodic protection (CP) of large hot-water storage reservoirs based on more than 35 years of experience on this type of system.

For a long time impressed current systems and soluble aluminium anodes with important current outputs were used to easily protect reservoirs with a great current distribution despite the absence, in many cases, of coating.

In 1985 platinized titanium anodes started been installed which later were replaced by titanium MMO.

The new CP systems demanded to take greater precautions to achieve a uniform cathodic protection in all surfaces or areas of the reservoir which obviously was related to a detail and carefully anode design but without taking in account other conditions.

On one side this presentation will analyse the influence of the water hardness, and therefore their  $\text{Ca}^{++}$  ions content, under both cathodic protection criteria and necessary current densities and on the other side by discussing the beneficial influence of applying a cemented based coating on the reservoir walls.

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## **1. Introduction**

In recent times there is a concern to analyse whether the cathodic protection criteria from standard EN 12954 is universally valid or if it's interesting to define its scope in some specific cases.

In particular it considers whether the most commonly used criteria, IR free potential of  $-0,85V$  (vs Cu/SO<sub>4</sub>Cu), is too restrictive when the cathodic protection achieved a significant increase of the pH at the cathode. The justification for this approach is the absence of corrosion with a less electronegative potential thanks to the metal passivation when an alkaline pH is reached.

On the contrary in cases where the cathodic protection doesn't achieve a pH higher enough, it is whether the usual IR free  $-0.85 V$  criteria is insufficient and a more electronegative potential should be achieved to ensure that it's situated at the immunity area.

It's clear that the increase of the pH due to cathodic protection depends on the electrolyte and its calcium content therefore the possibility arises that in some cases the electrolyte characteristics could be a factor to define the application field limits of the criterion.

The aim of this presentation is to provide some information based on our almost 40 years of experience in internal impressed current CP systems of major hot-water storage reservoirs.

In fact the information that will be provided is not linked to the cathodic protection criteria itself but rather over the protective current demands and their distribution or coverage due to several parameters such as the anode type, water hardness and the presence or not of a cemented based coating at the reservoir walls.

## 2. Water Limit Values according to Standards and Recommendations

Standard EN 12499 "Internal Cathodic Protection" notes that cathodic protection only is feasible when the electrolyte pH value is  $>4,5$  and the conductivity is greater than  $10^{-3}$  Siemens/m which is equal to a resistivity lower than  $100.000 \Omega \cdot \text{cm}$  or  $1.000 \Omega \cdot \text{m}$ .

The same standard indicates that special precautions shall be taken into account in internal CP to achieve a good current distribution and to avoid the risk due to dangerous gases formation if the electrolyte has a pH value  $<5,5$  or a conductivity lower than  $10^{-2}$  Siemens/m which is equal to a resistivity lower than  $10.000 \Omega \cdot \text{cm}$  or  $100 \Omega \cdot \text{m}$

Standard EN 14095 "Water conditioning equipment inside buildings - Electrolytic dosing systems with aluminium anodes — Part 1: Requirements for performance and safety, testing" shows the following water limit values to obtain an effective system:

$6.5 < \text{pH} < 8.5$

Conductivity :  $>100 \mu\text{S}/\text{cm}$  (equal to a resistivity lower than  $10.000 \Omega \cdot \text{cm}$  or  $100 \Omega \cdot \text{m}$ )

Calcium hydrogenocarbonate concentration :  $[\text{Ca}(\text{HCO}_3)_2] > 0.8 \text{ mmol/l}$

Phosphates and polyphosphates :  $< 2 \text{ mg/l}$  as  $\text{P}_2\text{O}_5$

Continuous circulation in the hot water circuit should be verified.

## 3. Aluminium Anodes

In 1924 the Danish engineer Alfred Guldager began with the impressed current CP of hot-water storage reservoirs using highly pure aluminium anodes in hard water and managed to avoid the phenomena of scale formation in both the tank and heat exchanger as in the water recirculating piping network.

In 1936 a new source of water supply was incorporated into the city of Copenhagen with a strong aggressive and corrosive nature proving that besides achieving the reservoir cathodic protection the piping internal corrosion also was avoided.

The GULDAGER system, effective in preventing both corrosion and scale formation at the reservoir and recirculating piping, is known as "electrolytic water treatment".

The electrolytic dissolution of the aluminium anodes, with alumina hydrate formation, facilitates the deposition of calcium carbonate and other very uniform products over the reservoir walls and the heat exchanger located inside the reservoir. This provided an outstanding current distribution despite the reservoir lack of internal coating, normally unpainted black iron.

Note that the use of important current densities to achieve the water treatment also facilitates the deposition on the cathode and the current distribution.

## 4. Titanium Anodes

To avoid any problems arising from the use of unsuitable currents in the electrolytic treatment, aluminium and platinized titanium anodes fed by independently current controlled rectifiers began to be installed inside the reservoirs.

In 1985 we started to install, in some reservoirs, only platinized titanium anodes which were subsequently replaced by MMO titanium anodes. In these cases the water electrolytic treatment function disappeared and the only objective was the cathodic protection of the reservoir.

At first most of these reservoirs were hot dip galvanized until gradually they began to be supplied coated with epoxy painting and in some cases with vitreous coating systems.

The end of using aluminium anodes created major difficulties for achieving a proper current distribution inside the reservoir especially if there was a heat exchanger inside of it.

To achieve a good current distribution in the entire reservoir a proper anode design was necessary taking into account both the reservoir geometrical characteristics and coating type, water resistivity and the presence or absence of copper ions that can enter inside the reservoir through the pipes if these are from the same metal.

## **5. Protection Criteria and Current Density**

The rectifiers used are automatically controlled, with an IR error correction system incorporated, and normally the equipment adjustment is quite conservative considering both the normal operating temperature of 60°C with higher peaks to prevent risks from legionella as the experience and history cases.

The required current density to achieve the chosen criteria varies widely according to different circumstances. For a given chosen reference potential the necessary current density obviously depends on the coating type but also depends highly on the water type and specifically on its hardness and therefore on the calcium carbonate difficulty degree of precipitation over the walls.

## **6. Water Softening**

To avoid the scale formation phenomena it's common to improve the water quality by the installation of softening systems for the water to be heated and in many cases the regulations requirement of mixing softened water with hard water to obtain a final hardness value between 6 and 15°HF is not accomplished.

There are numerous cases in which the reservoirs were well protected with small current densities in presence of a water hardness comprised between 6 and 30°HF.

When a softening system installed in series is started-up with water hardness near zero, the necessary current density to maintain the chosen potential criteria could increase between 3 to 30 times.

This shows the importance of the calcium ions and magnesium contents on water that allow the carbonates precipitation at the cathode.

## **7. Reservoir Internal Cemented based Coating**

When cathodic protection is applied at an existing reservoir in which a corrosion process has already started, after the reservoir improvement modifications which normally involves welding on the inside, it's usual to apply a cemented based coating at all or some of the internal surfaces.

This cemented based coating is applied after the old and poorly adhered existing coating and oxide is hand-removed and consists in a mixture of cement, water and approved sanitary glue.

The decrease of the surface to be protected, joined with the cemented based coating alkaline pH, results in a spectacular decrease of the necessary current densities and a clear improvement of the current distribution.

## **8. Conclusion**

Our experience shows that cathodic protection is easily achieved in the presence of hard water with high calcium contents, which facilitates the increase of the pH level at the cathode and the precipitation of calcium carbonate.

On the contrary in water with a near zero hardness high current densities are required to achieve cathodic protection.

Likewise the presence of a cemented based coating at the reservoir walls facilitates cathodic protection, decreases the current density and improves the current distribution.